Massachusetts
Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2024 Reporting Cycle

Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
Rebecca L. Tepper, Secretary
Massachusetts Department of Environmental Protection
Bonnie Heiple, Commissioner
Bureau of Water Resources
Kathleen M. Baskin, Assistant Commissioner

May 2025

CN 564.0

MassDEP

Massachusetts
Consolidated Assessment and Listing Methodology (CALM)
Guidance Manual for the 2024 Reporting Cycle

Prepared by:
Watershed Planning Program
Division of Watershed Management, Bureau of Water Resources
Massachusetts Department of Environmental Protection

May 2025

CN 564.0

Suggested Citation
MassDEP. 2025. Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2024 Reporting Cycle. CN 564.0, Massachusetts Department of Environmental Protection, Bureau of Water Resources, Division of Watershed Management, Watershed Planning Program. Worcester, MA.

Cover Photo
Left: Plainfield Pond, Plainfield, MA; Top Right: Green Frog at Moose Meadow Brook, Westfield, MA; Bottom Right: Little River, Westfield, MA. All photos courtesy of Daniel Davis, MassDEP.

Notice of Availability
This report is available on the Massachusetts Department of Environmental Protection website: https://www.mass.gov/service-details/water-quality-assessments.

Massachusetts Department of Environmental Protection
The mission of the Massachusetts Department of Environmental Protection (MassDEP) is to protect and enhance the Commonwealth's natural resources – air, water, and land – to provide for the health, safety, and welfare of all people, and to ensure a clean and safe environment for future generations. In carrying out this mission MassDEP commits to address and advance environmental justice and equity for all people of the Commonwealth; provide meaningful, inclusive opportunities for people to participate in agency decisions that affect their lives; and ensure a diverse workforce that reflects the communities we serve.

Watershed Planning Program
The mission of the Watershed Planning Program (WPP) in the Massachusetts Department of Environmental Protection is to protect, enhance, and restore the quality and value of the waters of the Commonwealth. Guided by the federal Clean Water Act, WPP implements this mission statewide through five Sections that each have a different technical focus: (1) Surface Water Quality Standards; (2) Surface Water Quality Monitoring; (3) Data Management and Water Quality Assessment; (4) Total Maximum Daily Load; and (5) Nonpoint Source Management. Together with other MassDEP programs and state environmental agencies, WPP shares in the duty and responsibility to secure the environmental, recreational, and public health benefits of clean water for all people of the Commonwealth.

Acknowledgements
The Massachusetts CALM Guidance Manual is a collaborative product, shaped by the dedication and expertise of past and present Watershed Planning Program (WPP) staff. Many thanks to all who have contributed to the advancement of water quality assessment over the years. A special note of appreciation goes to recently retired WPP colleagues, Arthur Johnson, Laurie Kennedy, & Jane Ryder. Their work continues to inspire and guide our ongoing efforts to protect, enhance, and restore the quality and value of the waters of the Commonwealth.

Contact Information
Watershed Planning Program
Division of Watershed Management, Bureau of Water Resources
Massachusetts Department of Environmental Protection
8 New Bond Street, Worcester, MA 01606
Website: https://www.mass.gov/guides/watershed-planning-program
Email address: dep.wpp@mass.gov

Table of Contents

List of Appendices

List of Tables

List of Figures

List of Acronyms

ATTAINS	Assessment and Total Maximum Daily Load Tracking and Implementation System
AU	Assessment Unit
BMPs	Best Management Practices
BPJ	Best Professional Judgment
CALM	Consolidated Assessment and Listing Methodology
CAMIS	Coastal and Marine Inventory System
CCC	Criterion Continuous Concentration
CFR	Code of Federal Regulations
C-HAB	Cyanobacterial Harmful Algal Bloom
CMC	Criterion Maximum Concentration
CMR	Code of Massachusetts Regulations
CSO	Combined Sewer Overflow
CWA	Clean Water Act
CWF	Coldwater Fishery
DADA	Day Average of the Daily Average (usually preceded by the number of days)
DADM	Day Average of the Maximum (usually preceded by the number of days)
DELTS	Deformities, eroded fins, lesions, tumors
DO	Dissolved Oxygen
DWM	Division of Watershed Management
EPA	United States Environmental Protection Agency
GM	Geometric Mean
HAB	Harmful Algal Bloom
IBI	Index of Biotic Integrity
IR	Integrated Report: Multi-part List of Waters
LTC	Long-term continuous
MA DFG (or DFG)	Massachusetts Department of Fish and Game
MDPH (or MA DPH)	Massachusetts Department of Public Health
MassDCR (or DCR)	Massachusetts Department of Conservation and Recreation
MassDEP (or DEP)	Massachusetts Department of Environmental Protection
MassGIS	Massachusetts Geographic Information System
MEP	Massachusetts Estuaries Project
NPDES	National Pollutant Discharge Elimination System
ORS	(MassDEP) Office of Research and Standards
PALIS	Pond and Lake Information System
PAHs	Polyaromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PFAS	Per- and Polyfluoroalkyl Substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
PWS	Public Water Supply
QAPP	Quality Assurance Project/Program Plan
SARIS	Stream and River Inventory System
SC	Specific Conductance
STC	Short-term continuous
SOP	Standard Operating Procedure
STV	Statistical Threshold Value
SWQS	Surface Water Quality Standards
TFC	Target Fish Community
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WPP	Watershed Planning Program
WWF	Warmwater Fishery
7Q10	Lowest mean flow for seven consecutive days occurring on average once in ten years

I. INTRODUCTION

The *Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual* describes the data evaluation procedures used to assess water quality conditions of surface waters in the state, the process used to identify causes and sources of impairment(s), and the reporting of this information to EPA and the public in the form of an *Integrated Report: Multi-part List of Waters* (IR). Included in this CALM Guidance Manual are: a brief summary of the Massachusetts Surface Water Quality Standards (SWQS) at 314 CMR 4.00 that define water quality goals (MassDEP 2021b); the requirements for assessing the quality of data to be used for reporting pursuant to the Federal Water Pollution Control Act (33 U.S.C. 1251 et seq.), otherwise known as the Clean Water Act (CWA) and the associated Water Quality Standards regulation (40 Code of Federal Regulation (CFR) section 131); the methods for evaluating water quality data and information used by Watershed Planning Program (WPP) analysts in the Division of Watershed Management (DWM), Massachusetts Department of Environmental Protection (MassDEP), to make designated use attainment decisions; and a description of the use of the U.S. Environmental Protection Agency's (EPA) Assessment and Total Maximum Daily Load Tracking and Implementation System (ATTAINS), for storing these decisions (including changes in use attainment status) and generating the IR.

The Clean Water Act and Water Quality Assessment

The objective of the CWA is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. As one step toward meeting this goal, the CWA directs states to monitor and report on the condition of their water resources. This water quality reporting process is an essential aspect of the Nation's water pollution control effort and 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. The directives of the CWA and the process by which MassDEP analysts assess and report on the status of Massachusetts' waters are illustrated in Figure 1 and described in more detail in this document.

The CWA §305(b) mandates that states prepare a water quality inventory report every two years that summarizes the status of their waters with regard to the attainment of designated use goals and water quality criteria established to protect those uses, as defined in the SWQS. Designated uses include suitable habitat for *Fish, other Aquatic Life and Wildlife* (hereafter referred to as *Aquatic Life)*, *Fish Consumption*, *Public Water Supply*, *Shellfish Harvesting*, *Primary* (e.g., swimming) and *Secondary* (e.g., boating) *Contact Recreation*, *Aesthetics, Agricultural, and Industrial* (MassDEP 2021b). The CWA distinguishes causes of impairments as either "pollutants" such as nutrients, metals, pesticides, solids and pathogens or "pollution" such as low flow, habitat alterations or non-native species infestations.

The Clean Lakes Program was established in 1972 as section 314 of the CWA, to provide financial and technical assistance to states in restoring publicly-owned lakes. CWA Nonpoint Source Management Program funding (Section 319) may be used to address restoration and protection needs of surface waters related to nonpoint source pollution.

Section 303(d) of the CWA and the implementing regulations at 40 CFR 130.7 require states to identify those waterbodies impaired by "pollutants" that are not expected to meet SWQS after the implementation of technology-based controls and to prioritize and schedule them for the development of total maximum daily loads (TMDLs). A TMDL establishes the maximum amount of a pollutant that may be introduced into a waterbody and still ensure attainment and maintenance of surface water quality standards. The formulation of the 303(d) *List of Impaired Waters* (303(d) List) includes a more rigorous public review process than does reporting under §305(b), and the final version of this list must be formally approved by the EPA. Restoration of waters impaired by "non-pollutants" requires measures other than TMDL development and implementation such as dam removal, habitat restoration, and/or implementation of Best Management Practices (BMPs).

Prior to 2002 states prepared and submitted to the EPA both a biennial *Summary of Water Quality Report* in accordance with the requirements of §305(b) as well as a separate 303(d) List. On November 19, 2001, the EPA released guidance for the preparation of an optional IR that would combine reporting elements of both sections 305(b) and 303(d) of the CWA. This integrated format allows states to provide the status of all their assessed waters and identify their impaired waters requiring restoration in a single, multi-part list. Since 2002, MassDEP has adopted the IR format to report on waters for CWA §305(b)/§303(d) purposes.

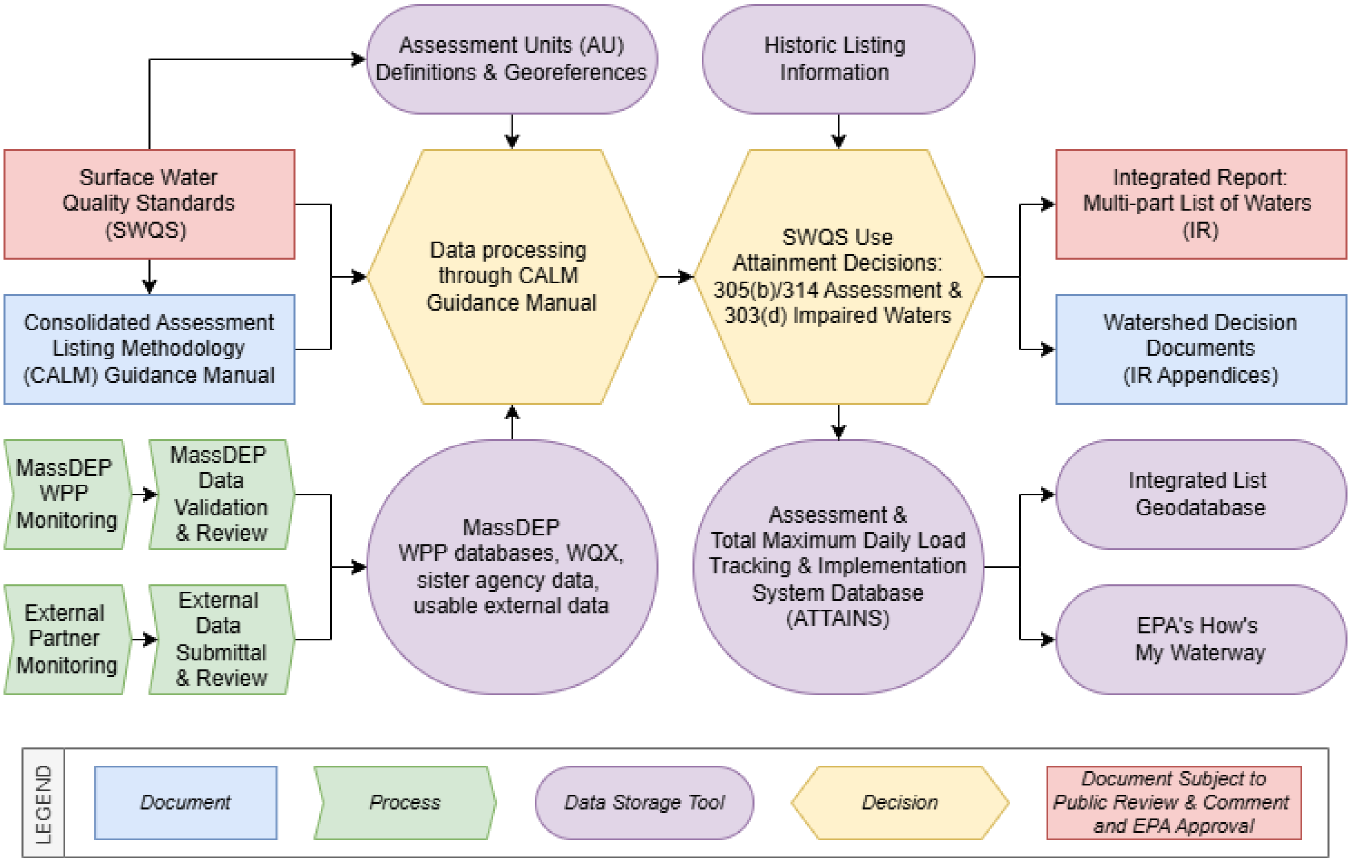


Figure 1. MassDEP Consolidated Reporting Process Schematic

Massachusetts' rivers, lakes, and coastal waters are partitioned into discrete assessment units (AUs) that are defined and maintained in the EPA-developed ATTAINS database. The 305(b) assessment process entails evaluating existing water quality conditions in each AU against the applicable criteria established in the SWQS and this CALM Guidance Manual for each designated use, and identifying wherever possible, causes and sources of use impairment. Through the 2012 reporting cycle, MassDEP documented use attainment decisions and the data used to make these decisions in individual, detailed watershed assessment reports (available on the MassDEP Water Quality Assessments webpage).

For the 2010 through 2014 reporting cycles, assessment decisions were stored in the Assessment Database (ADB V2.3.1) developed by EPA. MassDEP used this tool to both produce the IR and to provide the assessment data electronically to the EPA. Subsequently MassDEP transitioned to the use of EPA's ATTAINS database. ATTAINS is used to generate output files, which are then assembled into an IR in a single, multi-part list. Each AU is listed in one of five categories (see Table 8 for brief description of each List Category).

Starting with the 2018/20 reporting cycle, watershed decision documents are included as appendices to the IR to improve transparency for the public. These documents provide summaries of the data and information used to make the use attainment decisions along with the data supporting impairment removals. Each decision document includes a table of impairments *added, removed,* or *changed* from the prior IR cycle. A draft list is sent out for public as well as EPA review and comment. Comments are addressed and the proposed 303(d) list is submitted to EPA for approval. After the 303(d) list is approved by EPA, in fulfillment of the CWA reporting requirements, the ATTAINS data for each state, territory, or tribe can be accessed at EPA's How's My Waterway website. The final 2022 IR data are spatially presented in Massachusetts GIS products, including a geodatabase and shapefiles with supporting database tables, published through MassGIS, and the MassDEP Water Quality Data Viewer.

Notable Guidance Updates for 2024

The first CALM Guidance Manual, published in 2012, provided the methods and rationale for making the use attainment decisions embodied in the Integrated Reporting. MassDEP updates the CALM during each Integrated Reporting cycle to ensure compliance with state and federal surface water quality standards and to address emerging concerns. The process may include revisions to assessment thresholds, data evaluation techniques methodologies used for assessing waterbodies. Previous versions of the CALM Guidance Manual are available of the MassDEP Integrated Lists of Waters & Related Reports webpage. Substantial revisions of the CALM Guidance Manual for 2024 included:

2024 CALM Guidance Changes

- Section V. *Primary Contact Recreation Use:* The methods for evaluating Cyanobacterial Harmful Algal Bloom (CHAB) advisories (reported to DPH by local, state and federal partners) have been clarified to distinguish between an alert and an impairment based upon the duration of the advisory and availability of cyanobacteria and cyanotoxin data.
- Section V. *Secondary Contact Recreation Use*: new *E. coli* and *enterococcus* indicator organism thresholds (both GM and STV) to evaluate use attainment are provided in this section as well as in Appendix J. The new thresholds were developed from the 2024 EPA secondary contact recreation user guide (EPA 2024a).
- Appendix F - Development of a Linear Regression Tool for Estimating Chloride Concentrations in Freshwaters of Massachusetts: The linear regression model for estimating chloride concentrations from specific conductance data has been refined with additional data from both the MassDEP Watershed Planning Program and USGS which slightly changed (lowered/made more conservative) the acute and chronic threshold values.

2024 CALM Section Updates

- Acronyms: List of Acronyms Table has been provided with a list of commonly used acronyms.
- Section II. Surface Water Quality Standards. Updates included a new subsection titled Contaminants Without Criteria where three updates were made including *Secondary Contact Recreation Use* Bacteria Data Assessment Thresholds requested by EPA, PFAS guidance thresholds for Fish Consumption and *Primary Contact Recreation Use*s are included, and Cyanobacteria microcystins and cylindrospermopsin toxins guidance thresholds are provided for both recreational uses.
- Definitions of cause terms: As requested in some of the 2022 IR Public Comments, explanations on the differences between Trash and Debris, and Dewatering vs Flow Regime Modifications have been added to the *Aesthetics Use* section and *Aquatic Life Use* – Habitat and flow data section, respectively.
- Section V. Fish Consumption Use: new information has been provided regarding the process by which MDPH evaluates fish tissue toxicity data and issues a Fish Consumption Advisory when PFAS have been found to exceed the applicable action level.

2024 CALM Appendix Changes

- Update to Appendix A Evaluation Methods for Natural Background Conditions
- Update to Appendix C Literature Review of Fresh Water Nutrient Enrichment Indicators
- Update to Appendix D Derivation of Temperature and Dissolved Oxygen (DO) Assessment Thresholds
- Update to Appendix F Development of a Linear Regression Tool for Estimating Chloride Concentrations (updated formula based on additional study data resulting in slightly lower acute and chronic threshold values).
- Update to Appendix J Overview of the Processing and Evaluation Procedures Using *E. coli* and *enterococcus* Bacteria Data for Recreational Use Attainment Decisions (incorporation of EPA recommended thresholds).

II. SURFACE WATER QUALITY STANDARDS

The Massachusetts SWQS regulation (MassDEP 2021b) serves as the foundation for the state's water quality management program. The program includes water quality assessments (305(b)), lists of impaired waters (303(d)), TMDL development, National Pollutant Discharge Elimination System (NPDES) permits, and nonpoint source management measures. The SWQS regulation: 1) defines the goals for the surface waters of the Commonwealth by designating the most sensitive uses for which they shall be enhanced, maintained and protected; 2) prescribes minimum water quality criteria (both numeric and narrative) required to sustain the designated uses; 3) includes provisions to restore uses, and 4) includes provisions to maintain and protect existing uses and high quality waters (314 CMR 4.04 Antidegradation Provisions), which may include the prohibition of discharges (MassDEP 2021b). The federal water quality standards regulation (40 CFR Part 131.20) requires that state surface water quality standards regulations undergo regular public review.

Water Use Goals

The SWQS at 314 CMR 4.05 and 4.06 identify and classify certain surface waters or surface water segments and assign qualifiers that further define the designated uses of those surface waters or segments (MassDEP 2021b). The eight classes of surface waters (A, B, B(CSO), and C for freshwater and SA, SB, SB(CSO), and SC for coastal and marine waters), described below, are identified by the most sensitive, governing water uses to be achieved and protected. However, no surface waters in Massachusetts are currently designated as either Class C or Class SC. Tables 1 through 27 at 314 CMR 4.06(6)(b) of the SWQS list specific waterbodies or groups of waterbodies by classification and qualifiers; however, not all waters in the state are included. The default classifications for waters not specifically listed in Tables 1 through 27, as specified in 314 CMR 4.06(5) under "Other Waters", are Class B for inland waters and Class SA for coastal and marine waters. Additional use goals are applied to surface waters through qualifiers that indicate special considerations and uses applicable to specified waterbodies or segments (see 314 CMR 4.06(1)(d)). The qualifiers that affect assessment decisions include Public Water Supply (PWS), Cold Water, Warm Water, and Combined Sewer Overflow (CSO). Further discussion of these qualifiers and uses and how they are applied in the assessment decision-making process can be found in Section V, Use Attainment Decision Process. Inland cold water and warm water fisheries and coastal and marine shellfishing qualifiers are applied to unlisted waters as existing uses (those attained in waterbodies on or after November 28, 1975) on a case-by-case basis, as necessary. Wetlands generally adopt the class and qualifiers of the surface water they border or are otherwise designated Class B for inland waters and Class SA for coastal and marine waters; vernal pools are designated Class B Outstanding Resource Waters or ORWs (see 314 CMR 4.06(2)). Surface waters may be suitable for other beneficial uses but shall be regulated by MassDEP to protect and enhance both existing and designated uses.

Water Quality Criteria

The SWQS minimum criteria to sustain existing and designated uses and the classes of surface water to which they apply are summarized in Table 1. Additional information in Table 1 includes a summary of bacteria criteria from the MA Department of Public Health (MDPH 2014) at public bathing beaches and from the United States Food and Drug Administration (USFDA 2017) in shellfishing areas. Criteria for certain pollutants, such as color and turbidity, are only described in a narrative format. Numerical and narrative criteria for each class of water are outlined in Section 4.05 of the SWQS. Criteria applicable to all surface waters are listed at 314 CMR 4.06(6)(d): *Table 29: Generally Applicable Criteria*. In addition, those surface waters that are assigned a qualifier may have unique criteria applied to them. For example, surface waters or segments and their tributaries that are qualified as Cold Water are evaluated using Cold Water Fishery criteria. If a segment is not a designated or existing use Cold Water or a tributary to such water, it is assumed to be Warm Water and Warm Water Fishery criteria are applied. Surface waters exhibiting excursions from criteria due to natural background conditions are not interpreted as violations of the SWQS (per 314 CMR 4.03(5)) (see also guidance provided in Appendix A). It should also be noted that the SWQS contain site-specific criteria listed at 314 CMR 4.06(6)(c) (Table 28) that were developed for specific river segments, lakes, coastal and marine segments. These include copper, zinc, total phosphorus, and total nitrogen criteria. These criteria are only applied after EPA approval.

The SWQS also describe the hydrological conditions at which water quality criteria must be applied (314 CMR 4.03(3) (MassDEP 2021b)). In rivers, water quality criteria for the *Aquatic Life Use* must be applied at or above 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, aquatic life criteria must be applied when flows are equal to or exceeded 99% of the time on a yearly basis or when another minimum flow condition, as determined by MassDEP, is exceeded. In coastal and marine waters, and for lakes and ponds, MassDEP will determine on a case-by-case basis the most severe hydrological condition for which the aquatic life criteria must be applied. It should be noted that waterbodies affected by CSO discharges are qualified in the SWQS; however, unless a variance has been granted that states otherwise, excursions from criteria are not allowed during storm events (designated uses still need to be sustained).

CLASSIFICATION OF MASSACHUSETTS SURFACE WATERS – RIVERS, LAKES, ESTUARIES

INLAND WATER CLASSES

CLASS A *- These waters include waters designated as a source of public water supply, their tributaries and bordering wetlands, and certain surface waters designated in 314 CMR 4.06. They are designated as excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation, even if not allowed. These waters shall have excellent aesthetic value and are protected as Outstanding Resource Waters.*

CLASS B *- These waters, including certain wetlands and qualified waters, are designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. Where designated in 314 CMR 4.06, they shall be suitable as a source of public water supply with appropriate treatment ("Treated Water Supply"). Class B waters shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.*

CLASS B (CSO): *denotes those waters occasionally subject to short-term impairment of swimming or other recreational uses due to untreated CSO discharges, and the aquatic life community may suffer adverse impact yet is still generally viable. In these waters, the uses for Class B waters are maintained after the implementation of long term control measures described in an approved CSO long term control plan.*

CLASS C *- These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for secondary contact recreation. These waters shall be suitable for the irrigation of crops used for consumption after cooking and for compatible industrial cooling and process uses. These waters shall have good aesthetic value.*

COASTAL AND MARINE CLASSES

CLASS SA *– These coastal waters and certain qualified surface waters are designated as an excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, sea grass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas). These waters shall have excellent aesthetic value.*

CLASS SB *- These coastal waters and certain qualified surface waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas). These waters shall have consistently good aesthetic value.*

CLASS SB (CSO): *denotes those waters occasionally subject to short-term impairment of swimming or other recreational uses due to untreated CSO discharges, and the aquatic life community may suffer adverse impact yet is still generally viable. In these waters, the uses for Class SB waters are maintained after the implementation of long term control measures described in an approved CSO long term control plan.*

CLASS SC *- These coastal and marine waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for secondary contact recreation. They shall also be suitable for certain industrial cooling and process uses. These waters shall have good aesthetic value.*

Table 1. Summary of Massachusetts Surface Water Quality Standards.

Parameter	Criteria based on surface water classification*
Dissolved Oxygen*	Class A Cold Water Fishery (CWF) and Class B Cold Water Fishery (BCWF) and Class SA: ≥6.0 mg/l Class A and Class B Warm Water Fishery (BWWF) and Class SB: ≥5.0 mg/l Class C: Not <5.0 mg/l at least 16 hours of any 24-hour period and not <3.0 mg/l at any time. Class SC: Not <5.0 mg/l at least 16 hours of any 24-hour period and not <4.0 mg/l anytime. *For all classes, where natural background conditions are lower than the criteria stated for each class, DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall also be maintained.*
Temperature*	Class A CWF: ≤68°F (20°C) based on the mean of the daily maximum temperature over a seven day period in cold water fisheries, unless naturally occurring and ΔT due to a discharge ≤1.5°F (0.8°C). Class A WWF: ≤83°F (28.3°C) and ΔT due to a discharge ≤1.5°F (0.8°C). Class B CWF: ≤68°F (20°C) based on the mean of the daily maximum temperature over a seven day period in all cold water fisheries, unless naturally occurring, and ΔT due to a discharge ≤Δ3°F (1.7°C) Class B WWF: ≤83°F (28.3°C) and ΔT due to a discharge ≤5°F (2.8°C) in rivers (based on the minimum expected flow for the month) and ΔT due to a discharge ≤3°F (1.7°C) in the epilimnion (based on the monthly average of maximum daily temperatures) in lakes Class C and Class SC: ≤85°F (29.4°C) and ΔT due to a discharge ≤5°F (2.8°C) Class SA: ≤85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°C) and ΔT due to a discharge ≤1.5°F (0.8°C) Class SB: ≤85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°C) and Δ T due to a discharge ≤1.5°F (0.8°C) between July and September and ≤4.0°F (2.2°C) between October and June. *For all classes, natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. There shall be no changes from natural background conditions that would impair any uses assigned to each class, including those conditions necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms.* For CWF waters, where a reproducing cold water aquatic community exists at a naturally higher temperature, the temperature necessary to protect the community shall not be exceeded and natural daily and seasonal temperature fluctuations necessary to protect the community shall be maintained. Class B, C, SA, SB, and SC: See (MassDEP 2021b) for language specific to alternative effluent limitations relating to thermal discharges and cooling water intake structures.
pH*	Class A, Class BCWF and Class BWWF: 6.5 - 8.3 SU and Δ0.5 outside the natural background range. Class C: 6.5 - 9.0 SU and Δ1.0 outside the natural background range. Class SA and Class SB: 6.5 - 8.5 SU and Δ0.2 SU outside the natural background range. Class SC: 6.5 - 9.0 SU and Δ0.5 SU outside the natural background range. There shall be no change from natural background conditions that would impair any use assigned to each class.
Solids	All Classes: *These waters shall be free from floating, suspended, and settleable solids in concentrations or combinations that would impair any use assigned to each class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.*
Color & Turbidity	All Classes: *These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use.*
Oil and Grease	Class A and Class SA: *Waters shall be free from oil and grease, petrochemicals and other volatile or synthetic organic pollutants.* Class SA: *Waters shall be free from oil and grease and petrochemicals.* Class B, Class C, Class SB and Class SC: *Waters shall be free from oil, grease, and petrochemicals that produce a visible film on the surface of the water, impart an oily taste to the water or an oily or other undesirable taste to the edible portions of aquatic life, coat the banks or bottom of the water course, or are deleterious or become toxic to aquatic life.*
Taste and Odor	Class A and Class SA: *None other than of natural origin.* Class B, Class C, Class SB and Class SC: *None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to each class, or that would cause tainting or undesirable flavors in the edible portions of aquatic life.*
Aesthetics	All Classes: *All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.*
Bottom Pollutants or Alterations	All Classes: *All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propogation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms*.

Table 1. Summary of Massachusetts Surface Water Quality Standards.

Parameter	Criteria based on surface water classification*
Toxic Pollutants	All Classes: *All surface waters shall be free from pollutants in concentrations or combinations that are toxic to humans, aquatic life or wildlife. For each pollutant identified in 314 CMR 4.06(6)(d):Table 29: Generally Applicable Criteria, the concentrations identified or calculated for that pollutant in or pursuant to Table 29 shall be generally applicable criteria for all categories of surface waters, as specified therein; unless the Department determines that naturally occurring background concentrations are higher. Where the Department determines that naturally occurring background concentrations are higher, those concentrations shall be the allowable receiving water concentrations. (For purposes of convenience, Table 29 also references certain pollutants for which 314 CMR 4.05(3), (4)or (5)(a), (5)(b), (5)(c), (5)(d) or (5)(f) establish criteria.)*
Nutrients	*Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site-specific criteria developed in a TMDL or as otherwise established by the Department pursuant to these Standards.*
Radioactivity	*All surface waters shall be free from radioactive substances in concentrations or combinations that would be harmful to human, animal or aquatic life or the most sensitive designated use; result in radionuclides in aquatic life exceeding the recommended limits for consumption by humans; or exceed Massachusetts Drinking Water Regulations as set forth in 310 CMR 22.09*.
Bacteria Notes: Class A criteria apply to the Public Water Supply Use and *Primary Contact Recreation Use*. Class B and SB criteria apply to *Primary Contact Recreation Use* Class C and SC criteria were previously applied to *Secondary Contact Recreation Use* (see additional information & discussion in Contaminants without Criteria section below Table 1)	Class A: Inland Waters Class A: *At water supply intakes in unfiltered public water supplies: either fecal coliform shall not exceed 20 fecal coliform organisms per 100 mL in all samples taken in any six-month period, or total coliform shall not exceed 100 organisms per 100 mL in 90% of the samples taken in any six-month period. If both fecal coliform and total coliform are measured, then only the fecal coliform criterion must be met.* For all other Inland Waters Class A and B ([1, 2]see notes related to applicability below): For protection of primary contact recreation, surface waters shall meet the minimum criteria for bacteria as follows: *E. coli concentrations shall not exceed 126 colony-forming-units (cfu) per 100 mL (cfu/100mL), calculated as the geometric mean of all samples collected within any 90-day or smaller interval; and no more than 10% of all such samples shall exceed 410 cfu/100 mL (the statistical threshold value); or* *Enterococci concentrations shall not exceed 35 cfu/100 mL calculated as the geometric mean of all samples collected within any 90-day or smaller interval; and no more than 10% of all such samples shall exceed 130 cfu/100 mL (the statistical threshold value).* Coastal and Marine Waters Class SA and SB ([1, 2]see notes related to applicability below): SA *Waters designated for shellfishing: fecal coliform shall not exceed a geometric mean Most Probable Number (MPN) of 14 organisms/100 mL, nor shall more than 10% of the samples exceed an MPN of 28 organisms/100 mL, or other values of equivalent protection based on sampling and analytical methods used by the Massachusetts Division of Marine Fisheries and approved by the National Shellfish Sanitation Program in the latest revision of the Guide for the Control of Molluscan Shellfish (more stringent regulations may apply, see 314 CMR 4.06(1)(d)5.)* and SB *Waters designated for shellfishing: fecal coliform shall not exceed a fecal coliform median or geometric mean MPN of 88 organisms/100 mL, nor shall more than 10% of the samples exceed an MPN of 260 organisms/100 mL or other values of equivalent protection based on sampling and analytical methods used by the Massachusetts Division of Marine Fisheries and approved by the National Shellfish Sanitation Program in the latest revision of the Guide For The Control of Molluscan Shellfish (more stringent regulations may apply, see 314 CMR 4.06(1)(d)(5)).* For protection of primary contact recreation, surface waters shall meet the minimum criteria for bacteria as follows: *Enterococci concentrations shall not exceed 35 cfu/100 mL calculated as the geometric mean of all samples collected within any 90-day or smaller interval; and no more than 10% of all such samples shall exceed 130 cfu/100 mL (the statistical threshold value).* Class C ([3]see applicability note below): *Concentrations of E. coli bacteria shall not exceed 630 cfu/100 mL, calculated as the geometric mean of all samples collected within any 90-day-or-smaller interval and no more than 10% of all such samples shall exceed 1260 cfu/100 mL.* Class SC ([3]see applicability note below): *Enterococci concentrations shall not exceed 175 cfu/100 mL, calculated as the geometric mean of all samples collected within any 90-day or smaller interval; and no more than 10% of all such samples shall exceed 350 cfu/100 mL (the statistical threshold value).* Applicability notes: [1] Reduced intervals (30-days or fewer) are required at: waters adjacent to any public or semi-public beach, at a location used for bathing and swimming purposes as defined and regulated by the Massachusetts DPH, or segments impacted by CSO, B(CSO), SB(CSO), or POTW discharges. [2] Seasonal Exception: The year-round minimum criteria for bacteria may be applied on a seasonal basis upon MassDEP's determination that, because of a reduction in primary contact recreation during a specified period of time, such criteria are not needed to be protective. Bases for such determinations may include identification of periods when frequency of use is reduced due to cold weather (typically, from November through March); and/or consideration of other relevant and appropriate factors.[3]

Note: *Italics are direct quotations.*

* Excursions from criteria due to solely natural conditions shall not be interpreted as violations of standards and shall not affect the water use classifications adopted by the Department. Natural background conditions can be determined from monitoring, modeling, or by comparison with a reference, unimpaired watershed with similar hydrologic, land use, and pollutant loading characteristics (EPA 2005). However, if an impairment is caused by a combination of natural and anthropogenic sources, or if the impairment is related to human health criteria, the waterbody will be assessed as impaired (see Appendix A).

Contaminants Without Criteria

Secondary Contact Recreation Use Bacteria Data Assessment Thresholds:
Bacteria data thresholds used to assess the *Secondary Contact Recreation Use* were previously based on the Class C and Class SC criteria in the SWQS, but EPA's 2024 secondary contact recreation user guide (EPA 2024a) provided updated information on implementation thresholds. These thresholds are calculated with the estimated incidental ingestion rate while swimming (a Primary Contact Recreation activity) in comparison with the estimated incidental ingestion rate while kayaking (a Secondary Contact Recreation activity that may include capsizing). The thresholds include both a geometric mean (GM) and a statistical threshold value (STV) and are described in more detail in Section V. *Secondary Contact Recreation Use*, Table 7 for *E. coli* or *enterococcus* bacterial indicators in Class C and Class SC waters, respectively.

***Cyanobacteria (microcystins and cylindrospermopsin) toxins*:**
In 2019, EPA published recommended freshwater criteria for microcystins and cylindrospermopsin, toxins produced by some cyanobacteria species (cyanotoxins), that pose a human health risk from incidental ingestion. Microcystins are produced by a variety of toxigenic cyanobacteria genera, including *Microcystis, Anabaena, Dolichospermum, Nodularia, Nostoc, Oscillatoria, Fischerella, Planktothrix,* and *Gloeotrichia* spp*.* Cylindrospermopsin is produced by numerous toxigenic cyanobacteria taxa, including *Cylindrospermopsis raciborskii, Aphanizomenon, Anabaena, Lyngbya wollei,* and *Raphidiopsis* (EPA 2019). The assessment thresholds, based on EPA's recommendations and MassDEP's current HABs evaluation procedures, are that if either of the cyanotoxin assessment thresholds (mycrocystins and/or cylindrospermopsin) are exceeded within three or more 10-day evaluation periods during a single Primary and/or Secondary Contact Recreation season, MassDEP analysts will assess the waterbody as not supporting the Primary and/or *Secondary Contact Recreation Use*s. The thresholds are as follows:

Toxin	Magnitude	Duration	Frequency
Microcystins	8 µg/L	A single excursion is one or more concentrations of either or both toxins higher than the threshold magnitudes within a 10-day evaluation period	Three or more excursions in a single primary (April 1 – October 31) and/or secondary (year-round) contact recreation season
Cylindrospermopsin	15 µg/L		

Per- and Polyfluoroalkyl Substances (PFAS):
Harmful per- and poly-fluoroalkyl substances (PFAS) are an urgent public health and environmental issue facing communities worldwide. Thousands of different PFAS have been manufactured and used in a variety of industries in the United States (U.S.) and around the globe since the 1940s, and they are still being used today. PFAS are a family of fluorinated synthetic chemicals used to manufacture stain-resistant, water-resistant, and non-stick products. PFAS were widely used in common consumer products as coatings, on food packaging, outdoor clothing, carpets, leather goods, ski and snowboard waxes, and more. These chemicals were also historically used in firefighting foams (e.g., aqueous film forming foam – AFFF). Although manufacturing of certain PFAS has now ceased in the U.S. (e.g., PFOA and PFOS), PFAS are extremely persistent in the environment and have been found in some drinking water supplies, including in Massachusetts. PFAS can also bioaccumulate in aquatic species and wildlife, although the extent of bioaccumulation is highly dependent on environmental factors (e.g., dissolved organic matter) and the PFAS chemical characteristics (e.g., biotransformation of precursor PFAS) (Lewis, et al. 2022). Due to their widespread use and persistence in the environment, studies show that most people in the U.S. have been exposed to PFAS. Although research is ongoing, studies show exposures to certain concentrations of PFAS may lead to adverse health outcomes in humans (EPA 2023). Some PFAS analytes have been regulated in Massachusetts, beginning in 2020 with the adoption of a Massachusetts drinking water standard for the sum of six PFAS (PFOA, PFOS, PFNA, PFHxS, PFDA, and PFHpA) (MassDEP 2020).

In 2023, MDPH released their Technical Support Document outlining their risk management approach for evaluating consumption of fish and recreational safety at public and semi-public bathing beaches with respect to PFAS exposure (MDPH 2023). The MDPH thresholds for the *Fish Consumption Use* and *Primary Contact Recreation Use* are presented below and are incorporated into the 2024 CALM guidance (see the pertinent sub-headings under Section V for more information).

Organization	Type of Screener	Analytes Evaluated	Screener Value
Fish Consumption Use			
MDPH	Fish muscle, individual analyte (candidate Fish Action Level or cFAL)	PFOA, PFOS, PFNA, PFHxS, PFBA, PFBS, HFPO-DA (aka GenX)	0.22 ng/g (ppb)
Primary Contact Recreation Use			
MDPH	Surface water, individual analytes with toxicity criteria	PFOA, PFOS, PFNA, PFHxS, PFBA, PFBS, HFPO-DA (aka GenX)	90 ng/L (ppt)[1,2]

[1] *Primary Contact Recreation Use screening of surface water measurements based on Massachusetts Department of Public Health's 2023 Technical Support Document guidance for individual analytes with established toxicity criteria at public/semi-public bathing beaches in both fresh and marine waters* (MDPH 2023)*: ≤20 ng/L no restrictions; >20-90 ng/L public notification required; >90-500 ng/L site specific evaluation and public notification required, some restrictions on swimming may apply (situational swim advisory); >500 ng/L swimming not allowed and public notification required.*

[2] *For all other waters lacking public/semi-public beaches, MassDEP analysts will identify an Alert when >90 ng/L (ppt) of one of the analytes with established toxicity criteria is detected in a waterbody. MassDEP analysts may consult with ORS to further evaluate PFAS data as part of the use attainment decision for the Primary Contact Recreation Use.*

Antidegradation Policy

The third component of the SWQS is the antidegradation provisions (314 CMR 4.04) designed to preserve and protect existing uses and to minimize surface water degradation of the state's high quality waters, ORWs, and special resource waters. These provisions restrict or prohibit the authorization of wastewater discharges to these waters. The ORWs exhibit exceptional socio-economic, recreational, ecological and/or aesthetic qualities. ORWs include, but are not limited to, Class A public water supplies and their bordering vegetated wetlands and vernal pools certified as such by the Massachusetts Department of Fish and Game. Other waters designated as ORWs may include those protected by special legislation, as well as selected waters found in national parks, national wildlife refuges, state forests, parks, and sanctuaries, or areas of critical environmental concern (ACECs).

III. ASSESSMENT UNIT (AU) DEFINITIONS FOR MASSACHUSETTS

When defining AUs (sometimes referred to as “segments”) for reporting and listing the use-attainment status of its surface waters, Massachusetts takes into consideration any of the following:

- Waterbody inventory systems for rivers/streams, lakes/ponds, and coastal/marine features
- Waterbody type (lotic, lentic, estuarine)
- SWQS classification
- Features that affect water quality (wastewater discharges, dams, river confluences, etc.)
- Availability of recent water quality and/or biological monitoring data
- Development of TMDLs

The SWQS classification is the primary source for defining AUs used for CWA reporting requirements, and waterbodies must be broken into smaller AUs to reflect differences in SWQS Class (e.g., B, SA, etc.) and/or qualifiers (e.g., Cold Water, Shellfishing, etc.). Furthermore, because each AU is generally assumed to be fairly homogeneous in water quality, AUs are established to account for changes in water quality conditions that may be expected (i.e., at the confluence of a major tributary, at a dam, or at the site of a NPDES discharge).

To aid in monitoring, assessing and managing the water quality of Massachusetts’ surface waters, MassDEP (in conjunction with other agencies and institutions) developed waterbody inventory systems for rivers, lakes, and estuaries, where each waterbody was assigned a unique identifying code number tied to the watershed where it was located. The Stream and River Inventory System (SARIS) (Halliwell, Kimball and Screpetis 1982) was created to describe all Massachusetts’ perennial streams that were named on U.S. Geological Survey (USGS) topographic maps (unnamed tributaries were originally excluded from SARIS). The SARIS numbering system was built around a nested stream hierarchy within each watershed with lower numbers corresponding to the mainstem river and higher numbers corresponding to headwater tributaries. Each SARIS code is a seven-digit number starting with the two-digit number assigned to each of the 33 major watersheds in Massachusetts (see Figure 2). Each number was originally incremented by units of 25 to allow for the future addition of tributary streams. For example, the Ipswich River, located within the Ipswich River Watershed (92), was assigned a SARIS code of 9253500, and all tributaries to the Ipswich River have larger SARIS numbers. To accommodate new AUs where no SARIS number exists, new SARIS numbers are added as needed to the original inventory system (MassDEP Unpublished a). Likewise, approximately 3,000 lakes, ponds, reservoirs, and impoundments were included in the Pond and Lake Information System (PALIS), a numbering system originally developed by Godfrey et al. (1979) and later adopted by the MassDEP’s Clean Lakes Program (Ackerman, Batiuk and Beaudoin 1984, Ackerman 1989). Each PALIS code is a five-digit number starting with the two-digit watershed number (e.g., 82109 is Walden Pond, located in the Concord River Watershed (82)). PALIS codes are maintained for defining AUs by WPP. Finally, the Coastal and Marine Inventory System (CAMIS) (MassDEP Unpublished d) has been utilized to organize coastal waters, estuaries, and harbors based on their respective drainage areas as described in SARIS, and for which no SARIS or PALIS numbers have been assigned. Each five-digit CAMIS number begins with the two-digit watershed number followed by a 9 to indicate CAMIS waterbodies (e.g., 94906 is Plymouth Harbor; portions of the South Shore coastal drainage system (94) drains to this waterbody). Note that Boston Harbor (proper) (70) was added as a “watershed” for assessment purposes and is utilized within CAMIS, but was not included as one of the original 32 Massachusetts watersheds described under the SARIS and PALIS systems.

Massachusetts defines AUs using the following three waterbody types represented by the SARIS/PALIS/CAMIS inventories described above (units given in parentheses): rivers (miles), lakes (acres), and estuaries (square miles). However, AUs were never universally established for every waterbody in these inventories. Rather, AUs were (and continue to be) created over time, as actual assessments of those waterbodies are carried out for the first time. Therefore, the complete inventory of all of Massachusetts’ waterbodies is not represented by the AUs presented in the IR. When creating AUs, names are adopted directly from the associated SARIS, PALIS or CAMIS waterbody, although some exceptions do occur. Descriptions also help to identify the location of the AU. For lakes, the town where the AU is located is noted in the description. For rivers, the start and end points of the AU are described in terms of such features as tributaries, headwaters, outlets from ponds, and roads/bridges. Estuarine AUs may be described either way. Unlike lakes and ponds, a river or estuary represented by a single SARIS or CAMIS number may be divided into two or more AUs (see below). Therefore, AU identifiers (AUIDs) are assigned using two formats: 1) prefix “MA” followed by the five-digit PALIS code (lakes); or 2) prefix “MA” followed by “WW-XX” (rivers and estuaries), where WW is the two-digit watershed identification number and XX is a unique number beginning with “01”. Unlike the SARIS coding system there is no hierarchical numbering system used for an AUID. Each new AUID for a river or an estuary is incremented by one as it is added during a reporting cycle.

Prior to the use of geographic information systems, AUs were defined using USGS topographic maps, with sizes determined by map wheels (rivers) and planimetry (lakes and estuaries). AUs were first depicted using GIS in 2000 using two feature classes, one for linear features (rivers and a few estuaries) and one for polygon features (lakes and estuaries). Lake and river AUs were georeferenced using the 1:25,000 USGS hydrography dataset (later modified by MassDEP), which depicts waterbodies based on USGS topographic quadrangle maps. Today, Massachusetts Geographic Information System (MassGIS) color orthophotos, rasterized USGS topographic base maps, and professional judgment are used to help interpret and define individual river and lake AUs. Estuaries are defined using the USGS 1:25,000 topographic maps, National Oceanic and Atmospheric Administration (NOAA) nautical charts at several scales, and the original inventory and planimetry of Gil (1985) and Maietta (1984), respectively. In addition, coastal boundary definitions, landmarks (such as lighthouses), rock outcroppings, the extent of shellfishing beds, and professional expertise inform the creation of estuarine AUs.

With the completion of the 2016 IR, MassDEP analysts concluded a major effort to clarify AU designations and descriptions and eliminate cases where AUs overlapped. Specifically, since many of Massachusetts' lakes and ponds are impounded stream reaches, several were included in earlier IR reporting cycles as both lake and stream AUs. To avoid this "double-counting" in future IRs, MassDEP analysts began, with the 2008 reporting cycle, to review pertinent morphometric and hydrological data from impoundments as part of the watershed assessment process to determine whether they should continue to be defined and assessed as lake AUs or incorporated into stream AUs. As a general rule, those impoundments formerly identified as lake AUs, but exhibiting unidirectional flow and estimated average retention times of less than fourteen days, were eliminated and merged with their respective stream AUs, whether or not they were named lakes depicted on USGS topographic quadrangle maps and/or had been assigned PALIS numbers. The general approach used by MassDEP to calculate the retention times of impoundments is presented in Appendix G.

When a watershed is scheduled for an assessment update during a new CWA reporting cycle, new AUs may be established due to the sufficient availability of recent water quality or biological data, as a result of a TMDL study or public comment. Furthermore, as SWQS are updated, new information may become available that requires geospatial changes to existing AUs, such as new data that indicate support of an existing use (e.g., Cold Water), or changes in PWS/ORW status. Geospatial changes may require deleting an entire AU, splitting an AU into two or more segments, or joining all or part of one AU with another AU. Whenever an AU is resegmented, the former AU identifiers are listed within the AU description.

When assessing a major drainage system, river basin (i.e., watershed) or coastal drainage area for the *Aquatic Life Use*, all perennial Coldwater Fish Resource streams (or perennial portions thereof) that were sampled for temperature and fish population by MA Department of Fish and Game (MA DFG) biologists under a pre-2015 agreement with MassDEP and that were accepted for designation as Cold Waters in the SWQS will be added as AUs and existing use evaluations for these waters will include habitat and temperature data (see Section V. *Aquatic Life Use* – Water Quality Data – Temperature) following the guidance in the decision flowchart. Similarly, during the *Aquatic Life Use* assessment process, any remaining rivers and lakes where diadromous fish runs exist will be added as AUs if passage is restricted, severely restricted, or has no possible passage. Such AUs will be assessed according to the decision flowchart to address the diadromous fish habitat-related impairments (Section V. *Aquatic Life Use* – Habitat & Flow Data).

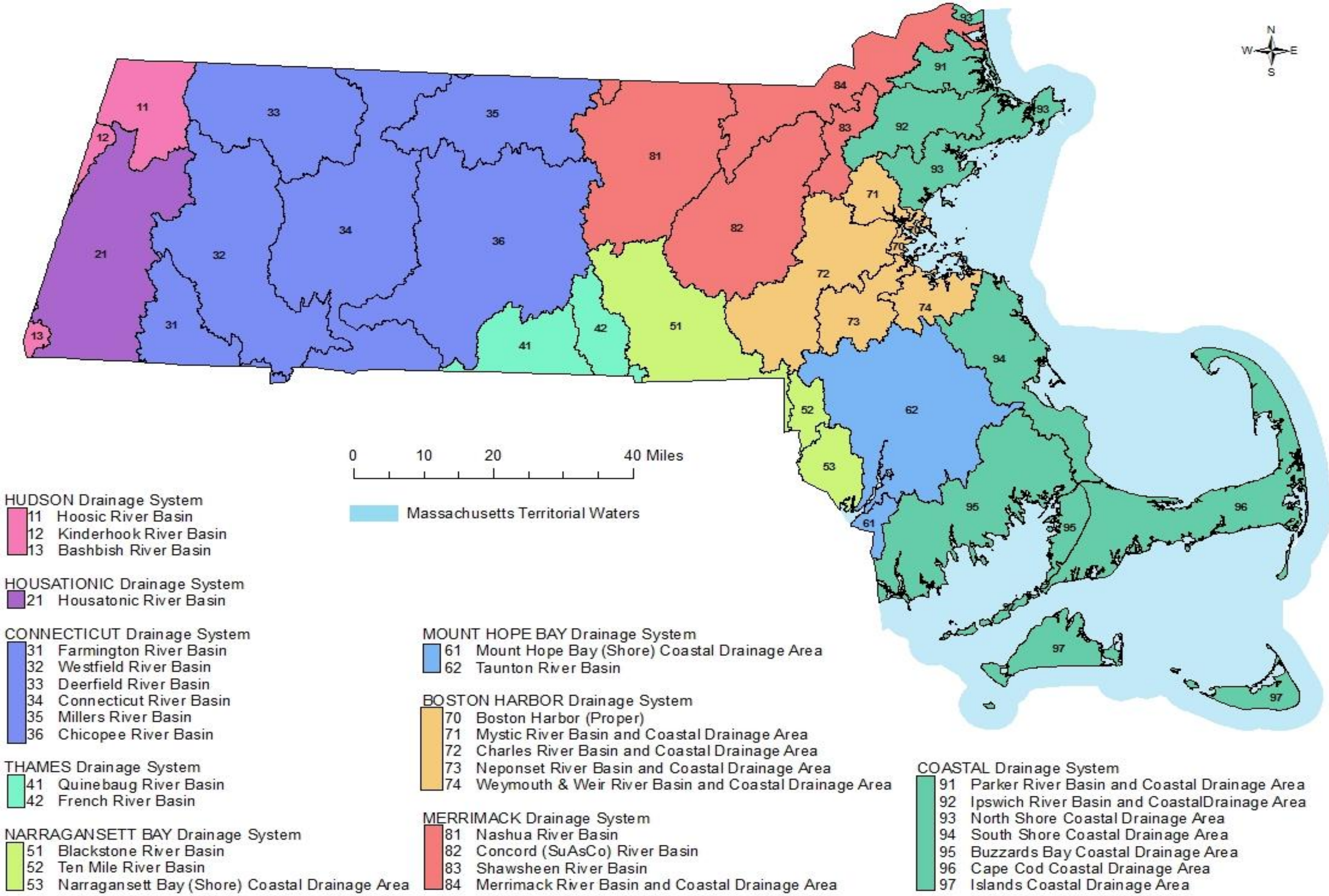


Figure 2. Major drainage systems, river basins (i.e., watersheds) & coastal drainage areas of Massachusetts with unique Stream and River Inventory System (SARIS) code numbers. *The river basins and coastal drainage areas serve as the fundamental planning units of MassDEP's surface water monitoring, assessment, and management programs.*

IV. DATA ACCEPTABILITY

The availability of appropriate and reliable scientific data and technical information is fundamental to the 305(b), 314 reporting and 303(d) listing process. It is EPA policy (EPA Classification No. CIO 2106.0) that any individual or group using EPA funding for any part of any work effort that results in generating data must establish a quality system to support the development, review, approval, implementation, and assessment of data collection operations. MassDEP's Quality Management Plan ensures that environmental data used by the Department are of known and documented quality and are suitable for their intended use. Although MassDEP relies most heavily on data collected as part of its ambient water quality monitoring program, "external" data from other state and federal agencies, local governments, drinking water utilities, National Pollutant Discharge Elimination System (NPDES) permittees, volunteer organizations and other sources are also solicited and often considered when making assessment decisions. Results of MassDEP's monitoring efforts, combined with all data deemed acceptable from other sources, constitute the basis for making water quality assessments in accordance with the requirements set forth in Sections 305(b) and 303(d) of the CWA.

Data Sources

WPP Monitoring

Each year, MassDEP staff monitor selected surface waters throughout the Commonwealth for chemical, physical, and biological parameters of interest (e.g., nutrients, *E. coli* bacteria, dissolved oxygen, temperature, benthic macroinvertebrates, chlorophyll a, algae, fish tissue contaminants, and fish communities). These data are collected by trained staff following a programmatic monitoring Quality Assurance Program Plan (QAPP) (MassDEP 2010a, MassDEP 2015a), including field and laboratory Standard Operating Procedures (SOPs). MassDEP water quality monitoring frequency depends on project objectives but most often includes a minimum of five rounds of water quality data collection augmented with probe deployments between May and September (inclusive of the summer months). Discrete, composite, continuous, depth-integrated sampling techniques, among others, are utilized depending on the monitoring plan and the stated objectives. In addition to MassDEP's Wall Experiment Station laboratory, contract labs may be used for sample analysis. All labs are evaluated for analytical accuracy and precision using double-blind QC samples, proficiency testing (PT) materials and/or inter-laboratory comparison testing. Resulting water quality data are evaluated against the data quality objectives (DQOs) specified in the QAPPs. Data validation procedures involve 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. Following QC-level and project-level reviews, water quality data are accepted, accepted with qualification, or censored. Through a separate review process biological data (benthic macroinvertebrate, algae, periphyton, fish communities) are evaluated considering QAPP DQOs, as well as best professional judgment regarding the quality of the data. For fish toxics data, MassDEP also relies on QC review at the state laboratory to assess usability. MassDEP's goal is to use the most recently validated data for making use attainment decisions. Long-term continuous data are considered more informative and reliable than discrete or short-term continuous data when multiple types of data are available for a given site.

The Use of External Data

Section B.9 of WPP's programmatic monitoring QAPP addresses the use of secondary or external data. External data are categorized into three general levels, which are related to the monitoring objectives (i.e., why the data were collected). While extremely 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. Although these data can be submitted, it is unlikely that these types of data would be used for 305(b), 314- and/or 303(d)-related decision-making. Screening-level-type data are also very important and welcome, but generally fail to meet one or more of MassDEP's criteria required for direct use in assessments or TMDLs. Screening-level data may meet the data quality objectives in the submitter's QAPP, but not those in the MassDEP's monitoring program QAPP approved by the EPA. While screening-level data may be helpful to direct future sampling efforts and as supporting evidence, these data are not currently used by MassDEP for use attainment decisions. Assessment-level data scored A and/or B have been deemed by MassDEP analysts, based on the external data review procedures, to be directly usable for 305(b), 314, and 303(d) decision-making. These data are typically the result of extensive planning, attention to detail, relatively stringent data quality objectives, 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 surface water quality standards or is impaired (i.e., not meeting surface water quality standards).

External Data Usability Review Process

Data can be submitted to MassDEP using guidelines found on the Department's web site: external-data-submittals. The data submittal deadline for the 2024 IR was January 18, 2023. All submitted external (or secondary) data are reviewed using consistent procedures. Once data are received, a standard data review process is conducted to facilitate and document MassDEP review (see below for an example of review form questions). Each potential secondary data source is evaluated using the following preliminary criteria:

1) adherence to an acceptable QAPP, including a laboratory Quality Assurance Plan (QAP) 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 quality control (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 group for accuracy, precision, and representativeness. External data meeting these criteria are further reviewed by one or more MassDEP staff to verify that the group's DQOs were met based on the QC data provided. These DQOs are then compared to MassDEP 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 (i.e., assessment-level data). External data are scored and the following guidelines are in place regarding their usability by WPP for assessment purposes.

Table 2. External Data Usability Review Score Guidelines

External Data Level	Data Usability Review Score*
3. Regulatory/Assessment-level*	A+ ASSESS/TMDL: All data should be considered <u>usable</u> by WPP for assessment purposes without caveat
	A- ASSESS/TMDL: All data appear to be <u>usable</u> for assessment purposes, but some data should be used with caveat (as noted) due to special circumstances.
	B ASSESS/TMDL: Some of the data appear to be usable (with caution), as explained in the review comments and summary

* Some data usability reviews are inconclusive due to a lack of information; such data sets may not be used for assessment purposes unless additional data/information are provided that justify revising the data usability review score to one in the Level 3 data category. For other data levels (i.e., 1, 2) see details on website: external-data-submittals.

Evaluation criteria from MassDEP's external data submittal usability review form for CWA 305(b), 314, and 303(d) reporting include the following questions:

- QAPP status for data year(s) and listed parameter(s)
- Training provided to samplers?
- Lab SOP for parameter provided?
- Laboratories used
- Lab Certification Status for Parameter
- Lab QC data provided?
- Other specific issues affecting data quality
- Quality Assurance/Quality Control (QA/QC) documentation (in project report or files)?
- Additional Review Notes (parameter-specific)
- Miscellaneous Notes (NOT parameter-specific)
- Parameter data collected using approved/standard field procedure(s)?
- Sample collection procedures for parameter documented?
- Field audit conducted for parameter?
- Field blanks collected by crew for parameter?
- Field duplicates collected by crew for parameter?
- Sampling locations precise and representative of waterbody?
- Sample holding times met for ALL parameter samples?
- Project DQOs for parameter met (accuracy, precision)?
- Are project DQOs for parameter generally comparable to WPP DQOs?

Age of Data
For the 2024 reporting cycle, MassDEP data from 2011 through 2020 will be utilized for use attainment decisions of the following uses: Primary Contact Recreation, Aesthetics, Shellfish Harvesting, and Fish Consumption. Similarly, external data (data from state/federal environmental agencies and data submitted from outside groups such as watershed associations, local governments, grantees, etc.) collected from 2011 through 2022 that passed the data usability review will be utilized to the extent possible.

EPA deferred action on the *Secondary Contact Recreation Use* attainment decisions in the 303(d) list included in MassDEP's 2022 Integrated Report (IR). To address EPA's deferral and in consultation with EPA, the 2024 reporting cycle will include a reevaluation of historic bacteria data for the *Secondary Contact Recreation Use*, including all readily available *E. coli* and enterococci data collected since 1997. With this approach, MassDEP will evaluate bacteria data across a 26-year period (1997-2022) for the *Secondary Contact Recreation Use*.

When multiple years of data are available, MassDEP analysts rely more heavily on the more recent data, especially when there is the appearance of an improving or deteriorating trend in water quality conditions. Data collected between 2018 and 2022 (≤5 years in age) will be used for the evaluation of use attainment including listing and delisting decisions. Data >5 years in age will also be used to support use attainment and listing decisions; however, in order for these data to be used for pollutant delisting decisions, satellite imagery will be consulted to determine whether land use changed in the intervening years (for delisting decision rationale based on land use changes, see Section VI. Consolidated Reporting: Impairment Removal Documentation Process for the 2024 IR). Additional information on the 2022 IR deferred action by EPA and MassDEP's approach to reevaluating the *Secondary Contact Recreation Use* (statewide) will be provided in the 2024 IR.

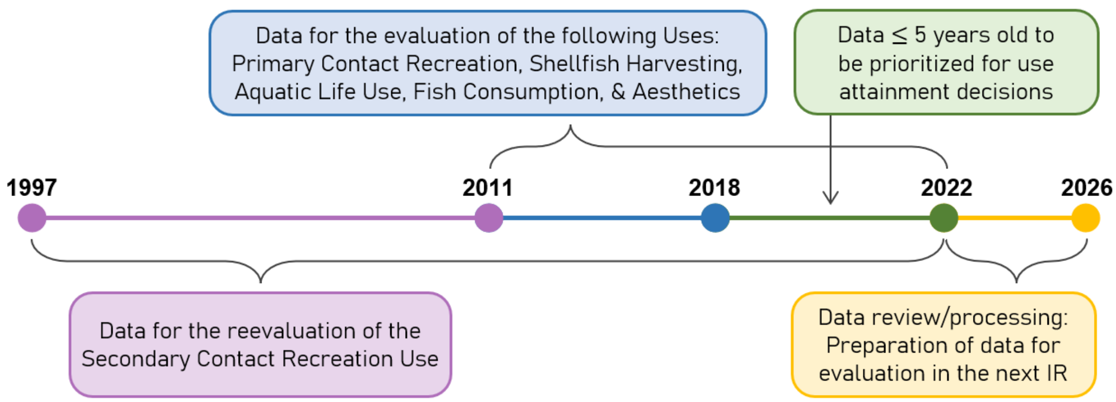


Figure 3. Data range for the 2024 reporting cycle

Data Extrapolation to Adjacent Assessment Units
Whenever possible, MassDEP analysts organize and evaluate data/information when making use attainment determinations in an upstream to downstream direction (both along an AU as well as within a watershed). This allows the analyst to assess a downstream AU with knowledge of the pollutants, discharges, and other factors affecting upstream tributaries. In general, only the data geographically associated with the AU are used to make assessment listing/delisting decisions. However, EPA guidance allows that a "*monitoring station can be considered representative of a stream waterbody for a distance upstream and downstream that has no significant influences that might tend to change water quality or habitat quality*" (EPA 1997), so the following exceptions to using AU-specific data can be made:

- Water quality data collected downstream of a river AU being evaluated (but upstream of any major discharges, dams, tributaries, etc.) may be used to make assessment decisions, especially if data are lacking from the lower portion of the AU. Data from such a location can provide a good representation of the river's condition upstream of that point. For example, water quality data collected in the Connecticut River 2.9 miles downstream of the Massachusetts-Connecticut state line, are used to assess use attainment of the most downstream Connecticut River AU in Massachusetts that ends at the state border.
- Assessment and listing decisions are occasionally extrapolated from an upstream AU, for example when the same non-native aquatic macrophyte species is known to be present in both an up and downstream AU, it can be presumed present in the middle AU.
- When evaluating diadromous fish passage conditions as part of assessment of the *Aquatic Life Use*, the presence of a physical barrier that restricts, severely impedes, or totally obstructs passage is identified as an impairment for both the mainstem river AU(s) as well as the upstream lake AU spawning habitat. In other words, diadromous fish should be able to reach their spawning habitat.

V. USE ATTAINMENT DECISION PROCESS

The Massachusetts SWQS designate the most sensitive uses for which the surface waters of the Commonwealth shall be enhanced, maintained and protected. The determination of whether a waterbody supports each of the applicable uses designated in the SWQS is a function of the type(s), quality and quantity of available current information. The EPA provides guidelines to states for making their use support determinations and recommends that states prepare their 2024 Integrated Reports (IRs) (available on the EPA Integrated Reporting Memoranda webpage) consistent with previous guidance including the EPA's 2006 IR Guidance (Keehner 2011), which supplements earlier EPA IR memoranda and guidance (EPA 2002, Grubbs and Wayland III 2000, Regas 2003, Regas 2005, Regas 2006, Schwartz 2009, Wayland III 2001). While the SWQS (Table 1) prescribe minimum water quality criteria to sustain the designated uses, numerical criteria are not available for every pollutant or indicator of pollution. Where necessary, best available guidance from available literature and/or MassDEP guidance and policies may be applied in lieu of actual numerical criteria (e.g., freshwater sediment data may be compared to *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* (Persaud, Jaagumagi and Hayton 1993)). Excursions from criteria due solely to "naturally occurring" conditions (e.g., slightly low pH in some areas) do not constitute violations of the SWQS in 314 CMR 4.03(5) (MassDEP 2021b).The designated uses of Massachusetts surface waters are described below (MassDEP 2021b).

DESIGNATED USES OF MASSACHUSETTS SURFACE WATERS

Fish, other aquatic life and wildlife *(AQUATIC LIFE)* - suitable habitat for sustaining a native, naturally diverse, community of aquatic flora and fauna, including, but not limited to, wildlife and threatened and endangered species and for their reproduction, migration, growth and other critical functions. Two subclasses of aquatic life are also designated in the SWQS for freshwater bodies: *Cold Water Fishery* - capable of sustaining a year-round population of cold water aquatic life, such as trout; *Warm Water Fishery* - waters that are not capable of sustaining a year-round population of cold water aquatic life. In certain [estuarine] waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass.

FISH CONSUMPTION - pollutants shall not result in unacceptable concentrations in edible portions of marketable fish or for the recreational use of fish, other aquatic life or wildlife for human consumption.

PUBLIC WATER SUPPLY - used to denote those waters used as a source of public drinking water. They may be subject to more stringent regulation in accordance with the Massachusetts Drinking Water Regulations (310 CMR 22.00). These waters are designated for protection as Outstanding Resource Waters under 314 CMR 4.04(3).

SHELLFISH HARVESTING (in SA and SB segments) – Class SA waters where designated shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas); Class SB waters where designated shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas).

PRIMARY CONTACT RECREATION - suitable for any recreation or other water use in which there is prolonged and intimate contact with the water with a significant risk of ingestion of water. These include, but are not limited to, wading, swimming, diving, surfing and water skiing.

