Commonwealth of Massachusetts

A Strategy for Monitoring and Assessing the Quality of Massachusetts' Waters to Support Multiple Water Resource Management Objectives

2016 – 2025

Commonwealth of Massachusetts
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Executive Summary

In September, 2005 the Massachusetts Department of Environmental Protection (MassDEP) published *A Water Quality Monitoring Strategy for the Commonwealth of Massachusetts* (the 2005 Monitoring Strategy). The 2005 Monitoring Strategy outlined a surface water monitoring program that was designed to fulfill the monitoring requirements of the Federal Clean Water Act (CWA). This program was consistent with guidance provided by the EPA in *Elements of a State Water Monitoring and Assessment Program* (March, 2003) and was to be fully implemented over a period of ten years. The revised monitoring plan presented here (2016 Strategy) describes how monitoring data from various water types will be acquired and used within the context of MassDEP's water resource management programs throughout the next ten years (i.e., 2016 – 2025).).

One area of discussion within the Commonwealth that would result in an update to the 2016 Strategy prior to 2025 is delegation of the National Pollutant Discharge Elimination System (NPDES) program. Over the past year, Massachusetts has taken steps to pursue this program; NPDES permits are currently issued by the U.S. Environmental Protection Agency (EPA) in the Commonwealth. Should Massachusetts receive NPDES delegation from EPA, MassDEP has committed to developing a robust water quality monitoring program to support NPDES permitting. MassDEP would need to revisit this Strategy to ensure that adequate resources are incorporated to support a monitoring program that will assist with NPDES permit development.

The overall need for credible scientific water monitoring data has not changed fundamentally since the publication of the 2005 Strategy. However, shifts in program priorities in response to new and emerging water management issues dictate that Massachusetts' water monitoring programs be examined from time to time to ensure that they continue to provide the kinds of data and information needed to support new and ongoing water management activities. A comprehensive water resource monitoring program for Massachusetts must continue to address the core requirements of the CWA while remaining flexible enough to respond to new water quality challenges. Environmental data and information are needed to identify and characterize water pollution problems, set priorities for water resource protection and restoration activities, support proactive decision-making on existing and emerging issues, and evaluate the effectiveness of past and ongoing measures undertaken to improve water quality. Where necessary, this updated Strategy will make recommendations for adjustments to the existing monitoring program in order to fulfill the informational needs of all of the various water management programs.

The ultimate goal embodied in the 2016 Strategy is to implement a comprehensive monitoring program for Massachusetts that serves all water quality management needs and addresses all waterbody types. As such, the monitoring program is designed to provide data and information from streams, rivers, lakes, reservoirs, estuaries, coastal areas and wetlands to support the five major objectives listed below.

1) Assess the status or condition of Massachusetts' waters
2) Develop, implement and evaluate pollution control strategies
3) Develop policies and standards and identify emerging issues
4) Measure the effectiveness of water quality management programs
5) Maintain reserve monitoring capacity to respond to unforeseen data needs

Massachusetts intends to allocate approximately 20 percent of its total monitoring capacity over the course of the next ten years to address each of the monitoring objectives; however, it is unlikely that monitoring resources will be evenly distributed among all five objectives in any given year. Rather, this overall resource allocation will be achieved over the course of the ten-year planning period.

The MassDEP has identified a number of themes or principles to guide the formulation of the strategic water monitoring plan for the next ten years, and they are reflected in the overall design of the recommended water monitoring program elements. Major themes, inherent in both the MassDEP's water

management programs and the monitoring elements that support them, are 1) the focus on the watershed as the fundamental planning unit for water quality management, 2) the assessment of biological communities, such as aquatic macroinvertebrates, fish, or algae as reliable indicators of water quality conditions and ecosystem health, 3) the application of new technology and streamlined systems for data processing and analysis to support monitoring and assessment activities, and 4) the formation and reliance on partnerships and collaboration to meet water quality goals.

A total of eighteen monitoring program elements are recommended here to meet the defined monitoring objectives. These monitoring elements include both deterministic (targeted) and probabilistic (random) sampling networks. Furthermore, these designs encompass both rotating watershed monitoring cycles as well as non-rotating, priority-driven schedules.

EPA encourages states to adopt networks of randomly selected sampling sites that will allow for statistically unbiased assessments that can be applied at larger scales (e.g., statewide). Because statistically-valid inferences can be drawn for an entire population of waterbodies by sampling a set of sites randomly selected from that population, a probabilistic design can, with a single sample, provide a snapshot of the percentage of waters attaining water quality standards and supporting designated uses. A single sample, however, does not allow for the assessment of individual waterbodies. Therefore, MassDEP has added adequate spatial, temporal and analytical coverage to its random survey designs to assess the designated use support status, and identify causes and sources of impairment, for individual waterbodies. MassDEP recently completed a five-year probabilistic survey of wadeable streams and is applying a similar sampling design to lakes and ponds during 2016 – 2018.

Several targeted monitoring networks are also proposed to obtain the data and information needed to identify causes and sources of impairments, and to develop and implement control strategies, such as TMDLs, watershed-based plans, NPDES permits and BMPs. Furthermore, targeted monitoring may provide data to define new and emerging issues or to support the development of water quality standards and policies.

MassDEP will continue to employ technology and enhance monitoring functions through the deployment of metered probes, remote sensing, data loggers and other emerging technologies. Ongoing efforts will be maintained to automate data validation as well as enhance data flows, through the application of Geographical Information Systems (GIS) and specialized programming used to evaluate data and make watershed assessment and listing decisions. MassDEP also intends to improve its electronic data management systems and to implement measures for reporting and distributing water monitoring data and information to multiple end users in government, the private sector and the general public. To that end, MassDEP has procured a commercially available, off-the-shelf water data storage and retrieval system that will manage data from multiple water monitoring program elements and facilitate the transfer of MassDEP data and information to EPA's Water Quality Exchange (WQX).

Monitoring resource needs of MassDEP are summarized following the description of each individual program element throughout this report. These needs generally fall into four categories: 1) staffing; 2) funding for equipment and supplies; 3) funding for contractual services; and 4) training. It is clear that several program enhancements are required, not only to implement the new program elements proposed in this strategic plan, but also to maintain existing programs that are impacted by the loss of staff through attrition. In addition, the implementation of each new monitoring program element will increase the demand for support services, such as quality assurance and data management. Long-term staffing and funding support are critical to the development and implementation of the comprehensive water monitoring program.

The demand for scientifically-valid water quality information is expanding. At the same time, numerous external parties and organizations are collecting water quality data and information with the intent that MassDEP will use that information for making use assessments and other watershed management

decisions. To make use of these external data sources, MassDEP will need to expand its outreach activities and communication, and develop the infrastructure required to review sampling protocols and project plans, and to accept, validate and analyze data from an increasing number of new sources.

List of Acronyms

ADB	Assessment Database
ATTAINS	Assessment TMDL Tracking and Implementation System
BMP	Best Management Practice
CALM	Consolidated Assessment and Listing Methodology
CAPS	Conservation Assessment and Prioritization System
COTS	Commercial Off-the-Shelf
CSOs	Combined Sewer Overflows
CWA	Clean Water Act
DCR	Massachusetts Department of Conservation and Recreation
DER	Massachusetts Division of Ecological Restoration
DFG	Massachusetts Department of Fish and Game
DMF	Massachusetts Division of Marine Fisheries
DPH	Massachusetts Department of Public Health
DQO	Data Quality Objective
DWP	Drinking Water Program
DWM-WPP	Division of Watershed Management-Watershed Planning Program
EOEA	Massachusetts Executive Office of Environmental Affairs
EOEEA	Massachusetts Executive Office of Energy and Environmental Affairs
EPA	U.S. Environmental Protection Agency
FTE	Full-time Equivalent
GIS	Geographic Information System
IEI	Index of Ecological Integrity
ITFM	Intergovernmental Task Force on Monitoring
LISS	Long Island Sound Study
MAP2	Massachusetts Monitoring and Assessment Program
MassDEP	Massachusetts Department of Environmental Protection
MDWPC	Massachusetts Division of Water Pollution Control
MEP	Massachusetts Estuaries Project
NARS	National Aquatic Resource Surveys
NGOs	Non-governmental Organizations
NHD	National Hydrography Dataset
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
N-STEPS	Nutrient Scientific Technical Exchange Partnership & Support
NWQI	National Water Quality Initiative
ORS	Office of Research and Standards
PCB	Polychlorinated Biphenyls
PPA	Performance Partnership Agreement
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project/Program Plan
QMP	Quality Management Plan for Federally Funded Programs
RBP	Rapid Bioassessment Protocols
RSN	Reference Site Network
SAP	Sampling and Analysis Plan
SDWA	Safe Drinking Water Act
SLAM	Site-Level Assessment Methodology
SOP	Standard Operating Procedure
SRF	Massachusetts State Revolving Fund

SWQS	Surface Water Quality Standards
TALU	Tiered Aquatic Life Use
TMDL	Total Maximum Daily Load
USGS	U.S. Geological Survey
WES	William X. Wall Experiment Station
WET	Whole-effluent Toxicity Testing
WLA	Waste Load Allocation
WPDG	Wetland Program Development Grant
WQX	Water Quality Exchange

Foreword

This report updates and expands on the document *A Water Quality Monitoring Strategy for the Commonwealth of Massachusetts* (the 2005 Monitoring Strategy), first released in September 2005. Major components of the proposed monitoring program fulfill requirements of the Federal Clean Water Act (CWA) and are consistent with design and implementation criteria suggested by the EPA in a guidance document entitled *Elements of a State Water Monitoring and Assessment Program* (EPA 2003). EPA acknowledges that the current status of state monitoring programs varies with respect to satisfactorily meeting all program elements called for in the guidance, and personnel and other resources are a significant constraint for all states. Therefore, EPA has provided these elements as overarching goals to be periodically reviewed and updated.

I. Introduction

The Federal Water Pollution Control Act of 1972 and subsequent Amendments in 1977, 1981 and 1987 are collectively known as the Clean Water Act (CWA). The objective of this statute is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Since its enactment 45 years ago, MassDEP, and its precursor agencies, has been administering a multi-faceted water quality management program for Massachusetts' rivers, lakes, wetlands and coastal waters that includes:

- Setting water-use goals through the implementation of surface water quality standards;
- Monitoring and assessment to determine if waters are meeting their goals, and to identify those in need of restoration and protection;
- Making recommendations for restoring waters through the development of total maximum daily loads (TMDL) to be used in setting wastewater effluent limits and as targets for ameliorating stormwater and non-point sources of pollution; and
- Providing financial grants and (later) loans for the construction of wastewater treatment facilities, sewerage systems and pollution controlling infrastructure, as well as funds for implementing Best Management Practices (BMP) for the control of nonpoint sources of pollution (NPS).

Each of the program elements listed above relies on credible water monitoring data and information. Water quality data inform a wide range of decision-making from identifying outstanding resource waters for special protection to assessing and prioritizing impaired waters for corrective actions. Monitoring data are also indispensable for the development of water quality criteria, the calibration and verification of predictive models for TMDL analyses and the evaluation of the effectiveness of pollution control and watershed restoration measures. In short, the basis for making scientifically defensible decisions with respect to water resource management rests with the availability of sufficient valid environmental monitoring data. With passage of the CWA, Congress acknowledged the importance of water monitoring and assessment by requiring states to report on the quality of their waters (s. 305b) and to identify and prioritize impaired waters for corrective actions (s. 303d).

EPA has provided federal guidance for meeting the monitoring objectives of the CWA. However, individual states were allowed flexibility to design and carry out their monitoring programs as they saw fit. While this offered the states considerable flexibility to determine where, what, and how much to monitor within their borders, there was little or no comparability between state monitoring programs, and any efforts to assemble the states' data and information into a comprehensive assessment of the nation's waters were seriously compromised. Not surprisingly, water monitoring programs differed substantially from state to state, both in their design and character, as well as in the amount and sources of funding allotted to them.

A brief history of water quality management in Massachusetts will serve to illustrate how the monitoring program was adapted over time in response to changing water quality problems and issues. During the 1970's the Massachusetts Division of Water Pollution Control (MDWPC) published river basin plans for over twenty river basins and coastal drainage areas. As part of this planning process, low-flow steady-state simulation models were developed for those watersheds where waste load allocations were needed to determine the level of wastewater treatment required and to derive wastewater effluent limits for permitting under the National Pollutant Discharge Elimination System (NPDES). For several years, the MDWPC designed and carried out intensive water quality surveys on main stem rivers to obtain the hydrological measurements, reaction rate coefficients and other input parameters that were needed to execute these models. Data from these surveys were also used for reporting the use support status of assessed waters pursuant to s. 305(b) of the CWA.

Monitoring of lakes and ponds was initiated in 1974 and expanded in 1979 to provide data and information in support of the Federal Clean Lakes Program authorized by s. 314 of the CWA, as well as the subsequent Massachusetts Clean Lakes and Great Ponds Act (Chapter 628, Acts of 1981). The

MDWPC carried out both baseline surveys to provide the data needed to classify lakes according to their trophic status, as well as a smaller number of more intensive year-round lake studies. Limited grant monies were available for eligible lake restoration projects through both federal and state programs. This program has not received funding since 1995 although today s. 319 funds may be used to support selected activities that were originally eligible for clean-lakes funding.

The 1980's saw an increased emphasis on the identification and control of toxic pollutants in the aquatic environment. The EPA announced the publication of individual ambient water quality criteria documents for pollutants listed as toxic in the CWA, and these, along with subsequent criteria, were used to screen ambient water quality and wastewater discharge data for potential toxic effects. Furthermore, new revisions to the Massachusetts Surface Water Quality Standards (SWQS) included the adoption by reference of the EPA's National Recommended Water Quality Criteria. Waterbodies impacted by toxic pollutants and wastewater discharges in need of "individual control strategies" for toxic pollutants were identified and prioritized for implementation. Most of these control strategies involved the issuance of NPDES permits with whole-effluent toxicity testing (WET) requirements and, in some cases, individual numerical effluent limits for toxic contaminants. Also at this time, an inter-agency task force was formed to assess and manage toxic contaminants in fish, and a monitoring program was initiated to measure the levels of polychlorinated biphenyls (PCBs) and heavy metals, including mercury, in the edible portions of fish. Data were provided to the Massachusetts Department of Public Health (DPH) for risk assessment and, where necessary, the release of fish edibility advisories.

By the mid-1980's most municipal wastewater treatment plants were providing a minimum of secondary treatment, and some included further removal of biochemical oxygen demand and/or various degrees of nitrification and phosphorus removal. Massachusetts' older urban centers, however, were still served by complex combined sewer collection systems that dated back to the late 1800's. Combined sewer overflows (CSOs) continued to contribute significant loadings of solids, nutrients and bacteria to receiving waters during storm events. Although limited in scope, the MDWPC initiated wet-weather monitoring upstream and downstream from CSOs to document the magnitude and extent of these discharges. Both CWA construction grants and the Massachusetts State Revolving Fund (SRF) have been utilized over the years to develop and implement strategies to control CSOs.

Massachusetts continued to rely on the use of intensive surveys for assessing and reporting on the condition of its waters; however, this monitoring was supplemented by more site- or issue-specific project-level investigations. For example, targeted sampling upstream and downstream from wastewater discharges served to evaluate the impacts of those discharges on the quality of their receiving waters. Rapid bioassessment techniques were developed that provided information pertaining to the effects of water quality conditions on instream macroinvertebrate and fish communities, and more emphasis was placed on the use of biological monitoring as a direct measure of the aquatic life use support status of Massachusetts' waters.

While Massachusetts' water quality management programs always focused on the river basin, (i.e., watershed) as the fundamental assessment and planning unit, in 1993 the MassDEP placed the 27 major watersheds and coastal drainage areas in Massachusetts on a rotating five-year schedule to synchronize monitoring, assessment and other components of its watershed management program. The goal was to allocate one year to each of five water management steps or phases (i.e., Year 1 – planning; Year 2 – monitoring; Year 3 – assessment; Year 4 – implementation of control strategies; and Year 5 – effectiveness evaluation), after which the process would begin again. Five years later the watershed approach to water quality management was formally adopted by the Massachusetts Executive Office of Environmental Affairs (EOEA), now the Executive Office of Energy and Environmental Affairs (EOEEA), through the implementation of its Watershed Initiative to include multiple organizations and interested parties. Fifteen watershed teams, consisting of representatives from state and federal agencies, municipalities and non-governmental organizations (NGOs), such as watershed associations, were established to focus on the restoration and preservation of the Commonwealth's watersheds. MassDEP's

monitoring program attempted to support the EOEA watershed teams in Year 2 of the management cycle. At the same time, however, the Watershed Initiative spurred the establishment or enhancement of a number of citizen monitoring programs throughout Massachusetts, and it became evident that state-citizen monitoring partnerships would be needed in the future in order to acquire adequate water quality data and information to support watershed management programs.

For the first several years following passage of the CWA, Massachusetts' water pollution abatement programs were focused on the control of point sources through waste load allocation and NPDES permitting, and little emphasis was placed on the assessment and control of NPS, although it could be argued (and was) that the Clean Lakes Program was, in effect, a NPS management program since there were no point discharges to Massachusetts' lakes. Nonetheless, NPS is not easily assessed or controlled, for it is intricately linked with the use of the land, and land-use decisions are primarily made at the local level. The management and remediation of non-point sources of pollution is typically accomplished through the implementation of BMPs. The CWA s. 319 provides grant monies for the implementation of BMPs. EPA has challenged states to design monitoring programs that will document improvement to water quality that may be realized through the implementation of individual BMPs and inform the preparation of water remediation "success stories."

Over the last 45 years, approximately $109 million in s. 106 funding has been used to support MassDEP's monitoring and assessment work. Water quality monitoring throughout the 1990's and beyond indicated that, while significant progress had been made toward the abatement of the most obvious water pollution problems in Massachusetts, water quality standards were still not met in many of Massachusetts' waters. Excessive nutrients (nitrogen and phosphorus) and bacteria, particularly during wet weather, were identified as the most pervasive pollutants requiring further controls. The planning tool informing the management of these and other pollutants is the TMDL. The TMDL process establishes the maximum allowable loading of pollutants that waterbodies can receive and still meet the water quality standards established for protecting public health and maintaining the designated beneficial uses of those waters. The TMDL establishes allowable loadings from both point and nonpoint sources of pollution. TMDL implementation is accomplished through adherence to prevailing regulations and program requirements such as those governing the NPDES permits for point source control and the stormwater management performance standards maintained by conservation commissions under the Wetlands Protection Act. Furthermore, funding priority for CWA s. 319 grants and the SRF is given to watershed clean-up projects that are consistent with TMDL program requirements.

Like the waste load allocations (WLA) derived in the 1970's and 80's, TMDLs are developed through the application of models that simulate waterbody conditions and predict the effects on the receiving water of a range of pollutant loading scenarios that are associated with various wastewater treatment options. Reliable environmental data and information are essential to the proper calibration and verification of these models, and their capacity to accurately predict future conditions is a direct reflection of the accuracy of the underlying data and assumptions supporting them.

From the previous discussion, it can be seen that Massachusetts' water monitoring programs have adapted over the years to respond to new and emerging water quality problems and issues, and this capacity to change, as needed, to provide the environmental data and information that will inform water resource management decision-making in the future must be a theme of any strategic monitoring plan developed for Massachusetts. Furthermore, in recent years the number and type of water data collection activities have expanded and dispersed beyond MassDEP and this presents unique challenges to meeting CWA program objectives.

In 2003, the EPA published *Elements of a State Water Monitoring and Assessment Program* (EPA 2003) in an effort to increase consistency among state water monitoring programs and to provide a framework for determining whether those programs meet the prerequisites of CWA s. 106(e)(1). This report called on each state to formulate a "comprehensive monitoring program strategy that serves all water management

needs and addresses all State water, including all waterbody types (e.g., streams, rivers, lakes, Great Lakes, reservoirs, estuaries, coastal areas, wetlands and groundwater)." In formulating this strategy, states were to incorporate the following ten basic elements of a water resource monitoring program:

- Long-term Monitoring Program Strategy
- Monitoring Objectives
- Monitoring Design
- Core and Supplemental Water Quality Indicators
- Quality Assurance
- Data Management
- Data Analysis/Assessment
- Reporting
- Programmatic Evaluation
- General Support and Infrastructure Planning

In addition, the monitoring strategy was to identify technical issues and resource needs that address CWA monitoring objectives and formulate a long-term plan for addressing gaps and implementing the program. Finally, the monitoring strategy was intended to be a "working document" with periodic updates.