SECONDARY CONTACT RECREATION - suitable for any recreation or other water use in which contact with the water is either incidental or accidental. These include, but are not limited to, fishing, including human consumption of fish, boating and limited contact incident to shoreline activities. Where designated, secondary contact recreation also includes shellfishing, including human consumption of shellfish. Human consumption of fish and shellfish are assessed as the *Fish Consumption* and *Shellfish Harvesting* uses, respectively.

AESTHETICS - all surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.

AGRICULTURAL - suitable for irrigation or other agricultural uses

INDUSTRIAL – suitable for compatible industrial cooling and process uses.

As part of the 305(b) reporting process, each designated use (*see exception note below*) of the surface waters in the state for each waterbody assessment unit (AU) is individually assessed as ***Fully Supporting*** or ***Not Supporting***. When too few current data or too little information exist 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"), but not enough data are available to make a use impairment decision, the use is identified as having Insufficient Information with an Alert Status and a recommendation is made for future water quality monitoring. It is important to note that not all waters are assessed. Many small and/or unnamed ponds, rivers, and estuaries have never been assessed. The status of their designated uses has never been reported to the EPA in the Commonwealth's 305(b) Report or the IR nor is information on these waters maintained in ATTAINS. These are considered ***not assessed other waters.***

> **Exception Note**: There are three uses - *Public Water Supply, Agricultural,* and *Industrial* - not assessed for 305(b) reporting purposes by MassDEP analysts. The *Public Water Supply Use* denotes those waters used as a source of public drinking water. These waters may be subject to more stringent regulation in accordance with the Massachusetts Drinking Water Regulations (310 CMR 22.00). They are designated for protection as Outstanding Resource Waters in 314 CMR 4.04(3). MassDEP's Drinking Water Program (DWP) has primacy for implementing the provisions of the Federal Safe Drinking Water Act (SDWA). Except for suppliers with surface water sources for which a waiver from filtration has been granted (these systems also monitor surface water quality), all public drinking water supplies are monitored as finished water (tap water). Monitoring includes the major categories of contaminants established in the SDWA: bacteria, volatile and synthetic organic compounds, inorganic compounds and radionuclides. DWP maintains current drinking supply monitoring data. The suppliers currently report to MassDEP and EPA on the status of the supplies on an annual basis in the form of consumer confidence reports. While EPA does provide guidance to assess the status of the *Public Water Supply Use* (impairment decision if there is one or more advisories, more than conventional treatment is required, or there is a contamination-based closure of the water supply), this use is currently not assessed. Rather, information on the drinking water program and finished water quality can be obtained from the following sources: MassDEP Drinking Water Program, EEA Online Data Portal for Drinking Water, and local public water suppliers. The *Agricultural* and *Industrial* uses have never been assessed or reported on to date.

The guidance used to assess the *Aquatic Life, Fish Consumption, Shellfish Harvesting, Primary* and *Secondary Contact Recreation,* and *Aesthetics* uses are provided in the following pages of this guidance manual. For each of these designated uses the background and context information on the data/indicators used for making the use attainment decision are provided. Depending on the waterbody type, assessment decision trees for the use attainment indicator(s) are also given. When too little data or information are available the use is identified as having insufficient information or not assessed.

Aquatic Life Use

Waters supporting the *Aquatic Life Use* should be suitable habitat for sustaining a native, naturally diverse, community of aquatic flora and fauna. This use includes reproduction, migration, growth and other critical functions. Two subclasses of aquatic life are designated in the SWQS for freshwater bodies - *Cold Water Fishery* - capable of sustaining a year-round population of cold-water stenothermic aquatic life, such as trout, and *Warm Water Fishery* - waters that are not capable of sustaining a year-round population of cold-water stenothermic aquatic life. In estuarine waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass (MassDEP 2021b).

Weight-of-Evidence Approach

Results from biological (and habitat), toxicological, physico-chemical, sediment, and body burden investigations are all considered in assessing the *Aquatic Life Use*. The sampling technique (e.g., discrete, composite, continuous, depth-integrated, etc.), as well as the type, quality, and amount of data generated for each of these indicators are first evaluated to determine if they are appropriate for use in the assessment decision-making process. Very often only one of the indicators is represented in the available data set or data from one indicator is obviously superior to the others. In these cases use attainment decisions are made based solely or mostly on one indicator. However, in cases where data are available from multiple indicators and the data are of equal quality the biological community data generally carry more weight in the decision-making process because they are considered an integration of the effects of pollutants and other conditions over time. Under these circumstances the biological community data, particularly evaluations/scores generated by an Index of Biological Integrity (IBI), or in the case of Cold Water Fisheries, the fish community data, are usually considered by MassDEP to be the best and most direct measure of the *Aquatic Life Use*. Additionally, monitoring of the primary producers (algal, macrophyte, and eelgrass community data) also provide good indicators for evaluating the *Aquatic Life Use*. Since toxicological testing data also measure biological response to environmental stressors in the absence of biological community data, they are given more weight than direct measurements of physico-chemical stressors. In the evaluation of chemical data, concentrations of toxic pollutants in surface water, sediment and fish tissue are evaluated against the generally applicable criteria listed at 314 CMR 4.06(6)(d): Table 29a, Aquatic Life Criteria, any sediment screening thresholds available, and whole-fish tissue criteria, respectively. In developing ambient water quality criteria for toxic pollutants, EPA either conducts its own toxicity tests or relies upon test information from the literature. Many of these laboratory tests are conducted using water low in organic carbon or other constituents that can bind to toxicants and make them less "bioavailable". In contrast, when pollutants are released into the natural environment, carbonaceous compounds (e.g., dissolved organic carbon) are more prevalent, rendering the toxicity of some pollutants less than predicted by laboratory tests. On the other hand, certain properties of natural waters, such as low pH, can increase the toxicity of certain pollutants. MassDEP and EPA recognize that natural conditions vary with location, and these variations necessitate evaluating data and information that more accurately reflect site conditions first, followed by those techniques that are less site-specific, in a weight-of evidence approach. Thus, assuming all data are of equal quality, the weight-of-evidence approach used by MassDEP WPP analysts follows this continuum: biological (including habitat) data first, followed by toxicological data, followed by chemical (physico-chemical, sediment chemistry data, whole-fish tissue residue) data.

The background and context information for the indicators used in the *Aquatic Life Use* attainment decision process are provided below in the order of the weight-of-evidence approach used by MassDEP. Within each indicator a summary decision tree (i.e., support decision and impairment decision) is provided. When too little data or information are available, the *Aquatic Life Use* is identified as having insufficient information or is not assessed. An overall summary of the indicators and the decision process used by MassDEP analysts for making the *Aquatic Life Use* attainment decisions can be found in Table 5 (see end of the *Aquatic Life Use* attainment guidance).

Natural Background Conditions

To evaluate whether the *Aquatic Life Use* should be assessed as impaired, the analyst must determine whether the condition is natural. Excursions from criteria deemed to be the result of natural background conditions are not evaluated as impairment. Appendix A details the methodology for screening for anthropogenic influence and lists the circumstances in which violations of criteria would not be considered natural.

Benthic Macroinvertebrate Data

BACKGROUND & CONTEXT

MassDEP Benthic Macroinvertebrate Biomonitoring Quality Assurance Project Plan (MassDEP 2021a)

The biological sampling methodology is described in an SOP (MassDEP 2021c) and is generally based on the USEPA Rapid Bioassessment Protocols (RBPs) (Plafkin, et al. 1989). The main objectives of biomonitoring are: (a) to determine the biological health of wadeable streams by conducting assessments based on aquatic macroinvertebrate communities; and (b) to identify stream AUs that are stressed so that efforts can be focused on developing or modifying NPDES and Water Management Act (WMA) permits, stormwater management, and control of other nonpoint source (NPS) pollution. Two IBIs for high gradient streams were developed for application in the Western Highlands and the Central Hills regions of Massachusetts, which were recognized for having naturally distinct biological expectations. The high gradient IBIs were developed and calibrated based on hundreds of samples previously collected by MassDEP biologists. Another IBI for low gradient streams was developed for statewide application (see Appendix I). IBIs are comprised of multiple biological metrics that are found to be responsive to a general stressor gradient. By scoring the metrics for each sample and averaging the scores, the resulting index indicates the biological condition of a given stream on a relative scale. Index values of the reference sites provide reasonable expectations for any stream in a given region. Scores that do not resemble the reference scores are indicative of potential stressors influencing the biological condition.

Rivers

Benthic macroinvertebrate sampling data generated by MassDEP biologists are typically from 300-organism subsamples, which are analyzed using Indices of Biotic Integrity (IBI). IBIs provide a measure of the biological condition of a given stream on a relative scale compared to least-disturbed streams within its site classification. Sampling takes place during the index period July through September when baseflows are at their lowest of the year and levels of stress to aquatic organisms are presumed to be at their peak. The sampling method varies depending on the characteristics of a given stream; the riffle method, which involves kicking or disturbing bottom substrate in riffles and catching the dislodged organisms in a net, is employed in higher gradient streams dominated by riffle habitat, whereas the multihabitat method involves sampling from representative habitats (e.g., vegetation, woody debris, banks) in streams where riffle habitat is not dominant (i.e., lower gradient streams) (MassDEP 2021c). Quality-assured external sources of benthic macroinvertebrate survey data, occasionally available from outside parties (e.g., other state/federal agencies, consultants, watershed associations, NPDES permittees), may be analyzed using the IBIs as well. The high gradient IBIs were developed for two naturally distinct regions of Massachusetts, the Western Highlands and the Central Hills. The low gradient IBI was developed and calibrated for statewide application. The proposed IBI thresholds for four biological condition categories (Exceptional Condition, Satisfactory Condition, Moderately Degraded, and Severely Degraded) being used for the 2024 reporting cycle are as follows:

	Biological Condition Score			
Index of Biotic Integrity	**Exceptional Condition**	**Satisfactory Condition[3]**	**Moderately Degraded[3]**	**Severely Degraded**
High Gradient – Central Hills[1]	100 - 75	74 - 55	54 - 35	34 - 0
High Gradient – Western Highlands[1]	100 - 75	74 - 55	54 - 35	34 - 0
Low Gradient – Statewide[2]	100 - 81	80 - 62	61 - 38	37 - 0

[1] Thresholds are appropriate for 100 and 300 count subsamples.
[2] Thresholds are appropriate for only 300 count subsamples
[3] Occasionally MassDEP biologists may use BPJ based on other lines of evidence for sites in the +/- 5 point range straddling the Satisfactory Condition - Moderately Degraded Condition threshold to recommend a different outcome than the one dictated by the Biological Condition Score.

Sites determined to be of Exceptional or Satisfactory Condition are assessed as Fully Supporting while sites determined to be Moderately or Severely Degraded are assessed as Not Supporting the *Aquatic Life Use*.

Waterbody	**Use is Supported**	**Use is Impaired**
Rivers	Biological Condition Score: Exceptional Condition/Satisfactory Condition	Biological Condition Score: Moderately Degraded/Severely Degraded

Lakes

Benthic macroinvertebrate data are not currently utilized to evaluate *Aquatic Life Use* of lentic waters.

Estuaries

MassDEP analysts occasionally utilize external sources of benthic macroinvertebrate data combined with other water quality monitoring data when making *Aquatic Life Use* attainment decision for estuarine waterbodies. While no standardized multi-metric analysis is currently employed, some quantitative benthic sampling has been conducted in Massachusetts estuaries (e.g., Massachusetts Water Resources Authority (MWRA) and Massachusetts Estuaries Project (MEP) projects). Sample attributes typically reported include number of species, number of individuals, diversity (H'), evenness (E), and organism-sediment relationship (e.g., opportunistic, deep burrowers, etc.) (Howes, Samimy and Dudley 2003). The overall analyses reported by these external data sources are utilized to make *Aquatic Life Use* attainment decisions.

Waterbody	Use is Supported	Use is Impaired
Estuaries	Relatively high number species, high number individuals, good diversity and evenness, moderate to deep burrowing, tube dwelling organisms present, as reported from external data sources.	Relatively low number species, low number individuals, poor diversity and evenness, presence of shallow dwelling opportunistic species, near absence of benthos, thin feeding zone, as reported from external data sources.

Fish Community Data

BACKGROUND & CONTEXT

MassDEP DWM Fish Collection Procedures for Evaluation of Resident Fish Populations Standard Operating Procedures (MassDEP 2011)

Monitoring of the fish assemblage is an integral component of the MassDEP water quality management program, and its importance is reflected in state stream class and use-support designations. Fish community information provides a valuable measure of the overall structure and function of the ichthyofaunal community and is indicative of biological integrity and surface water resource quality. This information is a key component used in the process to evaluate surface water resources in Massachusetts.

Species composition classifications:
Tolerance Classification – Tolerant (T), Moderately Tolerant (M), Intolerant (I)
Classification of tolerance to environmental stressors similar to that provided in (Plafkin, et al. 1989, Barbour, et al. 1999, Halliwell, et al. 1999)*. Final tolerance classes are those provided by Halliwell et al.* (1999)*.*

Macrohabitat Classification - ***Macrohabitat Generalists (MHG), Fluvial Specialists (FS), Fluvial Dependents (FD)***
Classification by common macrohabitat use as provided in (Armstrong, Richards and Levin 2011)*.*

Temperature Classification:
Classification of temperature tolerance provided in Halliwell et al. (1999)*. Note: To exclude potential stocked trout when evaluating the presence of multiple age classes size should be ≤140 mm (~5.5").*

There are two Cold Water "Existing Use" tiers:
Tier 1*: brook trout ≤140mm and/or slimy sculpin*
Tier 2: *brook trout, brown trout, rainbow trout and/or tiger trout ≤140mm; landlocked salmon <200mm; and any size range of the following fish species: American brook lamprey, Atlantic salmon, lake chub, lake trout, longnose sucker, and/or slimy sculpin*

See Appendix B for a complete list of species and their associated classifications -- habitat use, tolerances to environmental perturbations, and temperature.

Rivers

MassDEP biologists use electrofishing gear (i.e., backpack or barge shockers) to sample fish from 100 m reaches of wadeable streams. Typically, one survey is conducted per sampling site. Specimens that can be identified in the field are counted, examined for external anomalies, (i.e., deformities, eroded fins, lesions, and tumors) and this information is recorded on field data sheets. The procedures generally follow the protocols outlined in the RBP V (Plafkin, et al. 1989, Barbour, et al. 1999), however, the RBP V protocols call for the analysis of the data generated from fish collections using an established Index of Biotic Integrity (IBI) similar to that described by Karr et al. (1986). Since no formal fish IBI for Massachusetts currently exists, the data provided by MassDEP's (or others) sampling efforts, once evaluated for sample quality and collection efficiency, are used to semi-quantitatively assess the general condition of the resident fish community as a function of the overall richness (number of species) and abundance (number of individuals) and species composition classifications (see inset for more detail) (MassDEP 2011). MassDEP analysts also utilize fish community sampling data available from the MA DFG biologists (MA DFG 2023), as the goals, objectives, and sampling protocols are similar between the two groups. When evaluating the status of the *Aquatic Life Use* in lotic waters based on fish community information, the data are evaluated using the following approach as developed by MassDEP fisheries biologists:

- For waters designated as a Class B Cold Water Fishery or for those waters on MA DFG's Coldwater Fish Resource list, the fish community should contain multiple age classes or young of the year (YOY) of any cold-water fish excluding stocked trout (see Appendix B). An impairment decision is made if cold-water fish are absent or, in some cases, where their numbers are dramatically reduced compared to historic data.
- For waters designated as a Class B Warm Water Fishery, or those waters otherwise undesignated: in moderate to high gradient streams (riffle/run prevalent streams) the fish community should include two or more fluvial specialist/dependent species (see Appendix B) or at least one fluvial specialist/dependent species in moderate abundance to fully support the *Aquatic Life Use*. The absence of fluvial fish in these streams will result in an impairment decision. In low gradient streams (glide/pool prevalent streams) the fish community should include at least one fluvial specialist/dependent species or macrohabitat generalist species which are intolerant or moderately tolerant to environmental perturbations to fully support the *Aquatic Life Use*. If fish are absent in these streams, or if only tolerant macrohabitat generalist species are present, the *Aquatic Life Use* will be assessed as impaired.
- For waters designated as either a Class B Cold Water Fishery or Warm Water Fishery, external anomalies (i.e., deformities, eroded fins, lesions, tumors [DELTS]) are noted. If found in >10% of the sample, follow up histology may be conducted to evaluate pollution-related conditions. If it is determined that pollutants are the cause of these anomalies, an impairment decision will be made.

Cold Water designations are not determined during the assessment process; instead, they are completed as part of the revisions and updates to the Massachusetts Surface Water Quality Standards (SWQS). As part of each triennial review of the SWQS, MassDEP updates the designation any Cold Waters in accordance with MassDEP's guidance for designating freshwater streams and rivers as Cold Waters (MassDEP 2024).

For rivers where MA DFG biologists developed a Target Fish Community (TFC) model, and fish sampling data (collected using wadeable sampling methods, not by boat electrofishing) temporally and spatially represent the AUs being assessed, comparison of fish sample data to the TFC model may be used to assess the fish community. This analysis "measures, on a scale of zero (no similarity) to 100 percent (complete similarity), the degree to which the current and TFCs coincide based on species presence and relative abundance" (Kashiwagi and Richards 2009). For rivers where similarity scores are 50% or greater, the fish community will be assessed as supporting the *Aquatic Life Use*. For rivers where similarity scores are less than 50%, the fish community will be assessed as impaired. Usually, sampling data from the entire mainstem will be compared to the TFC model but under certain circumstances data from one or more AU(s) may be compared to the TFC model individually or as a group.

Fish community data are valuable for assessing the *Aquatic Life Use* and in many cases are all that is needed as described in the weight-of-evidence approach. In some cases, however, additional data are reviewed prior to making an assessment decision, including historic fisheries information, current water quality, and/or habitat evaluation data, potential pollution sources, etc. Even considering these other data sources, however, additional sampling may be needed before an assessment decision is made.

Fishery Designation	**Use is Supported**	**Use is Impaired**
Cold Water Fishery	Presence of cold-water fish indicative of reproducing populations (e.g., multiple age classes of any cold-water fish or YOY cold-water fish), or fish community ≥ 50% similarity with TFC.	Absence of cold-water fish indicative of reproducing populations, dramatic population reductions relative to historical samples, presence of DELTS (>10% sample) associated with pollutant(s), or fish community < 50% similarity with TFC.
Warm Water Fishery	In moderate to high gradient (riffle/run prevalent) streams fish community includes fluvial specialist/dependents species or at least one fluvial species in moderate abundance. In low gradient (glide/pool prevalent) streams, at least one fluvial species, or macrohabitat generalist species which are intolerant or moderately tolerant to environmental perturbations should be present. In either high or low gradient habitat fish community ≥ 50% similarity with TFC.	In moderate to high gradient (riffle/run prevalent) streams fluvial fish are absent. In low gradient (glide/pool prevalent) streams no fish found, absence of fluvial fish, or the presence of only tolerant macrohabitat generalists. In either high or low gradient habitat: presence of DELTS (>10% sample) associated with pollutant(s), and/or fish community < 50% similarity with TFC.

Lakes and Estuaries

Fish community data are not currently utilized to make *Aquatic Life Use* support determination for either lentic or estuarine waters. However, impact evaluations based on studies of site-specific fish community data (e.g., those associated with large power plant type operations relating to impingement and entrainment) and/or the presence of DELTS with abnormal fish histology have been used to determine that the *Aquatic Life Use* is impaired.

Waterbody	Use is Supported	Use is Impaired
Lakes & Estuaries	None made	> 5% population losses estimated, presence of DELTS (>10% sample) associated with pollutant(s)

Primary Producer Data

Rivers, Lakes, and Estuaries

Cyanobacteria, algae and aquatic vascular plants (macrophytes) represent additional biological communities that may be sampled as part of MassDEP's biomonitoring efforts. Referred to, collectively, as autotrophs or "primary producers", these organisms contain chlorophyll, a pigment with light absorption properties. Through a process known as photosynthesis, they utilize light energy from the sun to convert inorganic carbon to carbohydrates, the precursors of all of the complex molecules that make up the structure of living cells. As such, the primary producers represent the first trophic level within the intricate food webs of aquatic ecosystems. Freshwater and marine algae, freshwater macrophytes and marine seagrasses are all examples of primary producers.

Freshwater algae are one important autotrophic component of both lake (lentic) and stream (lotic) ecosystems. They may occur as phytoplankton floating freely in the water column or as members of the periphyton community attached to substrata, such as rocks and stones (epilithic), other plants (epiphytic), or even animals (epizoic). Periphytic algae typically appear as a thin film, often green or blue-green, or as a brown floc (loose material without any structure that breaks up when touched or removed) or as green filaments.

Because algae lack true stems, roots, or leaves, they must obtain nutrients directly from the surrounding water. In the presence of excessive levels of available nutrients, such as phosphorus, both phytoplankton and attached algae may exhibit rapid rates of growth and accumulation. Phytoplankton blooms may consist of thousands, or even millions, of algal cells per milliliter of water, resulting in severe turbidity and discoloration of the water. The rapid die-off and decomposition of individual organisms following a bloom can contribute to hypoxia. Harmful algal blooms (HABs) may cause impacts through the production of toxins or by their accumulated biomass, which can affect co-occurring organisms and alter food-web dynamics (US National Office for Harmful Algal Blooms 2019). Impacts include human illness and mortality following consumption of or indirect exposure to HAB toxins and HAB-associated fish, bird and mammal mortalities. The majority of the freshwater HAB problems reported in the United States and worldwide are due to one group of algae, the cyanobacteria (or "blue-green algae"), but other groups of algal blooms can also be harmful (Lopez, et al. 2008). Some cyanobacteria produce natural substances that are toxic to other organisms, either during blooming conditions or when the algae cells break down and release these substances to the water.

Attached algae also exhibit abundant growth in response to nutrient enrichment which, under suitable conditions of light and temperature, may lead to nuisance levels. Often a single species population flourishes to the detriment of natural diversity and the loss of critical elements of the food web - vital for *Aquatic Life Use* support - may result from this alteration of community structure. In addition, the decay of large amounts of algal biomass can fill the interstitial spaces of the substrates and limit this habitat for benthic invertebrates, further compromising aquatic life.

As with other aquatic communities, MassDEP biologists assess the periphyton community in shallow streams, or the phytoplankton in deeper rivers and lakes, to determine the degree of enrichment exhibited by these waterbodies, and as another indicator of whether the *Aquatic Life Use* is supported. These assessments may employ an indicator species approach whereby inferences pertaining to water quality conditions are drawn from knowledge of the environmental preferences and tolerances of the individual species present. Alternatively, more quantitative methods may be used to estimate the amount of biomass present. The percent cover of duckweed (*Lemna* sp.) or other non-rooted forms of macrophytes in lakes and chlorophyll concentration are useful indicators of the trophic status of lakes, ponds, and impoundments. Likewise, estimates of periphyton coverage in shallower waters provide information with regard to nutrient effects on aquatic life and recreational use support. However, because the algal community typically exhibits dramatic spatial and temporal shifts in species composition throughout a single growing season, the information gained from the algal community assessment is more useful as a supplement to assessments of other communities that serve to integrate conditions over a longer time period.

Changes in the spatial extent of the seagrass community are indicators of water quality conditions in coastal waters. Eelgrass is considered a sentinel species for embayment health and is an important species in the ecology of shallow coastal systems providing habitat structure and sediment stability. Losses of bed area and/or thinning of beds (decreases in density) are generally both linked to nutrient enrichment. The MassDEP Wetlands Conservancy Program's Eelgrass Mapping Project routinely maps eelgrass beds statewide for comparison to historic records for determination of the stability of this resource and to measure temporal trends in habitat quality. The Massachusetts Estuaries Project (MEP) incorporates eelgrass mapping information into their assessment of nutrient-related health of coastal embayments in southeastern Massachusetts (Howes, Samimy and Dudley 2003). The MEP also uses the presence and degree of accumulation of nuisance species of macroalgae as an indication of nutrient impairment in coastal embayments.

Benthic Algae

BACKGROUND & CONTEXT
Percent Periphyton Cover/Benthic Algae - Micro & Macro Identifications (MassDEP 2002, MassDEP Unpublished c)

Benthic algae are useful biological indicators of water quality. The fast-growing algae are sessile and take-up their entire nutrient and mineral needs from the water column. They are important primary producers in streams and are critical in oxygen production as well as carbon dioxide use and have been used by many to examine changes in nutrient (nitrogen and phosphorus) levels since they integrate nutrient concentrations over time… algal cover can be estimated by a trained biologist with the use of a viewing bucket. Along with macroinvertebrate and habitat assessments, the benthic algae provide another biological community to help evaluate the condition of aquatic life as well as the impacts from toxicity or nutrient enrichment. Exposure to low nutrient concentrations over time will result in algal populations represented by genera that can utilize nutrients at those levels. These sites are also likely to have reduced algal biomass. Higher algal biomass is often found in streams with elevated nutrient levels.

Rivers
In wadeable rivers, MassDEP biologists currently conduct attached benthic algae surveys that include, at a minimum, scraping of substrates for taxonomic identifications. Samples are usually collected in the stream's riffle/run area. Identifications are currently only being performed on the "soft-bodied" algae, and not the diatoms, to determine the community assemblage. Where potential problem locations are found, based upon an estimate of the percent filamentous algal cover and abundance, they are noted and the information is evaluated in context with other habitat assessment information, such as canopy cover.

Sampling is typically conducted three times during the summer growth period with the level of sampling intensity dependent on the project objectives. Currently, when the filamentous algal cover is estimated to be >40% in a sampling reach more than once during a survey season it is considered by MassDEP analysts to be indicative of increased productivity. Sites exceeding this threshold are considered to be indicative of enriched conditions. The relative abundance of genera that appear most frequently in the algae samples may also help to inform whether he taxa indicate nutrient enrichment or some other environmental impact.

Chlorophyll *a* (Rivers, Lakes, Estuaries)

BACKGROUND & CONTEXT
Measures of Biomass *(MassDEP 2023)*

Chlorophyll is a plant pigment found in plants that allows them to use radiant energy to convert carbon dioxide into organic compounds through a process called photosynthesis. Several types of chlorophyll exist and these and other pigments are used to characterize the algae. One type, chlorophyll a, is most widely used for biomass estimates since it is found in all algae. A knowledge of chlorophyll a concentrations provides qualitative and quantitative estimations of phytoplanktonic and periphytic biomass for comparative assessments of geographical, spatial and temporal variations (APHA 1981). Chlorophyll a is an indicator of algal biomass since it constitutes approximately 1-2% of the dry weight of organic material. Chlorophyll a measurements are made from both phytoplankton and periphyton samples from lakes, streams, rivers, and estuarine waters. Excerpt from Wise et al. (2009): "The level of algal biomass depends on the physical, chemical, and biological characteristics of a stream, including water velocity, water temperature, light availability, and nutrient concentrations (Biggs and Close, 1989; Steinman, 1996). Hydrologic conditions also may affect algal biomass through physical scouring, especially during high flow events, and grazing by benthic invertebrates and herbivorous fish also can reduce algal biomass (Steinman, 1996)."

Rivers & Lakes
Either discrete and/or depth-integrated samples are commonly collected by MassDEP staff for chlorophyll and phytoplankton analysis following procedures in MassDEP (2023). Chlorophyll *a* samples from the periphyton (attached algae) can be collected using different methods, but most are collected by scraping clean a known area of natural substrate (rocks, vegetation etc.). The loosened material is subject to chlorophyll *a* analysis (MassDEP

2002). MassDEP analysts currently are using chlorophyll *a* thresholds of 16 µg/L for phytoplankton and 200 mg/m^2 for periphyton at benthic algae sites. If either of these thresholds is exceeded more than once during a survey season the waterbodies are considered to be at risk of increased productivity. Sites exceeding these thresholds warrant additional scrutiny for all indicators of enrichment (see nutrients).

Estuaries
According to the MEP critical indicators report, when chlorophyll *a* concentrations are ≤ 5 µg/L the overall health of the system is generally good to excellent (Howes, Samimy and Dudley 2003). Higher concentrations (>10 µg/L) are typically associated with systems experiencing enrichment and degraded overall health.

Aquatic Macrophytes

BACKGROUND & CONTEXT
Visual Surveys Ponds and Impoundments - Percent Cover of Floating, Non-rooted Vegetation (MassDEP 2014b) ***and Aquatic Plant Mapping*** (MassDEP 2006)

Aquatic plants represent an important part of the biota of lakes and the density, diversity, and growth patterns of aquatic plants are unique to each lake. MassDEP has established a standard set of procedures for identifying and semi-quantitatively mapping the aquatic macrophytes of a lake or impoundment. The maps can be used over time to document changes in species composition and the density and extent of plant beds as well as non-rooted forms that may impair designated uses. Mapping percent cover gives a semi-quantitative assessment of the general density of plants. The species distribution map is used for determining the type of plant community and for tracking changes in species dominance or expansion of beds across the lake over time. Excerpt from Wise et al. (2009)*: "Light availability, rather than nutrient availability, is a common factor limiting macrophyte growth (Madsen and others, 2001)—turbidity levels, phytoplankton abundance, and water depth all affect light availability (Barko and others, 1986; U.S. Environmental Protection Agency, 2000a). Rooted macrophytes obtain nitrogen and phosphorus either through roots in the bed sediment or through shoots in the water column, and macrophytes with extensive root systems are able to meet their nutrient needs predominantly from the bed sediment (Carignan, 1982; Chambers and Prepas, 1989; Barko and others, 1991)." Like algae the non-rooted forms are able to obtain their nutrient supply directly from the water column. Therefore, the percent cover of non-rooted forms such as Wolffia sp. and Lemna sp. are also noted on lake survey fieldsheets during WPP surveys when water quality samples are being collected.*

Field staff record visual observations made during lake water quality monitoring surveys (via boat or shoreline vantage points) on lake survey field sheets. Visual observations are made of both the open water areas and the bank/littoral areas. Lake surveys are typically carried out monthly during the summer index period. During these surveys the percent coverage of floating non-rooted aquatic macrophytes (i.e., *Lemna* sp. and *Wolffia* sp.) and algal films/clumps are visually estimated in both open water and littoral areas and recorded as a percentage of the whole-lake area covered (MassDEP 2014b). When more rigorous data collection efforts are required, detailed methods currently being utilized by staff are available (e.g., the Long-Term Duckweed Monitoring on the Assabet River Impoundments (MassDEP 2014a)). Field staff also occasionally conduct more detailed plant surveys of lakes yielding information on species distribution, dominant species, frequency of occurrence of species, percent cover, and percent biovolume during the height of the growing season (MassDEP 2006).

Lakes
When the total surface area of a lake is estimated to be >25% covered by non-rooted macrophyte(s) and/or algal mats/films/clumps during more than one survey per season it is considered by MassDEP analysts to be exhibiting symptoms of increased productivity. Lakes exceeding this threshold warrant additional scrutiny for all indicators of enrichment (see Nutrients).

Estuaries
According to the MEP critical indicators report, macroalgae is one of the biological habitat indicators of ecological embayment health and nitrogen assimilative capacity. In nitrogen overloaded systems, eelgrass distribution tends to be much less widespread across an embayment and macroalgae presence typically increases. The MEP uses the following categories of visual observations of macroalgae as one of a suite of indicators to evaluate nitrogen enrichment: macroalgae absent to present in limited amounts is considered supportive of fair to excellent habitat health; and a range of some macroalgae accumulations present to large and pervasive accumulations is considered an indication of moderately to significantly impaired habitat health (Howes, Samimy and Dudley 2003). Certain marine macroalgae species including *Ulva*, *Enteromorpha*, (greens) (both sheet formers), *Pilayella* (brown), and *Porphyra* (red) may be particularly good indicators of enrichment. Nuisance growths of these indicator macroalgae can occur both in the northern rocky estuaries as well as the southern sandy coastline (Beskenis 2014).

Algal Blooms

Rivers, Lakes, Estuaries

An algal bloom is a rapid accumulation of algae that often occurs in response to a surplus of nutrients combined with abundant light and other variables that promote their growth. Algal blooms are typically indicative of over-enrichment that, in addition to altering algal community structure, may cause changes in water quality (e.g., turbidity, oxygen depletion) and/or habitat conditions (e.g., siltation). Blooms caused by cyanobacteria (C-HAB) may result in the presence of toxins that can negatively affect aquatic organisms. Counts and IDs of cyanobacteria are used to provide a means of determining if toxins may be present in potentially harmful amounts. Sources of information and data related to the magnitude, frequency, and duration of blooms include notes on MassDEP field sheets, technical memoranda, C-HAB counts and MDPH advisories. Because waterbodies experiencing frequent and/or prolonged algal and/or C-HAB blooms are likely to be adversely affected (enrichment, habitat degradation, and/or toxicity), the presence of such blooms is an indication of stress and the waters affected will likely be assessed as not supporting the *Aquatic Life Use*.

Eelgrass bed mapping data

BACKGROUND & CONTEXT

MassDEP Eelgrass Mapping Project (MassGIS 2020, Costello and Kenworthy 2011)

Seagrass beds are critical components of shallow coastal ecosystems. They provide food and cover for important fauna and their prey, their leaf canopy calms the water, filters suspended matter and together with extensive roots and rhizomes, stabilizes sediment. Eelgrass, Zostera marina, is the most common seagrass present on the Massachusetts coastline. The other species found in embayments is Ruppia maritima, widgeon grass, which is present in areas of less salinity along the Cape Cod and Buzzards Bay coast.

Often considered a sentinel species for evaluating ecosystem health, the distribution and abundance of eelgrass beds can be documented with aerial photographs, digital imagery and field verification. Much of the Massachusetts coast has a sandy substrate which provides a useful color contrast to map the darker seagrass photo signatures. Accuracy estimates of this quantitative mapping project were reported to be >85% in the 1994 to 1996 effort, 94% in 2006 to 2007, 90% in 2010, 95% in 2012 but not stated for 2015-2017. These eelgrass data layers are currently the best available information on general eelgrass extent in Massachusetts.

With appropriate temporal and spatial scaling, monitoring environmental quality and mapping the changes in seagrass distribution and abundance can provide scientists and managers with a sensitive tool for detecting and diagnosing environmental conditions responsible for the loss or gain of seagrasses. For example, unlike situations where degraded optical water quality reduces light penetration and threatens plants mostly in the deeper water, the effects of multiple stressors associated with eutrophication cause more widespread losses of eelgrass which are not just confined to the deepest edges of the seagrass beds.

Estuaries

The primary biological information used to make assessment decisions for the *Aquatic Life Use* in marine or estuarine waters is obtained from eelgrass bed maps based on surveys conducted by the Wetlands Conservancy Program (WCP) at MassDEP, as part of the Eelgrass Mapping Project. Currently the best available information on the general eelgrass extent along the Massachusetts coastline comes from these various eelgrass (seagrass) mapping efforts, which are available as data layers through the MassGIS. The statewide seagrass mapping project has been conducted in phases beginning in 1994 (note here that the 1994 – 1996 mapping effort is referred to as 1995 dataset) and the fifth coastwide effort was between 2015 and 2017. The sixth statewide mapping effort is currently underway (2019 to 2023). Data acquisition and image interpretation are detailed in Costello and Kenworthy (2011) and are available on the MassDEP Eelgrass Mapping Project webpage. The first statewide mapping phase as part of this project was conducted between 1994 and 1996. The most recently complete statewide data available are from 2015 - 2017 (MassGIS 2020).

Eelgrass Mapping along Massachusetts River Basins and/or Coastal Drainage Areas*	Years of Mapping Effort	
	1995	2015-2017
Boston Harbor (Proper)	X	X
Boston Harbor: Weymouth & Weir	X	X
Buzzards Bay	X	X
Cape Cod	X	X
Islands	X	X
North Coastal	X	X
South Coastal	X	X

** mapping efforts did not include Merrimack, Mount Hope Bay (Shore) and Taunton*

Assessment decisions for the 2024 reporting cycle will be based on a comparison between the data derived from the first phase of the Eelgrass Mapping Project (1995) with the most recently completed statewide dataset available (2019-2023) to determine whether the eelgrass beds within the AU are stable or are being lost. If the areal coverage of the beds is fairly stable or increasing (i.e., minimal {<10%} or no loss), the AU is considered to be supporting the *Aquatic Life Use*. Loss of eelgrass beds equal to or exceeding 10% is considered to be a "substantial decline" and the *Aquatic Life Use* is not supporting. For example, if the percentage of the AU area determined to be eelgrass was 50% in 1995, but only 40% in 2015-2017, the percent loss is (50-40)/50 = 0.2 or 20%. Loss of the deeper water edge of the eelgrass beds is indicative of declining water quality conditions (Costello 2015). [Note here: while the earliest *estimated* eelgrass data are available from 1951, these data were only anecdotally validated and, therefore, these data are no longer used as the baseline. Rather, current assessment methods require the eelgrass data evaluations to be made with data generated from the standardized eelgrass mapping protocols (Costello and Kenworthy 2011).]

Waterbody	Use is Supported	Use is Impaired
Rivers	Wadeable rivers: benthic chlorophyll *a* samples <u><</u>200 mg/m^2*, benthic filamentous algal cover <u><</u>40%*, occasional non-harmful ephemeral algal blooms* Deep rivers: phytoplankton Chlorophyll a <16 µg/L*, occasional non-harmful ephemeral algal blooms*	Wadeable rivers: benthic chlorophyll *a* samples >200 mg/m^2*, benthic filamentous algal cover >40%*, recurring and/or prolonged (>20 days in a year) algal and/or C-HAB blooms* Deep rivers: phytoplankton Chlorophyll a >16 ug/L*, recurring and/or prolonged algal and/or C-HAB blooms*
Lakes	phytoplankton Chlorophyll *a* <u><</u>16 µg/L*, <u><</u>25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps*, occasional non-harmful ephemeral algal blooms*	phytoplankton Chlorophyll *a* >16 µg/L*, >25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps*, recurring and/or prolonged (>20 days in a year) algal and/or C-HAB blooms*. **These indicators may also be applied to impounded reaches of River AUs**
Estuaries	Eelgrass bed habitat in AU area is increasing or fairly stable (i.e., no or minimal loss), Chlorophyll *a* <u><</u>5 µg/L*, little to no macroalgae accumulations*	Substantial decline in AU (= or exceed 10% of eelgrass bed area), Chlorophyll *a* >10 µg/L*, some macroalgae accumulations*, recurring and/or prolonged (>20 days in a year) algal and/or HAB blooms*

Habitat & Flow Data
Rivers, Lakes, and Estuaries
Most often evaluations of instream habitat support the biological survey results and enhance the interpretation of the biological data. Habitat qualities are scored using a modification of the evaluation procedure in Plafkin et al. (1989). Most parameters evaluated are instream physical attributes often related to overall land use and are potential sources of limitation to the aquatic biota. Key physical characteristics of the waterbody and surrounding land use include the following: instream cover, epifaunal substrate, embeddedness, sediment deposition, velocity/depth combinations, channel flow status, right and left bank vegetative protection, right and left bank stability, right and left bank riparian vegetative zone width. Habitat parameters are scored, totaled, and compared to a regional reference station and/or a site-specific control (upstream reference) station to provide a final habitat ranking. When biological communities are determined to be impaired, obvious habitat stresses (e.g., sedimentation) are evaluated as possible causes of the impairment. Occasionally, however, the habitat perturbations themselves are severe enough to warrant an impairment decision. These situations include, but are not limited to, absence of visible streamflow, dewatered streambed, and/or extreme low flow in a perennial stream or lake due to anthropogenic removal of water from the waterbody such as through water diversions or subsurface pumping (a Dewatering impairment); anthropogenic alteration of the natural flow pattern of a waterbody, for example, a decrease in flood pulses due to hydrostructures, or flow modification resulting from dams (a Flow Regime Modifications impairment); and lack of natural habitat structure due to the stream being channelized or flowing through an underground conduit (a Physical Substrate Habitat Alterations impairment).

BACKGROUND & CONTEXT
Diadromous Fish Habitat

Diadromous fish are migratory and spend part of their life cycle in both fresh and salt water. In Massachusetts these fishes include alewives and blueback herring (collectively known as river herring), American shad, rainbow smelt, sea lamprey, and American eel. These fish used to be highly abundant, compared to today's numbers, occurring in most coastal rivers and streams in Massachusetts.

River herring populations along the eastern seaboard are presently at or near historic low levels (ASMFC 2012, ASMFC 2017) *with some populations estimated to be less than 10% of historical abundance* (Limburg and Waldman 2009). *Recent declines of river herring in Massachusetts prompted DMF to impose a moratorium on their harvest and sale throughout the state beginning in January 2006. That moratorium is still in effect today. Moreover, the National Marine Fisheries Service has listed both species of river herring as "Species of Concern" within their Endangered Species Act review process.*

According to Limburg and Waldman (2009)*, dam removal, wherever possible, is the single broadest and most useful recovery action in the effort to restore the decimated diadromous fish populations, and where dams cannot be removed installation and/or maintenance of fish passage structures is recommended. In addition to fish passage, other improvements with regard to water quality and/or quantity may also need to be addressed. DMF staff, with the help of local citizens and watershed groups, actively monitor many of the runs and, in some cases, have reported modest and steady improvement since the moratorium, although diadromous fish populations, overall, remain at drastically reduced levels compared to times past. DMF staff continue to monitor and maintain fish passage structures and advocate for dam removals or installation of fish passage structures when appropriate.*

River surveys were historically conducted by MassDEP analysts during low-flow, dry-weather conditions which generally represented the worst-case scenario with respect to the assessment of impacts on receiving water quality from point source discharges. Today, increased attention is given to the identification and control of nonpoint source pollution, and survey methods are changing to reflect this shift in emphasis. For example, wet-weather sampling may provide the most reliable information pertaining to nonpoint source pollutant loadings from stormwater runoff and, when compared with dry-weather survey data, may further distinguish the effects of point and nonpoint pollution sources (MassDEP 2005, MassDEP 2018a).

MassDEP analysts can evaluate habitat quality and streamflow conditions using the habitat assessment field sheets and scores (usually reported in technical memoranda), observations recorded on the water quality monitoring field sheets (water quality technical memoranda or WPP's open files), USGS real-time and historical streamflow data, and the occasional site-specific flow data collected during WPP surveys. Up through the 2016 reporting cycle, information contained in DMF technical reports on surveys of anadromous fish passage in coastal Massachusetts were also utilized.

In April 2022, DMF biologists provided MassDEP staff with their Diadromous Fish Restoration Priority List (Version 5.0) which documents the status of the state's diadromous fish passageways and barriers, and prioritizes waters for fish passage restoration projects using a scoring system made up of 13 valuation parameters and 15 location attributes (Chase 2022). MassDEP staff used this update to document surface waters with diadromous fish runs and to identify habitat impediments that limit the use of migratory habitat by diadromous fish and/or exclude these fish from reaching spawning and nursery habitats.

When evaluating the status of the *Aquatic Life Use* based on diadromous fish habitat, the scoring criteria for two DMF valuation parameters are used: "Population Status" and "Passage". "Population Status" scores range from 0 (no run present) to 10 (one of largest local runs). "Passage" scores range from 0 (no obstruction) to 10 (no possible passage). Both scores are primarily based on DMF biologist's best professional judgment (BPJ); however, in the case of waterbodies with no existing diadromous fish runs, documented historical runs were assigned "Population Status" scores of 1-3. For the 2024 reporting cycle, all remaining diadromous fish runs with "population status" scores of >0 were added as river or lake AUs, as appropriate. For all AUs with a "Population Status" score greater than 0 and a "Passage" score of 4 (restricted passage) or greater, the *Aquatic Life Use* will be assessed as not supporting due to the presence of one or more fish passage barriers (the single exception being barrier beach sites without any other anthropogenic disturbance when a passage score of 4 or greater is not evaluated as an impairment). Where a barrier occurs with passage scores ≥4, impairment decisions are made for adjacent/adjoining AUs within the river system to the spawning area habitat (often within the same named stream or to the upstream lake AU and the downstream river AU). Where DMF staff conducted more intensive site-specific habitat assessments, additional stressors identified in their technical reports may be added as appropriate (e.g., water quality, low flow alterations, other flow regime alterations, etc.). For all waters with a "Population Status" score greater than 0, and a "Passage" score of less than or equal to 3 (minor obstruction), additional data/information, such as water chemistry, benthic macroinvertebrates, fisheries population, etc. is needed to assess the *Aquatic Life Use*. In the absence of any additional data the *Aquatic Life Use* is assessed as "Insufficient Information".

BACKGROUND & CONTEXT
Diadromous Fish Habitat

Passage

"Scores for this metric are based on the best professional judgement (BPJ) and increase (from 0 to 10) as the severity of the impediment to fish passage increases. Depending on the species present and level of blockage, no obstruction= 0 points; a minor obstruction = 1-3 points; restricted passage = 4-6 points; severe impediment= 7-9 points; and 10 points for no possible passage. If available, a site-specific river herring spawning and nursery habitat assessment will document the actual condition of passage impediments using the impairment list below. The same BPJ scoring scale will apply when habitat assessment data are available, however, a classification of Impaired for a given structure will result in a minimum score of 5, and a classification of Suitable will be scored no higher than 4." Passage impediments may include one or more of the following: excess vertical rise or grade change, excess water velocity at outlet, high turbulence or irregular flow, low or no flow (via stream flow) or due to diversion operations, inadequate attraction flow for passage, shallow water depth for passage (<6"), sediment impacts, in-stream debris/plant growth obstruction, beaver dam blocking passage, vegetation blocking passage, degraded passage structure.

Population Status

"A positive BPJ score running from 0 (no run present) to 10 (one of the largest river herring runs in the coastal drainage area) is awarded to sites for this metric. Non-river herring projects can substitute for those other species. Documented records of historical populations can allow the assignment of positive scores of 1-3 despite "no run present" depending on the suitability of migratory/spawning/nursery habitat."

In the Massachusetts coastal drainage areas, waters listed by DMF with diadromous fish runs identified with anything greater than a minor obstruction to passage limiting the use of migratory habitat by diadromous fish and/or excluding these fish from reaching spawning and nursery habitats (Chase 2022) will be considered an impairment of the *Aquatic Life Use*. [Note: for other waters not on the aforementioned diadromous fish restoration priority list, where impediments to fish passage (such as dams) exist but fish passage structure(s) are absent, no impairment decision is currently made.] Impacts associated with water intakes in rivers, lakes, and estuaries (i.e., power plants, cooling water intake structures) are evaluated on a case-by-case basis by MassDEP biologists by examining impingement, entrainment, and fish returns. Evidence of impact(s) (i.e., determination of unhealthful habitat or community impact) may result in a determination that the *Aquatic Life Use* is impaired.

Diadromous Fish Passage Score	Outcome
Passage Score ≥ 4	*Aquatic Life Use* Impairment for Fish Passage Barrier*
Passage Score < 4	Insufficient Information to assess *Aquatic Life Use***

** Additional stressors may be added if they are identified in site-specific habitat assessment technical reports.*
*** Presence of a strong diadromous fish Population Status Score (5-10) is indicative of good water quality and habitat conditions, but without other additional information (i.e., benthic macroinvertebrates, water quality data, etc.) this score alone is too limited to support the Aquatic Life Use.*

MassDEP evaluates the hydrologic conditions encountered during the surveys against the estimated 7Q10 flow. One of the following methods, in preferential order, may be utilized to estimate the 7Q10: the USGS supported program called StreamStats (provides estimated streamflow statistics for ungaged sites), a drainage area ratio transform method, a flow factor estimate based on drainage area, or DFLOW, a software program used by the EPA permit writers. For lakes and estuaries, the extreme hydrologic condition at which the aquatic life criteria must be applied will be established by MassDEP on a case-by-case basis. The presence of dams, flood control projects, water supply withdrawals, hydropower projects, and intake structures are considered potential habitat alterations.

Use is Supported	Use is Impaired
No direct evidence of severe physical habitat or stream flow regime alterations	Physical habitat impacted by anthropogenic stressors (e.g., lack of flow, lack of natural habitat -- concrete channel, underground conduit), a lack of passage or restricted fish passage where diadromous fish populations have been documented (Passage Score ≥ 4).

Non-Native Aquatic Species Data

> **BACKGROUND & CONTEXT**
> ***Massachusetts Surface Water Quality Standards*** *(MassDEP 2021b)* ***and***
> ***Guide to Selected Invasive Non-native Aquatic Species in Massachusetts*** *(MA DCR 2007)*
>
> *The Massachusetts Surface Water Quality Standards (MassDEP 2021b) definition of Aquatic Life is a "native, naturally diverse, community of aquatic flora and fauna including, but not limited to, wildlife and threatened and endangered species." Since all waters are designated as habitat for aquatic life, WPP analysts use the presence of non-native aquatic organisms as an impairment of the Aquatic Life Use.*
>
> *According to MA DCR (2007), non-native (exotic) species have been introduced to our region in a variety of ways including: hitching rides in ship ballast water, accidental release from aquariums, escape from water gardens and intentional introduction. Exotic species are further spread unintentionally by boaters when plant fragments are tangled on boats, motors, trailers, fishing gear, and dive gear. Some species, including the zebra mussel, have a microscopic larval form that can travel undetected in ballast water, cooling water, live-well water and bait bucket water to new locations. Once an exotic species is established, it is almost impossible to eradicate and very expensive to control. The best way to protect a waterbody is through prevention, education, early detection and rapid response.*

Rivers and Lakes

Waters supporting the *Aquatic Life Use* are suitable for sustaining a native, naturally diverse, community of aquatic flora and fauna. Non-native (or exotic) species, unlike the natural biota, have few or no controls, are often extremely invasive (dominating and/or eliminating native biota), and can displace a healthy and desirable aquatic community and produce economically and recreationally severe impacts even though no other change has occurred in the watershed (Mattson, Godfrey and Barletta, et al. 2004). Therefore, the documented presence of an introduced, non-native aquatic species in a waterbody is considered an impairment of the *Aquatic Life Use*.

For the 2024 reporting cycle MassDEP analysts will use the presence of non-native aquatic macrophytes or other aquatic organisms historically noted (as documented in prior listing cycles) and will add any confirmed new infestations documented by field staff based on MassDEP surveys conducted since 2011 or as confirmed/verified by external sources. The ATTAINS database contains more specific non-native species available as causes of impairment. For AUs with historical non-native species impairments, MassDEP analysts will determine whether the generic non-native species code can be replaced by the specific species code(s). The most commonly identified non-native aquatic species (macrophytes and invertebrates) in Massachusetts surface waters are listed below; those in bold include the species-specific impairments available in ATTAINS.

- **Curly-leaf Pondweed (*Potamogeton crispus*)**
- **Fanwort (*Cabomba caroliniana*)**
- **Water chestnut (*Trapa natans*)**
- **Brittle naiad (*Najas minor*)**
- **Eurasian water milfoil (*Myriophyllum spicatum*)**
- **Variable water milfoil (*Myriophyllum heterophyllum*)**
- **South American waterweed (*Egeria densa*)**
- **Swollen bladderwort (*Utricularia inflata*)**
- **European water clover (*Marsilea quadrifolia*)**
- European naiad (*Najas minor*)
- **Parrot feather (*Myriophyllum aquaticum*)**
- Water fringe (*Nymphoides peltata*)
- Common water hyacinth (*Eichornia crassipes*)
- **Hydrilla (*Hydrilla verticillata*)**
- **Zebra mussel (*Dreissena polymorpha*)**
- **Asian clam (*Corbicula fluminea)***

The presence of a non-native wetland or semi-terrestrial macrophyte(s) (e.g., *Phragmites* sp., *Lythrum salicaria*) is not usually considered an impairment of the *Aquatic Life Use* unless they have eliminated the open water area of the waterbody. In waterbodies where active aquatic plant management has occurred it is particularly important to have up-to-date information to accurately reflect the conditions during the time period in which the assessment is conducted. In these cases, the mere historical presence of a non-native species may not be appropriate for an automatic impairment decision.

Use is Supported	Use is Impaired
Non-native aquatic species absent	Non-native aquatic species present

Toxicity Testing Data

BACKGROUND & CONTEXT
Whole Effluent Toxicity *(EPA 2020)*

Whole Effluent Toxicity (WET) is a term used to describe the aggregate toxic effect of an aqueous sample (e.g., whole effluent wastewater discharge) as measured by an organism's response upon exposure to the sample (e.g., lethality, impaired growth or reproduction). WET tests replicate the total effect and actual environmental exposure of aquatic life to toxic pollutants in an effluent without requiring the identification of the specific pollutants. WET testing is a vital component of surface water quality standards implementation through the NPDES permitting process and supports meeting the goals of the Clean Water Act (Section 402), "maintain the chemical, physical and biological integrity of the nation's waters".

Fresh water organisms used in WET tests include Ceriodaphnia dubia *(freshwater flea) and* Pimephales promelas *(fathead minnow). Estuarine organisms used in WET tests include Americamysis bahia (mysid shrimp), and Menidia beryllina (inland silverside). These species serve as indicators or surrogates for the aquatic community to be protected, and a measure of the real biological impact from exposure to the toxic pollutants. WET tests are designed to predict the impact and toxicity of effluents discharged from point sources into receiving waters. WET limits developed by permitting authorities are included in NPDES permits to ensure that water quality criteria for aquatic life protection (WET) are met.*

Rivers, Lakes, and Estuaries

MassDEP maintains a toxicity testing database (ToxTD) to manage external toxicity testing data (both whole-effluent and ambient upstream sample data) submitted by facilities as part of their National Pollutant Discharge Elimination System (NPDES) permits. Validation procedures are implemented prior to uploading final data to the database. Testing frequency varies by facility and is associated with the instream waste concentration of the discharge; many Massachusetts facilities conduct quarterly testing, some conduct tests twice per year, and some conduct tests on an annual basis or a different schedule.

Survival information for test organisms exposed to ambient (rivers, lakes, estuary) water samples utilized as either the dilution water or site control during the whole effluent toxicity test is maintained in the ToxTD database (MassDEP Undated e). Survival data for these test organisms are recorded for exposures at 24 and 48 hours and at the end of chronic test (~ 7-days) and are utilized by MassDEP analysts in the *Aquatic Life Use* attainment decision. Survival information is summarized for each test species since the last assessment was completed for a given waterbody AU. The survival data summary should include the number of tests conducted over the time period specified and indicate the time of exposure (e.g., 48 hours, 7 days, etc. depending on the test). MassDEP has concluded that a survival rate of the test organisms exposed to the ambient river water samples should be greater than or equal to 75% to warrant a use attainment decision of support. When survival of test organisms exposed to the river water samples is less than 75% the frequency and magnitude (with respect to temporal patterns) of the low-survival events are considered. The analyst notes any pattern of problems (e.g., seasonal) and reviews associated chemistry data to identify potential cause(s)/source(s). An impairment decision for the *Aquatic Life Use* is typically made when low organism survival (i.e., <75%) occurs in more than 10% of the tests performed since the last assessment was completed. With few data points (n≤10), however, MassDEP analysts will not impair a waterbody unless there is more than one exceedance of the guideline.

Whole effluent toxicity testing results are also typically evaluated for compliance with permit requirements, species sensitivity, and any other patterns that may be of note. For assessment purposes, NPDES facility compliance with whole effluent toxicity test and other limits may be used to identify possible causes/sources of impairment but is not utilized, solely, for assessment decisions.

Other toxicity testing data sources may include EPA investigations or testing carried out as part of waste-site investigations and may also include sediment toxicity testing results. Survival of test controls is always reviewed for data quality assurance. Typically, the average survival of organisms exposed to the river water/sediment is calculated and any other test results (e.g., statistically significant change from controls) are also noted but are not utilized for assessment decisions of impairment by themselves.

Use is Supported	Use is Impaired
≥75% survival of test organisms to water column or sediment samples in either 48 hr (acute) or 7-day exposure (chronic) tests.	<75% survival of test organisms to water column or sediment samples in either 48 hr (acute) or 7-day exposure (chronic) tests occurs in >10% of test events or more than once when limited data are available.

Water Quality Data

BACKGROUND & CONTEXT
MassDEP Monitoring Strategy *(MassDEP 2005, MassDEP 2018a)*

One of WPP's main programmatic objectives is to conduct surface water quality monitoring (collection of chemical, physical and biological data) to assess the degree to which designated uses, such as aquatic life, are being met in waters of the Commonwealth (CWA 305(b) purposes) (MassDEP 2005, MassDEP 2018a). Massachusetts has selected a set of monitoring program elements that utilize a combination of deterministically and probabilistically derived sampling networks. Targeted designs may be used to identify causes and sources of impairments for reporting pursuant to sections 305(b) and 303(d) of the CWA, and to develop and implement control strategies such as TMDLs, NPDES permits, or Best Management Practices (BMPs). Furthermore, targeted monitoring may provide data and information to define new and emerging issues or to support the formulation of surface water quality standards and policies.

River & stream water quality surveys generally consist of five or six monthly sampling events from April 1 to October 15 (primary contact recreation period). Typical analytes include pH, dissolved oxygen (DO), temperature, conductivity, turbidity, total suspended solids, true color, chloride, nutrients (TP, TN, NH3-N), dissolved metals and indicator bacteria (E. coli for freshwater and Enterococcus for coastal areas). Lake surveys typically include such limnological measurements as chlorophyll a and Secchi depth, in-situ measurements using metered probes, and water quality sampling to provide data for the calculation of TMDLs or the derivation of nutrient criteria. Lake surveys are generally conducted during the summer months when productivity is high.

The use of single or multi-probe sondes for physical and chemical monitoring is now also an integral component of WPP's ambient monitoring program. It allows for the acquisition of short-term, attended data, using hand-held multi-probe units in the field, and long-term, unattended datasets, using stand-alone data loggers deployed for 2-6 days, to collect continuous monitoring data for such analytes as DO and temperature, pH, and specific conductance. Continuous water temperature monitoring units are also available for deployments of three to four months from June through September. Deep-hole profiling for DO and temperature in lakes are usually taken between mid-July and early September to reflect the worse-case conditions

Rivers, Lakes, and Estuaries

The Massachusetts SWQS include specific numeric physical and chemical water quality criteria adopted to protect aquatic life and human health from the effects of pollution. The SWQS also contain narrative criteria for other constituents (e.g., nutrients, toxics) that must also be evaluated as part of the *Aquatic Life Use* attainment decision.

The use of water quality monitoring data for evaluating the *Aquatic Life Use* depends, in part, on the data set(s) available. MassDEP analysts rely most heavily on internal monitoring program data to assess use attainment. Over the past 10 years the program has transitioned from a targeted, synoptic survey program, consisting typically of a minimum of three rounds of water quality sampling during the summer months, to a more intensive effort (a minimum of five rounds of water quality monitoring during the sampling season augmented with probe deployments). The quality-assured and validated sampling results from MassDEP surveys are published in the form of technical memoranda/reports, typically by watershed and/or sampling year. Water quality data published online by the USGS (http://waterdata.usgs.gov/ma/nwis/qw/, http://ma.water.usgs.gov/) are also available for stations across Massachusetts and are utilized for making *Aquatic Life Use* attainment decisions. There are also many other external sources of physico-chemical water quality monitoring data (e.g., environmental consultants, watershed and lake associations, and citizen monitoring programs, etc.). As resources allow, all external data from these and other sources are reviewed for quality/reliability according to MassDEP's external data validation procedures to determine their acceptability for use in making assessment decisions.

When analyzing datasets for determining use attainment the analyst documents the total number of samples in the data set, the ranges of the data, and, if appropriate, the number of measurements that did not meet the criterion for each analyte. All validated water quality monitoring data are compared to the appropriate criteria, as noted below under individual analytes, in the Massachusetts SWQS (MassDEP 2021b). Every attempt is made to consider the frequency, duration and magnitude of exceedances of criteria or guidance in making impairment decisions. However, since the datasets available are usually limited, it is often difficult to have a clear indication of the frequency and/or duration of exceedances. Since a single high or low result can skew the data, an impairment decision is never based on a single sample result.

Dissolved oxygen (DO)

DO is a very important indicator of a waterbody's ability to support aquatic life. DO enters water by diffusion directly from the atmosphere, by mechanical aeration (e.g., a spillway or dam), or as a result of photosynthesis by aquatic plants and algae and is generally removed from the water by respiration of aquatic organisms and decomposition of organic matter. Its solubility in water is mainly a function of temperature and pressure and content is reported in terms of concentration (mg/l or ppm) or as a percentage of saturation (% saturation). DO exhibits natural daily and seasonal fluctuations.

The Massachusetts SWQS (MassDEP 2021b) criteria for Dissolved Oxygen (DO) in mg/l are as follows:

Class A Cold Water Fishery (CWF) and Class B Cold Water Fishery (BCWF) and Class SA: *≥6.0 mg/l*
Class A and Class B Warm Water Fishery (BWWF) and Class SB*: ≥5.0 mg/l.*
Class C: *Not <5.0 mg/l at least 16 hours of any 24-hour period and not <3.0 mg/l at any time.*
Class SC: *Not <5.0 mg/l at least 16 hours of any 24-hour period and not <4.0 mg/l anytime.*
For all classes*…where natural background conditions are lower…DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall also be maintained. There shall be no changes from natural background conditions that would impair any uses assigned to each class, including those conditions necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms. In cases where a segment has the qualifier "Aquatic Life" added to the class, the Class C DO criteria are applied.*

Nationally recommended criteria for DO in freshwater (EPA 1986, 1988b) were derived using biological production impairment estimates to protect survival and growth of aquatic life below which detrimental effects are expected. The national criteria accommodate an exposure concept (frequency, magnitude and duration of condition). The national criteria daily minima (1.0 mg/l less than the 7-day mean) were set to protect against acute mortality of sensitive species and they were also designed to prevent significant episodes of continuous or regularly recurring exposures to dissolved oxygen at or near the lethal threshold. In 2005, MassDEP's ambient monitoring program for rivers was enhanced by the deployment of single and/or multi-probe sondes for physical and chemical monitoring (e.g., DO, temperature, % saturation, specific conductivity, and/or pH). Sondes that recorded DO were typically deployed three to five separate times during the summer months (June to September) for 3- to 5-day periods. More recently (2012 forward), optic DO/temperature sondes have been deployed for several months. Given the availability of these continuous DO datasets, the 2012 assessment methodology for DO needed revision. Rather than try to develop frequency and duration values for the assessment methodology, MassDEP staff made the decision it would be most appropriate and defensible to apply the 1986 EPA national DO criteria for freshwater aquatic life as the basis for determining assessment/impairment decisions, since both frequency and duration were incorporated into the EPA criterion document. Furthermore, the national criteria include specific protection for early life stages, which are absent from the current Massachusetts SWQS. More details pertaining to the derivation of these assessment guidelines can be found in Appendix D.

Rivers

The assessment methodology used by MassDEP analysts is to compare calculated statistics from the available long-term and/or short-term DO datasets, as well as DO minima from any of the available DO data source(s), to the appropriate EPA national DO criteria based on the timing (e.g., presence or absence of early life stages of fish) and frequency of the data measurements (Table 3). Since there was generally very little variation within the daily DO patterns during the 3-5 day deployments at a given site, MassDEP analysts will compare the means from their 3-5 day DO sonde deployments against both the national 7-day mean and mean minimum criteria. In the case of single measurement datasets, a minimum of three, but preferably five, pre-dawn sampling events during the summer sampling season is required.

If all DO data statistics and/or minima meet (i.e., are above) all relevant thresholds, DO is considered sufficient to support the *Aquatic Life Use*. When the threshold is not met the analyst must consider whether or not the condition is natural or not as previously described (see also Appendix A). DO is identified as a cause of impairment if excursions from the thresholds are not natural.

Lakes

Low DO is considered an impairment if the area exhibiting oxygen depletion is >10% of the lake surface area (the oxygen depleted area is calculated using data from the depth profile along with the lake bathymetry). In deeper, stratified lakes impairment decisions are sometimes made using DO profile data collected from one deep-hole during the later part of the summer growing season. Data requirements for shallow, unstratified lakes follow those described above for rivers.

Table 3. Comparing long-term, short-term, and single measurement datasets to 1986 EPA nationally recommended dissolved oxygen criteria and quantitative effect levels for the protection of freshwater aquatic life.
[Note: this table does not include early life stage cold-water thresholds since these life stages of cold-water species in Massachusetts do not occur during the summer sampling period.]

	Cold-water Criteria	**Warm-water Criteria**		**DO Measurement Types**
	Other Life Stages	**Early Life Stages*** (assume present through July in MA coastal streams)	**Other Life Stages**	**Long-term continuous (LTC) Short-term continuous (STC) Single (S)**
30-Day Mean	8.0	NA	6.0	LTC[1]
7-Day Mean** (7-Day Avg of Daily Avg or 7DADA)	NA***	6.5	NA	LTC, STC [1,2]
7-Day Mean Minimum** (7-Day Avg of Daily Minima or 7DADMin)	6.0	NA	5.0	LTC, STC[1,2]
1-Day Minimum* **	5.0	5.0	4.0	LTC, STC, S

anadromous fish runs present
***Continuous monitoring data from sondes deployed between 3-5 days will also be utilized to evaluate the 7-day mean statistic since MassDEP analysts determined that there was generally very little variation within the daily DO patterns during the deployments at a given site.*
****NA (not applicable)*
****All minima should be considered as instantaneous concentrations to be achieved at all times.*
[1] Exclude the first day of the deployment if it does not contain pre-dawn measurements.
[2] A minimum of three continuous (not necessarily consecutive) days with pre-dawn measurements required.

Estuaries

MassDEP analysts compare DO data to the appropriate criteria (depending on a waterbody's classification) for surface water and depth measurements. If all DO data meet (i.e., are equal to or above) the criteria, DO is considered sufficient to support the *Aquatic Life Use*. The analyst must evaluate the frequency and duration of excursions (whether or not they exceed 10% of the measurements) as well as the magnitude of any excursions (i.e., >1.0 mg/l below the applicable criterion). DO is identified as a cause of impairment if data indicate frequent, prolonged and/or severe excursion(s) from the appropriate criteria.

Note: DO as an indicator related to nutrient enrichment is discussed later under *Nutrients.*

Waterbody	**Use is Supported**	**Use is Impaired**
Rivers	Deployed (LTC, STC) probe datasets: Calculated mean and mean minimum statistics meet EPA criteria Single (S) measurement datasets: No more than one excursion from criteria (minimum three preferably five measurements representing critical --i.e., pre-dawn, conditions)	Deployed (LTC, STC) probe datasets: Calculated mean and mean minimum statistics below EPA criterion Single (S) measurement datasets: Frequent (>10%) and/or prolonged or more than one measurement below EPA 1 day minimum criterion
Lakes	No/little depletion (the criterion is met in all depths over ≥90% of the lake surface area during summer season)	The criterion is not met at all depths for >10% of the lake surface area during periods of maximum oxygen depletion
Estuaries	No/infrequent (≤10%) prolonged or severe excursions from criteria in surface or bottom waters	Frequent (>10%) and/or prolonged or severe excursions (>1.0 mg/l below standards) from criteria

pH

The pH of water is a measure of its hydrogen ion (H+) concentration on a negative logarithmic scale, which ranges from 0 to 14 standard units (SU). A pH value less than 7 indicates higher H+ content (acidic solutions), whereas pH values above 7 denote alkaline solutions. Natural waters exhibit a wide range of pH values depending upon their chemical and biological characteristics. Unpolluted river water usually has a pH between 6.5 and 8.5 SU (Hem 1970). In productive segments, diurnal fluctuations in pH may occur as photosynthetic organisms take up dissolved carbon dioxide during the daylight hours reducing the acidity of the water and raising pH. Respiration and decomposition during the night produces CO_2 that dissolves in water as carbonic acid, thereby lowering the pH. The pH of water affects the solubility, reactivity and biological availability of chemical constituents, such as nutrients (e.g., phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.).

The Massachusetts SWQS criteria for pH are as follows (MassDEP 2021b):

Class A & Class B *6.5 - 8.3 SU and Δ 0.5 outside the natural background range.*
Class C: *6.5 - 9.0 SU and Δ 1.0 outside the natural background range.*
Class SA & Class SB: *6.5 - 8.5 SU and Δ 0.2 SU outside the natural background range.*
Class SC: *6.5 - 9.0 SU and Δ 0.5 SU outside the natural background range.*
There shall be no change from natural background conditions that would impair any use assigned to each class.

Geographical differences in the acidity of surface waters in Massachusetts have been demonstrated (Walk, et al. 1991). The regions with the lowest average pH and acid neutralizing capacity (ANC) are the southeastern and north-central areas of the state, while the highest average pH and ANC are in the west where significant limestone deposits are found. Mattson et al. (1992) used the state map of bedrock formations produced by Zen et al. (1983) to delineate the boundaries between six regions of similar bedrock geology and water quality. According to Portnoy et al. (2001), the seashore kettle ponds are naturally acid (varying between pH 4 and 6 SU).

Rivers and Estuaries
MassDEP analysts compare pH data to the appropriate criteria range. If all pH data are within the range the *Aquatic Life Use* is considered to be supported. When two or more measurements are outside the range analysts must consider whether the conditions are natural given the tendency towards acidic conditions described above (e.g., low pH in a wetland dominated sampling area based on field sampling notes and MassGIS topographic maps, orthophotos, and/or land use coverage). The magnitude of the excursion (i.e., >0.5 SU outside the criterion range), and the frequency of the excursions (e.g., non-consecutive vs. consecutive low or high pH measurements) should be considered. pH is identified as a cause of impairment if data indicate frequent, prolonged and/or severe excursion(s) from the criteria. The use may be impaired if criteria are exceeded in >10% of measurements that are not considered to be due to natural conditions.

Lakes
An impairment decision can be made using one deep-hole probe profile during the summer growing season that indicates an extreme excursion from the criteria range.

Waterbody	Use is Supported	Use is Impaired
Rivers	No or slight pH excursions (<0.5 SU) from criteria (minimum five measurements)	Frequent (>10%) and/or prolonged or severe pH excursions (>0.5 SU) from criteria
Lakes	No or slight pH excursions (<0.5 SU) from criteria (minimum one deep-hole profile during summer growing season)	Excursion from pH criteria (>0.5 SU) during summer growing season
Estuaries	No or slight pH excursions (<0.5 SU) from criteria (minimum five measurements)	Frequent (>10%) and/or prolonged or severe pH excursions (>0.2 SU) from criteria

Temperature

Most aquatic organisms are unable to internally regulate their core body temperature. Therefore, temperature exerts a major influence on the biological activity and growth of aquatic organisms and the ability of organisms to tolerate certain pollutants. Temperature is also important because of its influence on water chemistry. Temperature affects the solubility of oxygen in water. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. Some compounds are also more toxic to aquatic life at higher temperatures.The Massachusetts SWQS criteria for temperature are as follows (MassDEP 2021b):

Class A CWF: *≤68 F (20°C) based on the mean of the daily maximum temperature over a seven day period in cold water fisheries, unless naturally occurring and ∆ T due to a discharge ≤1.5°F (0.8°C).*
Class A WWF: *≤83°F (28.3°C) and ∆ T due to a discharge ≤1.5°F (0.8°C).*
Class B CWF: *≤68°F (20°C) based on the mean of the daily maximum temperature over a seven day period in all cold water fisheries, unless naturally occurring, and ∆ T due to a discharge ≤3°F (1.7°C).*
Class B WWF: *≤83°F (28.3°C) and ∆ T due to a discharge ≤5°F (2.8°C) in rivers (based on the minimum expected flow for the month) and ∆T due to a discharge ≤3°F (1.7°C) in the epilimnion (based on the monthly average of maximum daily temperatures) in lakes.*
Class C and Class SC: *≤85°F (29.4°C) and ∆T due to a discharge ≤5°F (2.8°C).*
Class SA: *≤85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°C) and ∆T due to a discharge ≤1.5°F (0.8°C).*
Class SB: *≤85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°C) and ∆T due to a discharge ≤1.5°F (0.8°C) between July and September and ≤4.0°F (2.2°C) between October and June.*

For all classes, natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. There shall be no changes from natural background conditions that would impair any uses assigned to each class, including those conditions necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms. Alternative effluent limitations established in connection with a variance for a thermal discharge issued under 33 U.S.C § 1251 (FWPCA, § 316(a)) and 314 CMR 3.00 are in compliance with 314 CMR 4.00. As required by 33 U.S.C. § 1251 (FWPCA, § 316(a)) and 314 CMR 3.00, for permit and variance renewal, the applicant must demonstrate that alternative effluent limitations continue to comply with the variance standard for thermal discharges.

The definition of "Cold Water Fishery" in the SWQS is *"Waters in which the mean of the maximum daily temperature over a seven day period generally does not exceed 68°F (20°C) and, when other ecological factors are favorable (such as habitat), are capable of supporting a year-round population of cold-water stenothermal aquatic life such as trout (salmonidae)"* (MassDEP 2021b). As part of each triennial review of the SWQS, MassDEP updates the designation any Cold Waters in accordance with MassDEP's guidance for designating freshwater streams and rivers as Cold Waters (MassDEP 2024). However, for streams identified by the Massachusetts Department of Fish and Game's (MA DFG) Division of Fisheries and Wildlife as Coldwater Fish Resources (CFRs), the SWQS regulation protects these cold water fish populations and their habitat as existing uses (314 CMR 4.06(1)(d)7).

MassDEP analysts reviewed the definition for Cold Water Fisheries, the thermal criteria, and the definition of "Existing Use" in the SWQS, and determined that two subcategories of the "Existing Use" would be needed to protect all fish classified as cold-water fish by the MA DFG. An evaluation of thermal tolerances of different cold-water fish resulted in the development of two Cold Water "Existing Use" categories: Tier 1 and Tier 2 (see detail below and additional information provided in Appendices B and D). The thermal tolerance evaluation was based on both a literature review as well as on data collected in Massachusetts from fish community samples and data from long-term thermistors that were deployed in areas where the fish community samples were collected. These "paired" datasets were collected by both MassDEP and MA DFG staff. MassDEP staff also reviewed information from shorter-term "sonde" deployments. The two existing uses, and methods of determining these, are listed below:

Tier 1 Cold Water Existing Use: These are waters that have contained at least two fish of either of the following two species and size ranges: *S. fontinalis* (eastern brook trout) less than or equal to 140 mm (~5.5"), and/or *Cottus cognatus* (slimy sculpin) of any size during a single sampling event (defined as sampling that took place over a single day) during the months of June through mid-September after November 28, 1975. Larger EBT may also qualify in establishing an Existing Tier 1 use if stocking records indicate that the fish (minimum of 2 fish) were not stocked or did not likely come from a stocked waterbody. Both brook trout and slimy sculpin require clean, cold-water habitat. The recommended temperature evaluations for the Tier 1 Cold Waters are summarized below.

Tier 2 Cold Water Existing Use: These are waters that have been shown (via sampling) to contain at least two fish from any combination of the following categories and size ranges: brook trout, brown trout, rainbow trout and tiger trout less than or equal to <140mm; landlocked salmon less than or equal to <200mm; and any size range of the following fish species: American brook lamprey, Atlantic salmon, lake chub, lake trout, longnose sucker, and slimy sculpin. These species also require clean, cold-water habitat, however, the thermal tolerances of all the species (exclusive of brook trout and slimy sculpin) are slightly higher than those listed in Tier 1. The recommended temperature evaluations for the Tier 2 Cold Waters are summarized below.

In addition, as a rebuttable presumption, MassDEP will assume that any tributary, perennial or intermittent, entering a Tier 1 or Tier 2 segment upstream of the point where the fish sample used to identify a particular Cold Water "Existing Use" was collected, is of the same Tier as the water into which it flows.

<u>Evaluating thermal impairment of cold-water streams</u>: Factors influencing water temperature can be both natural and/or anthropogenic. Natural factors include elevation, channel gradient and orientation, surficial geology and groundwater input, air temperature and even the damming of streams by *Castor canadensis* (beaver). Human development disturbances include fragmentation associated with dams or roadways, stormwater runoff resulting in sedimentation, and riparian and/or instream habitat (e.g., stream hardening and/or widening with concrete, flood control manipulation, loss of trees), alterations all of which can result in increased instream temperatures. For the purpose of this reporting cycle, when temperatures are found to exceed the recommended metrics an additional evaluation of natural and/or anthropogenic factors are evaluated through a land-use analysis to identify potential anthropogenic source(s). Waters found to exceed the recommended temperature metrics will be listed as impaired for the *Aquatic Life Use* even if cold-water species are present in stream samples when one or more anthropogenic influence(s) are present (see also methods in Appendix A) that are known to increase thermal input to streams. While this assessment procedure is not in line with the weight-of-evidence approach described in the *Aquatic Life Use* attainment guidance, it is deemed necessary and appropriate at this time to protect against any further loss of these cold-water habitats where anthropogenic influences can be minimized and/or mitigated. The flowchart used to evaluate fish and temperature data for cold waters is illustrated in Figure 4. It should be noted however that the presence of cold-water fish alone may be sufficient to support the *Aquatic Life Use* (see fish community data guidance on pages 19 and 20).

Depending upon the type of data (i.e., large long-term continuous (LTC) datasets, shorter-term continuous (STC) datasets, or discrete/infrequent measurements), and the designated or existing use (i.e., Cold Water, unlisted Tier 1 cold-water fish existing use, unlisted Tier 2 cold-water fish existing use, warm water, other unlisted water) of the waterbody, the evaluations are made using the decision matrix below. The guidelines for evaluating the temperature data are based on the SWQS and associated use attainment protocols (based on toxicity formulae provided in EPA, 1977 Temperature Criteria for Freshwater Fish: Protocol and Procedures (EPA600/3-77-061), and information from other published and unpublished data sources) for sentinel fish species (see details in Appendix D). An allowed exceedance (~10%) of the chronic criterion has been calculated as up to 11 times within the June 1st through September 15th index period (or a proportionate number of exceedances for datasets <107 days in length). This allowed exceedance is considered to be a reflection of the term "generally" in the definition of a Cold Water Fishery in the SWQS ("mean of the maximum daily temperature over a seven day period generally does not exceed…") (MassDEP 2021b). No exceedances of the 24-hour average (acute) criteria provided below are allowed. For small datasets (occasional discrete measurements), only infrequent or small exceedances from the SWQS are allowed. For sites impacted by large thermal discharges, site-specific evaluations are made with regard to the rise in *in-situ* temperatures due to the discharge. Changes over the ΔT criteria result in impairment decisions.

Rivers

Designated Cold Waters and Tier 1 Existing Use Cold Waters are evaluated the same way while Tier 2 Existing Use Cold Waters have slightly higher temperature thresholds. For designated Cold Waters and Tier 1 Existing Use Cold Waters, long-term datasets are evaluated against the SWQS criterion (7-day rolling average of the daily maximum temperatures or 7-DADM). For Tier 2 Existing Use Cold Waters, long-term datasets are evaluated against a 7-day rolling average of the daily average temperature (7-DADA) use attainment threshold (see decision matrix below). Continuous temperature data are used whose anchor dates fall within the June 1 through September 15 summer index period (the anchor date is the middle date among seven days used to calculate a 7-DADM or 7-DADA; note that because of the placement of the anchor date within the middle of the 7-day rolling periods, data collected as much as three days before the index period and three days after the index period may be used in 7-DADM/7-DADA calculations).The 3-5 day deployed sonde data are also evaluated in the same manner as the rolling 7-day averages; however, these deployed dataset endpoints are expressed as a 3-5 DADM or 3-5 DADA. None of these shorter-term deployments should exceed the SWQS or the chronic use attainment thresholds in the table below; however, an impairment decision will not be made. Instead, any exceedance will be identified with an Alert Status and follow-up sampling (long-term deployment data collection) will be recommended. For both the long-term and short-term deployments an evaluation of the maximum 24-hour rolling average will be compared to the acute criteria in the table below. Discrete data may be evaluated which are collected during the summer index period (June 1 through September 15).

For Warm Water Fisheries (WWF) and other unlisted waters not identified as having a Tier 1 or Tier 2 existing use, the analyst evaluates the temperature datasets with anchor dates falling during the summer index period (June 1 through September 15) for continuous datasets or, for discrete datasets, those data collected during the summer index period. The long-term datasets are evaluated against the MassDEP-derived 7-DADM criterion (or 3-5 day DADM) and the SWQS warm-water criterion.

Estuaries

Temperature measurements collected during the summer index period (June 1 through September 15) are evaluated against the acute SWQS criteria (shall not exceed 29.4°C nor a maximum daily mean of 26.7°C).

Data Type	Waterbody	Designated or Existing Use	Use is Supported	Use is Impaired*
Chronic Evaluation Large (>one month usually all summer) long-term continuous (LTC) Datasets	Cold Water Fishery	*Designated Cold Waters*	No more than 10%** of 7-DADM ≤20.0°C	Greater than 10%** of 7-DADM >20.0°C
		Tier 1 Existing Use Waters	No more than 10%** of 7-DADM ≤20.0°C	Greater than 10%** of 7-DADM >20.0°C
		Tier 2 Existing Use Waters	No more than 10%** of 7-DADA ≤21.0°C	Greater than 10%** of 7-DADA >21.0°C
	Warm Water Fishery	*Designated Warm Waters & Unlisted Class B Waters not Tier 1 or Tier 2:*	No more than 10%** of 7-DADM ≤27.7°C	Greater than 10%** of 7-DADM >27.7°C
	Estuarine	-	No more than 10%** of 24-hour averages ≤26.7°C	Greater than 10%** of 24-hour averages >26.7°C
Chronic Evaluation Short-term (3-5 day) continuous (STC) Datasets	Cold Water Fishery	*Designated Cold Waters*	3-5-DADM <20.0°C	No impairment decision***
		Tier 1 Existing Use Waters	3-5-DADM <20.0°C	No impairment decision***
		Tier 2 Existing Use Waters	3-5-DADA <21.0°C	No impairment decision***
	Warm Water Fishery	*Designated Warm Waters & Unlisted Class B Waters not Tier 1 or Tier 2:*	3-5-DADM <27.7°C	No impairment decision***
	Estuarine	-	Not Applicable	Not Applicable
Acute Evaluation Large long-term continuous (LTC) and Short-term continuous (STC) Datasets	Cold Water Fishery	*Designated Cold Waters*	Max. 24-hour average ≤23.5°C	Max. 24-hour average >23.5°C
		Tier 1 Existing Use Waters	Max. 24-hour average ≤23.5°C	Max. 24-hour average >23.5°C
		Tier 2 Existing Use Waters	Max. 24-hour average ≤24.1°C	Max. 24-hour average >24.1°C
	Warm Water Fishery	*Designated Warm Waters & Unlisted Class B Waters not Tier 1 or Tier 2:*	Max. 24-hour average <28.3°C	Max. 24-hour average >28.3°C
	Estuarine	-	No more than one day with SWQS criterion exceedance (29.4°C)	More than one day with SWQS criterion exceedance (29.4°C)
Acute Evaluation Small (discrete/infrequent measurements) Datasets	Cold Water Fishery	*Designated Cold Waters*	Infrequent excursions (≤10% measurements) or only small excursions (<2°C) above SWQS criterion (20°C)	Frequent exceedances (>10% measurements) of SWQS criterion (20°C) or excursions of SWQS criterion by >2°C (22°C).
		Tier 1 Existing Use Waters		
		Tier 2 Existing Use Waters		
	Warm Water Fishery	*Designated Warm Waters & Unlisted Class B Waters not Tier 1 or Tier 2:*	Infrequent excursions (≤10% measurements) above SWQS criterion (28.3°C)	Frequent exceedances (>10% measurements) of SWQS criterion (28.3°C) or excursions of SWQS criterion by >2°C (30.3°C).
	Estuarine	-	No more than one day with SWQS criterion exceedance (29.4°C)	More than one day with SWQS criterion exceedance (29.4°C)

** Impaired due to anthropogenic influences (see Appendix A for guidance to evaluate if excursions/exceedances can be considered natural).*
*** MassDEP has adopted a 10% exceedance to reflect the term "generally" in the SWQS. The allowed number of 7-DADM or 7-DADA exceedances is 11 occurrences during the critical index period June 1st through September 15th or a proportionate number of exceedances (10% of days) for datasets less than 107 days in length. See Appendix D for additional information.*
**** No impairment decision made but identify exceedance with an Alert Status and recommend follow up sampling.*

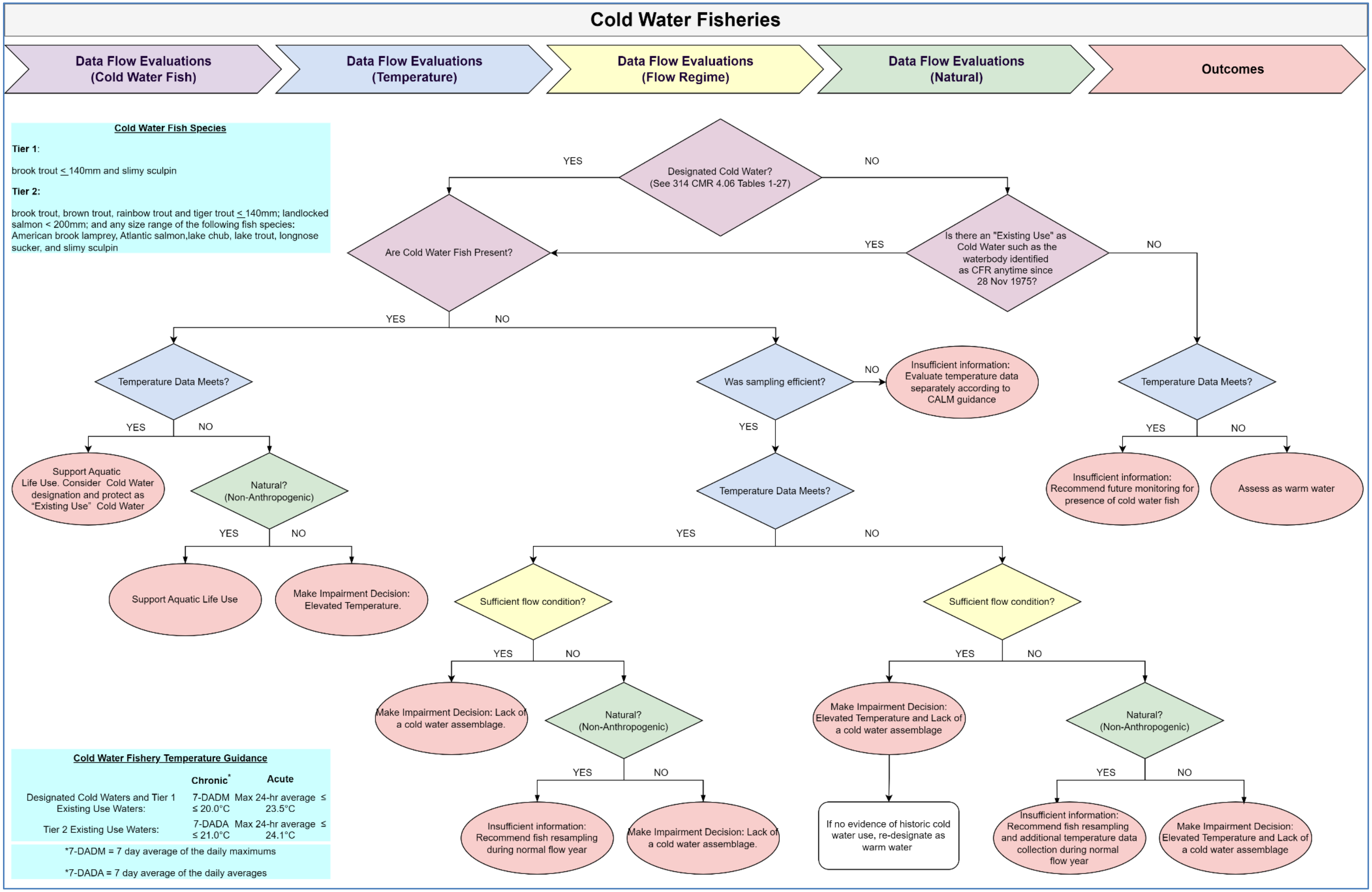


Figure 4. Decision flowchart used to evaluate fish and temperature data for Cold Waters

Nutrients

BACKGROUND & CONTEXT
Nutrient Criteria Development Status for MA

EPA implemented a strategy to develop ambient water quality nutrient criteria by ecoregions for the US (EPA 2000d, 2000c, 2001c). Massachusetts is encompassed by two of these freshwater ecoregions – the Eastern Coastal Plain (Ecoregion XIV) and the Nutrient-Poor, Largely Glaciated Upper Midwest and Northeast (Ecoregion VIII) and two Estuarine and Coastal Marine Waters provinces- the Acadian Province (northern Cape Cod) and the Virginian Province (southern Cape Cod). EPA has since published their recommended nutrient criteria documents for both rivers and streams, and lakes and reservoirs for each of these ecoregions. They include recommended criteria for total phosphorus, total nitrogen, chlorophyll a, and turbidity or Secchi disk depth intended to address the adverse effects of excess nutrient inputs (EPA 2000b, 2000a, 2001b, 2001a). EPA has not yet published recommended nutrient criteria documents for either the Acadian or Virginian provinces. In 2021, EPA issued recommended ambient water quality criteria to address nutrient pollution in lakes and reservoirs that replace those published in 2001 and 2002 (EPA 2021). EPA's recommended criteria consist of four stressor-response models to calculate candidate numeric criteria for chlorophyll a, total phosphorus and total nitrogen protective of Aquatic Life (Zooplankton and Hypoxia models) or Drinking Water or Recreational uses (Microcystin model). These models are currently under review by MassDEP.

MassDEP evaluated EPA's approach along with other published literature and is using these to guide the development of its Nutrient Strategy. The ultimate goal of the state's effort is to quantitatively translate its narrative nutrient criterion with both biological response thresholds and recommended nutrient concentrations that will support CWA goals (MassDEP Unpublished b) and provide a clean and transparent process for protecting high quality waters, identifying impaired waters, and establishing associated restoration targets for degraded waters.

The Massachusetts SWQS include both narrative nutrient and aesthetic criteria (see excerpts below) that are applicable to all surface waters (MassDEP 2021b).

"Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site-specific criteria developed in a TMDL or as otherwise established by the Department pursuant to 314 CMR 4.00 including, but not limited to, those established in 314 CMR 4.06(6)(c): Table 28: Site-specific Criteria… Any existing point source discharge containing nutrients in concentrations that would cause or contribute to cultural eutrophication [defined elsewhere in the SWQS as 'The human induced increase in nutrients resulting in acceleration of primary productivity, which causes nuisance conditions, such as algal blooms or dense and extensive macrophyte growth, in a waterbody.'], including the excessive growth of aquatic plants or algae, in any surface water shall be provided with the most appropriate treatment … to remove such nutrients [point and nonpoint source controls] to ensure protection of existing and designated uses…"

And "All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance [growth or amount] species of aquatic life."

To evaluate a waterbody for nutrient-related impairment, MassDEP analysts rely on *multiple* supporting indicators as evidence of nutrient enrichment. Biological indicators of nutrient enrichment (one or more of which is documented as problematic), include the presence of nuisance growths of primary producers or population changes in certain critical species (see detail in primary producer data). Secondly, indications of high primary productivity are often observed as changes to certain physico-chemical analytes, as well. Taken together, these biological and physico-chemical indicators are utilized for making nutrient-related impairment decisions for the *Aquatic Life Use*. A literature review of the freshwater nutrient enrichment indicators used by MassDEP is provided in Appendix C. The more combinations of these indicators are documented, the stronger the case for the *Aquatic Life Use* to be assessed as not supporting. For example, while total phosphorus or nitrogen concentration data alone are not currently utilized to determine impairment due to nutrient enrichment, they are used to corroborate indicator data and can help to identify potential sources (e.g., release of phosphorus from anoxic sediments).

Nutrient enrichment is not considered to be problematic when biological response indicator data are below threshold values for primary producer data, even if nutrient concentrations exceed the thresholds based on EPA recommended criteria. However, when multiple biological (particularly primary producer) and physico-chemical response indicators suggest that nutrient enrichment is problematic and concentration data exceed the recommended thresholds or SWQS site-specific criteria, either total phosphorus or total nitrogen (total nitrogen data will be compared to a site-specific bioactive nitrogen criterion where needed as a conservative evaluation) is also identified as a cause of impairment. For the 2024 reporting cycle, the summer seasonal (May through September) average ($n \geq 3$ samples) of the total phosphorus concentration data will be screened against the 1986 EPA recommended "Gold Book" concentrations for rivers (0.1 mg/l flowing waters, 0.05 mg/l for rivers entering a lake/reservoir) and lakes (0.025 mg/l) or SWQS site-specific criteria. For estuarine waters, a summer seasonal average ($n \geq 3$ samples) of the total nitrogen concentration data collected during an ebb tide will be screened against the MEP critical indicator threshold of >0.5 mg/l for waters where eelgrass habitat has not been documented and >0.4 mg/l for waters where eelgrass habitat has been confidently documented at some point in time. According to the MEP critical indicators report, when total nitrogen concentrations are ≤ 0.5 mg/l the overall health of the system is generally good to excellent except in areas of eelgrass loss that may begin to occur at somewhat lower concentrations (~0.4 mg/l) (Howes, Samimy and Dudley 2003). Higher concentrations (>0.5 mg/l) are typically associated with systems experiencing degraded overall health.

Screening guidelines for making nutrient-related impairment decisions (rivers, lakes, estuaries)

Rivers:
MassDEP analysts do not assess the *Aquatic Life Use* as support based solely on the absence of nutrient enrichment indicators [i.e., no/limited observable nuisance growths of algae in forms such as filamentous coverage, planktonic blooms, or mats, or macrophytes (particularly non-rooted forms) during the summer index period (see primary producer data indicator summary)]. However, when excessive growths are observed during more than one site visit during the summer index period, the analysts also consider changes in physico-chemical data, such as: DO (concentration and supersaturation), pH, and chlorophyll *a*. If a *combination* of these indicator data strongly suggests high productivity/nutrient enrichment, the *Aquatic Life Use* is assessed as impaired. Total phosphorus is included as a cause of impairment if the concentrations exceed EPA's "Gold Book" concentration or any SWQS site-specific criterion. For river AUs with impoundments, a conservative evaluation of nutrient-related response indicators following the guidance described for lakes may be conducted.

***Lakes*:**
Unlike the rivers, the *Aquatic Life Use* for lakes is first evaluated using primary producer biological data. The use is assessed as support for lakes when the nutrient enrichment indicator thresholds based on survey data are not exceeded. The *Aquatic Life Use* for lakes is assessed as impaired when there is more than one nutrient enrichment indicator present more than once during the survey season (i.e., the occurrence of planktonic blooms particularly blue-greens, extensive cover of non-rooted aquatic macrophytes -- particularly duckweed or water meal covering >25% of the surface, decreased Secchi disk transparency <1.2 m, oxygen supersaturation ≥125%, elevated pH values >8.3 SU, and elevated chlorophyll *a* concentrations >16 µg/L). Total phosphorus is included as a cause of impairment if the concentrations exceed EPA's "Gold Book" concentration or a SWQS site-specific criterion.

Estuaries:
MassDEP analysts currently utilize areal coverage of seagrasses or other submerged aquatic vegetation and, when available, the MEP habitat health indicator analysis. Assessment decisions are based on whether the eelgrass beds within the AU area are stable or are being lost. For embayments in Southeastern Massachusetts the MEP has also generated a significant amount of enrichment indicator data based on a weight-of-evidence approach that includes several response variables (e.g., eelgrass, infauna, macroalgae, chlorophyll *a*, DO, Secchi disk, TN concentrations). Since this project intends to develop site-specific nutrient (nitrogen) thresholds for these systems, their overall analysis of habitat health are utilized to make *Aquatic Life Use* attainment decisions. The *Aquatic Life Use* of an estuarine AU is assessed as support if eelgrass bed habitat is found to be increasing or fairly stable or the MEP analysis provided in a site-specific technical report indicates excellent to good/fair health. Conversely, the *Aquatic Life Use* is assessed as impaired if there is a substantial decline (>10%) of eelgrass bed habitat or the MEP analysis provided in a site-specific technical report indicates moderate to severe impairment. Total nitrogen is listed as a cause of impairment in MEP project sites evaluated as moderately to severely impaired.

Primary Producer Biological Screening Guidelines		
Waterbody	**Use is Supported**	**Use is Impaired**
Rivers	Wadeable rivers: benthic chlorophyll *a* samples ≤200 mg/m^2*, filamentous algal cover ≤40%*, occasional non-harmful ephemeral algal blooms* Deep rivers: phytoplankton Chlorophyll a <16 µg/L*, occasional non-harmful ephemeral algal blooms*	Wadeable rivers: benthic chlorophyll *a* samples >200 mg/m^2*, filamentous algal cover >40%*, recurring and/or prolonged algal and/or C-HAB blooms* Deep rivers: phytoplankton Chlorophyll a >16 ug/L*, recurring and/or prolonged algal and/or C-HAB blooms*
Lakes & Riverine Impoundments	phytoplankton Chlorophyll *a* ≤16 µg/L*, ≤25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps*, occasional non-harmful ephemeral algal blooms*	phytoplankton Chlorophyll *a* >16 µg/L*, >25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps*, recurring and/or prolonged algal and/or C-HAB blooms*.
Estuaries	Eelgrass bed habitat in AU area is increasing or fairly stable (i.e., no or minimal loss), Chlorophyll *a* ≤5 µg/L*, little to no macroalgae accumulations*	Substantial decline in AU (= or exceed 10% of eelgrass bed area), Chlorophyll *a* >10 µg/L*, some macroalgae accumulations*
Physico-chemical Screening Guidelines		
Waterbody	**Use is Supported**	**Use is Impaired**
Rivers	Small diel changes in oxygen/saturation/pH (Δ <3 mg/l, < 125% saturation, <8.3 SU, respectively), summer seasonal (May through September) average (n≥3) total phosphorus concentrations below EPA Gold Book concentrations. (≤0.1 mg/l flowing waters, ≤0.05 mg/l for rivers entering a lake/reservoir) or SWQS site-specific criteria	Large diel changes in oxygen/saturation/pH (Δ ≥3 mg/l, ≥ 125% saturation,≥8.3 SU, respectively), elevated summer seasonal (May through September) average (n≥3) Phosphorus (Total) above EPA Gold Book concentrations (>0.1 mg/l flowing waters, >0.05 mg/l for rivers entering a lake/reservoir) or above SWQS site-specific criteria
Lakes & Riverine Impoundments	Secchi disk transparency ≥1.2 m, summer seasonal (May through September) average Phosphorus (Total) below EPA Gold Book concentrations ≤0.025 mg/l or SWQS site-specific criteria	Secchi disk transparency <1.2 m, in combination with secondary indicators high oxygen super-saturation, elevated pH, elevated summer seasonal (May through September) average (n≥3) Phosphorus (Total) above EPA Gold Book concentrations >0.025 mg/l or above SWQS site-specific criteria.
Estuaries	MEP analysis provided in a site-specific technical report indicates support (overall health evaluated between excellent to good/fair health) summer seasonal average mid-ebb (outgoing) tide total nitrogen concentration generally ≤0.4 mg/l*	MEP analysis provided in a site-specific technical report indicates moderately to severely degraded health due to nitrogen enrichment, summer seasonal (May through September) average mid-ebb tide total nitrogen concentration generally >0.5 mg/l*

** Denotes that an Aquatic Life Use attainment decision not made based on the Primary Producer Biological Screening Guideline indicator thresholds alone. If exceedances(s) are found, the Physico-chemical Screening Guidelines are also evaluated in order to make a use attainment/listing decision. Site-specific MEP analyses may supersede the screening guidelines above.*

Toxic Pollutants

Rivers, Lakes, and Estuaries

Pollutants, such as metals, ammonia, chloride, chlorine, polycyclic aromatic hydrocarbons, and chlorinated organics, are considered toxic to humans, wildlife, and aquatic life when concentrations exceed criteria in the Massachusetts SWQS. The SWQS include *Generally Applicable Criteria* for all categories of surface waters at 314CMR 4.06(6)(d): Table 29: *Generally Applicable Criteria*. Table 29a: Aquatic Life Criteria identifies the criteria (i.e., concentrations, models, or equations) for each toxic pollutant to protect aquatic life (MassDEP 2021b).

Unless otherwise noted in Table 29a, the average ambient surface water pollutant concentration over any 1-hour period shall not exceed the criterion maximum concentration (CMC or acute criterion) more than once during any three year period and the average ambient surface water pollutant concentration over any 4-day period shall not exceed the criterion continuous concentration (CCC or chronic criterion) more than once during any three year period to protect against short- and long-term effects, respectively.

For evaluation of the *Aquatic Life Use*, toxic pollutant data are evaluated against their respective CMC or CCC criteria in the SWQS. MassDEP analysts develop the ratios of the toxic pollutant concentrations measured in the water column against their respective acute and chronic criteria values (referred to as a “Toxic Unit” or TU calculation) for samples collected at each monitoring station. When the TU is greater than 1.0 the toxicant concentration exceeds its criterion. Exceedance can be defined as a result (i.e., a concentration, an average concentration, or other appropriate statistically derived concentration as applicable) that does not meet the criterion as specified in the SWQS (MassDEP 2021b). The TU calculation provides the relative magnitude of the exceedance which, together with its frequency and duration, are important factors in evaluating toxicants.

Water quality samples for toxicants may be collected using either discrete or composite techniques (see inset). A single discrete sample is considered to be representative of an acute exposure period (typically one-hour) and its pollutant concentrations are therefore compared directly against acute criteria. Composite sample pollutant concentrations can also be compared directly to acute criteria. A minimum of two exceedances (TU >1.0) of an acute criterion within a three-year time period must be found prior to making an impairment decision.

Chronic toxicant criteria evaluations require additional considerations based on both sample type and the toxicant’s CCC exposure period (e.g., a 4-day period for most metals, a 30-day period for ammonia, etc.). To evaluate against chronic criteria, samples (discrete or composite) should be collected under relatively stable flow conditions (i.e., excluding samples collected during major storm events or flow conditions below 7Q10). Multiple discrete and/or composite samples are needed to evaluate whether two or more chronic criterion exceedances have occurred within the three-year time period. Independent samples are defined as those separated in time by more than a toxicant’s CCC exposure period and these include both discrete or composite samples that do not represent a CCC exposure period. Where toxicant concentrations are documented with TUs >1 but the data are insufficient to make an impairment decision, these sites will be targeted for additional data collection. Sampling scenarios for determining chronic criteria impairments for toxic pollutants can be found in Table 4.

Metals.

Since 2007 WPP staff have utilized clean sampling techniques for gathering freshwater instream metals sample data. While this dataset is very limited (typically three samples collected per site), validated data collected using clean sampling techniques will be used in the *Aquatic Life Use* attainment decisions for the 2024 reporting cycle. In addition, these data will be used to evaluate whether historical impairment decisions, based on older metals data not collected using clean sample techniques, were appropriate.

Evaluation of WPP freshwater metals data, typically collected as discrete samples, is conducted according to the TU method described above and further detailed in Appendix E. Other usable external data sources may also be evaluated. The metals data evaluated for the 2024 reporting cycle based on the dissolved fraction include cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), silver (Ag), and zinc (Zn). Aluminum (Al), arsenic (As), and selenium (Se) data are evaluated against criteria based on the total recoverable concentration. Details (e.g., translation tables, equations, etc.) related to metals criteria are described in Appendix E. The SWQS also include Coastal and Marine metals criteria in Table 29 (except for Aluminum and Chromium III), which are also available to utilize if quality-assured marine metals data are available for an estuarine AU.

Table 4. Toxic pollutant sample scenarios used to evaluate chronic criteria exceedances.

Chronic criteria exceedance evaluations within a three-year period for determination of impairment		
Discrete sample scenarios	**Limited frequency** *(e.g., less than monthly)*	a. Out of 3 independent[1] samples, all 3 have TUs >1
		b. Out of 4 or more independent[1] samples, >50% have TUs >1
		c. Two or more sets of averaged[2] samples have TUs >1
	Moderate frequency *(e.g., monthly)*	a. Out of 6 or more independent[1] samples, either >50% have TUs >1 or 2 or more sets of consecutive samples[3,4] have TUs >1
		b. Two or more sets of averaged[2] samples have TUs >1
	High frequency *(every 2 weeks, at minimum)*	a. Out of 6 or more independent[1] samples, 2 or more sets of consecutive samples[3] have TUs >1
		b. Two or more sets of averaged[2] samples have TUs >1
Composite sample scenarios		a. Two or more composite[5] samples have TUs >1
Combination of discrete and composite sample scenarios		a. One composite[5] sample has a TU >1 and 2 independent[1] samples have TUs >1
		b. One composite[5] sample has a TU >1 and either ≥50% of 3 or more independent[1] samples have TUs >1 (under a limited discrete sample scenario) or at least one set of consecutive samples[3] has TUs >1 (under moderate or high frequency discrete sample scenarios)
		c. One composite[5] sample has a TU >1 and at least one set of averaged[2] samples has a TU >1

[1] *Independent samples are defined as those separated in time by more than the CCC exposure period for a toxicant. These include both discrete and composite samples that do not represent a CCC exposure period.*
[2] *Samples collected during two or more days within the toxicant's CCC exposure period (e.g., 4 days) will be averaged (or average TUs for toxicants with criteria that are equation or model based, i.e., site dependent) to best represent the exposure period.*
[3] *Under the discrete moderate and high frequency sample scenarios, one exceedance is defined as two consecutive samples with TUs >1.*
[4] *For any toxicant with a CCC exposure period >14 days (e.g., ammonia), the determination of an impairment will be in accordance with the analyst's best professional judgment given a sample monitoring frequency that is only moderate (monthly).*
[5] *Composite samples that best represent the toxicant's CCC exposure period are preferred.*

For metals with hardness-based criteria (Cd, Cr, Cu, Pb, Ni, Ag, Zn), the actual instream hardness (calculated from calcium and magnesium concentration data) is used. The criteria and hardness-dependent equations can be found in Table E3 of Appendix E. For Cu, its hardness-based criteria are only used if site-specific criteria established in Table 28 of the SWQS or site-dependent criteria calculated using the Biotic Ligand Model (BLM) cannot be used (for more detail see Appendix E). With the exception of Cape Cod and the Islands coastal drainage areas, aluminum default criteria shall be used unless site-dependent criteria can be calculated (see Appendix E).

Exception:

- Although EPA updated their recommended freshwater selenium criteria in 2016, these criteria have not been fully evaluated by MassDEP staff and, therefore, were not adopted into Table 29a of the SWQS. The selenium criteria adopted in the SWQS are based on EPA's 1999 recommended criteria.

Ammonia.

According to the SWQS in Table 29a (MassDEP 2021b), the freshwater acute and chronic criteria for ammonia, expressed as total ammonia nitrogen (TAN or NH_3 + NH_4+), are dependent on pH and temperature. At lower temperatures (<15.7 ºC) the recommended acute criterion is also dependent on the presence or absence of the Genus *Oncorhynchus* (rainbow trout). The acute criterion duration represents a one-hour average. The chronic criterion duration represents a 30-day rolling average with the additional restriction that the highest 4-day average within the 30 days be no greater than 2.5 times the chronic criterion magnitude. These values are not to be exceeded more than once in three years on average. Because the ammonia criterion is a function of pH and temperature the analyst *screens* for acute and chronic criteria exceedances using the highest pH and temperature measurements taken at each sampling location during the course of the surveys to determine the most conservative acute and chronic ammonia criteria. The concentration data are then compared to these conservative ammonia criteria values. Where screening exceedances are found, sample-specific acute and chronic criteria are calculated, and the data are compared to these criteria. Alternatively, analysts can omit the screening approach and can calculate sample-specific acute and chronic ammonia criteria and compare them directly to all the ammonia data. A minimum of two exceedances of acute ammonia criteria must be found prior to making an impairment decision. In the absence of sample-specific temperature and pH data, a sample-specific criterion cannot be calculated, therefore an impairment decision is not made.

It is notable that of the two principal variables that determine chronic ammonia toxicity, pH plays a larger role than does temperature (see ammonia as a toxicant in (MassDEP 2016a)). Although the MassDEP water quality monitoring program staff often deploy thermistors to collect continuous temperature data at many sites, pH is usually measured during the water quality sampling survey when the nutrient (including ammonia) samples are being collected (typically~5 samples collected between April and October). Given the long CCC exposure period for ammonia (i.e., 30-day) the typical monthly discrete sample data are insufficient to evaluate chronic ammonia criteria exceedances. If, however, sufficient datasets are available containing more than one discrete sample or one or more representative composite samples within the thirty-day averaging period, comparisons against chronic criteria and impairment determinations may be made according to the guidance in Table 4 above.

The determination of coastal and marine ammonia criteria using TAN data requires concurrent pH, temperature, and salinity data whereas un-ionized (NH_3) ammonia data can be compared directly to CMC or CCC criteria (see Table 29a of the SWQS (MassDEP 2021b).

<u>Chloride.</u>

While chloride occurs naturally in aquatic environments, elevated levels of chloride often result from anthropogenic sources. Road deicing salts, urban and agricultural runoff, discharges from municipal wastewater and industrial plants, and drilling of oil and gas wells are the major anthropogenic sources of chloride (EPA 1988a). The acute criterion for chloride is 860 mg/L (one-hour average) and the chronic criterion is 230 mg/L (four-day average) and neither value is to be exceeded more than once every three years (MassDEP 2021b).

MassDEP analysts updated the linear regression model from the 2022 CALM (MassDEP 2022). The model is used to estimate chloride concentrations from specific conductance (SC) measurements (Appendix F). Model validation testing also proved it to be sufficiently accurate and robust to reliably predict chloride concentrations using SC as a surrogate in Massachusetts freshwaters according to the following equation:

$$\boldsymbol{Y = 0.3361X - 39.011} \quad (R^2=0.987,\ P=0.000),$$

where Y is chloride concentration and X is specific conductance at 25°C.

For the purpose of evaluating chloride toxicity data used to make assessment decisions, data can be either discrete laboratory results for chloride and/or estimated discrete/continuous chloride values based on the above equation. Instantaneous exceedances of the acute and chronic chloride criteria are estimated to occur at SC readings greater than 2,675 and 800 µS/cm, respectively. Best professional judgement should be used regarding confounding site-specific conditions that might affect the accuracy of the model, and a 10% safety factor should always be applied to SC measurements to account for model uncertainty- this equates to 2,940 and 880 µS/cm (acute and chronic thresholds, respectively).

<u>Chlorine.</u>

Chlorine is primarily used as a biocide to disinfect municipal wastewater effluents, to control fouling organisms in cooling water systems, as a bleaching agent in textile mills and paper-pulping facilities, and in cyanide destruction in electroplating and other industrial operations. The freshwater ambient water quality criteria for this toxicant are expressed as total residual chlorine (TRC) which is the sum of the concentrations of free and combined residuals as measured by amperometric titration or an equivalent method. The acute criterion for TRC is 0.019 mg/l (one-hour average), and the chronic criterion for TRC is 0.011 mg/l (four-day average) and neither criterion is to be exceeded more than once every three years (MassDEP 2021b). The most recent minimum quantification level for TRC in NPDES permits and WET testing guidelines is 0.02 mg/l, and concentrations reported at or below this level are considered by EPA to be meeting the criteria.

<u>Toxic pollutant assessment guidance summary:</u>

Use is Supported	Use is Impaired
For any toxic pollutant there is no more than a single exceedance of the acute or chronic criterion (i.e., analyte-specific TU $\leq$1 using the applicable exposure period) within the most recent 3-year period.	For any toxic pollutant there is more than one exceedance of the acute or chronic criterion (i.e., analyte-specific TU >1 using the applicable exposure period) within the most recent 3-year period.

Sediment Quality Data

BACKGROUND & CONTEXT
Sediment and tissue chemistry (CCME 1999b)***:*** *Highly persistent, bioaccumulative compounds, such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), toxaphene, dioxin and furans, and mercury, are not often detectable in water because they readily partition into other environmental media, including sediment and biota* (CCME 1999b)*.* *Organochlorine compounds, which include insecticides and PCBs, had been in widespread use since World War II but have since been restricted or banned because of their toxic effects on wildlife and human health. According to Coles (1998), "[t]hey are resistant to biochemical degradation…which contributes to excessive buildup in aquatic environments…they are prone to atmospheric transport…have a high affinity for sediment organic matter…tend to partition strongly into the lipid component of aquatic organisms…they can be passed up the food chain to higher trophic feeders through bioaccumulation…the National Academy of Science/National Academy of Engineering's (NAS/NAE) recommended guidelines for the protection of fish-eating wildlife apply to whole fish tissue. These guidelines were based on experimental studies showing induction of eggshell thinning in birds by DDT and metabolites. More conservative guidelines for other organochlorines were set by analogy to DDT, based on their greater toxicity to wildlife."*

Rivers, Lakes, and Estuaries

The Massachusetts SWQS do not currently contain numeric sediment quality criteria. To evaluate the potential for adverse biological effects, surficial sediment quality data for heavy metals, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs),and pesticides are compared to the Canadian Interim Sediment Quality Guidelines (ISQL), which represent the concentration below which adverse biological effects are expected to rarely occur and to the Probable Effect Levels (PEL), which represent the levels for which adverse biological effects are expected to frequently occur (CCME 2002). For those analytes measured in surficial sediment samples where ISQL and PEL guidance are available a matrix of analytes and their respective guidance values is developed. Ratios of the sediment concentration for each analyte to its respective ISQL and PEL are then calculated. When the ratio of the contaminant to the guideline exceeds a value of 1.0 the concentration is considered to be of concern. To assess the overall quality of the sediment at a site all of the ratios that exceed a value of 1.0 are added together. This sum is noted as the total factor over the ISQL and/or PEL.

Sediment quality data alone are not typically used to assess the *Aquatic Life Use* as impaired. However, when there are exceedances of sediment screening values (ISQLs and/or PELs) along with other indicators of impairment (e.g., fish tissue contamination or impaired biological community) the analyst will use best professional judgment (BPJ) and likely add the sediment screening value exceedances as a cause of impairment for the *Aquatic Life Use*. It should be noted here that for areas in Massachusetts where the sediments are known to be severely contaminated and are undergoing remedial actions (e.g., Housatonic River or Inner New Bedford Harbor.) sediment contamination is identified as one source of the impairment.

Use is Supported	Use is Impaired
No/infrequent excursions of ISQL/PEL guidelines and no other indicators of impairment.	Frequent excursions over ISQL/PEL guidelines along with other evidence of impairment, waterbody known to have sediment contamination undergoing remedial actions.

Tissue Residue Data

BACKGROUND & CONTEXT
Body Burdens *(CCME 1999a, 1999c, 2000, 2001)* *As described in the Canadian Tissue Residue Guidelines for the Protection of Wildlife Consumers of Aquatic Biota, DDT, a chlorinated hydrocarbon insecticide, was used worldwide since the 1940s to control insects (CCME 1999a). "DDT, as well as its breakdown products, is highly lipophilic and presents serious problems for wildlife that feed at high trophic levels in the food chain…for aquatic-based wildlife species, food resources provide the main route of exposure…exposure to DDT and its metabolites [DDD and DDE] is known to reduce longevity and alter cellular metabolism, neural activity and liver function…mutagenic and carcinogenic effects, as well as adverse effects on reproduction, growth, and immunocompetence" (CCME 2001). Toxaphene "(chlorinated camphenes known as campheclor, chlorocamphene, or polychlorocamphene (PCC)) was developed in 1946 and used as a contact insecticide for crops, as an herbicide and to control ectoparasites on livestock… also applied to lakes and streams in Canada and the northern US to eliminate undesirable fish, lamprey, and invertebrate communities…exposure to toxaphene is known to induce adverse effects on cardiovascular, hepatic, renal, endocrine, immunological, and neurological systems, and to decrease longevity in birds and mammals…while contamination of surface waters may continue to occur as a result of erosion of toxaphene-contaminated soils, atmospheric deposition is a main source" (CCME 1999c).* *Dioxin and Furans "(polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurnas (PCDFs) are planar tricyclic aromatic compounds…while they have never been intentionally produced they are byproducts formed as a result of anthropogenic activities including waste incineration, chemical manufacturing, petroleum refining, wood burning, metallurgical processes, fuel combustion (autos), residential oil combustion, and electric power generation…natural sources include forest fires and volcanic activity…the 2,3,7,8-substituted PCDD/Fs are thought to elicit most of their toxicity via the aryl hydrocarbon (Ah) receptor, a protein present in mammals, birds, and fish…by binding however linkages between enzyme induction and specific organ toxicity are unclear" (CCME 2001). Mortality and a multitude of sublethal effects on organisms were described.* *Methyl mercury, "the most toxicologically relevant form, is a potent neurotoxicant for animals and humans…It is produced through the biological and chemical methylation of inorganic mercury…Methyl mercury is not very lipid soluble but it binds strongly with sulfhydryl groups in proteins and is therefore readily accumulated and retained in biological tissues" (CCME 2000).*

Rivers, Lakes, and Estuaries

Body burdens of chemicals in aquatic organisms (i.e., fish, shellfish and other invertebrates, and plants) also provide a mechanism to evaluate risk to wildlife consumers of aquatic biota. According to Coles (1998) the National Academy of Science/National Academy of Engineering (NAS/NAE) guidelines based on whole fish for the protection of fish-eating wildlife are as follows:

Total PCBs:	$\leq$ 500 µg/kg (ppb) wet weight
Total DDT, DDE, DDD:	$\leq$ 1,000 µg/kg (ppb) wet weight
Chlordane and Heptachlor epoxide:	$\leq$ 200µg/kg (ppb) wet weight*

**also applies to total residues of aldrin, benzene hexachloride (BHC), chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, and toxaphene either singly or in combination*

Residues of contaminants in whole body samples of fish are compared to the NAS/NAE recommended guidelines based on whole fish for the protection of fish-eating wildlife. If the concentration of contaminants is below the guideline(s) (e.g., [total PCB] $\leq$ 500 µg/kg (ppb) wet weight) then no impairment decision for the *Aquatic Life Use* is made. However, if whole body burden residue(s) exceed the recommended guideline(s), best professional judgment is used by the analyst to evaluate whether an impairment decision is warranted. While an impairment decision will not be made on one or two samples, an impairment decision will be made based on several samples exceeding NAS/NAE guidelines, combined with any other data types that corroborate an impairment decision (see DELTS/abnormal fish histology in Fish Community Section).

Use is Supported	**Use is Impaired**
Residue of contaminants in samples do not exceed NAS/NAE whole body or EPA body burden guidelines	Residue of contaminants in samples frequently exceed NAS/NAE whole body or EPA body burden guidelines, DELTS with abnormal fish histology.

Aquatic Life Use Attainment Summary

Table 5. *Aquatic Life Use* attainment decision indicator summary by weight-of-evidence approach.

Indicator for *Aquatic Life Use* Evaluation	**Use is Supported**	**Use is Impaired**
BIOLOGICAL MONITORING INFORMATION		
Benthic macroinvertebrate data (rivers)	IBI analysis indicative of Excellent Condition/Satisfactory Condition	IBI analysis indicative of Moderately Degraded/Severely Degraded Condition
Benthic macroinvertebrate data (estuaries)	Relatively high # species, high # individuals, good diversity and evenness, moderate to deep burrowing, tube dwelling organisms present, as reported from external data sources	Relatively low # species, low # individuals, poor diversity and evenness, presence of shallow dwelling opportunistic species or near absence of benthos, thin feeding zone, as reported from external data sources
Fish community data (rivers)	**Cold Water Fishery** Presence of cold-water fishes, multiple age classes (indicative of reproducing populations) of any salmonid, presence of YOY salmonids. **Warm Water Fishery** In moderate to high gradient (riffle/run prevalent) streams the fish community should include fluvial specialist/dependents species or at least one fluvial species in moderate abundance. In low gradient (glide/pool prevalent) streams, at least one fluvial species, or species which are intolerant or moderately tolerant to environmental perturbations should be present. In either high or low gradient habitat: fish community $\geq$ 50% similarity with TFC	**Cold Water Fishery** Absence of cold-water fishes, or dramatic population reductions relative to historical samples, DELTS with abnormal fish histology. **Warm Water Fishery** In moderate to high gradient (riffle/run prevalent) streams fluvial fish are absent. In low gradient (glide/pool prevalent) streams no fish found or the absence of fish which are intolerant or moderately tolerant to environmental perturbations. In either high or low gradient habitat presence of DELTS (>10% sample) due to pollutant(s), and/or fish community < 50% similarity with TFC.
Fish community data (lakes, estuaries)	None made	> 5% population losses estimated , DELTS with abnormal fish histology
Primary Producer Data* (rivers, lakes, riverine impoundments estuaries)	**<u>Benthic Algae</u>** Wadeable rivers: benthic chlorophyll *a* samples $\leq$200 mg/m^2, filamentous algal cover $\leq$40% **<u>Chlorophyll a</u>** Deep rivers: phytoplankton Chlorophyll *a* $\leq$16 µg/L, Lakes: phytoplankton Chlorophyll *a* $\leq$16 µg/L Estuaries:Chlorophyll *a* $\leq$5 µg/L **<u>Aquatic Macrophytes</u>** Lakes: $\leq$25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps Estuaries: little to no macroalgae accumulations **<u>Algal Blooms</u>** Rivers, lakes, estuaries: occasional non-harmful ephemeral algal blooms **<u>Eelgrass bed mapping data</u>** Estuaries: Eelgrass bed habitat in AU area is increasing or fairly stable (i.e., no or minimal loss) between 1994-1996 and 2010-2013 mapping efforts	**<u>Benthic Algae</u>** Wadeable rivers: benthic chlorophyll *a* samples >200 mg/m^2, filamentous algal cover >40% **<u>Chlorophyll a</u>** Deep rivers: phytoplankton Chlorophyll *a* >16 ug/L Lakes: phytoplankton Chlorophyll *a* >16 µg/L, Estuaries: Chlorophyll *a* >10 µg/L **<u>Aquatic Macrophytes</u>** Lakes: >25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps Estuaries: some macroalgae accumulations **<u>Algal Blooms</u>** Rivers , lakes, estuaries: recurring and/or prolonged algal and/or C-HAB blooms* **<u>Eelgrass bed mapping data</u>** Estuaries: Substantial decline in AU (= or exceed 10% of eelgrass bed area between 1994 – 1996 and 2010 – 2013 mapping efforts
Habitat & flow data (rivers, lakes, estuaries)	No direct evidence of severe physical habitat or stream flow regime alterations	Physical habitat structure impacted by anthropogenic stressors e.g., lack of flow (Dewatering or Flow Regime Modification impairment), lack of natural habitat structure such as concrete channel, underground conduit (Physical Substrate Habitat Alterations impairment), a lack of or restricted fish passage where diadromous fish populations have been documented (Fish Passage Barrier impairment)
Non-native aquatic species data (rivers, lakes)	Non-native aquatic species absent	Non-native aquatic species present

Indicator for *Aquatic Life Use* Evaluation	Use is Supported	Use is Impaired
TOXICOLOGICAL MONITORING INFORMATION		
Toxicity testing data (rivers, lakes, estuaries)	≥75% survival of test organisms to water column or sediment samples in either 48-hr (acute) or 7-day exposure (chronic) tests.	<75% survival of test organisms to water column or sediment samples in either 48-hr (acute) or 7-day exposure (chronic) tests occurs in >10% of test events or more than once when limited data are available.
PHYSICO-CHEMICAL WATER QUALITY INFORMATION		
Water quality data - DO (rivers)	Deployed (LTC, STC) probe datasets: Calculated mean and mean minimum statistics meet EPA criterion (cold or warm-water dependent) Single (S) measurement datasets: No more than one excursion from criteria (minimum three preferably five measurements representing critical --i.e., pre-dawn, conditions)	Deployed (LTC, STC) probe datasets: Calculated mean and mean minimum statistics below EPA criterion (cold or warm-water dependent) Single (S) measurement datasets: Frequent (>10%) and/or prolonged or more than one measurement below EPA 1 day minimum criterion
Water quality data - DO (lakes)	No/little depletion (the criterion is met in all depths over ≥90% of the lake surface area during summer season)	The criterion is not met at all depths for >10% of the lake surface area during periods of maximum oxygen depletion
Water quality data - DO (estuaries)	No/infrequent prolonged or severe (≤10%) excursions from criteria in surface or bottom waters	Frequent (>10%) and/or prolonged or severe excursions (>1.0 mg/l below standards) from criteria
Water quality data - pH (rivers)	No or slight excursions (<0.5 SU) from criteria (minimum five measurements)	Frequent (>10%) and/or prolonged or severe excursions (>0.5 SU) from criteria
Water quality data - pH (lakes)	No or slight excursions (<0.5 SU) from criteria (minimum one deep-hole profile during summer growing season)	Excursion from criteria (>0.5 SU) summer growing season
Water quality data - pH (estuaries)	No or slight excursions (<0.5 SU) from criteria (minimum five measurements)	Frequent (>10%) and/or prolonged or severe excursions (>0.2 SU) from criteria
Water quality data - temperature (rivers, lakes, estuaries) [Note here: Allowed (~10%) exceedance up to 11 times June-September (reflects the term "generally" in the SWQS).]	**Cold Water Fishery** Chronic evaluation large thermistor dataset: Designated Cold Water:7-DADM ≤20.0°C Tier 1 Existing Use Waters: 7-DADM ≤20.0°C Tier 2 Existing Use Waters: 7-DADA ≤21.0°C (Exceedances ≤11 times) Chronic evaluation 3-5 day sonde deployment: Designated Cold Waters: 3-5-DADM ≤20.0°C Tier 1 Existing Use Waters: 3-5-DADM ≤20.0°C Tier 2 Existing Use Waters: 3-5-DADA ≤21.0°C (No exceedances) Acute evaluation thermistor / sonde deployment: Acute (Maximum 24-hour average), Tier 1 fish: ≤ 23.5°C, Tier 2 fish: ≤ 24.1°C No exceedances of mean (acute criterion) Small dataset: no/infrequent/small excursions (1 to 2°C) above 20°C **Warm Water Fishery** Chronic evaluation large thermistor dataset: Designated Warm Waters and Unlisted Class B Waters not Tier 1 or Tier 2: 7-DADM ≤27.7°C (Exceedances ≤11 times) Chronic evaluation 3-5 day sonde deployment: 3-5-DADM ≤27.7°C (No exceedances) Acute evaluation thermistor /sonde deployment: Maximum 24-hour average ≤ 28.3°C No exceedances of mean (acute criterion) Small dataset: no/infrequent excursions above criteria (28.3°C)	**Cold Water Fishery** Chronic evaluation large thermistor dataset: Designated Cold Waters: 7-DADM >20.0°C Tier 1 Existing Use Waters: 7-DADM >20.0°C Tier 2 Existing Use Waters: 7-DADA >21.0°C (Exceedances > 11 times) Chronic evaluation 3-5 day sonde deployment: No impairment decision made but identify exceedance with an Alert Status and recommend followup sampling Acute evaluation thermistor / sonde deployment: Acute (Maximum 24-hour average) Designated Cold Waters: > 23.5°C, Tier 1 fish: > 23.5°C, Tier 2 fish: > 24.1°C Small dataset: criterion frequently exceeded (10%) or by >2°C (22°C) **Warm Water Fishery** Chronic evaluation large thermistor dataset: Designated Warm Waters and Unlisted Class B Waters not Tier 1 or Tier 2: 7-DADM >27.7°C (Exceedances > 11 times) Chronic evaluation 3-5 day sonde deployment: No impairment decision made but identify exceedance with an Alert Status and recommend follow-up sampling Acute evaluation thermistor/sonde deployment: Maximum 24-hour average > 28.3°C Small dataset: SWQS criterion frequently exceeded (>10% measurements) or by >2°C (30.3°C).

Indicator for *Aquatic Life Use* Evaluation	**Use is Supported**	**Use is Impaired**
Water quality data - temperature *(continued)*	**Estuary** <u>Chronic evaluation large thermistor dataset:</u> 24-hour average ≤ 26.7°C (Exceedances ≤11 days) <u>Acute evaluation of large thermistor /deployed sonde (3- 5 day) dataset:</u> No more than one day with exceedance of 29.4°C <u>Small dataset:</u> No more than one day with exceedance of 29.4°C	**Estuary** <u>Chronic evaluation large thermistor dataset:</u> 24-hour average > 26.7°C (Exceedances > 11 times) <u>Acute evaluation of large thermistor/deployed sonde (3- 5 day) dataset:</u> More than one day above criteria 29.4°C <u>Small dataset:</u> More than one day above criteria 29.4°C <u>Other:</u> rise due to discharge exceeds ΔT standards
Physico-chemical nutrient screening guidelines (rivers)	Small diel changes in oxygen/saturation/pH (Δ <3 mg/l, < 125% saturation, <8.3 SU, respectively), seasonal summer average (n≥3) total phosphorus concentrations below EPA Gold Book concentrations. (≤0.1 mg/l flowing waters, ≤0.05 mg/l for rivers entering a lake/reservoir) with primary producer biological response indicators (as described above) generally minimal or below SWQS site-specific criteria	Combination of primary producer biological screening guidelines present (more than one site visit) as mentioned above as well as some combination of physicochemical screening guidelines including: Large diel changes in oxygen/saturation/pH (Δ ≥3 mg/l, ≥ 125% saturation, ≥8.3 SU, respectively), elevated seasonal summer average (n≥3) Phosphorus (Total) above EPA Gold Book concentrations >0.1 mg/l flowing waters, >0.05 mg/l for rivers entering a lake/reservoir or above SWQS site-specific criteria
Physico-chemical nutrient screening guidelines (lakes, impounded reaches of river)	Secchi disk transparency ≥1.2 m, seasonal average Phosphorus (Total) below EPA Gold Book concentrations ≤0.025 mg/l or below SWQS site-specific criteria with primary producer biological response indicators (as described above) generally minimal	Combination of primary producer biological screening guidelines present (more than one site visit) as mentioned above as well as some combination of physicochemical screening guidelines including: Secchi disk transparency <1.2 m, in combination with secondary indicators high oxygen super-saturation, elevated pH, elevated seasonal average (n≥3) Phosphorus (Total) above EPA Gold Book concentrations >0.025 mg/l or above SWQS site-specific criteria.
Physico-chemical nutrient screening guidelines (estuaries)	MEP analysis provided in a site-specific technical report indicates support (overall health evaluated between excellent to good/fair health) seasonal average mid-ebb (outgoing) tide total nitrogen concentration generally ≤0.4 mg/l with primary producer biological response indicators (as described above) generally minimal	Combination of primary producer biological screening guidelines present (more than one site visit) as mentioned above as well as some combination of physicochemical screening guidelines including: MEP analysis provided in a site-specific technical report indicates moderately to severely degraded health due to nitrogen enrichment, seasonal average mid-ebb tide total nitrogen concentration generally >0.5 mg/l
Water quality data Toxic and other pollutants (rivers, lakes, estuaries)	For any toxic pollutant there is no more than a single exceedance of the acute or chronic criterion (i.e., analyte-specific TU ≤1 using the applicable exposure period) within a 3-year period.	For any toxic pollutant there is more than one exceedance of the acute or chronic criterion (i.e., analyte- specific TU >1 using the applicable exposure period) within a 3-year period.
SEDIMENT AND TISSUE RESIDUE INFORMATION		
Sediment quality data (rivers, lakes, estuaries)	No/infrequent excursions of ISQL/PEL guidelines and no other indicators of impairment.	Frequent excursions over ISQL/PEL guidelines along with other evidence of impairment, waterbodies known to have sediment contamination undergoing remedial actions.
Tissue residue data (rivers, lakes, estuaries)	Residue of contaminants in samples do not exceed NAS/NAE whole body or EPA body burden guidelines	Residue of contaminants in samples frequently exceed NAS/NAE whole body orEPA body burden guidelines, DELTS with abnormal fish histology.