MassDEP published the 2005 Monitoring Strategy in accordance with the aforementioned EPA guidelines. This plan was to cover the ten-year period 2005 – 2015 and consisted of a combination of probabilistic, fixed-site and targeted sampling networks designed to provide data and information for better water resource management decision-making. The 2005 Monitoring Strategy identified shortfalls to implementing a comprehensive monitoring program that would meet all of Massachusetts' water quality management needs. These shortfalls were not addressed; as a result, monitoring program priorities must be re-examined to determine how to best meet CWA requirements.

The 2016 Monitoring Strategy encompasses a planning horizon of approximately ten years (i.e., 2016 – 2025). Each of EPA's ten basic elements is described in a chapter of this report. *The ultimate goal of the Commonwealth is to implement a comprehensive monitoring program that serves all water quality management needs and addresses all waterbody types.* To this end, the revised Monitoring Strategy re-examines program priorities and data needs and sets forth a plan for achieving a comprehensive water resource monitoring program that continues to embody EPA's fundamental ten elements and meets the prerequisites of s. 106(e)(1) of the CWA.

II. Monitoring Program Strategy

This planning document describes how monitoring data from various water types will be acquired and used within the context of MassDEP's water resource management programs. The overall need for credible scientific water monitoring data has not changed fundamentally since the publication of the 2005 Strategy. However, shifts in program priorities in response to new and emerging water management issues dictate that Massachusetts' water monitoring programs be examined from time to time to ensure that they continue to provide the kinds of data and information needed to support new and ongoing water management activities. A comprehensive water resource monitoring program for Massachusetts must continue to address the core requirements of the CWA while remaining flexible enough to respond to new water quality challenges. Environmental data and information are needed to identify and characterize water pollution problems, set priorities for water resource protection and restoration activities, support proactive decision-making on existing and emerging issues, and evaluate the effectiveness of past and ongoing measures undertaken to improve water quality. Where necessary, this updated strategy will make recommendations for adjustments to the existing monitoring program in order to fulfill the informational needs of all of the various water management programs.

One area of discussion within the Commonwealth that would result in an update to the 2016 Strategy prior to 2025 is delegation of the National Pollutant Discharge Elimination System (NPDES) program. Over the past year, Massachusetts has taken steps to pursue this program; NPDES permits are currently issued by EPA in the Commonwealth. Should Massachusetts receive delegation from EPA, MassDEP has committed to developing a robust water quality monitoring program to support NPDES permitting. MassDEP would need to revisit this Strategy to ensure that adequate resources are incorporated to support a monitoring program that will assist with NPDES permit development.

In addition to EPA's *Elements of a State Water Monitoring and Assessment Program,* MassDEP has identified a number of themes or principles to guide the formulation of a strategic water monitoring plan for the next ten years. These principles are discussed briefly here and are reflected in the overall design of the water monitoring program elements presented later in this report. Three major themes inherent in both MassDEP's water management programs and the monitoring elements that support them are 1) the focus on the watershed as the fundamental planning unit for water quality management, 2) the formation and reliance on partnerships and collaboration to meet water quality goals, as set forth in the SWQS, TMDL implementation plans and the NPS management program plan, and 3) the application of new technology and streamlined systems for data processing and analysis to support monitoring and assessment activities.

Watershed protection is the dominant theme of many state water quality management programs, and EPA has endorsed this approach by providing financial and technical support for watershed-based water quality management activities. Although the Watershed Initiative was discontinued as a formal EOEA program in 2003, MassDEP continues to utilize the watershed as the focus for monitoring and other water management program elements. The completion of all of the steps in the watershed management process within a five-year time-frame has proven to be impracticable, however. The practice of watershed management is inherently complex, resource-intensive and time-consuming and project demand often outpaces available funding and other resources. Therefore, while MassDEP's water management program continues to progress in a step-wise fashion to restore impaired waters and protect waters that meet water quality standards, in practice these steps are typically not completed within a five-year timeframe as originally conceived. In fact, monitoring is the only component of the watershed management program that continues to follow a 5-year schedule, and in 2010 the watersheds were regrouped on a regional basis to take advantage of potential benefits to monitoring survey logistics of more closely aligned watersheds, and to more equitably distribute Massachusetts' total river miles among the five groups. This new spatial arrangement is described in more detail at http://www.mass.gov/eea/agencies/massdep/water/watersheds/adjustments-to-surface-water-monitoring-program.html. Finally, it should be acknowledged that, while some monitoring will be performed in accordance with the rotating watershed cycle, other watersheds or individual waterbodies may be prioritized for monitoring separate from this schedule based on identified monitoring needs from year to year.

Although short-lived as a formal program, the Watershed Initiative established partnerships between a variety of government agencies, NGOs and other stakeholders all focused on the restoration and protection of Massachusetts' watersheds. Because resources were limited across all state agencies, care was taken to avoid duplication of effort, and emphasis was placed on sharing environmental data and information among all interested parties. Over the years the number of external data providers has increased substantially, providing new and varying sources of information to support water management decision-making. For example, s. 604(b) water quality planning and assessment grants to outside parties have substantially supported NPS and other assessments. Other parties include: volunteer monitoring organizations, academic institutions, government agencies, stream teams, watershed associations, NPDES permit holders and environmental consultants. MassDEP continues to work collaboratively with these groups to optimize the utilization of their data. In doing so, MassDEP can focus its monitoring efforts in areas that are not covered by outside parties. The acquisition of valid scientific data is achieved,

in part, by ensuring that interested monitoring parties develop standard operating procedures (SOPs) and quality assurance project plans (QAPPs) that will increase the likelihood that these external data sources can be used to fulfill selected CWA requirements (e.g., s. 305b/303d assessment and listing functions). MassDEP has developed protocols for external data providers to follow when preparing and submitting their quality-assured surface water data for such uses. More information pertaining to the submittal of external water resources data to MassDEP can be found at http://www.mass.gov/eea/agencies/massdep/water/watersheds/external-data-submittals-for-the-wpp.html.

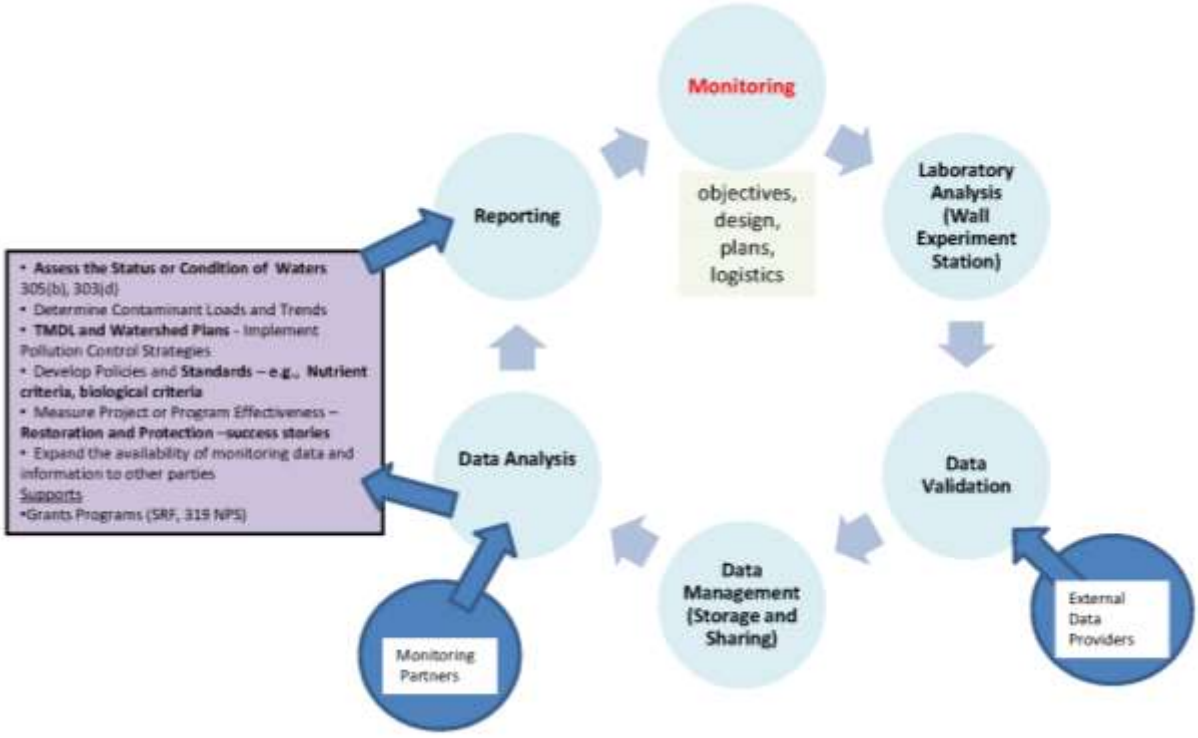
MassDEP's recognizes that the effectiveness of its monitoring program is not only contingent upon the successful implementation of sampling operations in the field, but is equally dependent on the availability of essential laboratory analytical support, data validation and management (storage and sharing) and data analysis and reporting as depicted in the figure at the end of this section. Annual reviews will be conducted to ensure that necessary resources and tools are in place to support all elements.

MassDEP will continue to employ technology and enhance monitoring functions through the deployment of metered probes, remote sensing, data loggers and other emerging technologies. Laboratory and analytical resources will be adequately supported so that data are analyzed in accordance with standard methods and established quality assurance protocols. Ongoing efforts will be maintained to automate data validation as well as enhance data flows, through the application of Geographical Information Systems (GIS) and specialized programming used to evaluate data and make watershed assessment and listing decisions. MassDEP also intends to improve its electronic data management systems and to implement measures for reporting and distributing water monitoring data and information to multiple end users in government, the private sector and the general public. To that end, MassDEP has procured a commercially available, off-the-shelf water data storage and retrieval system that will manage data from multiple water monitoring program elements and facilitate the transfer of MassDEP data and information to EPA's Water Quality Exchange (WQX).

In addition to monitoring and managing water resources at the watershed level and relying increasingly on the development of partnerships to meet water quality objectives, a number of other program enhancements will be integrated in the design of the strategic monitoring plan. For example, MassDEP will continue to place emphasis on the use of biological communities, such as macroinvertebrates and fish, as the most effective indicators of water quality conditions and ecosystem health. Biological monitoring will continue to be a critical component of the surface water monitoring program and the use of various techniques for interpreting biological data (e.g., multi-metric indices; tiered aquatic life use) will be explored.

While the restoration of impaired waters will remain a primary goal of the MassDEP and its many partners, the preservation of healthy watersheds will also be emphasized more in the future. The surface water monitoring program will be designed to not only identify impaired waters and support clean-up activities, but to highlight high-quality waters in need of further measures to ensure their protection. Consistent with EPA's Healthy Watershed Initiative, protection measures may be implemented through the development of watershed-based plans and s. 319 grant projects.

Elements of a Statewide Monitoring Strategy



III. Monitoring Objectives

The identification of monitoring objectives is a critical first step in designing a monitoring program that is efficient and effective in generating data that support important water quality management decisions. The monitoring program for Massachusetts is designed to provide data and information from streams, rivers, lakes, reservoirs, estuaries, coastal areas and wetlands to support the major objectives described below. Massachusetts' goal is to allocate approximately 20 percent of its total monitoring capacity over the course of the next ten years to address each of the four major monitoring objectives, while reserving additional capacity to meet unforeseen needs, such as technical support to other MassDEP programs. It is unlikely that monitoring resources will be evenly distributed among all five objectives in any given year. Rather, this overall resource allocation will be achieved over the course of the ten-year planning period. In any case, both MassDEP's monitoring data, as well as data from external sources, will be needed to meet these objectives.

MONITORING OBJECTIVE 1: Assess the status or condition of Massachusetts' waters – This objective is to determine the water-quality status of the Commonwealth's waters relative to the attainment of their designated uses, as defined in the SWQS (*Aquatic Life*, *Fish Consumption*, *Public Water Supply*, *Shellfish Harvesting*, *Primary* (e.g., swimming) and *Secondary* (e.g., boating) *Contact Recreation and Aesthetics)*. Monitoring data are needed to assess and report on the use-support status of their waters pursuant to s. 305(b) of the CWA, and to list impaired waters in accordance with the requirements of s. 303(d). In addition, these assessments should identify causes and sources of those impairments. This objective will be realized by combining a probabilistic sampling design to estimate the percentage of waters that are impaired for each use statewide with targeted sampling to confirm impairment causes,

identify sources of pollution and, where uses are restored, remove waterbodies or applicable impairments from the 303(d) List.

A brief word about Drinking Water: *While included as a designated use in the SWQS, MassDEP's Watershed Planning Program does not assess the use-support status of public water supplies for the purpose of assessing and listing waters in accordance with ss. 305(b) and 303(d) of the CWA. Public water supplies in Massachusetts are regulated by MassDEP's Drinking Water Program (DWP) which acts as EPA's Primacy Agent for administering the federal Safe Drinking Water Act (SDWA). The DWP protects public health by implementing new source approvals, water supply treatment and distribution requirements, source water protection, emergency preparedness, and reporting of raw and finished drinking water quality data. The 1996 amendments to the SDWA required every state to examine existing and potential threats to the quality of all its public water supply sources and to develop a Source Water Assessment and Protection (SWAP) Program. As part of this program, the DWP: 1) delineated protection areas for all public ground and surface water sources; 2) inventoried uses in these areas that may present potential threats to water quality; 3) determined the susceptibility of water supplies to contamination from these sources; and 4) publicized the results in source water assessment reports. The top five potential threats to public water sources that were identified through the SWAP were: 1) residential lawn care/gardening; 2) residential septic systems and cesspools; 3) residential fuel oil storage; 4) stormwater discharge; and 5) state-regulated underground storage tanks.*

Selected data flows from the DWP may be useful for focusing both regulatory and non-regulatory restoration and preservation measures, authorized by the CWA, in the watersheds of public water supplies. For example, such activities as NPDES permitting (including stormwater), s. 604(b) assessments and s. 319 BMP implementation could be used to lessen or eliminate threats to water supplies identified during the SWAP process. In addition, monitoring proposed herein with the objective to identify emerging issues such as Cyanobacteria blooms or new and unforeseen pollutants may have implications for many surface waters including, in some instances, public water supplies. It is a goal of MassDEP to continue to link data flows and information from SDWA and CWA program elements to better protect public health and the environment.

MONITORING OBJECTIVE 2: Develop, implement and evaluate pollution control strategies – This objective is to provide data and information needed for the development and implementation of various measures to restore impaired waters. Such measures include, but are not limited to, the derivation and application of TMDLs to point and nonpoint sources of pollution, issuance of NPDES wastewater discharge permits, and installation of stormwater controls and BMPs. Targeted monitoring will be used to characterize and quantify pollution sources as the first step toward their remediation. Limited fixed-site monitoring may be required to quantify pollutant loadings. Monitoring may also be needed to acquire input parameters for predictive water quality models to be used to derive WLAs and effluent limits for discharge permits, or to define NPS loading reduction goals to be included in NPS watershed-based plans.

MONITORING OBJECTIVE 3: Develop policies and standards and identify emerging issues – This objective is to conduct short-term investigations directed at the establishment or revision of water quality standards and policies, and to identify and characterize emerging and ongoing water quality issues and problems, such as fish tissue contamination and toxic algae blooms. Monitoring to meet this objective may be triggered by the results of other monitoring programs or may be initiated in response to new information on potential risks to human or ecological health. For example, monitoring data collected for

assessment purposes may be used to identify high-quality waters in need of protection from degradation, and additional monitoring data could be useful for defining the level of protection required. This objective will be achieved through the implementation of a number of targeted monitoring program elements.

MONITORING OBJECTIVE 4: Measure the effectiveness of water quality management programs – This objective is to identify, through monitoring, waters that exhibit measurable improvement in water quality as the result of the implementation of various water resource management activities and programs. Effectiveness monitoring can be designed and carried out at various scales ranging from the local, waterbody or segment-specific level to broader-scale watershed or statewide levels of coverage. Monitoring at broader scales will provide more comprehensive assessments of entire systems of control measures for improving water quality, such as the institution of a new water policy or regulatory program. In general, targeted monitoring designs will be most suitable for evaluating the effectiveness of water-body and watershed restoration activities, such as the issuance of NPDES wastewater discharge permits. However, repeated statewide probabilistic surveys may also be useful in demonstrating, more holistically, the longer-term environmental benefits of Massachusetts' entire water resource management program. In any case, the efficacy of various water resource management activities in ameliorating water pollution will be reported through the preparation and release of water quality "Success Stories" for waters where monitoring data confirm the restoration of one or more beneficial uses.

MONITORING OBJECTIVE 5: Maintain reserve monitoring capacity to respond to unforeseen data needs – This objective is to set aside some field and lab resources each year to accommodate unforeseen monitoring projects or requests for assistance that may arise unexpectedly and outside of the normal program planning process.

IV. Core and Supplemental Water Quality Indicators

EPA guidance calls for the State monitoring program to include "a core set of baseline indicators selected to represent each applicable designated use, plus supplemental indicators selected according to site-specific or project-specific decision criteria." These indicators or variables (e.g., water quality parameters) include physical/habitat, chemical/toxicological, and biological/ecological endpoints that impart information pertaining to the integrity of the water resource, and provide the information-base for making water quality-related assessment and management decisions, such as determining the impairment status of the resource.

Environmental indicators have received a lot of attention in recent years, but have also led to some confusion as to their purpose and use. The Intergovernmental Task Force on Monitoring Water Quality (ITFM) defined an environmental indicator as "a measurable feature which singly or in combination provides managerial and scientifically useful evidence of environmental and ecosystem quality or reliable evidence of trends in quality" (ITFM 1995). Inherent in this definition is a hierarchy of indicator types ranging from those emphasizing program-focused activities, such as the *number of discharge permits issued*, to greater reliance on resource-focused measures, such as the assessment of *biological integrity*. Note that the former represents, at best, "managerial evidence of environmental quality" as defined above, whereas the latter provides direct "scientific evidence" of ecosystem quality (EPA 1995). The kinds of indicators comprising the hierarchy are:

- Response Indicators - Measures of integrated or cumulative reactions to exposure and stress, such as biological community indices.

- Exposure Indicators - Measures of environmental variables that suggest a degree of exposure to stressors, such as water-column pollutant levels or ambient toxicity.

- Stressor Indicators - Activities that impact the aquatic environment, such as pollutant discharges and changes in land-use and habitat.

- Administrative Indicators - Regulatory actions by the EPA, the State, and local entities and responses by the regulated community.

Each indicator type in this hierarchy represents a step closer to the direct measure of the integrity of the resource than does the category below it. For example, reliance on administrative and stressor indicators is presumptive - actual instream pollutant concentrations are estimated based on knowledge of the magnitude and quality characteristics of upstream discharges, or conditions are assumed to be improved if a regulatory action is taken. Exposure indicators, such as pollutant concentrations that can be compared to numerical criteria, provide more reliable evidence of instream conditions but still do not account for site-specific factors influencing the biological response to those pollutant concentrations. Therefore, the site-specific application of biological response indicators, such as macroinvertebrate or fish community analyses, allows for greater confidence in the final water resource assessment. By focusing more in the future on indicators that reflect the actual condition of the resource, the s. 305(b)/303(d) assessment and listing process will be strengthened and attention will be shifted toward solving the most important environmental problems.

In general, monitoring programs focus on measuring exposure, response and, to a lesser degree, stressor indicators. Administrative indicators, which are tracked by counting the number of permits issued or enforcement actions taken, are typically not the subjects of environmental monitoring programs. Massachusetts' water monitoring programs feature a wide variety of water quality, habitat, and public health-related variables that represent the higher tiers in the hierarchy of indicators. For example, emphasis is placed on exposure and response indicators for assessing the attainment of water quality standards and/or designated uses.

As outlined in *Elements of a State Water Monitoring and Assessment Program* EPA distinguishes between core indicators that are used routinely to assess attainment with applicable water quality standards at a broader state-wide or watershed scale, and supplemental indicators that are used when core indicators identify impairment, or when there is an expectation that a particular pollutant may be present. Supplemental indicators are often useful for identifying causes and sources of impairment and for targeting appropriate source controls.

EPA's suggested indicators for states to include in their monitoring programs are presented in the tables below with slight modification to reflect Massachusetts' existing and proposed program elements. Table 1 provides a breakdown of core (state-wide and watershed scale) and supplemental (impairment or pollutant specific) indicators used for assessing and managing the aquatic life and water contact recreational uses (including rivers, lakes, and coastal waters), as defined in the Massachusetts SWQS. Likewise, Table 2 provides a breakdown of core and supplemental indicators that can be used to assess and manage the human health-related water uses designated in the SWQS.

Table 1. Core and supplemental indicators used for assessing the aquatic life and water contact recreational uses for rivers **(R)**, lakes **(L)**, and coastal waters **(C)**, as designated in the Massachusetts SWQS.

INDICATOR CATEGORY	AQUATIC LIFE*	RECREATION
Core	Macroinvertebrate community **(R, C)** Fish community **(R, L)** Periphyton/Phytoplankton blooms **(R, L, C)** Chlorophyll **(R, L, C)** Seagrasses (e.g., Eelgrass) **(C)** Habitat and Flow** **(R, L, C)** Dissolved oxygen **(R, L, C)** pH **(R, L, C)** Temperature **(R, L, C)** Transparency (e.g. Secchi depth) **(L)**	*Escherichia coli* **(R, L)** *Enterococcus* **(C)** Transparency (e.g. Secchi depth) **(R, L, C)** Harmful algal blooms **(R, L, C)** Macrophyte density **(R, L)** Bathing beach closures **(R, L, C)**
Supplemental	Toxic pollutants (e.g., metals, chloride) **(R, L, C)** Ammonia **(R, L, C)** Toxicity tests (water, sediment) **(R, L, C)** Tissue residue assays **(R, L, C)** Nutrients (nitrogen, phosphorus) **(R, L, C)** Turbidity **(R, L, C)** New and emerging contaminants **(R, L, C)** Sediment quality **(R, L, C)** Non-native species **(R, L)** Land-use/% impervious cover **(R, L, C)**	Cyanotoxins **(R, L, C)** Objectionable scums, sheens, débris, deposits **(R, L, C)** Flow/water level **(R, L)** Sediment chemistry **(R, L, C)** Water contaminants of concern **(R, L, C)** Turbidity **(R, L, C)** pH **(R, L, C)**
* It should be noted that, historically, chemical and physical indicators were emphasized; however, biological monitoring and assessment has assumed a more prominent role in the Massachusetts monitoring program (especially in assessment monitoring). ** Stream discharge/lake water level Geomorphology (slope, bank stability, channel morphology) Stream substrate (sediment type, embeddedness) Riparian zone (shoreline vegetation, canopy)		

Table 2. Core and supplemental indicators used to assess human health-related water uses for rivers **(R)**, lakes **(L)**, and coastal waters **(C)**, as designated in the Massachusetts SWQS.

INDICATOR CATEGORY	FINFISH/SHELLFISH CONSUMPTION	DRINKING WATER*
Core	Mercury **(R, L, C)** PCBs **(R, L, C)** Pesticides **(R, L, C)** Shellfish bed closures (non-management) **(C)**	Primary drinking water standards (legally enforceable under the SDWA)
Supplemental	Other contaminants of concern **(R, L, C)** Fecal coliform bacteria **(C)**	Secondary drinking water standards or other health-based advisories (unenforceable guidelines)
*While included as a designated use in the SWQS, MassDEP does not assess the use-support status of public water supplies for the purpose of assessing and listing waters in accordance with ss. 305(b) and 303(d) of the CWA.		

While the above indicators are typically used to assess the use-support status of waters and to identify causes and sources of impairment, many of these same variables are measured when monitoring to meet other program objectives, such as developing pollution control strategies and policies, or evaluating the effectiveness of water quality management programs. In these cases, monitoring designs may be more site- or issue-specific, but the indicators are largely the same.

V. Monitoring Design

The EPA guidelines for the development of state monitoring programs call for the development of sampling networks that will provide comprehensive assessments of all waters and waterbody types (e.g., shallow streams, large rivers, lakes, wetlands, etc.) over time. To provide complete coverage, both spatially and temporally, states are encouraged to adopt networks of randomly selected sampling sites that will allow for statistically unbiased assessments that can be applied at larger scales. Because statistically-valid inferences can be drawn for an entire population of waterbodies by monitoring a set of sites randomly selected from that population, a probabilistic design can provide, with a stated level of confidence, the percentage of waters attaining water quality standards and supporting designated uses. The actual number of sites chosen for monitoring will affect the overall confidence that can be placed in extrapolating up to a scale beyond the individual sites or waters sampled. These probabilistic monitoring designs are in contrast with deterministic, or targeted, designs that utilize non-random site selection based on previous knowledge of conditions at the sites.

Targeted monitoring networks will continue to be needed to identify causes and sources of impairments, and to develop and implement control strategies, such as TMDLs, watershed-based plans, NPDES permits and BMPs. Furthermore, targeted monitoring may provide data to define new and emerging issues or to support the development of water quality standards and policies. MassDEP will carry out some targeted monitoring elements while also relying on partners to fulfill additional data needs.

In short, Massachusetts has selected a set of monitoring program components that utilize a combination of targeted and probabilistically-derived sampling networks best suited to meet the monitoring objectives described in Section III. These monitoring elements incorporate a number of different design components such as intensive and screening-level targeted monitoring, and randomization. Furthermore, these designs encompass both rotating watershed monitoring cycles as well as non-rotating priority-driven schedules.

The existing and proposed monitoring networks or program elements that will be needed to support Massachusetts' water resource management programs throughout the next ten years and beyond are presented here by monitoring objective. Some monitoring networks will yield data and information that may meet more than one objective. These are described under the monitoring objective that they are primarily designed to fulfill and other objectives that may, in part, be met are duly noted. Finally, an approximate time frame for implementing many of the monitoring program elements described in this document is presented in Appendix 1.

OBJECTIVE 1 – Assess the status or condition of Massachusetts' waters

Monitoring Objective 1 is to assess the water-quality status of Massachusetts' waters relative to the attainment of their beneficial uses, as designated in the SWQS. Requirements for a monitoring program designed to assess the status of designated uses are that it be statewide in scale, comprehensive (all waterbodies in the Commonwealth are assessed), and repeated at regular intervals. Furthermore, the design of this monitoring element should strengthen the s. 305(b) assessment process by increasing the number of stream miles and lake acres assessed and reducing the historical bias toward monitoring waters with known or suspected water quality problems. This expanded spatial coverage can be achieved through the use of probabilistic sampling designs that provide for statistically valid estimates of the use support status of 100% of the waters in a target population (e.g., shallow streams, deep rivers, lakes, etc.) with data and information collected from a random sample of those waters. EPA strongly encourages all states, nationwide, to adopt this approach for one or more waterbody types and/or designated uses. The following probabilistic and targeted monitoring networks will be used to assess the status of Massachusetts' waters for reporting in accordance with the requirements of s. 305(b) and s. 303(d) of the CWA. It should be noted that the data generated by the following networks do not constitute the only data and information used by MassDEP when assessing the condition of Massachusetts' waters. Depending upon the designated use under consideration, data and information from multiple sources may be used to make use assessment decisions. For example, bathing beach water quality is regulated by DPH under Massachusetts General Law and the Code of Massachusetts Regulations ("Beaches Bill"). These regulations require that all public and semi-public bathing beaches (e.g., beaches at camps, campgrounds, hotels, condominiums, country clubs) in the state be monitored for bacterial, and on occasion other environmental contamination during the bathing beach season. If water samples from a beach are found to be in exceedance of regulatory standards, the beach waters must be closed, and beach closures are considered when assessing the primary contact recreational use. Likewise, the Massachusetts Division of Marine Fisheries (DMF) monitors water quality and classifies shellfish growing areas. This information is used to assess the support status of the shellfish harvesting use. Finally, water quality status and trend information is available from EPA's National Aquatic Resource Surveys and National Estuaries Program (see text boxes below). Additional information on data sources can be found in Section VIII (Data Analysis and Assessment).

The EPA National Aquatic Resource Surveys: *The EPA National Aquatic Resource Surveys (NARS) employ statistically-valid, random sampling designs to assess the condition of aquatic resources on a national scale and track changes over time. Coastal waters, rivers, lakes and wetlands are surveyed on a rotating schedule. Each survey uses standardized field and lab methods and is designed to yield unbiased estimates of the condition of the whole water resource under evaluation. This program has demonstrated the utility of these designs for inferring conditions on a watershed, ecoregion, state, or larger scale. The use of NARS results for assessing Massachusetts' waters has been limited by the small number of randomly-chosen sites that fall within the Commonwealth, as well as some difficulty comparing NARS indicators and endpoints with Massachusetts' SWQS. For this reason, Massachusetts has not actively participated in the field or lab activities of the national surveys. However, Massachusetts has developed and implemented state-scale probabilistic sampling designs.*

The EPA National Estuary Program: *The National Estuary Program (NEP) is a non-regulatory program, authorized by s. 320 of the CWA, aimed at the protection and restoration of the water quality and ecological integrity of estuaries of national significance. Currently, 28 estuaries nation-wide are included in this program. Each NEP study area encompasses the estuary and surrounding watershed. The NEPs*

develop and implement Comprehensive Conservation and Management Plans (CCMPs), which are long-term plans that contain actions to address water quality and living resource challenges and priorities that are defined by municipal, state, federal, private and non-profit organizations. Each NEP has a Management Conference (MC) that consists of a diverse group of interested parties and uses a collaborative, consensus-building approach to implement the CCMP. Three NEP study units are focused entirely or partially on Massachusetts waters: 1) the Massachusetts Bays NEP (MassBays) which comprises 47 separate estuaries extending from the Merrimack/Black Rock Creek estuary near the New Hampshire boundary to Provincetown Harbor at the terminus of Cape Cod; 2) the Buzzards Bay NEP which covers 233 sq. mi. of estuaries and open bay along the 350 mi. coastline from the Rhode Island border to the tip of Cuttyhunk Island; and 3) the Narragansett Bay NEP which is focused on 196 sq. mi. of estuarine waters draining 1,700 sq. mi. of watershed located in Massachusetts (60%) and Rhode Island (40%).

1.1 The Massachusetts Monitoring and Assessment Program (MAP2) *(Rivers, Lakes)*

In 2010, MassDEP's surface water monitoring program initiated the implementation of a new, statistically-valid sampling design for Massachusetts' shallow streams. While making up the vast majority of river miles in the Commonwealth, many of these headwater streams and small tributaries to main stem rivers had not been monitored in the past, and a probabilistic design was chosen to provide an estimate of the condition of those waterbody types. The goals of the MAP2 were to provide an unbiased assessment of the aquatic life, recreational and aesthetic uses in wadeable, non-tidal perennial streams of Massachusetts, and, over time, to provide an analysis of trends in the use status of those streams.

The design framework for this probabilistic monitoring network is presented in Appendix 2. The random sampling design employed allows for the determination, with a known statistical confidence, the percentage of wadeable stream miles supporting and not supporting their designated uses. To implement the MAP2 survey, Massachusetts' 1^{st} – 4^{th} order streams were apportioned into five separate groups or strata, one of which – the "Northeast" – was chosen to be monitored in 2010. Likewise, the "Central," "Western," "Southeastern" and "Midwestern" watersheds were monitored in 2011, 2012, 2013 and 2014, respectively. However, because changes were made to the survey design after the first monitoring season (2010), a decision was made to repeat the monitoring in the "Northeast" watersheds in 2015 in accordance with the new sampling framework. Following the 2015 survey season, water quality and biomonitoring data were made available from approximately 180 randomly selected shallow stream sites, statewide, allowing for an assessment of the aquatic life, recreational and aesthetic use-support status of all shallow streams in Massachusetts. Furthermore, the MAP2 study was designed such that sufficient data would be collected from each of the monitoring sites in the network to allow them to be assessed individually for these same designated uses.

In addition to shallow streams, there exists a need to establish a more comprehensive monitoring program for assessing the condition of Massachusetts' lakes and ponds. Once again, a probabilistic sampling design will allow for statewide inferences to be drawn on the status of all lakes from an assessment of a random sample. To that end, MassDEP has initiated a statistically valid survey of approximately 75 lakes and ponds that will be completed over a period of three years (2016 – 2018). MassDEP reviewed the elements of the EPA's National Lake Assessment, along with its own data needs, to develop the monitoring objectives, select appropriate indicators and define the sampling frame for the network. The lakes survey design is presented in Appendix 3. Adequate spatial, temporal and analytical coverage is provided to assess the support status of designated uses at the individual lakes in the sampling network.

Estuaries and coastal areas are receiving increased attention as water quality problems become more apparent. Many estuaries in southeastern Massachusetts and Cape Cod, for example, are exhibiting signs of severe nutrient enrichment and efforts are underway to develop TMDLs and other restorative plans for these waters (see Massachusetts Estuaries Project). Further concerns pertaining to climate change and ocean acidification have also been raised. While MassDEP does not intend to include a probabilistic monitoring element for its coastal waters in this strategic plan, the need for targeted monitoring of these waters is currently under evaluation.

MassDEP will continue to employ random sampling designs to assess one or more designated uses in multiple waterbody types and report statewide survey results through the EPA web-based application designed for this purpose.

Resources needed to implement this monitoring element:

- *Funding to support full-time and seasonal monitoring staff*
- *Funding for field and laboratory equipment and supplies*
- *Funding for contract laboratory services for bacteriological and other biological analyses, such as taxonomic identifications of macroinvertebrates and phytoplankton*
- *Collaboration with the Department of Fish and Game (DFG) for fish community assessments (tentative)*

1.2 Targeted monitoring to support assessment and listing decisions *(Rivers, Lakes, Coastal waters)*

While the probabilistically derived sampling networks discussed above determine the percentage of stream miles or lake acres that are meeting water quality standards, they are not as useful for identifying individual impaired waters for listing pursuant to s. 303(d) of the CWA. Targeted monitoring designs will be used to confirm causes and identify sources of impairment or, alternatively, demonstrate that previously impaired waters are now supporting their beneficial uses and can be removed from the 303(d) list. The need for further data and information from specific waterbodies will be identified as part of the watershed assessment process, and these waters will then be targeted for monitoring. This monitoring may be performed in rivers, lakes or coastal waters, and can be carried out in accordance with a rotating watershed schedule such as the five-year cycle described earlier, or in selected watersheds in response to shifting program priorities.

It should be noted here that a number of water management functions rely on the availability of more directed and comprehensive sampling and analytical coverage. For this reason, MassDEP will continue to rely on deterministic monitoring to provide data in support of multiple watershed management objectives, as discussed later in this report. In any case, the scope of the targeted monitoring effort will depend upon the resources available and the prevailing water quality issues within each watershed.

Resources needed to implement this monitoring element:

- *Funding to support full-time and seasonal monitoring staff*
- *Expand laboratory and data analysis capabilities at WES, including equipment and staff*
- *Funding for equipment and supplies*
- *Funding to support outreach staff to increase data flow of quality-assured external data along with management and validation of data*

- *Investment in resources for data analysis and reporting*

1.3 Targeted monitoring to assess the fish consumption use *(Rivers, Lakes)*

Two MassDEP programs monitor contaminant levels in the edible tissues of freshwater fish: a screening program to provide data for the assessment of the risk to human consumers associated with the consumption of freshwater fish; and a research program designed to examine whether mercury levels in fish tissue are changing with time (i.e., trend analysis). The screening surveys support the determination of the edibility of freshwater fish and, thus, allow for the assessment of the fish consumption use as designated in the SWQS. This program is described in further detail below. The research program measures the overall effectiveness of multiple programs aimed at eliminating or reducing releases of mercury to the environment throughout Massachusetts and New England. More information on the research program is presented under Monitoring Objective 4.

The program to assess fish edibility, known as the "Toxics-in-Fish" monitoring program, is a cooperative effort that began over 30 years ago between MassDEP's Division of Watershed Management-Watershed Planning Program (DWM-WPP) and Office of Research and Standards (ORS), DPH and the Department of Fish and Game (DFG). The goal of this monitoring element is to provide data for the assessment of the risk to human consumers associated with the consumption of freshwater fish, and the majority of the fish are collected from waters requested by the public. Initially, fish collection efforts were generally focused on waterbodies where wastewater discharge data or previous water quality studies indicated potential toxic contamination problems. Fish were typically screened for the presence of mercury and other heavy metals, PCBs and organochlorine pesticides and their derivatives. Later, concerns about mercury contamination from both local and far-field sources led to a broader survey of waterbodies throughout Massachusetts. In both cases, the analyses have been restricted to edible fish fillets.

Uniform protocols, designed to assure accuracy and prevent cross-contamination of samples, are followed for fish collection, processing and shipping. Fish are typically obtained with electrofishing gear or gill nets. Lengths and weights are measured and fish are visually examined for tumors, lesions, or other indications of disease. Fish of the same species collected from the same location are typically analyzed as composites. DPH performs risk assessments and issues public health advisories (see http://www.mass.gov/eohhs/gov/departments/dph/programs/environmental-health/exposure-topics/fish-wildlife/fish/freshwater-fish-consumption-advisory-list-and-map.html.).

MassDEP intends to continue to work cooperatively with DPH and DFG to sample 5 -10 waters each year in response to public requests and provide contaminant data to DPH for risk assessment and management. In addition, there exists a need to expand the scope of fish toxics monitoring to include previously monitored waters, particularly those for which site-specific edibility advisories have been issued, to assess whether those advisories are still appropriate. This latter goal will not be realized without expanding staff and analytical laboratory capacity.

Resources needed to implement this monitoring element:

- *Funding to support full-time and seasonal monitoring staff*
- *Expand laboratory, risk assessment and data analysis capabilities at WES and ORS, including equipment and staff*
- *Funding for equipment and supplies*

1.4 The Conservation Assessment and Prioritization System (CAPS) and Rotating Wetland Assessments *(Wetlands)*

Detailed information pertaining to MassDEP's Wetland Monitoring and Assessment Program can be found at http://www.mass.gov/eea/agencies/massdep/water/watersheds/wetlands-protection.html#2. The MassDEP's Wetlands Program has been working collaboratively with the University of Massachusetts-Amherst (UMass) and the Massachusetts Office of Coastal Zone Management Program since 2006 to develop a strategy to monitor and assess wetlands for purposes of reporting on the status and trends of all wetlands across the state and for developing criteria to monitor and assess the physical, chemical and biological integrity of wetlands for reporting under s. 305(b) of the CWA.

The central feature of the Massachusetts strategy is the CAPS, a landscape-level assessment model that has been under development by UMass since 2000 (see http://www.umasscaps.org/about/index.html). CAPS combines land-cover mapping derived from GIS and aerial photography with 26 inland and coastal stressor or resiliency metrics, each representing a stressor on the environment, to calculate a value between 0 and 1 for each 30 square meter plot on the landscape. A complete list of metrics can be found at: http://www.umasscaps.org/about/metrics.html. The CAPS computer model can analyze individual metrics, or combine them to derive an Index of Ecological Integrity, or IEI. Wetland IEI values generated from the CAPS model define a continuous gradient that is inversely proportional to the magnitude of stressors acting on those wetlands (generalized stressor gradient). High IEI scores (approaching 1.0) are indicative of communities that are relatively free from stressors. The IEI is a *predictor* of the capacity of a wetland to sustain its ecological condition in the long term and to recover from stress.

MassDEP's Wetland Program monitoring and assessment strategy development is currently funded through the use of EPA Wetland Program Development Grants (WPDG's). In 2013 MassDEP's Wetland Program was awarded a WPDG to use the monitoring and assessment tools developed to date to sample 40 forested wetlands in the Chicopee River Watershed and use CAPS to assess those sites. This work was undertaken in 2014 to coincide with the MassDEP's five-year rotating watershed monitoring and assessment cycle. The sampling was conducted in accordance with the approved QAPP for Forested Wetland Monitoring and Assessment: Chicopee Watershed (available on-line at http://www.mass.gov/eea/agencies/massdep/water/watersheds/quality-assurance-project-plans-qapps.html). MassDEP intends to report the results, pursuant to s. 305(b) of the CWA, in the 2016 Massachusetts Integrated List of Waters. Wetlands monitoring was initiated in 2015 in the Shawsheen, Ipswich and Parker River watersheds in the northeast region of Massachusetts, and these assessments will be reported in future biennial integrated reports.

It should be noted here that the WPDG's awarded by EPA are specifically earmarked for the *development* of wetland monitoring and assessment programs, but are not to be used for program *implementation*. Therefore, MassDEP's wetland monitoring and assessment activities, beyond those currently funded through the WPDG, cannot be accomplished in the future without other/additional sources of funding. As such, the availability of a reliable source of funding is essential for the successful transition of MassDEP's wetland monitoring and assessment program from the development phase to implementation.

Resources needed to implement this monitoring element:

- *Funding to support full-time staff for monitoring, data management and analysis, and reporting*
- *Funding to support seasonal monitoring staff*
- *In-house or contract laboratory resources for processing macroinvertebrate and other biological samples*
- *Investment in GIS, statistical and other analytical capabilities*
- *Funding for equipment and supplies*

1.5 The MassDEP eelgrass mapping project *(Coastal Waters)*

The condition of seagrass meadows is a core indicator of the aquatic life use-support status of Massachusetts' shallow marine and estuarine waters. Seagrass beds provide food and cover for important fauna and their prey. Their leaf canopy calms the water, filters suspended matter and, together with their extensive system of roots and rhizomes, stabilizes sediment. Eelgrass, *Zostera marina,* is the most common seagrass present on the Massachusetts coastline. Seagrasses are sensitive to degraded water quality and the loss of seagrass beds has been linked to eutrophication resulting from excessive contributions of nitrogen from coastal watersheds. Therefore, the change in the distribution and abundance of seagrass over time is a sensitive indicator of environmental condition.