*Note: An *Aquatic Life Use* attainment decision generally not made based on primary producer data alone, if exceedances(s) of any threshold indicators found, additional evaluation of other water quality monitoring data (see nutrients) is required to make a use attainment decision.

Fish Consumption Use

The definition of the "Secondary Contact Recreation" designated use in the Massachusetts Surface Water Quality Standards (SWQS) includes the statement that waters supporting the *Secondary Contact Recreation Use* are suitable for "[a]*ny recreation or other water use in which contact with the water is either incidental or accidental. These include but are not limited to fishing, including human consumption of fish, boating and limited contact incident to shoreline activities*" (MassDEP 2021b). For the purpose of assessment and 305(b)/303(d) IR reporting, however, the status of the *Fish Consumption Use* (human consumption of fish) is reported as its own use rather than part of the *Secondary Contact Recreation Use*. The SWQS also state that "*pollutants shall not result in unacceptable concentrations in edible portions of marketable fish or for the recreational use of fish, shellfish, other aquatic life or wildlife for human consumption*" (see 314 CMR 4.05(5)(e)3b in (MassDEP 2021b)). The Fish & Shellfish Consumption criteria at 314 CMR 4.06(6)(d): *Table 29b*, *Generally Applicable Human Health Criteria* are water column concentrations that protect against harmful bioaccumulation in organisms such as fish that are consumed by humans. Exposure criteria listed in Table 29b, unless otherwise noted, are based on carcinogenicity of 10^{-6} risk.

BACKGROUND & CONTEXT
MassDEP WPP Fish Toxics Monitoring (MassDEP 2010b)

"Originally, monitoring was conducted either in the vicinity of known or suspected waste sites or in conjunction with much larger watershed surveys to attempt to assess the potential for bioaccumulative effects of past or present wastewater treatment plant or other discharges…the objective of DWM's sampling is primarily to screen edible fillets of fishes for a variety of contaminants (i.e. mercury, polychlorinated biphenyls (Aroclors), and organochlorine pesticides). Due to the highly variable concentrations of bioaccumulative contaminants in fish tissue and the wide range of environmental conditions which affect bioaccumulation (bioconcentration, bioaccumulation, and biomagnification), screening is conducted in an effort to sample as many of the Commonwealth's waters as possible during a given sampling season. Although screening may not accurately predict bioaccumulation patterns among a full range of year classes of any given fish species, sampling a three fish composite of average sized individuals answers the questions with regard to the presence/absence of any given analyte and its relative concentration. All screening analyses are performed at the Senator William X. Wall Experiment Station (WES). All data are sent to the MDPH and the MassDEP Office of Research and Standards (ORS) for assessment and advisory issuance if appropriate…"

"In order to assess the level of contamination present in fish of different trophic guilds and habitat types, screening involves the collection of three to five fish composites representing fishes of three trophic groups (i.e. predators, water column feeders, bottom feeders). Fish species targeted include at a minimum; largemouth bass, Micropterus salmoides, and/or chain pickerel, Esox niger, (predators); yellow perch, Perca flavescens, and/or white perch, Morone americana, (water column invertivores/omnivores); and bullhead, Ameiurus sp. and/or common carp, Cyprinus carpio, (bottom feeding omnivores). Average-sized fish (above legal length limit when applicable) are analyzed as composite samples. Additional species or substitute species are chosen on a site-by-site basis."

Use Attainment Decision-Making Process:

MassDEP biologists have been conducting fish toxics monitoring, mostly in freshwaters, since 1983. Over time, it became increasingly clear that the major problems in Massachusetts (as in the other New England states) were related to the widespread atmospheric deposition of mercury and/or to the historic use and disposal of PCBs (MassDEP 2010b). Most recently, data collection efforts are documenting widespread contamination of edible fish due to PFAS. Currently, freshwater fish tissue contaminant testing in Massachusetts is conducted by MassDEP in cooperation with the MA Department of Public Health (MDPH) and the Department of Fish and Game (MA DFG). The three agencies work together as the Interagency Committee on Freshwater Fish Toxics Monitoring and Assessment to facilitate the communication, coordination, and dissemination of information pertaining to contaminants in freshwater fish (MassDEP 2010b, MassDEP 2016b). The collaborative efforts of MassDEP, MDPH, and MA DFG ensure the state's ability to conduct limited testing and evaluation of contaminants in fish tissue for purposes of protecting public health and the environment. Each of the three agencies named in this MOU has responsibilities unique to their mission. While MassDEP provides much of the field and analytical support (refer to background/context inset on MassDEP WPP Fish Toxics Monitoring), all data are submitted to MDPH and the MassDEP Office of Research and Standards (ORS) for risk assessment and issuance of advisories, if appropriate. Ultimately, MDPH is responsible for decisions regarding the need for and/or implementation of public health advisories. The guidance used to assess the *Fish Consumption Use* is summarized below.

BACKGROUND & CONTEXT
Fish Consumption Advisory for Marine and Fresh Water Bodies (MDPH 2017)

Fish is good for you and your family. It may also protect you against heart disease. It is a good source of protein and it is low in fat. A varied diet, including safe fish, will lead to good nutrition and better health. If you may become pregnant or are pregnant or nursing, you and your children under 12 years old may safely eat 12 ounces (about 2 meals) per week of fish or shellfish not covered in this advisory. This recommendation includes canned tuna, the consumption of which should be limited to 12 ounces per week. Very small children, including toddlers, should eat less. Consumers may wish to choose to eat light tuna rather than white or chunk white tuna, the latter of which may have higher levels of mercury. Otherwise, it is important to follow the Safe Eating Guidelines included in this advisory.

Guidelines for pregnant women, women who may become pregnant, nursing mothers and children under 12 years old:
Do Not Eat: *Freshwater fish caught in streams, rivers, lakes, and ponds in Massachusetts* (Hg)*
Safe To Eat: *Fish that are stocked in streams, rivers, lakes, and ponds in Massachusetts*
Safe To Eat: *Cod, haddock, flounder and pollock in larger amounts*
Do Not Eat: *Lobster from New Bedford Harbor (PCB)*
Do Not Eat: *Bluefish caught off the Massachusetts coast (PCB)*
Do Not Eat: *Lobsters, flounder, soft-shell clams and bivalves from Boston Harbor (PCB and other contaminants).*
This Boston Harbor advisory is also recommended for people with weakened immune systems.
NOTE: For assessment purposes Boston Harbor is broadly defined to include all coastal waters that drain into it.
Guidelines for everyone:
Do Not Eat: *Fish, shellfish, or lobsters from Area I of New Bedford Harbor, Lobsters or bottom feeding fish from Area II of New Bedford Harbor, Lobsters from Area III of New Bedford Harbor (PCB)*
Do Not Eat: *Lobster tomalley (PCB)*

In 2017, the federal government issued additional advice about safe fish consumption.
Please visit: www.fda.gov/fishadvice and www.epa.gov/fishadvice

**More specific consumption advice is available for certain freshwater bodies that have been tested at: http://www.mass.gov/dph/fishadvisories or by calling the MDPH, Bureau of Environmental Health at 617-624-5757.*

DPH Fish Consumption Advisories
MDPH provides a guide to eating fish safely in Massachusetts (MDPH 2017) that summarizes the current statewide fish consumption advisories. In addition to the statewide fish advisories, the MDPH periodically (every one to three years) updates their Freshwater Fish Consumption Advisory List. This list provides specific consumption advice for individual waterbodies that is to be considered in addition to the statewide advisories. This list identifies the waterbody, the town(s), the fish consumption advisory language, and the hazard. EPA considers fish and shellfish consumption advisories (based on waterbody specific information) to be indicative of non-attainment of the “fishable” use. This applies to all pollutants that constitute potential risks to human health, regardless of the source of the pollutant. EPA recommends that states should use fish and shellfish consumption advisories as a source of data and information for section 303(d) determinations (Grubbs and Wayland III 2000).

The assessment of the *Fish Consumption Use* for the 2024 IR cycle relied on the January 2025 freshwater fish consumption advisory list issued by the MDPH Bureau of Climate and Environmental Health (MDPH 2025). For those waters covered by site-specific MDPH advisories, the *Fish Consumption Use* is assessed as impaired due to the hazard(s) identified (e.g., mercury, PCB, PFAS, etc.), and the waters are listed in the Integrated Report, accordingly. Due to the statewide fish edibility advisories targeting sensitive populations (i.e., women who may become pregnant or are pregnant or nursing, and children under 12 years of age), the *Fish Consumption Use* of all surface waters in Massachusetts can be considered impaired. However, based on EPA guidance (Grubbs and Wayland III 2000), waters are not individually listed as impaired in the Integrated Report unless site-specific advisories based on actual fish tissue data apply to them. MDPH has removed a few waterbodies from their advisory list where fish have tested high for mercury, but fishing is not permitted for various reasons. MassDEP analysts will continue to assess these waters as impaired until such a time as the concentration of mercury in the fish tissue meets the human health criterion of 0.3 ppm or less.

Mercury
When waters are assessed as impaired for the *Fish Consumption Use* due to elevated mercury and no source of mercury other than atmospheric deposition is identified, atmospheric deposition is listed as the source since it is anticipated that the waterbody will be restored in accordance with the Northeast Regional Mercury TMDL (Northeast States 2007). This TMDL is mandated by the CWA and identifies the pollutant load reductions necessary for regional waterbodies to meet and maintain compliance with state and federal surface water quality standards. The TMDL document was prepared by the New England Interstate Water Pollution Control Commission (NEIWPCC) for the

six New England states and New York and was approved by the EPA in December 2007. The TMDL target for Massachusetts is 0.3 ppm or less of methyl mercury in fish tissue. The TMDL also called for a 75% reduction of in-region and out-of-region atmospheric sources by 2010 and a 90% or greater reduction in the future (NEIWPCC 2007). The TMDL will be reassessed in the future based on an evaluation of new, on-going monitoring and air deposition data. Waters for which MDPH mercury advisories have been issued since the approval date of the TMDL are considered on a case-by-case basis for coverage under that document.

Per- and Polyfluoroalkyl Substances (PFAS)
In 2021, MDPH sponsored a pilot study evaluating PFAS analytes in fish tissue (and water) samples collected from recreational waterbodies on Cape Cod (MDPH 2021). Fish tissue concentrations for each of four individual PFAS analytes (perfluorooctanoic acid - PFOA; perfluorooctane sulfonic acid – PFOS; perfluorononanoic acid – PFNA; perfluorohexane sulfonic acid - PFHxS) were compared to a candidate Fish Action Level (cFAL) of 0.22 ng/g (ppb), resulting in the first Massachusetts freshwater fish consumption advisories for PFAS. In 2022, a second MDPH study focused on recreational waterbodies located in state parks (MDPH 2023). Three additional PFAS analytes, perfluorobutanoic acid (PFBA), perfluorobutane sulfonic acid (PFBS), and hexafluoropropylene oxide dimer acid (HFPO-DA, also referred to as GenX) were added to the list (see table below) and compared individually to the 0.22 ng/g (ppb) cFAL. This study also resulted in freshwater fish advisories for PFAS.

Organization	***Fish Consumption Use*** **Screener Based on MDPH Action Level**	Analytes Evaluated	Screener Value
MDPH	Fish muscle, individual analyte (candidate Fish Action Level or cFAL) for individual analytes	PFOA, PFOS, PFNA, PFHxS, PFBA, PFBS, HFPO-DA (also known as GenX)	0.22 ng/g (ppb)

Generally Applicable Human Health Criteria
Regarding the water column Fish & Shellfish criteria in Table 29b of the Massachusetts SWQS, there are 17 pollutants that are more stringent or potentially more stringent than the aquatic life criteria. When data on one or more of these 17* pollutants are available for evaluation of human health, the applicable criteria in Table 29b are compared directly to the water column or fish tissue pollutant concentration with no duration or frequency (i.e., only a single exceedance is allowed). Only the human health criteria that are more stringent than the aquatic life criteria or that are tissue-based (i.e., mercury) will be evaluated.
**including aldrin, arsenic, chlordane, dieldrin, endrin, heptachlor, heptachlor epoxide, methoxychlor, polychlorinated biphenyls (PCBs), toxaphene, and 4,4'-DDT. For toxic pollutant aquatic life criteria that are calculated (pentachlorophenol, and freshwater cadmium, chromium III, copper, nickel, and zinc), calculation of the criteria would be necessary to determine if the human health criteria would be more stringent.*

Fish Consumption Use Attainment

Use is Supported	Use is Impaired
Not applicable in Massachusetts, precluded by statewide advisories (Hg and/or PCBs)	Waterbody has site-specific MDPH Fish Consumption Advisory with hazard (e.g., mercury, PCBs, pesticides, DDT, PFAS, etc.) Waterbody exceeds generally applicable human health criteria.

Shellfish Harvesting Use

The definition of the "Secondary Contact Recreation" designated use in the Massachusetts SWQS includes the statement that "*[w]aters supporting the Secondary Contact Recreation Use are suitable for any recreation or other water use in which contact with the water is either incidental or accidental…. Where designated, secondary contact recreation also includes shellfishing, including human consumption of shellfish*" (MassDEP 2021b). For the purpose of assessment and 305(b)/303(d) IR reporting, however, the status of the *Shellfish Harvesting Use* (human consumption of shellfish) is reported as its own use rather than part of the *Secondary Contact Recreation Use*. At 314 CMR 4.05(5)(e)3b the SWQS state that "pollutants shall not result in unacceptable concentrations in edible portions of marketable fish or for the recreational use of fish, shellfish, other aquatic life or wildlife for human consumption" (MassDEP 2021b).

Use Attainment Decision-Making Process:

Grubbs and Wayland (2000) provided states the following guidance for 305(b)/303(d) reporting: "*For purposes of determining whether a waterbody is impaired and should be included on a section 303(d) list, EPA considers a shellfish consumption advisory, a NSSP classification, and the supporting data, to be existing and readily available data and information that demonstrates non-attainment of a section 101(a) "fishable" use when: 1. the advisory is based on fish and shellfish tissue data. 2. a lower than "Approved" NSSP classification is based on water column and shellfish tissue data (and this is not a precautionary "Prohibited" classification or the state water quality standard does not identify lower than "Approved" as attainment of the standard) 3. the data are collected from the specific waterbody in question*".

Shellfish Growing Area Classifications

BACKGROUND & CONTEXT

DMF Shellfish Sanitation and Management Overview (MA DFG 2021, USFDA 2017)

The Shellfish Program has two primary missions, public health protection and both direct and indirect management of the Commonwealth's molluscan shellfish resources. Public health protection is afforded through the sanitary classification of overlying waters within the states territorial sea in accordance with the provisions of the National Shellfish Sanitation Program (NSSP). The NSSP is the federal/state cooperative program recognized by the U.S. Food and Drug Administration (FDA) and the Interstate Shellfish Sanitation Conference (ISSC) for the sanitary control of shellfish produced and sold for human consumption.

Public health protection is achieved as a result of sanitary surveys of shellfish growing areas to determine their suitability as shellfish sources for human consumption. The principal components of a sanitary survey include: 1) an evaluation of pollution sources that may affect an area, 2) evaluation of hydrographic and meteorological characteristics that may affect distribution of pollutants, and 3) an assessment of microbiological water quality.

Each growing area must have a complete sanitary survey every twelve years, a triennial evaluation every three years and an annual review in order to maintain a classification which allows shellfish harvesting. Minimum requirements for sanitary surveys, triennial evaluations, annual reviews and annual water quality monitoring are established by the ISSC and set forth in the NSSP. As of May 2024 there are 302 growing areas in Massachusetts' coastal waters (MassGIS 2024)*. DMF also reports a total of ~2,700 sampling station locations associated with their designated growing areas* (MassGIS 2008)*. Water and shellfish samples are tested for fecal coliform bacteria at two DMF laboratories located in Gloucester and New Bedford using a Most Probable Number (MPN) method (American Public Health Association) for classification purposes and a membrane filtration technique (usually M-tec) for pollution source identification.*

The Massachusetts DFG, Division of Marine Fisheries (DMF), is responsible for implementing the Shellfish Sanitation and Management Program (see inset). Based on the results of their sanitary surveys, triennial evaluations and annual reviews the DMF biologists assign a sanitary classification to each shellfish growing area. DFG's designated shellfish growing area is an area of potential shellfish habitat. Growing areas are managed with respect to shellfish harvest for direct human consumption, including commercial shellfishing. The DFG classifications range from Approved (shellfish taking permitted) to Prohibited (no shellfish taking permitted) (see descriptions in inset on next page). Administrative or Management Closure's may be assigned by DFG if sufficient work has not been done to properly classify a growing area or if the associated risks to the fishery cannot be managed in a manner that ensures public health.

According to the SWQS (MassDEP 2021b), shellfish harvesting goals for SA and SB waters are as follows:

- Class SA waters, where designated, shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas);
- Class SB waters, where designated, shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas).

MassDEP analysts assess the *Shellfish Harvesting Use* using the most recent DMF classification of the shellfish growing areas available at the time that the assessments are made. For the 2024 reporting cycle, the Designated Shellfish Growing Areas shapefile, provided by DMF staff on 21 June 2024 (MassGIS 2024), will be used by MassDEP analysts to assess the *Shellfish Harvesting Use*, with guidance summarized below. Shellfish growing areas under administrative or management closures are not assessed (see note below).

BACKGROUND & CONTEXT
DMF Shellfish Growing Area Classifications (MA DMF Undated, USFDA 2017)

Approved: *"...open to shellfish harvesting for direct human consumption subject to local rules and regulations... An approved area is open all the time and closes only due to hurricanes or other major coastwide events."*

Conditionally Approved: *"… closed some of the time due to runoff from rainfall or seasonally poor water quality or other predictable events. When open, it is treated as an Approved area." During the time the area is open, it is "open to shellfish harvesting for direct human consumption subject to local rules and regulations…"*

Restricted: *"… contains a limited degree of contamination at all times. When open, shellfish can be relayed to a less contaminated area or harvested for depuration."*

Conditionally Restricted: *"...Contains a limited degree of contamination at all times. Subject to intermittent pollution events and may close due to poor water quality from rainfall events or season." During the time the area is open, "only commercial harvesting of soft shell clams for depuration is allowed."*

Prohibited: *"Closed to the harvest of shellfish under all conditions, except the gathering of seeds for municipal propagation programs under a DMF permit."*

Shellfish Harvesting Use **Attainment**

An impairment decision for this use presumes that the cause is the result of elevated fecal coliform bacteria in the water column and, therefore, in shellfish. The source(s) of impairment may be identified based on DMF reports and information, TMDL reports, and/or BPJ of MassDEP analysts using orthophotos, land-use, and urbanized area MassGIS data layers.

Waterbody	Use is Supported	Use is Impaired
SA Waters	Shellfish Growing Area Classification: *Approved*	Shellfish Growing Area Classification: *Conditionally Approved,* *Restricted,* or *Conditionally Restricted*
SB Waters	Shellfish Growing Area Classification: *Approved*, *Conditionally Approved*, or *Restricted*	Shellfish Growing Area Classification: *Conditionally Restricted*

Note: Information pertaining to whether a shellfish growing area was classified as prohibited based on water quality data or as a precautionary measure (e.g., proximity of wastewater treatment discharge, marina) is not readily available to the MassDEP analysts. For previous assessment cycles, impairment decisions were made based on the prohibited classification alone when, in fact, no impairment decision should have been made for precautionary prohibitions. Therefore, for the 2024 assessment cycle the "Prohibited" classification areas will not be used to make an impairment decision since there is insufficient information available to determine whether a particular closure is due to poor water quality conditions.

Aesthetics Use

The narrative aesthetics criteria in the Massachusetts SWQS states that surface waters should be "*free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life*" (MassDEP 2021b). Waters supporting the *Aesthetics Use* are pleasing to the senses for both active and passive activities: to look upon, to walk or rest beside, to contemplate, to recreate on, and should enhance the visual scene wherever it appears (Federal Water Pollution Control Administration 1968).

Use Attainment Decision Making Process:

The *Aesthetics Use* is assumed to be supported unless field notes indicate otherwise. While the aesthetic assessments are somewhat subjective, issues of concern (e.g., the presence of trash/debris, one very dense algal bloom noted during the summer survey season) *may* be identified with an Alert Status to flag the need for more detailed information gathering, whereas gross-level aesthetic impairments are identified as not supporting. A waterbody will not be assessed as impaired for the occasional presence of trash or debris, but rather for persistent and/or other more serious indicators of aesthetic degradation. Note that MassDEP does not consider there to be any difference between a "Trash" or "Debris" impairment. However, Trash is considered a "pollutant" as defined by 40 CFR §122.2, and results in a Category 5 impairment, while Debris is considered "pollution" as defined by 40 CFR §502.19, and results in a Category 4a impairment. With MassDEP's implementation of the EPA ATTAINS Database reporting system in the 2018/2020 IR cycle, all prior Debris/Floatables/Trash impairments were converted to two separate impairments for Trash and Debris. Going forward, MassDEP analysts will add new impairments for Trash only. Additional guidelines for interpreting aesthetic observations are provided below.

Aesthetic observations

Rivers, Lakes, and Estuaries

MassDEP field staff note aesthetically objectionable and abnormal conditions encountered at sampling stations. Based on these notes, an evaluation is made regarding the aesthetic quality of a waterbody. The field sheets provide documentation of conditions that exist at a site which may be indicative of nutrient enrichment (e.g., algal growth/blooms) or other aesthetically objectionable conditions (e.g., deposits, sheens, odors, unnatural color, turbidity (clarity), trash/debris, etc.). Field data are recorded at each site during each survey so analysts can later determine the general magnitude and frequency of any objectionable conditions over the course of the sampling period. External sources of information related to aesthetic quality may include, but are not limited to, volunteer stream team/shoreline surveys and lake reports, and field sheet survey documentation.

Algal Blooms

Rivers, Lakes, and Estuaries

Rivers and streams with greater than 40% percent cover of benthic algae (filamentous green) may also exhibit aesthetic impairment (Barbour, et al. 1999). MassDEP analysts currently utilize this general guideline of 40% cover of the substrata in a stream reach with visible filamentous forms of algae to evaluate whether or not the aesthetics of a stream AU is supported. When more than 40% of the stream bottom is covered by filamentous algae, the *Aesthetics Use* is generally considered to be impaired for Algae.

Similar to the *Primary Contact Recreation Use* attainment guidance, *Aesthetic Use* Harmful Algal Bloom (HAB) impairment decisions are made based on MDPH advisories, cyanobacteria cell counts, and cyanotoxin concentrations (for more detail see *Primary Contact Recreation Use*). MassDEP analysts assess the *Aesthetic Use* as impaired if the *Primary Contact Recreation Use* of a waterbody is assessed as impaired for Harmful Algal Blooms.

Macroalgae

Estuaries

Certain marine macroalgae species including *Ulva*, *Enteromorpha* (greens), *Pilayella* (brown), and *Porphyra* (red) may form nuisance growths. The presence of objectionable growths of these and/or other species may result in an impairment of the *Aesthetics Use*.

Macrophyte Cover

Lakes and Riverine Impoundments

Determining whether recreational uses are impaired due to overabundant (i.e., undesirable or nuisance) growths of aquatic macrophytes requires some judgment decisions. In the case of macrophytes, a combination of factors may be considered, including: the area of the lake that is covered, the percentage of biovolume that is filled (if those data are available), the growth habit and overall species composition, and the dominance of the species within the plant community. Areal coverage is considered excessive if more than 25% of the lake is affected, particularly if the area encompasses bathing areas. Within the areas covered by plant populations/communities the biovolume would need to be dense (>50 – 75%) or very dense (>75 – 100%) to be considered impaired. There are certain species with growth habits that tend to grow from the bottom to the surface in close proximity and, thus, fill the biovolume and cause a safety hazard for extended or incidental contact with the water, as well as undesirable aesthetic conditions. Among the species that exhibit this growth habit are the non-native *Myriophyllum heterophyllum*, *M. spicatum*, and *Cabomba caroliniana,* but also native species, such as *Ceratophyllum demersum* or *Elodea* sp. Note that there are often cases where dense/very dense macrophyte populations/communities are found in lakes whose natural morphometry typically include extensive shallow areas that provide ideal habitat for the proliferation of aquatic plants. Unless accompanied by notes of algae and/or turbidity, lakes or impoundments with >25% dense/very dense macrophytes are assessed as impaired with Aquatic Plant (Macrophytes), a "non-pollutant" noted as the cause of impairment.

Appendix K details cases where certain floating macrophyte species, like *Lemna* sp. or *Wolffia* sp., can "bloom" to cause unsafe and aesthetically undesirable conditions, almost always as a result of increased enrichment. In these cases, Nutrient/Eutrophication Biological Indicators, a "pollutant", will be noted as the cause of impairment and will require the development of a TMDL.

Aesthetics Use Attainment

Use is Supported	Use is Impaired
No aesthetically objectionable conditions; waterbodies are generally "*free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life"*	Aesthetically objectionable conditions frequently observed [e.g., blooms, scums, water odors, discoloration, taste, visual turbidity highly cloudy/murky, excess algal growth (>40% filamentous cover in rivers, nuisance growths >25% dense/very dense macrophytes* or blooms in lakes (or the impounded reaches of a river AU), nuisance growths of marine macroalgae)]; *Primary Contact Recreation* Use Impairment for Harmful Algal Blooms (HABs);

**Cause identification can be either Aquatic Plant (Macrophyte) non-pollutant or Nutrient/Eutrophication Biological Indicators (pollutant)*

Primary Contact Recreation Use

Waters supporting the *Primary Contact Recreation Use* are suitable for any recreation or other water uses in which there is prolonged and intimate contact with the water with a significant risk of ingestion of water during the primary contact recreation season. These include, but are not limited to: wading, swimming, diving, surfing and water skiing (MassDEP 2021b). For purposes of 305(b) reporting, the "bathing season" each year is defined as 1 April to 31 October.

Use Attainment Decision Making Process:
The assessment of the *Primary Contact Recreation Use* is based on sanitary/health (i.e., bacteria, harmful algal blooms), safety (e.g., Secchi depth) considerations, and/or aesthetics (i.e., desirability) of the waters. MassDEP analysts assess this use as support when sanitary, safety, and aesthetic conditions are suitable (e.g., low bacteria densities, low turbidity, infrequent beach closures/postings for bacteria or harmful algal blooms) and when aesthetics are good (e.g., the narrative aesthetics criteria is met – see *Aesthetics Use* attainment guidance for details). The bacteria criteria in the SWQS include both a geometric mean (GM) and a statistical threshold value (STV) for *E. coli* and/or *Enterococcus* bacterial indicators for Class A, B, SA, and SB waters (MassDEP 2021b). *Primary Contact Recreation Use* bacteria impairment decisions are made according to the thresholds as described in Table 6. A 90-day interval is applied for most waters, but a 30-day interval is applied for waters containing public beaches, POTW and/or CSO discharges. Occasionally, site-specific health risk assessments performed by consultants, the MDPH, and/or MassDEP's ORS are utilized to evaluate dangers posed to organisms and humans by contaminants in the aquatic environment. Routes of exposure can include ingestion, dermal contact, or inhalation. When risk is calculated to be greater than acceptable (e.g., total hazard index value exceeds a threshold of 1) some or all of the designated use(s) may be assessed as impaired for the contaminant of concern. If there is some indication of anthropogenically caused water quality impairment, but not enough data are available to make a use impairment decision, the use is identified as Insufficient Information with an Alert Status and a recommendation is made for future water quality monitoring. An overview of the data types and the decision process used by MassDEP analysts to make assessment decisions for the *Primary Contact Recreation Use* is as follows.

Aesthetics
Rivers, Lakes, and Estuaries
The narrative aesthetics criteria are applicable to all surface waters (see *Aesthetics Use* attainment guidance). MassDEP analysts therefore assess the *Primary Contact Recreation Use* as impaired when the *Aesthetics Use* of a waterbody is assessed as impaired. However, when aesthetics observations are indicative of good water quality and are the only available data, there is insufficient information to assess the *Primary Contact Recreation Use*.

Bacteria

BACKGROUND & CONTEXT
Bacteria Standards for Recreation *(EPA 2003, EPA 2012)*

"Fecal bacteria have been used as an indicator of the possible presence of pathogens in surface waters and the risk of disease, based on epidemiological evidence of gastrointestinal disorders from ingestion of contaminated surface water or raw shellfish. Contact with contaminated water can lead to ear or skin infections, and inhalation of contaminated water can cause respiratory diseases. The pathogens responsible for these diseases can be bacteria, viruses, protozoans, fungi, or parasites that live in the gastrointestinal tract and are shed in the feces of warm-blooded animals… concentrations of fecal bacteria, including fecal coliforms, Enterococcus, and Escherichia coli, are used as the primary indicators of fecal contamination. The latter two indicators are considered to have a higher degree of association with outbreaks of certain diseases than fecal coliforms and were recommended as the basis for bacterial surface water quality standards (both for freshwaters, Enterococcus for marine waters)." In 2012 EPA released an update to its Recreational Water Quality Criteria which MassDEP adopted in the 2021 SWQS (EPA 2012, MassDEP 2021b).

Rivers, Lakes, and Estuaries
For freshwater AUs (rivers and lakes), the results of MassDEP water quality surveys serve as one primary source of bacteria data. The validated (quality-assured) bacteria data from these surveys are usually published in technical memoranda/reports or are available online. There are also many other external sources of bacterial quality monitoring data (e.g., environmental consultants, watershed and lake associations, and citizen monitoring programs, etc.). As resources allow, data from these external sources are reviewed for quality/reliability according to MassDEP WPP's external data validation procedures and, when approved, are also utilized for use attainment decisions.

Bacteria	Fresh Water (Class A & B)		Coastal & Marine Waters (Class SA & SB)	
	GM (CFU/100 mL)	STV (CFU/100 mL)	GM (CFU/100 mL)	STV (CFU/100 mL)
E. coli	126	410	-	-
Enterococcus	35	130	35	130

The geometric mean (GM) magnitude value is the calculated GM of the number of colony-forming units (CFU) of bacteria in 100 ml water samples that the waterbody should not exceed in any 30-day interval, and the statistical threshold value (STV) is the number of CFU of bacteria that should not be exceeded in more than 10 percent of the same water samples that were used to calculate the GM (EPA 2024a). GM calculations use the Method Detection Limit (MDL) and the Upper Quantification Limit (UQL). Assessment guidance differs depending on factors such as bacterial indicator organism, interval duration, sampling frequency, and number of years of available, quality-assured data (e.g., single year or multi-year data sets) for each site (see Table 6). Details regarding data processing and evaluation can be found in Appendix J.

Table 6. Bacteria Impairment Decision Schema based on bacteria sampling frequency scenarios during the Primary Contact Recreation Season (April 1 – October 31).
[Note: units in CFU/100mL or MPN/100mL; the minimum sample size for geometric mean (GM) interval calculations is two for 30-day intervals and three for 90-day intervals; STV is the Statistical Threshold Value (although STV exceedances are calculated for data years with zero GM intervals, by default, they are excluded from analysis in this schema); the term "cumulative" refers to the total percent GM interval exceedances over all years being analyzed.]

Sample Data Frequency Scenarios	Bacteria Indicator	Single Year of Data Available	Multiple Years of Data Available[1]: TWO OF THE THREE CONDITIONS MUST BE MET
Limited frequency (e.g., less than monthly) <7 samples	*E. coli*	1) ≥80% of GM intervals >126 OR 2) a. <80% of GM intervals >126 AND b. two or more samples > 410 (STV) AND c. the overall GM is >126 [2]	1) >20% of GM intervals >126 in two or more years 2) >20% of cumulative GM intervals >126 3) ≥2 samples each year > 410 (STV) in more than two years [4]
	Enterococcus	1) ≥80% of GM intervals >35 OR 2) a. <80% of GM intervals >35 AND b. two or more samples > 130 (STV) AND c. the overall GM is >35 [3]	1) >20% of GM intervals >35 in two or more years 2) >20% of cumulative GM intervals >35 3) ≥2 samples each year > 130 (STV) in more than two years [4]
Moderate frequency (e.g., monthly) 7 to 14 samples	*E. coli*	1) ≥60% of GM intervals >126 OR 2) a. >10% to <60% of GM intervals >126 AND b. >2 samples > 410 (STV)	1) >20% of GM intervals >126 in two or more years 2) >20% of cumulative GM intervals >126 3) ≥2 samples each year > 410 (STV) in more than two years [4]
	Enterococcus	1) ≥60% of GM intervals >35 OR 2) a. >10% to <60% of GM intervals >35 AND b. >2 samples > 130 (STV)	1) >20% of GM intervals >35 in two or more years 2) >20% of cumulative GM intervals >35 3) ≥2 samples each year > 130 (STV) in more than two years [4]
High frequency (Every two weeks, at minimum) ≥15 samples	*E. coli*	1) ≥40% of GM intervals >126 OR 2) a. ≥30% to <40% of GM intervals >126 AND b. >10% of samples exceed 410 (STV) OR 3) a. >0% to <30% of GM intervals >126 AND b. >20% of samples > 410 (STV)	1) >10% of GM intervals >126 in two or more years 2) >10% of cumulative GM intervals >126 3) >10% of samples > 410 (STV) in more than two years [4]
	Enterococcus	1) ≥40% of GM intervals >35 OR 2) a. ≥30% to <40% of GM intervals >35 AND b. >10% of samples > 130 (STV) OR 3) a. >0% to <30% of GM intervals >35 AND b. >20% of samples > 130 (STV)	1) >10% of GM intervals >35 in two or more years 2) >10% of cumulative GM intervals >35 3) >10% of samples > 130 (STV) in more than two years [4]

[1] The five most recent years of sufficient data will be preferentially evaluated (note, the five most recent sufficient data years may not be consecutive), but the analyst has the discretion to utilize all years of data.
[2] For *E. coli* single year of low frequency data: in cases where <80% of GM intervals are >126 CFU/100mL and any samples are >410 CFU/100mL (STV) but the overall GM (i.e., April-October) is <126 CFU/100mL, insufficient information is available to make a use impairment decision.
[3] For enterococci single year of low frequency data: in cases where <80% of GM intervals are >35 CFU/100mL and any samples are >130 CFU/100mL (STV) but the overall GM (i.e., April-October) is <35 CFU/100mL, insufficient information is available to make a use impairment decision.
[4] In the case of only two years of data the STV use attainment threshold must be exceeded in both years.

Beach Postings

BACKGROUND & CONTEXT
Beaches Bill *(MDPH 2019a)*

"There are over 1,100 public and semi-public bathing beaches in Massachusetts, both freshwater and marine…bathing beach water quality is regulated by the Massachusetts Department of Public Health (MDPH) under Massachusetts General Law and the Code of Massachusetts Regulations. These 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. The exact dates of a given bathing season vary from beach to beach and are determined by the operators of each individual beach. Some beaches open as early as Memorial Day, but the majority begin operation when the school year ends in mid-June, and most close for the season during the week of Labor Day.

Most freshwater samples are analyzed at private laboratories hired by beach operators or boards of health, while a small number are analyzed at municipal laboratories. The vast majority of beach water sampling in Massachusetts is conducted by local boards of health, the Barnstable County Department of Health and the Environment, and the Massachusetts Department of Conservation and Recreation (MDCR). Most marine beach samples are analyzed at laboratories under contract with MDPH's Bureau of Environmental Health (BEH). BEH utilizes federal Environmental Protection Agency (USEPA) funds to support these costs. Bathing water samples that are found to contain levels of bacterial contamination in excess of regulatory standards are termed exceedances. If water samples from a beach are found to be in exceedance of regulatory standards, the beach waters must be closed. When this happens signs must be posted at access points to the beach notifying the public that swimming is unsafe due to bacterial contamination. For marine beaches, the public is also notified via the Beach Water Quality Locator, on the MDPH/BEH website, which is operated in collaboration with local health officials and MDPH contract laboratories. Local health officials and MDPH/BEH contract laboratories collect and analyze the samples and perform the majority of the data entry onto the website. MDPH/BEH is notified of exceedances within 24 hours (105 CMR 445.040). Beaches are to remain closed until their bacteria counts decrease to levels below the applicable standard, at which point the postings can be removed and MDPH/BEH is notified of the beach reopening."

Estuaries and Fresh Water DCR beaches

The Beaches Bill monitoring program is a major source of bacteria data and beach posting/closing information. Pursuant to this legislation, the MDPH requires communities to report monitoring data from their beaches (most beaches sampled weekly) and decisions to post/close their beaches over the course of the beach season (see inset for details). MDPH publishes annual reports of these data (MDPH 2019a) and, approximately every two years, provides MassDEP analysts with a copy of their database (MDPH 2019b). MDPH has expressed that more uncertainty exists with the reporting accuracy of *freshwater* beach posting information than with coastal beaches, and, with one notable exception, this has precluded MassDEP analysts from making assessment decisions based on the information from freshwater beaches. The exception is the posting information from inland beaches managed by DCR. To date, rather than using the actual bacteria data, MassDEP analysts have utilized the beach closing/posting information as a surrogate indicator of water quality conditions when assessing the recreational use for waters governed by the Beaches Bill. This surrogate was chosen for use by MassDEP analysts until such a time as all data quality assurance considerations (e.g., QAPP, QA/QC, sample collection, analysis, data quality and validation procedures) for the bacteria data are in place. When considering beach closure information for making assessments, MassDEP contends that postings/advisories at public bathing beaches should be neither frequent nor prolonged during the swimming season (i.e., the number of days posted or closed should not, or rarely exceed 10% during the locally operated swimming season). MassDEP analysts calculate the number of days and the percentage of time during each beach season that each marine and DCR freshwater beach is posted/closed. For the 2024 IR reporting cycle, beach posting data from 2014 through 2022 are being utilized. The pathogen indicator used for marine beach monitoring as well as the DCR freshwater beach monitoring is *Enterococcus* bacteria (the rare exception being DCR beaches sampled by local municipalities).

The *Primary Contact Recreation Use* is assessed as supporting if marine beaches and DCR freshwater beaches are rarely posted for more than 10% of the swimming season. If postings often exceed 10% of the swimming season(s) the *Primary Contact Recreation Use* is assessed as impaired. More weight is given by the MassDEP analyst to the more recent years of posting data when an improvement or decline in posting at a beach occurred. Data for multiple beaches located along the shoreline of an AU that may lead to conflicting assessment decisions are handled on a case-by-case basis by MassDEP analysts.

Approved Shellfish Growing Area Classification

Estuaries

Although the bacteria indicator species are different (i.e., fecal coliform bacteria for shellfish and enteroccoci for bathing beach areas) an "*approved*" shellfish growing area classification is indicative of excellent water quality ("Approved" areas are "*open for harvest of shellfish for direct human consumption subject to local rules and regulations. An approved area is open all the time and closes only due to hurricanes or other major coastwide events*" (see additional detail in *Shellfish Harvesting Use*). MassDEP analysts consider water quality to be excellent in terms of bacterial quality and, therefore, supportive of the *Primary Contact Recreation Use* when the DMF Designated Shellfish Growing Area classification is "Approved" (MassGIS 2024). However, when the shellfish classification is anything less than "approved" there is insufficient information to assess the *Primary Contact Recreation Use* using this indicator data.

Presence of Active CSO Discharge

Rivers, Lakes, and Estuaries

Other than in waters where limited combined sewer overflow (CSO) discharges are authorized*, the presence of an active (i.e., open to discharge at some point) CSO discharge will be utilized by MassDEP analysts to make a presumptive impairment decision for the *Primary Contact Recreation Use* for *E. coli* (freshwaters) or *enterococcus* spp. (saline waters).

** Limited CSO discharges are authorized in the following waters: Boston Inner Harbor (the Class SB (CSO) waters described as the entire inner harbor, inclusive of the Reserved, Fort Point and Little Mystic channels, from the respective mouths of the Charles, Mystic, and Chelsea rivers, southeasterly to its seaward boundary formed by a straight line drawn from the southern tip of Governors Island to Fort Independence, Boston); the entire Island End River, Everett/Chelsea, to confluence with the Mystic River; the entire Chelsea River from the confluence of Mill Creek, Chelsea/Revere to its mouth at Boston Inner Harbor, Boston/Chelsea; the Mystic River from the Amelia Earhart Dam, Somerville/Everett to its mouth at Boston Inner Harbor, Chelsea/Charlestown; and the entire length of Muddy River in the Charles River Basin.*

Harmful Algal Blooms

BACKGROUND & CONTEXT

Harmful BlueGreen Blooms *(MassDEP 2010c, MassDEP 2015b).*

Blooms of cyanobacteria can be toxic to humans, wildlife, and to pets. Anabaena, Nostoc, Microcystis and Nodularia may contain the hepatotoxin microcystin, which can damage the liver. Others, like Aphanizomenon flos-aquae, Anabaena circinalis and Cylindrospermopsis raciborskii, may carry neurotoxins such as saxitoxin or anatoxin a. Fresh water cyanobacteria blooms often occur in lakes and ponds, but slow moving rivers like the Charles River can also be sites where blooms occur. In the summer of 2006, the lower basin of the Charles River experienced a massive bloom of Microcystis sp. and counts carried out on samples collected from sites in the lower basin indicated that the risk potential for long-term illness as a result of ingesting the water during contact recreation was moderate. Thus, in order to determine what level of risk existed, a method was developed to count the cyanobacteria present. Cyanobacteria counts are performed to determine if the amount present would be enough to indicate a moderate level of risk to the public using the waterbody. The World Health Organization (WHO 1999) has found that when cyanobacteria cell counts exceed 100,000 cells/ml the risk is then considered moderate. Massachusetts Dept. of Public Health (MDPH Undated) used the WHO cell count and developed a relationship between cyanobacteria cell counts and associated toxin levels based upon modified average weights and amount of ingestion and determined that a cell count of 70,000 cells/ml would correspond to a microcystins toxin level of approximately 14 ppb. In 2008, the MDPH developed Guidelines for Cyanobacteria in Freshwater Recreational Waterbodies in Massachusetts, and since then has updated their guidelines to include a lower threshold for microcystins (8 µg/L) and added a guideline value for cylindrospermopsin (15 µg/L) (MDPH 2022).

In 2019, EPA published recommended freshwater criteria recommendations for microcystins and cylindrospermopsin toxins produced by some cyanobacteria species (cyanotoxins) that pose a human health risk from incidental ingestion. Microcystins are produced by a variety of toxigenic cyanobacteria genera, including Microcystis, Anabaena, Dolichospermum, Nodularia, Nostoc, Oscillatoria, Fischerella, Planktothrix, and Gloeotrichia. Cylindrospermopsin is produced by numerous toxigenic cyanobacteria taxa, including Cylindrospermopsis raciborskii, Aphanizomenon, Anabaena, Lyngbya wollei, and Raphidiopsis (EPA 2019).

Rivers, Lakes, and Estuaries

MDPH guidelines for evaluating potential health concerns regarding cyanobacteria in fresh waterbodies in Massachusetts and other information is published on the MassDEP Guidelines for Cyanobacteria at Recreational Freshwater Locations webpage. MDPH guidelines (MDPH 2022) recommend an advisory or closure of a waterbody to avoid contact with the water when at least one of the following is met:

- a visible scum or mat layer is present,
- cyanobacteria cell counts exceed 70,000 cells/mL,
- microcystin concentration exceeds 8 µg/L, and/or cylindrospermopsin concentration exceeds 15 µg/L.

MDPH maintains a record of waterbodies with Cyanobacterial Harmful Algal Bloom (C-HAB) Advisories in Massachusetts. As noted by MPDH, the record should not be considered a complete list of all advisories in Massachusetts. The MDPH record includes only those waterbodies that have been reported to MDPH by local, state and federal partners that manage or regulate the respective waterbody. MassDEP uses the MDPH C-HAB data when assessing primary, secondary, and aesthetic uses for C-HAB presence. For the 2024 IR cycle, MassDEP is utilizing data reported to MDPH from 2015-2022. The reporting of a cyanobacteria advisory to MPDH does not, in and of itself, lead to the decision that a waterbody is impaired because an advisory could be reported for a suspected cyanobacteria bloom regardless of its duration or cyanobacteria cell count or cyanotoxin concentration. MassDEP does not consider occasional or ephemeral algae blooms to be indicative of overall use impairment and, therefore, the frequency and duration of cyanobacteria blooms are always considered before making a use-attainment determination.

MassDEP considers C-HABs to be “frequent” or “prolonged” if they were reported for >20 days in a calendar year. MDPH *Cyanobacteria in Recreational Waters in Massachusetts 2022 Local Board of Health Guidance* states that “MDPH/BEH recommends C-HAB advisories be lifted only after two rounds of samples (collected at least one week apart) show levels below the MDPH/BEH guideline values.” In light of MDPH’s policy, waters exhibiting reported advisories totaling more than 20 days and based on reported cyanobacteria cell count or cyanotoxin concentration in accordance with MDPH guidelines, would be considered by MassDEP to be impaired for Harmful Algal Blooms. Waters exhibiting advisories totaling more than 15 days (but less than 20 days) and based on any rationale (e.g. visual evidence, field testing, microscope identification, cell count, cyanotoxin concentration) would be issued an alert and recommended for additional collection of cyanobacteria cell count and cyanotoxin concentration data, as well as continued reporting to MDPH.

EPA (2019) published recommended freshwater criteria for microcystins and cylindrospermopsin cyanotoxins of 8 and 15 µg/L, respectively. In addition to the cyanobacteria cell count threshold of 70,000 cells/mL, MassDEP is applying these recommended criteria as assessment thresholds in *Primary Contact Recreation Use* evaluations. If any of these assessment thresholds are exceeded within three or more 10-day evaluation periods during a single recreation season (April 1 – October 31), an impairment for Harmful Algal Blooms will be made to the *Primary Contact Recreation Use*. While MDPH guidelines specifically pertain to freshwater C-HABs, marine and/or estuarine HABs involving microalgae are addressed on a case-by-case basis.

Secchi disk depth

BACKGROUND & CONTEXT
“Green Book” *(Federal Water Pollution Control Administration 1968)*

According to the “Green Book” (Federal Water Pollution Control Administration 1968) “For primary contact waters, clarity should be such that a Secchi disc is visible at a minimum depth of 4 feet. In “learn to swim” areas, the clarity should be such that a Secchi disc on the bottom is visible. In diving areas, the clarity shall equal the minimum required by safety standards, depending on the height of the diving platform or board”.

Lakes
MassDEP analysts apply the 4-foot (1.2 m) Secchi disk transparency guideline to indicate when conditions are unsafe for recreational use. When waters fail to meet this guideline, hazardous objects are not visible to someone diving (or falling) into the water and rescuers are unable to easily locate a possible drowning victim. Currently, three Secchi disk transparency readings are considered to be a minimum acceptable number of sampling events taken during the summer months when productivity is high. MassDEP analysts will not impair a waterbody unless there is more than one exceedance of the guideline. This approach applies to cases where low Secchi disk transparency results from algal or non-algal turbidity but does not include highly tannic, tea-stained waters with high color that may result in low Secchi readings. This is considered to be a naturally-occurring condition resulting from associated wetland influence.

Per- and Polyfluoroalkyl Substances (PFAS)

Rivers, Lakes, and Estuaries
In 2023, MDPH released their Technical Support Document outlining their risk management approach for evaluating recreational safety with respect to PFAS exposure (MDPH 2023). According to their guidance (see table below), surface water sample data from public/semi-public bathing beaches are evaluated for the seven individual analytes with established toxicity criteria [perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), perfluorononanoic acid (PFNA), perfluorohexane sulfonic acid (PFHxS), perfluorobutanoic acid (PFBA), perfluorobutane sulfonic acid (PFBS), hexafluoropropylene oxide dimer acid (HFPO-DA also known as GenX)]. When >90 ng/L (ppt) of one of the analytes with established toxicity criteria is detected in a waterbody, the guidance directs MDPH to conduct a site-specific evaluation and notify the public. If MDPH makes a determination that swimming is unsafe, either for sensitive populations or the general public, MassDEP analysts will assess the waterbody as not supporting the *Primary Contact Recreation Use*.

Primary Contact Recreation Use **Screener Based on MDPH 2023 Technical Support Document**	**Analytes**	**MDPH Screener Value**
Surface water, individual analytes with toxicity criteria	PFOA, PFOS, PFNA, PFHxS, PFBA, PFBS, HFPO-DA (aka GenX)	90 ng/L (ppt)[1]

[1]*Primary Contact Recreation Use screening of surface water measurements based on Massachusetts Department of Public Health's 2023 Technical Support Document guidance for individual analytes with established toxicity criteria at public/semi-public bathing beaches in both fresh and marine waters* (MDPH 2023)*: ≤20 ng/L no restrictions; >20-90 ng/L public notification required; >90-500 ng/L site specific evaluation and public notification required, some restrictions on swimming may apply (situational swim advisory); >500 ng/L swimming not allowed and public notification required.*

For all other freshwaters lacking public/semi-public beaches, MassDEP analysts will identify an Alert when >90 ng/L (ppt) of one of the analytes with established toxicity criteria is detected in a waterbody. MassDEP analysts may consult with ORS to further evaluate PFAS data as part of the use attainment decision for the *Primary Contact Recreation Use*.

Primary Contact Recreation Use Attainment Decision

Waterbody	Use is Supported	Use is Impaired
Rivers & Lakes	No aesthetic use impairment; Bacteria do not exceed impairment decision schema; fewer than ≤20 days of MDPH cyanobacteria advisories; ‘ Two or fewer exceedances of the cyanobacteria cell count threshold (70,000 cells/mL) evaluated in 10-day periods during the recreation season Two or fewer exceedances of cyanotoxin thresholds evaluated in 10-day periods during the recreation season; Secchi disk transparency ≥4 feet at least 3 times during the survey season; beach postings at DCR freshwater beaches generally ≤10% season	Aesthetics Use impairment; Bacteria exceed impairment decision schema; >20 days of MDPH cyanobacteria advisories (based on reported cyanobacteria cell count or cyanotoxin concentration) in a year; Three or more exceedances of the cyanobacteria cell count threshold (70,000 cells/mL) evaluated in 10-day periods during the recreation season Three or more exceedances of the cyanotoxin thresholds (microcystins >8 µg/L and/or cylindrospermopsin >15 µg/L) evaluated in 10-day periods during the recreation season Secchi disk transparency <4 feet at least twice during survey season; beach postings at DCR beaches often >10% of season; any swimming advisories related to PFAS; presence of an active CSO outfall in waterbody without an approved variance risk calculation exceeds hazard threshold for contaminant of concern;
Estuaries	No aesthetic use impairment; Bacteria do not exceed Impairment Decision schema; beach postings generally <10% season; DMF “Approved” Shellfish Growing Area Classification	Aesthetic use impairment; Bacteria exceed Impairment Decision schema; beach postings often >10% of season; presence of an active CSO outfall in waterbody without an approved variance risk calculation exceeds hazard threshold for contaminant of concern;

Secondary Contact Recreation Use

Waters supporting the *Secondary Contact Recreation Use* are suitable for any recreation or other water use in which contact with the water is either incidental or accidental. These include, but are not limited to, the following: fishing, including human consumption of fish, boating, and limited contact incident to shoreline activities. Where designated, secondary contact recreation also includes shellfishing, including human consumption of shellfish. [Note: For the purpose of assessment and 305(b) reporting, the status of the consumption of fish and shellfish are reported as the *Fish Consumption* and *Shellfish Harvesting* uses, respectively, and are not reported as part of the *Secondary Contact Recreation Use*.] For purposes of 305(b) reporting the *Secondary Contact Recreation Use* is assumed to occur year-round. Since water quality conditions during the *Primary Contact Recreation* season are often considered representative of worse-case (e.g., higher temperatures, increases in population density at bathing beaches) data collected during that season are considered appropriate for making *Secondary Contact Recreation Use* attainment decisions in addition to data collected under a year-round sampling scheme.

Use Attainment Decision Making Process:
Similar to the *Primary Contact Recreation Use* attainment guidance, the assessment of the *Secondary Contact Recreation Use* is based on sanitary (i.e., bacteria) and/or aesthetics (i.e., desirability) of the waters. *Secondary Contact Recreation Use* bacteria impairment decisions are made according to the thresholds as described in Table 7, including both a geometric mean (GM) and a statistical threshold value (STV) for *E. coli* or *enterococcus* bacterial indicators for fresh and marine waters. Occasionally, site-specific health risk assessments performed by consultants, MDPH, and/or MassDEP's ORS are utilized to evaluate dangers posed to organisms and humans by contaminants in the aquatic environment. Routes of exposure can include ingestion, dermal contact, or inhalation. When risk is calculated to be greater than acceptable (e.g., total hazard index value exceeds a threshold of 1), some or all of the designated use(s) may be assessed as impaired for the contaminant of concern. If there is some indication of anthropogenically caused water quality impairment, but not enough data are available to make a use impairment decision, the use is identified with an Alert Status and a recommendation is made for future water quality monitoring. An overview of the data types and the decision process used by MassDEP analysts to make assessment decisions for the *Secondary Contact Recreation Use* is described below.

Aesthetics
Rivers, Lakes, and Estuaries
MassDEP analysts assess the *Secondary Contact Recreation Use* as impaired when the *Aesthetics Use* of a waterbody is assessed as impaired. However, when aesthetics observations are indicative of good water quality and are the only available data, there is insufficient information to assess the *Secondary Contact Recreation Use*.

Bacteria
Rivers, Lakes, and Estuaries
Previously, data used to assess the *Secondary Contact Recreation Use* were compared to the water quality criteria for Class C and Class SC waters in the Massachusetts SWQS. However, in 2022 EPA deferred action on current bacteria criteria amendments in the SWQS. EPA further indicated that the applicable CWA criteria for Massachusetts are the 1997 fecal coliform criteria that were adopted in the Massachusetts SWQS. Because *E. coli* and *enterococcus* are now the generally accepted indicator organisms for pathogens, with general concurrence from EPA, the thresholds for the assessment of the *Secondary Contact Recreation Use* for the 2024 cycle are those calculated per EPA's 2024 Secondary Contact Recreation User Guide (EPA 2024a), which advises multiplying the Massachusetts SWQS primary contact criteria values for *E. coli* and *enterococcus* by the ratio of the magnitude of incidental water ingestion during Primary Contact Recreation activities (e.g., swimming, wading, surfing) to the magnitude of incidental water ingestion during Secondary Contact Recreation activities (e.g., fishing, boating, shellfishing). The incidental ingestion rate for Secondary Contact Recreation activities is chosen conservatively based on kayaking "all activities," which includes kayaking events where capsizing occurred, as well as those where it did not occur. The *Secondary Contact Recreation Use* thresholds, presented in Table 7, include both a geometric mean (GM) and a statistical threshold value (STV) for *E. coli* or *enterococcus* bacterial indicators for fresh and marine waters. For freshwater AUs (rivers and lakes), the results of MassDEP water quality surveys serve as one primary source of bacteria data. The validated (quality-assured) bacteria data from these surveys are usually published by MassDEP in technical memoranda/reports or are available online. There are also many other external sources of bacterial quality monitoring data (e.g., environmental consultants, watershed and lake associations, and citizen monitoring programs, etc.). As resources allow, all external data from these and other sources are reviewed for quality/reliability according to the MassDEP's external data validation procedures and, when approved, can also be utilized for assessment decisions. In contrast to the *Primary Contact Recreation Use*, it is important to note that enterococci bacteria data are not used to evaluate use attainment of the *Secondary Contact Recreation Use* for freshwaters.

Bacteria	Fresh Water (Class A & B)		Coastal & Marine Waters (Class SA & SB)	
	GM (CFU/100 mL)	STV (CFU/100 mL)	GM (CFU/100 mL)	STV (CFU/100 mL)
E. coli	244	794	-	-
Enterococcus	-	-	68	252

The geometric mean (GM) magnitude value is the calculated GM of the number of colony-forming units (CFU) of bacteria in 100 ml water samples that the waterbody should not exceed in any 30-day interval, and the statistical threshold value (STV) is the number of CFU of bacteria that should not be exceeded in more than 10 percent of the same water samples that were used to calculate the GM (EPA 2024a). GM calculations use the Method Detection Limit (MDL) and the Upper Quantification Limit (UQL). The bacteria data evaluation methods in the Bacteria Impairment Decision Schema differ depending on factors such as bacterial indicator organism, sampling frequency, and number of years of available, quality-assured data (e.g. single year or multi-year data sets) for each site (see Table 7 and Appendix J for more information).

Table 7. Bacteria Impairment Decision Schema based on bacteria sampling frequency scenarios during Secondary Contact Recreation Season (Year-Round).

[Note: units in CFU/100mL or MPN/100mL; the minimum sample size for geometric mean (GM) interval calculations is three for 90-day intervals; STV is the Statistical Threshold Value (although STV exceedances are calculated for data years with zero GM intervals, by default, they are excluded from analysis in this schema); the term "cumulative" refers to the total percent GM interval exceedances over all years being analyzed.]

Sample Data Frequency Scenarios	Bacteria Indicator	Single Year of Data	Multiple Years of Data Available[1]: TWO OF THE THREE CONDITIONS MUST BE MET
Limited frequency (e.g., less than monthly) <7 samples	*E. coli*	1) ≥80% of GM intervals >244 OR 2) a. <80% of GM intervals >244 AND b. two or more samples >794 (STV) AND c. the overall GM is >244 [2]	1) >20% of GM intervals >244 in two or more years 2) >20% of cumulative GM intervals >244 3) ≥2 samples each year >794 (STV) in more than two years [4]
	Enterococcus	1) ≥80% of GM intervals >68 OR 2) a. <80% of GM intervals >68 AND b. two or more samples >252 (STV) AND c. the overall GM is >68 [3]	1) >20% of GM intervals >68 in two or more years 2) >20% of cumulative GM intervals >68 3) ≥2 samples each year >252 (STV) in more than two years [4]
Moderate frequency (e.g., monthly) 7 to 14 samples	*E. coli*	1) ≥60% of GM intervals >244 OR 2) a. >10% to <60% of GM intervals >244 AND b. >2 samples exceed 794 (STV)	1) >20% of GM intervals >244 in two or more years 2) >20% of cumulative GM intervals >244 3) ≥2 samples each year >794 (STV) in more than two years [4]
	Enterococcus	1) ≥60% of GM intervals >68 OR 2) a. >10% to <60% of GM intervals >68 AND b. >2 samples exceed 252 (STV)	1) >20% of GM intervals >68 in two or more years 2) >20% of cumulative GM intervals >68 3) ≥2 samples each year >252 (STV) in more than two years [4]
High frequency (Every two weeks, at minimum) ≥15 samples	*E. coli*	1) ≥40% of GM intervals >244 OR 2) a. ≥30% to <40% of GM intervals >244 AND b. >10% of samples >794 (STV) OR 3) a. >0% to <30% of GM intervals >244 AND b. >20% of samples >794 (STV)	1) >10% of GM intervals >244 in two or more years 2) >10% of cumulative GM intervals >244 3) >10% of samples >794 (STV) in more than two years [4]
	Enterococcus	1) ≥40% of GM intervals >68 OR 2) a. ≥30% to <40% of GM intervals >68 AND b. >10% of samples >252 (STV) OR 3) a. >0% to <30% of GM intervals >68 AND b. >20% of samples >252 (STV)	1) >10% of GM intervals >68 in two or more years 2) >10% of cumulative GM intervals >68 3) >10% of samples >252 (STV) in more than two years [4]

[1] The five most recent years of sufficient data will be preferentially evaluated (note, the five most recent sufficient data years may not be consecutive), but the analyst has the discretion to utilize all years of data.
[2] For *E. coli* single year of low frequency data: in cases where <80% of GM intervals are >244 CFU/100mL and any samples are >794 CFU/100mL (STV) but the overall GM (i.e., January-December) is <244 CFU/100mL, insufficient information is available to make a use impairment decision.
[3] For enterococci single year of low frequency data: in cases where <80% of GM intervals are >68 CFU/100mL and any samples are >252 CFU/100mL (STV) but the overall GM (i.e., January-December) is <68 CFU/100mL, insufficient information is available to make a use impairment decision.
[4] In the case of only two years of data the STV use attainment threshold must be exceeded in both years.

Beach Postings

Estuaries and Fresh Water DCR beaches

The *Secondary Contact Recreation Use* is assessed as support if marine beaches and DCR freshwater beaches are rarely, if ever, posted for more than 10% of the swimming season. If postings exceed 10% of the swimming season(s) then there is insufficient information to assess the *Secondary Contact Recreation Use* using this indicator data.

Approved Shellfish Growing Area Classification

Estuaries

MassDEP analysts consider water quality to be excellent in terms of bacterial quality and, therefore, supportive of the *Secondary Contact Recreation Use* when the DMF Designated Shellfish Growing Area classification is “Approved” (MassGIS 2024). However, when the shellfish classification is anything less than “approved” then there is insufficient information to assess the *Secondary Contact Recreation Use* using this indicator data.

Presence of Active CSO Discharge

Rivers, Lakes, and Estuaries

MassDEP analysts assess the *Secondary Contact Recreation Use* as impaired when the *Primary Contact Recreation Use* of a waterbody is assessed as impaired for the presence of an active CSO discharge.

Harmful Algal Blooms

Rivers, Lakes, and Estuaries

Similar to the *Primary Contact Recreation Use* attainment guidance, *Secondary Contact Recreation Use* Harmful Algal Bloom (HAB) impairment decisions are made based on MDPH advisories, cyanobacteria cell counts, and cyanotoxin concentrations (for more detail see *Primary Contact Recreation Use*). MassDEP analysts assess the *Secondary Contact Recreation Use* as impaired when the *Primary Contact Recreation Use* of a waterbody is assessed as impaired for Harmful Algal Blooms.

Secondary Contact Recreation Use **Attainment**

Waterbody	Use is Supported	Use is Impaired
Rivers & Lakes	No *Aesthetics* use impairment; Bacteria do not exceed Impairment Decision Schema; beach postings at DCR freshwater beaches generally ≤10% season	*Aesthetics* use impairment; Bacteria exceed Impairment Decision Schema; *Primary Contact Recreation* Use Impairment for Harmful Algal Blooms (HABs); *Primary Contact Recreation* Use Impairment for presence of an active CSO discharge
Estuaries	No aesthetic use impairment; Bacteria do not exceed Impairment Decision schema; beach postings generally ≤10% season; “Approved” Shellfish Growing Area Classification	Aesthetic use impairment; Bacteria exceed Impairment Decision schema; *Primary Contact Recreation* Use Impairment for Harmful Algal Blooms (HABs); *Primary Contact Recreation* Use Impairment for presence of an active CSO discharge

Causes and Sources of Use Impairments

When a waterbody is assessed as **not supporting** for a particular designated use the 305(b) reporting process requires that the pollutant(s)/pollution causing the impairment and the source(s) of the pollutants/pollution be identified, if possible. EPA maintains lists of domain values (allowed values for restricted fields in ATTAINS), including cause (parameters) and source codes on the ATTAINS Resources webpage.

The typical cause(s) of impairment used by MassDEP analysts for each designated use are based on the indicator(s) used to make an impairment decision as described in the preceding use attainment guidance. As an example, Figure 5 illustrates the decision process for identifying whether nutrient enrichment is present in lakes and, if so, the causes of impairment.

Sources are the discharges or activities that contribute pollutants or stressors resulting in impairment of designated uses in a waterbody. Sources of impairments may include both point sources and nonpoint sources of pollution. Point sources discharge pollutants directly into surface waters from a conveyance and include, but are not limited to: industrial facilities, municipal sewage treatment facilities, CSO discharges, and storm sewers. Nonpoint sources deliver pollutants to surface waters from diffuse origins. Nonpoint sources include: urban runoff that is not captured in a storm sewer, agricultural runoff, leaking septic tanks, and landfills. The source(s) of impairment may be identified based on DMF reports (e.g., sanitary surveys) and information and/or BPJ of MassDEP analysts using MassGIS data layers (e.g., orthophotos, land-use, urbanized areas) for example, but in general the actual sources of impairment are not confirmed until a TMDL or similar analysis is conducted on the waterbody.

A summary of the typical cause(s) associated with the impairment decisions (based on the indicator(s) as appropriate) and the typical source(s) of the impairment for each designated use evaluated by MassDEP analysts can be found in Appendix H.

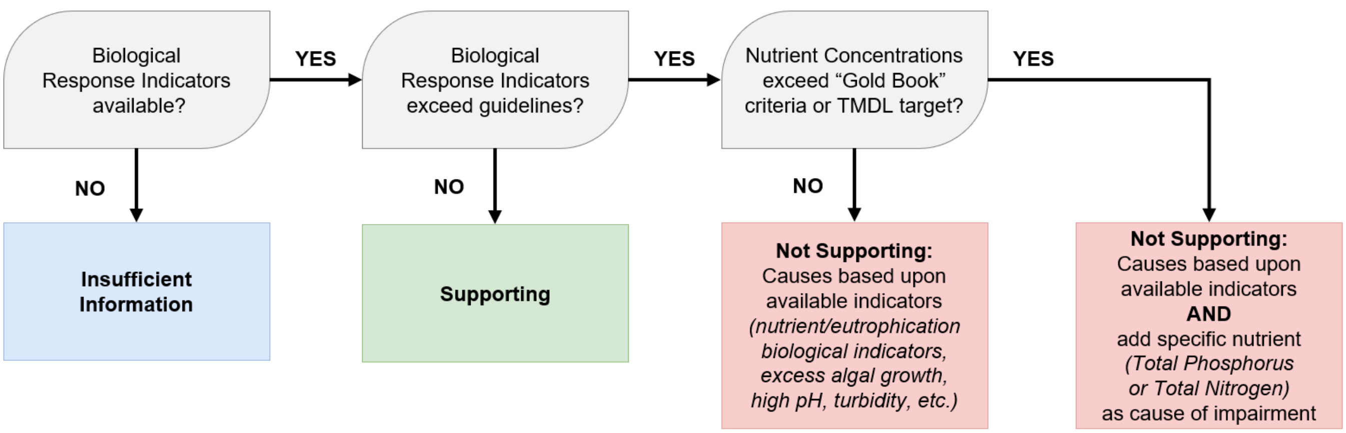


Figure 5. Impairment and cause identification decision tree for evaluating nutrient enrichment in lakes.