Losses or gains in seagrass beds are documented through the use of aerial photography, digital imagery and field verification. Furthermore, substrates are sandy along much of the Massachusetts coastline and this offers a useful color contrast for mapping the darker seagrass photo signatures. MassDEP initiated a program to map the distribution and abundance of seagrasses in Massachusetts' coastal watersheds in 1994. Prior to that time little was known of the areal extent of the eelgrass resource statewide and isolated reports had suggested that the resource was in significant decline. Known as the Eelgrass Mapping Project, the statewide seagrass mapping was completed in four phases beginning in 1994 and ending in 2012. The results of these individual mapping efforts provide the best available information on the coverage of eelgrass beds in Massachusetts and are available as data layers through the MassGIS (http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/eelgrass2013.html).

Resources needed to implement this monitoring element:

- *Funding to support full-time staff for monitoring, data management and analysis, and reporting*

OBJECTIVE 2 - Develop, implement and evaluate pollution control strategies

Targeted monitoring of lakes, rivers and estuaries is needed to provide data and information to support the development and implementation of various measures to restore impaired waters. These measures include the identification or verification of causes and sources of impairment, calculation and implementation of TMDLs and watershed-based plans to manage point and nonpoint sources of pollution, issuance of NPDES wastewater discharge permits, and installation of stormwater controls and BMPs. Monitoring to provide data to NPDES permit writers could be carried out on a rotating watershed regimen if it adhered to the schedule for issuing those permits. In most cases, however, monitoring to develop and implement control strategies is more likely to be scheduled to address high-priority-waters without regard to where they fall on a rotating monitoring plan.

In 2013, EPA announced a new framework for prioritizing and implementing TMDLs and related pollution control strategies. Guidance entitled *A Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program* (Vision) allows the states to adopt strategies for carrying out the requirements of s. 303(d) that are tailored to individual state water quality program goals and priorities. Furthermore, while the statutory and regulatory obligations to develop TMDLs for waters identified on s. 303(d) lists remain in place, and TMDLs will continue to be the prevailing mechanisms for addressing those waters, it is acknowledged in the Vision that under certain circumstances there are alternative restoration approaches that may be more immediately beneficial or practicable in achieving WQS than pursuing the TMDL approach from the beginning.

Regardless of whether states choose to derive TMDLs or opt for alternative approaches to restoring their impaired waters, the Vision guidance calls for the states to identify by 2016 their long-term s. 303(d) program priorities through fiscal year 2022 or beyond. This will provide states the opportunity to strategically focus their efforts and demonstrate progress over time in achieving environmental results. In addition, the Vision allows states to integrate s. 303(d) program priorities with other water quality programs. For example, integration with water quality monitoring programs can lay the groundwork for gathering the needed data to assess baseline conditions in priority waters, to develop TMDLs, watershed-based plans or other restoration and protection plans, or to determine progress in restoring or protecting those waters. It is anticipated that monitoring to support Objective 2 throughout the ten-year time horizon of this strategy will be closely tied to the priorities established as part of the s. 303(d) program Vision. Completed TMDLs reports can be found at the following link http://www.mass.gov/eea/agencies/massdep/water/watersheds/total-maximum-daily-loads-tmdls.html.

2.1 Targeted monitoring to support TMDL development *(Rivers)*

The TMDL process establishes the maximum allowable loading of pollutants that a waterbody can receive and still meet the standards established for protecting public health and maintaining the designated beneficial uses of those waters. Targeted monitoring is needed to: 1) characterize pre-TMDL baseline conditions; 2) support the calibration and verification of predictive computer simulation models; 3) estimate pollutant loads; and 4) evaluate alternatives and recommend management strategies to address impaired waters. Furthermore, monitoring will be needed to evaluate the effectiveness of pollution control measures after they are put in place (see Monitoring Objective 4 – Effectiveness Monitoring).

Bacteria and nutrients (i.e., phosphorus and nitrogen) account for over 60 percent of the use impairment of Massachusetts' waters, and the development of TMDLs or alternative plans to restore water quality has been, and will continue to be, focused on these pollutants over the next several years. To date, nutrient loading estimates and/or TMDLs have been derived for the Assabet, Blackstone, Charles, Nashua, and Taunton watersheds, primarily, through collaboration with the USGS and various other partners. Additional projects which include monitoring components are underway in the Merrimack (US Army Corps of Engineers and CDM Smith Inc.) and Mystic (Mystic River Watershed Association, MassDEP, EPA and USGS) watersheds. Finally, data from MassDEP's discontinued fixed-site monitoring network in central Massachusetts watersheds (1998 – 2013) are also available for making long-term pollutant load estimates. Bacteria TMDLs have been completed for the Charles, Cape Cod, Buzzards Bay, Taunton, Mount Hope Bay, Neponset, North Coastal and South Coastal watersheds.

MassDEP will continue to review monitoring needs for watersheds requiring TMDL or alternative plan development. In addition, it is anticipated that monitoring resources may be needed to inform adaptive management decisions in areas where TMDLs have been developed and water quality has improved due to the implementation of restorative measures. For example, the Assabet, Blackstone and Ten Mile watersheds are all considered potential candidates for intensive water quality surveys in the next few years. Data from a biological survey of the Blackstone River could serve to augment ongoing data collection efforts related to the development of a TMDL for phosphorus, and data from the Ten Mile River would be useful in evaluating TMDLs completed in Rhode Island for nutrients, metals and bacteria. Surveys of all three of these watersheds would provide measures of the effectiveness of TMDL implementation and/or NPDES permit issuance toward meeting water quality goals in these watersheds (see Monitoring Objective 4).

Resources needed to implement this monitoring element:

- *Funding to support full-time and seasonal monitoring staff*
- *Funding to support outreach staff to increase data flow of Quality Assured external data along*

with management and validation of data

- *Expand laboratory analytical capabilities at WES*
- *Funding to support USGS's Blackstone Stateline Monitoring Station for quantification of nutrient loads*
- *Ability to coordinate with bordering states on cross-border water quality investigations and monitoring*

2.2 Targeted monitoring to support TMDL development *(Lakes)*

The majority of the monitoring undertaken by MassDEP to support TMDL development by agency personnel has been performed in lakes. Historically, monitoring of lakes and ponds was conducted to: a) determine baseline lake conditions for assessment purposes, b) monitor post-implementation effects of lake restoration projects, and c) respond to public concerns about lake problems. In 1991 the MassDEP Clean Lakes Program, which for many years had provided federal and state grants to fund lake restoration projects, was eliminated and the responsibility for managing lake recreational areas was transferred to the Department of Conservation and Recreation (DCR). Lake monitoring at MassDEP was reduced to the use of synoptic surveys to provide limited assessments of the aquatic life and contact recreational uses.

Beginning in 1999, efforts were substantially increased to obtain lake data in support of the TMDL program. That year, approximately two dozen s. 303(d)-listed lakes and ponds were surveyed to provide information for the development of TMDLs for those waterbodies. The lakes chosen for study were all situated within the watersheds scheduled for monitoring by MassDEP. During the ensuing five years several lakes were monitored each year in accordance with MassDEP's rotating watershed schedule, and the data were subsequently used to develop nutrient TMDLs for selected lakes and ponds.

A multi-year, intensive effort to derive TMDLs and focus restoration activities on lakes impaired by commercial cranberry operations in southeastern Massachusetts was initiated in 2007 with the monitoring of both the east and west basins of White Island Pond (Plymouth). Data collection focused on phosphorus and nitrogen, but data on Secchi disk transparency, color, chlorophyll a and multi-probe data were also collected. Additional nutrient samples were taken from commercial cranberry bog waters as they were discharged to the lake. Sampling at White Island Pond continued annually through 2014 to support the development of the phosphorus TMDL and to assess the effectiveness of BMPs that were implemented at commercial cranberry bogs as part of the restoration of the lake. White Island Pond is expected to support aquatic life and recreational designated uses in the next few years and has been identified by EPA as a water quality improvement success story.

In addition to White Island Pond, several other lakes in the Plymouth area that were reported to be impacted by cranberry bogs were sampled in 2007 and 2008. These included Billington Sea, Bartletts Pond and Indian Brook Reservoir as well as some tributaries and/or commercial cranberry bog discharges thereto. In 2009, MassDEP initiated a sampling program for East and West Monponsett ponds (Halifax) as the next likely targets for TMDL development. Again, data collection focused on nutrients (i.e., phosphorus and nitrogen) and samples were collected from both the ponds themselves, inlet streams and cranberry bogs if they were discharging. This monitoring program has continued through 2015. Finally, in 2015, MassDEP initiated the sampling of two more southeastern lakes: Stetson Pond (Pembroke) and White Oak Reservoir (Hanson). MassDEP will continue to prioritize lakes and ponds for TMDL development in accordance with the CWA s. 303(d) Program Vision and, where necessary, formulate and carry out sampling plans to support that effort.

Resources needed to implement this monitoring element:

- *Funding to support full-time and seasonal monitoring staff*
- *Expand laboratory analytical capabilities at WES*
- *Investment in outreach staff to increase data flow of Quality Assured external data along with management and validation of data*

2.3 Targeted monitoring to locate sources of bacterial contamination *(Rivers)*

Bacterial contamination is one of the leading causes of water use impairment in Massachusetts waters. To combat this problem laboratory and limited personnel resources have been established in MassDEP's regional offices aimed at the formulation and implementation of protocols for locating sources of bacteria. While targeted monitoring is an integral component of the source locating process, the protocols also make recommendations for using the monitoring results to implement follow-up corrective actions. While the methodologies developed thus far are aimed at bacteria monitoring, the conceptual framework could be modified to identify sources of other contaminants, as well. A detailed QAPP has been prepared that outlines the details of each of the following steps in the process:

- Identify and prioritize contaminated subwatershed(s) for locating sources;
- Characterize the priority subwatershed(s);
- Design and carry out screening-level sampling; and
- Evaluate screening level data and design and perform source location monitoring.

Highlights of this targeted monitoring design include the use of GIS land-use coverages, other overlays, and orthophotos to identify potential sources, and the use of both dry-weather and wet-weather sampling to determine the contribution of stormwater runoff to the bacterial content of surface waters. The monitoring design employs an iterative sampling process that involves the adjustment of sampling site locations in response to a timely review of previous results in an effort to narrow down the exact location of the bacteria sources.

A key element of this program is the capacity to analyze a large number of samples while maintaining rapid turn-around time between the collection of those samples and the availability of the analytical results. This is essential for the determination of how to proceed with subsequent sampling. To this end, the MassDEP purchased and installed the IDEXX, Inc. Colilert® and Enterolert® testing systems at its regional offices. Use of this EPA-approved technology eases the burden placed on MassDEP's William X. Wall Experiment Station (WES) for bacterial analyses and decreases sample delivery time.

The sampling strategy includes the bracketing of suspected point sources (e.g., pipes, ditches, culverts) and non-point sources (e.g., specific land-use types, small tributaries, neighborhoods). Sampling stations also include baseline "pour point" stations established during screening level sampling to document and track reference conditions. Sampling results, associated subwatershed information, and local input are used to identify sources of bacterial contamination to the extent of the agency's jurisdictional authority, at a minimum. Appropriate authorities are notified of the suspected source(s) and recommendations for further source tracking work (e.g., for likely illicit discharges to storm sewer), clean-up, or enforcement action are made.

Resources needed to implement this monitoring element:

- *Funding to support BST monitoring staff and procure supplies in all four regions*
- *Expand laboratory analytical capabilities at WES*
- *Expand capabilities for identifying non-human sources (e.g., animal biomarkers, etc.)*

2.4 Massachusetts Estuaries Project (MEP) *(Coastal Waters)*

MassDEP continues to collect water quality data and hydrodynamic information, and derive TMDLs for nutrient-impaired coastal embayments in southeastern Massachusetts (i.e., Cape Cod, Buzzards Bay and the Islands) through collaboration with the School of Marine Science and Technology at UMass-Dartmouth and several municipalities that have been targeted for this project. This effort was initiated in 2001 to determine existing nutrient loads and to assist in the evaluation of future nutrient load scenarios for 89 estuaries located in 32 coastal communities. In 2009, the number of estuaries to be included in the MEP was reduced to 70 due to a lack of local matching funds and other project delays. The development of TMDLs to address nutrient impairments in shallow embayments in southeastern Massachusetts will continue to be a high priority for MassDEP for the foreseeable future.

The MEP utilizes a linked-model to quantify nitrogen inputs to targeted bays and estuaries and, where applicable, develop TMDLs to control those loadings. While most of the waterbodies selected for analysis were on the s. 303(d) list of impaired waters prior to the initiation of the MEP, some waters are actually assessed for the first time as part of the data evaluation and TMDL development process. In these instances, the monitoring component of the MEP also fulfills Monitoring Objective 1. As the MEP TMDLs are completed, monitoring will be needed to evaluate the effectiveness of their implementation. This effectiveness monitoring is discussed, briefly, under Monitoring Objective 4. More information pertaining to the MEP is presented at http://www.mass.gov/eea/agencies/massdep/water/watersheds/the-massachusetts-estuaries-project-and-reports.html.

2.5 Long Island Sound Study (LISS) *(Coastal Waters)*

Authorized by Congress in 1985, the LISS is a collaborative effort of the EPA, the states of Connecticut and New York and several other federal, state and local partners who are working to implement a Comprehensive Conservation and Management Plan to restore and protect the waters of the Sound. While the LISS has focused on a number of critical issues pertaining to the restoration of water quality and coastal habitats, a central feature of the program is the implementation of a TMDL to control hypoxia in the Sound that was formulated by Connecticut and New York and approved by the EPA in 2001. The TMDL calls for a 58.5 percent reduction of nitrogen loadings to the Sound from point and nonpoint sources of pollution. Following EPA's approval of the TMDL, the New England Interstate Water Pollution Control Commission established a Long Island Sound TMDL work group consisting of the representatives of the LISS, EPA and the five states with watersheds draining to Long Island Sound. This work group has identified the need to develop nitrogen loadings from the portions of the Connecticut Watershed lying within Massachusetts, New Hampshire and Vermont. Massachusetts will continue to work with the members of this committee to develop scientifically-defensible nitrogen load allocations, as well as an implementation strategy, for the Connecticut River Watershed in Massachusetts, New Hampshire, and Vermont, which are consistent with TMDL allocations established for the LISS.

Water quality monitoring of Long Island Sound has been an integral component of the LISS since its inception, and various monitoring programs aimed at obtaining data and information to support TMDL implementation and to document how the Sound responds to nitrogen loading reductions are described at

http://longislandsoundstudy.net/research-monitoring/water-quality-monitoring/. On behalf of the LISS the Connecticut Department of Energy and Environmental Protection, carries out a monitoring program in Long Island Sound. However, there is a need for water quality data from upstream sites along major rivers, such as the Connecticut, that discharge to Long Island Sound. For example the work group has identified the need for a monitoring station at the boundary between Massachusetts and Vermont and New Hampshire.

Resources needed to implement this monitoring element:

- *Funding for a project to establish state-line monitoring stations for quantification of loads*

OBJECTIVE 3 – Develop policies and standards and identify emerging issues

Short-term, project-scale investigations will be needed to support revisions to water quality standards and policies, and to identify and characterize emerging and ongoing water quality issues. Monitoring to meet this objective may be triggered by the results of other monitoring programs or by new information indicating potential risks to human or ecological health. For example, monitoring data collected for assessment purposes may be used to identify high-quality waters in need of protection from degradation, and additional monitoring data could be useful for defining the level of protection required. This objective will be achieved through the implementation, on a case-by-case basis, of various targeted monitoring program elements.

3.1 The Massachusetts Reference Site Network (RSN) to define reference conditions *(Rivers)*

MassDEP has identified the need to characterize the reference condition for Massachusetts' surface waters to support multiple program objectives including, but not limited to, the interpretation of biological data obtained from the probabilistic monitoring network (see Monitoring Objective 1), the development of nutrient criteria and biocriteria, and the assessment of climate change. For example, MassDEP is currently exploring the development of tiered aquatic life uses that will increase the accuracy of aquatic life use assessments and improve water quality goal-setting processes. An understanding of the inter-year and intra-year variation within indices of biotic integrity used for assessment is a critical initial step toward the development and implementation of biocriteria and tiered aquatic life use. Furthermore, long-term monitoring of least-impaired streams will help to define how global changes in climate are affecting water chemistry and biota in Massachusetts' waterbodies. Finally, although not the primary objective of this monitoring program element, data obtained from this network may also provide sufficient information to perform use assessments of these particular streams (i.e., Objective 1).

Least-disturbed reference sites on shallow streams were selected from the two most prominent Level III ecoregions (Northeastern Highlands, Northeastern Coastal Plain) in Massachusetts through the application of a Human Disturbance Index that was derived from six individual streamflow and landscape disturbance indicators. A total of ten (10) sites were chosen for intensive study beginning in 2011. Six additional sites were added to this network in 2012. While a few sites have been dropped over the years due to such factors as beaver activity or intermittency, the overall network had expanded to a total of 28 sites by 2015. The primary objective at each sampling site is to collect sufficient data to begin evaluating inter-year and intra-year variation in the biological communities at the end of the project. Monitoring activities include habitat assessment; macroinvertebrate, fish population and periphyton assessments; and physicochemical sampling.

Approximately monthly, from May to September, grab water samples are collected at each site in the RSN and analyzed for nutrients (total phosphorus, total nitrogen and ammonia nitrogen), chloride, turbidity and color. In addition, temperature sensors are deployed at all sites from May to October to obtain long-term, continuous water temperature data. The benthic macroinvertebrate community is sampled once a year at each site in accordance with Rapid Bioassessment Protocols (RBP) III or a modification thereof, depending upon available habitat. For example, typical RBP III kick-sampling protocols cannot be used at low-gradient sites so a multi-habitat sampling method (i.e., multiple net sweeps) is employed. Fish community sampling for the presence/absence of resident fish species is performed at each site once during the late summer. Finally, periphyton community assessments are performed at a subset of the sampling sites.

Resources needed to implement this monitoring element:

- *Funding to support full-time and seasonal monitoring staff*
- *Expand laboratory and data analysis capabilities at WES and ORS, including equipment and staff*
- *Funding for equipment and supplies*

3.2 Monitoring to support criteria development *(Rivers, Lakes, Coastal waters)*

The MAP2 and RSN monitoring networks described above continue to provide phosphorus and nitrogen data from wadeable rivers and streams that support multiple water management objectives, including the derivation and refinement of nutrient criteria. In addition to these stream data, MassDEP sampled a total of 70 lakes and ponds statewide in 2003 and 2005 specifically to obtain data in support of the development of phosphorus criteria. MassDEP utilized phosphorus data from both streams and lakes to establish recommended guidance concentrations for total phosphorus in Massachusetts' waters. The technical analysis that formed the basis for these recommendations was supported, in part, by EPA's Nutrient Scientific Technical Exchange Partnership & Support (N-STEPS) program and is presented in *Draft Phase I Phosphorus Guidance for the Restoration of Massachusetts Lakes, Rivers, and Streams*. This report describes how Massachusetts' rivers and lakes were categorized for the analysis and how the water quality data collected from those rivers and lakes were used to relate total phosphorus concentrations to threshold values established for biological response indicators adopted in Massachusetts' Consolidated Assessment and Listing Methodology (CALM) manual (see Section VIII for more information on the CALM manual). Likewise, MassDEP has obtained support from N-STEPS to develop numeric nitrogen targets aimed at restoring impaired estuaries and coastal waters. The overall objective of this project is to establish nitrogen concentration goals for various classes of coastal waters that are not presently covered by TMDLs, as well as to develop target nitrogen concentrations for rivers that discharge to those coastal ecosystems. These nitrogen guidance values will be used to support NPDES permitting decisions.

As resources allow, MassDEP will continue to collect and analyze nutrient data and biological information from Massachusetts' waters to further refine guidance on the assessment and control of nutrients. For example, a greater understanding is needed of how environmental factors, such as light availability, substrate type, flow and the presence of wetlands, in combination with a range of instream nitrogen and phosphorus concentrations, all affect the amount of instream algal biomass present at any point in time. For rivers, in particular, additional efforts are needed, to refine the threshold values for the biological response indicators of nutrient enrichment, and to improve sampling designs aimed at measuring those thresholds.