VI. CONSOLIDATED REPORTING

Since 2001, the EPA has recommended that states combine their 305(b) and 314 water quality assessment reporting elements with their 303(d) List of Impaired Waters into a consolidated IR report. The IR is submitted to the EPA every two years for review and, in the case of waters identified pursuant to Section 303(d), EPA approval.

The Section 305(b) reporting process entails determining the attainment status of each of the designated uses, where applicable, for rivers, lakes and coastal waters in the state, and identifying, wherever possible, causes and sources of any use impairment. Use attainment determinations are made for each waterbody AU for which adequate data and information are available. However, many waters are not assessed for one or more uses in any given reporting cycle, and many small and/or unnamed streams and ponds have never been monitored and/or assessed.

Under Section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters those waters that are too polluted or otherwise degraded to meet the state's surface water quality standards. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop TMDLs for these waters or establish alternative restoration approaches to restore the waters. The formulation of the 303(d) List includes a more rigorous public review and comment process than does reporting under Section 305(b), and the final version of the 303(d) List must be formally approved by the EPA.

The ATTAINS Database

The EPA-developed ATTAINS database is a relational database designed for tracking water quality assessment decisions, including use attainment status and causes and sources of impairment, for reporting required by sections 305(b), 314, and 303(d) of the CWA. ATTAINS also integrates the former National TMDL Tracking System (NTTS) database within its structure. ATTAINS is designed to make the assessment and listing process accurate, straightforward and user-friendly for states, tribes and other water quality reporting agencies. EPA requires all states to submit their IR information through ATTAINS, which is the system of record for the IR. After EPA approval of an IR cycle, the ATTAINS data for each state, territory, or tribe can be accessed at EPA's How's My Waterway website.

The Integrated Report: Multi-part List of Waters

ATTAINS is used to generate output files, which are then assembled into an IR in a single, multi-part list by overall AU category. Each AU is listed in one of five categories (see Table 8 for brief description of each List Category). ATTAINS and its precursor databases contain assessment information for only those waters defined by each state, territory, or tribe within their jurisdiction as AUs and not for every surface water in Massachusetts. New AUs are defined as new data become available or as SWQS classifications change, resulting in greater representation of Massachusetts' surface waters in each subsequent IR reporting cycle. MassDEP acknowledges that with the multi-part listing format, all surface waters could be categorized whether or not they have ever been assessed; however, time and resources are currently not available to define all surface waters in Massachusetts as AUs in ATTAINS. While many surface waters that have never been assessed are not included in the IR, these waters are by default considered Category 3 (Not Assessed).

Table 8. MassDEP Integrated Reporting Categories

Category	Definition
Category 1	Fully Supporting all designated uses
Category 2	Fully Supporting some uses, Insufficient Information/Not Assessed other uses
Category 3	Insufficient Information/Not Assessed
Category 4a	Not Supporting one or more uses - Total Maximum Daily Load (TMDL) has already been established.
Category 4b	Not Supporting one or more uses - but not requiring the calculation of a TMDL because other pollution control measures are reasonably expected to result in attainment of water quality standard in near future
Category 4c	Not Supporting one or more uses - but not requiring the calculation of a TMDL because the impairment is due to "pollution" such as low flow, habitat alterations or non-native species infestations.
Category 5	Not Supporting one or more uses and requires a TMDL (impairment due to pollutant(s) such as nutrients, metals, pesticides, solids and pathogens) for at least one AU-pollutant impairment.
Category 5a	Not Supporting one or more uses and requires a TMDL for at least one AU-pollutant impairment. An alternative plan intended to achieve surface water quality standards has been associated with the water.

***Integrated List of Waters*.**

List Categories 1 - 3

IR categories 1-3 include those waters that are *Fully Supporting*, have *Insufficient Information* to assess, or are *Not Assessed* with respect to their attainment of designated uses. No Massachusetts waters are listed in Category 1 because a statewide Department of Public Health advisory pertaining to the consumption of fish precludes any waters from being in full support of the *Fish Consumption Use*, as previously described in the use attainment decision process. Waters listed in Category 2 were found to support the uses for which they were assessed, but other uses had too limited or no available data to evaluate. Finally, Category 3 contains those waters for which insufficient or no information was available to assess any uses.

List Category 4

The CWA distinguishes between “pollutant impairments” such as nutrients, metals, pesticides, solids and pathogens that all require TMDLs and non-pollutant impairments (“pollution”) such as low flow, habitat alterations or non-native species infestations that do not require TMDLs. Waters exhibiting impairment for one or more uses are placed in either Category 4 (impaired but not requiring TMDLs) or Category 5 (impaired and requiring one or more TMDLs) according to the EPA guidance. 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) has already been completed and approved by EPA. However, because MassDEP lists each AU 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. Impaired waters can be placed in Category 4b if other pollution control requirements are reasonably expected to result in the attainment of the water quality standard by the time of the next IR reporting cycle (i.e., within two years). Due to the uncertainty associated with predicting such an outcome, Massachusetts has typically chosen not to use this category when formulating the IR. Waterbodies impaired solely by non-pollutants are included in Category 4c. The restoration of these waters requires measures other than TMDL development and implementation. Waters that have one or more approved TMDLs, but also continue to be impaired by non-pollutants, are listed in Category 4a.

List Category 5 – The 303(d) List of Impaired Waters Requiring Development of TMDL

While the EPA guidance provides the overall framework for a five-part list of waters, the development, submittal, and review of Category 5 remain subject to the implementing regulations at 40 CFR 130.7 as they pertain to Section 303(d) of the CWA. This regulation requires states to identify and list those waterbodies that are not expected to meet surface water quality standards after the implementation of technology-based controls and, as such, require the development of TMDLs. Specific cause(s) of the impairment (if known) are included in the 303(d) List.

Reporting on impaired waters as required by Section 303(d) includes a more rigorous public review and comment process than does reporting under Section 305(b), and the final version of the list must be formally approved by the EPA. Once a waterbody is identified as impaired by a pollutant, MassDEP is required to develop a pollutant budget designed to restore the health of the impaired waterbody. The process of developing this pollutant budget (the TMDL), includes: identifying the pollutant cause and its source, determining how much of the pollutant is from direct discharges (point sources) or indirect discharges (nonpoint sources), determining, with a margin of safety, the allowable amount of the pollutant that can be discharged to a specific waterbody while maintaining surface water quality standards, and developing an implementation plan to meet that goal. In short, a TMDL is a clean-up plan that is required under the CWA to restore water quality and enable waters to attain designated uses. The EPA tracks the states' progress with completing TMDLs in the ATTAINS database. A unique identification number is assigned to each approved TMDL and is included for reference in categories 4a and 5 of the Massachusetts IR report for each pollutant impairment to which the TMDL applies. There may be AUs in Category 5 that are impaired for non-pollutants and/or for a pollutant(s) with an associated TMDL(s), however the AU remains in Category 5 until all pollutants are addressed.

Category 5 includes one sub-category – 5a. States are allowed to include waterbodies in Category 5a that have an Alternative Restoration Plan (ARP) in place. An alternative restoration approach is a near-term plan, or description of actions, with a schedule and milestones, that is more immediately beneficial or practicable for attaining SWQS. An ARP is developed for a waterbody to allow for a direct-to-implementation approach to increase efficiency and improve water quality in a timely manner. Because statutory and regulatory obligations to develop TMDLs for waters identified on states' CWA 303(d) lists remain unchanged, a TMDL may be required for a waterbody with an ARP if adequate, timely progress is not made to achieve SWQS. Therefore, waters for which a state pursues an ARP to achieve SWQS remain on the CWA 303(d) list (i.e., Category 5) and may still require a TMDL(s) until SWQS are attained. Taking into account the severity of the pollution and the impaired uses of the AU on the CWA 303(d) list, such waters might be assigned lower priority for TMDL development as alternatives expected to achieve SWQS are pursued in the near-term.

Changes from the prior reporting cycle

During any given IR cycle, the overall use attainment status of an AU may or may not change from the previous cycle. Changes from the previous cycle may be due to a lack of data/information (e.g., from Fully Supporting to Insufficient Information or Not Assessed), or to the availability of new data/information resulting in a change in attainment status (e.g., from Not Assessed or Insufficient Information to Fully Supporting or Not Supporting).

According to CWA regulation CFR 130.7(b)(6)(iv), states must demonstrate "good cause" for any decisions related to adding an impairment (a 303(d) listing) or removing an impairment. A change in the list category may or may not occur for an AU when a pollutant/non-pollutant ("pollution") is being listed or removed. For example, an AU with a newly approved TMDL for its sole impairment moves into Category 4a. In contrast, an AU with a newly approved TMDL that has additional pollutant impairments not covered by a TMDL remains in Category 5 because each AU can only be placed in one category in the IR.

Removing an Impairment

Impairment removals take one of two forms: 1) delisting of a pollutant (removal from Category 5/the 303(d) list) or 2) restoration of a pollutant (removal from Category 4a) or a non-pollutant (removal from Category 4c). Since MA reports on the overall AU status in the IR, removal of an impairment by delisting or restoration may not necessarily result in a change of the category of the AU in the IR if there are additional causes of impairment (i.e., the AU can appear in only one category). Both delistings and restorations follow the same procedure, but pollutant delistings require approval by EPA.

Documentation of delistings and restorations includes selecting a good cause removal reason from a controlled list in ATTAINS (see Table 9), providing a justification statement to support the impairment removal, and providing any data tables or relevant information that support the removal.

Table 9. Impairment removal reasons available in ATTAINS.

Good Cause Impairment Removal Reason	Impairment Removal Scenario
Clarification of listing cause	Impairment requires refinement; one impairment is being replaced with another more specific impairment (e.g., clarification from generic non-native aquatic plants impairment to a species-specific impairment; change from “Lead” to “Lead in Sediment”)
Applicable WQS attained, based on new data	The assessment and interpretation of more recent or more accurate data demonstrate that the applicable WQS is being met
Applicable WQS attained, due to restoration activities	Specific to restoration activities (e.g., dam removal, upgrade of NPDES wastewater treatment plant, prohibition of discharges, implementation of BMPs, etc.) leading to demonstrable improvements in water quality
Applicable WQS attained, original basis for listing was incorrect	Demonstration that flaws in the original analysis of data and information led to the water being incorrectly listed
Applicable WQS attained, according to new assessment method	The development of a new evaluation methodology (according to the state’s CALM guidance), consistent with state WQSs and federal listing requirements, and a reassessment of the data that led to the prior listing, conclude that the WQSs are now attained
Applicable WQS attained, due to change in WQS	Used when standard or indicator has changed (e.g., fecal coliform indicator replaced by *E. coli* indicator); delisting of original impairment cannot be made until new data exist showing new indicator meets the new criteria
TMDL Approved or established by EPA (4a)	TMDLs approved since the last 303(d) list; not applicable to new impairments listed and delisted in same cycle
Not caused by a pollutant (4c)	Original impairment was mistakenly identified as a pollutant or a change in assessment methodology requires specific impairment be changed to a non-pollutant
Data and/or information lacking to determine WQ status, original basis for listing was incorrect	Rarely used by MassDEP
WQS no longer applicable	Not yet used by MassDEP
Water determined to not be a water of the state	Not yet used by MassDEP (e.g., at the boundary with another state, tribal jurisdiction)
Applicable WQS attained, reason for recovery unspecified	Used only when one of the other removal reasons cannot be applied
Not specified	Not used by MassDEP (users must select a valid reason) but is default removal reason in ATTAINS
Other pollution control requirements (4b)	Not yet used by MassDEP

Impairment Removal Documentation Process

MassDEP analysts follow the guidance below to evaluate, justify, and document an impairment removal decision in ATTAINS and to effectively communicate findings of good cause to EPA and the public:

1. If the listed impairment cause simply requires clarification (e.g., change from generic non-native aquatic plants impairment to a species-specific impairment; change from "Lead" to "Lead in Sediment"):
    a. Select the impairment cause to remove in ATTAINS.
    b. Select "Clarification of listing cause" as the good cause impairment removal reason that will be applied in ATTAINS.
    c. Create a simple justification statement that the more generic impairment is being removed and the more specific impairment is being added.
2. If current cycle assessment data for a listed impairment cause indicate it should be removed, proceed through the delisting/restoration line of evidence as follows:
    a. Review listing history and identify original listing cycle.
    b. Summarize historical data used to trigger the original listing.
        i. Provide dates, location(s), and climatological/flow data if available (e.g., survey conditions). [Note, it is preferable that the current cycle sampling location be the same as the historical station, but nearby locations are acceptable if satellite imagery are consulted and a determination is made that there is no/little difference between the sampling sites.]
        ii. Provide historical data tables/figures and reference the source(s) of information.
    c. Provide current cycle assessment data tables/figures noting source(s) of information that support the attainment decision.
        i. Include climatological/flow data if available (e.g., screen captures of MA DCR "Recent Drought History" table, recent precipitation data available in technical memoranda, etc.).
        ii. Note potential restoration activities (e.g., dam removals, implementation of BMPs, treatment plant upgrades for NPDES dischargers) that help explain improved water quality conditions.
    d. If current cycle assessment data are greater than 5 years old), use Google Earth satellite imagery to manually review/compare land use in the AU's subwatershed (especially the area upstream of the sampling location) in the year the data were collected with land use in a more recent year(s).
        i. If changes (e.g., development, clearing, etc.) are observed, consider their extent and location and use best professional judgment whether or not to proceed with the impairment removal. If large changes near the waterbody are observed, the removal decision cannot be justified (i.e., data collected prior to changes in land use may not be representative of current conditions). Make a recommendation to conduct additional monitoring so an evaluation can be made in a future reporting cycle whether impairment removal can be justified. The impairment remains for the current reporting cycle.
        ii. If little/no land use change is observed (e.g., slight changes in the subwatershed away from the waterbody that are not likely to result in degraded water quality conditions), continue with the impairment removal.
    e. Select the impairment cause to remove in ATTAINS.
    f. Select the most appropriate good cause removal reason (Table 9) that will be applied in ATTAINS.
    g. Construct a delisting/restoration statement, concisely presenting the original listing information, recent data, and justification for the impairment removal (including comparison to CALM guidelines and/or SWQS).
3. Provide supporting documentation for impairment removal to EPA and the public in some form (e.g., watershed-specific decision document, delisting document, fact sheet) for their review, comment, and in the case of a delisting, subsequent EPA approval.

Delisting Example: Aquatic Plant (Macrophytes)

Specifically for the 2024 reporting cycle, MassDEP analysts are hoping to complete a re-evaluation of AUs listed as impaired for Aquatic Plant Macrophytes (APM). Details relating to the rationale for defining APM as a non-pollutant impairment rather than a pollutant impairment are provided in Appendix K. A schematic depicting the data review process and associated changes in use attainment decisions/impairments is also provided (see Figure K1).

Spatial Documentation

Another component of consolidated reporting is the spatial georeferencing of the river, lake, and estuary AUs (Figure 6). MassDEP analysts maintain geospatial information for each waterbody AU stored in ATTAINS. Two georeferenced ArcMap shapefiles contain the geospatial documentation delineating these waterbody AUs. These two feature classes include an arc (primarily river) shapefile and a polygon (primarily lake and estuary areas) shapefile. The geo-referencing of individual AUs relied on linework derived from the MassGIS 1:25,000 Hydrography based on USGS topographic maps. Additional on-screen editing was performed as needed using USGS Topographic-Quadrangles and/or MassGIS 2019 Aerial Imagery as a base map for all river AUs. Occasionally National Oceanic and Atmospheric Administration nautical charts at several scales and the "Planimetry of Harbors for the 1984 305(b) Report" were utilized. Where definitions were still ambiguous after using these references, WPP staff members were consulted to define and geo-reference individual AUs. No two river AUs overlap nor do any two lake features nor do any two estuary features. In addition to the georeferenced AU locations, data from ATTAINS can be related to each shape and spatially displayed. This allows mapping to display the Massachusetts IR by category as well as the ability to obtain more detailed information for each AU. A table generated from ATTAINS containing the support status for each individual use with associated cause(s) and source(s) of impairment, as well as approved TMDL information, can be linked and displayed through the waterbody AU shapefiles. Additional tools to access this information without the need for ArcMap may also be made available through the MassMapper Interactive Map and the MassDEP Integrated Lists of Waters & Related Reports webpage.

The Massachusetts 2022 Integrated List of Waters (305(b)/303(d)) data layers and all of the data elements (including metadata) are available at the Commonwealth of Massachusetts' Office of Geographic Information (MassGIS) MassDEP 2022 Integrated List of Waters data layer webpage. The data layers for the current IR will be developed by MassDEP analysts once the 303(d) list (Category 5 waters) is approved by EPA.

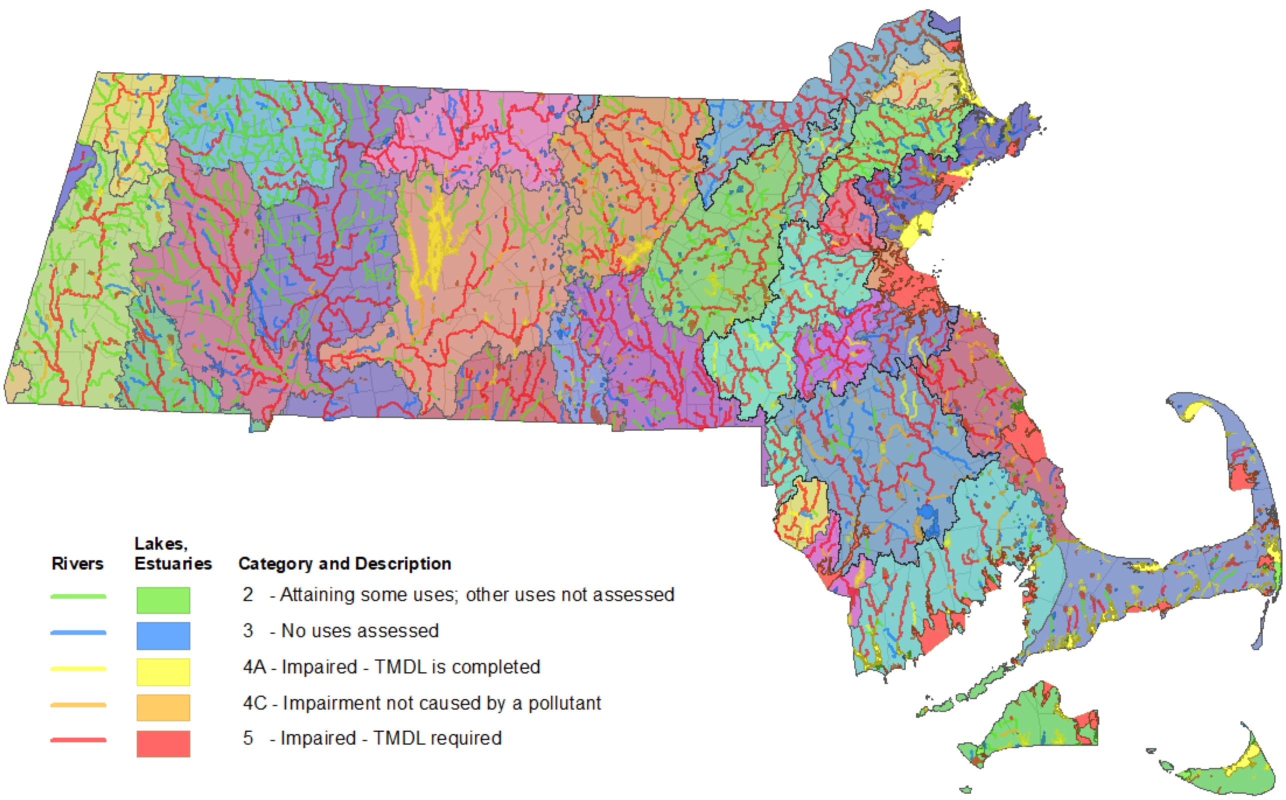


Figure 6. MassDEP geo-referenced waterbody assessment unit (AU) locations and 2022 listing category.

VII. REFERENCES

Ackerman, M. T. 1989. "Compilation of Lakes, Ponds, Reservoirs and Impoundments Relative to the Massachusetts Lake Classification Program." Publication #15901-171-50-4-89-c.r., Technical Services Branch, Massachusetts Division of Water Pollution Control, Department of Environmental Quality Engineering, Westborough, MA.

Ackerman, M. T., R. A. Batiuk, and T. M. Beaudoin. 1984. "Compilation of Lakes, Ponds, Reservoirs and Impoundments Relative to the Massachusetts Lake Classification Program." Publication #13786-216-30-8-84-c.r., Technical Services Branch, Massachusetts Division of Water Pollution Control, Department of Environmental Quality Engineering, Westborough, MA.

Armstrong, D. S., T. A. Richards, and S. B. Levin. 2011. "Factors influencing riverine fish assemblages in Massachusetts." U.S. Geological Survey Scientific-Investigations Report 2011–5193 (58p.). http://pubs.usgs.gov/sir/2011/5193.

ASMFC. 2012. "River Herring Benchmark Stock Assessment Volume I." *Stock Assessment Report No. 12-02.* Atlantic States Marine Fisheries Commission. http://www.asmfc.org/uploads/file/riverHerringBenchmarkStockAssessmentVolumeIR_May2012.pdf.

—. 2017. "River Herring Stock Assessment Update Volume I: Coastwide Summary." Atlantic States Marine Fisheries Commission. Accessed January 13, 2021. http://www.asmfc.org/uploads/file/59b1b81bRiverHerringStockAssessmentUpdate_Aug2017.pdf.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. "Rapid Bioassessment Protocol for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition." EPA 841-B-99-002, Office of Water, United States Environmental Protection Agency, Washington, D.C.

Beskenis, J. B. 2014. "Marine macroalgae species that may be good indicators of enrichment." Personal communication, Watershed Planning Program, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

CCME. 2002. "Canadian Sediment Quality Guidelines for the Protection of Aquatic Life --Summary Tables Updated 2002." Canadian Council of Ministers of the Environment, Winnipeg, MB, Canada.

CCME. 1999a. "Canadian tissue residue guidelines for the protection of wildlife consumers of aquatic biota: DDT (total)." In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg, MB, Canada.

CCME. 1999b. "Canadian tissue residue guidelines for the protection of wildlife consumers of aquatic biota: Introduction." In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg, MB, Canada.

CCME. 2000. "Canadian tissue residue guidelines for the protection of wildlife consumers of aquatic biota: Methylmercury." In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg, MB, Canada.

CCME. 1999c. "Canadian tissue residue guidelines for the protection of wildlife consumers of aquatic biota: Toxaphene." In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg, MB, Canada.

CCME. 2001. "Canadian tissue residue guidelines for the protection of wildlife consumers of aquatic biota: Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/Fs)." In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg, MB, Canada.

Chase, Brad. 2022. "Diadromous Fish Restoration Priority List Version 5.0 All Regions (Excel sheet)." Massachusetts Division of Marine Fisheries, New Bedford, MA.

Coles, J. F. 1998. "Organochlorine compounds in fish tissue for the Connecticut, Housatonic, and Thames River Basins study unit, 1992-94." USGS Water-Resources Investigations Report 98-4075, Water Resources Division, National Water Quality Assessment Program, U.S. Geological Survey, Marlborough, MA.

Costello, C. T. 2015. "Personal Communication with DWM-WPP program staff 28 April 2015: the loss of eelgrass along deep water edge of eelgrass meadow as an indicator of degrading water quality conditions." Wetlands Program, Division of Watershed Management, Massachusetts Department of Environmental Protection, Boston, MA.

Costello, C. T., and W. J. Kenworthy. 2011. "Twelve-Year Mapping and Change Analysis of Eelgrass (Zostera marina) Areal Abundance in Massachusetts (USA) Identifies Statewide Declines." [published by Springer online 20 January 2011. DOI 10.1007/s12237-010-9371-5], Coastal and Estuarine Research Federation.

EPA. 2024a. "Adopting Water Quality Criteria for Secondary Contact Recreation: A User Guide." EPA 820-B-24-001, Office of Science and Technology, Office of Water, U. S. Environmental Protection Agency. July. Accessed August 2024. https://www.epa.gov/system/files/documents/2024-07/scr-user-guide.pdf.

EPA. 1988a. "Ambient Water Quality Criteria for Chloride-1988." EPA-440/5-88-001, EPA Office of Water, Washington, D.C.

EPA. 2000a. "Ambient Water Quality Criteria Recommendations Lakes and Reservoirs in Nutrient Ecoregion VIII, Information Supporting the Development of State and Tribal Nutrient Criteria." EPA-822-B-00-010, EPA Office of Water, Washington, D.C.

EPA. 2001a. "Ambient Water Quality Criteria Recommendations Lakes and Reservoirs in Nutrient Ecoregion XIV, Information Supporting the Development of State and Tribal Nutrient Criteria." EPA-822-B-01-011, EPA Office of Water, Washington, D.C.

EPA. 2001b. "Ambient Water Quality Criteria Recommendations Rivers and Streams in Nutrient Ecoregion VIII, Information Supporting the Development of State and Tribal Nutrient Criteria." EPA-822-B-01-015, EPA Office of Water, Washington, D.C.

EPA. 2000b. "Ambient Water Quality Criteria Recommendations Rivers and Streams in Nutrient Ecoregion XIV, Information Supporting the Development of State and Tribal Nutrient Criteria." EPA-822-B-00-022, EPA Office of Water, Washington, D.C.

EPA. 2021. "Ambient Water Quality Criteria to Address Nutrient Pollution in Lakes and Reservoirs." EPA-822-R-21-005, Office of Science and Technology, Office of Water, United States Environmental Protection Agency. August. Accessed 2024. https://www.epa.gov/system/files/documents/2021-08/nutrient-lakes-reservoirs-report-final.pdf.

EPA. 2003. "Bacterial Water Quality Standards for Recreational Waters (Freshwater and Marine Waters) Status Report." EPA-823-R-03-008, Office of Water, U.S. Environmental Protection Agency, Washington, D.C.

EPA. 2002. "Consolidated Assessment and Listing Methodology. Toward a Compendium of Best Practices." Office of Wetlands, Oceans and Watersheds, US Environmental Protection Agency, Washington, D.C.

EPA. 1988b. "Dissolved Oxygen Water Quality Standards Criteria Summaries: A compilation of State/Federal Criteria." EPA 440/5-88/024, EPA Office of Water, Washington, D.C.

EPA. 2024b. "Fact Sheet: Final Recommended Aquatic Life Criteria and Benchmarks for Select PFAS." United States Environmental Protection Agency. September. Accessed October 2024. https://www.epa.gov/system/files/documents/2024-09/pfoa-pfos-pfas-final-factsheet-2024.pdf.

EPA. 2005. "Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act." Assessment and Watershed Protection Division, Office of Wetlands, Oceans and Watersheds, Office of Water, US Environmental Protection Agency. July 29. Accessed January 29, 2021. https://www.epa.gov/sites/production/files/2015-10/documents/2006irg-report.pdf.

EPA. 1997. "Guidelines for Preparation of the Comprehensive State Water Quality Assessments (305(b) Reports) and Electronic Updates: Supplement." *EPA/841/B-97-002B.* Assessment and Watershed Protection Division (4503F), Office of Wetlands, Oceans, and Watersheds, Office of Water, US Environmental Protection Agency. Accessed January 26, 2021. https://www.epa.gov/sites/production/files/2015-09/documents/guidelines_for_preparation_of_the_comprehensive_state_water_quality_assessments_305b_reports_and_electronic_updates_1997_supplement-volume2.pdf.

EPA. 2020. "National Pollutant Discharge Elimination System (NPDES): Permit Limits-Whole Effluent Toxicity (WET)." United States Environmental Protection Agency. August 31. Accessed January 5, 2021. https://www.epa.gov/npdes/permit-limits-whole-effluent-toxicity-wet.

EPA. 2001c. "Nutrient Criteria Technical Guidance Manual Estuarine and Coastal Marine Waters." EPA-822-B-01-003, EPA Office of Water, Washington, D.C.

EPA. 2000c. "Nutrient Criteria Technical Guidance Manual Lakes and Reservoirs, First Edition." EPA-822-B-00-001, Office of Science and Technology, EPA Office of Water, Washington, D.C.

EPA. 2000d. "Nutrient Criteria Technical Guidance Manual Rivers and Streams." EPA-822-B-00-002, Office of Science and Technology, EPA Office of Water, Washington, D.C.

EPA. 2023. "Our Current Understanding of the Human Health and Environmental Risks of PFAS." United States Environmental Protection Agency. June 7. Accessed June 2023. https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas.

EPA. 1986. "Quality Criteria for Water 1986." EPA 440/5-86-001, EPA Office of Water, Washington, D.C.

EPA. 2019. "Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin." *EPA Document Number: 822-R-19-001 .* Health and Ecological Criteria Division, Office of Water, United States Environmental Protection Agency. May. Accessed 2023. https://www.epa.gov/sites/default/files/2019-05/documents/hh-rec-criteria-habs-document-2019.pdf.

EPA. 2012. "Recreational Water Quality Criteria." 820-F-12-058 , EPA Office of Water, Washington, D.C. https://www.epa.gov/sites/production/files/2015-10/documents/rwqc2012.pdf.

Federal Water Pollution Control Administration. 1968. "Water Quality Criteria. [known as the Green Book]." Report of the National Technical Advisory Committee to the Secretary of the Interior, Washington, D.C.

Gil, L. 1985. "Inventory of Massachusetts Estuaries, Harbors, Salt Ponds." Technical Memorandum for the Record, Technical Services Branch, Massachusetts Division of Water Pollution Control, Westborough, MA.

Godfrey, P. J., S. A. Joyner, E. L. Goldstein, and L. Ross. 1979. "The Development of PALIS: A Ponds and Lakes Information System for Massachusetts." Publication No. 108, Water Resources Research Center, University of Massachusetts, Amherst, MA.

Grubbs, G. H., and R. H. Wayland III. 2000. "EPA recommendations on the use of fish and shellfish consumption advisories and certain shellfish growing area classifications in determining attainment of water quality standards and listing impaired waterbodies under section 303(d) of the Clean Water Ac." Letter to Colleague dated 24 October 2000, Office of Wetlands, Oceans and Watersheds, United States Environmental Protection Agency, Washington, D.C.

Halliwell, D. B.(1), W. A. (2) Kimball, and A. J. (2) Screpetis. 1982. "Massachusetts Stream Classification Program Part I: Inventory of Rivers and Streams." (1) Massachusetts Department of Fisheries, Wildlife, and Recreational Vehicles, Division of Fisheries and Wildlife, Westborough, MA, (2) Massachusetts Department of Environmental Quality Engineering, Division of Water Pollution Control, Westborough, MA.

Halliwell, D. B., R. W. Langdon, R. A. Daniels, J. P. Kurtenbach, and R. A. Jacobson. 1999. "Classification of Freshwater Fish Species of the Northeastern United States for Use in the Development of Indices of Biological Integrity, with Regional Applications." In *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities*, edited by T. P. Simon, 301-338. Boca Raton, FL: CRC Press.

Hem, J. D. 1970. "Study and Interpretation of the Chemical Characteristics of Natural Water." Second Edition, United States Government Printing Office, Washington.

Howes, B. L., R. Samimy, and B. Dudley. 2003. "Massachusetts Estuaries Project Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators Interim Report Revised December 22, 2003." University of Massachusetts Dartmouth, School of Marine Science and Technology (SMAST), Coastal Systems Laboratory (New Bedford, MA), Massachusetts Department of Environmental Protection (Lakeville, MA).

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. "Assessing Biological Integrity in Running Waters: A Method and Its Rationale." Special Publication 5, Illinois Natural History Survey, Champaign, IL.

Kashiwagi, M., and T. Richards. 2009. "Development of Target Fish Community Models for Massachusetts Mainstem Rivers Technical Report." Division of Fisheries and Wildlife, Massachusetts Department of Fish and Game, Westborough, MA.

Keehner, D. 2011. "Information Concerning 2012 Clean Water Act Sections 303(d), 305(b) and 314 Integrated Reporting and Listing Decisions." Memorandum to Water Division Directors et al. dated March 21, 2011, EPA Office of Wetlands, Oceans and Watersheds, Washington, D.C.

Lewis, Asa J, Xiaoyan Yun, Daniel E Spooner, Marie J Kurz, Erica R McKenzie, and Christopher M Sales. 2022. "Exposure pathways and bioaccumulation of per- and polyfluoroalkyl substances in freshwater aquatic ecosystems: Key considerations." *Science of the Total Environment* (Elsevier B.V.) 822. https://www.sciencedirect.com/science/article/abs/pii/S0048969722006532.

Limburg, K. E., and J. R. Waldman. 2009. "Dramatic Declines in North Atlantic Diadromous Fishes." *BioScience* 59 (11): 955-965.

Lopez, C. B., E. B. Jewett, Q. Dortch, B. T. Walton, and H. K. Hudnell. 2008. "Scientific Assessment of Freshwater Harmful Algal Blooms." Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology, Washington, D.C.

MA DCR. 2007. "A Guide to Selected Invasive Non-native Aquatic Species in Massachusetts." Revised March 2007, Lakes and Ponds Program, Massachusetts Department of Conservation and Recreation, Boston, MA.

MA DFG. 2023. *Fish Community Data 1964-2020.* Database submitted to MassDEP on February 13, 2023. Division of Fisheries and Wildlife, Massachusetts Department of Fish and Game. Westborough, MA.

MA DFG. 2021. "Learn about shellfish sanitation." Accessed January 19, 2021. https://www.mass.gov/service-details/learn-about-shellfish-sanitation.

MA DMF. Undated. "Shellfish classification areas." Division of Marine Fisheries, Massachusetts Department of Fish and Game. Accessed January 13, 2021. https://www.mass.gov/service-details/shellfish-classification-areas.

Maietta, Robert J. 1984. "Technical Memorandum. Planimetry of Harbors for the 1984 305(b) Report." Technical Services Branch, Massachusetts Division of Water Pollution Control, Westborough, MA.

MassDEP. 2020. "310 CMR 22: The Massachusetts Drinking Water Regulations." Massachusetts Department of Environmental Protection. October 2. Accessed 2023. https://www.mass.gov/regulations/310-CMR-22-the-massachusetts-drinking-water-regulations.

MassDEP. 2018a. "A Strategy for Monitoring and Assessing the Quality of Massachusetts' Waters to Support Multiple Water Resource Management Objectives 2016-2025." CN 203.5, Watershed Planning Program, Massachusetts Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2005. "A Water Quality Monitoring Strategy for the Commonwealth of Massachusetts." CN 203.0, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. Unpublished a. "Additions to the Massachusetts Stream Classification Program Inventory of Rivers and Streams (SARIS) codes." Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2024. "Data Requirements and Procedures to Support the Designation of Freshwater Streams and Rivers as Cold Waters in the Massachusetts Surface Water Quality Standards." CN 587.0, Watershed Planning Program, Division of Watershed Management, Bureau of Water Resources, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. Unpublished b. "Draft Phase I Phosphorus Guidance for the Restoration of Massachusetts Lakes, Rivers, and Streams dated August 18, 2015." CN 407.0, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2021a. "Draft Quality Assurance Project Plan Benthic Macroinvertebrate Biomonitoring and Habitat Assessment." CN XXX.X, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. Unpublished c. "Draft Sampling Plan for Year 2010 Periphyton Percent Cover and Biomass Monitoring in the Northeast Region Watersheds." CN 370.0, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. Unpublished d. "Massachusetts Coastal and Marine Inventory System (CAMIS)." Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2016a. "Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2016 Reporting Cycle." CN 445.0, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2022. "Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2022 Reporting Cycle." CN 564.0, Watershed Planning Program, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2021b. "Massachusetts Surface Water Quality Standards (Revision of 314 CMR 4.00, effective November 12, 2021, corrected December 10, 2021 and January 7, 2022)." Available at https://www.mass.gov/regulations/314-CMR-4-the-massachusetts-surface-water-quality-standards, Massachusetts Department of Environmental Protection, Boston, MA.

MassDEP. Undated e. "Open Files of NPDES permit information, whole effluent toxicity testing (ToxTD) data, and associated georeferencing data." Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, Massachusetts.

MassDEP. 2015a. "Quality Assurance Program Plan Surface Water Monitoring & Assessment Massachusetts Department of Environmental Protection Division of Watershed Management-Watershed Planning Program 2015-2019." CN 460.0 (Rev. 1.1), Watershed Planning Program, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2010a. "Quality Assurance Program Plan Surface Water Monitoring & Assessment MassDEP-Division of Watershed Management 2010-2014." CN 365.0 MS-QAPP-27 (Rev. #1), Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2010b. "Quality Assurance Project Plan Fish Toxics Program." CN 096.0 revised February 2010, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2006. "Standard Operating Procedure Aquatic Plant Mapping." CN 67.2, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2002. "Standard Operating Procedure Benthic Algae: Micro and Macro Identifications and Biomass Determinations." CN 060.0, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2023. "Standard Operating Procedure Chlorophyll a Analysis by EPA Method 445 with the Welschmeyer modification." CN 003.43, Watershed Planning Program, Division of Watershed Management, Bureau of Water Resources, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2015b. "Standard Operating Procedure Enumeration of Cyanobacteria in Water Samples." CN 150.1, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2010c. "Standard Operating Procedure Enumeration of Cyanobacteria in Water Samples." CN 150.0, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2011. "Standard Operating Procedure Fish Collection Procedures for Evaluation of Resident Fish Populations (Method 003/11.20.95)." CN 075.1, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2016b. "Standard Operating Procedure Fish Toxics Monitoring--Fish Collection and Preparation." CN 40.3, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2014a. "Standard Operating Procedure Long-term Duckweed Monitoring on the Assabet River Impoundments." CN 201.7, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2021c. "Standard Operating Procedure Water Quality Monitoring In Streams Using Aquatic Macroinvertebrates." CN 039.3, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2014b. "Visual Surveys Ponds and Impoundments: Percent Cover of Floating, Non-Rooted Vegetation SOP." CN 151.5, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassGIS. 2024. "MassGIS Data: Designated Shellfish Growing Areas, data provided by the Department of Fish and Game's Division of Marine Fisheries." Bureau of Geographic Information, Boston, MA. June. Accessed June 2024. https://www.mass.gov/info-details/massgis-data-designated-shellfish-growing-areas.

MassGIS. 2020. "MassGIS Data: MassDEP Eelgrass Mapping Project, 2015-2017 shapefile." Data contributed by the MA Department of Environmental Protection and available at https://www.mass.gov/info-details/massgis-data-massdep-eelgrass-mapping-project, Bureau of Geographic Information, Boston, MA.

MassGIS. 2008. "MassGIS Data: Shellfish Sampling Stations datalayer, October 2000." Data contributed by the MA Division of Marine Fisheries and available at https://www.mass.gov/info-details/massgis-data-shellfish-sampling-stations, Bureau of Geographic Information, Boston, MA.

Mattson, M. D., P. J. Godfrey, M. F. Walk, P. A. Kerr, and O. T. Zajicek. 1992. "Regional Chemistry of Lakes in Massachusetts." *Water Resources Bulletin* (American Water Resources Association) 28 (6).

Mattson, M. D., P. J. Godfrey, R. A. Barletta, and A. Aiello. 2004. "Eutrophication and Aquatic Plant Management in Massachusetts. Final Generic Environmental Impact Report." Edited by Kenneth J. Wagner, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA and Massachusetts Department of Conservation and Recreation, Boston, MA.

MDPH. 2014. "105 CMR 445.00: State sanitary code chapter VII: Minimum standards for bathing beaches." *Massachusetts Department of Public Health.* Boston, MA. June 6. Accessed January 5, 2021. https://www.mass.gov/regulations/105-CMR-44500-state-sanitary-code-chapter-vii-minimum-standards-for-bathing-beaches.

MDPH. 2017. "A Guide to Eating Fish Safely in Massachusetts." Bureau of Environmental Health, Massachusetts Department of Public Health, Boston, MA. Accessed January 7, 2021. https://www.mass.gov/files/documents/2016/07/si/fish-eating-guide.pdf.

MDPH. 2019a. "Annual beach reports, 2014 through 2019." *Marine and freshwater beach testing in Massachusetts, provided by the Environmental Toxicology Program.* Bureau of Environmental Health, Massachusetts Department of Public Health, Boston, MA. Accessed January 5, 2021. https://www.mass.gov/lists/annual-beach-reports.

MDPH. 2019b. "Beaches Bill Reporting Database 2014 - 2019." Environmental Toxicology Program, Massachusetts Department of Public Health, Boston, MA.

MDPH. 2021. "Emerging Contaminant Surveillance in Surface Water and Fish: Results from Cape Cod Pilot Study." Bureau of Environmental Health, Massachusetts Department of Public Health. November 2. Accessed April 2023. https:https://www.mass.gov/doc/summary-of-fish-sampling-data-for-cape-cod-waterbodies-0/download.

MDPH. 2023. "Emerging Contaminants in Surface Water and Fish: Results from Statewide Monitoring." Environmental Toxicology Program, Massachusetts Department of Public Health. December 26. Accessed March 2024. https://www.mass.gov/doc/2022-summary-of-sampling-data-for-dcr-waterbodies-0/download.

MDPH. 2023. "Evaluation of PFAS in Recreational Waterbodies in Massachusetts, Technical Support Document." Environmental Toxicology Program, Bureau of Environmental Health, Massachusetts Department of Public Health. March. Accessed 2024. https://www.mass.gov/doc/technical-basis-for-issuing-fish-advisories-0/download.

MDPH. 2025. "Freshwater Fish Consumption Advisory List." Bureau of Climate and Environmental Health, Massachusetts Department of Public Health. January. Accessed January 2025. https://www.mass.gov/doc/public-health-freshwater-fish-consumption-advisories-2025-0/download.

MDPH. 2022. "Massachusetts Department of Public Health Cyanobacteria in Recreational Waters in Massachusetts 2022 Local Board of Health Guidance." Environmental Toxicology Program, Bureau of Environmental Health, Massachusetts Department of Public Health, Boston, MA. May. Accessed December 2023. https://www.mass.gov/doc/guidance-for-local-health-on-responding-to-cyanohabs/download.

MDPH. Undated. "MDPH Guidelines for Cyanobacteria in Freshwater Recreational Waterbodies in Massachusetts." Bureau of Environmental Health, Massachusetts Department of Public Health, Boston, MA. Accessed January 7, 2021. https://www.mass.gov/files/documents/2016/07/qk/protocol-cyanobacteria.pdf.

NEIWPCC. 2007. "Northeast Regional Mercury TMDL Fact Sheet October 2007." New England Interstate Water Pollution Control Commission, Lowell, MA. October. Accessed January 8, 2021. http://neiwpcc.org/our-programs/nps/mercury/mercury-tmdl/.

Northeast States. 2007. "Northeast Regional Mercury Total Maximum Daily Load." CT DEP, ME DEP, MA DEP, NH DES, NYS DEC, RI DEM, VT DEC, NEIWPCC.

Persaud, D., R. Jaagumagi, and A. Hayton. 1993. "Guidelines for the protection and management of aquatic sediment quality in Ontario." Water Resources Branch, Ontario Ministry of the Environment, Ontario, Canada.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. "Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish." EPA/444/4-89-001, U.S. Environmental Protection Agency, Washington, D.C.

Portnoy, J. W., M. G. Winkler, P. R. Sanford, and C. N. Farris. 2001. "Kettle Pond Data Atlas: Paleoecology and Modern Water Quality." Cape Cod National Seashore, National Park Service, U.S. Department of Interior. Accessed January 8, 2021. https://www.nps.gov/caco/learn/nature/upload/Pondatlasfinal.pdf.

Regas, D. 2003. "Information Concerning 2004 Clean Water Act Sections 303(d), 305(b) and 314 Integrated Reporting and Listing Decisions." Memorandum to Water Division Directors et al. dated July 21, 2003, Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency, Washington, D.C.

Regas, D. 2005. "Information Concerning 2006 Clean Water Act Sections 303(d), 305(b) and 314 Integrated Reporting and Listing Decisions." Memorandum to Water Division Directors et al. dated July 29, 2005, Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency, Washington, D.C.

Regas, D. 2006. "Information Concerning 2008 Clean Water Act Sections 303(d), 305(b) and 314 Integrated Reporting and Listing Decisions." Memorandum to Water Division Directors et al. dated October 12, 2006, Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency, Washington, D.C.

Schwartz, S. 2009. "Information Concerning 2010 Clean Water Act Sections 303(d), 305(b) and 314 Integrated Reporting and Listing Decisions." Memorandum to Water Division Directors et al. dated May 5, 2009, Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency, Washington, D.C.

US National Office for Harmful Algal Blooms. 2019. "Harmful Algae website." US National Office for Harmful Algal Blooms, Woods Hole Oceanographic Institution, Supported by NOAA's National Centers for Coastal Ocean Science. Accessed January 8, 2021. https://hab.whoi.edu/.

USFDA. 2017. "Guide for the Control of Molluscan Shellfish 2017 Revision." National Shellfish Sanitation Program, United States Food and Drug Administration, Department of Health and Human Services. Accessed January 8, 2021. https://www.fda.gov/media/117080/download.

Walk, M. I., P. J. Godfrey, A. Ruby III, O. T. Zajicek, and M. Mattson. 1991. "Acidity Status of Surface Waters in Massachusetts." Water Resources Research Center, Blaisdell House, and Department of Chemistry of the University of Massachusetts, Amherst, MA.

Wayland III, R. H. 2001. "Re: 2002 Integrated Water Quality Monitoring and Assessment Report Guidance." Memorandum to EPA Regional Water Management Directors, et al. dated 19 November 2001, Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency, Washington, D.C.

WHO. 1999. "Toxic Cyanobacteria in Water: A Guide to Their Public Health Consequences, Monitoring and Management." Edited by I. Chorus and J. Bartram. World Health Organization, published by E & FN Spon, London. Accessed January 8, 2021. Individual chapters available at https://www.who.int/water_sanitation_health/publications/toxicyanobact/en/.

Wise, D. R., M. L. Zuroske, K. D. Carpenter, and R. L. Kiesling. 2009. " Assessment of eutrophication in the Lower Yakima River Basin, Washington, 2004–07." U.S. Geological Survey Scientific Investigations Report 2009–5078, 108 p.

Zen, E., R. Goldsmith, N. Ratcliffe, P. Robinson, R. S. Stanley, N. L. Hatch, A. F. Shride, E. G. A. Weed, and D. R. Wones. 1983. "Bedrock Geologic Map of Massachusetts (Scale 1:250,000)." US Geological Survey. Accessed January 8, 2021. https://ngmdb.usgs.gov/Prodesc/proddesc_16357.htm.

VIII. APPENDICES

List of Appendices

APPENDIX A
EVALUATION METHODS FOR
NATURAL BACKGROUND CONDITIONS (NBC)

<u>Introduction and Background</u>

NBC rationale

The Massachusetts Surface Water Quality Standards (SWQS) (314 Code of Massachusetts Regulations (CMR) 4.00) are the foundation of the state's water quality management program. This regulation defines the most sensitive uses for surface waters, prescribes minimum water quality criteria to sustain those uses, and protects existing uses and high-quality waters. However, the SWQS state that waters exhibiting excursions from criteria solely due to natural background conditions (NBC) are not interpreted as violations of surface water quality standards (per 314 CMR 4.03(5)). In addition, at 314 CMR 4.05(5)(e)1.: Generally Applicable Criteria, the SWQS state that "[f]or each pollutant identified in 314 CMR 4.06(6)(d): Table 29: Generally Applicable Criteria, the concentrations identified or calculated for that pollutant in or pursuant to Table 29 shall be generally applicable criteria for all categories of surface waters, as specified therein; unless the Department determines that naturally occurring background concentrations are higher. Where the Department determines that naturally occurring background concentrations are higher, those concentrations shall be the allowable receiving water concentrations." The SWQS define background conditions as "water quality which exists or would exist in the absence of pollutants requiring permits and other controllable cultural factors that are subject to regulation under [Massachusetts General Laws] M.G.L. c. 21, §§ 26 through 53" (314 CMR 4.02).

NBC evaluation procedures

In 2023, MassDEP completed a contractor-assisted project to develop a more comprehensive, transparent, and scientifically defensible framework to consistently identify NBC that can occur independently of anthropogenic influences in inland surface waters for certain water quality parameters (MassDEP 2023). Beginning with the NBC evaluation procedures described in the 2022 Consolidated Assessment and Listing Methodology (CALM) Guidance Manual (MassDEP 2022), refinements to the procedures were suggested, and an NBC screening tool, the RShiny-based "MassNBCtools" application, was developed to streamline and improve consistency and efficiency for the NBC evaluation process (MassDEP 2023). The procedures outlined in this appendix document the rationale and improved evaluation methods used by MassDEP analysts to determine whether an observed SWQS exceedance can be attributed to NBC. [Note, an observed criterion exceedance can be greater than the criterion like in the case of temperature, or less than the criterion as is the case for dissolved oxygen (DO).]. During the NBC evaluation, a standardized review process is used to demonstrate that anthropogenic stressors (e.g., impervious land cover) have not impacted an Assessment Unit (AU), but rather that an excursion from a criterion is a result of natural conditions, and therefore, should not be interpreted as an impairment. Land use/cover evaluation thresholds were developed to exclude AUs with anthropogenic stressors from NBC consideration. In addition, NBC can only be considered the sole cause if there is evidence of natural mechanisms that result in the observed water quality violation (e.g., a profusion of upstream wetland land cover). Natural mechanisms for water quality excursions were reviewed for water temperature, DO, and pH, and used for the development of parameter-specific criteria evaluation procedures (MassDEP 2023). Natural mechanisms for water quality excursions for total phosphorus and metals were also reviewed; however, adoption of these analytes in the NBC evaluation process will require further study.

Limitations

The NBC determination process applies to freshwater streams and rivers. Currently, freshwater lakes and reservoirs, coastal waterbodies, and wetlands of any type are not evaluated for NBC.

Land Cover Categorization

As part of the NBC determination process, the contributing drainage area to each AU is delineated and intersected with the land-use, impervious surface polygon coverages, dams or other coverages for each AU's drainage area. The 19 codes of Land Cover from the MassGIS 2016 Land Cover/Land Use (MassGIS 2019) were grouped into categories (Table A1) for the analysis of each drainage area and the development of land use/cover pie charts.

Table A1 – MassDEP Assessment Land Use/Cover Categories

Land Use/Cover Category	MassGIS 2016 Land Cover Code
Agriculture	cultivated land, pasture/hay
Developed	impervious, developed open space, bare land (barren land)
Natural	grassland, deciduous forest, evergreen forest, scrub/shrub, unconsolidated shore, open water, palustrine aquatic bed (C-CAP), estuarine aquatic bed (C-CAP)
Wetland	palustrine forested wetland (C-CAP), palustrine scrub/shrub wetland (C-CAP), palustrine emergent wetland (C-CAP), estuarine forested wetland (C-CAP), estuarine scrub/shrub wetland (C-CAP), estuarine emergent wetland (C-CAP)
Impervious	impervious

NBC Thresholds

As part of the NBC determination process, an AU must first pass a series of land evaluation thresholds to eliminate the possibility of a water quality exceedance being caused by anthropogenic stressors. Once an AU successfully passes the land use/cover evaluation thresholds, parameter-specific guidelines are applied depending on the observed water quality exceedance. An NBC determination can only be made if there is evidence of natural mechanisms that likely result in the water quality criterion exceedance (MassDEP 2023).

Land use/cover NBC evaluation

1. The data used to derive MassDEP's land use pie charts are used as a data source for the NBC tool. For the land cover charts, complete watersheds are delineated, as well as the proximal (5 km) watershed, and proximal (5 km) 100-m stream buffer for each Assessment Unit (AU) (Figure A1). Note that in the case of a small watershed (<25 mi^2), the proximal stream buffer may encompass the entire upgradient stream network. The following statistics are calculated for each watershed and pulled into the NBC tool: 1) the percentage of natural land (see footnote 1 under Table A2), 2) the percentage of wetland area, 3) the percentage of impervious area, and 4) the percentage of agricultural land within each spatial delineation (Allen 2004; Schiff and Benoit 2007; MassGIS 2019). If the land use/cover percentages meet <u>all</u> the thresholds outlined below, the water quality exceedance may be considered natural (Table A2).

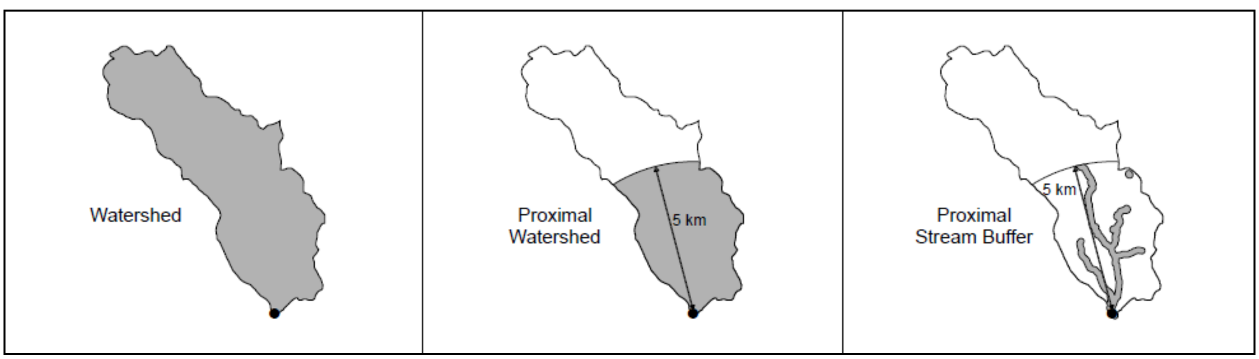


Figure A1. Illustration of the different spatial scales used to evaluate the landscape guidelines (grey shaded area clips used in calculations). Note, that in cases of small watersheds <25 mi^2, the proximal stream buffer may encompass the entire upgradient stream network.

Table A2. *The land use/cover thresholds that are used to evaluate the prevalence of anthropogenic stressors.*

Land Use/Cover Type	Complete & Proximal Watersheds	Complete[2] or Proximal Stream Buffer
Natural & Wetland[1]	>80%	>90%
Impervious	<4%	<2%
Agricultural	<10%	<5%

[1] Natural & Wetland includes grassland, deciduous forest, evergreen forest, scrub/shrub, unconsolidated shore, open water, palustrine aquatic bed (C-CAP), estuarine aquatic bed (C-CAP), palustrine forested wetland (C-CAP), palustrine scrub/shrub wetland (C-CAP), palustrine emergent wetland (C-CAP), estuarine forested wetland (C-CAP), estuarine scrub/shrub wetland (C-CAP), estuarine emergent wetland (C-CAP).

[2] Watersheds <25 mi^2

2. Determine the presence of dams along the AU and in its contributing watershed and their potential to be the source of the observed water quality violation. In addition to dam presence, consider dam type, size, storage volume, proximity to the waterbody, etc. (Poff and Hart 2002). If the presence of man-made dams can reasonably be suspected as the source of the violation, then the water quality violation will not be considered natural.
3. Verify the presence of point source discharges- wastewater treatment plants (WWTP), stormwater (consult the USA Census Urban Areas feature class (U.S. Census Bureau and Esri 2023)), non-contact cooling water, etc., - and/or water withdrawals along the AU and in its contributing watershed, and determine their potential to be the source of the observed water quality violation (Paul and Meyer 2001). In addition to presence, consider effect, size, and proximity to the waterbody. If the presence of point source discharges and/or water withdrawals can reasonably be suspected as the source of the exceedance, then the water quality violation will not be considered natural.
4. Use BPJ to evaluate the density of roads and the density of road-stream crossings within the AU watershed area and assess their potential to be the source of the observed water quality exceedance (in the future, a quantitative GIS desktop evaluation may be developed). Roads include those that are paved, forest/logging roads, and recreational paths (Forman and Alexander 1998; Coffin 2007). If the presence of roads can reasonably be suspected as the source of the violation, then the water quality violation will not be considered natural.
5. Confirm the presence of any localized human disturbances within the riparian area of the AU from recorded habitat observations (i.e., field sheets) and GIS. Examples of localized human disturbances include channel modifications, clearance of riparian and floodplain vegetation, and agriculture or silviculture activities. If the presence of localized human disturbances can reasonably be suspected as the source of the violation, then the water quality violation will not be considered natural.
6. Consult satellite imagery bracketing sampling collection date (e.g., 5-10 years prior to sample collection compared to shortly post-sample collection). Evaluate the upstream watershed and determine whether any historical land uses (e.g., land clearing, channel modifications, woody debris removal, mining) may contribute legacy effects that would cause the observed water quality exceedances (Allen 2004). Use the National Land Cover Change Analysis ArcPRO 3.0/3.1 Toolbox (note that in its current form, the Toolbox can be used for comparisons at the AU watershed scale but does not analyze land cover differences in time at the pixel level). If historical land uses can reasonably be suspected as the source of the violation, then the water quality violation will not be considered natural.

Next Steps

If the AU passes all the land use/cover thresholds above, then the exceedance might be wholly or partially natural in origin. Go to the appropriate parameter-specific evaluation procedures to complete the NBC determination. If the AU failed any of the above steps, then the exceedance is assumed to result from anthropogenic influence and not NBC.

Water Temperature NBC evaluation

Natural influences that may increase water temperature include the amount of wetland land cover in the upstream watershed, high light conditions in adjacent/upstream wetlands or riparian zones naturally low in tree cover, lower channel gradient, channel orientation, and the occurrence of heat waves or drought conditions when temperature data are being collected (MassDEP 2023). Apply the following guidance (after the land use/cover NBC evaluation) when evaluating an AU for a water temperature violation:

1. Determine which temperature criteria were violated, the cold-water (20.0°C) or warm-water (28.3°C). If the warm-water criteria were violated, then the temperature violation will not be considered natural.
2. Determine the general nature of the temperature criteria violation. Consider the magnitude, frequency, and duration of isolated spike(s). If the violation is the result of isolated spike(s), then the temperature violation will not be considered natural.

Dissolved Oxygen NBC evaluation
Natural influences on DO may include the amount of wetland land cover in the upstream watershed, the presence of beaver ponds in the upstream watershed, low topographic slope, low light conditions in adjacent/upstream wetlands (leading to decreased photosynthetic activity and therefore decreased DO), and others as described in Appendix C of MassDEP's 2023 Natural Background Conditions report (MassDEP 2023). Apply the following guidance (after the land use/cover NBC evaluation) when evaluating an AU for a DO violation:

1. Determine the general nature of the DO criteria violation. Consider the magnitude, frequency, and duration of isolated spike(s). If the violation is the result of isolated spike(s), then the DO violation will not be considered natural.
2. Determine the diurnal shift in DO concentration. If the maximum diurnal shift is greater than 3 mg/L, then the DO violation will not be considered natural.
3. Calculate the percentage of wetland land cover within the AU's proximal watershed. If the percentage of wetland land cover is less than or equal to 7%, then the DO violation will not be considered natural.
4. Determine the gradient of the AU. If the AU is low gradient (i.e., limited riffle habitat), then the DO violation can be considered natural.

pH NBC evaluation
Natural influences on pH may include the amount of wetland land cover in the upstream watershed (lower pH with increased wetlands), increased shading in the riparian zone (lower pH with increased shading), and the type of bedrock geology in the subwatershed, as described in Appendices C and I of MassDEP's 2023 Natural Background Conditions report (MassDEP 2023). Apply the following criteria (after the land evaluation criteria) when evaluating an AU for a pH violation:

1. Calculate the percentage of wetland land cover within the AU's proximal watershed. If the percentage of wetland land cover is less than or equal to 7%, then the pH violation will not be considered natural.

Other analytes to be included in the NBC evaluation procedure for a future IR cycle
Additional data are needed to further develop NBC evaluation procedures for total phosphorus and metals, as well as for further refinement of the pH evaluation (inclusion of lithology data).

The NBC Determination

The NBC determination is nestled within the assessment and listing process as outlined in the Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual. A WPP analyst reviews all the data associated with a given Assessment Unit (AU) to reach a use attainment decision. If the analyst determines that there are exceedances of criteria or CALM thresholds for one or more parameters and suspects that the observed violation may be due to NBC, then the analyst initiates the NBC determination process.

The analyst utilizes the MassNBCtools application, to aid in making an NBC determination for the AU. The tool contains a series of questions designed to systematically and consistently step through NBC guidelines outlined in this appendix. The analyst weighs the evidence provided to them within the tool, as well as any additional data not within the tool, to make a final NBC determination: Is the water quality condition a result of NBC? Yes: NBC likely result in the WQS excursions or No: NBC are unlikely to cause the SWQS exceedances. The analyst notes whether data are unavailable to evaluate any of the NBC thresholds, and if the data are insufficient to make an informed decision, then the default is to identify an Alert and make a recommendation for additional sampling.

The analyst can share the output of the application, along with their determination, for review by another WPP analyst. Subjective indicators, such as whether the proximity of dams to an AU is sufficient to exclude it from NBC consideration, can be reviewed and discussed between the analyst and reviewer. Natural mechanisms for water quality criteria exceedances can be drawn from the conceptual models (MassDEP 2023). For any borderline cases, WPP analysts seek consensus with other WPP staff (Assessment, Monitoring, or Standards) to resolve any conflicting NBC determinations. Once consensus has been reached, the use attainment status of the AU will be provided in the IR watershed decision documentation.

References

Allan, J. D. 2004. Landscapes and riverscapes: The influence of land use on stream ecosystems. Annual Review of Ecology, Evolution, and Systematics 35:1, 257-284.

Coffin, A. W. 2007. From roadkill to road ecology: A review of the ecological effects of roads. Journal of Transport Geography 15:396-406.

Forman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology, Evolution, and Systematics 29:207–31.

MassDEP. 2022. "Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2022 Reporting Cycle." CN 564.0, Watershed Planning Program, Division of Watershed Management, Massachusetts Department of Environmental Protection, Worcester, MA.

MassDEP. 2023. Freshwater Natural Background Conditions Determinations and Use Attainment Decisions in Massachusetts. Massachusetts Department of Environmental Protection, Bureau of Water Resources, Division of Watershed Management, Watershed Planning Program. Worcester, MA. In cooperation with Tetra Tech Inc., Center for Ecological Sciences.

MassGIS. 2019. MassGIS Data: 2016 Land Cover/Land Use datalayer. Bureau of Geographic Information, Boston, MA. Available at https://docs.digital.mass.gov/dataset/massgis-data-2016-land-coverland-use.

Paul, M. J., and J. L. Meyer. 2001. Streams in the urban landscape. Annual Review of Ecology, Evolution, and Systematics 32:333–65.

Poff, N. L. and D. D. Hart. 2002. How dams vary and why it matters for the emerging science of dam removal: An ecological classification of dams is needed to characterize how the tremendous variation in the size, operational mode, age, and number of dams in a river basin influences the potential for restoring regulated rivers via dam removal. BioScience 52(8):659-668.

Schiff, R., and G. Benoit. 2007. Effects of impervious cover at multiple spatial scales on coastal watershed streams. Journal of the American Water Resources Association 43(3):712-730.

U.S. Census Bureau and Esri. 2022. USA Census Urban Areas feature class providing information about Urbanized Areas and Urban Clusters documented during the 2010 Census, queried for only Urban Areas. Data sources, United States Census Bureau and Esri. Available at ArcGIS Online.

APPENDIX B
FISH SPECIES OF MASSACHUSETTS
AND THEIR ASSOCIATED CLASSIFICATIONS

Table B1. Fish Species of Massachusetts and their associated classifications -- habitat use, tolerances to environmental perturbations, and temperature.