In addition to nutrients, MassDEP anticipates the need for data and analytical support for developing criteria for several other pollutants and indicators of water integrity to be adopted in future revisions of the

SWQS. For example, in order to understand water quality conditions in Mount Hope Bay and the Taunton River Estuary, MassDEP in partnership with the Rhode Island Department of Environmental Management (RIDEM), and the University of Rhode Island (URI) Marine Ecosystem Research Laboratory (MERL) collected data during the 2016-2017 field season using two buoys located in Mount Hope Bay south of the mouths of the Cole and Taunton rivers. The buoys fill critical data gaps and are an extension of the Narragansett Bay Fixed-Site Monitoring Network (NBFSMN). The buoys were used to collect continuous measurements of dissolved oxygen, temperature, salinity, pH, nitrate-nitrogen, and chlorophyll a. This information will be used as part of a larger monitoring strategy (in development) for the Mount Hope Bay and the Taunton River Estuary. The information will be used to understand water quality, guide nutrient management decisions and to inform MassDEP's review of its marine dissolved oxygen criteria. In addition, clarification of instream aluminum criteria for fresh water may be needed. Finally, MassDEP is pursuing the development of biological criteria which will strengthen the process for assessing the status of the Aquatic Life use. To that end, biological monitoring will continue to be a critical component of the DWM-WPP surface water monitoring program, and the use of various techniques for interpreting biological data (e.g., multi-metric indices of biotic integrity; biocondition gradient; tiered aquatic life use, etc.) will be explored.

The above discussion presents examples of the issues confronting MassDEP over the next several years. To address them, partnerships with federal agencies like EPA or USGS and/or other potential contractors will be needed for data exploration, analysis, modeling and other technical support.

Resources needed to implement this monitoring element:

- *Funding to support full-time and seasonal monitoring staff*
- *Funding for equipment and supplies*
- *Expand laboratory analytical capabilities at WES*
- *Funding for contractual support (e.g. N-STEPS, biocriteria development, aluminum, marine dissolved oxygen etc.)*

3.3 Assessing and managing potentially toxic algae blooms *(Rivers, Lakes)*

MassDEP provides technical expertise and laboratory support to the investigation of potentially toxic algae (cyanobacteria) blooms. Working in collaboration with DPH, MassDEP performs cyanobacterial counts and identifications on water samples to determine whether cell counts exceed DPH's advisory levels for recreational waters, resulting in the issuance of public advisories against swimming or contact due to toxic cyanobacteria.

MassDEP intends to continue to work in collaboration with its sister environmental agencies, public health officials and other interested parties to develop a comprehensive program aimed at monitoring and managing the human health and ecological risks associated with algal blooms in Massachusetts' waters. Beginning in 2015, increased attention was focused on the use of metered probes to measure the magnitude and extent of cyanobacteria blooms. These probes analyze for the presence of phycocyanin, the dominant pigment of the cyanobacteria. After enough data of each type have been gathered, the relationships between phycocyanin levels, concentrations of individual algal toxins and cell counts will be determined so that taxonomic identifications and cell counts, which are time consuming and require specialized training, will not be needed to indicate that a cyanobacteria bloom is occurring. However, some identifications and counts will still be needed to verify the dominant taxa present in the bloom since the potential to produce different toxins is species-specific.

The ongoing development of methods to make cyanobacteria population measurements easier to obtain will be a benefit to those monitoring both recreational and drinking water, and may provide some means of monitoring our coastal waters, as well. Phycocyanin probes and dataloggers can provide real benefit to emergency responders or others monitoring recreational waterbodies or drinking water reservoirs since results are obtained quickly. Measurements can also be obtained over a large spatial area or at depth. Efforts are being made to train MassDEP staff in the use of these probes in case an emergency occurs. MassDEP is currently formalizing procedures for documenting reports of algae blooms and developing data systems to manage this information. The information will be used to map and monitor the incidents of potentially toxic algae (i.e., cyanobacteria) blooms in Massachusetts.

In addition to the activities described above, MassDEP is participating in the EPA Region 1 Cyanobacteria Monitoring and Bloom Watch Pilot Program. A work group consisting of state environmental and public health officials from the New England states and New York, as well as tribes, public water suppliers, NGOs and other interested parties has initiated a pilot cyanobacteria monitoring program that is designed to be integrated into existing monitoring programs and uses consistent sampling and analytical protocols to allow for region-wide data analysis and interpretation.

Resources needed to implement this monitoring element:

- *Funding to support full-time and seasonal monitoring staff*
- *Expand laboratory, risk assessment and data analysis capabilities at WES and ORS*
- *Funding for equipment and supplies*

3.4 Monitoring to assess climate change *(Rivers)*

As suggested earlier, data and information from the RSN may provide baseline data and information for documenting the effects of climate change on Massachusetts' waters. In addition, MassDEP staff continue to monitor air and water temperature and collect macroinvertebrate samples at five sites in Massachusetts as part of an ongoing collaborative effort among multiple federal and state agencies, NGOs, and academic institutions across New York and New England to assess the effects of climate change in the Northeast. Spearheaded by EPA, this effort is aimed at coordinating temperature and biological data collection across the region. Similar "regional" collaborations have been established across the country. The five Massachusetts sites are Hubbard River in Granville, Brown's Brook in Holland, Parker's Brook in Oakham, West Branch Swift River in Shutesbury, and Cold River in Florida. UMass/Amherst and DFG's Division of Ecological Restoration (DER) are the other partners on the "Massachusetts Team." DER has installed flow-gauging equipment at the three sites without USGS gauges and is developing flow rating curves for them. UMass is playing a coordinating role and also plans to address the fisheries component.

Resources needed to implement this monitoring element:

- *Funding for equipment and supplies*
- *Funding for full-time and seasonal monitoring staff*

3.5 Monitoring new and unforeseen contaminants *(All water types)*

Monitoring data may be needed in the future to assess and manage currently unregulated and unforeseen contaminants. For example, the fate and transport of pharmaceuticals and personal care

products in the environment and their potential effects on public health and aquatic life are emerging issues that are in need of further investigation. Priority-driven targeted monitoring of selected contaminants in water, sediments or biota may be performed, in limited instances, to respond to emergency situations or to answer specific questions pertaining to the presence of new or unusual contaminants in selected waterbodies. This could include monitoring of emerging contaminants, such as perfluorinated compounds, in biota.

The introduction of non-native species to Massachusetts' waters, while not a new problem, continues to emerge as an issue of critical concern. Invasive, non-native species populations disrupt or replace indigenous species populations, reduce biological diversity and impair aquatic life use support. MassDEP intends to work with other agencies and partners to document the presence of non-native species populations and, where applicable, develop strategies for their control.

Resources needed to implement this monitoring element:

- *Funding to support full-time and seasonal monitoring staff*
- *Funding for equipment and supplies*
- *Expand laboratory risk assessment and data analysis capabilities at WES and ORS*
- *Funding for field sample collection and analyses*

OBJECTIVE 4 – Measure the effectiveness of water quality management programs

Working with its many and varied partners, MassDEP administers a number of water quality management programs and activities including, but not limited to, TMDL development, NPDES wastewater discharge permitting and s. 319 NPS control. Data and information are needed to assess the effectiveness of all of these programs in restoring and protecting Massachusetts' water resources. Effectiveness monitoring can be designed and carried out at various scales ranging from the local, waterbody or segment-specific level to broader-scale watershed or statewide levels of coverage. In any case, the need exists to periodically resurvey those waters that were originally determined to be impaired, and for which pollution abatement activities have been carried out, in order to document water quality improvements or demonstrate the need for further restoration through adaptive management.

Waters exhibiting improved water quality, whether fully restored or not, may be candidates for the preparation and release of water quality "Success Stories", as called for in s. 319 guidance. The EPA's National Water Program Guidance has established performance measures to be used to report on waters that have been fully or partially restored (measures "L" and "Y", respectively), or that have exhibited demonstrable improvement in water quality (measure "W"). Monitoring program elements will be designed to assess the efficacy of Massachusetts' water resource management activities in ameliorating water pollution, and the findings will be reported to the EPA through the use of the "L", "Y" and "W" performance measures. While the ultimate goal is for all impaired uses associated with a particular waterbody to be fully restored, resulting in its removal from the s. 303d list, the use of these performance measures will demonstrate interim progress toward meeting that goal.

In general, targeted monitoring designs will be most suitable for evaluating the effectiveness of water-body and watershed restoration activities, and feedback from the watershed assessment process may be useful for selecting waters for future investigation. Statewide probabilistic surveys, repeated every five or ten years, may also be useful in demonstrating, more holistically, the longer-term environmental benefits of Massachusetts' water resource management programs including, but not limited to, NPDES, TMDL implementation plans, watershed-based plans, and NPS implementation grants.

4.1 Targeted monitoring to measure success of TMDL implementation *(All water types)*

To date, most TMDLs for Massachusetts' impaired waters are focused on controlling nutrients (e.g., phosphorus and nitrogen) and bacteria and many have been completed through the use of contractual services. However, post-TMDL monitoring is now a high priority of the EPA, and MassDEP will place increased emphasis over the next ten years on evaluating the effectiveness of TMDL implementation plans in reducing pollutant loadings to impaired waters. Post-implementation monitoring will be conducted outside of MassDEP's five-year rotating watershed cycle and priority will be given to watersheds where approved nutrient or bacteria TMDLs are already in place and there is evidence to suggest that monitoring is warranted.

For example, the Assabet River watershed is a likely candidate for intensive monitoring. All wastewater treatment plant upgrades in this watershed were completed in 2012, and data from weekly, flow-proportional composite instream samples collected since that time by the USGS indicate that annual median total phosphorus concentrations have been reduced by approximately 50 percent. Results of MassDEP's duckweed monitoring efforts in the Assabet River (2009 – 2014) suggest that duckweed levels are on the decline. However, preliminary indications are that other vascular plant and algal populations remain at levels that would preclude the removal of the Assabet River from the s. 303(d) list. One or more intensive water quality and biological surveys will be needed to provide the spatial, temporal and analytical coverage required to determine whether designated uses have been restored in the Assabet River, thus allowing for its delisting.

Massachusetts' CALM document describes the kinds of data and information that are needed to carry out the use assessment process. MassDEP will continue to explore opportunities to use monitoring data collected by the Organization for the Assabet, Sudbury and Concord Rivers to measure long-term water quality trends. To do so will likely necessitate adding winter time sampling and flow measurements to their existing monitoring program. Likewise, the need exists for data and information from the Charles River watershed to evaluate the effectiveness of ongoing TMDL implementation activities. Once again, existing data from external partners, such as the Massachusetts Water Resources Authority and the Charles River Watershed Association may be suitable for this purpose. Intensive water quality and biological surveys may be needed to assess whether formerly impaired waters have been restored.

Intensive monitoring in the Blackstone River Watershed is expected to continue over the next few years in collaboration with the Upper Blackstone Water Pollution Abatement District, UMass-Amherst, and other groups. Although a TMDL for phosphorus has not been approved for the Blackstone River, NPDES permits with stringent effluent limits on phosphorus have been issued, and improvements designed to meet those limits have been made at municipal wastewater treatment plants. Biological monitoring of the Blackstone River is needed to augment past and ongoing monitoring and inform future water quality management activities.

Finally, data will be needed in the future to document water quality improvements at sentinel stations in coastal waters where nitrogen TMDLs are being implemented as part of the MEP. While it is anticipated that this monitoring will be the responsibility of individual municipalities, MassDEP will provide guidance on the design and implementation of these monitoring programs.

Resources needed to implement this monitoring element:

- *Funding to support full-time and seasonal monitoring staff*
- *Funding for equipment and supplies*
- *Expand laboratory and data analysis capabilities at WES*
- *Invest in outreach staff to increase data flow of Quality Assured external data along with management and validation of data*
  Funding for contractual support

4.2 Cape Cod Section 208 Plan *(Coastal Waters)*

In September 2015 EPA approved Cape Cod's final Section 208 Areawide Water Quality Management Plan Update. This is a watershed-based approach to restoring coastal embayments on Cape Cod. The plan recommends strategies for reducing or eliminating excess nitrogen, a primary cause of coastal degradation on the Cape. The Cape Cod Section 208 Plan Update can be found at http://www.capecodcommission.org/index.php?id=491&maincatid=76.

Through the MEP program, discussed in Section 2.4, MassDEP continues to support the collection of water quality data and hydrodynamic information, and derive TMDLs for nutrient-impaired coastal embayments on Cape Cod. These TMDLs help Cape communities target implementation and monitoring efforts to reduce or eliminate nitrogen inputs into coastal waters.

4.3 CWA Section 319 effectiveness monitoring

The demonstration of measurable improvements to water quality associated with the implementation of s. 319-funded NPS pollution control projects is an important component of state NPS monitoring programs. EPA encourages states to identify waters impaired by NPS pollution that have been the focus of restoration activities, such as the installation of BMPs, and perform monitoring to demonstrate resulting improvements. As described above, waters exhibiting improved water quality, whether fully restored or not, may be candidates for the preparation and release of water quality "Success Stories."

Many of MassDEP's surface water monitoring program elements are aimed at collecting data to support assessment and listing decisions and to identify causes and sources of use impairment in accordance with the requirements of s. 305(b) and s. 303(d), or to support TMDL development and implementation. Monitoring to detect changes in water quality brought about by the implementation of s. 319-funded projects will likely need to be carried out at a smaller local scale than that performed to meet other CWA objectives. Even in a small watershed, a substantial amount of s. 319 funded work will need to be completed (e.g., more than just a single BMP installation) in order to discern a measurable water quality response. Furthermore, EPA s. 319 effectiveness monitoring guidance calls for statistical sampling designs that will document, with a stated level of confidence, that water quality improvements have been achieved. Monitoring to meet the exacting standards of the NPS monitoring guidance will present a challenge to MassDEP over the next several years.

The National Water Quality Initiative (NWQI), administered by the Natural Resources Conservation Service (NRCS), provides financial assistance to farmers and ranchers for the application of conservation systems to reduce nitrogen, phosphorous, sediment and pathogen contributions to surface waters from agricultural land. The NRCS has worked closely with its partners, including federal and state agencies, and soil and water conservation districts, to identify from one to twelve priority watersheds in each state

where on-farm conservation investments will result in the greatest water quality benefits. The Palmer River Watershed was chosen as the priority watershed for focusing NWQI funding in Massachusetts.

EPA guidelines require the state water quality agency (i.e., MassDEP) to undertake monitoring to demonstrate the effectiveness of conservation practices implemented by the NRCS in the Palmer River Watershed. EPA developed a monitoring plan that found significant challenges associated with this requirement. MassDEP, with EPA, has been conducting a bacteria source tracking program in the target watershed for several years, and it was hoped that this would provide adequate baseline data for the NWQI task. EPA found that significant additional sample collection over several years would be necessary to detect a meaningful signal, and only if conservation practices could be applied over a very large portion of the watershed using a carefully designed implementation plan. Furthermore, s. 1619 of the federal Farm Bill prohibits water quality regulatory agencies from accessing the location and details pertaining to BMP implementation or other farm practices that may have been implemented and, therefore, monitoring cannot be designed to measure the effectiveness of those practices. Nonetheless, MassDEP will continue to explore various sampling designs that can be employed in waters where discernible water quality responses to conservation practices are anticipated. Where feasible, s. 319 effectiveness monitoring will be prioritized and integrated with other targeted surface water monitoring elements to facilitate planning and make efficient use of existing monitoring resources and logistics.

Resources needed to implement this monitoring element:

- *Funding to support full-time and seasonal monitoring staff*
- *Funding for equipment and supplies*
- *Expand laboratory and data analysis capabilities at WES*
- *Funding to support outreach staff to increase data flow of Quality Assured external data along with management and validation of data*
- *Funding for contractual support*

4.4 Monitoring trends in the mercury content in fish *(Lakes)*

Since 1994, MassDEP's Office of Research and Standards (ORS) has carried out a series of research projects designed to monitor, both spatially and temporally, the tissue burdens of mercury in fish as part of its larger efforts to understand and control the inputs and effects of mercury in the environment in Massachusetts. Furthermore, the use of statistically valid study designs allows for the determination of long-term trends in mercury concentration, thus providing a measure of the overall effectiveness of multiple programs aimed at the elimination or reduction of mercury releases to the environment.

A statewide survey of mercury in freshwater fish was conducted in 1994, and this was followed in 1999 by an investigation of fish in a specific region of the state that was thought to receive greater atmospheric deposition of mercury. In addition, seasonal variation in fish tissue mercury was examined in 2001 and 2002, and this led to the decision to limit future collections of fish for the assessment of trends in mercury content to the spring.

In 2001, MassDEP initiated long-term monitoring at 20 lakes to track temporal changes in the mercury contamination of fish. Since that time, the number of lakes monitored has expanded to almost 50. Due to resource constraints current monitoring is focused on a subset of water-bodies with about 7-9 sampled each year on a rotating basis. A statistically-valid sampling regimen is employed in order to determine, at a specified level of confidence, whether mercury concentrations in fish are significantly higher in some areas of the state than others and whether, over time, those concentrations are increasing, decreasing or remaining constant. Lakes are sampled on a rotating schedule. During each sampling event an attempt is

made to obtain edible muscle tissue samples from 30 yellow perch and 12-15 largemouth bass and each individual sample is assayed for total mercury. This sample size allows for a more rigorous statistical analysis of the data. MassDEP intends to continue the long-term monitoring program as resources allow. Data on water quality parameters for sampled lakes are also collected. A list of the lakes and ponds included in ORS' long-term monitoring program, and their sampling history is provided in Appendix 4.

Resources needed to implement this monitoring element:

- *Expand laboratory and data analysis capabilities at WES and ORS*
- *Funding for equipment and supplies*
- *Funding for contracting services to conduct field sampling*

OBJECTIVE 5: Maintain reserve monitoring capacity to respond to unforeseen data needs

MassDEP has a goal to reserve some field and lab resources each year to accommodate unforeseen monitoring projects or requests for assistance that may arise unexpectedly and outside of the normal program planning process. Unanticipated data needs and emergencies can usurp monitoring resources and disrupt planned monitoring activities, particularly when all of the monitoring resources have already been allocated to those planned activities. Recent (2016) examples of unforeseen projects include support in QAPP development for the Lowell Regional Waste Water Treatment Utility, the National Water Quality Monitoring initiative in the Palmer River Watershed, the deployment of ISCO samplers and sondes in the Mystic River and the deployment of two Marine Monitoring Buoys in Mount Hope Bay and the Taunton River. The goal is to devise an annual monitoring program that utilizes less than 100 percent of the available monitoring personnel resources and laboratory capacity in order to ensure that unforeseen monitoring needs are met with minimal impact on planned monitoring activities.

VI. Quality Assurance

A system for assuring the reliability of scientific data and related information is an essential component of any environmental monitoring program. It is an EPA requirement (EPA Classification No. CIO 2106.0) that any individual or group performing work for or on behalf of the EPA needs to establish a quality system to support the development, review, approval, implementation, and assessment of data collection operations. MassDEP is committed to ensuring that the monitoring data used to support the various water quality management activities specified in the CWA are of known and documented quality. Fundamental support for MassDEP's quality system is the EPA-approved Quality Management Plan for Federally Funded Programs (QMP). The QMP describes each element of the total quality system employed by MassDEP, including the policies and procedures used by MassDEP to make certain that all data and information collected in support of programs to assess, protect and improve the environment are sufficient for their intended purposes.

Within the DWM-WPP, surface water monitoring is conducted under an EPA-approved, programmatic QAPP. DWM-WPP's programmatic monitoring QAPP is consistent with the intent of EPA's Quality Policies and guidance for non-EPA organizations. The 2015-2019 QAPP, for example, documents in detail all aspects of the monitoring program, including goals and objectives, sampling design(s) and logistics, data quality objectives (DQO), equipment, personnel and training needs, quality control sampling data validation and management, and reporting elements. The program QAPP and supporting documentation are submitted to EPA for review and approval before project work is initiated. In addition to this overarching QAPP, individual Sampling and Analysis Plans (SAP) are prepared annually for each monitoring project. SOP documents are maintained for all field and laboratory operations and are revised

as needed to reflect changes in methodologies. All field and laboratory personnel receive periodic training in the execution of the SOPs. Monitoring SOPs include but are not limited to sampling and analysis for benthic macroinvertebrates, fish tissue toxics, ambient water quality, benthic algae, fish communities and aquatic plants. In addition to the WES laboratory, the DWM-WPP often uses contract labs for sample analysis. All laboratories are evaluated for analytical accuracy and precision using double-blind QC samples, Proficiency Testing materials and/or inter-laboratory comparison testing.

In order to ensure a high degree of relevance and validity for computer modeling results, DWM-WPP developed an EPA-approved TMDL modeling QAPP in 2010. The modeling QAPP covers quality assurance and quality control aspects of water quality modeling, with specific emphasis on model applications related to TMDL development, and is intended to generally cover the most important factors that affect the credibility of model results, such as model selection, quality of input data, meeting DQOs for model parameterization (calibration), adherence to good modeling practices, sensitivity analyses and overall uncertainty estimates for model output. The TMDL modeling QAPP is an appendix to the DWM-WPP programmatic QAPP that was re-approved for five years in July, 2016 (see Appendix C here: http://www.mass.gov/eea/agencies/massdep/water/watersheds/environmental-monitoring-quality-management-program.html).