Scientific Name	Common Name	Fish Code	Family	Habitat Use Classification[1]	Tolerance Classification[2]	Temperature Classification[3]
Lampetra appendix	American Brook Lamprey	BL	Petromyzontidae		I	C
Petromyzon marinus	Sea Lamprey	SL	Petromyzontidae		M	W
Amia calva	Bowfin	BF	Amiidae	MG	T	W
Anguilla rostrata	American eel	AE	Anguillidae	MG	T	W
Alosa aestivalis	Blueback herring	BBH	Clupeidae	FS	M	W
Alosa sapidissima	American shad	S	Clupeidae		M	W
Alosa pseudoharangus	Alewife	A	Clupeidae	MG	M	W
Notropis hudsonius	Spottail shiner	SS	Cyprinidae	MG	M	W
Rhinichthys atratulus	Blacknose dace	BND	Cyprinidae	FS	T	W
Notropis bifrenatus	Bridle shiner	BM	Cyprinidae	MG	I	W
Cyprinus carpio	Common carp	C	Cyprinidae	MG	T	W
Rhinicthys cataractae	Longnose dace	LND	Cyprinidae	FS	M	W
Pimephales notatus	Bluntnose Minnow	BNM	Cyprinidae	MG	T	W
Luxillus cornutus	Common shiner	CS	Cyprinidae	FD	M	W
Hybognathus regius	Eastern Silvery Minnow	ESM	Cyprinidae	MG	I	W
Exoglossum maxillingua	Cutlips Minnow	CLM	Cyprinidae	FS	I	W
Semotilus atromaculatus	Creek chub	CRC	Cyprinidae	FS	T	W
Pimephales promelas	Fathead Minnow	FM	Cyprinidae	MG	T	W
Semotilus corporalis	Fallfish	F	Cyprinidae	FS	M	W
Carassius auratus	Goldfish	G	Cyprinidae	MG	T	W
Notemigonus crysoleucas	Golden shiner	GS	Cyprinidae	MG	T	W
Couesius plumbeus	Lake chub	LC	Cyprinidae	MG	M	C
Catostomus catostomus	Longnose Sucker	LNS	Catostomidae	FD	I	C
Catostomus commersoni	White sucker	WS	Catostomidae	FD	T	W
Erimyzon oblongus	Creek chubsucker	CCS	Catostomidae	FS	I	W
Ameiurus nebulosus	Brown bullhead	BB	Ictaluridae	MG	T	W
Ameiurus natalis	Yellow bullhead	YB	Ictaluridae	MG	T	W
Ameiurus catus	White catfish	WC	Ictaluridae	MG	M	W
Ictalurus punctatus	Channel catfish	CC	Ictaluridae	MG	M	W
Noturus gyrinus	Tadpole Madtom	TMT	Ictaluridae	FS	M	W
Noturus insignis	Margined Madtom	MM	Ictaluridae		M	W
Esox lucius X Esox masquinongy	Tiger muskellunge	TM	Esocidae	MG		W
Esox niger	Chain pickerel	CP	Esocidae	MG	M	W
Esox americanus americanus X Esox niger	Hybrid Redfin/Chain Pickerel	RPXCP	Esocidae	MG		W

Scientific Name	Common Name	Fish Code	Family	Habitat Use Classification[1]	Tolerance Classification[2]	Temperature Classification[3]
Esox lucius	Northern pike	NP	Esocidae	MG	I	W
Esox americanus americanus	Redfin pickerel	RP	Esocidae	MG	M	W
Umbra limi	Central Mudminnow	CM	Umbridae		T	W
Osmerus mordax	Rainbow smelt	RS	Osmeridae		I	C
Salmo trutta	Brown trout	BT	Salmonidae	FS	I	C
Salvelinus fontinalis X Salmo trutta	Tiger Trout	TT	Salmonidae	FS		C
Salvelinus fontinalis	Brook trout	EBT	Salmonidae	FS	I	C
Salvelinus namaycush	Lake trout	LT	Salmonidae	MG	I	C
Salmo salar	Atlantic salmon	AS	Salmonidae	FS	I	C
Oncorhynchus mykiss	Rainbow trout	RT	Salmonidae	FS	I	C
Salmo salar	Landlocked salmon	LLS	Salmonidae	FD	I	C
Fundulus heteroclitus	Mummichog	M	Fundulidae		T	W
Fundulus diaphanus	Banded killifish	K	Fundulidae	MG	T	W
Gambusia affinis holbrooki	Eastern Mosquitofish	EM	Poeciliidae	MG	T	W
Pungitius pungitius	Ninespine Stickleback	NSS	Gasterosteidae		M	W
Gasterosteus aculeatus	Threespine stickleback	TSS	Gasterosteidae		M	W
Apeltes quadracas	Fourspine stickleback	FSS	Gasterosteidae		M	W
Cottus cognatus	Slimy sculpin	SC	Cottidae	FS	I	C
Morone americana	White perch	WP	Moronidae	MG	M	W
Morone saxatilis	Striped bass	SB	Moronidae	FD	I	W
Lepomis cyanellus	Green sunfish	GSF	Centrarchidae	MG	T	W
Lepomis auritus	Redbreast sunfish	RBS	Centrarchidae	MG	M	W
Micropterus salmoides	Largemouth bass	LMB	Centrarchidae	MG	M	W
Lepomis macrochirus X Lepomis gibbosus	Hybrid Bluegill/Pumpkinseed	BXP	Centrarchidae	MG		W
Lepomis gibbosus	Pumpkinseed	P	Centrarchidae	MG	M	W
Pomoxis annularis	White crappie	WR	Centrarchidae	MG	T	W
Lepomis macrochirus	Bluegill	B	Centrarchidae	MG	T	W
Ambloplites rupestris	Rock bass	RB	Centrarchidae	MG	M	W
Enneacanthus obesus	Banded sunfish	BS	Centrarchidae	MG	I	W
Pomoxis nigromaculatus	Black crappie	BC	Centrarchidae	MG	M	W
Micropterus dolomieu	Smallmouth bass	SMB	Centrarchidae	MG	M	W
Stizostedion vitreum	Walleye	W	Percidae	MG	M	W
Perca flavescens	Yellow perch	YP	Percidae	MG	M	W
Etheostoma fusiforme	Swamp Darter	SD	Percidae	MG	I	W
Etheostoma olmstedi	Tesselated darter	TD	Percidae	FS	M	W
Channa sp.	Snakehead	SH	Channidae	MG	T	W

[1] Habitat Use Classification codes: FD = fluvial dependent species, FS = fluvial specialist species, MG=macrohabitat generalist species
[2] Tolerance Classification Codes: I = Intolerant, M = Moderately Tolerant, T = Tolerant
[3] Temperature Classification Codes: C = Cold Water, W = Warm Water

APPENDIX C
LITERATURE REVIEW OF FRESH WATER NUTRIENT ENRICHMENT INDICATORS

October 2023

1.0 Introduction

Nutrients, such as total phosphorus (TP) in freshwaters, were identified as the primary causes of anthropogenic (cultural) eutrophication in Massachusetts (MassDEP 2012). The addition of nutrients to freshwater systems often stimulates rapid growth of primary producing autotrophs containing chlorophyll (e.g., cyanobacteria, algae, non-rooted macrophytes, etc.). Anthropogenic enrichment can lead to impairment of the designated uses of Massachusetts surface waters including public water supply, aesthetics, recreation, as well as aquatic life.

With the exception of total phosphorus (TP) criteria assigned to specific lakes and ponds in Table 28 at 314 CMR 4.06(6)(c), the Massachusetts Surface Water Quality Standards (SWQS) have a narrative criterion that MassDEP analysts apply to evaluate unacceptable nutrient impacts from anthropogenic sources on fresh surface waters. To assess fresh surface waters for impairment against the narrative standard in compliance with Section 305(b) of the federal Clean Water Act, MassDEP has increasingly applied quantitative screening assessment thresholds for nutrient enrichment response indicators, along with total phosphorus (TP) threshold concentrations, in a weight-of-evidence approach.

A combination of surface water depth, substrate type, shading, color, grazing, herbivory, the nature of inputs, and hydrology all play a role in the degree of nutrient response; therefore, the preferred approach has been to use field measurements of the primary producers' responses as the first indicators for assessing surface waters for impairment. Massachusetts currently follows the "Designated Use Approach" (USEPA, 2000a), establishing nutrient enrichment response indicator screening assessment thresholds to evaluate whether or not designated uses such as aquatic life, recreation, and aesthetics are being met.

Biological indicators of nutrient enrichment include the presence of nuisance growths of primary producers, such as cyanobacteria, algae and aquatic vascular plants (macrophytes). Physico-chemical indicators of high primary productivity include low clarity (as Secchi depth), elevated pH, elevated TP, elevated dissolved oxygen saturation and significant diel fluctuation in dissolved oxygen. Total phosphorus concentration data alone are not used to determine impairment due to nutrient enrichment; rather, they are used to corroborate indicator data and can help to identify potential sources. This Appendix provides the supportive literature and basis for the nutrient enrichment indicator screening assessment thresholds used in the 2024 Consolidated Assessment and Listing Methodology (CALM) Guidance Manual.

2.0 Summary of Massachusetts Nutrient Enrichment Indicator Screening Assessment Thresholds

To assess nutrient enrichment, Massachusetts has grouped its inland waterbodies into three categories:
1. wadeable rivers and streams; 2. deep (non-wadeable) rivers, and 3. lakes, ponds, and impoundments generally greater than two meters in depth. The surface waters are grouped in this way because each is distinct in the sampling methodology applied (e.g., wading vs. boat), the exhibition of biological responses (benthic growth vs. planktonic growth), the retention times, and in hydraulic conditions such as scouring.

For wadeable rivers and streams, the selected nutrient enrichment indicators include:

- benthic chlorophyll-*a*,
- benthic percent filamentous algal cover (visual estimate)
- algal blooms,
- diel changes in dissolved oxygen concentration,
- elevated saturation of dissolved oxygen,
- elevated pH, and
- elevated TP.

The indicators used for non-wadeable (deep) rivers are:

- phytoplankton chlorophyll-*a*,
- non-rooted vegetation percent visual coverage,

- diel changes in dissolved oxygen concentration
- elevated saturation of dissolved oxygen,
- elevated pH,
- elevated TP, and
- the frequency and duration of cyanobacteria blooms.

For lakes, ponds and impoundments, the indicators include:

- Secchi disk transparency,
- non-rooted vegetation percent visual coverage,
- planktonic chlorophyll-*a,*
- elevated saturation of dissolved oxygen,
- elevated pH,
- elevated TP, and
- the frequency and duration of cyanobacteria blooms.

MassDEP has selected its nutrient enrichment indicators and their respective numeric screening assessment thresholds based on historical precedent, best professional judgment (BPJ) and the scientific literature. MassDEP's response indicator assessment thresholds for each waterbody type, the literature reviewed for each indicator, along with the thresholds mentioned or recommended by the literature are provided in Table C1.

These basic nutrient enrichment screening assessment thresholds represent thresholds that shall not be exceeded in more than one site visit (generally one visit per month) depending on which designated use is being evaluated (the primary contact recreation season is April 1 through October 31 while the summer growing season for the *Aquatic Life Use* is May 1 through September 30). If the assessment thresholds are exceeded repeatedly, MassDEP uses a weight-of-evidence approach to assess impairment of surface waters, outlined as follows:

- In the assessment of rivers and streams, MassDEP analysts evaluate whether there are excessive primary-producer growths observed two or more times, and also consider changes in the physico-chemical data (e.g., dissolved oxygen concentration and supersaturation, pH, and chlorophyll-*a*). If a combination of these indicator data suggests nutrient enrichment, an impairment decision will likely be made unless other biological data (e.g., benthic IBI and/or fish sampling results) indicate otherwise and in those cases an Alert will be identified along with recommendations for additional monitoring.

- Lakes are assessed and potentially impaired using mostly primary producer biological data (i.e., planktonic blooms, cover of non-rooted aquatic macrophytes); and, the evaluation may also include physicochemical data such as oxygen saturation, pH, chlorophyll-*a*, and Secchi disk transparency. These surface waters would be impaired when more than one of these indicators exceed assessment thresholds more than once during the survey season.

- If the surface water is assessed as impaired using biological and/or physicochemical indicators, total phosphorus is then included as a cause of impairment if the concentrations exceed MassDEP's assessment thresholds based on EPA's ecoregional or "Gold Book" criteria (for rivers/streams); or MassDEP's site-specific criteria at 314 CMR 4.06(6)(c) (for certain lakes and ponds); Note: EPA's Ambient Water Quality Criteria to Address Nutrient Pollution in Lakes and Reservoirs guidance document (USEPA, 2021), describes analyses of new data and provides models from which numeric nutrient criteria, including chlorophyll-a, can be derived. The criterion models replace the recommended numeric nutrient criteria of 2000 and 2001. The potential for adopting this approach is currently under review by MassDEP. Considering significant updates to MassDEP's assessment data analysis methodologies must be performed to apply values other than those cited in the 1986 Gold Book, MassDEP will continue primarily using the 1986a Gold Book threshold for lakes in this CALM cycle (USEPA, 1986a). The proposed assessment thresholds apply to freshwaters but exclude darkly colored waters, as well as marine or brackish waters that have salinity greater than 0.5 ppt.

To develop appropriate assessment thresholds as listed in Table C1, MassDEP conducted a detailed literature review of biological and physical characteristics related to nutrient enrichment that support attainment of surface water's designated uses.

Table C1- Recommended Nutrient Enrichment Indicator Screening Assessment thresholds and Literature Sources for Various Surface Water Types

Waterbody Type	Nutrient Enrichment Indicator	Recommended Indicator Screening Guideline(s)	Water Use Goal Potentially Impacted	Reference	Literature Thresholds
Wadeable Rivers and Streams	Benthic Filamentous Algae % Visual Coverage	>40% coverage	Aquatic Life/ Recreation/ Aesthetics	Welch et al., 1988	20% (Aquatic Life no effect level*)
				USEPA, 2000a	Variable (Aesthetic)
				Biggs and Price, 1987	>40% (Visual)
				Zurr, 1992	>40% (Primary recreation)
	Benthic Algae as Chlorophyll-*a*	>200mg/m^2	Aquatic Life	Dodds et al., 1997	>200 mg/m^2 (Nuisance)
				Welch et al., 1988	>100 - 150 mg/m^2 (Nuisance)
				USEPA, 2000a	>100 - 200 mg/m^2 (Nuisance)
	Diel Changes in DO Concentration	∆>3 mg/l	Aquatic Life	Gower, 1980	∆2.5 mg/l (generally nutritionally balanced) ∆10 mg/l (generally nutritionally imbalanced)
				Mathews, 1998	∆> 3.6 - 6 mg/l
	DO Saturation	≥125%	Aquatic Life	MassDEP BPJ	≥125% saturation (DO)
	Elevated pH	>8.3 SU	Aquatic Life	USDI, 1968	>8.3 SU (human eye irritation)
				USEPA, 1976	>9 SU (freshwater organisms)
	Elevated TP- Summer Seasonal Average (May through September): used to confirm nutrient enrichment	>0.1 mg/l flowing waters >0.05 mg/l entering a lake/reservoir (n≥3 samples)	See preceeding indicators for potential impacts	Mackenthun, 1973 USEPA, 1986a	>0.1 mg/l flowing waters >0.05 mg/l entering a lake/reservoir
				USEPA, 2002	>0.010 mg/l - 0.031 mg/l (range within Massachusetts Ecoregions)
Non-Wadeable (Deep) Rivers	Non-rooted Vegetation % Visual Coverage	>25% coverage	Aquatic Life/ Recreation/ Aesthetics	Wolverton, 1986; Landolt 1986, cited in Ozbay, 2002; Leng et al., 1995;	100% cover results in anoxia and suppression of algae and submerged plant growth.
				Gee et al., 1997	>25% (for O_2 saturation, swimming, and aesthetics)
	Phytoplankton Chlorophyll-*a*	>16 mg/l	Aquatic Life	Dodds, et al., 1998	>30 µg/l (mesotrophic-eutrophic rivers)
				USEPA, 2000/2001	0.63 - 3.75 ug/l (rivers + streams)
	Diel Changes in DO Concentration	∆>3 mg/l	Aquatic Life	Gower, 1980	∆ 2.5 mg/l (generally nutritionally balanced) ∆ 10 mg/l (generally nutritionally imbalanced)
				Mathews, 1998	∆> 3.6 - 6 mg/l
	DO Saturation	≥125%	Aquatic Life	MassDEP BPJ	>125% saturation (DO)
	Elevated pH	>8.3 SU	Aquatic Life	USDI, 1968	>8.3 SU (human eye irritation)
				USEPA, 1976	>9 SU (freshwater organisms)
	Cyanobacteria Blooms	Recurring and/or Prolonged, Resulting in Advisories	Aquatic Life/ Recreation/ Aesthetics	WHO, 1999 MassDPH, 2007	Advisory = a cell count of 70,000 cells/mL or more corresponding to a toxin level of approx. 14 ppb
	Elevated TP- Summer Seasonal Average (May through September): Used to confirm nutrient enrichment	>0.1 mg/l flowing waters >0.05 mg/l entering a lake/reservoir (n≥3 samples)	See preceeding indicators for potential impacts	Mackenthun, 1973 USEPA, 1986a	>0.1 mg/l flowing waters >0.05 mg/l entering a lake/reservoir
				USEPA, 2002	>0.010 mg/l - 0.031 mg/l (range within Massachusetts Ecoregions)

Waterbody Type	Nutrient Enrichment Indicator	Recommended Indicator Screening Guideline(s)	Water Use Goal Potentially Impacted	Reference	Literature Thresholds
Lakes, Ponds and Impoundments (Generally >2m Depth)	Secchi Disk Transparency	≤ 1.2 m	Recreation	USDI, 1968; MassDPH; BPJ	≤ 4' (1.2 m) (swimming safety)
				USEPA, 2000 a,b, c,d; USEPA, 2001 a,b	≤4.50-4.93 m (range within Massachusetts Ecoregions)
	Non-Rooted Vegetation % Visual Coverage	>25%	Aquatic Life/ Recreation/ Aesthetics	Wolverton, 1986; Landolt, 1986, cited in Ozbay, 2002; Leng et al., 1995	<100% cover (anoxia, suppression of algae and submerged plant growth)
				Gee et al., 1997	>25% (for O_2 saturation, swimming, and aesthetics)
	Planktonic Chlorophyll-*a*	> 16 mg/l	Aquatic Life	USEPA, 2000/2001	>2.43-2.90 ug/l (25th Percentile range within Massachusetts Ecoregions)
				Wetzel, 2001.	14.3 µg/l (mean, eutrophic) 42.6 µg/l (max, eutrophic) 16.1 µg/l (max, mesotrophic)
	DO Saturation	≥125%	Aquatic Life	MassDEP BPJ	>125% saturation (DO)
	Elevated pH	>8.3 SU	Aquatic Life	USDI, 1968	>8.3 SU (human eye irritation)
				USEPA, 1976	>9 SU (freshwater organisms)
	Cyanobacteria Blooms	Recurring and/or Prolonged, Resulting in Advisories	Aquatic Life/ Recreation/ Aesthetics	WHO, 1999 MassDPH, 2007	Advisory= a count of 70,000 cells/mL or more corresponding to a toxin level of approx. 14 ppb
	Elevated TP-Seasonal Summer Seasonal Average (May through September): Used to confirm nutrient enrichment	>0.025 mg/l (n≥3 samples)	See preceeding indicators for potential impacts	USEPA, 1986a	>0.025 mg/l
				USEPA, 2000b	>0.008 mg/l (within Massachusetts Ecoregions)
				Gower, 1980	>0.01 mg/l
				Hutchinson, 1957	>0.01-0.03 mg/l

Notes:

mg/m^2	= milligrams per square meter	cells/mL	= bacteria cells per milliliter
mg/l	= milligrams per liter	m	= meter
SU	= standard units	T	= total
µg/L	= micrograms/L	DO	= dissolved oxygen
ppb	= parts per billion	*	= No apparent effects on DO, pH, or benthic invertebrates

3.0 Literature Summaries

Over the last decade a wealth of research has been generated to help identify appropriate nutrient criteria for protection and restoration of water resources. MassDEP reviewed EPA's technical support and guidance documents, scientific literature and the extensive surface water sampling data collected by MassDEP.

3.1 USEPA General Nutrient-Related Background Information

The United States Environmental Protection Agency (EPA) has published technical support documents to help guide efforts for numeric nutrient criteria development by waterbody type (e.g., estuarine and coastal waters, lakes and reservoirs, rivers and streams, and wetlands). In addition, EPA conducted studies that divided the US into 14 distinct ecoregions and finalized reports that derive numeric nutrient criteria by waterbody type and region (USEPA, 2001a and 2001b). Massachusetts is within two major Ecoregions, dividing the state roughly in half vertically. The western portion of the state, approximately along the Connecticut river valley and to the west, is within Ecoregion VIII. The eastern portion of the State is within Ecoregion XIV. The state also contains three subregions, the Northeastern Highlands (58), the Northeastern Coastal Zone (59), and the Atlantic Coastal Pine Barrens (84). EPA has published their recommended nutrient criteria documents for both rivers and streams and lakes and reservoirs for each of these ecoregions. They include recommended criteria for total phosphorus, total nitrogen, chlorophyll a, and turbidity or Secchi disk depth intended to address the adverse effects of excess nutrient inputs (USEPA 2000c, 2000d, 2001a, and 2001b). Massachusetts evaluated EPA's approach along with other published literature to establish its nutrient enrichment screening assessment thresholds for freshwater systems. See Figure C1 for the EPA Ecoregions within Region 1, and the Sub-Ecoregions specific to Massachusetts.

EPA provides a description of the characteristics of the Sub-Ecoregions in its Nutrient Guidance documents. Information pertaining to the ecoregions within Massachusetts, as defined in the EPA guidance documents, is paraphrased below.

(a) Ecoregion 58 - Northeastern Highlands
The Northeastern Highlands comprise a relatively sparsely-populated region characterized by nutrient-poor soils blanketed by northern hardwood and spruce fir forests. Land-surface form in the region grades from low mountains in the southwest and central portions to open high hills in the northeast. Many of the numerous glacial lakes in this region have been acidified by atmospheric sulfur depositions.

(b) Ecoregion 59 - Northeastern Coastal Zone
Like the Northeastern Highlands, the Northeastern Coastal Zone contains relatively nutrient-poor soils and has concentrations of continental glacial lakes, some of which are sensitive to acidification; however, this Ecoregion contains considerably less surface irregularity and much greater concentrations of human population. Current land use consists mainly of forests and residential development.

(c) Ecoregion 84 - Atlantic Coastal Pine Barrens
This Ecoregion is distinguished by its coarser grained soils and oak-pine natural vegetation, as compared to forests including hickory. Appalachian Oak forests and northern hardwoods were found in the northern portion of this Ecoregion. This Ecoregion is not as irregular as that of the Northeastern Coastal Zone.

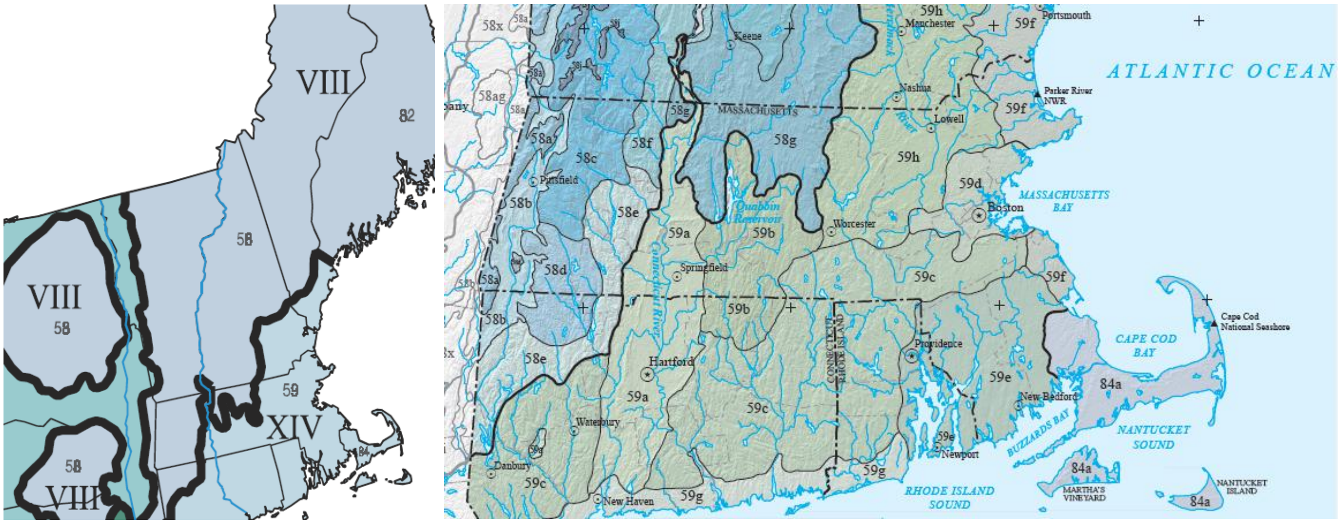


Figure C1 - EPA Ecoregions for the National Nutrient Strategy**,**
Massachusetts lies within two major Ecoregions: VIII and XIV (see left image), and three Sub-Ecoregions: 58, 59 and 84, (see right image),(from Griffith, G.E., et al, 2009).

3.2 MassDEP Literature Review by Waterbody Type

The following are brief synopses of the literature and field data that support the selected quantitative nutrient enrichment screening assessment thresholds.

(a) Wadeable Streams and Rivers

- **(1) Benthic Percent Filamentous Algal Cover (Visual Estimate)**
  Benthic algal biomass can be measured as percent cover by filamentous algae. Filamentous algae are the most commonly-noted nuisance growth in nutrient-enriched wadeable streams and various threshold values have been proposed by a number of scientists. Welch et al. (1988) studied 22 streams in northwestern United States and Sweden. The Welch et al. (1988) study noted that when benthic chlorophyll was lower than 100-150 mg/m^2, filamentous algae covered less than 20 percent of the stream bottom. A survey of New Zealand rivers found that when filamentous algae exceeded 40 percent the algal community became very conspicuous from shore (Biggs and Price, 1987). Streambed coverage by filamentous algae of <20 percent had no apparent effects on DO or benthic invertebrates (Welch et al. 1988). New Zealand Ministry for the Environment has established guidelines to protect contact recreational use of streams and recommended that the seasonal maximum cover by filamentous algae should not exceed 40% (Zurr, 1992). Based on the above and the general recommendations in the EPA rivers nutrient guidance document (USEPA 2000a), the proposed maximum screening guideline for filamentous macroalgae is set at 40 percent coverage in streams.

  MassDEP Assessment Threshold: to support the designated uses of aquatic life, recreation, and aesthetics, visible filamentous periphyton exceeding 40% coverage in the streambed in more than one monthly site visit during the primary contact recreation and summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

  (2) Benthic Algae as Chlorophyll-*a*
  In most cases, aesthetic and recreational nuisance algal growth in wadeable streams is associated with benthic growths. The Welch et al. (1988) study suggested nuisance conditions occur when benthic chlorophyll exceeds 100-150 mg/m^2. However, the same study concluded that other measures of water quality related to the aquatic life designated use such as dissolved oxygen and benthic macroinvertebrates were unaffected by either benthic chlorophyll or filamentous algae. In a study of a trout fishery, Montana's Clark Fork River, Dodds et al. (1997) used a benthic chlorophyll mean of 100 mg/m^2 to define nuisance conditions and suggested a maximum benthic chlorophyll-*a* screening guideline of 200 mg/m^2.

  The studies of Dodds et al. (1998) and Welch et al. (1988) and recommendations of a number of studies compiled in USEPA (2000a) suggest a benthic algae chlorophyll-*a* threshold at a maximum of 200 mg/m^2 for recreational and aesthetic use in streams. Levels of benthic algae chlorophyll-*a* can vary significantly within single segments depending on the physical conditions at each sampling location; therefore, case-by-case decisions need to be made as to whether conditions can represent the entire segment.

MassDEP Assessment Threshold: to support the designated uses of recreation and aesthetics, benthic chlorophyll-a exceeding 200mg/m^2 in more than one monthly site visit during the primary contact recreation season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(3) Diel Changes in Dissolved Oxygen Concentration

Generally, for warm-water organisms, the optimum DO concentration is 6 mg/l, and it is best that levels not decrease below 5 mg/l (USDI 1968). Only in very favorable conditions is it considered tolerable for the DO to fall to between 4 and 5 mg/l, and then only for brief periods (USDI 1968). For cold water fish, the lowest tolerable in favorable condition is between 5 and 6 mg/l, with the optimum oxygen concentration of 7 mg/l (USDI 1968).

Daytime photosynthetic activities of algae and macrophytes can increase dissolved oxygen (DO) levels, and continued decomposition and respiration at night can significantly decrease DO, particularly in slow-moving streams and rivers (Wetzel 2001). If the biomass of algae and macrophytes is very high, this diel swing in DO may be severe (USEPA 1998, Sharpley et al. 2000). Such large daily swings in DO can be harmful to aquatic animal life (Jones 2011).

Studies have shown that growth of largemouth bass under any DO fluctuation is reduced compared to growth under steady DO concentrations (USEPA 1986b). Similar results were exhibited in studies with yellow perch and channel catfish (USEPA, 1986b). Spawning of mature black crappies was not successful when DO fluctuated between 1.8 mg/l and 4.1 mg/l (a fluctuation of 2.3 mg/l) (USEPA 1986b).

Quantification of the diel changes in DO in defined river sections has been used as a measure of photosynthetic production (Wetzel 2001). Gower (1980) depicts that DO levels in a “nutritionally balanced” stream fluctuate by approximately 2.25 to 2.5 mg/l of DO; whereas a eutrophic stream can exhibit diel DO fluctuations of 10 mg/l. This is supported by a 1977 study reviewed by Mathews (1998). The study indicated that in August, after measurement of DO at 13 sites within a 1 kilometer segment of a stream in Norman, Oklahoma, a mean morning-afternoon increase of 3.6 mg/l DO was observed. Yet, at individual “backwaters with algae” locations, DO increased by 6 mg/l or more.

MassDEP Assessment Threshold: to support the designated use of aquatic life, the diel change in dissolved oxygen greater than 3 mg/l during the summer growing season (May 1 to September 30), is considered an indicator of nutrient enrichment.

(4) Dissolved Oxygen Saturation

Percent saturation is the amount of dissolved oxygen in a water sample compared to the maximum amount that could be present (at the same temperature). For example, a water sample that is 50% saturated only has half the amount of oxygen that it could potentially hold at that temperature. Dissolved oxygen (DO) in surface waters can exceed expected saturations when photosynthetic processes by algae or rooted aquatic plants produce oxygen more quickly than it can diffuse into the atmosphere. Algal blooms often accompany an increase in water temperature and this higher temperature further contributes to supersaturation (USEPA 1986a).

To protect aquatic life, EPA (1986a) recommends a total dissolved gas concentration in water not to exceed 110 percent of the saturation value for gases at existing atmospheric and hydrostatic pressures. Water at this level of saturation and above may lead to fish mortalities when dissolved gases in their circulatory system form emboli which block the capillary flow of blood. This condition is commonly referred to as "gas bubble disease”. Studies have also shown, however, that it is high nitrogen and carbon dioxide (CO_2) saturation that is potentially harmful to fish due to gas bubble disease, and not high oxygen saturation (Weitkamp and Katz 1980). Therefore, MassDEP is applying the 125% saturation level of DO as simply an additional indicator of high primary producer photosynthesis levels. However, DO saturation is not recommended as a primary variable to assess nutrient enrichment in some cases because the supersaturation may not be apparent due to surface turbulence and/or other non-nutrient-related factors (USEPA 2000a).

MassDEP Assessment Threshold: to support the designated use of aquatic life, a dissolved oxygen saturation exceeding 125% in more than one site visit during the summer growing season (May 1 to September 30) is considered an indicator of nutrient enrichment.

(5) Elevated pH
According to EPA, pH in surface water in the range of 6.5-9 standard units (SU) is protective of freshwater fish and benthic organisms (USEPA 1976). Very few organisms tolerate pH above 10 SU (USDI 1968). In aquatic systems, during the day photosynthesis usually exceeds respiration, and as carbon dioxide is extracted from the water pH increases (Tucker and D'Abramo 2008). This photosynthetic activity can be represented by the following chemical equation: $CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$. The system is in equilibrium under constant conditions, but when these conditions are disrupted, the reactions flow to the left or the right to maintain equilibrium. Removing carbon dioxide shifts the equation to the left, thereby removing hydrogen ions and causing pH to increase. The degree of variation from the initial pH depends on the amount of carbon dioxide removed and alkalinity, which tends to buffer, or reduce, the effect of changes in carbon dioxide concentrations (Tucker and D'Abramo 2008). The amount of bicarbonate and carbonate (CO_3^{2-}) are the anions contributing the most to a water's capacity to neutralize acid, or its alkalinity (Tucker and D'Abramo 2008).

When primary producers are growing rapidly, more carbon dioxide is removed each day by photosynthesis than is added each night by respiration, causing pH to rise to abnormally high levels during the afternoon and may even remain high through the night (Tucker and D'Abramo 2008). This cycle means that pH can be a useful indicator of unusually high primary productivity and hence a nutrient enrichment indicator; however, in surface waters with high alkalinity ("buffering capacity"), pH is not as useful a nutrient indicator (MassDEP BPJ).

Elevated pH can also affect the toxicity of other constituents in the water column which then may impact aquatic life, but these effects are not relevant to pH as a nutrient enrichment indicator and are therefore discussed briefly in other sections of the CALM document.

For primary contact, the recommended pH of surface water is 6.5-8.3 to protect the human eye from irritation (USDI 1968).

MassDEP Assessment Threshold: to support the designated uses of recreation and aquatic life, a pH of >8.3 SU during the primary contact recreation and summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(6) Elevated Total Phosphorus (TP)
As noted in EPA's Gold Book, for prevention of primary producer over-abundance in streams, it is recommended that TP be maintained at 0.05 mg/l where streams are entering lakes, ponds, or impoundments, or 0.1 mg/l in streams or other flowing waters (EPA 1986a). Phosphorus is commonly the initial limiting nutrient to algae (Wetzel 2001). In addition to point sources, there are three major sources of TP to surface waters: atmospheric precipitation, groundwater, and land runoff (Wetzel 2001). The effects of phosphorus vary by region and are dependent on physical factors such as the size, hydrology, and depth of rivers and lakes.

According to the EPA frequency analysis of surface water data collected in Massachusetts, the aggregate recommended TP criterion level for rivers and streams is 0.010 mg/l for Ecoregion VIII (Western Mass), and 0.031 mg/l for Ecoregion XIV (Eastern Mass) (USEPA 2002).

However, because many biological, chemical, and physical characteristics influence whether a river or stream responds to certain levels of TP, MassDEP uses phosphorus concentrations as a confirming measurement when the weight of evidence points to nutrient enrichment. Specifically, when multiple biological and physico-chemical nutrient enrichment indicator thresholds are exceeded, then the summer seasonal average (typically three or more samples) of the TP concentration data are screened against the 1986a EPA recommended "Gold Book" TP concentrations. As noted in the Gold Book, for prevention of primary producer over-abundance in streams, it is recommended that TP not exceed 0.05 mg/l where streams are entering lakes, ponds, or impoundments, or 0.1 mg/l in streams or other flowing waters (EPA 1986a).

MassDEP Assessment Threshold: When multiple biological and physico-chemical nutrient enrichment indicator screening assessment thresholds are exceeded, the summer seasonal average for TP exceeding 0.1 mg/l in flowing waters, or exceeding 0.05 mg/l for rivers entering a lake or reservoir during the primary contact recreation and/or summer growing season (April 1 to October 31), is considered additional confirmation that there is a condition of nutrient enrichment.

(7) Application of the Wadeable Streams and Rivers Screening Assessment Thresholds

More information is needed on applicability of benthic and filamentous algae screening assessment thresholds to cold water streams. Future guidance may have to be revised as additional water quality data are collected for cold water streams in Massachusetts in what has been called Phase II of the MassDEP nutrient-related guidance documents.

In addition, it is important to consider project goals when applying the above thresholds. If the intent is to judge the frequency, duration, and magnitude (or extent) of a periphyton bloom as it impacts designated uses over a 5-20 mile stretch of river segment over a given period of time, then careful selection of a sampling design is needed to avoid bias. Blooms may develop preferentially in areas without tree canopy (increased light), in areas of cobble, shallow riffles, moderate flow velocities and when rare periods of low flow and a lack of scouring allow excessive biomass accrual. Extreme low-flow conditions have the potential to produce bloom conditions in reference streams and these may be considered natural events. Likewise, high flow events and high velocity sites have the potential to scour benthic algal growth (Biggs 2000, Biggs 2012).

The EPA Nutrient Criteria Guidance suggests that light, cobbles, flow velocity, and accrual time be considered and to determine the degree to which these are "common in the stream or reach" (USEPA 2000a). If the sampling plan focuses on such times and places that favor blooms the data will be biased high, and if such conditions are avoided the data may be biased low. With random sampling or representative sampling, the goal is to produce an unbiased estimate of the mean biomass of the segment that represents the mean biomass of the time interval. Given year-to-year variability in climate it is suggested that if rare hydrologic conditions were present during sampling, the sampling should be repeated in following year(s) to confirm impairment was not a spurious result.

(b) Non-Wadeable Rivers

The biological response to excessive nutrients in non-wadeable rivers occurs primarily within the water column and surface rather than at the bottom of the river. There are fewer instances and published reports of impairments caused by excessive planktonic algae or surface accumulations of algae or floating macrophytes in such systems, presumably because the short water residence time results in flushing of algae and floating plants out of such systems.

(1) Non-Rooted Vegetation % Visual Coverage

Floating non-rooted macrophytes such as *Lemna* sp. or *Wolfia* sp., or algal scums formed by either green algae or bluegreen algae (cyanobacteria) may impair aquatic life, recreation, and aesthetic designated uses of non-wadeable rivers; however, this is unlikely unless there are eutrophic impoundments upstream. Again, the short residence times within flowing rivers usually preclude large biomass accumulations of duckweed or algae. Because these impairments are usually associated with impoundments, the threshold to be applied to rivers will be the same as for impoundments, discussed below in Section 3.2(c)(2).

MassDEP Assessment Threshold: to support the designated uses of recreation and aesthetics, floating duckweed/scum exceeding 25 % of surface coverage in more than one site visit within the primary contact recreation season (April 1-October 31) is considered an indicator of nutrient enrichment.

(2) Planktonic Chlorophyll-*a*

The MassDEP threshold for planktonic chlorophyll-a was developed to differentiate between mesotrophic (unimpaired) and eutrophic (impaired) waterbodies. Trophic levels and associated chlorophyll-*a* concentrations have been well defined for lakes. Researchers have cited ranges of chlorophyll-*a* of 2-15 for mesotrophic freshwater lakes (Wetzel 2001). Although trophic levels are not well defined for rivers, Dodds et al. (1998) suggests a reasonable mesotrophic-eutrophic boundary of 30 µg/l sestonic chlorophyll-*a* in the water column based on a large number of reported rivers. A maximum water quality screening guideline of 16 µg/l is proposed here based on the above literature and MassDEP experience. This value falls between the Dodds et al. (1998) value and the EPA-derived values of 0.63 and 3.75 µg/l reported in Table C2 below.

Table C2 - Summary of EPA Statistically-Derived Nutrient Criteria for Massachusetts By Ecoregion and Waterbody Type (USEPA 2000 a,b,c,d; 2001 a,b).

Parameter	EPA Ecoregion VIII* Western Massachusetts	EPA Ecoregion XIV* Central & Eastern Massachusetts
Rivers and Streams		
Chlorophyll a (µg/l) (planktonic)	0.63	3.75

*All values based on 25th percentile all data

As noted previously, the EPA criteria are based on a frequency distribution and presumably include wadeable streams that are often very low in planktonic chlorophyll-*a*. Historically, such low levels of chlorophyll-*a* in the water column are not associated with impairments of uses in Massachusetts.

MassDEP Assessment Threshold: to support the designated uses of recreation and aesthetics, water column chlorophyll-a >16 mg/l in more than one monthly site visit during the primary contact recreation season (April 1-October 31) is considered an indicator of nutrient enrichment.

(3) Diel Changes in Dissolved Oxygen Concentration
See Section 3.2(a)(3) for the discussion of diel changes in dissolved oxygen.

MassDEP Assessment Threshold: to support the designated use of aquatic life, the diel change in dissolved oxygen greater than 3 mg/l during the summer growing season (May 1 to September 30), is considered an indicator of nutrient enrichment.

(4) Dissolved Oxygen Saturation
See 3.2(a)(4) for the discussion of DO saturation.

MassDEP Assessment Threshold: to support the designated use of aquatic life, a dissolved oxygen saturation equal to or greater than 125% in more than one site visit during the summer growing season (May 1 to September 30), is considered an indicator of nutrient enrichment.

(5) Elevated pH
See 3.2(a)(5) for discussion of pH.

MassDEP Assessment Threshold: to support the designated uses of recreation and aquatic life, a pH of >8.3 SU during the primary contact recreation and summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(6) Elevated Total Phosphorus (TP)
See 3.2(a)(6) for discussion of elevated TP.

MassDEP Assessment Threshold: When multiple biological and physico-chemical nutrient enrichment indicator screening assessment thresholds are exceeded, the summer seasonal average for TP exceeding 0.1 mg/l in flowing waters or exceeding 0.05 mg/l for rivers entering a lake or reservoir during the primary contact recreation and/or summer growing season (April 1 to October 31) is considered additional confirmation of a condition of nutrient enrichment.

(7) Frequency and Duration of Cyanobacteria Blooms
MassDEP does not provide a specific numerical screening guideline for detection of cyanobacteria blooms within surface waters. Instead, MassDEP tracks the frequency of cyanobacteria advisories placed on surface waters by the Massachusetts' Department of Public Health (MDPH). In 2007 MDPH issued a guidance outlining monitoring procedures for cyanobacteria and/or the toxins they produce designed to prevent adverse health effects before they reach levels of concern.

Cyanobacteria blooms occur most often in late summer or early fall. The most common types of blooming cyanobacteria are *Microcystis* and *Anabaena*, which may produce toxins called microcystin and anatoxin, respectively. If these cyanobacteria are ingested, the cell walls break down and the toxin may be released.

MDPH guidelines are designed to encourage action to be taken prior to exposure, thereby mitigating possible health concerns. The guidelines recommend various combinations of three monitoring methods, while cautioning that the measurement of the toxin is less feasible than conducting cell counts:

1. Observation of visible algae layer;
2. Total cell count of cyanobacteria (units of total cells/mL water); and/or
3. Concentration of cyanobacteria toxin (units of µg toxin/L of water).

Using World Health Organization's (WHO) research on cell counts and toxin levels, MassDPH determined that a cell count of 70,000 cells/mL would correspond to a toxin level of approximately 14 ppb which is the current guideline for contact recreational waters (MDPH 2007).

MassDEP Assessment Threshold: to support the designated uses of aquatic life, recreation and aesthetics, a surface water containing cyanobacteria at levels where the MDPH issues an advisory (i.e., at a cell count of 70,000 cells/mL or more, corresponding to a toxin level of approximately 14 ppb) generally more than once during the primary contact recreation and summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(c) Lakes, Ponds, and Impoundments (Generally >2m Depth)

Massachusetts is somewhat unusual for New England in that impoundments dominate the 'lake' types. Impoundments are differentiated from rivers by having standing water behind a dam, a lack of unidirectional flow, and an estimated detention time greater than 3 days. According to the state records of registered dams (MassGIS 2012) there are 2979 dams in the state and at least 1487 are located on 'lakes' listed among the 2951 lakes of the Pond and Lake Information System database (Ackerman 1989). Most of the natural, groundwater-fed seepage lakes are located in glacial outwash plains characterized by sandy areas along the coast and on Cape Cod, while impoundments and lakes with inlets are more frequently found farther inland.

The discussion in this section mentions data collected by EPA as a part of its Ecoregion sampling program. Combined for the ecoregions that include Massachusetts, EPA collected samples from 2,881 lakes and reservoirs from a total of 4,656 stations. Table C3 lists the total number of samples for each region.

(1) Secchi Disk Transparency

Particulate matter suspended in the water column (total suspended solids or TSS) attenuates light and reduces transparency. The suspended matter could consist of algae, algal detritus or inorganic sediment. Surface water may also have high concentrations of light-absorbing dissolved compounds that originate from wetland areas that border the waterbody. This type of surface water is often referred to as "tea-stained".

Historically, Massachusetts has used the 1.2 meter (4 foot) transparency standard for swimming beaches to assess *Primary Contact Recreation Use*. This visibility standard originated from the "Green Book" (USDI 1968) which stated that *"clarity in recreational waters is highly desirable [to provide] for visual appeal, recreational enjoyment, and safety".* For primary recreation*, "clarity should be such that a Secchi disc is visible at a minimum depth of 4 feet."* This threshold was used at the Massachusetts Department of Health (MassDPH) to reduce risk of injury from swimming. Because swimming is a designated use in nearly all waters, the 1.2 m Secchi disk was selected as a screening guideline for all lakes, ponds and impoundments where swimming is a use. This guideline is less than the 4.50-4.93 m proposed by the EPA based on the cumulative transparency frequency of lakes in the Ecoregions (see Table C4).

Table C3 - Lake Records for Aggregate Ecoregions VIII and XIV

Record	Aggregate Ecoregion VIII	Sub Ecoregion 58	Aggregate Ecoregion XIV	Sub Ecoregion 84	Sub Ecoregion 59
# of Lakes / Reservoirs	2,234	849	647	92	485
# of Lake Stations	3,746	1,898	910	100	602
# of records* for Secchi depth	82,656	24,451	14,581	79	13,174

Record	Aggregate Ecoregion VIII	Sub Ecoregion 58	Aggregate Ecoregion XIV	Sub Ecoregion 84	Sub Ecoregion 59
# of records* for Chlorophyll *a* (all methods)	21,223	11,478	5,977	73	4,548

**Note:* # of records refers to the total count of observations for that parameter over the entire decade (1990-1999) for that particular aggregate or subecoregion. These are counts for all seasons over that decade. # of lake stations refers to the total number of lake and reservoir stations within the aggregate or subecoregion from which nutrient data were collected. Since lakes and reservoirs can cross ecoregional boundaries, it is important to note that only those portions of a lake or reservoir (and data associated with those stations) that exist within the Ecoregion are included within this table. (USEPA 2001a and 2001b). Aggregate Ecoregion and SubecoRegions may include data from multiple states.*

Table C4 - Summary of EPA Statistically-Derived Secchi Disk Transparency for Massachusetts By Ecoregion and Waterbody Type (USEPA 2000a,b,c,d; 2001a,b).

Parameter	EPA Ecoregion VIII* Western Massachusetts	EPA Ecoregion XIV* Central & Eastern Massachusetts
Lakes and Impoundments		
Secchi Disk Transparency (m)	4.93*	4.50*

**Transparency based on 75th percentile of all data.*

The EPA Ecoregions include the natural deep lakes found in Maine, Vermont, and New Hampshire, whereas a large proportion of lakes in Massachusetts are shallow lakes and impoundments, with correspondingly higher trophic conditions (i.e., more eutrophic) and lower transparencies.

Where surface water inflows dominate, impoundments tend to be much shallower and smaller than natural lakes, with large watersheds and large surface area drainage ratios resulting in median retention times of only 8 days. Impoundments have lower Secchi disk transparencies than natural lakes of any type except for highly colored, tea stained/bog-type lakes.

Because of the prevalence of shallow lakes and impoundments that tend toward eutrophic conditions, a Secchi depth of 1.2 meters is appropriate for Massachusetts as an initial water quality guideline with regard to swimming use and as a potential indication of nutrient enrichment.

The use of the 1.2 meter Secchi screening guideline will not be effective in protecting the conditions of surface waters such as lakes with inlets and clear seepage lakes. The Antidegradation section of the Surface Water Quality Standards that relates to High Quality Waters (314 CMR 4.04(2)) and the associated Antidegradation Implementation Policy (10-21-2009) serves to protect these surface water types.

MassDEP Assessment Threshold: to support the designated uses of recreation and aesthetics for lakes, ponds and impoundments, if transparency is less than or equal to 1.2 meters during more than one site visit within the primary contact recreation season (April 1-October 31), it is considered an indicator of nutrient enrichment.

Note: Natural conditions exemptions to the 1.2 meter Secchi threshold apply to highly colored, humic waters. A site-specific screening guideline for these types of surface waters may be developed. A single exceedance of this threshold in a given site visit should not be enough to place the surface water on the impaired waters list.

(2) Non-Rooted Vegetation % Visual Coverage

Mats of non-rooted vegetation **("**scums") may form on lakes, ponds, and impoundments as a result of high nutrient concentrations. These scums may be due to floating, non-rooted macrophytes such as duckweed (*Lemna* sp. or *Wolfia* sp.) or may be due to algal scums formed by either green algae or blue-green algae (cyanobacteria) or some combination of the above. Impairment may be aesthetic or recreational, if for example, the lake is oligotrophic or mesotrophic, and duckweed cover is not expected nor desired. Some waterfowl such as ducks and geese use naturally eutrophic ponds, impoundments, and wetlands as important feeding sites, and as such, the presence of duckweed or patches of floating algae on such waters is not necessarily an impairment.

Dense continuous (100 percent) cover of duckweed is known to inhibit the growth of algae and submersed plants and may result in anoxia (Wolverton, 1986; Landolt 1986, cited in Ozbay, 2002; Leng et al., 1995). The minimum percent oxygen saturation in waters is known to be correlated negatively with percent cover of floating unattached plants and one study (Gee et al., 1997) suggests a coverage of 25% or less is associated with relatively high oxygen saturation. Impairment to aquatic life support may occur if the scum significantly inhibits oxygen exchange across the water surface and results in low dissolved oxygen.

MassDEP Assessment Threshold: to support the designated uses of recreation and aesthetics, if non-rooted vegetation exceeds 25% surface coverage in more than one site visit within the primary contact recreation season (April 1-October 31), it is considered an indicator of nutrient enrichment.

Note: Impairment of uses may occur at levels lower than 25 percent coverage if the lake is a coldwater fishery (typically oligotrophic), or if swimming is impaired or if the scum consists of toxic blue-green algae (cyanobacteria) in which case the waterbody could be considered impaired under the existing narrative standard. In the case of cyanobacteria blooms, swimming and contact recreation may be impaired if surface scum is present in the area of contact. The aesthetic screening guideline may be exceeded in some site-specific cases where duckweed accumulates on the downwind shorelines.

(3) Plankton as water column Chlorophyll-*a*

Chlorophyll-*a* is a commonly used indicator of algal biomass. The uses impaired by high chlorophyll-*a* (a measure of algal biomass) in the water column are likely to be swimming, aesthetics and biotic integrity. Unlike other uses, assessment of biotic integrity depends on the natural trophic conditions expected in the lake, and Massachusetts has a wide range of natural trophic conditions ranging from oligotrophic to eutrophic.

According to the general trophic classification, eutrophic lakes have mean chlorophyll-*a* of 14.3 µg/l and maxima of 42.6 µg/l, while mesotrophic lakes are expected to have chlorophyll-*a* maxima of 16.1 µg/l according to experienced investigators (Wetzel 2001). A threshold of 16 µg/l is proposed as an upper boundary for Massachusetts lakes as this would agree with typical eutrophic lakes and also roughly correspond to the Secchi disk transparency threshold of 1.2 m noted above.

The proposed threshold is higher than the 2.43-2.90 µg/l proposed by the cumulative frequency approach of the EPA (see Table C5).

Table C5 - Summary EPA Statistically-Derived Chlorophyll-*a* Criteria for Massachusetts By Ecoregion and Waterbody Type (USEPA 2000a,b,c,d; 2001a,b).

Parameter	EPA Ecoregion VIII* Western Massachusetts	EPA Ecoregion XIV* Central & Eastern Massachusetts
Lakes and Impoundments		
Chlorophyll-*a* (µg/l) (planktonic)	2.43	2.90

**All values based on 25th percentile all data*

While such low chlorophyll concentrations may be applicable to oligotrophic lakes (see Table 13-18 in Wetzel, 2001), they are not appropriate as a limit to maintain designated uses in shallow water impoundments commonly found in Massachusetts. The designated uses in Massachusetts include warm water fisheries that are inconsistent with such low chlorophyll-*a* levels. Future studies are planned to evaluate thresholds that may be needed for oligotrophic waters.

MassDEP Assessment Threshold: to support the designated uses of recreation and aesthetics, if planktonic chlorophyll-a exceeds 16 mg/l in surface waters in more than one site visit within the primary contact recreation season (April 1-October 31), it is considered an indicator of nutrient enrichment.

(4) Dissolved Oxygen Saturation

See 3.2(a)(4) for discussion of DO Saturation.

MassDEP Assessment Threshold: to support the designated use of aquatic life, a dissolved oxygen saturation exceeding 125% in more than one site visit during the summer growing season (May 1 to September 30), is considered an indicator of nutrient enrichment.

(5) Elevated pH
See 3.2(a)(5) for discussion of pH.

MassDEP Assessment Threshold: to support the designated uses of recreation and aquatic life, a pH of >8.3 SU in more than one site visit during the primary contact recreation and summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(6) Elevated Total Phosphorus (TP)
Phytoplankton blooms can occur in lakes having concentration as low as 0.01 mg/l TP (Gower 1980). Relatively uncontaminated lake districts contain water with TP concentrations ranging from 0.01-0.03 mg/l (Hutchinson, G.E. 1957). EPA's 1986a recommended "Gold Book" states that if TP concentrations exceed 25 µg/L (0.025 mg/L) in a lake or reservoir at the time of spring turnover it may stimulate excessive algae and plant growth (USEPA, 1986a). More recently, because both soil enrichment and precipitation are variable across the U.S., in 2000 EPA took an Ecoregion frequency approach to the TP criterion (USEPA 2000b). EPA recommended a TP criterion of 0.008 mg/l for lakes in both Massachusetts Ecoregions (USEPA, 2000d and USEPA, 2001a).

Because many biological, chemical, and physical characteristics influence whether a lake responds to certain levels of TP, MassDEP uses phosphorus concentrations as a confirming measurement when the weight of evidence points to nutrient enrichment. Specifically, when multiple biological and physico-chemical nutrient enrichment indicator thresholds are exceeded, then the summer seasonal average (greater than three samples) of the TP concentration data are screened against the USEPA's 1986a ("Gold Book') TP concentration or the applicable site-specific criteria in the SWQS.

MassDEP Assessment Threshold: When multiple biological and physico-chemical nutrient enrichment indicator screening assessment thresholds are exceeded, if the summer seasonal average for TP also exceeds 0.025 mg/L for lakes, ponds and impoundments or site-specific criteria in the SWQS during the primary contact recreation and/or summer growing season (April 1 to October 31), it is considered additional confirmation of nutrient enrichment.

(6) Frequency and duration of cyanobacteria blooms
See discussion of cyanobacteria blooms in section 3.2(b)(6).

MassDEP Assessment Threshold: to support the designated uses of aquatic life, recreation and aesthetics, a surface water containing cyanobacteria at levels where the MDPH issues an advisory (i.e., a cell count of 70,000 cells/mL or more, corresponding to a toxin level of approximately 14 ppb) generally more than once during the primary contact recreation and summer growing season (April 1 to October 31) it is considered an indicator of nutrient enrichment.

4.0 Potential Future Data and Indicators not used in the 2024 CALM:

Assessment thresholds for rooted aquatic plants as nutrient enrichment indicators were not developed. This is because the relationship between nutrients and plant abundance and biomass is influenced by many factors, some of which are natural. A key influence on the growth rate of rooted aquatic plants is the nutrient content in bottom sediments rather than the water column. As a result, rooted aquatics do not respond readily to fluctuation of phosphorus concentrations in the water column.

Secondary variables and response indicators that were considered but not included in the literature review were turbidity and predawn dissolved oxygen (DO). In addition, confounding variables such as canopy, flow, depth, hydrology and color, should be considered in the sub-classification of waters.
Trout space is a cold water characteristic for lakes, ponds, and impoundments that is monitored by MassDEP in selected waterbodies. MassDEP is developing physical and chemical thresholds for the management of lakes that may be designated as cold water in the future. In these lakes MassDEP may recommend the maintenance of a minimum depth of trout space, level of dissolved oxygen and a maximum temperature.

References

Ackerman, M. 1989. Compilation of Lakes, Ponds, Reservoirs and Impoundments Relative of the Massachusetts Clean Lakes Program. Mass. Div. Water. Pollut. Control. DEQE Westborough, MA.

Biggs, B. J. F. and Price, G. M. 1987. A Survey of Filamentous Algal Proliferations in New Zealand Rivers. N. Z. J. Mar. Freshwater Res. 21.175-191.

Biggs, B. J. F. 2000. New Zealand Periphyton Guideline: Detecting and Monitoring and Managing Enrichment of Streams. Ministry for the Environment, NIWA, Christchurch, June 2000.

Biggs, B. J. F. 2012. Personal communication e-mail dated November 4, 2012. B.J.F. Biggs to J. Beskenis.

Dodds, W. K., V. H. Smith, and B. Zander. 1997. Developing nutrient targets to control benthic chlorophyll levels in streams: a case study of the Clark Fork River. *Wat. Res*. Vol. 31 No 7. pp. 1738-1750.

Dodds, W. K. Jones, J. R. and Welch, E. B. 1998. Suggested classification of stream trophic state : distributions of temperate stream types by chlorophyll, total nitrogen, and phosphorus. *Wat.Res*. 32. pp.1455-1462.

Federal Interagency Stream Restoration Working Group (FISRWG 1998). Stream Corridor Restoration Principles, Processes, and Practices. EPA841_R_98_900 FISRWG 1998.

Gee, J.H.R., B.D. Smith, K.M. Lee, and S.W. Griffiths. 1997. The ecological basis of freshwater pond management for biodiversity. Aquatic Conservation: Marine & Freshwater Ecosystems 7:91-104.

Gower, A.M., 1980. *Ecological Effects of Changes in Water Chemistry*. Water Quality in Catchment Ecosystems. John Wiley & Sons Ltd. 1980. pp. 145-171

Griffith, G.E., et al. 2009. *Ecoregions of New England* (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,325,000).

Hutchinson, G.E. 1957. *A Treatise on Limnology*, v. 1. Geography, Physics and Chemistry. Wiley. 1015p.

Jones, Bill. 2011. *Oxygen—The Most Important Water Quality Parameter? The Water Column,* a Technical Publication of the Indiana Department of Environmental Management (IADEM). Vol. 23, No 1. Spring 2011.

Landolt. E. 1986. *The family of Lemnaceae – a monograph study*. Vol . I Morphology, karyology, ecology, geographic distribution, systemic position, nomenclature, descriptions. pp. 1-556. Zurich: Veroff Geobot. Inst. ETH, Stiftung, Rubel.

Leng. R.A. Stambolie, J.H., and R. Bell. 1995. *Duckweed – a potential high-protein feed resource for domestic animals and fish.* Livestock Research for Rural Development. Volume 7, Article#5. Retrieved September 2, 2015, from http://www.lrrd.org/lrrd7/1/3.htm.

MacKenthun**,** K. M. 1973. *Toward a Cleaner Aquatic Environment.* Environmental
Protection Agency, Office of Air and Water Programs. Washington, D.C. 273 p.

MADPH. 2007. *MDPH Guidelines for Cyanobacteria in Freshwater Recreational Waterbodies in Massachusetts*. Massachusetts Department of Public Health. Boston, MA

MassDEP. 2010a. *STANDARD OPERATING PROCEDURE Enumeration of Cyanobacteria in Water Samples.* CN 150.0. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

MassDEP. 2012. *2012 Environmental Progress Report: Clean Water – Surface Waters*. MassDEP Division of Watershed Management, 2012.

MassDEP. 2012a. *Massachusetts Nutrient Criteria Initiative: Analysis, Recommendations and Path Forward.* [*Draft*] MassDEP Division of Watershed Management.

MassDEP. 2021. *Massachusetts Surface Water Quality Standards* (effective November 12, 2021, corrected December 10, 2021 and January 7, 2022). Available at *https://www.mass.gov/regulations/314-CMR-4-the-massachusetts-surface-water-quality-standards,* Massachusetts Department of Environmental Protection, Boston, MA.

MassGIS. 2012. *MassGIS Data-Dams.* Database Compiled by the Massachusetts Office of Dam Safety (ODS), February 2012. https://docs.digital.mass.gov/dataset/massgis-data-dams.

Mathews, William J. 1998. *Stream Ecology and Limnology as Related to Freshwater Fishes,*
Springer Science & Business Media. Jan 31, 1998. pp.144-146.

Ozbay, H. 2002. *An Experimental Approach to Examining the Effect of Water Depth and Lemna minor L. on Algal Growth*. Turk. J. Bot. 26:5-11.

Sharpley, A., B. Foy, and P. Withers. 2000. Practical and innovative measures for the control of agricultural phosphorus losses to water: an overview. Journal of Environmental Quality 29(1):1-9.

Tucker, C.S. and D'Abramo, L.R. 2008. *Managing High pH in Freshwater Ponds.* Southern Regional Aquacultural Center (SRAC), Publication No. 4604. pp. 1-5.

US Department of the Interior (USDI). 1968. *Water Quality Criteria, (the "Green Book")*, Federal Water Pollution Control Administration, Report of the National Technical Advisory Committee to the Secretary of the Interior.

USEPA. 1976. *Quality Criteria for Water (the "Red Book")*, July 1976. Environmental Protection Agency, Washington DC.

USEPA. 1986a. EPA Quality Criteria for Water, (the "Gold Book")1986. EPA 440/5-86-001.

USEPA. 1986b. *Ambient Water Quality Criteria for Dissolved Oxygen*, April 1986. EPA 440/5-86-003. 39 pp.

USEPA. 1998. *National Strategy for the Development of Regional Nutrient Criteria.* EPA-
822-R-98-002. Washington, D.C., U. S. Environmental Protection Agency, Office of Water:
45.

USEPA. 2000a. *Nutrient Criteria Technical Guidance Manual. Rivers and Streams.* EPA-822-B-00-002. Environmental Protection Agency, Washington DC.

USEPA. 2000b. *Nutrient Criteria Technical Guidance Manual. Lakes and Reservoirs.* First Edition. EPA-822-B-00-001. Environmental Protection Agency, Washington DC.

USEPA. 2000c. *Ambient Water Quality Criteria Recommendations. Information supporting the development of state and tribal Nutrient criteria for Rivers and Streams in Nutrient Ecoregion XIV.* US Environmental Protection Agency, Office of Water, EPA 822-B-00-022.

USEPA. 2000d. *Ambient Water Quality Criteria Recommendations. Information supporting the development of state and tribal Nutrient criteria. Lakes and Reservoirs in Nutrient Ecoregion VIII*. US Environmental Protection Agency, Office of Water, EPA 822-B-01-010.

USEPA. 2001a. *Ambient Water Quality Criteria Recommendations. Information supporting the development of state and tribal Nutrient criteria. Lakes and Reservoirs in Nutrient Ecoregion XIV.* US Environmental Protection Agency, Office of Water, EPA 822-B-01-011.

USEPA. 2001b. *Ambient Water Quality Criteria Recommendations. Information supporting the development of state and tribal Nutrient criteria Rivers and Streams in Nutrient Ecoregion VIII*. US Environmental Protection Agency, Office of Water, EPA 822-B-01-015.

USEPA. 2002. *Summary Table for the Nutrient Criteria Documents.* US Environmental Protection Agency, 2002. 3 pp.

USEPA. 2021. Ambient Water Quality Criteria to Address Nutrient Pollution in Lakes and Reservoirs. US Environmental Protection Agency, Office of Water, EPA-822-R-21-005.

Weitcamp, DE., and Katz, M. 1980. *A Review of Dissolved Gas Supersaturation Literature.* Transactions of the American Fisheries Society L0 9:659-702. Copyright by the American Fisheries Society 1980. pp. 659-702.

Welch E. B., J.M. Jacoby, R. R. Horner, and M. R. Seeley. 1988. *Nuisance biomass levels of periphytic algae in streams.* Hydrobiologia. pp. 157, 161-168.

Wetzel, R.G. 2001. *Limnology. Lake and River Systems*. 3rd Ed. Acad. Press, San Diego. 1006 pp.

World Health Organization (WHO). 1999. *Toxic Cyanobacteria in Water: A Guide to Their Public Health Consequences, Monitoring and Management*. I. Chorus and J. Bartram editors. World Health Organization. Spon Press. London [as cited in MassDEP 2010a]

Wolverton, B.C. 1986. *Aquatic Plants and Wastewater Treatment* (An overview). Chapter I. Proceedings of a Conference on Res. And applications of Aquatic Plants for Water Treatment and Resource Recovery. Orlando FL. NASA-TM-108066. 18 pp.

Zurr, B. 1992. *Water quality Guidelines #1: Guidelines for the Control of Undesirable Biological Growths in Water*. New Zealand Ministry for the Environment. Wellington.

APPENDIX D
DERIVATION OF TEMPERATURE & DISSOLVED OXYGEN (DO) ASSESSMENT THRESHOLDS FOR USE IN MASSDEP/WPP 305B ASSESSMENTS

Background

There has been so much research on the effects of temperature and dissolved oxygen (DO) on aquatic organisms that it is "common knowledge" that these two variables play vital roles in determining the distribution of aquatic life in surface waters. Researchers have found that not only are there certain fish that need cold, well-oxygenated water to successfully move through their lifecycle, but other organisms also require these conditions. The latter includes certain macroinvertebrates. Although the documentation for this group is not as voluminous, it is building and others developing criteria for DO and temperature in the future should ensure that they familiarize themselves with this literature. Because there is so much research available for fish, this memo primarily utilizes that body of research.

In the past, temperature and DO criteria listed in the MA Surface Water Quality Standards (SWQS: 314 CMR 4.00) were used by WPP in 305(b) assessments to evaluate impairment. These criteria were established during a time when sampling equipment for these variables was limited to hand-held thermometers and bottles. Technological advances now allow for the deployment of measurement and recording equipment that can provide DO and temperature measurements many times per hour, can be left in place for months and the information can be downloaded from this equipment at the end of the deployment period, although it is important to verify that the equipment was submerged during the deployment. Information from these devices provides analysts with a fairly "continuous" dataset over an entire sampling season that allows for an evaluation of magnitude, duration and frequency of high-temperature and low-oxygen events, both of which can be detrimental to aquatic life.

The assessment thresholds for DO and temperature are, in some cases, different than the criteria in 314 CMR 4.00. New, longer-term datasets allow WPP staff to evaluate both acute (short-term) and chronic (longer-term) toxic events. The current SWQS criteria for these two variables are, in most cases, inadequate for this task. New thresholds are needed to allow for such assessments.

The assessment thresholds presented in this document were vetted by a group of WPP staff that met on a regular basis to review and improve the Consolidated Assessment and Listing Methodology (CALM) used to conduct 305(b) assessments.