It should be noted that the demand for valid water quality information is expanding while the state resources to meet that demand are declining. Water quality data and information are being collected by numerous parties and organizations with the intent that DWM-WPP will use their information for making use assessments and other watershed management decisions. In order for the information gathered by external data collectors to be used by the DWM-WPP, infrastructure must be developed to support outreach activities and communication, formulation and review of SOPs, SAPs and QAPPs and data validation and analysis. This need is compounded by gaps in the baseline program resources that are needed to coordinate staff training exercises, coordinate with laboratories, perform field and laboratory audits, manage data validation, and serve as a liaison between DWM-WPP and EPA quality assurance personnel.

DWM-WPP's commitment and strong emphasis on quality data and quality decision-making remains a core operating principle. To the extent feasible, QA duties have been prioritized and redistributed among staff as needed. Each DWM-WPP staff person is responsible for adhering to the requirements of MassDEP's QMP and ensuring that MassDEP-endorsed quality control processes, procedures and policies are applied to the collection, management and analysis of data. This includes becoming familiar with the QMP and his/her individual duties and responsibilities, applying QA/QC principles and practices when appropriate, attending QA/QC-related training sessions as needed, developing SOPs and guidelines for staff use, following approved QA/QC protocols (QAPPs, SOPs, etc.) and maintaining competency in individual duties and responsibilities.

Resources needed to implement this program element:

- *Funding for full-time staff resources to manage DWM-WPP QA/QC Program*
- *Funding for full-time staff resources to assist with data validation of external data sources*

VII. Data Management

Since 1994, DWM-WPP has maintained several independent stand-alone databases in several different formats to store monitoring results from its surface water quality monitoring program. In 2015, DWM-WPP procured and began using EQuIS, a commercial off-the-shelf software solution, in order to consolidate,

streamline and standardize data handling and QA/QC activities, as well as provide tools for data sharing with the public and EPA via WQX. The primary purpose of implementing EQuIS is to provide safe long-term storage of quality assured physical, chemical, and biological sampling data and appropriate metadata for water quality assessments and other planning needs at the DWM-WPP.

DWM-WPP's implementation of EQuIS will include the following data types:

- Ambient surface water quality data (Physical/Chemical results)
- Benthic macroinvertebrate data
- Fish community data
- Fish toxics data
- Algal data
- Fieldsheet metadata

The data/information maintained in EQuIS, other DWM-WPP databases and information warehouses facilitates MassDEP meeting its key obligations under the CWA. The data systems at DWM-WPP support statewide waterbody assessment and cleanup activities and production of the s. 305(b)/303(d) Integrated Report, development of TMDLs, and use of the EPA assessment databases (see below).

Attention to quality is a fundamental principle applied to all phases of DWM-WPP's data systems, from primary collection of data and metadata to final presentation and storage. Critically important functions supporting data management include QA/QC planning, documentation, data entry, waterbody identification, station registration using GIS, data validation procedures, Laboratory Information Systems coordination and the use of Electronic Data Deliverables.

In order to translate preliminary data collected in the field, logged on continuous probes and generated by analytical laboratories into final data, DWM-WPP applies extensive standardized procedures to compile, automate and validate the data. These procedures are well documented in DWM-WPP SOPs, and include review of both field-recorded data and laboratory analytical data for conformance with the DQOs established in project-specific or programmatic QAPPs and SAPs. Detailed analysis of all available information, such as field notes, survey conditions, field and lab QC data and audit results that could affect data quality is performed. WPP's data validation process is in addition to separate quality assurance and quality control activities performed at the WES laboratory (or any other analytical laboratory). Using this system, DWM-WPP can accept, qualify or censor data results. Qualified data are still considered usable, albeit with caveat. Once data are validated, they are batch-uploaded to the main COTS database, and available via a separate data warehouse. Biological data are finalized through separate QC review procedures.

DWM-WPP stores the results of its watershed assessments segment-by-segment in the Assessment Database (ADB) developed by the EPA. The ADB is a relational database for tracking water quality assessment data, including use attainment decisions, and causes and sources of impairment. The ADB was designed to make the reporting of assessment and listing decisions accurate, straightforward and user-friendly. A new Assessment TMDL Tracking and Implementation System (ATTAINS) will be replacing the ADB for reporting for the 2018 s. 305(b)/303(d) reporting cycle and beyond.

Data are made available to outside parties via the following MassDEP web page: http://www.mass.gov/eea/agencies/massdep/water/watersheds/water-quality-monitoring-program-data.html In addition, the DWM-WPP transmits data and information to the MassDEP regional offices, other programs, EPA, and the general public in response to formal requests.

Resources needed to implement this program element:

- *Funding for EQuIS in FY18 and beyond*
- *Funding for electronic tablets for field survey metadata using the EQuIS module; this will eliminate paper records and streamline field data collection*
- *Investment in resources to manage continuous data sets*
- *Funding for Exchange Network Grant applications*
- *Investment in technology and/or expertise to develop an on-line data viewer*

VIII. Data Analysis and Assessment

Results of MassDEP's monitoring efforts, combined with other credible data and information, constitute the basis for making water quality assessments in accordance with the requirements set forth in s. 305(b) of the CWA. Use-attainment determinations are made for each waterbody segment for which adequate data and information are available. However, many waters are not assessed for one or more uses in any given assessment cycle, and many small and/or unnamed streams and ponds have never been monitored or assessed. In the past, individual use assessment decisions, along with supporting water quality data and information, were documented in individual watershed assessment reports. These earlier reports are available for all of Massachusetts' watersheds and coastal drainage areas at http://www.mass.gov/eea/agencies/massdep/water/watersheds/water-quality-assessments.html.

In 2002, EPA published the *Consolidated Assessment and Listing Methodology – Toward a Compendium of Best Practices* or CALM Document (EPA 2002) aimed at improving states' monitoring and assessment programs and making data and information more available to the public. The CALM Document provided guidance to the states on how to update and clarify the decision making process for assessing the attainment of water quality standards. Prior to the 2012 CWA integrated reporting cycle the MassDEP included its assessment procedures in individual watershed assessment reports. For the 2012 IR, however, MassDEP published a stand-alone CALM Guidance Manual that contained a brief summary of the SWQS that define the goals for water quality in the state, the requirements for assessing the quality of data to be used for CWA reporting, the methods of reviewing water quality data and information used by the MassDEP to make use assessment decisions, and the use of the ADB for storing and reporting those decisions in the IR format. Extensive revisions were made to the Massachusetts CALM manual in anticipation of the 2016 CWA assessment and reporting cycle. The 2016 CALM Guidance Manual (MassDEP 2016) incorporates evaluation methods for long-term continuous monitoring datasets (e.g., dissolved oxygen and temperature), screening methods to determine whether or not conditions are natural, more detailed screening guidelines used to make nutrient enrichment decisions and updated evaluation methods for toxic pollutants. In addition, guidance was developed for the documentation and submittal to MassDEP of external data from nongovernmental sources, such as volunteer monitoring groups, that wish to have their data considered for use in assessing and listing waters. The 2016 CALM Guidance Manual can be found online at http://www.mass.gov/eea/docs/dep/water/resources/07v5/2016calm.pdf.

The availability of appropriate and reliable scientific data and technical information is fundamental to the s. 305(b) reporting and s. 303(d) listing process. Under the auspices of MassDEP's QMP and DWM-WPP's quality assurance program, environmental data of known and documented quality and suitable for their intended use are consistently generated. Although MassDEP relies most heavily on "internal" data collected as part of the DWM-WPP's ambient water quality monitoring program, "external" data from other state and federal agencies, local governments, drinking water utilities, volunteer organizations and other sources are also solicited and often considered when making assessment decisions. Results of

MassDEP's monitoring efforts, combined with all other external data deemed reliable and usable, constitute the basis for making water quality assessments in accordance with the requirements set forth in s. 305(b) and s. 303(d) of the CWA. DWM-WPP's most recently validated data are utilized for making use assessment decisions. Ideally, these data are five years old or less.

Section B.9 of DWM-WPP's programmatic monitoring QAPP addresses the use of secondary or external data. DWM-WPP categorizes external data into three general levels, which are related to the monitoring objectives (i.e., why the data were collected):

- Educational/Stewardship-level
- Screening-level
- Regulatory/Assessment-level

While very important, data collected primarily for educational and/or stewardship purposes generally do not meet the rigor (i.e., accuracy, precision, frequency, comparability, overall confidence, etc.) required for use in waterbody assessments or TMDL development. It is unlikely this type of data would be used for s. 305(b) and/or s. 303(d)-related decision-making. Screening-level-type data are also very important, but generally fail to meet one or more DWM-WPP criteria required for direct use in assessments or TMDLs. Screening-level data may meet the DQOs specified in the original QAPP, but not those in the DWM-WPP's monitoring program QAPP approved by the EPA. Screening-level data are typically used to direct future sampling efforts and as supporting evidence only. Assessment-level data have been deemed by MassDEP, based on DWM-WPP's external data review procedures, to be directly usable for s. 305(b) and s. 303(d) decision-making. These data are typically the result of extensive planning, attention to detail, relatively stringent DQOs, training, standard field and lab procedures, metadata collection, project organization and data verification---all of which contribute to data that are scientifically sound and legally-defensible. Contingent on review and approval, these data can help determine if a waterbody is meeting water quality standards or is impaired.

External data can be submitted to DWM-WPP using guidelines found on MassDEP's web site here: http://www.mass.gov/eea/agencies/massdep/water/watersheds/external-data-submittals-for-the-wpp.html. All submitted external data are reviewed using a consistent procedure. Once data are received by WPP, a standard data review spreadsheet is used to facilitate and document the review. Each potential secondary data source is evaluated using the following preliminary criteria: 1) adherence to an acceptable QAPP, including a laboratory quality assurance plan and associated SOPs for field sampling and laboratory analyses; 2) use of a state-certified (or as otherwise acceptable to the MassDEP) analytical laboratory; and 3) availability of QC data supporting the validity of the data.

Meeting these criteria provides a basic level of confidence that the data were generated using appropriate field sampling and analytical methods and that the data were assessed by the external group for accuracy, precision and representativeness. External data meeting these criteria are then further reviewed by one or more DWM-WPP staff to verify that the group's DQOs were met based on the QC data provided. These DQOs are then compared to DWM-WPP's DQOs to look for any large discrepancies that could affect acceptability. In cases where additional information is needed, the external data group is contacted for the information. If available information is deemed insufficient to complete the review, the data are not used. Data can also be considered unusable due to poor or undocumented QAPP implementation, lack of project documentation, incomplete reporting of data or information, poor quality control results and/or project monitoring objectives unsuitable for MassDEP assessment purposes. Best professional judgment is used to make the final determination regarding data validity and usability for assessment purposes. External data are not qualified by DWM-WPP in any way, but are considered either acceptable for use or not (as a whole or in part). External data greater than five years old, with few exceptions, are generally considered unusable for assessment decisions. MassDEP is committed to periodically reviewing its assessment procedures and making appropriate updates as necessary.

Sources of Information

The existing monitoring networks and program elements described under Monitoring Objective 1 in Section V constitute a major source of data and information for making assessment and listing decisions, but are, by no means, the only sources utilized. Additional sources typically include monitoring data and information from other state and federal agencies and nongovernmental organizations, as well as reports on projects resulting from state or local grants or federally funded through the CWA (e.g., ss. 314, 319, 104(b)3, or 604(b). For example, s. 314 provided for cooperative agreements between federal, state and local entities to restore publicly owned freshwater lakes and ponds and protect them against degradation. During the late 1970s through the early 1990s diagnostic and feasibility studies were completed for several lakes and ponds throughout Massachusetts and these were used in earlier s. 305(b) assessments and s. 303(d) listing decisions. Information from these studies continues to carry over into new assessment and listing cycles unless new monitoring information results in a change in their assessment and listing status. Likewise, information contained in the nonpoint source assessment report prepared in 1989 in accordance with the requirements of s. 319 is also reflected in s. 305(b) and s. 303(d) reporting elements unless more recent information has resulted in a modification of the original assessment.

For the assessment of some designated uses, MassDEP is entirely reliant on data and information provided by other agencies. For example, the GIS datalayer on shellfish classification areas, maintained and updated annually by DMF, is used to assess the support status of the shellfish harvesting use. Similarly, while MassDEP collects data on mercury and other contaminants in fish tissue to support fish edibility risk assessments, the actual assessment of the fish consumption use relies on whether or not DPH fish consumption advisories have been issued.

While not exhaustive, the following list highlights a number of agencies and programs from which DWM-WPP staff derive environmental data or other records to inform the integrated assessment and listing process:

- DFG fish population assessments are available statewide, primarily for freshwater riverine sites, and these are utilized in the assessment of the aquatic life use.

- DMF anadromous fishery technical reports are available for each coastal system. These reports provide data for evaluating barriers to fish passage as part of the aquatic life use assessment decision. Special studies conducted by DMF biologists (i.e., river herring habitat assessments and smelt spawning area studies) may also be utilized.

- The frequency and duration of public beach closures, at marine and DCR-managed freshwater facilities, are derived from the Beaches Bill database maintained by the DPH.

- WET data, submitted as a requirement of NPDES wastewater discharge permits, provide information on the survival of test organisms exposed to ambient river water samples, and may be used to determine the support status of the aquatic life use.

- Presumptive assessments of recreational use impairment are made downstream from CSOs discharging to waters that are not covered by variances in the SWQS.

- Stream discharge data from continuous gaging sites, as well as estimated streamflows from ungauged sites (Streamstats), are available from the USGS. Data on such water quality variables as bacteria, chloride, ammonia, metals, nutrients, polycyclic aromatic hydrocarbons, and pesticides are also available from the USGS from fewer than 100 sites statewide (2005 – 2014).

- DER is managing over 150 Habitat Restoration Projects statewide involving such stream improvement measures as dam removal, tidal flow restoration, culvert size remediation and urban river revitalization. Information generated by these projects may be used as part of the aquatic life use assessment.

- Precipitation and other climatic data are available from the Global Historical Climatology Network maintained by the National Oceanic and Atmospheric Administration's National Climatic Data Center, and from DCR's Rainfall Program.

Assessment Process Overview

Detailed assessment methodologies for individual designated uses are presented in the Massachusetts CALM manual and are not reproduced here. Instead, a brief overview of the assessment process is provided.

The CWA s. 305(b) water quality reporting process used to generate the Massachusetts integrated list of waters, is an essential aspect of the Nation's water pollution control effort. It is the principal means by which the EPA, Congress, and the public evaluate existing water quality, assess progress made in maintaining and restoring water quality, and determine the extent of remaining problems. In so doing, the states report on waterbodies within the context of supporting their designated uses. These uses include: *Aquatic Life, Fish Consumption, Drinking Water, Primary Contact Recreation, Secondary Contact Recreation, Shellfish Harvesting* and *Aesthetics*. Two subclasses of Aquatic Life that are also designated in the SWQS are Cold Water Fishery (capable of sustaining a year-round population of cold water stenothermal aquatic life, such as trout), and Warm Water Fishery (waters that are not capable of sustaining a year-round population of cold water stenothermal aquatic life).

The SWQS prescribe minimum water quality criteria to sustain the designated uses. Furthermore, the standards describe the hydrological conditions at which water quality criteria must be applied: *"For rivers and streams, the lowest flow condition at and above which aquatic life criteria must be applied is the lowest mean flow for seven consecutive days to be expected once in ten years (7Q10)…In waters where flows are regulated by dams or similar structures, the lowest flow condition at which aquatic life criteria must be applied is the flow equaled or exceeded 99% of the time on a yearly basis, or another equivalent flow agreed upon by the Department and the federal, state or private entity controlling the flow…In coastal and marine waters and for lakes and ponds, the Department will establish extreme hydrologic conditions at which aquatic life criteria must be applied on a case-by-case basis."* [314CMR 4.03(3)].

The determination of whether or not a waterbody supports each of its designated uses is a function of the type(s), quality and quantity of available current information. Although data/information older than five years are usually considered "historical" and used for descriptive purposes, they can be utilized in the use attainment determination provided they are known to reflect the current conditions. While the SWQS prescribe minimum water quality criteria to sustain the designated uses, numerical criteria are not available for every indicator of pollution. Best available guidance in the literature may be applied in lieu of actual numerical criteria. Excursions from criteria due solely to "naturally occurring" conditions do not constitute violations of the SWQS and are not causes of use impairment.

Each use, within a given segment, is individually assessed as **supporting** or **not supporting**. When too little current data/information exists, the use is identified as having **insufficient information**. When no reliable data are available, the use is **not assessed**. However, if there is some indication of water quality impairment, which is not naturally-occurring, the use is identified with an "Alert Status". It is important to note that not all waters are assessed. Many small and/or unnamed rivers, lakes, and estuarine areas have never been assessed; the status of their designated uses has never been reported to EPA in the Commonwealth's Summary of Water Quality Report (s. 305(b) Report) nor is information on these waters maintained in the ADB. These are considered **not assessed other waters**.

The assessment process described above is typically applied to those waterbodies for which adequate targeted data and information are available and, as such, reporting on the condition of Massachusetts' waters has been limited in the past to a small percentage of all of the water resources in the state. To provide complete coverage of selected waterbody types, both spatially and temporally, Massachusetts has adopted two networks of randomly selected sampling sites (i.e., shallow streams and lakes) that allow for statistically unbiased assessments that can be applied statewide. At the same time, DWM-WPP's has designed its statistically-valid surveys with enough sampling replication at each randomly chosen site to provide the necessary data and information to actually complete assessments for those sites. The probabilistic survey design achieves the goal of reporting in accordance with s. 305(b) the status of all waters without actually having to monitor them all; those water bodies that are actually monitored can be assessed, input to the ADB and reported on individually. DWM-WPP will report the results of the state-scale assessments through the EPA's web-based application designed specifically for that purpose.

Resources needed to implement this program element:

- *Investment in licenses for SAS statistical software*
- *Cross-training in R package, PROP design, etc.*
- *Outreach/external data use*

IX. Reporting on Massachusetts Waters

Monitoring Reports and Technical Memoranda

DWM-WPP reports the results of its watershed-based water quality and biological monitoring surveys in individual technical reports or memoranda. A technical report or memorandum typically includes a brief explanation of why the monitoring was performed, the field and laboratory methods employed, and the sampling results with interpretive discussion if applicable.

Watershed Assessment Documentation

MassDEP stored assessment decisions in the electronic database known as the ADB through the 2016 integrated reporting cycle. For each segment in the ADB a use-support determination was made and, whenever possible, causes and sources of impairment were specified. The ADB was designed to improve the quality and consistency of water quality reporting, improve water quality data analysis, and reduce the burden of preparing reports under ss. 305(b), 303(d), 314 and 319 of the CWA. The ATTAINS database replaces the ADB database for the 2018 and subsequent reporting cycles.

For the 2016 reporting cycle, DWM-WPP analysts have chosen to store summary statements related to each individual use assessment and listing decision for each segment in each use comment field in the ADB database. The actual data sources and decisions are also maintained in a watershed "repository" document that is not intended for publication, but contains the data and information reviewed when making the assessment and listing decisions.

A spatial representation of the assessment and listing decisions is made available to the public through an ArcGIS 10 geodatabase file and its supporting shapefiles and databases. These files can be downloaded from the MassGIS website once the integrated list of Massachusetts waters is finalized

(approved) (see, for example: http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/wbs2012.html).

The Integrated List of Massachusetts Waters

EPA guidance provides to the states the option of presenting the status of all of their assessed waters in a single integrated report and accompanying multi-part list, thus combining the reporting requirements of ss. 305(b), 303(d) and 314 of the CWA (EPA 2001). States choosing this option list each assessment unit (i.e., waterbody or segment thereof) in one of the following five categories:

1) Unimpaired and not threatened for all designated uses;
2) Unimpaired for some uses and not assessed for others;
3) Insufficient information to make assessments for any uses;
4) Impaired or threatened for one or more uses, but not requiring the calculation of a Total Maximum Daily Load (TMDL); or
5) Impaired or threatened for one or more uses and requiring a TMDL.

Category 4 is further divided into three sub-categories – 4a, 4b and 4c – depending upon the reason that TMDLs are not needed. Category 4a includes waters for which the required TMDL(s) have already been completed and approved by EPA. However, since MassDEP chooses to list each segment in only one category, waters that have an approved TMDL for some pollutants, but not others, remain in Category 5 until TMDLs are approved for all of the pollutants impairing those waters. Category 4b was proposed by EPA to list waters for which pollution control measures other than TMDLs are expected to attain all designated uses. Finally, the CWA distinguishes between "pollutants," such as nutrients, metals, pesticides, solids and pathogens, that all require TMDLs and "pollution," such as low flow, habitat alterations or non-native species infestations, that do not require TMDLs. Waterbodies impaired solely by "pollution" are included in Category 4c unless there are also TMDLs approved for them, in which case they appear in Category 4a.