Cold Water Temperature Thresholds

Regulatory Considerations:

There is a range of tolerance with regard to increasing summertime water temperatures among the different fish species considered to be "cold water fish". The MA Department of Fish and Game (DFG) has a list of cold water fish that it uses to develop its "cold water fishery resources", a list of streams considered by that agency to be important surface-water resources for cold water fisheries. The surface waters on that list that are not already designated as "Cold Water" in 314 CMR 4.00 are protected as cold water "Existing Uses" (see the definitions of Cold Water Fishery and Existing Uses at 314 CMR 4.02 and the description of the Cold Water qualifier at 314 CMR 4.06 (1)(d) 7). The protection of Cold Water Existing Uses extends to both the populations of fish found in those waters *as well as the protection of their habitat*. Thus, there does not need to be any determination that a population has deteriorated over time, only that the habitat does not meet criteria needed to support a Cold Water Fishery. If fish have to move from that habitat, the habitat would only meet a "partial use" as cold water habitat. These habitats would be considered to be degraded for the Cold Water Use. The same applies to "designated" (i.e., under 314 CMR 4.00) Cold Water surface waters. Moreover, *any* surface water that has held a population of cold water fish at any time since November 28, 1975, *even if that population has been extirpated since that time*, is protected as a Cold Water Existing Use under 314 CMR 4.00.

As a result of the considerations above, those conducting 305(b) assessments needed to consult:

1. GIS maps provided by MA DFG that depicted cold water fishery resources;
2. Tables 1-27 in the 314 CMR 4.00 which list and describe streams designated as Cold Water; and
3. fish sampling data from collections made on or after November 28, 1975

to determine which waterbodies should undergo 305(b) assessments for Tier 1 and Tier 2 Cold Water fish as described below. The reader should know also that both cold water fishery resources and designated Cold Waters receive protection under the stormwater section of 310 CMR 10.0 (the MA Wetlands Protection Act: see definitions for Cold Water Fisheries and Critical Areas in section 10.04 of that Act). Because so many cold water streams have been lost due to:

a) dams which slow water velocity and widen streams allowing for much greater solar input per unit of stream volume and per mile of stream length;
b) agricultural practices which remove shade from streamsides;
c) non-point runoff from impervious surfaces such as roads, parking lots, roofs and other surfaces impervious to rain which introduce heated water during rain events; and
d) point discharges,

much of the focus in developing temperature criteria for streams is the protection and restoration of existing Cold Waters. High temperature events considered to be “natural” (e.g., those resulting from the damming of waters caused by beaver activities) are not considered to be “impairments”.

Tier 1 and Tier 2 Cold Water Fish:

The CALM Committee developed different temperature assessment thresholds for each of two different groups of cold water fish. Because the Cold Water classification in 314 CMR 4.00 only applies to streams and rivers but not to lakes or ponds, we considered only the *fluvial* cold water fish species and assigned these to one of the following two categories based on their tolerance to high-temperature events:

Tier 1 cold water fish: brook trout (*Salvelinus fontinalis*); and slimy sculpin (*Cottus cognatus*); these are fluvial cold water fish species that need the coldest summertime temperatures for survival;

Tier 2 cold water fish: brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*) and all other species classified by MA DFG as cold water fish; these fish can survive slightly warmer temperatures than brook trout and slimy sculpin but still need cold summertime temperatures for survival.

A procedure for determining which MA-designated Cold Water streams and Existing Use Cold Water streams (further defined in the CALM) would be considered Tier 1 and Tier 2 was developed by the CALM Committee. Basically, if there were fish-community information from any stream to demonstrate that at some time after the Clean Water Act “Existing Use” clause took effect (i.e., after November 28, 1975) there were reproducing brook trout and/or slimy sculpin at the site in question, the site became a Tier 1 designated (if already designated as Cold Water in the SWQS) or Existing Cold Water Use stream. All other streams where there was evidence of reproducing cold water fish of any species other than brook trout or slimy sculpin were considered to be Tier 2 designated (if already designated as Cold Water in the SWQS) or Existing Cold Water Use streams. Streams were assessed according to the assessment thresholds in the category into which they fell.

Acute and chronic assessment thresholds, used to evaluate thermal habitat impairment, were developed for the two tiers of cold water fish and are discussed below. To calculate the acute thresholds, formulae developed by EPA (1977) were used and listed by species in Appendix B (Thermal Tables) of that document. EPA’s basic formula for the TL50 (50% kill of exposed organisms) is:

Log10(time in minutes) = a +b (Temperature as °C)

Where: **a** and **b** are constants (provided in the 1977 document referenced above, that were derived from multiple toxicity tests on the organism in question); and

Temperature (as °C) is the temperature that will kill 50% of the organisms exposed for the **time in minutes** listed.

The time estimates in minutes provided for each TL50 apply only to the particular Acclimation Temperature chosen, and EPA warns that its species-specific formulae in Appendix B should only be used within the Temperature Data Limits listed (in EPA, 1977) for those species. EPA based its acute toxicity formulae on laboratory toxicity tests in which fish were first acclimated to a certain temperature and then stressed with higher temperatures. The 24- hr. (i.e., 24-hr. exposure) No Observed Effect Level (NOEL, i.e., just below the point where toxicity is expected) was estimated by subtracting 2°C from the approximate 24-hr. TL50 as recommended by EPA (1977).

In developing the cold-water chronic recommended criteria EPA (1977) looked at growth of exposed fish and compared this growth to fish kept at optimal-growth temperatures. We used EPA's results and other information for the chronic thresholds below.

Tier 1 Acute Threshold = 23.5°C as a 24-hr. average not to be exceeded: This threshold was taken from data and formulae relating to brook trout (from a hatchery in PA) in EPA (1977). Exposures to temperature/duration combinations beyond those specified by this threshold are expected to be toxic to juvenile brook trout. As a result, even a one-time occurrence of this threshold should result in a judgment of "impairment" to cold water habitat in 305(b) assessments if the high-temperature event is thought to be due to un-natural (i.e., anthropogenic) sources.

Tier 1 Chronic Threshold = **20°C as a 7-day average of the daily maximum temperatures (allowable exceedances <u><</u>11)**. This threshold is the same as the criterion for Cold Water found in 314 CMR 4.00 and applies to Tier 1 cold water habitat unless the high-temperature events are deemed to be due to natural causes. The number of allowable exceedances was based on considerations outlined below.

The SWQS uses the following phrase to define the temperature regime for Cold Water:

> <u>*Cold Water Fishery*</u>*. Waters in which the mean of the maximum daily temperature over a seven day period generally does not exceed 68°F (20°C) and, when other ecological factors are favorable (such as habitat), are capable of supporting a year-round population of cold water stenothermal aquatic life such as trout (Salmonidae).*

Note the term "generally" implies that a Cold Water Fishery does not *always* have to meet the 20°C maximum. The CALM group reviewed how other states handled assessment data relative to their SWQS criteria. Many of those reviewed allow 10% exceedances of their criterion prior to making a judgment of "impaired". This approach would make little sense with reference to temperature, however, if the analyst were to review data for an entire year, and the CALM Committee had to determine what period of time was reasonable to evaluate in assessing impairment. We reviewed our long-term temperature datasets from a subset of streams considered to be high-quality Cold Water streams (based on fish population surveys) and found that if exceedances occurred, they primarily took place in July and August but some also occurred in early June and into the first couple of weeks in September. Based on this information, we decided to calculate 7-day rolling average temperatures (one for each 7-day period: i.e., day 1-7, day 2-8, day 3-9, etc.) for each 7-day period over the June 1-Sept. 15 time period and to use a 10% exceedance threshold for making impairment decisions. This threshold (and, for that matter, all the thresholds described in this document) may change in the future based on new information and/or new considerations.

Tier 2 Acute Threshold = 24.1°C as a 24-hr. average not to be exceeded: Based on our literature review, brown trout (*Salmo trutta*) is the fish species that is the most sensitive to high water temperatures of all the fluvial cold water fishes in MA exclusive of brook trout and slimy sculpin. Although brown trout are not native to Massachusetts, and stocking of streams with brown trout by MA DFG is controversial for this reason, they have become important to fishermen in MA and are one of the species used by MA DFG to delimit its "cold water fishery resources". The acute threshold listed above was developed from EPA (1977) as described above using that document's formula for 24-hr. acute toxicity to brown trout at an acclimation temperature of 20°C. Any temperature/duration exposures in combinations greater than the 24.1°C value as a 24-hr. average are expected to be acutely toxic to brown trout. As a result, even a one-time excursion of this threshold should result in a judgment of "impairment" to Tier 2 cold water fish habitat in 305(b) assessments if the high temperature event is considered to be due to un-natural (i.e., anthropogenic) sources.

Tier 2 Chronic Threshold = 21.0°C as a 7-day average of the daily average temperatures; allowable exceedances <u><</u>11. This threshold was based on best-professional judgment after a review of EPA 1973, EPA 1977 and an un-published collection of published literature values used by the state of Colorado in setting their criteria for Tier II Cold Water Streams. The allowable number of exceedances of this threshold was based on the ideas expressed for the Tier 1 chronic threshold. As with other thresholds, the assessment of "impairment" only applies when the high temperature events are considered to be due to non-natural causes.

<u>Warm Water Temperature Thresholds</u>

The CALM committee reviewed thermal toxicity information for five fluvial fish species found in MA: common shiner (*Luxilus cornutus*), long-nose dace (*Rhinichtys cataractae)*, creek chubsucker (*Erimyzon oblongus*), redfin pickerel (*Esox americanus americanus*) and white sucker (*Catostomus comersoni*). Based on literature reviewed, white sucker is the most thermally-sensitive fluvial fish species of those above. None of these fish species is listed as a cold water species by MA DFG. By default these species fall into the warm water fish category. White suckers are a native species and are fairly ubiquitous in Massachusetts. We set our thresholds to be protective of this species. As more thermal-toxicity information becomes available for other MA fluvial fish not found to be cold water species, WPP should review that information to ensure that the thresholds developed using this species are protective for other fluvial warm-water species in MA.

Acute Threshold = 28.3°C as a 24-hr. average not to be exceeded: This threshold was developed using the EPA (1977) formula and an acclimation temperature of 25°C. Based on these specifications, an NOAEL of 28.4 would have resulted from a 23-hour exposure, so we subtracted 0.1°C from that value to yield an approximate NOAEL for a 24-hr. exposure. As with the other acute thresholds described above, even one-time exposures to temperature/duration combinations above this threshold are expected to result in acute toxicity to adult white suckers and should result in a judgment of "impairment" in 305(b) assessments of warm-water streams if the high-temperature event is judged to be due to un-natural (i.e., anthropogenic) causes.

Chronic Threshold = 27.7°C as a 7-day average of the daily maximum temperatures (allowable exceedances = ≤11. EPA (1977) provides a maximum weekly average temperature value of 27.8°C for white sucker. The state of Colorado (unpublished) provided a number of additional references beyond that of EPA and arrived at a temperature of 27.7°C for a maximum weekly average temperature which we chose for this application. The number of allowable exceedances was based on considerations outlined in the Tier 1 cold water chronic threshold discussion.

Dissolved Oxygen (DO) Thresholds

Tables 1 and 2 and text from EPA's 1986 water quality criteria document (section on dissolved oxygen, EPA, 1986) were used to develop DO-assessment thresholds for MA streams. The 2016 CALM assessment thresholds for DO are listed below:

	Cold Water Thresholds	**Warm Water Thresholds**	
	Other Life Stages	**Early Life Stages*** *(assume present through July in MA coastal streams)*	**Other Life Stages**
30 Day Mean	8.0	NA	6.0
7 Day Mean	NA**	6.5	NA
7 Day Mean Minimum	6.0	NA	5.0
1 Day Minimum***	5.0	5.0	4.0

** Anadromous fish runs present*
***NA (not applicable)*
****All minima should be considered as instantaneous concentrations to be achieved at all times.*

Oxygen saturation in water varies with temperature and high temperature events in streams typically result in low oxygen concentrations. Because of this link between these two variables, the CALM committee decided to use the June 1- Sept. 15 index period for evaluating low DO in streams as this was the period found most likely to result in high temperature events. EPA (1986) reviewed information from "early life stages" (i.e., eggs, larvae, and juvenile stages up to 30 days following hatching) of fish and from "other life stages" (i.e., juveniles 30 days or more following hatching and adults) of fish and developed recommended criteria for each. Eggs and larvae of brown trout, rainbow trout and brook trout are not typically found in MA streams over the June-Sept. 15 period. As a result, cold water DO assessment thresholds for "early life stages" were not developed. In the future, WPP should review egg/larval seasonal presence for other species besides those mentioned to ensure that cold water thresholds should not also be considered for early life stages in the summer months. The term "production impairment", the studies that were used to develop this term, and the DO values associated with each risk level are described fully in EPA 1986a.

Cold Water Thresholds

A 30-day mean of 8.0 mg/l for "other life stages" (i.e., life stages other than early life stages) was chosen after considering the information in EPA's (1986) Table 2 which notes that both salmonids and invertebrates had "no production impairment" at DO levels of 8.0 mg/l and above. The CALM committee also reviewed DO information from streams in the Deerfield River Basin, which contains many cold water streams known to produce fairly high-quality fish and invertebrate samples. Long-term DO concentrations from cold water streams in that basin rarely fell below 8.0 mg/l.

The 7-day mean minimum (mean of each day's minimum DO value) threshold **for "other life stages"** (see above) chosen **was 6.0 mg/l**. Invertebrates showed some production impairment at a DO concentration of 5 mg/l and none at DO concentration of 8 mg/l; salmonids were not impaired at a DO concentration near 8 mg/l and showed "moderate production impairment" at a DO concentration around 5 mg/l or less. Unpublished information from MA fish population records showed that the highest densities of cold water fish were typically found in water with DO values >6 mg/l.

A 1-day minimum threshold **of 5 mg/l** was chosen **for "other life stages"** (see above) based EPA's (1986) use of this figure in Table 1 and on information in Table 2 of that document. Table 2 (EPA, 1986) notes that "some" production impairment of invertebrates" and "moderate" production impairment of salmonids" were found at DO values around 5 mg/l.

Warm Water Thresholds

Early life stages of certain warm water fish are found during the June 1-Sept. 15 period prompting the need to develop DO assessment thresholds for both "early" and "other" life stages.

The 7-day mean for early life stages of warmwater fish chosen for a threshold is 6.5 mg/l. This is slightly higher than the criterion (6.0 mg/l) recommended by EPA (Table 1; EPA, 1986). EPA's Table 2 lists "no production impairment" at DO near 6.5 mg/l. EPA did not have a recommendation for the 30-day mean category for early life stage warmwater fish, and the CALM committee felt that, absent any 30-day average recommendation from that agency, at least one of the threshold categories should reflect a "no impairment" status.

A 1-day minimum threshold for early, warmwater life stages of 5 mg/l is the same as that in EPA's Table 1 (EPA, 1986) for this category. Moderate production was found at DO concentrations around 5 mg/l and below and slight production impairment was found at DO concentrations around 5.5 mg/l. "Some" production impairment to invertebrates was found at DO concentrations near 5 mg/l.

A 30-day mean threshold for "other" life stages of warmwater fish of 6.0 mg/l is 0.5 mg/l higher than that in EPA's Table 1 (EPA, 1986) for this category. We chose this value to correspond to a "no production impairment" value (as we had for the cold water 30-day mean threshold) which is supported by EPA's Table 2 (EPA, 1986) recommendation for this category.

A 7-day mean minimum threshold for "other life stages" of warmwater fish of 5.0 mg/l is 1.0 mg/l higher than EPA's recommendation. EPA's Table 2 (EPA, 1986) shows "slight" production impairment to "other life stages" of warmwater fish at DO values near 5.0 mg/l and "some" production impairment to invertebrates at DO values near 5.0 mg/l. EPA's recommendation of 4.0 mg/l for this category appeared to be much too low to the CALM Committee as it was listed as the "Acute Mortality Limit" for invertebrates in EPA's Table 2.

The 1-day minimum threshold for warmwater fish of "other life stages" is 4.0 mg/l. EPA (Table 2, EPA 1986) found "moderate production impairment" to warmwater fish of "other life stages" at this DO concentration and, as mentioned above, this is the Acute Mortality Limit (EPA, 1986, Table 2) for invertebrates.

Note:
This appendix was developed by Gerald M. Szal, WPP Aquatic Ecologist in September 2015. The appendix was then updated in November 2023. Updates were related to terminology (i.e., replacing "criteria" with "thresholds" as necessary).

Literature Citations:

EPA. 1973. Ecological Research Series; Water Quality Criteria, 1972. EPA/R3/73/033/March 1973.
EPA. 1977. Temperature Criteria for Freshwater Fish: Protocol and Procedures. EPA600/3-77-061. May 1977.
EPA. 1986. Quality Criteria for Water. EPA 440/5-86-001. May 1, 1986.
EPA. 1986a. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003. April 1986.

APPENDIX E
FRESH WATER METALS DATA COMPARISONS TO WATER QUALITY CRITERIA

The following is guidance related to evaluations of Toxic Metals.
The Massachusetts Surface Water Quality Standards (SWQS) numerical criteria for metals contain two expressions of allowable magnitude: Criterion Maximum Concentrations (CMC) and Criterion Continuous Concentrations (CCC). Their definitions are the following:

- The **CMC** is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect.
- The **CCC** is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.

The CMC and CCC are just two of the six parts of an aquatic life criterion; the other four parts include the following:

- acute averaging period,
- chronic averaging period,
- acute frequency of allowed exceedance, and
- chronic frequency of allowed exceedance.

To simplify comparisons, “Toxic Units” (TUs) are developed using the ratio of the pollutant concentration to the calculated criterion. The TU calculation also provides the relative magnitude of the exceedance, which together with frequency and duration of exceedances, are important factors in evaluating toxicants.

WPP analysts use an Excel spreadsheet (*CN 101.8 - SOP_MetalsCriteriaCalculations_2021.xls* dated February 2022) with embedded equations to calculate hardness-dependent freshwater criteria values for certain metals. Additionally, updated aluminum and copper criteria calculation methodologies have been adopted that take precedence over the use of these hardness dependent equations and are described in detail below.

Aluminum
EPA’s Aluminum Criteria Calculator V.2.0 (the Calculator) should be used to calculate site-dependent acute and chronic criteria values[1] when sufficient concurrently-collected DOC[2], pH, and total hardness[3] data are available. Each concurrent set of inputs (DOC, pH, and total hardness) produces outputs of instantaneous CMC and CCC criteria values for total recoverable aluminum. When 10 or fewer sets of calculated criteria outputs are available for a site (which may be defined as a single location, or as a collection of locations within an AU given similar natural and land use characteristics), the lowest acute and chronic criteria values are the site-dependent criteria, used to compare against aluminum concentrations and provide the most protection for aquatic life possible (for data sets with limited variability). For sites with >10 sets of calculated criteria outputs, a statistical process is used to determine the final site-dependent criteria values (i.e., the 5th percentile of criteria values for watersheds/watershed groups containing state/federal endangered species of freshwater mussels or sturgeon (Atlantic, shortnose); the 10th percentile of criteria values for other watersheds/watershed-groups). The ranges of acceptable inputs to the Calculator are as follows, but when data are outside these ranges, the Calculator will default to the closest minimum or maximum (e.g., if DOC is 0.06 mg/L, the Calculator will use 0.08 mg/L in the calculation) (MassDEP 2021a):

Input Parameter	Aluminum Calculator Range
pH (SU)	5.0 – 10.5
DOC (mg/L)	0.08 – 12.0
Total Hardness (mg/L)	0.01 – 430

[1] To access the Aluminum Criteria Calculator, visit “314 CMR 4: The Massachusetts Surface Water Quality Standards”, scroll down to the Software section, and click on the “*Aluminum Criteria Calculator, V.2.0*” link for the Excel version. For the R version of the Calculator, visit EPA’s “Aquatic Life Criteria - Aluminum” website and scroll down to the “*Aluminum Criteria Calculator R Code and Data v2.0 (Zip)*” link.
[2] To convert TOC to DOC, use the following conversion equation developed by USGS and presented in (MassDEP 2021a):

$$DOC\left(\frac{mg}{L}\right) = 0.858 * TOC\left(\frac{mg}{L}\right) - 0.196$$

[3] Total hardness is based on a calculation using dissolved calcium and magnesium values.
(see CN 101.8 -SOP_MetalsCriteriaCalculations_2021.xls dated October 2021)

When sufficient input data are not available to utilize the Calculator, watershed or watershed-group default freshwater aluminum criteria are applied, as presented in Table E1 below (MassDEP 2021b). For the two watersheds without default criteria (Cape Cod Coastal and Islands Coastal), criteria comparisons cannot be conducted unless sufficient concurrently collected data are available to use the Calculator.

Table E1. Default Fresh water Aluminum Criteria by Watershed (River Basin or Coastal Drainage Area)‡*

River Basin or Coastal Drainage Area	Acute Criterion Maximum Concentration or CMC (µg/L)	Chronic Criterion Continuous Concentration or CCC (µg/L)
Blackstone	532	262
Boston Harbor/Charles	978	380
Buzzards Bay/Mt Hope Bay/Narragansett Bay/Ten-Mile	451	230
Cape Cod Coastal*	--	--
Chicopee (5th percentile)	290	170
Connecticut (5th percentile)	600	290
Deerfield	440	220
Farmington/Westfield (5th percentile)	299	169
French/Quinebaug	570	0.270
Housatonic/Hudson	1400	515
Ipswich/North Coastal/Parker	932	396
Islands Coastal*	--	--
Merrimack/Shawsheen (5th percentile)	460	249
Millers	329	200
Nashua (5th percentile)	368	200
South Coastal	1200	460
Sudbury, Assabet, and Concord (SuAsCo)	940	394
Taunton (5th percentile)	300	190

† Defaults are based on 10th percentile criteria calculated from concurrent pH, DOC, and total hardness data, except watersheds marked as 5th percentile to protect state and federal endangered species.
** Insufficient data are available to calculate watershed-based default criteria.*

Copper

Site-specific freshwater copper criteria (acute 25.7 µg/L, chronic 18.1 µg/) in the SWQS (MassDEP 2021b) for certain waterbody segments (see Table E2) have been approved by EPA. Dissolved copper concentrations in these waters can be compared directly to these criteria, and where copper exceedances (i.e., TUs >1) are found, they may result in an impairment decision (see guidance for Toxic Pollutants and Table 4 of the CALM).

In waters where these site-specific freshwater copper criteria do not apply, available copper data are compared to criteria values calculated using the Copper Biotic Ligand Model (BLM) V 2.2.3 software[1] and applicable statistical approach (applicable only if sufficient data for the input parameters are available for use in the BLM; input parameters include alkalinity, calcium, chloride, DOC[2], magnesium, pH, potassium, sodium, sulfate, and temperature). The input data for the BLM may be collected from a single location, or from a collection of locations within an AU given similar natural, land use, and temporal characteristics. While concurrently collected data are not required for the BLM method, the BLM provides instantaneous acute and chronic water quality criteria value outputs, similar to the Aluminum Criteria Calculator. To generate final site-dependent copper criteria with 10 or fewer sets of criteria outputs, the lowest acute and chronic criteria values are the site-dependent criteria and will be used to provide the most protection for aquatic life possible (for data sets with limited variability). With >10 sets of criteria outputs for a site, statistical procedures (i.e., the lowest 5th percentile for watersheds or watershed-groups containing state/federal endangered species; the lowest 10th percentile for other watersheds/watershed-groups) must be employed.

If sufficient data are not available for the BLM input parameters, the final option for generating site-dependent copper criteria values is to use the hardness-based equations in Table E3.

[1] To access the copper Biotic Ligand Model software, visit "314 CMR 4: The Massachusetts Surface Water Quality Standards", scroll down to the Software section, and click on the "*Copper Biotic Ligand Model, V. 2.2.3*" link.
[2] Note: TOC can be converted to DOC using the equation presented in Footnote 2 of the aluminum discussion above.

Zinc

Site-specific zinc criteria (Acute: 167.2 µg/L at 60 mg/L hardness; Chronic: 168.6 µg/L at 60 mg/L hardness) should be used for the Squannacook River (Nashua River Basin), where applicable (MassDEP 2021b). For all other surface waters, the hardness-based equations in Table E3 should be used to calculate site-dependent zinc criteria values.

Other Metals/Metalloids Commonly Sampled by WPP

WPP analysts use an Excel spreadsheet (CN 101.8 - SOP_MetalsCriteriaCalculations_2021.xls updated February 2022) to calculate freshwater criteria for metals/metalloids commonly sampled for by WPP. This SOP spreadsheet contains embedded formulas to calculate hardness-dependent criteria values for certain metals (e.g., cadmium, copper, lead), and formulas or constants for conversion factors to calculate total-to-dissolved criteria values. Sample-specific hardness data are used to calculate the actual CMC and CCC criteria. For illustrative purposes, only, a hardness of 10 mg/L was used to calculate the hardness dependent criteria shown in Table E3. For other metals/metalloids that are not hardness dependent (e.g., arsenic, chromium VI), criteria and total-to-dissolved conversion factors are also provided. For metals with criteria expressed as total, both the total criteria and the calculated dissolved criteria are provided.

Table E2. Site-Specific Copper Criteria (as dissolved fraction) in the SWQS (MassDEP 2021b): Acute 25.7 µg/LChronic 18.1 µg/L

Watershed	Waterbody Name	Waterbody Description
BLACKSTONE RIVER BASIN	Blackstone River	From the Upper Blackstone POTW discharge to the MA-RI state line (river mile 45.2 to 20.0)
	Mumford River	From the Douglas POTW discharge to confluence with the Blackstone River (river mile 9.0 to 0.0)
	West River	From the Upton POTW discharge to confluence with Blackstone River (river mile 8.8 to 0.0)
BUZZARDS BAY COASTAL DRAINAGE AREA	Unnamed Brook	The unnamed brook located approximately 1/4-mile northeast of and parallel to Aucoot Creek, from the Marion POTW discarge in Marion to confluence with Aucoot Cove (river mile 0.75 to 0.0)
CHARLES RIVER BASIN	Charles River	From the Milford POTW discharge to the Watertown Dam (river mile 73.4 to 9.8)
	Stop River	From MCI-Norfolk Water Pollution Control Facility discharge to confluence with Charles River (river mile 4.4 to 0.0)
CONNECTICUT RIVER BASIN	Bachelor Brook	River mile 12.4 to 0.0 (its mouth at the confluence with Connecticut River, South Hadley)
FRENCH RIVER BASIN	French River	River mile 27.3 to 7.0 (at the MA-CT state line, Dudley/Webster)
HUDSON RIVER BASIN	Hoosic River (South Branch Hoosic River)	From Adams POTW discharge to confluence with the North Branch Hoosic River, North Adams (river mile 15.4 to 10.3)
HOUSATONIC RIVER BASIN	Housatonic River	From Pittsfield POTW discharge to the MA-CT state line, Sheffield (river mile 50.9 to 0.0)
IPSWICH RIVER BASIN	Unnamed tributary (Greenwood Creek)	From Ipswich POTW discharge to confluence with the Ipswich River, Ipswich (river mile 0.7 to 0.0)
NASHUA RIVER BASIN	North Nashua River	River mile 36.5 to 0.0 (its mouth at the confluence with the Nashua River, Lancaster)
	Nashua River (South Branch)	The portion of the Nashua River from its confluence with the North Branch Nashua River, Lancaster, to 3.3 miles upstream, Clinton
QUINEBAUG RIVER BASIN	Cady Brook	From the Charlton POTW discharge to confluence with the Quinebaug River, Southbridge (river mile 5.1 to 0.0)
	Quinebaug River	River mile 19.7 to 7.9 (at the MA-CT state line, Dudley)
SOUTH COASTAL DRAINAGE AREA	French Stream	River mile 3.3 to 0.0 (its mouth at the confluence with the Drinkwater River, Hanover)
SUASCO RIVER BASIN	Assabet River	River mile 30.4 to 0.0 (its mouth at the confluence with the Sudbury River, Concord)
TAUNTON RIVER BASIN	Nemasket River	River mile 5.5 to 0.0 (its mouth at the confluence with the Taunton River, Middleborough)
	Salisbury Plain River	River mile 2.0 to 0.0 (its mouth at the confluence with Beaver Brook, both surface waters forming the headwaters of the Matfield River, East Bridgewater)
	Three Mile River	River mile 6.0 to 0.0 (its mouth at the confluence with the Taunton River, Dighton/Taunton)
	Town River	River mile 2.2 to 0.0 (its mouth at the confluence with the Matfield River, both surface waters forming the headwaters of the Taunton River, Bridgewater)
TEN MILE RIVER BASIN	Ten Mile River	River mile 14.0 to 0.0 (at the MA-RI state line, Seekonk)
WESTFIELD RIVER BASIN	Westfield River	River mile 10.8 to 0.0 (its mouth at the confluence with the Connecticut River)

Table E3. Fresh water Metals Aquatic Life Criteria (as dissolved fraction, unless otherwise stated)
Updated 2/2022 (to reflect Table 29a at 314 CMR 4.06(d) in the SWQS, MassDEP 2021b) with minor edits in 10/2021 and 2/2022

Use best-available hardness data (no lower limit); max=400 mg/L	*italics = not hardness dependent*	**Example Calculation:**	HARDNESS (mg/L as CaCO3) =2.497*Ca + 4.118*Mg		
		Example Inputs & Hardness Result:	**Ca (mg/L)**	**Mg (mg/L)**	**HARDNESS (mg/L) =**
			1.9	1.2	9.8

Step 1: Enter hardness value		**Step 2: Use calculated CMC and CCC values**		**Conversion Factors**		**Notes**
Metal	Enter Hardness	CMC (Criteria Maximum Concentration) **including conversion**, µg/L	CCC (Criterion Continuous Concentration), **including conversion**, µg/L	CMC Conversion Factor (CF) used in the hardness-based equation to convert to a dissolved criterion	CCC Conversion Factor (CF) used in the hardness-based equation to convert to a dissolved criterion	
	mg/L as CaCO3	*acute*	*chronic*	*acute*	*chronic*	
Cadmium	10	**0.21**	**0.13**	1.040	1.005	Equations based on 2016 Cd Criteria
Chromium III	10	**86.44**	**11.24**	*0.316*	*0.860*	Equations based on 2002 Cr III Criteria
Copper [1]	10	**1.54**	**1.25**	*0.960*	*0.960*	Equations based on 2002 Cu Criteria
Lead	10	**4.91**	**0.19**	1.127	1.127	Equations based on 2002 Pb Criteria
Nickel	10	**66.75**	**7.41**	*0.998*	*0.997*	Equations based on 2002 Ni Criteria
Silver	10	**0.06**	**NA**	*0.850*	--	Equations based on 2002 Ag Criteria
Zinc [2]	10	**16.66**	**16.79**	*0.978*	*0.986*	Equations based on 2002 Zn Criteria
Arsenic (as total)	*NA*	***340***	***150***	*1.000*	*1.000*	From 2002 As Criteria
Mercury [3]	*NA*	***1.4***	***0.77***	*0.850*	*0.850*	From 2002 Hg Criteria
Chromium VI	*NA*	***16***	***11***	*0.982*	*0.962*	From 2002 Cr VI Criteria
Selenium (as total) [4]	*NA*	***NA***	***5 (4.61 dissolved)***	*0.996*	*0.922*	From 2002 Se Criteria (2016 EPA criteria have not been adopted by MassDEP)
Aluminum (as total recoverable)	*EPA's Aluminum Criteria Calculator should be used to calculate site-dependent acute and chronic criteria values when sufficient concurrently-collected DOC, pH, and total hardness data are available. When sufficient input data are not available, watershed or watershed-group default freshwater aluminum criteria should be used as applicable. See Metals Criteria Calculations SOP CN 101.8 for more information (MassDEP 2022).*					

[1] The hardness-based Cu equations should be used ONLY if 1) there are no site-specific criteria that apply or 2) for all other waters, if sufficient input data are not available to use the BLM.
[2] The hardness-based Zn equations should be used ONLY if there are no site-specific criteria that apply.
[3] These are water column criteria for Hg, not fish tissue-based criteria for methyl-Hg.
[4] For the selenium acute criteria, the equation to calculate the CMC requires that both fractions be measured (selenate and selenite). Since these fraction data are neither available nor advised, no evaluations of acute selenium toxicity will be made as part of the 2022 reporting cycle. Use of the water column chronic criteria for selenium should be used with caution. See Metals Criteria Calculations SOP CN 101.8 for more information (MassDEP 2022)

References:

MassDEP. 2021a. *Fresh Water Aquatic Life Water Quality Criteria for Aluminum: Application of the Aluminum Criteria Calculator for National Pollutant Discharge Elimination System (NPDES) and Massachusetts Surface Water Discharge (SWD) Permits*. CN 560.0. Division of Watershed Management, Massachusetts Department of Environmental Protection. Worcester, MA.

MassDEP. 2021b. *Massachusetts Surface Water Quality Standards (Revision of 314 CMR 4.00, effective November 12, 2021, corrected December 10, 2021 and January 7, 2022)*. Massachusetts Department of Environmental Protection. Boston, MA.

MassDEP. 2022. *SOP for calculating freshwater metals Aquatic Life Criteria. CN 101.8*. Division of Watershed Management, Massachusetts Department of Environmental Protection. Worcester, MA.Appendix F (Updated) Development of a Linear Regression Tool for Estimating Chloride Concentrations in Freshwaters of Massachusetts

APPENDIX F
DEVELOPMENT OF A LINEAR REGRESSION TOOL FOR ESTIMATING CHLORIDE CONCENTRATIONS IN FRESHWATERS OF MASSACHUSETTS

March 2023

CN# 583.0

Prepared by:
Mason Saleeba, Richard Chase, Shervon De Leon and Peter Mitchell

Watershed Planning Program
Division of Watershed Management, Bureau of Water Resources
Massachusetts Department of Environmental Protection

Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
Rebecca L. Tepper, Secretary
Massachusetts Department of Environmental Protection
Bonnie Heiple, Commissioner
Bureau of Water Resources
Kathleen M. Baskin, Assistant Commissioner

Summary

For assessment purposes and to better determine the potential chloride impairments in fresh surface waters, MassDEP analysts updated their linear regression model to estimate chloride concentrations from Specific Conductance (SC) measurements. This updated (recalibrated) linear model was developed by the Watershed Planning Program using a total of 8,473 paired SC and chloride data points collected at 1,108 inland freshwater stations across Massachusetts (Figure F1). 3,700 of the paired data points were generated by the Massachusetts Department of Environmental Protection Watershed Planning Program (MassDEP WPP) from 1995 to 2020 across 525 stations. The MassDEP WPP dataset was supplemented with 4,773 paired data points generated by the United States Geological Survey (USGS) from 1952 to 2020 across 583 stations.

The resulting linear regression equation for estimating chloride concentrations is:

$$y = 0.3361\,x - 39.011$$

where:

y represents chloride concentration (mg/L)

x represents specific conductance (µS/cm)

Based on this linear regression equation, instantaneous exceedances of the acute and chronic chloride criteria are estimated to occur at specific conductance readings greater than 2,675 and 800 µS/cm, respectively. Applying a 10% safety factor to SC measurements to account for cumulative uncertainty in the model, this equates to approximately 2,940 and 880 µS/cm.

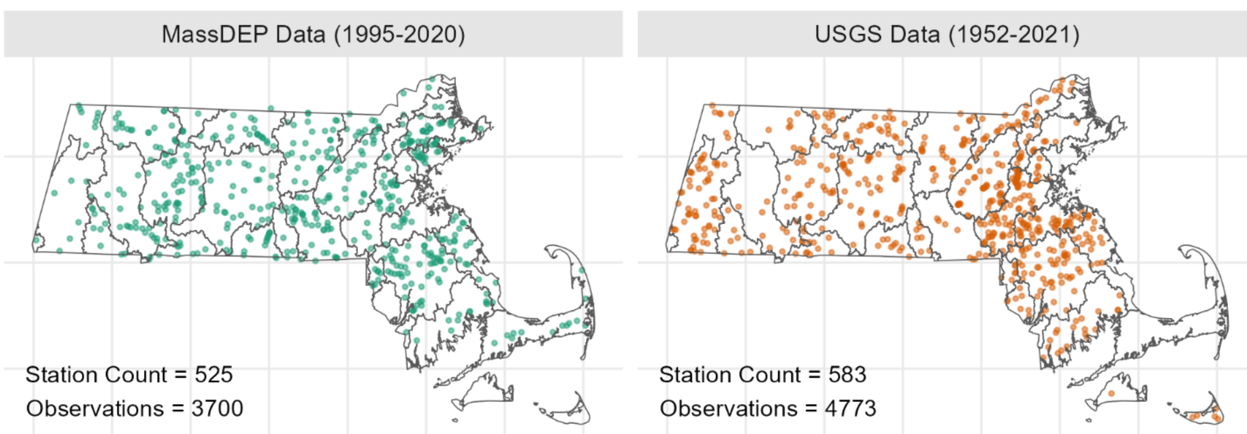


Figure F1. *Distribution of the MassDEP & USGS sampling stations with paired SC and chloride data*

Sample Collection, Chloride Analyses and Specific Conductance Measurements

<u>MassDEP Data</u>

From summer 1995 through 2020, water samples for chloride were collected by MassDEP staff at 525 sites across Massachusetts. Discrete samples were collected using new sample bottles that were generally rinsed two to three times in ambient water prior to sample collection. In general, samples were collected by plunging the sample containers into the water to about 6 inches below the water surface. Samples were stored in insulated coolers packed with wet ice (<6°C) and transported to the MassDEP Wall Experiment Station (WES) laboratory. When chloride samples were collected in the same bottle as nutrient analytes, multi-parameter samples were preserved with 9-18N H_2SO_4 to pH <2. Samples were analyzed by the WES laboratory for chloride using the argentometric titration method (Standard Methods 4500-Cl^{-}, B; from 1994 to 2006) and the automated ferricyanide method (Standard Methods 4500-Cl^{-}, E; from 2007 to 2020) (APHA 2005). A small subset of samples was analyzed at the EPA-Chelmsford lab using EPA 300.0. Lab results using different methods are considered comparable for this analysis. All chloride concentration data were reported in units of mg/L.

During the water sample collection surveys, multi-probe sonde instruments (primarily Hydrolab® were used to measure in-situ SC levels (normalized to 25°C) contemporaneous with water samples. Detailed SOPs for instrument pre-calibration, field use and post-survey instrument check were applied. Typically, multiprobe sonde precalibration for freshwater surveys consisted of a single point calibration at 1,413 µS/cm and a check at 718 µS/cm. For the stations that were not wadable, sondes were lowered from bridges using an anchored guideline and the probes were kept off the bottom sediments at all times. Readings were recorded every 30 seconds for five minutes only after all sonde parameters, including SC, were stable. The last 30 second reading (after approximately 5 minutes) was typically used as the dataset of record for the location, date and time. All SC data were recorded in units of µS/cm.

USGS Data
Consistent with the mission of the U.S. Geological Survey (USGS) to provide the information and understanding needed for wise management of the Nation's water resources, USGS environmental sampling and analytical staff are committed to collecting data that accurately describe the physical, chemical, and biological attributes of water systems. These data are used for environmental and resource assessments by the USGS, other government agencies and scientific organizations, and the general public. Reliable and quality-assured data are essential to the credibility of subsequent data evaluations. For decades, the National Field Manual for the Collection of Water-Quality Data (and the prior, associated USGS Techniques of Water-Resources Investigations (TWRI) series) has guided USGS water data collections by providing consistent scientific methods and procedures for a variety of water quality parameters, including SC and chloride (USGS 2018). The NWQA Field Guide (USGS 1995) has also guided sampling efforts for SC and chloride. Historically, laboratory analysis of chloride water samples by USGS were conducted using comparable ion chromatography methods (USGS 1996).

Quality Assurance and Control

MassDEP Data
Chloride and SC data generated by MassDEP followed approved procedures in place at the time of sampling, including Quality Assurance Program Plans (QAPPs), Sampling & Analysis Plans (SAPs), and Standard Operating Procedures (SOPs). Site conditions and observations, and the use of non-routine sampling techniques, were noted on standard sample collection fieldsheets. Discrete water samples were collected by trained MassDEP water quality monitoring personnel, and efforts were made to ensure sample representativeness, accuracy, and precision. With minor exception, all field surveys and lab analyses included the use of blank and duplicate quality control samples, accounting for approximately 10% of total samples. Data were validated by the MassDEP WES laboratory personnel and by the Principal Investigators and/or Quality Assurance Officers at the MassDEP, Division of Watershed Management, Watershed Planning Program. All MassDEP data used in model development are considered final.

USGS Data
The USGS has a long-established adherence to quality assurance principles and a tradition of generating quality-controlled environmental data throughout the country. While various QA/QC measures were in place and implemented over the span of the data record used for the regression, the overall results used for non-provisional data are considered to be generally valid and accurate for their intended purpose, and of known and documented quality. The current systems in place at USGS to ensure quality and data validity represent the more recent efforts to produce consistently accurate, precise and representative surface water data using in-situ probes and laboratory analyses. Foundational support is provided by the USGS Office of Science Quality and Integrity[1], the overarching Quality Management System[2], and national procedure documents for field[3] and laboratory[4] methods, as well as data management practices[5]. The field and lab methods employed by USGS include the collection of both field and lab QC samples, including blanks, duplicates, matrix spikes and QC standards as appropriate.

Data Retrieval for Model Development

MassDEP Data
Water quality monitoring data generated by the MassDEP Watershed Planning Program were filtered to include only routine samples collected within inland freshwaters (i.e., rivers, streams, lakes, or impoundments). Data from stations associated with or located immediately downstream of any treatment facilities or storm sewers were excluded. A total of 3,700 paired observations of specific conductance and chloride were available across 525 MassDEP stations with sample dates ranging from June 1995 to September 2020.

---

[1] https://www.usgs.gov/office-of-science-quality-and-integrity
[2] https://www.usgs.gov/survey-manual/im-osqi-2022-01
[3] https://www.usgs.gov/mission-areas/water-resources/science/national-field-manual-collection-water-quality-data-nfm
[4] https://www.usgs.gov/labs/national-water-quality-laboratory
[5] https://www.usgs.gov/data-management/manage-quality

<u>USGS Data</u>:
The USGS dataRetrieval R package (De Cicco et al. 2022) was utilized to retrieve all available specific conductance[6] and chloride[7] data from any National Water Information System (NWIS) USGS stations located in Massachusetts (only). The retrieved SC and chloride dataset was filtered to include only reviewed and approved[8], regular[9], fresh surface water samples with no associated remark codes. Data from stations associated with or located immediately downstream of any treatment facilities were excluded. A total of 4,773 paired observations of specific conductance and chloride were available across 583 USGS stations with sample dates ranging from April 1952 to December 2021.

Regression Analysis

The MassDEP WPP and USGS datasets of paired SC and chloride observations were combined (n = 8,473) and used to develop a statewide linear model to estimate chloride concentration using SC data. All statistical analyses and model estimations were performed using R programming language (R Core Team 2022). The resulting linear model (Figure F2; r-squared = 0.987, P<0.000) shows a strong linear relationship between SC and chloride concentration:

$$\mathbf{y = 0.3361\,x - 39.011}$$

where:
y represents chloride concentration (mg/L)
x represents specific conductance (µS/cm)

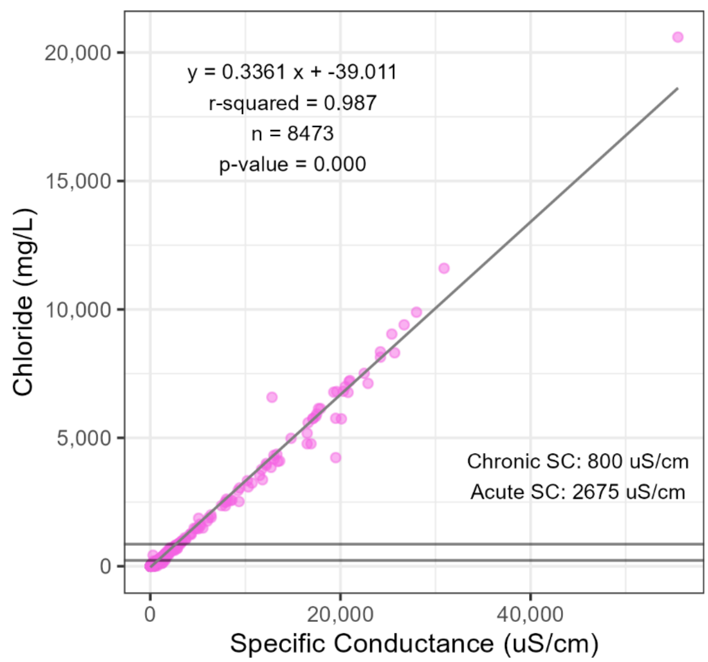


Figure F2. *Relationship between specific conductance and chloride for Massachusetts freshwaters.*

[6] USGS Parameter Code: 00095 [Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius]
[7] USGS Parameter Code: 00940 [Chloride, water, filtered, milligrams per liter]
[8] USGS Data Quality Indicator Code: A [Historical Data] or R [Reviewed and approved]
[9] USGS Sample Type: 9 [Regular]

Model Uncertainty and Applicability

As a result of acceptable validations, the chloride assessment tool for MA freshwaters has been determined to be sufficiently accurate and robust enough to reliably predict chloride concentrations using SC values ranging from approximately 120 - 55,500 µS/cm. The freshwater model can be applied using both instantaneous and/or continuous SC measurements. The model is not reliable at SC readings <120 µS/cm. Since the linear regression line in the model is not set at a 0,0 intercept SC levels below about 120 µS/cm result in a negative predicted chloride concentration, which would not be consistent with the actual chloride concentration in the water. Therefore, for the purposes of the tool, **a predicted chloride concentration lower limit of 10 mg/L (SC=145 µS/cm) was established to account for this low-level error.** The model has greater accuracy at higher SC levels, including near and above ambient criteria-based concentrations. For very high SC readings (>5000 µS/cm), however, caution should be used due to the potential for unique site-specific water chemistry conditions contributing to elevated water conductivity.

Due to the cumulative uncertainty[10] **of estimated chloride values, best professional judgment should be applied at all times when using the tool, and especially for values within 10% of criterion values**. Careful assessment is also needed to evaluate site-specific issues (e.g., the presence of treated wastewater and/or industrial discharges, CSOs, agricultural activities, etc.) that may compromise the accuracy of predictions. A minimum level of corroboratory sampling and laboratory analysis for chloride is required to confirm model accuracy and applicability.

Calculated chloride values are used for freshwater assessment purposes. The tool is not applicable for coastal areas with salt- water influences (e.g., tides, saline intrusion, etc.). Note: Predicted chloride values generated using the regression tool are not maintained in MassDEP's water quality database.

Conclusion

Based on these latest regression analyses, the regression equation documented here is applicable to assessment and listing decisions for the 2024 reporting cycle and beyond, until such time as the model is updated. While the historical decisions based on the previously used regression equation remain valid, the current regression improves on the previous one (used in the 2018/20 and 2022 cycles; see Appendix F in 2022 CALM[11]) by significantly increasing the number of paired data points across the full range of freshwater values (using 26 years of WPP data and 71 years of USGS data), and by incorporating additional data points at higher chloride concentrations. The current regression is more conservative than the previous one with respect to potential impairments (i.e., exceedances of chloride numerical standards (acute and chronic) are estimated to occur at lower SC levels).

Due to model uncertainty described above and the potential site-specific variations in ionic constituents contributing to conductivity, **a 10% safety factor in applying the model is recommended. Applying the 10% safety factor to SC measurements results in estimated exceedances of the acute and chronic chloride criteria occurring at specific conductance readings greater than approximately 2,940 and 880 µS/cm**, respectively.

The 2024 MassDEP Chloride Technical Memorandum (MassDEP, 2024) summarizes chloride concentrations observed in Massachusetts freshwaters between 2015 and 2020. While the updated regression equation was not utilized in this data report, the technical memorandum serves as the established format for future data reporting. The updated regression will be applied for assessment and listing purposes, future technical memorandums, and Integrated Reports.

---

[10] Factors contributing to the cumulative uncertainty of chloride prediction include conductivity probe accuracy (typically 3% of reading), associated temperature probe accuracy (typ. 0.2ºC), probe drift (typically <3%/year), sensor fouling in-between cleanings, transformation of conductivity readings at ambient temperatures to SC at 25ºC using an assumed value for temperature coefficient of variation, and regression model error. For the regression analyses, no assumptions were made for when SC or chloride values were zero. Therefore, the regression was not suppressed to a 0,0 intercept. While chloride is theoretically near zero when SC=0, the opposite is not true for ambient waters (i.e., when chloride = 0, SC is typically positive due to the presence of other ions).

[11] https://www.mass.gov/doc/2022-consolidated-assessment-and-listing-methodology-guidance/download

References

APHA (2005). Standard Methods for the Examination of Water and Wastewater. American Public Health Association, American Water Works Association, and Water Pollution Control Federation.

De Cicco LA, Lorenz D, Hirsch RM, Watkins W, Johnson M (2022). dataRetrieval: R packages for discovering and retrieving water data available from U.S. federal hydrologic web services. doi:10.5066/P9X4L3GE, https://code.usgs.gov/water/dataRetrieval.

MassDEP (2024). Chloride Concentrations in Massachusetts Rivers: Data Report (2015 – 2020). CN 571.0, Massachusetts Department of Environmental Protection, Bureau of Water Resources, Division of Watershed Management, Watershed Planning Program. Worcester, MA. https://www.mass.gov/doc/technical-memorandum-cn-5710-chloride-concentrations-in-massachusetts-rivers-and-streams-data-report-2015-2020/download

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ## URL https://www.R-project.org/.

USGS (1995). Field guide for collecting and processing stream-water samples for the National Water-Quality Assessment Program; https://www.usgs.gov/publications/field-guide-collecting-and-processing-stream-water-samples-national-water-quality

USGS (1996) Method for the determination of dissolved chloride, nitrate, and sulfate in natural water using ion chromatography; https://www.usgs.gov/publications/method-determination-dissolved-chloride-nitrate-and-sulfate-natural-water-using-ion.

USGS (2018). National Field Manual for the Collection of Water-Quality Data. U.S. Geological Survey Techniques of Water-Resources Investigations; https://www.usgs.gov/mission-areas/water-resources/science/national-field-manual-collection-water-quality-data-nfm.

APPENDIX G
STANDARD PRACTICES FOR WATER DATA REDUCTION AND ANALYSIS

Some of the standard practices implemented by the MassDEP, Division of Watershed Management (DWM), Watershed Planning Program (WPP) when reducing and analyzing environmental data for the purposes of assessing and listing waters pursuant to sections 305(b) and 303(d) of the Clean Water Act (CWA) are described below. More detailed information on how individual data types are used for each designated use attainment decision is provided in the main body of the Consolidated Assessment and Listing Methodology (CALM) Guidance Manual. Depending on the specific designated use evaluation and data type, practices other than those defined here may be used.

Age, Status, and Sources of Data Used

Water quality and biological monitoring data used for assessment decisions by MassDEP analysts are ideally five years old or less, although older data (up to ~10 years old) may be utilized. Data ≤5 years in age are used for use attainment evaluations, including both new impairment and impairment removal decisions. Older data can also be used for use attainment and new impairment decisions, but in order to be used for impairment removal decisions, satellite imagery is reviewed to determine if there have been significant land use changes in the drainage basin since the data were collected. These data may be determined by WPP to be not representative of existing water quality conditions if significant land use changes have occurred.

In general, validated final MassDEP data, sister environmental state agency data, federal environmental agency data, and data submitted from outside groups (e.g., including watershed associations, local governments, grantees, etc.) that have been reviewed and considered usable by MassDEP will be utilized for making use attainment and listing decisions.

Data Collected During Extreme Low Flows (<7Q10) or in designated mixing zones

- 7Q10 low flow
  Assessments for waterbodies downstream from wastewater discharges are based on samples taken when river flows were documented or assumed based on best available information to have been at, or above, the seven-day low flow that occurs, on the average, once every ten years (7Q10 low flow). This approach is consistent with the Massachusetts SWQS (specifically, 314 CMR 4.03(3)). Water quality criteria do not apply at flows below the 7Q10 in waters receiving wastewater discharges.

- Mixing Zones
  Whenever possible, ambient water quality monitoring conducted downstream from permitted wastewater treatment facility discharges is done at a sufficient distance downstream to allow for mixing of the effluent with the receiving water and for the resulting data to be considered representative of ambient conditions. Mixing zones are formally defined in the MA SWQS Implementation Policy for Mixing Zones (1993) as an area or volume of a waterbody in the immediate vicinity of a discharge where the initial dilution of the discharge occurs. The quality of water within a mixing zone must a) protect public health b) protect aquatic life and c) prevent nuisance conditions. However, excursions from certain surface water quality standards may be tolerated under certain conditions. Mixing zones shall be limited to an area or volume as small as feasible, should not interfere with migration or free movement of fish or other aquatic life (there should be safe and adequate passage for swimming and drifting organisms with no deleterious effects on their populations), and they shall not create nuisance conditions. Whenever data are determined by MassDEP analysts to represent conditions within a mixing zone, such data may be used with extreme caution or excluded from analysis for the purpose of assessment and listing decisions based on their best professional judgement.

Wet-weather vs. Dry-weather Conditions

For each monitoring survey, hydrologic and climatic conditions up to five days prior to the survey and on the survey date are typically reviewed to determine whether monitoring survey conditions and resulting data are representative of wet-weather or dry-weather conditions. Hydrologic and climatic data from the United States Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA) and other sources are used for the evaluation. Criteria for what defines wet- and dry-weather data can vary by project. The documentation and evaluation of survey conditions and wet/dry determinations are typically contained in WPP technical memoranda presenting project-specific data.

Retention Time Calculations for Impoundments

In order to identify lake segments vs. run-of-the-river impoundments, estimated water retention times are calculated using best available information. When the estimated retention time calculations of the dammed waterbody are $\geq$14 days, the waterbody is evaluated as a lake AU. Estimated retention times <14 days are generally considered run-of-the-river impoundments and considered part of a river AU. An exception to this methodology is when the impounded area shape contains lobes (not just a widened river) and does not likely have unidirectional flow. In these situations, the impounded waterbody will be maintained as a lake AU. Other exceptions may be made on a case-by-case basis. Information used to calculate the estimated retention times in a standardized spreadsheet calculator is gathered from several sources:

- Massachusetts Department of Environmental Management's (now the Department of Conservation and Recreation) Dam Safety Database: nominal storage (acre feet) of the dam's impoundment.
- ArcMap analysis: drainage area to the dam (mi^2) calculated using watershed delineation tools.
- USGS gaging stations: average discharge (ft^3/s) over the period of record and gage drainage area (mi^2). Two USGS gaging stations within a watershed are used to estimate the two most extreme (high and low) flow scenarios. USGS gages are selected within the impounded "waterbody under review" watershed unless stream discharge at a gage is noted as being heavily regulated by industries or municipalities in which case USGS gage station(s) in a nearby watershed are used instead.

Non-Detects

Historical and current MassDEP data analyses for 305(b) assessments have been based on a simplistic, conservative approach where the lower limit of reference/detection is substituted for the "less than" result. Depending on the laboratory used or the project, the lower limit of reference can be the Method Detection Limit (MDL), Reporting Detection Limit (RDL), Lower Quantitation Limit (LQL) or Minimum Reporting Limit (MRL). *Example: A reported value of "<0.2" becomes "0.2" for calculation purposes.* This approach includes any data reported as zero, where the lower limit is substituted when possible and appropriate. Project-specific variations of this approach (such as substituting ½ the MDL value) or more sophisticated statistical approaches [1] may be used with appropriate documentation.

[1] An alternative approach for analyses involving non-detect results is to apply appropriate statistical techniques that account for the distribution and probability of non-detects in the dataset, rather than substitute values for the "less than" result (i.e., the Detection Limit (DL) value, ½ the DL value or other calculated value). Statistical approaches that account for the distribution and probability of non-detects, such as contingency tables, Robust Order Statistics (ROS), Kaplan-Meier method, the Kruskel-Wallis test, and survival analysis methods (e.g., Maximum Likelihood Estimation (MLE), Generalized Wilcoxon test), avoid the introduction of "invasive data" that are estimated and that can introduce false patterns in the data and poor statistical estimates. These techniques may be more appropriate for datasets containing multiple detection limits. In cases where the percentage of non-detects is greater than approximately 20%, use of Cohen's method, Winsorized mean, or tests for proportions may be more appropriate.

Values exceeding the Upper Quantitation Limit (UQL)

For calculation purposes, a simplistic approach is used in cases where results exceed the upper limit, whereby the upper limit of reference (e.g., Upper Quantitation Limit or UQL) is substituted for the "greater than" result. *Example, ">2920" becomes 2920 for calculation purposes.* Similarly to the non-detect alternative approaches described above, project-specific variations or more sophisticated statistical approaches may be employed for datasets involving one or more "greater-than" results.

Zero values in calculations

It is generally recommended that zero values be replaced with the lower limit of reference, when available. If the lower limit of reference is not available or does not apply (as in the case of true zero values, e.g. temperature data), the zero value is replaced with a positive, near-zero value, using applicable significant figures, and using the numeral closest to zero (e.g., 0.01, 0.001).

Subtracting blank values from sample results

Sample results are not adjusted by subtracting parameter-specific blank values (e.g., ambient field blanks, equipment blanks, etc.) from associated sample results. Quality control (QC) blank samples are collected for quality assurance (QA) purposes (bias) only, not to "shift" the data.

Correction Factors
The application of correction factors (e.g., adjusting *in-situ* probe readings based on co-located, same-time QC readings) to adjust analytical results is currently not included in WPP's data validation procedures. Project-specific variations may apply.

Averaging of field duplicate results
Field duplicate results, when collected for QC purposes, are not averaged to attempt to derive more precise estimates for results. QC field duplicate samples, collected during WPP monitoring surveys, are collected at approximately 10-20% of sites visited for QA purposes (field precision) only, and the "first" duplicate is generally reported as the sample result and used to make assessment decisions. In contrast, non-QC sample replicates, when collected, can be averaged to arrive at more precise and representative results.

Outliers
Reviews for outlier values are made during systematic data validation procedures using one or more outlier tests (e.g., Dixon, Barnett-Lewis, standard normal, etc.) and/or best professional judgment. Outliers can also be identified and flagged during data analyses by Principal Investigators. Outliers may be censored (i.e. removed from reporting and analysis) where they have been determined to be invalid during QC review. Outliers are retained if they are determined to most likely represent conditions during known episodic events or for known site conditions at the time of sampling. Suspect (qualified) outlier data may be removed from calculations based on the best professional judgment of MassDEP analysts for assessment related purposes.

Continuous Data --- Summary Statistics
During validation of MassDEP-collected data, continuous datasets (e.g., temperature, dissolved oxygen) are systematically processed to generate standardized file outputs. These standardized files include daily statistics as well as summary statistics for each probe deployment. These data are available for each individual deployment at a station and combined where multiple deployments occurred at a station over the course of a sampling season (i.e., station summary statistics). Additional statistics (e.g., amount of time greater than or less than a target surface water quality standard and/or use attainment guideline) are also calculated.

Continuous Data --- Out-of-Water Analyses
When evidence points to a deployed probe having been out of the water for any amount of time, an investigation is conducted to determine which data points need to be censored from the record based on available collective information. This analysis involves examining the temperature "buffering" capacity (i.e., the ability to resist changes in water temperature from air temperature fluctuations) of water compared to air temperatures during the deployment period, identifying aberrant patterns in the data, reviewing field sheet notes, etc., in order to make decisions on whether to censor all or portion(s) of a continuous record dataset.

Data Procedures

- Conductivity to Specific Conductance:
  For standardized data reporting and to estimate chloride values using the regression tool, continuous conductivity readings measured in µS/cm at ambient water temperatures are converted to specific conductance at 25°C using the following equation:

  $$Specific\ conductance\ (SC)\ @\ 25°C = \frac{Measured\ conductivity}{1 + r * (T - 25)}$$

  where *r*= the temperature coefficient of variations (TCV), ≈ 2.0% per °C
  and *T*= temperature of measured conductivity in °C

- Data Transformations:
  For statistical data analyses, logarithmic or other data transformations may be made where necessary to achieve a normal distribution.

- <u>Calculating Water Quality Criteria</u>
  For water quality criteria that vary with hardness (e.g., metals), pH, temperature and/or other variables, applicable criteria values must be calculated before direct comparisons with actual sampling data are made. WPP analysts rely on the use of standardized spreadsheet calculator tools that have been tested and verified to be accurate, or other vetted approaches (e.g., use of the Biotic Ligand Model (BLM) for copper in freshwater) to calculate a criterion. Whenever possible, site-specific and contemporaneous data are used to derive applicable criteria. When this type of data is lacking, estimated values for supporting data may be used for criteria calculation purposes using best available information (which may include EPA ecoregional default values).

- <u>Toxic Unit (TU):</u>
  The ratio of a toxicant concentration to its criterion. This TU calculation provides the relative magnitude of the exceedance.

- <u>Comparing toxicant data to Water Quality Criteria</u>:
  A single discrete or composite sample is considered to be representative of the one-hour average exposure period and is therefore appropriate to compare directly against an acute criterion. Multiple discrete or representative composite samples collected within a three-year timeframe are needed to determine exceedances of a chronic criterion. When multiple samples have been collected from the same sampling location within a toxicant's chronic exposure period (e.g., 4-days) then these results will be averaged and used to calculate a single TU. For example, two or more discrete samples collected during two or more days will be averaged (or average TUs for toxicants with criteria that are equation or model based, i.e., site dependent) to better represent the CCC four-day exposure period. The representativeness of composite samples will be evaluated on a case-by-case basis with preference given to those that best represent the toxicant's CCC exposure period. Samples separated by more than the exposure period of the toxicant are considered independent samples that are not averaged. Independent samples separated in time by more than a toxicants' CCC exposure period include discrete or composite samples that do not represent a CCC exposure period.

- <u>Geometric Mean Calculation for Bacteria Data</u>:
  The geometric mean is a mean or average, which indicates the central tendency or typical value of a set of numbers by using the product of their values (as opposed to the arithmetic mean which uses their sum). The geometric mean is defined as the *n*th root of the product of *n* numbers. Rolling Backward Unique (RBU) averages of bacteria data are calculated for either a 30 or 90-day interval determined on a case-by-case basis by WPP analysts to assess the recreational uses (in addition to using Statistical Threshold Values (STVs)) using a minimum of two samples in a 30-day interval and three samples in a 90-day interval. The *Primary Contact Recreation Use* season is 1 April through 31 October while the *Secondary Contact Recreation Use* season is year-round. For more information, see Appendix J.

<u>Modeled/Estimated Results</u>
With minor exceptions as detailed below, data based on the use of predictive models, conversions and translators are generally not used directly in assessment-related determinations. Exceptions include:

1) <u>Chloride – Specific Conductance regression (freshwater, statewide)</u>
   Estimates of chloride concentrations are made using a validated regression model between specific conductance (SC) levels and associated chloride concentrations in Massachusetts freshwater streams:
   $$Cl = 0.3361*(SC) - 39.011$$
   Estimated chloride values are compared with EPA criteria for assessment purposes (using rolling 4-day averages). It is strongly recommended that chloride samples also be collected and analyzed for each site where the model is applied to confirm the accuracy of model output. At present, there are no site-specific or regional freshwater SC/Cl regressions developed for MA. As more data are generated, WPP plans to refine the model. For more information, see Appendix F.

2) Dissolved-fraction-only results for metals that have criteria expressed as total (i.e., arsenic, mercury, selenium) (MassDEP 2021):
   a. Arsenic (As): The conversion factor for determining the dissolved criterion from the total recoverable criterion for arsenic is 1.0. After converting the total recoverable criterion to a dissolved criterion, the dissolved As concentration may be compared to it (or mean concentration over its acute or chronic criteria's averaging period).
   b. Mercury (Hg): The conversion factor for determining the dissolved criteria from total recoverable criteria for mercury is 0.850.
   c. Selenium (Se): The conversion factor for determining the chronic dissolved criteria from total recoverable criteria for selenium is 0.922.

3) Use of the Copper Biotic Ligand Model (BLM) to derive freshwater copper criteria (MassDEP 2021): When evaluating copper data, the EPA BLM for copper will be applied using best available information. BLM software version 2.2.3 will be used to calculate the copper criteria if sufficient water quality data (i.e., the input parameters) are available. Updated BLM versions, such as those that accommodate new operating systems, may only be used with MassDEP approval. Multiple input parameter datasets (using the 10 BLM input values) will be used to run the model. For each input parameter dataset, the BLM calculates Instantaneous Water Quality Criteria (IWQC) that include both a 1-hour acute exposure criterion (criterion maximum concentration, CMC) and a 96-hour chronic exposure criterion (criterion continuous concentration, CCC). Multiple IWQCs are generated and then have to be reduced to single CCC and CMC values using appropriate statistical procedures.

4) Use of the Fresh Water Aluminum Criteria Calculator to derive aluminum criteria (MassDEP 2021): When evaluating aluminum data, the Aluminum Criteria Calculator V.2.0 is used with local water chemistry inputs (DOC, pH and hardness) to calculate aluminum criteria. Updated Aluminum Criteria Calculator versions, such as those that accommodate new operating systems, may only be used with MassDEP approval.

Metals data generated using Clean vs. Non-Clean Techniques
Only metals data collected using documented clean sampling techniques are utilized in the use attainment and listing decision process.

10% Rule
A threshold of >10% of samples violating an applicable criterion (frequency of occurrence) is often used prior to making a judgment of "impaired", under the condition that more than one violation is needed to make an impairment decision. See specific use determinations for more information.

R statistical program
The R statistical program is used for analysis of data (see Appendix J) and for other data analyses as needed and appropriate. The R statistical program (R Core Team, 2021) is a free and open-source software environment used by MassDEP for data organization, statistical analysis, Quality Assurance/Quality Control (QA/QC), and data visualization. Standard best practices (e.g., https://waterdata.usgs.gov/blog/intro-best-practices/) are used in most instances when implementing this software. Exceptions can occur when analyses and visualizations are exploratory, when analytical procedures must interface with software other than R (e.g., MS Excel), when existing MassDEP data maintenance protocols conflict with standard best practices, and other situations. Best practices implemented for the bacteria assessment include (but are not limited to):

- Clear listing of all input files and packages used at beginning of a script (i.e., a single code file).
- Separate scripts for separate analyses to organize code blocks.
- Explanatory comments throughout all scripts used for analysis and data visualization.