Waters listed in Category 5 constitute the s. 303(d) list of waters impaired by one or more pollutants and requiring the derivation of TMDLs. As such, this list is subject to public review and comment, and must be formally approved by EPA. Categories 1 – 4 are submitted in fulfillment of the requirements under s. 305(b). The most recent EPA-approved integrated report and related information, such as the associated public comment document and EPA approval letter, can be found at http://mass.gov/dep/water/resources/tmdls.htm.

X. Programmatic Evaluation

A high priority of MassDEP is assuring that "programmatic evaluation" occurs for all aspects of the monitoring design and at varying levels of detail. To this end, a comprehensive program evaluation was carried out for DWM-WPP in 2013. One outcome of this initiative was the development and implementation of a strategic program planning process. A steering committee, made up of program supervisors and two rotating at-large staff members, meets approximately six times a year to establish short- and long-term program goals. Steering committee meetings are alternated with all-staff meetings to provide the opportunity for staff input. Annual planning activities of DWM-WPP are initiated in the summer and are completed by the end of the calendar year. Annual goals are reviewed with the entire staff in January and used for allocating available resources. Monitoring needs are addressed during this process and are integrated with all DWM-WPP planning elements. (See Appendix 5 for a time line for the development, review and implementation of DWM-WPP's annual monitoring plan.)

DWM-WPP prepares QAPPs for all the monitoring efforts, which are submitted to EPA for review. Detailed SAPs are prepared by DWM-WPP monitoring coordinators and reviewed by the supervising

staff. Mid-course corrections are implemented, as needed and routine changes and additions are recommended and incorporated into future monitoring cycles. Progress on individual projects is communicated to management at weekly staff meetings. Finally, the EPA conducts quality system assessments, approximately every three years, to evaluate Massachusetts' adherence to the QMP.

Outreach to stakeholders is an ongoing process consisting of meetings with volunteers and sister agencies, and attendance at workshops and conferences. One recent initiative to engage the public was the development of an interactive map that displays assessment information. MassDEP hosts an annual volunteer monitoring summit to communicate plans and interact with external data collectors.

Strategic planning for the Monitoring Program is performed as needed, but is triggered by the addition (or loss) of personnel or other resources, the release of new monitoring and assessment guidance from the EPA, or changes in the SWQS or other pertinent policies.

XI. General Support and Infrastructure Planning

MassDEP takes water monitoring and related activities very seriously, and will continue to do so going forward in an effort to provide the timely scientific data and information that are essential for resource management decision-making. Monitoring resource needs of MassDEP are summarized following the description of each individual program element throughout this report. It is clear that several program enhancements are required, not only to implement the new program elements proposed in this strategic plan, but also to maintain existing programs. In addition, the implementation of each new monitoring program element will increase the demand for support services, such as QA/QC and data management. Long-term staffing and funding support are critical to the development and implementation of the comprehensive water monitoring program.

The resources needed to continue to implement the monitoring plan effectively generally fall into four categories: 1) staffing; 2) funding for equipment and supplies; 3) funding for contractual services and 4) training. A brief summary of these needs is presented below.

Staffing

Over the past several years MassDEP's has made a concerted effort to ensure an appropriate level of monitoring and support personnel, and continues to utilize partnerships with other government agencies and NGOs. While MassDEP continues to utilize a highly trained workforce to achieve watershed management program goals, full-time monitoring coordinators and seasonal staff are both needed to support program elements designed to fulfill all four major monitoring objectives outlined in Section V. Additional full-time personnel will assist MassDEP as the Department continues to plan and carry out targeted monitoring to support assessment and listing decisions, TMDL development, criteria development and water management program effectiveness. The DWM-WPP relies each year on the CWA s. 106 supplemental monitoring grants to fund five seasonal employees to support its existing monitoring program.

To further MassDEP's commitment to water monitoring and quality, a Quality Assurance Analyst would be established to oversee the development of SOPs, SAPs and QAPPs, coordinate staff training exercises, coordinate with laboratories, perform field and laboratory audits, manage data validation, and serve as the liaison between DWM-WPP and EPA quality assurance personnel. Furthermore, a full-time analyst and dedicated volunteer monitoring coordinator would expedite the use of data from volunteer groups; they would review QAPPs, data from external sources to confirm validity and completeness, and make recommendations for their use in watershed assessments.

MassDEP also seeks to continue its successful eelgrass mapping program. The status (i.e., extent and health) of eelgrass populations constitutes the primary source of information used to assess the aquatic life use in estuarine waters, and is an important biological indicator for the MEP. As such, successional planning will ensure the effective continuation of the program.

The Wetlands Program will continue to grow and effectively implement its mission through the hiring of an individual with an expertise in botany, GIS and/or statistics to develop and implement the rotating wetlands assessments. The tasks of this person would be similar to those currently undertaken and include QAPP development, site selection, access permission, equipment purchase, field sampling, sample processing and taxonomic identification of biological specimens (e.g., macroinvertebrates), the management, analysis and presentation of data, report development and collaboration with outside groups.

As the William X. Wall Experiment Station continues to grow, additional individuals to assist current staff will ensure the continued effective analysis of samples generated by both existing and new monitoring program elements. One of the five seasonal employees funded by the s. 106 supplemental monitoring grant is assigned to WES each year to assist with the processing of water samples collected by the DWM-WPP.

Additionally, the BST monitoring program will continue to achieve tangible results through the assignment of additional personnel to the three other regional offices.

Funding for Monitoring Equipment and Supplies

To continue MassDEP's effective and wide-ranging monitoring of watersheds throughout the Commonwealth, funding will be needed for the purchase of monitoring equipment and supplies for all of the monitoring elements covered by this plan. The majority of the equipment and supplies purchased each year to support existing monitoring programs is funded by federal CWA grant monies (i.e., ss. 106 and 319). Likewise, MassDEP's Wetlands Program and ORS will need funding for equipment and supplies in order to continue wetland assessments and research on mercury levels in fish, respectively. Increased funding beyond present levels will be required before the new program elements proposed in this plan can be initiated.

Additionally, a continuous commitment to replace and update antiquated analytical instrumentation at WES is needed to realize the effective implementation of ongoing and proposed monitoring programs. Furthermore, purchasing new instrumentation for newly emerging contaminants of concern will expand WES' capabilities. This support should be planned well in advance for anticipated needs of MassDEP and other agencies serviced by WES.

Contractual Support

MassDEP will continue to rely, to a limited extent, on in-kind laboratory services from EPA and, even more extensively, on the use of contractual services to fill a number of resource gaps in the existing water monitoring and management program. Additional funding will be needed from time to time to secure commercial laboratories or contractors to perform non-routine analyses, or to keep within prescribed sample holding times when monitoring activities are performed in remote watersheds. Private laboratory support will also be needed for bacteriological analyses of samples obtained from waterbodies far from WES, as well as for taxonomic identifications of macroinvertebrates and phytoplankton.

Funding will be needed in the future to support work to carry out important monitoring activities that are beyond the existing monitoring capabilities of MassDEP. A need exists for the establishment of long-term monitoring stations in selected interstate rivers (e.g., Blackstone and Connecticut rivers, etc.) to quantify

pollutant loads at state boundaries and to measure the effectiveness of measures taken to reduce those loads.

MassDEP has relied on the use of N-STEPS to support ongoing activities aimed at deriving phosphorus and nitrogen criteria. Further technical support of this kind will be needed to complete the nutrient criteria development and to further the establishment and implementation of biocriteria over the next several years. Furthermore, contractual support will likely be needed to facilitate the development of criteria for aluminum and dissolved oxygen in marine waters.

MassDEP's Wetlands Program and ORS are both in need of contractual support to continue ongoing monitoring, assessment and research activities. WPDG funds will continue to be needed to fund the development of assessment methods for freshwater emergent marshes and other freshwater and coastal resources (e.g. bogs and fens, rocky intertidal shores, etc.). Funding for additional consulting expertise such as invertebrate identification may also be needed. ORS will need to procure field sample collection services to support its research on trends in the mercury content in fish.

DWM-WPP has made great strides in the area of data management as evidenced by the recent procurement of the EQuIS software solution that will streamline and standardize data handling as well as provide tools for data sharing with the EPA via the WQX. MassDEP will need to develop a new three-year licensing agreement in 2019.

Finally, DWM-WPP received funding through the National Environmental Information Exchange Network Grant program to begin to enhance access to its ambient monitoring data. The following goals have been established to make use of this and potential future grant funding:

- Adopt and update the high resolution National Hydrography Dataset (NHD)
- Create statewide monitoring stations, CWA ss. 305(b) and 303(d) assessment units and SWQS classifications as NHD Events, and
- Provide public access to DWM-WPP surface water quality data via an interactive, geospatial web tool

While the primary purpose for requesting funding is to seek assistance in expanding public access to DWM-WPP ambient monitoring data, additional work related to adopting and enhancing the NHD will also improve data analysis and reporting. If it is determined that all of the above-stated goals cannot be attained through the expenditure of existing grant funds, DWM-WPP may seek additional funding in the future.

Training

While DWM-WPP conducts in-house training each year in the safe and proper conduct of its field and laboratory techniques, more opportunities for skill enhancement and career development through attendance at conferences and mini-courses are also desirable. As new staff members are hired, competition for limited travel and training resources will increase unless these are included in program budgets. While future training costs are not actually estimated for the purpose of this monitoring strategy, career development will be an important consideration for existing and future monitoring and assessment staff.

XII. References

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Appendix 1

Time Frame for the Implementation of the 2016 Massachusetts Water Quality Monitoring Strategy

EPA Design Element	Monitoring Program Goal	Time Horizon		
		0-2 years	3-5 years	>5 years
Monitoring Program Strategy				
	Create TMDL vision document	X		
	Expand monitoring partnerships	X	X	X
	Develop targeted watershed monitoring	X	X	
Monitoring Indicators/Objectives/Design				
Assess the status of waters	Implement lakes probabilistic monitoring	X		
	Develop and implement Taunton River strategy	X	X	
	Maintain continuous dissolved oxygen data collection (coastal)	X	X	
	Implement targeted chloride monitoring	X	X	X
	Continue fish toxics monitoring program	X	X	X
	Continue eelgrass mapping program	X	X	X
	Perform rotating wetlands assessments	X	X	X
	Plan temperature network	X		
Develop, implement and evaluate pollution control strategies	Massachusetts Estuaries Project	X	X	X
	Implement Long Island Sound strategy	X	X	X
	Develop targeted monitoring to support TMDL development	X	X	X
	Assist with targeted monitoring at UBWPAD and Lowell Regional WWTPs	X	X	
Develop policies and standards and identify emerging issues	Review & implement aluminum criteria	X	X	
	Review and implement marine dissolved oxygen criteria	X	X	
	Develop biological indicators/criteria - macroinvertebrates	X		
	Develop biological indicators/criteria - fish	X	X	
	Develop biological indicators/criteria – algae/diatoms		X	
	Continue reference site network	X	X	X
	Continue climate change network	X	X	X

	Assess harmful algae blooms	X	X	X
Measure the effectiveness of water quality management programs	Continue monitoring mercury trends in fish	X	X	X
	Develop targeted monitoring to measure success of TMDL implementation	X	X	X
	Develop post-MEP macroinvertebrate monitoring program (estuaries)	X		
Quality Assurance				
	Build capacity for 3rd-party QAPP, data review and outreach	X	X	
Data Management				
	Test electronic field sheets	X		
	Flow water quality data to WQX	X		
	Flow macroinvertebrate, fish population, fish toxics data to WQX	X	X	
Data Analysis/Assessment				
	Probabilistic rivers	X	X	
	Probabilistic lakes		X	X
	Assessment streamlining	X	X	
Reporting				
	Implement ATTAINS	X		
	Report on probabilistic rivers/lakes		X	X
Programmatic Evaluation				
	Conduct annual reviews	X	X	X
General Support and Infrastructure Planning				
	Perform periodic needs assessments	X	X	X

Appendix 2

Massachusetts Department of Environmental Protection
Probabilistic Monitoring Component – Wadable Rivers Sampling Design
2011 – 2015

Monitoring Goals and Objectives

Goals:

1. Provide an unbiased assessment (Support/Impaired) of aquatic life, recreational and aesthetic uses in wadable non-tidal perennial streams of Massachusetts.
2. Provide an analysis of trends in aquatic life, recreational and aesthetic use assessments in wadable non-tidal perennial streams of Massachusetts.

Objectives:

1. Determine with a known statistical confidence the percentage of wadable non-tidal perennial stream miles supporting and not supporting aquatic life uses in each design stratum and statewide.
2. Determine with a known statistical confidence the percentage of wadable non-tidal perennial stream miles supporting and not supporting recreational uses in each design stratum and statewide.
3. Determine with a known statistical confidence the percentage of wadable non-tidal perennial stream miles supporting and not supporting aesthetic uses in each design stratum and statewide.

Design Constraints or Assumptions

1. Division of Watershed Management (DWM) personnel will be responsible for all sampling associated with the probabilistic component.
2. A minimum of 30 sites will be sampled yearly as part of the probabilistic component.
3. A maximum of 35 percent of the total sampling personnel resources in each monitoring group (water quality, macroinvertebrate, fish) will be dedicated to the probabilistic monitoring component (Dependent on continued outsourcing of some macroinvertebrate taxonomy).
4. Existing DWM methodologies and protocols will be used to sample each site and assess designated use support.
5. Stratification of the probabilistic sites will be designed to increase sampling efficiency and based on a five year rotating basin model.

Target Population

The target population is all wadable (1^{st} – 4^{th} Strahler Order) non-tidal perennial river miles within the Commonwealth of Massachusetts.

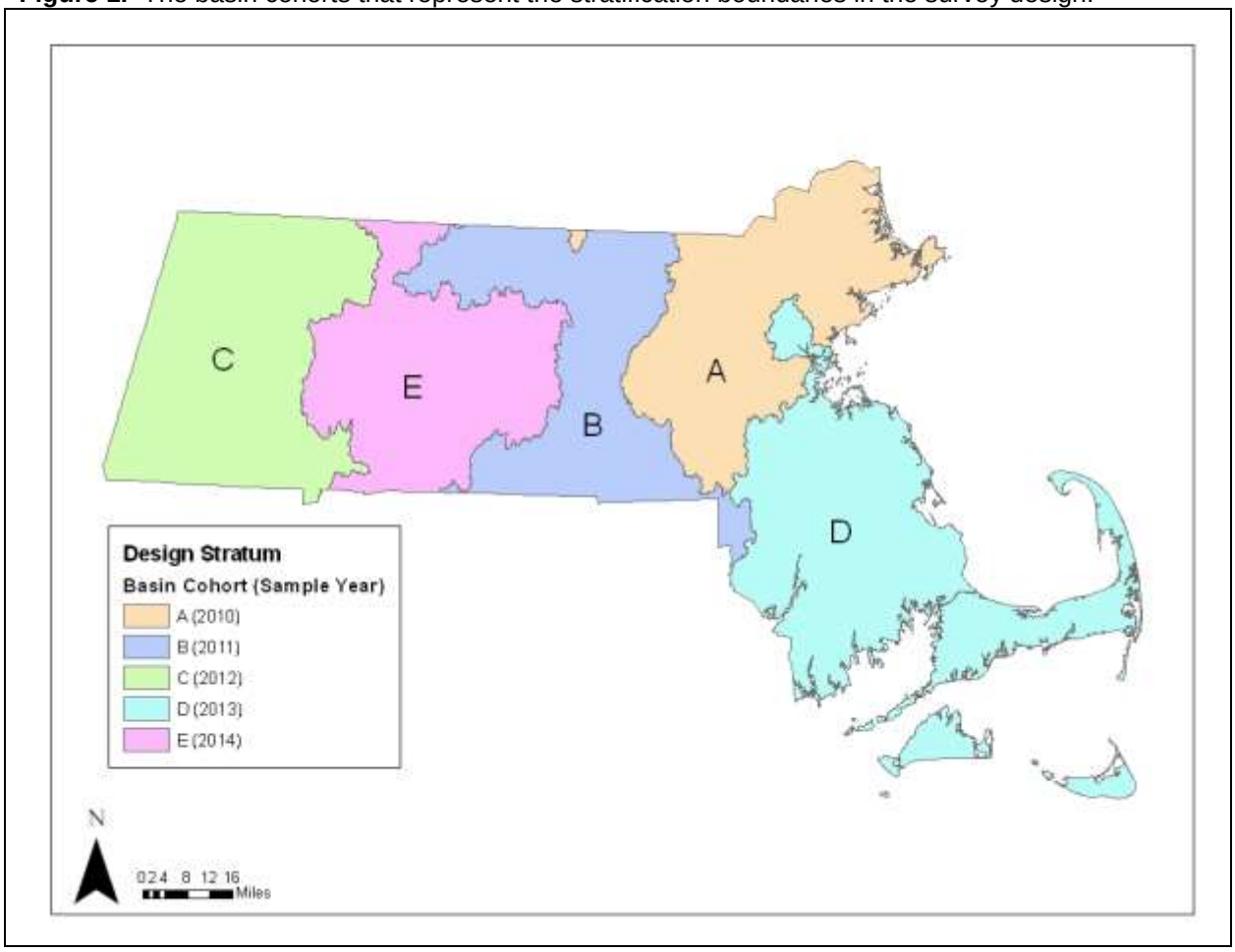
1. Stream/River – a flow of water confined in a defined channel (bed and banks) under normal flow conditions. Artificial manmade channels such as canals and pipelines are not included in this definition unless the origins of the manmade feature was a natural stream feature and recognized as such in previous classifications.
2. 1^{st} – 4^{th} Strahler Order - Approximately 95% of the non-tidal perennial river miles in Massachusetts are in this population.

3. Wadable – Shallow enough that a representative sample of the indicator can be collected during the index period under normal hydrological condition.
4. Non-tidal – Not influence either chemically or physically by tidal changes.
5. Perennial – Continuous flow in part of the stream bed all year around during normal rainfall years. This characteristic does not exclude streams that are unnaturally intermittent due to human impact.

Stratification

The target population will be stratified into five separate groups or strata. The spatial boundaries for the five strata will be defined by grouping the 27 basins identified in the existing Massachusetts 5-Year Basin Cycle into five basin cohorts (Figure 1). The goal of the groupings is to provide operational efficiency and balance the number of river miles and sampling effort in each cohort. A 5-year rotating basin design will be used for the sampling allocation with one basin cohort or design stratum sampled each year. This design will provide statewide coverage after 5 years.

Figure 1. The basin cohorts that represent the stratification boundaries in the survey design.



Sampling Frame

Sample Frame Materials:

1. National Hydrographic Dataset Plus 1:100,000 (NHDPlus) GIS coverage
2. Commonwealth of Massachusetts state boundary GIS coverage
3. Stream Reach Codes: Strahler Order, NHDPlus FCODES (Intermittent, Perennial, Canal, Artificial Pathway, Etc.)
4. Basin Cohort Boundary GIS coverage

The sample frame materials will be used to create a sampling frame that reflects the target population as best as possible. The sampling frame will not be an exact representation of the target population. The medium resolution (1:100,000) NHDPlus does not include some channels that appear on higher resolution maps such as the USGS maps (1:24,000) and the high resolution NHD coverage (1:24,000) and includes some features that are not streams. Post processing of the GIS coverage will be conducted to eliminate the obvious non-target features. However, this will not completely eliminate the selection of non-target sites. A determination if a site is non-target will be done on a case by case basis during reconnaissance of the sites. Due to a lack of stream order attributes and significant overcoverage in the coastal basins, the higher resolution NHD coverage was not selected as the basis of the sampling frame. The long-term goal is to modify the higher resolution NHD by adding stream order attributes and reducing the overcoverage so that it can be used as the basis of the sampling frame in the future.

Survey Design

Generalized Random Tessellation Stratified Design (GRTS)

Characteristics (as taken from EPA-ORD-NHEERL-WED-Aquatic Resource Monitoring webpage)

1. Spatially balances sample across the resource (improved precision)
2. Enables design-based estimators including variances
    a. Precise control over inclusion probabilities
    b. Element & region variable probability assignment
    c. Joint inclusion probability can be determined
3. Controls sample and subsample spatial balance
4. Nested subsamples easily selected
5. Unified theory for point, network, and areal resources such as lakes, streams, and coastal waters

Design Options (as taken from the EPA-ORD-NHEERL-WED-Aquatic Resource Monitoring webpage)

1. Multiple density categories to allocate samples, supports unequal selection probability
2. Nested subsamples for measuring additional indicators or duplicate samples
3. Panels for monitoring over time
4. Over-sample selection to address non-target and inaccessible sites
5. Special study areas within study-wide design
6. Explicit stratification
7. Incorporate multiple stage sampling

Allocation of Sampling Sites

Unequal selection probabilities will be used to create multi-density categories and allocate sites equally into Strahler Orders 1st, 2nd, 3rd, and 4th.

Sample Size

The total sample size for the survey design will be 150 sites and 300 oversample sites. This sample size total consists of approximately 30 sites per design stratum per year. This design would enable the

calculation of population estimates on an annual and regional basis with moderate precision (+/- 3 to 15 percent with 90% confidence) and on a statewide basis after 5 years with a higher precision (+/- 1%-7% with 90% confidence). The precision of the population estimates will increase each year of the 5-year basin rotation as more sites are sampled by DWM (Figure 1).

Response/Indicator Design

See Table 1 for the indicators that will be sampled at each probabilistic site. The primary objective at each site will be to collect sufficient data to assess, using DWM assessment methodology, the status (support/impaired) of aquatic life, recreational and aesthetic uses. All sampling and QA/QC will be conducted in accordance with DWM standard operating procedures and the Surface Water Monitoring and Assessment Quality Assurance Plan.

Table 1. Indicators sampled at probabilistic sites.

Indicators	Sample Frequency (Minimum)
Bacteria (E. coli)	5
Nutrients (TN,TP, Ammonia)	5
Color	5
Turbidity	5
Total Suspended Solids	5
Dissolved Oxygen Probe Deploys (48-120 hours)	3
Temperature Probe Deploys (July-September)	1
Habitat Assessment	1
Fish Community	1
Macroinvertebrate Community	1

Statistical Analysis/Reporting

The statistical analysis will be conducted with spsurvey, a software package developed by EPA EMAP Design Team. The spsurvey library is used with the R statistical program and is capable of selecting sites based on GRTS for probabilistic surveys and calculating population estimates using data collected during the survey. All software needed to conduct the statistical analysis is available at no cost. The primary product of the statistical analysis will be an estimate on the portion of the target population in each assessment category (Support, Impaired, and Not Assessed). As the data collection in each design stratum is completed, the data will be analyzed for the individual stratum and then added to the data from any other stratum within the 5-year cycle and analyzed together. Details of other statistical analysis to be completed will be determined later in the design phase but could include population means and variance, cumulative distribution function (CDF) estimates of a variable, and testing for difference of two CDF.

Appendix 3

Massachusetts Probabilistic Monitoring and Assessment (MAP2) Lakes Survey Design 2016 – 2018

Monitoring Goals and Objectives

Goals:

1. Provide an unbiased assessment (Support/Impaired) of aquatic life and recreational uses in target population lakes.
2. Provide an analysis of trends in aquatic life and recreational uses assessments in target population lakes.

Objectives:

1. Determine with a known statistical confidence the percentage of target population lakes supporting and not supporting aquatic life uses statewide.
2. Determine with a known statistical confidence the percentage of target population lakes supporting and not supporting recreational uses statewide.

Design Constraints or Assumptions

1. Watershed Planning Program (WPP) personnel will be responsible for all sampling associated with the probabilistic component.
2. A minimum of 25 lakes will be sampled yearly as part of MAP2.
3. A maximum of 35 percent of the total sampling personnel resources in each monitoring group (water quality, macroinvertebrate, fish) will be dedicated to the probabilistic monitoring component (Dependent on continued outsourcing of macroinvertebrate taxonomy).
4. Stratification of the probabilistic lakes will be designed to increase sampling efficiency and based on a three year rotating basin model.

Target Population

The target population is defined as all permanent freshwater lakes, reservoirs, and ponds greater than or equal to 2 hectare (2 ha) in surface area and greater than or equal to 2 meters at maximum depth within the Commonwealth of Massachusetts. The word “lake” includes lakes, reservoirs and ponds. Lakes that are saline are excluded as are those used for aquaculture, disposal-tailings, sewage treatment, evaporation, or other unspecified disposal use.

Sample Frame

The sample frame was derived from the high resolution National Hydrography Dataset 1:24,000(NHD). Once the initial shapefile that included all waterbody objects in NHD was prepared, additional attributes (e.g. Feature type, area) included in the shapefile were used to construct the final sample frame.

Waterbodies included in the sample frame were those lakes with feature codes equal to:
Lake/Pond: feature type only: no attributes
Lake/Pond: Hydrographic Category = perennial
Lake/Pond: Hydrographic Category = perennial; Stage = average water elevation
Lake/Pond: Hydrographic Category = perennial; Stage = normal pool
Lake/Pond: Hydrographic Category = perennial; Stage = spillway elevation

Reservoir: feature type only: no attributes
Reservoir: Reservoir Type = water storage; Construction Material = non-earthen
Reservoir: Reservoir Type = unspecified; Construction Material = earthen
Reservoir: Reservoir Type = unspecified; Construction Material = non-earthen

Waterbodies excluded in the sample frame were those lakes with feature codes equal to:
Reservoir: Reservoir Type = aquaculture
Reservoir: Reservoir Type = disposal-unspecified
Reservoir: Reservoir Type = treatment-cooling pond
Reservoir: Reservoir Type = treatment-filtration pond
Reservoir: Reservoir Type = treatment-sewage treatment pond
Reservoir: Reservoir Type = treatment
Swamp/Marsh: feature type only: no attributes

There are other feature codes within the NHD classification scheme that are not represented in Massachusetts. The inclusion list combined with the exclusion list accounts for all the feature codes that are represented in Massachusetts. The last step was to remove any lakes with a surface area greater than 2 ha. Any remaining non-target categories (e.g. tidal) will be identified during the candidate lake evaluation process.

Survey Design

A Generalized Random Tessellation Stratified (GRTS) survey design for a finite resource was used with stratification and unequal probability of selection. The design includes reverse hierarchical ordering of the selected lakes.

Stratification

The survey design is stratified by three geographic regions within Massachusetts to improve sampling logistics (Figure 1). One region will be targeted and sampled each year from 2016 to 2018, starting with the west region in 2016 and concluding with southeast in 2018.

Unequal Probability Categories

The MAP2 lakes design is an unequal probability design within each regional stratum. The two unequal probability categories were defined based on lake area: 2 to 20 ha and greater than 20 ha.

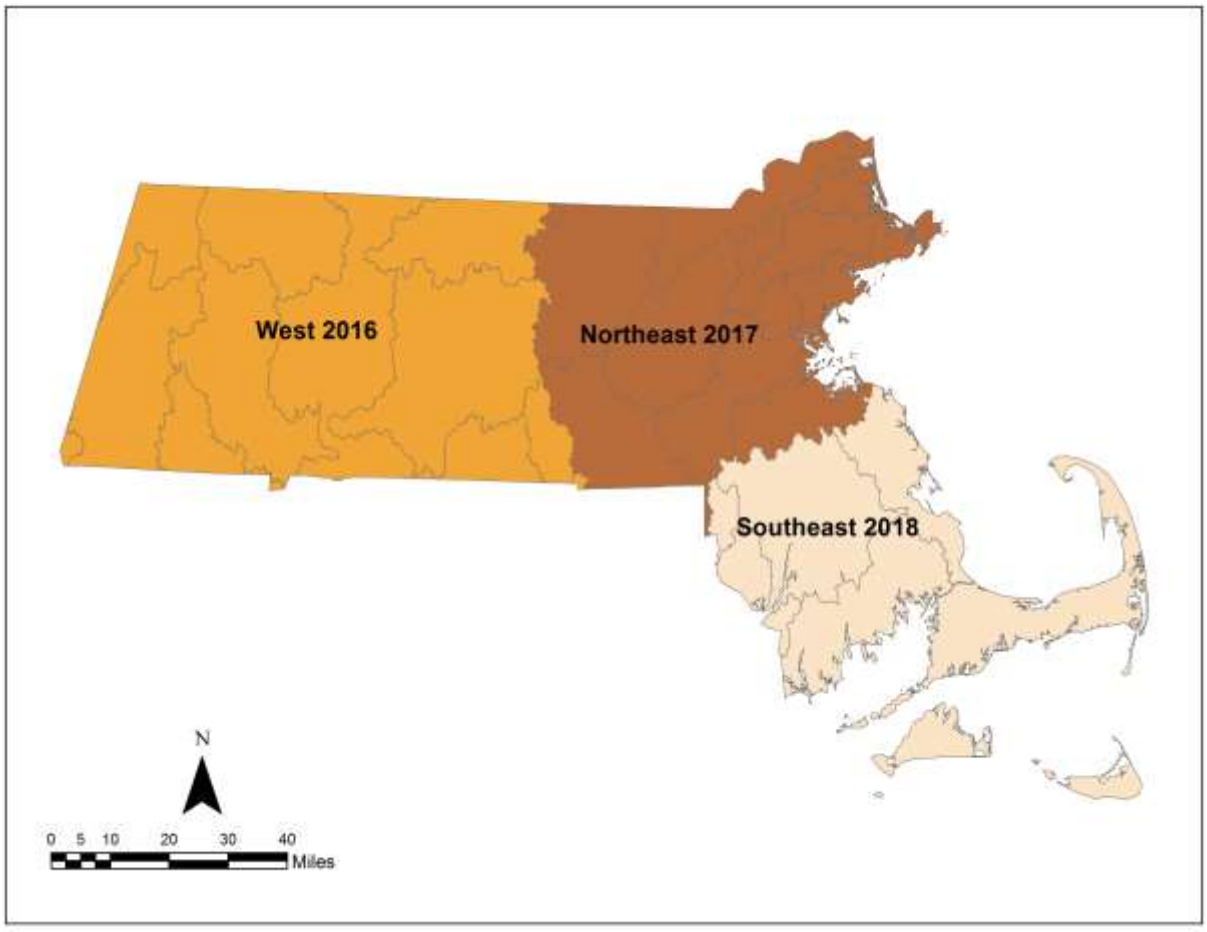
Panels

This survey design has a single panel.

Expected Sample Size

The designed sample size is a total of 75 lakes for the state with 25 lakes in each stratum. In addition 100 oversample sites were selected in each stratum. The sample size within each stratum for the unequal probability categories was set at 13 for the 2 to 20 ha category and 12 for the greater than 20 ha category. The rationale for this assignment of sample sizes is based on experience that smaller lakes are more likely not to be lakes or be inaccessible than larger lakes. When lakes are replaced, the process is expected to result in an equal number of lakes sampled by lake area category.

Figure 1. MAP2 Lakes Stratification Regions



Lake Use and Replacement

Each lake selected to be sampled is given unique site identification (siteID). Site numbers consist of the project abbreviation (MAP2L) and a number between 001 and 375. Within each region stratum, lakes evaluated for potential sampling must have all site IDs from the largest to the lowest number evaluated. For example, if MAPL-178 is the largest site ID evaluated within the northeast stratum, then all site IDs that are lower than 178 within the northeast stratum must be evaluated. Even more critical is that if MAP2L-178 is the largest site ID that is actually sampled in the field, then all lower site IDs within the northeast stratum that are evaluated to be a target lake and are accessible must be sampled in the field.

Sample Frame Summary

Stratum	Lakes 2 to 20 ha	Lakes > 20 ha	Total
West	593	180	773
Northeast	678	204	882
Southeast	800	163	963
Total	2071	547	2618

Site Selection Summary

	Stratum	Lakes 2 to 20 ha	Lakes > 20 ha	Total
Primary	West	13	12	25
	Northeast	12	13	25
	Southeast	14	11	25
	Total	39	36	75
Oversample	West	43	57	100
	Northeast	43	57	100
	Southeast	48	52	100
	Total	134	166	300

Description of Sample Design Output

Variable Name	Description
siteID	Unique identification label for each lake in the sample.
Longitude	Lake location longitude in decimal degrees coordinates (see projection below for datum).
Latitude	Lake location latitude in decimal degrees coordinates (see projection information below).
xcoord	X-coordinate of lake centroid (see projection information below).
ycoord	Y-coordinate of lake centroid (see Albers projection information below).
Mdcaty	Multi-density categories used for unequal probability selection
Weight	Weight (lakes), inverse of inclusion probability, to be used in statistical analyses
Stratum	Strata used in the survey design
Panel	Identifies and Oversample
EvalStatus	Site evaluation decision for site: TS: target and sampled, LD: landowner denied access, etc.
EvalReason	Site evaluation text comment
auxiliary variables	Remaining columns are from the sample frame provided

Response/Indicator Design

See Table 1 for the indicators that will be sampled at each lake. The primary objective at each site will be to collect sufficient data to assess, using WPP assessment methodology, the status (support/impaired) of aquatic life and recreational uses. All sampling and QA/QC will be conducted in accordance with WPP standard operating procedures and the Surface Water Monitoring and Assessment Quality Assurance Plan.

Table 1. Indicators sampled at the probabilistic lakes.

Parameter	Frequency
Profiles (DO, temperature, conductivity, pH)	3
Nutrients (TP, TN)	3
Dissolved silica	3
Dissolved organic carbon (DOC)	3
Chlorophyll a	3
True color	3
Alkalinity	3
Phytoplankton community	3
Cyanobacteria	3
Algal toxins	3
Zooplankton	3
Pathogens (*E. coli*)	5
Bathymetric map (depth contours)	1

Human disturbance assessment	1
Macrophytes (percent cover, biovolume, exotics)	1
Fish tissue	1
Fish community	1
Macroinvertebrate community	1

Statistical Analysis/Reporting

The statistical analysis will be conducted with spsurvey, a software package developed by EPA EMAP Design Team. The spsurvey library is used with the R statistical program and is capable of lakes based on GRTS for probabilistic surveys and calculating population estimates using data collected during the survey. All software needed to conduct the statistical analysis is available at no cost. The primary product of the statistical analysis will be an estimate on the portion of the target population in each assessment category (Support, Impaired, and Not Assessed). Once the data are collected, additional statistical analyses may be employed as part of the data analysis phase and could include population means and variance, cumulative distribution function (CDF) estimates of a variable, and testing for difference of two CDF.

Appendix 4

Sampling History of Lakes and Ponds Included in the MassDEP-ORS Long-term Investigation of Mercury in Freshwater Fish[1]

Waterbody *(Municipality)*	Year														
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Ashfield Pond *(Ashfield)*	--	--	--	--	--	--	--	--	X	--	--	--	--	--	X
Bog Pond *(Savoy)*	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--
Buckley-Dunton Lake *(Becket)*	--	--	X	X	--	X	--	X	--	X	--	--	--	--	X
Laurel Lake *(Lee/Lenox)*	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--
North Watuppa Pond *(Fall River)*	X	X	--	X	X	--	X	--	X	--	X	--	--	X	--
Plainfield Pond *(Plainfield)*	--	--	--	--	--	X	--	X	--	X	--	--	--	X	--
Sheomet Pond *(Warwick)*	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Somerset Reservoir *(Somerset)*	--	--	--	--	--	--	--	--	X	--	--	X	--	--	--
Upper Naukeag Lake *(Ashburnham)*	--	--	--	--	--	--	X	--	X	--	X	--	--	--	X
Upper Reservoir *(Westminster)*	X	X	--	X	--	--	X	--	X	--	--	X	--	--	--
Lake Wampanoag *(Ashburnham/Gardner)*	X	X	--	X	--	X	--	X	--	X	--	--	X	--	--
Baldpate Pond *(Boxford)*	--	--	--	X	--	X	--	X	--	X	--	X	--	--	--
Bare Hill Pond *(Harvard)*	--	--	--	X	--	X	X	--	X	--	X	--	--	--	X
Chadwicks Pond *(Boxford/Haverhill)*	--	--	--	X	--	X	--	X	--	X	--	--	X	--	--
Lake Cochichewick *(North Andover)*	X	X	--	X	--	X	--	X	--	X	X	--	--	--	--
Haggetts Pond *(Andover)*	--	--	X	X	X	--	X	--	X	--	X	--	--	--	X
Johnsons Pond *(Boxford/Groveland)*	--	--	--	X	--	X	X	--	X	--	X	--	--	--	--
Lake Attitash *(Amesbury/Merrimac)*	--	--	--	X	--	X	--	X	--	X	--	--	X	--	--
Lake Pentucket *(Haverhill)*	--	--	--	--	--	--	--	--	X	--	--	--	--	X	--
Lake Saltonstall *(Haverhill)*	--	--	X	--	--	--	--	--	--	--	--	X	--	--	--
Long Pond *(Dracut/Tyngsborough)*	--	--	--	--	--	--	--	--	X	--	--	--	X	--	--
Lowe Pond *(Boxford)*	--	--	--	X	--	X	--	X	--	X	--	--	X	--	--
Massapoag Pond *(Dunstable/Groton/Tyngsborough)*	--	--	--	X	--	X	X	--	X	--	--	X	--	--	--
Millvale Reservoir *(Haverhill)*	--	--	--	--	--	--	--	--	X	--	--	--	X	--	--
Newfield Pond *(Chelmsford)*	--	--	--	--	--	--	--	--	X	--	--	X	--	--	--

Pomps Pond *(Andover)*	X	--	--	X	--	--	X	--	X	--	X	--	--	--	--
Rock Pond *(Georgetown)*	--	--	--	X	X	--	X	--	X	--	X	--	X	--	--
Stevens Pond *(North Andover)*	X	--	--	X	--	--	--	--	X	--	X	--	--	--	X
Kenoza Lake *(Haverhill)*	X	X	--	X	--	X	--	X	--	X	--	X	--	--	--
Onota Lake *(Pittsfield)*	X	X	--	X	--	X	--	X	--	X	X	--	--	--	--
Wequaquet Lake *(Barnstable)*	X	X	--	X	--	X	--	X	--	X	X	--	--	--	--
Lake Lashaway *(N. Brookfield/E. Brookfield)*	--	--	X	--	X	--	X	--	X	--	X	--	--	--	X
Lake Nippenicket *(Bridgewater)*	--	--	X	--	X	--	X	--	X	--	--	X	--	--	--
Massapoag Lake *(Sharon)*	--	--	X	--	X	--	X	--	X	--	X	--	--	--	X
Wickaboag Pond *(West Brookfield)*	--	--	X	--	X	--	X	--	X	--	--	X	--	--	--
Echo Lake *(Milford/Hopkinton)*	--	--	--	X	--	X	--	X	--	X	--	X	--	--	--
Quabbin Reservoir *(multiple[2])*	--	--	--	--	X	--	--	--	X	--	--	--	--	--	--
Chebacco Lake *(Essex/Hamilton)*	--	--	--	--	--	X	--	X	--	X	--	--	--	X	--
Goose Pond *(Lee/Tyringham)*	--	--	--	--	--	X	--	X	--	X	X	--	--	--	--
Lake Buel *(Monterey/New Marlborough)*	--	--	--	--	--	X	--	X	--	X	--	--	--	X	--
Lake Garfield *(Monterey)*	--	--	--	--	--	X	--	X	--	X	X	--	--	--	--
Pelham Lake *(Rowe)*	--	--	--	--	--	X	--	X	--	X	X	--	--	--	--
Stockbridge Bowl *(Stockbridge)*	--	--	--	--	--	X	--	X	--	X	--	--	--	X	--
Crystal Lake *(Haverhill)*	--	--	--	--	--	--	X	--	--	--	X	--	--	X	--
Dyer Pond *(Wellfleet)*	--	--	--	--	--	--	X	--	--	--	X	--	--	X	--
Slough Pond *(Truro)*	--	--	--	--	--	--	X	--	--	--	X	--	--	X	--
Horseleach Pond *(Truro)*	--	--	--	--	--	--	--	X	--	X	--	--	X	--	--
Round Pond (East) *(Truro)*	--	--	--	--	--	--	--	X	--	X	--	--	X	--	--

[1] Lakes sampled are indicated by an X
[2] (Petersham/Pelham/Ware/Hardwick/Shutesbury/Belchertown/New Salem)

Appendix 5

Timeline for the development, review and implementation of the DWM-WPP's annual monitoring plan

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Internal												
Internal Call for Monitoring Needs												
Annual Review of Monitoring Priorities												
Field Recon												
Logistics Planning												
Prepare DRAFT SAPs												
Post Seasonal Vacancy Announcements												
Annual Lab Resources Planning Meetings												
Final SAP												
Execute Monitoring												
Post Season Debrief												
Coordination with EPA												
P&C Review – Set-up												
Pre-season Review (Chelmsford and Region 1)												
Annual Meeting – EPA Chelmsford												
Monitoring Summaries Posted												
P& C Review – Deliverables reporting												
Communication with Agencies and Stakeholders												
Ongoing Communications with Stakeholders												
Open Solicitation for Data												
Volunteer Summit												
Web Posting of Monitoring Summaries												