The intermediate output of any individual analysis that requires an excessive amount of time (e.g., > 12 hours) is created as a comma separated value (csv) file to avoid having to re-run extensive analyses. All code used for data analyses and visualizations is checked by an individual with experience using R who is not involved in the assessment.

References

Ackerman, M. 1989. *Compilation of Lakes, Ponds, Reservoirs and Impoundments Relative of the Massachusetts Clean Lakes Program*. Massachusetts Department of Environmental Quality Engineering, Division of Water Pollution Control, Westborough, MA.

MassDEP. 1993. *Massachusetts Surface Water Quality Standards Implementation Policy for Mixing Zones January 8, 1993.* http://www.mass.gov/eea/docs/dep/water/laws/numeric/92mz2.doc

MassDEP. 2021. *Massachusetts Surface Water Quality Standards (Revision of 314 CMR 4.00, effective November 12, 2021, corrected December 10, 2021 and January 7, 2022)*. Massachusetts Department of Environmental Protection. Boston, MA.

Socolow, R.S., L.Y. Comeau, and D. Murino, Jr. 2004*. USGS Water Resources Data Massachusetts and Rhode Island Water Year 2004.* Water-Data Report MA-RI-04-1. U.S. Geological Survey, Water Science Center, Northborough, MA.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

APPENDIX H
LIST OF TYPICAL CAUSE(S) AND SOURCE(S) OF DESIGNATED USE IMPAIRMENTS

Typical cause(s) and source(s) of use impairments (*Aquatic Life, Fish Consumption, Shellfish Harvesting, Primary Contact Recreation, Secondary Contact Recreation,* and *Aesthetics*) used for the 2012 through 2024/2026 Integrated Reporting cycles.

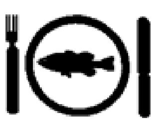
***AQUATIC LIFE USE* IMPAIRMENT CAUSES AND SOURCES**			
***Aquatic Life Use* Attainment Indicators**	**Use is Impaired**	**Typical Cause(s) of Impairment**	**Typical Source(s) of Impairment**
BIOLOGICAL MONITORING INFORMATION			
Benthic macroinvertebrate data	**Rivers** Moderately Degraded/Severely Degraded **Estuaries** Low #species, low # individuals, poor diversity and evenness, shallow dwelling opportunistic species or near absence of benthos, thin feeding zone, as reported from external data sources	Benthic Macroinvertebrates Bioassessments Organic Enrichment (Sewage) Biological Indicators Nutrient/Eutrophication Biological Indicators Combined Biota/Habitat Bioassessments	Municipal Point Source Discharges Dam or Impoundment Unspecified Urban Stormwater Impacts from Hydrostructure Flow Regulation/Modification Discharges from Municipal Separate Storm Sewer Systems (MS4) Source Unknown
Fish community data	**Rivers - *Cold Water Fishery*** No fish found or cold water species absent, DELTS with abnormal fish histology **Rivers - *Warm Water Fishery*** Moderate and high gradient: No fish found or fluvial fish were absent or relatively scarce (few in number), DELTS with abnormal fish histology Low gradient: No fish found or presence of only tolerant macrohabitat generalists, DELTS with abnormal fish histology **Lakes, Estuaries** > 5% population losses estimated , DELTS with abnormal fish histology	Lack of a Coldwater Assemblage Low Flow Alterations Physical Substrate Habitat Alterations Fish Bioassessments Fish Kill(s) Pathogens or contaminants (associated with DELTS)	Municipal Point Source Discharges Dam or Impoundment Source Unknown
Habitat and flow data	**Rivers, Lakes, Estuaries** Physical habitat structure impacted by anthropogenic stressors (e.g., lack of flow, lack of natural habitat structure such as concrete channel, underground conduit), non-functioning anadromous fishway present	Fish Passage Barrier Low Flow Alterations Habitat Assessment Flow Regime Modification Other Anthropogenic Substrate Alterations Physical Substrate Habitat Alterations Sedimentation/Siltation Bottom Deposits Alteration in Stream-side or Littoral Vegetative Covers Petroleum Hydrocarbons Total Suspended Solids (TSS) Turbidity	Hydrostructure Impacts on Fish Passage Dam or Impoundment Channelization Streambank Modifications/destabilization Flow Alterations from Water Diversions Impacts from Hydrostructure Flow Regulation/Modification Habitat Modification - other than Hydromodification Loss of Riparian Habitat Unspecified Urban Stormwater Source Unknown
Eelgrass bed mapping data	**Estuaries** Substantial decline (more than 10% of the in bed size or total loss of beds no matter their size)	Estuarine Bioassessments	Source Unknown

AQUATIC LIFE USE IMPAIRMENT CAUSES AND SOURCES			
***Aquatic Life Use* Attainment Indicators**	**Use is Impaired**	**Typical Cause(s) of Impairment**	**Typical Source(s) of Impairment**
Non-native aquatic species data	**Rivers, Lakes** Non-native aquatic species present	Non-Native Aquatic Plants Non-Native Fish/Shellfish/Zooplankton Brittle Naiad, *Najas minor* Curly-leaf Pondweed *Potamogeton crispus* Eurasian Water Milfoil, *Myriophyllum spicatum* Fanwort *Cabomba caroliniana* Hydrilla *Hydrilla verticillata* Water Chestnut *Trapa natans* Zebra mussel, *Dreissena polymorpha*	Introduction of Non-native Organisms (Accidental or Intentional) Source Unknown
Periphyton/algal blooms	**Rivers, Lakes, Estuaries** Frequent and/or prolonged algal blooms or growths of periphyton, cyanobacteria blooms result in advisories (recurring and/or prolonged), >25% cover noxious aquatic plants (e.g. *Lemna* sp.), periphyton cover within stream AU >40%	Excess Algal Growth Harmful Algal Blooms Nutrient/Eutrophication Biological Indicators	Municipal Point Source Discharges Unspecified Urban Stormwater Internal Nutrient Recycling Discharges from Municipal Separate Storm Sewer Systems (MS4) Source Unknown
TOXICOLOGICAL MONITORING INFORMATION			
Toxicity testing data	**Rivers, Lakes, Estuaries** <75% survival of test organisms to water column or sediment samples in either 48 hr (acute) or 7-day exposure (chronic) tests occurs in >10% of test events.	Ambient Bioassays -- Acute Aquatic Toxicity Ambient Bioassays -- Chronic Aquatic Toxicity Sediment Bioassay Whole Effluent Toxicity (WET)	Contaminated Sediments Municipal Point Source Discharges Source Unknown
PHYSICO-CHEMICAL WATER QUALITY INFORMATION			
Water quality data - DO	**Rivers and lake surface waters** Frequent (>10%) and/or prolonged or severe excursions (>1.0 mg/l below standards) from criteria **Lakes** In deep lakes (with a hypolimnion), the criterion is not met in a hypolimnetic area >10% of the lake surface area during maximum oxygen depletion (summer growing season) **Estuaries** Frequent (>10%) and/or prolonged or severe excursions (>1.0 mg/l below standards) from criteria	Dissolved Oxygen Dissolved Oxygen Supersaturation	Municipal Point Source Discharges Discharges from Municipal Separate Storm Sewer Systems (MS4) Unspecified Urban Stormwater Industrial Point Source Discharge Dam or Impoundment Combined Sewer Overflows Impacts from Hydrostructure Flow Regulation/Modification Source Unknown
Water quality data – pH	**Rivers** Frequent (>10%) and/or prolonged or severe excursions (>0.5 SU) from criteria, **Lakes** Excursion from criteria (>0.5 SU) summer growing season, **Estuaries** Frequent (>10%) and/or prolonged or severe excursions (>0.5 SU) from criteria	pH, Low pH, High	Municipal Point Source Discharges Source Unknown

***AQUATIC LIFE USE* IMPAIRMENT CAUSES AND SOURCES**			
***Aquatic Life Use* Attainment Indicators**	**Use is Impaired**	**Typical Cause(s) of Impairment**	**Typical Source(s) of Impairment**
Water quality data - temperature	**Rivers - *Cold Water Fishery*** Criterion frequently exceeded (>10%) or by >2°C **Rivers and Lakes - *Warm Water Fishery*** Criterion frequently exceeded (>10% measurements) or by >2°C. **Estuaries** Criterion frequently exceeded, rise due to discharge exceeds ΔT standards	Temperature	Dam or Impoundment Baseflow Depletion from Groundwater Withdrawals Source Unknown
Water quality data nutrient indicators	**Rivers** Combination of indicators present: excessive visible nuisance algae (filamentous, blooms, mats), large diel changes in oxygen/saturation/pH, elevated chlorophyll *a*	Chlorophyll-a Excess Algal Growth Phosphorus, Total pH, High Transparency/Clarity Turbidity Dissolved Oxygen Supersaturation Nutrient/Eutrophication Biological Indicators	Municipal Point Source Discharges Unspecified Urban Stormwater Internal Nutrient Recycling Discharges from Municipal Separate Storm Sewer Systems (MS4) Non-Point Source Urban Runoff/Storm Sewers Source Unknown
	Lakes Combination of indicators present: excessive visible nuisance algal blooms or macrophytes, low Secchi disk transparency, high oxygen super-saturation, elevated pH elevated chlorophyll *a*	Chlorophyll-a Excess Algal Growth Phosphorus, Total Turbidity Aquatic Plants (Macrophytes) Transparency/Clarity Dissolved Oxygen Supersaturation Nutrient/Eutrophication Biological Indicators	Municipal Point Source Discharges Unspecified Urban Stormwater Internal Nutrient Recycling Discharges from Municipal Separate Storm Sewer Systems (MS4) Non-Point Source Urban Runoff/Storm Sewers Source Unknown
	Estuaries Substantial decline (> 10% of bed size or total loss of beds no matter their size, MEP analysis indicates moderately to severely degraded health due to nitrogen enrichment	Nitrogen, Total Nutrient/Eutrophication Biological Indicators Chlorophyll-a Excess Algal Growth	Municipal Point Source Discharges Unspecified Urban Stormwater Internal Nutrient Recycling Discharges from Municipal Separate Storm Sewer Systems (MS4) Industrial Point Source Discharge On-site Treatment Systems (Septic Systems and Similar Decentralized Systems) Septage Disposal Source Unknown
Water quality data toxic and other pollutants	**Rivers, Lakes, Estuaries** Frequent and/or prolonged excursions from criteria (more than a single exceedance of acute criteria or >10% samples exceed chronic criteria).	Ammonia, Un-ionized Chlorine, Residual (Chlorine Demand) Heavy metals* (e.g., Arsenic, Mercury) PAHs* (e.g., Acenaphthene, Naphthalene) chlorinated organic* (e.g., Aldrin, Heptachlor) "Non priority pollutants" (e.g., Choride, Aluminum, Hydrogen Sulfide)	Municipal Point Source Discharges Highway/Road/Bridge Runoff (Non-construction Related) Combined Sewer Overflows Contaminated Sediments Source Unknown

AQUATIC LIFE USE IMPAIRMENT CAUSES AND SOURCES			
Aquatic Life Use **Attainment Indicators**	**Use is Impaired**	**Typical Cause(s) of Impairment**	**Typical Source(s) of Impairment**
SEDIMENT AND TISSUE RESIDUE INFORMATION			
Sediment quality data	**Rivers, Lakes, Estuaries** Frequent excursions over PEL guidelines along with other evidence of impairment, waterbodies known to have sediment contamination undergoing remedial actions.	Sediment Screening Value (Exceedence) Arsenic, Cadmium, Chromium, Total, Copper, Lead, Mercury, Nickel, and/or Zinc in Sediment Petroleum Hydrocarbons Polycyclic Aromatic Hydrocarbons (PAHs) (Aquatic Ecosystems)	Contaminated Sediments CERCLA NPL (Superfund) Sites Inappropriate Waste Disposal
Tissue residue data	**Rivers, Lakes, Estuaries** Residue of contaminants in whole body samples frequently exceed NAS/NAE guidelines, DELTS with abnormal fish histology.	Abnormal Fish Deformities, Erosions, Lesions, Tumors (DELTS), PCBs (polychlorinated biphenyls), Mercury, DDT (and its metabolites DDD and DDE), Chlordane, PAHs*, Dioxin (TCDD), PFAS in Fish Tissue	Contaminated Sediments Inappropriate Waste Disposal Releases from Waste Sites or Dumps Source Unknown

* *Asterisk indicates there are many possible contaminants that belong to these classes of pollutants, the cause of impairment however is the individual pollutant. EPA maintains lists of domain values (allowed values for restricted fields in ATTAINS), including cause (parameters) and source codes on the ATTAINS Resources webpage.*

FISH CONSUMPTION USE IMPAIRMENT CAUSES AND SOURCES			
Indicator for *Fish Consumption Use* Attainment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Waterbody has site-specific MDPH Fish Consumption Advisory with hazard (e.g., mercury, PCBs, pesticides, DDT, etc.)	Mercury in Fish Tissue PCB in Fish Tissue Dioxin (including 2,3,7,8-TCDD) Pentachlorophenol (PCP)* Chlordane DDT and/or its metabolites DDD and DDE Polycyclic Aromatic Hydrocarbons (PAHs) (Aquatic Ecosystems) PFAS in Fish Tissue	Atmospheric Deposition - Toxics Contaminated Sediments CERCLA NPL (Superfund) Sites Inappropriate Waste Disposal Releases from Waste Sites or Dumps Source Unknown

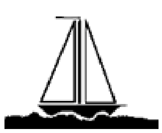
SHELLFISH HARVESTING USE **IMPAIRMENT CAUSES AND SOURCES**			
Indicator for *Shellfish Harvesting Use* Attainment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	SA Waters: Conditionally Approved, Restricted, Conditionally Restricted, or Prohibited SB Waters: Conditionally Restricted or Prohibited	Fecal Coliform Polychlorinated Biphenyls (PCBs)	Discharges from Municipal Separate Storm Sewer Systems (MS4) Combined Sewer Overflows Marina/boating Pumpout Releases Marina/Boating Sanitary On-vessel Discharges Unspecified Urban Stormwater Municipal Point Source Discharges Illicit Connections/Hook-ups to Storm Sewers Sanitary Sewer Overflows (Collection System Failures) On-site Treatment Systems (Septic Systems and Similar Decentralized Systems) Source Unknown

AESTHETICS USE **IMPAIRMENT CAUSES AND SOURCES**			
Indicator for *Aesthetics Use* Attainment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Aesthetically objectionable conditions frequently observed (e.g., blooms, scums, water odors, discoloration, taste, visual turbidity highly cloudy/murky, excess algal growth (>40% filamentous cover in rivers, nuisance growths >25% dense/very dense macrophytes or blooms in lakes), Secchi disk transparency < 4 feet at least twice during survey season.)	Excess Algal Growth Debris* Trash Scum/Foam Flocculant Masses Oil and Grease Turbidity Nutrient/Eutrophication Biological Indicators Taste and Odor Color Sedimentation/Siltation Harmful Algal Blooms	Municipal Point Source Discharges Unspecified Urban Stormwater Municipal (Urbanized High Density Area) Combined Sewer Overflows Internal Nutrient Recycling Discharges from Municipal Separate Storm Sewer Systems (MS4) Introduction of Non-native Organisms (Accidental or Intentional) Source Unknown

** In the 2018/2020 IR cycle, all prior Debris/Floatables/Trash impairments were converted to two separate impairments for Trash and Debris. Going forward, MassDEP analysts will add new impairments for Trash only.*

PRIMARY CONTACT RECREATION USE **IMPAIRMENT CAUSES AND SOURCES**			
Indicator for *Primary Contact Recreation Use* Attainment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Bacteria concentrations exceed impairment decision schema, aesthetic use impairment Beach Postings >10% season	*Enterococcus* *Escherichia coli* (E. coli) Polychlorinated Biphenyls (PCBs)** Harmful Algal Blooms Transparency/Clarity Any applicable aesthetic causes (see list above)	Municipal Point Source Discharges Combined Sewer Overflows Municipal (Urbanized High Density Area) Discharges from Municipal Separate Storm Sewer Systems (MS4) Unspecified Urban Stormwater Wet Weather Discharges (Non-Point Source) Illicit Connections/Hook-ups to Storm Sewers Urban Runoff/Storm Sewers Waterfowl Introduction of Non-native Organisms (Accidental or Intentional) Source Unknown

** *Example of risk calculation exceeds hazard threshold for (contaminant of concern)*

SECONDARY CONTACT RECREATION USE **IMPAIRMENT CAUSES AND SOURCES**			
Indicator for *Secondary Contact Recreation Use* Attainment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Bacteria concentrations exceed impairment decision schema, aesthetic use impairment	*Enterococcus* *Escherichia coli* Harmful Algal Blooms Any applicable aesthetic causes (see list above)	Municipal Point Source Discharges Combined Sewer Overflows Municipal (Urbanized High Density Area) Discharges from Municipal Separate Storm Sewer Systems (MS4) Unspecified Urban Stormwater Wet Weather Discharges (Non-Point Source) Illicit Connections/Hook-ups to Storm Sewers Urban Runoff/Storm Sewers Waterfowl Introduction of Non-native Organisms (Accidental or Intentional) Source Unknown

APPENDIX I
MASSACHUSETTS BENTHIC MACROINVERTEBRATE INDICES OF BIOTIC INTEGRITY (IBI): ADDITIONAL REGIONAL AND GRADIENT-DEPENDENT IBI METRIC DETAILS

Two regional benthic macroinvertebrate Indices of Biotic Integrity (Western Highlands and Central Hills IBIs) appropriate for high gradient sites (those dominated by riffle habitat), as well as a Low Gradient IBI suitable for statewide application (for sites where riffle habitat is not dominant) were developed for wadeable streams in Massachusetts. Details in this Appendix relate to the spatial extent of each IBI (see Figure I1, Table I1), the metrics incorporated into each IBI (Tables I2 and I3), and the threshold values for four biological condition categories (Table I4).

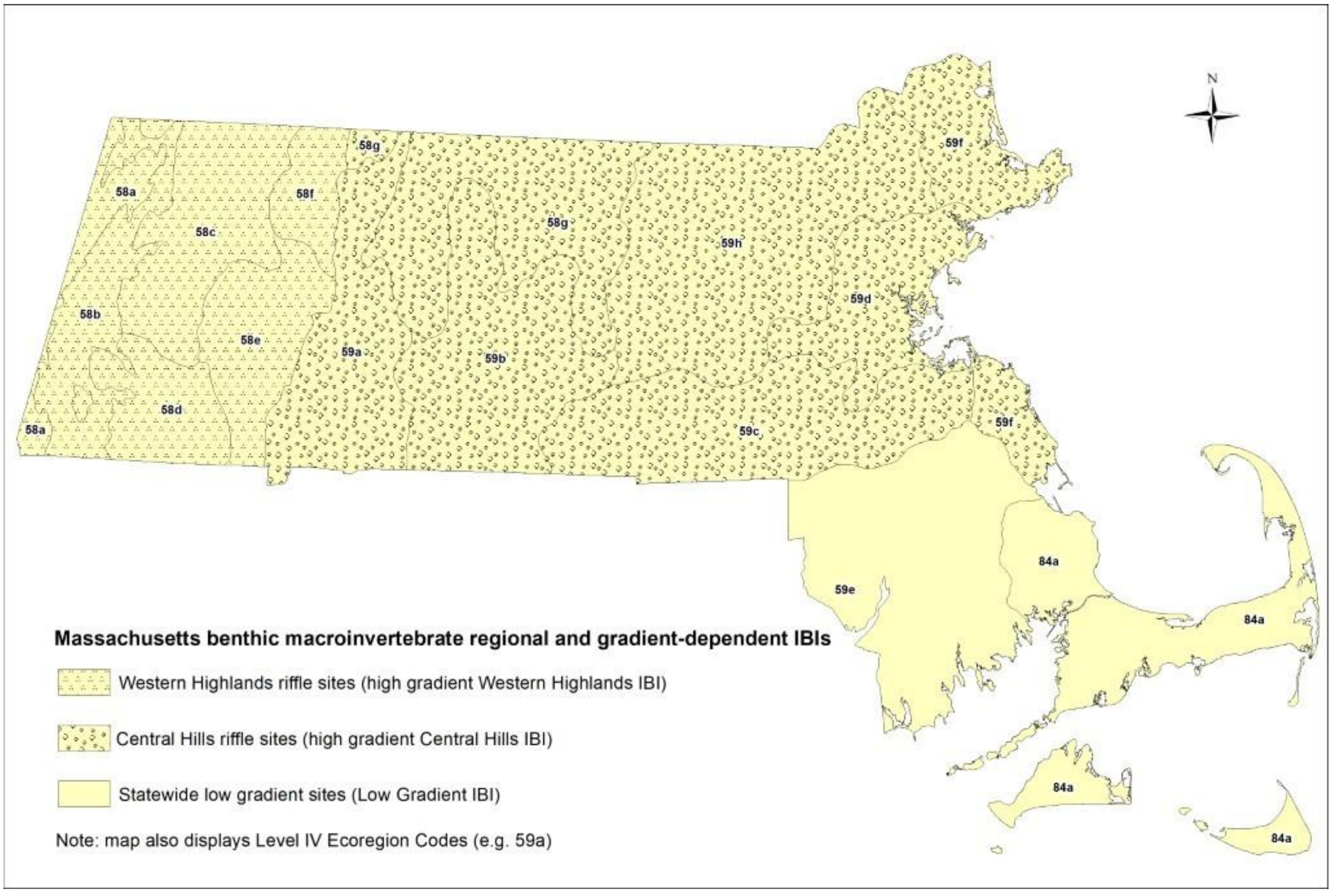


Figure I1. *For IBI development, Omernik Level IV ecoregions were grouped into two regions for high gradient streams: Western Highlands and Central Hills. An IBI for each of these high gradient regions was developed. The southeastern portion of the state was grouped exclusively under the jurisdiction of the newly-developed Low Gradient IBI, which can also be utilized for low-gradient streams located in the Western Highlands and Central Hills regions. See Table I1 for ecoregion code descriptions. Source: Adapted from Jessup and Stamp 2020.*

Table I1. Application of Indices of Biotic Integrity (IBI) used to evaluate benthic macroinvertebrate sample data in Massachusetts regions. Source: Adapted from Jessup and Stamp 2020.

Region	Level IV ecoregion code	Level IV ecoregion name	IBI
Central Hills	58g	Worcester/Monadnock Plateau	Central Hills IBI for high gradient sites, Low Gradient IBI for low gradient sites
	59a	Connecticut Valley	
	59b	Lower Worcester Plateau/Eastern Connecticut Upland	
	59c	Southern New England Coastal Plains and Hills	
	59d	Boston Basin	
	59f	Gulf of Maine Coastal Lowland	
	59h	Gulf of Maine Coastal Plain	
Western Highlands	58a	Taconic Mountains	Western Highlands IBI for high gradient sites, Low Gradient IBI for low gradient sites
	58b	Western New England Marble Valleys	
	58c	Green Mountains/Berkshire Highlands	
	58d	Lower Berkshire Hills	
	58e	Berkshire Transition	
	58f	Vermont Piedmont	
Southeastern	59e	Narragansett/Bristol Lowland	Low Gradient IBI
	84a	Cape Cod/Long Island	

Table I2. Details on the metrics used in the Central Hills and Western Highlands 300-count riffle habitat IBIs (high gradient) as well as the 300-count Low Gradient multi-habitat IBI (used statewide). Sources: Adapted from (Block et al. 2020) and (Jessup et al. 2021).

Central Hills 300-count riffle habitat IBI (high gradient)			
Metric (abbreviation)	**Category**	**Response to stress**	**Scoring formula**
Total number of taxa (nt_total) [1]	Richness	Decrease	100*(metric)/55.8
% EPT taxa (pt_EPT)	Richness	Decrease	100*(metric)/54.5
% Ephemeroptera individuals, excluding Caenidae and Baetidae (pi_Ephem NoCaeBae)	Composition	Decrease	100*(metric)/13.9
% Collector-filterer individuals (pi_ffg_filt)	Functional Feeding Group	Increase	100*(79.9-metric)/66.9
% Predator taxa (pt_ffg_pred)	Functional Feeding Group	Decrease	100*(metric)/28.5
% Intolerant taxa, tolerance value ≤3 (pt_tv_intol)	Tolerance	Decrease	100*(metric)/39.1
Western Highlands 300-count riffle habitat IBI (high gradient)			
Metric (abbreviation)	**Category**	**Response to stress**	**Scoring formula**
Total number of taxa (nt_total) [1]	Richness	Decrease	100*(metric)/61.8
% Plecoptera individuals (pi_Pleco)	Composition	Decrease	100*(metric)/18.3
% Collector-filterer individuals (pi_ffg_filt)	Functional Feeding Group	Increase	100*(50.5-metric)/40.7
% Shredder individuals (pi_ffg_shred)	Functional Feeding Group	Decrease	100*(metric)/23
% Intolerant individuals, tolerance value ≤3 (pi_tv_intol)	Tolerance	Decrease	100*(metric)/51.5
Becks Biotic Index (x_Becks) [1,2]	Tolerance	Decrease	100*(metric)/50.6
Low Gradient 300-count multi-habitat IBI			
Metric (abbreviation)	**Category**	**Response to stress**	**Scoring formula**
% Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET) taxa (pt_POET)	Richness	Decrease	100*(metric)/40
% Predator taxa (pt_ffg_pred)	Functional Feeding Group	Decrease	100*(metric)/32
% Non-insect taxa (pt_NonIns)	Richness	Increase	100*(46-metric)/42
% Odonata, Ephemeroptera, and Trichoptera (OET) individuals (pi_OET)	Composition	Decrease	100*(metric)/49
% Tolerant taxa (pt_tv_toler)	Tolerance	Increase	100*(36-metric)/33
% Semivoltine taxa (pt_volt_semi)	Life Cycle/ Voltinism	Decrease	100*(metric)/12

[1] – These metrics were adjusted in the two high gradient IBIs for 100 count subsamples to allow the calculation of an IBI score for 300-count subsamples (Block et al. 2020). MassDEP switched from collecting 100-count benthic subsamples to collecting 300-count subsamples in 2013.

[2] – Beck's Biotic Index (Terrell and Perfetti 1996) = 2[Class 1 Taxa]+[Class 2 Taxa] where Class 1 taxa have tolerance values of 0 or 1 and Class 2 taxa have tolerance values of 2, 3 or 4. Source: (Block et al. 2020).*

Table I3. Details on the metrics used in the Central Hills and Western Highlands 100-count riffle habitat IBIs (high gradient). Sources: Adapted from (Block et al. 2020) and (Jessup et al. 2021).

Central Hills 100-count riffle habitat IBI (high gradient)			
Metric (abbreviation)	**Category**	**Response to stress**	**Scoring formula**
Total number of taxa (nt_total) [1]	Richness	Decrease	100*(metric)/34.9
% EPT taxa (pt_EPT)	Richness	Decrease	100*(metric)/54.5
% Ephemeroptera individuals, excluding Caenidae and Baetidae (pi_Ephem NoCaeBae)	Composition	Decrease	100*(metric)/13.9
% Collector-filterer individuals (pi_ffg_filt)	Functional Feeding Group	Increase	100*(79.9-metric)/66.9
% Predator taxa (pt_ffg_pred)	Functional Feeding Group	Decrease	100*(metric)/28.5
% Intolerant taxa, tolerance value ≤3 (pt_tv_intol)	Tolerance	Decrease	100*(metric)/39.1
Western Highlands 100-count riffle habitat IBI (high gradient)			
Metric (abbreviation)	**Category**	**Response to stress**	**Scoring formula**
Total number of taxa (nt_total) [1]	Richness	Decrease	100*(metric)/33.8
% Plecoptera individuals (pi_Pleco)	Composition	Decrease	100*(metric)/18.3
% Collector-filterer individuals (pi_ffg_filt)	Functional Feeding Group	Increase	100*(50.5-metric)/40.7
% Shredder individuals (pi_ffg_shred)	Functional Feeding Group	Decrease	100*(metric)/23
% Intolerant individuals, tolerance value ≤3 (pi_tv_intol)	Tolerance	Decrease	100*(metric)/51.5
Becks Biotic Index (x_Becks) [1,2]	Tolerance	Decrease	100*(metric)/36.8

[1] – These metrics were adjusted in the two high gradient IBIs for 100-count subsamples to allow the calculation of an IBI score for 300-count subsamples (Block et al. 2020). MassDEP switched from collecting 100-count benthic subsamples to collecting 300-count subsamples in 2013.

[2] – Beck's Biotic Index (Terrell and Perfetti 1996) = 2[Class 1 Taxa]+[Class 2 Taxa] where Class 1 taxa have tolerance values of 0 or 1 and Class 2 taxa have tolerance values of 2, 3 or 4. Source: (Block et al. 2020).*

Table I4. IBI thresholds for four biological condition categories for the two high gradient regional IBIs and the low gradient statewide IBI. Sources: Adapted from (Stamp and Jessup 2020) and (Jessup et al. 2021).

	Biological Condition Score			
Index of Biotic Integrity	**Exceptional Condition**	**Satisfactory Condition[3]**	**Moderately Degraded[3]**	**Severely Degraded**
High Gradient – Central Hills[1]	100 - 75	74 - 55	54 - 35	34 - 0
High Gradient – Western Highlands[1]	100 - 75	74 - 55	54 - 35	34 - 0
Low Gradient – Statewide[2]	100 - 81	80 - 62	61 - 38	37 - 0

[1] – Thresholds are appropriate for 100 and 300 count subsamples.
[2] – Thresholds are appropriate for only 300 count subsamples.
[3] – Occasionally MassDEP biologists may use BPJ based on other lines of evidence for sites in the +/- 5 point range straddling the Satisfactory Condition - Moderately Degraded Condition threshold to recommend a different outcome than the one dictated by the Biological Condition Score.

References

Jessup, B., and J. Stamp. 2020. Development of Indices of Biotic Integrity for Assessing Macroinvertebrate Assemblages in Massachusetts Freshwater Wadeable Streams. Prepared for the Massachusetts Department of Environmental Protection by Tetra Tech. Montpelier, VT.

Stamp, J., and B. Jessup. 2020. Establishing numeric biological condition thresholds. Prepared for the Massachusetts Department of Environmental Protection by Tetra Tech. Montpelier, VT.

Block, B., J. Stamp, and B. Jessup. 2020. Calibration of Indices of Biotic Integrity for 300-organism macroinvertebrate riffle habitat samples in Massachusetts freshwater wadeable streams. Prepared for the Massachusetts Department of Environmental Protection by Tetra Tech. Montpelier, VT.

Jessup, B., B. Block, and J. Stamp. 2021. Development of an Index of Biotic Integrity for Macroinvertebrates in Freshwater Low Gradient Wadeable Streams in Massachusetts Draft Report. Prepared for the Massachusetts Department of Environmental Protection by Tetra Tech. Montpelier, VT.

APPENDIX J
OVERVIEW OF THE PROCESSING AND EVALUATION PROCEDURES USING *E. COLI* AND *ENTEROCOCCUS* BACTERIA DATA FOR RECREATIONAL USE ATTAINMENT DECISIONS

Primary Contact Recreation Bacteria Criteria in the SWQS

Bacteria criteria for both fresh and coastal/marine waters in the Massachusetts Surface Water Quality Standards (SWQS), 314 CMR 4.00, are based on EPA's 2012 criteria recommendations that reflect the rate of 36 gastrointestinal (GI) illnesses per 1,000 persons for surface waters designated for primary contact recreation (Class A, B, SA, and SB waters; MassDEP 2021) (Table J1). The criteria include geometric mean (GM) not-to-exceed magnitudes and statistical threshold values (STVs) that are not to be exceeded by more than 10% of samples.

Table J1. Bacteria criteria in the Massachusetts Surface Water Quality Standards (314 CMR 4.00) based on the 2012 EPA criteria recommendations for Primary Contact Recreation.

Bacteria	Fresh Water (Class A & B)		Coastal & Marine Waters (Class SA & SB)	
	GM (CFU /100 mL)	STV [c] (CFU /100 mL)	GM (CFU /100 mL)	STV [c] (CFU /100 mL)
E. coli	126	410	-	-
Enterococcus	35	130	35	130

Notes: GM is the Geometric Mean and STV is the Statistical Threshold Value. GM calculations use the Method Detection Limit (MDL) and the Upper Quantification Limit (UQL) for "<MDL" and ">UQL" results, respectively. Colony Forming Units (or some results may be reported as MPN, Most Probable Number, which for practical purposes are deemed by MassDEP to be equivalent to CFUs on a volume-to-volume basis). For simplicity in IR related material, all references to CFU/100mL results may also refer to MPN/100mL results. The SWQS define Primary Contact [b] *Recreation as: "Any recreation or other water use in which there is prolonged and intimate contact with the water with a significant risk of ingestion of water. These include, but are not limited to, wading, swimming, diving, surfing and water skiing."*

The primary contact recreation bacteria criteria are applied using 90-day evaluation intervals for most surface waters throughout the calendar year. MassDEP can apply these criteria seasonally in accordance with 314 CMR 4.05(5)(f)4. and considers the primary contact recreation season to occur April 1 through October 31. A shorter (30-day) interval is used for waters with a high frequency of primary contact recreation (i.e., public and semi-public beaches during the bathing season; reverting to a 90-day interval outside of the bathing season) and surface waters impacted by discharges from combined sewer overflows (CSOs) and publicly-owned treatment works (POTWs). CSO- and POTW-impacted surface waters include those segments with a "CSO" qualifier or those described as having a POTW discharge at the beginning of the segment in Tables 1 through 27 at 314 CMR 4.06(6)(b). These impacted segments start at the point of discharge and continue to the defined boundary of the segment, as described in the tables. If surface waters that are not listed in the SWQS tables receive these types of discharges, the 30-day evaluation interval applies, at minimum, from the discharge point downstream to the confluence with a named surface water. The length of the impacted reach may extend farther depending on the size of the drainage area and any tributary surface water(s) and the presence of other upstream or downstream CSO and/or POTW discharges. For coastal and marine segments that are not described in the SWQS, evaluations would apply to the surface water as described in MassDEP's current Integrated List of Waters.

For beach closure decisions, MDPH has communicated to EPA that their approach using GMs and Beach Notification Thresholds (BNTs) is as protective as the 2014 National Beach Guidance and Required Performance Criteria for Grants, as demonstrated by a comprehensive analysis of local water quality data. The 2014 guidance is based on the 2012 EPA criteria recommendations. Therefore, the amended SWQS regulation does not conflict with MDPH's regulation.

The SWQS Primary Contact Recreation Criteria and Use Attainment

MassDEP analysts developed bacteria data assessment methods for making use attainment evaluations of the *Primary Contact Recreation Use* based on the SWQS. The methods differ depending on the 1) bacterial indicator organism, 2) sample frequency, 3) number of years of quality-assured data available for a site (e.g., single year or multi-year data sets), and 4) applicable interval (either a 30- or 90-day interval). For the purposes of making use attainment decisions, bacteria GMs are calculated using a "Rolling Backwards – Unique" (RBU) approach (described in more detail below) using either 30- or 90-day interval durations from April through October. These calculated GMs are compared to the applicable GM criterion.

EPA notes in the 2012 guidance document that “[S]tates should not include a minimum sample size as part of their criteria submission”. However, EPA recommends at least weekly sampling in their 2012 guidance, as “a larger dataset will more accurately characterize the water quality in a waterbody”. While MassDEP removed the minimum sample requirement from the SWQS to be consistent with EPA’s criteria recommendations, use attainment evaluations require a sufficient sample size (minimum of either two or three samples for 30- or 90-day interval GM calculations, respectively). Data years with some data but with zero GM intervals are considered “insufficient” data years. For STV evaluations, the individual (discrete) bacteria concentrations are compared directly to the STV criterion using either the number or percentage of samples exceeding the threshold depending on the sampling frequency. For insufficient data years (i.e., years with zero GM intervals), STV evaluations are presented, but they are, by default, excluded from the use attainment decision. Any concerns (e.g., elevated seasonal GM, instances of STV exceedances) not resulting in an impairment decision will be identified with an Alert along with a recommendation for additional sampling.

Description of the Interval Analysis.

The term “interval” refers to either a 30- or 90-day duration in the Rolling Backwards Unique (RBU) Interval approach. Under the RBU approach, a unique interval is created when either a sample is gained or lost from the preceding 29 or 89 days (i.e., a 30- or 90-day interval duration, respectively) for samples collected in the period April 1 through October 31. The calendar day used as the basis for evaluating interval uniqueness is referred to as the “anchor date”, and a GM is calculated for the samples contained within that interval. GMs are calculated for all possible unique intervals from April 1 through October 31. A final summary of the GM statistics is produced at the end of the process. Figure J1 depicts intervals created for an example dataset using a RBU 30-day interval duration. In this figure, the first interval is created with an anchor date on September 1 with the addition of the first sample. The next interval is created on September 7, the date when the second sample is added. An interval is also created on October 2 because the interval on that date would not contain the first sample collected on September 1. Figure J1 also demonstrates that anchor dates can be associated with calendar days when no physical sample was collected in the field. The 30-day RBU interval analysis creates some intervals with anchor dates outside the Primary Contact Recreation season, even though all samples used for GM calculations are collected from April 1 to October 31 (the Primary Contact Recreation season); for analyses using 90-day interval durations, anchor dates may extend into the next calendar year.

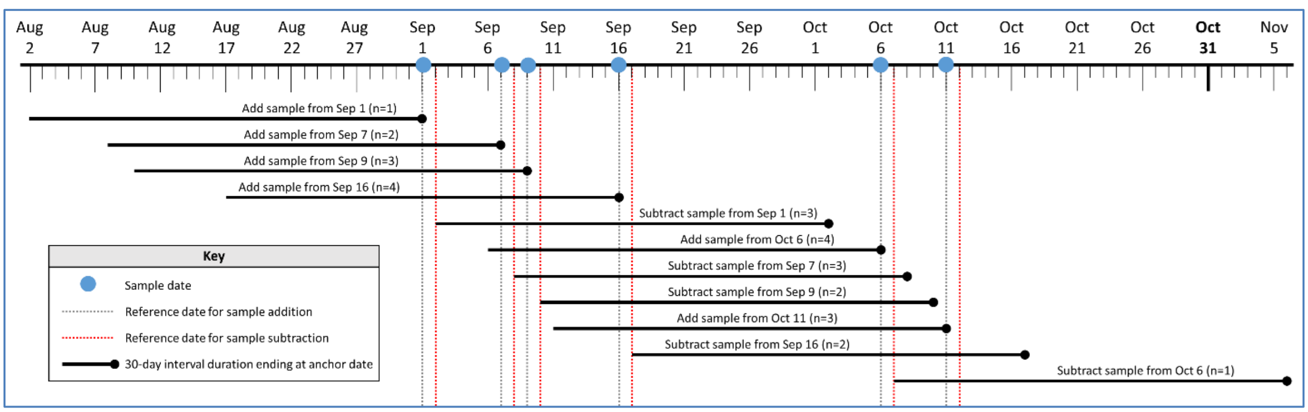


Figure J1. Intervals Created for an Example Dataset Using a 30-Day Rolling Backwards Unique (RBU) Interval Approach.

Interval GM Analysis.

As mentioned above, GM calculations for use attainment evaluations require a minimum of two samples for 30-day interval analyses and three samples for 90-day interval analyses (see “Derivation of Minimum Sample Requirements” for more details). GM calculations for intervals that do not meet the minimum sample requirements are presented in the figures but are not utilized in use attainment decisions.

Graphical Presentation of Bacteria Data.

Given the need to analyze multiple GMs (30- or 90-day intervals) and single sample concentrations (for STV comparisons) for a site, bacteria data are presented in graphical format to aid in making use attainment evaluations. Figures include graphs displaying time-series information (e.g., all GMs) and tables summarizing yearly data statistics (as well as overall statistics for multi-year datasets). See Figure J2 as an example of a 90-day interval graphic displaying sample concentration values plotted by collection date, as well as interval GMs plotted by anchor date. For this 90-day interval example, the blue dots represent GMs of intervals meeting the minimum sample requirement, while the grey dots represent interval GMs not meeting the requirement. Note that for some data years, insufficient data may exist (GM intervals = 0) and such data years are excluded from use attainment decisions. Figure J3 provides further detail of how data are graphically presented to allow comparisons with the GM and STV criteria.

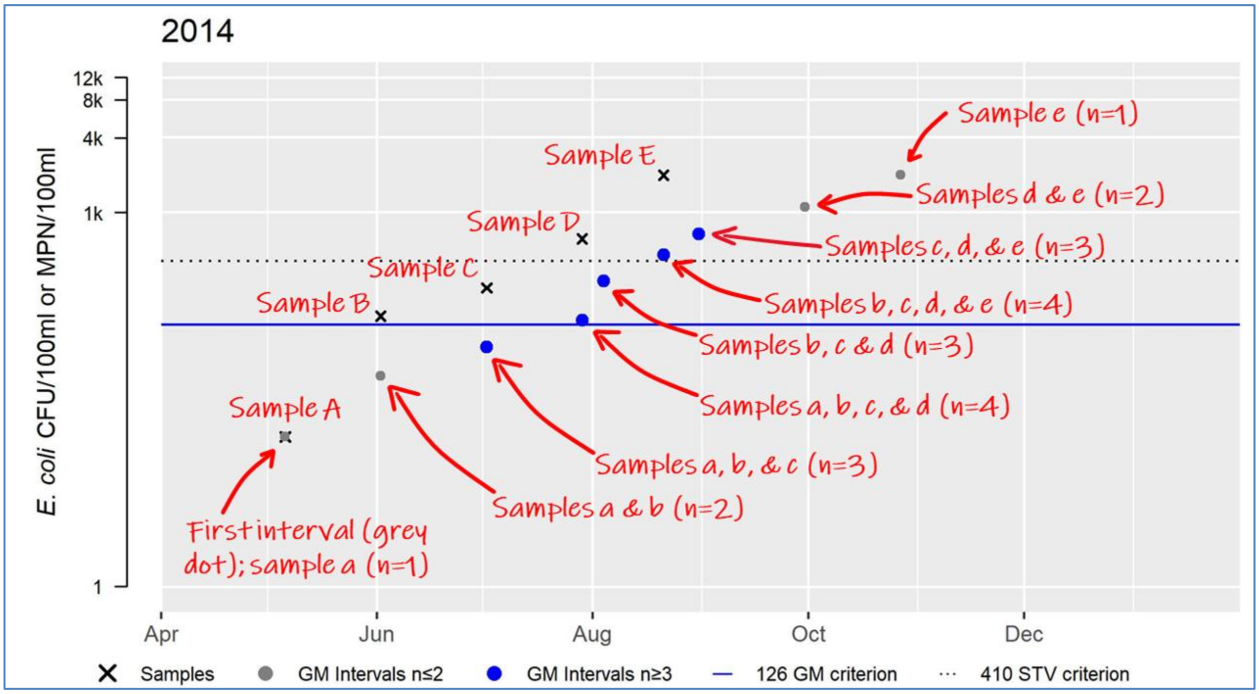


Figure J2. Bacteria Sample Data and 90-Day Interval GMs for an Example *E. coli* Dataset.

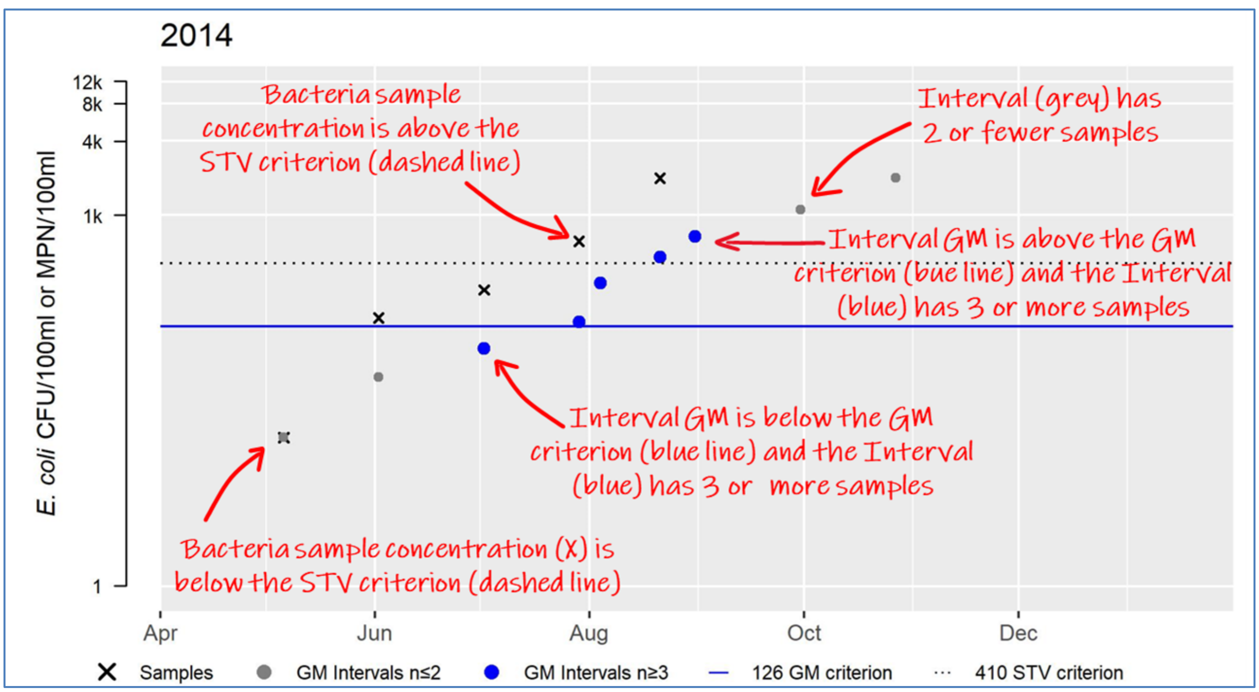


Figure J3. Comparison of Interval GMs and Bacteria Sample Concentrations to GM and STV Criteria for an Example *E. coli* Dataset. [Note: criteria are specific to the indicator organism and recreational use].

Summary statistics for the Primary Contact Recreation season (April 1 – October 31) are included in tabular form in the figures (See Figures J4a and J4b) along with a key to abbreviations. Data tables include the following:

- ‘Samples’ is the total number of discrete bacteria samples (April 1 – October 31)
- ‘SeasGM’ is the GM calculated for all samples within the period April 1 – October 31
- ‘#GMI’ is the number of intervals that meet the minimum sample requirement for the applicable interval duration (i.e., two samples for 30-day intervals, three samples for 90-day intervals)
- ‘#GMI Ex’ is the number of intervals meeting the minimum sample requirement whose GM value exceeds the criterion
- ‘%GMI Ex’ is the percentage of intervals meeting the minimum sample requirement with GM values exceeding the criterion
- ‘n>STV’ is the number of discrete bacteria samples with concentrations that exceed the STV criterion within the period April 1 – October 31
- ‘%n>STV’ is the percent of discrete bacteria samples with concentrations that exceed the STV criterion out of all samples from April 1 – October 31

Additionally, for multi-year datasets with six or more years of available, sufficient data, the cumulative %GMI Ex is calculated over the entire dataset as well as separately for the most recent five years of sufficient (not necessarily consecutive) data (See Figure J4b). These summary statistics are used in conjunction with the graphical representations to evaluate data according to the Bacteria Impairment Decision Schema (Table 6).

Table of summary statistics for the individual year represented in the plot below

Var	Res
Samples	5
SeasGM	235
#GMI	5
#GMI Ex	4
%GMI Ex	80
n>STV	2
%n>STV	40

Abbreviations: Samples = #samples; SeasGM = Seasonal Geometric Mean (GM); #GMI = number GM Intervals; #GMI Ex = number GMI Exeedances; %GMI Ex = percent GMI Exeedances; n>STV = #samples>Statistical Threshold Value (STV); %n>STV = percent samples>STV

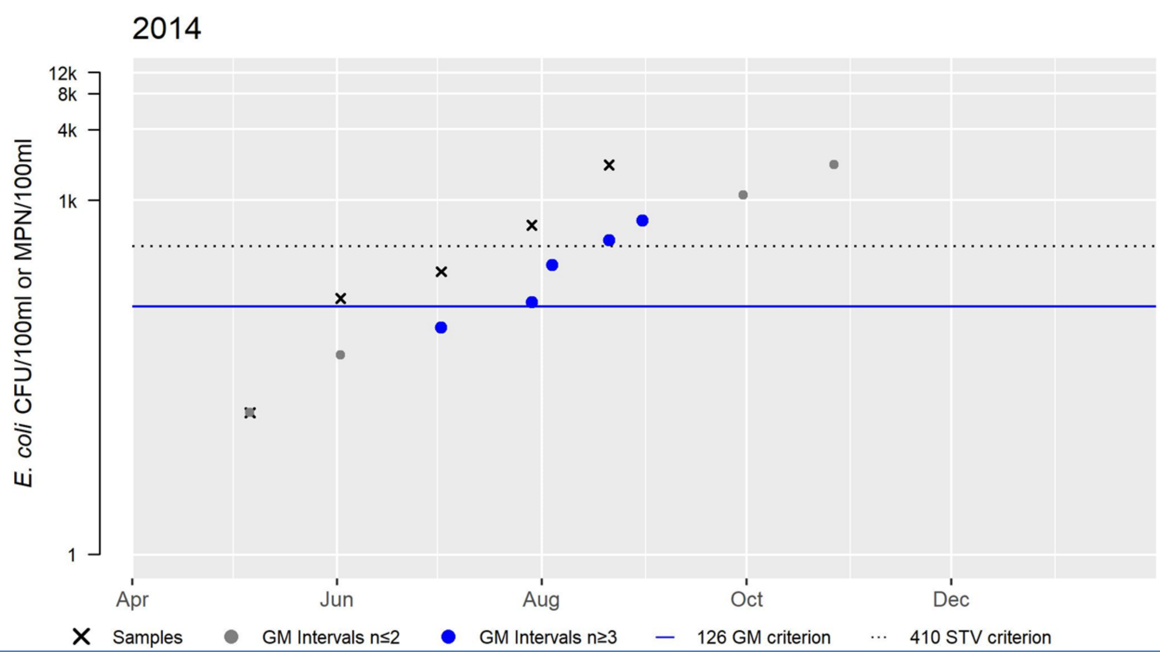


Figure J4a. Bacteria Sample Data, 90-Day Interval GMs, and Summary Statistics for Single-Year Datasets.

Var	Res	Var	Res	Var	Res	Var	Res	Var	Res	Var	Res	Var	Res
Samples	30	Samples	16	Samples	19	Samples	8	Samples	8	Samples	5	Samples	10
SeasGM	79	SeasGM	123	SeasGM	74	SeasGM	46	SeasGM	102	SeasGM	24	SeasGM	159
#GMI	52	#GMI	25	#GMI	31	#GMI	11	#GMI	11	#GMI	5	#GMI	13
#GMI Ex	21	#GMI Ex	12	#GMI Ex	11	#GMI Ex	0	#GMI Ex	6	#GMI Ex	0	#GMI Ex	7
%GMI Ex	40	%GMI Ex	48	%GMI Ex	35	%GMI Ex	0	%GMI Ex	55	%GMI Ex	0	%GMI Ex	54
n>STV	4	n>STV	4	n>STV	2	n>STV	0	n>STV	1	n>STV	0	n>STV	3
%n>STV	13	%n>STV	25	%n>STV	11	%n>STV	0	%n>STV	12	%n>STV	0	%n>STV	30

Abbreviations: Samples = #samples; SeasGM = Seasonal Geometric Mean (GM); #GMI = number GM Intervals; #GMI Ex = number GMI Exeedances; %GMI Ex = percent GMI Exeedances; n>STV = #samples>Statistical Threshold Value (STV); %n>STV = percent samples>STV

Lists the percent of GM's that exceeded the criterion in all years

Variable	Cumulative %GMI Ex (all years)	Cumulative %GMI Ex (last 5 years)
Result	39	34

Lists the percent of GM's that exceeded the criterion in the most recent five years with any data

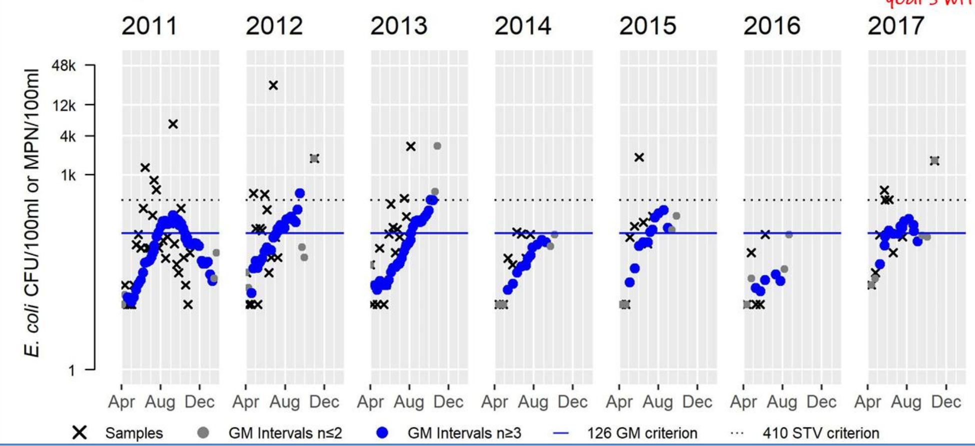


Figure J4b. Bacteria Sample Data, 90-Day Interval GMs, and Summary Statistics for Multi-Year Datasets.

<u>Derivation of the Primary Contact Recreation Bacteria Impairment Decision Schema.</u>
MassDEP analysts developed an impairment decision schema for the *Primary Contact Recreation Use* (Table 6) that can be implemented for diverse bacteria datasets (i.e., limited-frequency single year to high-frequency multi-year datasets). The approach to categorizing datasets based on sample frequency was modeled on methods developed by MassDEP SWQS analysts for toxics. The use of data frequency scenarios helped tailor use attainment evaluations to individual datasets using an intuitive process. Three data frequency scenarios were used to differentiate datasets for analysis:

- Limited frequency: sampling less than once a month [<7 samples, April 1 – October 31]
- Moderate frequency: sampling monthly [7 to 14 samples, April 1 – October 31]
- High frequency: sampling every two weeks [≥15 samples, April 1 – October 31]

Additional information related to schema development is provided in the "Technical Information Related to Threshold Development (Justification)" section.

Bacteria Data Processing & Evaluation Procedures for *Secondary Contact Recreation Use* Attainment
Unlike the *Primary Contact Recreation Use*, the *Secondary Contact Recreation Use* is assumed to occur year-round. The SWQS define secondary contact recreation as "…*Any recreation or other water use in which contact with the water is either incidental or accidental. These include but are not limited to fishing, including human consumption of fish, boating and limited contact incident to shoreline activities*. *Where designated, secondary contact recreation also includes shellfishing including human consumption of shellfish*" (MassDEP 2021)].

The bacteria thresholds for the assessment of the *Secondary Contact Recreation Use* are derived from EPA's 2024 secondary contact recreation user guide (EPA 2024). The Massachusetts SWQS primary contact criteria values are multiplied by the ratio of the magnitude of incidental water ingestion during Primary Contact Recreation activities to the magnitude of incidental water ingestion during Secondary Contact Recreation activities. Key here, is that the incidental ingestion rate for Secondary Contact Recreation activities is chosen conservatively based on kayaking "all activities" which includes kayaking events where capsizing occurred, as well as those where it did not occur.

The thresholds include both a geometric mean (GM) and a statistical threshold value (STV) and are described in Table J3 for *E. coli* and *Enterococcus* bacterial indicators. Note that the evaluation interval was revised from 6 months to 90-days to be consistent with criteria applicable to primary contact recreation.

MassDEP analysts updated evaluation procedures for the *Secondary Contact Recreation Use* for closer alignment with new procedures for the *Primary Contact Recreation Use*. The GM criteria are evaluated using the RBU interval approach for 90-day intervals (as described in Figure J1). The anchor date for intervals may extend into the following calendar year because *Secondary Contact Recreation Use* data span an entire calendar year. A minimum of three samples is required for calculating 90-day interval GMs. The GMs for intervals that do not meet minimum sample requirements are calculated and presented but are not included in the data evaluations. However, if the analyst notes water quality concerns (e.g., elevated annual GM, instances of STV exceedances) in a dataset with no GM intervals meeting minimum sample requirements, an Alert may be identified along with a recommendation for additional sampling. Depending on the sampling frequency, STV evaluations are made using either the number or percentage of samples exceeding the threshold. Similar to the process used for *Primary Contact Recreation Use* evaluations, bacteria data collected in the calendar year are presented in figures with graphs displaying time-series information (e.g., all GMs) and tables summarizing yearly data statistics (as well as cumulative statistics for multi-year datasets), but data are evaluated against *Secondary Contact Recreation Use* thresholds (see Figures J2, J3, J4a, J4b; Table J3). Also note that *Enterococcus* cannot be used as an indicator organism for *Secondary Contact Recreation Use* attainment decisions for freshwaters, unlike their use in evaluations for the *Primary Contact Recreation Use*.

Table J3. Bacteria thresholds required to evaluate *Secondary Contact Recreation Use* attainment

Bacteria	Fresh Water (Class A & B)		Coastal & Marine Waters (Class SA & SB)	
	GM (CFU/100 mL)	**STV** (CFU/100 mL)	**GM** (CFU/100 mL)	**STV** (CFU/100 mL)
E. coli	244	794	-	-
Enterococcus	-	-	68	252

[Notes: GM is the Geometric Mean and STV is the Statistical Threshold Value. GM calculations use the Method Detection Limit (MDL) and the Upper Quantification Limit (UQL) for "<MDL" and ">UQL" results, respectively.] The bacteria data evaluation methods in the Bacteria Impairment Decision Schema differ depending on factors such as bacterial indicator organism, sampling frequency, and number of years of available, quality-assured data (e.g. single year or multi-year data sets) for each site.

Summary statistics for the *Secondary Contact Recreation Use* are included in tabular form in the figures (presented similarly to Figures J4a and J4b) along with a key to abbreviations. Data tables include the following:

- 'Samples' is the total number of discrete bacteria samples within the calendar year
- 'SeasGM' is the geometric mean calculated for all samples within the calendar year
- '#GMI' is the number of intervals that meet the minimum sample requirement (i.e., three for 90-day intervals)
- '#GMI Ex' is the number of intervals meeting the minimum sample requirement with GM values exceeding the criterion
- '%GMI Ex' is the percentage of intervals meeting the minimum sample requirement with GM values exceeding the criterion
- 'n>STV' is the number of discrete bacteria sample concentrations that exceed the STV criterion out of all samples for the calendar year
- '%n>STV' is the percent of discrete bacteria sample concentrations that exceed the STV criterion out of all samples for the calendar year

Additionally, for multi-year datasets with six or more years of available, sufficient data, the cumulative %GMI Ex is calculated over the entire dataset as well as separately for the last five years of sufficient (not necessarily consecutive) data (See Figure J4b).

The summary statistics are used in conjunction with the graphical representations to evaluate year-round data according to the Bacteria Impairment Decision Schema for the *Secondary Contact Recreation Use* (Table 7). The same threshold percentages are applied as those described in "Derivation of the Primary Contact Recreation Bacteria Impairment Decision Schema."

Technical Information Related to Threshold Development (Justification)
MassDEP analysts took an empirical approach to develop use attainment thresholds for both GM and STV criteria. EPA recommends both criteria be applied concurrently using static or rolling evaluations. MassDEP adopted an approach (described below) that uses both criteria for making use attainment evaluation decisions and reduces statistical bias due to low data availability and sampling frequency.

<u>Derivation of Minimum Sample Requirements</u>
EPA recommends that states refrain from including a minimum sample size as part of criteria submissions but acknowledges that low sample number and frequency may result in biased use attainment evaluation decisions. MassDEP evaluates all available, quality-assured data as part of the use attainment evaluation process. Yet, GM calculations from intervals with low sample numbers may misrepresent the 'average' concentration for an interval. Variability of interval GMs increases with decreasing sample size in the interval, and high variability of sample concentrations may limit statistical confidence in interval GMs. Ignoring the effect of interval sample size on variability in interval GM calculations could result in biased use attainment evaluations. To address this, the minimum number of samples required for use attainment evaluations was determined through an empirical analysis of the data that balances data loss and potential bias. The use of two samples for 30-day intervals and three samples for 90-day intervals represents a conservative approach that accounts for potential bias while maximizing data utilization.

<u>Selection of the Rolling Backwards Unique Interval Approach</u>
EPA recommends the use of rolling or static intervals of 30 days to evaluate bacteria data. Rolling and static intervals are similar methods for generating ordered (i.e., chronological) groupings of subsets of data. The interval "width" is the duration of the interval, and the interval "frequency" describes how often the interval repeats. The interval duration and frequency determine how many intervals are produced for a dataset. Similarly, the frequency of sampling determines the number of samples in a particular interval. Large interval durations, high frequency intervals, and high frequency sampling typically lead to a high number of samples in an interval. MassDEP analysts used a hypothetical dataset to evaluate different types of intervals (e.g., static, forward rolling, backwards rolling, different interval durations). The Rolling Backwards Unique Interval approach creates an interval for each unique sample combination (as samples are added and removed from intervals) and was selected as the most appropriately comprehensive and protective analysis.

The GM for each interval represents an 'average' condition within that interval. Data comparisons in an interval to an STV criterion complement the GM by evaluating the frequency of periodic high concentrations (excursions of discrete measurements). EPA recommends that intervals be used to group STV excursion evaluations as a percentage "not to exceed" criterion. However, this method requires high frequency sampling (i.e.,10 samples or more) to avoid biasing use attainment evaluations and is impractical given the limited nature of bacteria data available. MassDEP has adopted a rolling window approach for determining GM intervals, and an approach where, depending on the sampling frequency, the STV criterion is evaluated by either the overall number or percentage of all samples exceeding the STV criterion.

<u>Use Impairment Threshold Development</u>
The specific structure of the Bacteria Impairment Decision Schema is designed to be protective of public health and to provide high confidence in assessment decisions based on available, quality-assured data (Tables J2, J4). Bacteria concentrations are often highly variable; therefore, more conservative assumptions are applied when making impairment decisions with limited data (i.e., <7 samples in a year). The percentages for GM and STV criteria exceedance thresholds in the decision schema are based on an empirical data analysis that simulated the number of impairments that would occur in single-year datasets when applying various proposed thresholds.

Threshold percentages were chosen that:
a) were protective by utilizing multiple metrics (i.e., GM, STV, cumulative GM for multi-year datasets)
b) were more conservative for limited data than high frequency data (representing increasing confidence in assessment decisions with more data),
c) were based on scientifically sound and detailed analyses,
d) placed higher weight on the most recent five years of sufficient data in datasets with six or more years of data, and
e) were readily understandable and practical.

Additionally, it is important to note that although bacteria analysis outputs are auto-generated through the R statistical package, the use attainment decisions themselves are made by WPP analysts. In cases where any concerns are noted, an Alert is identified, and recommendations are made for follow-up monitoring.

Figures J5 and J6 illustrate the results of the *E. coli* and/or enterococci data simulation exercises used to derive GM and STV threshold percentages for the Bacteria Impairment Decision Schemas. Single-year datasets were evaluated for the number of impairment decisions using the structure of the Bacteria Impairment Decision Schema but with a range of different threshold percentages. The number of impairment decisions using the overall GM (i.e., the previous guidance) is plotted as a horizontal red line for reference to assure a similar or greater number of overall impairments under the new impairment decision schema. Results of the empirical analysis for determining threshold percentages are similar for *E. coli* and enterococci bacteria concentrations.

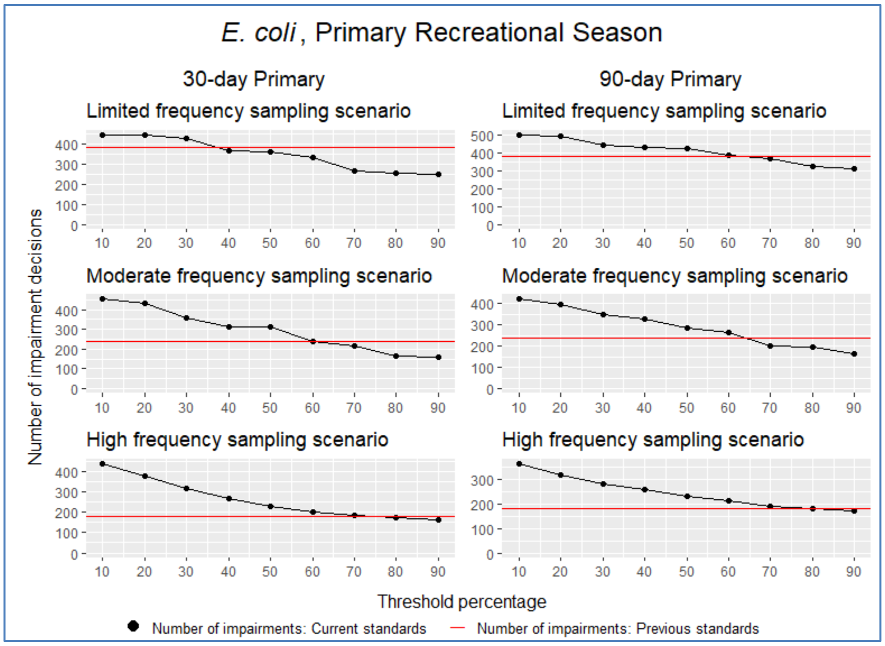


Figure J5. Simulation Exercise Results Used in the Development of *E. coli* Threshold Percentages for the Primary Contact Recreation Bacteria Impairment Decision Schema.

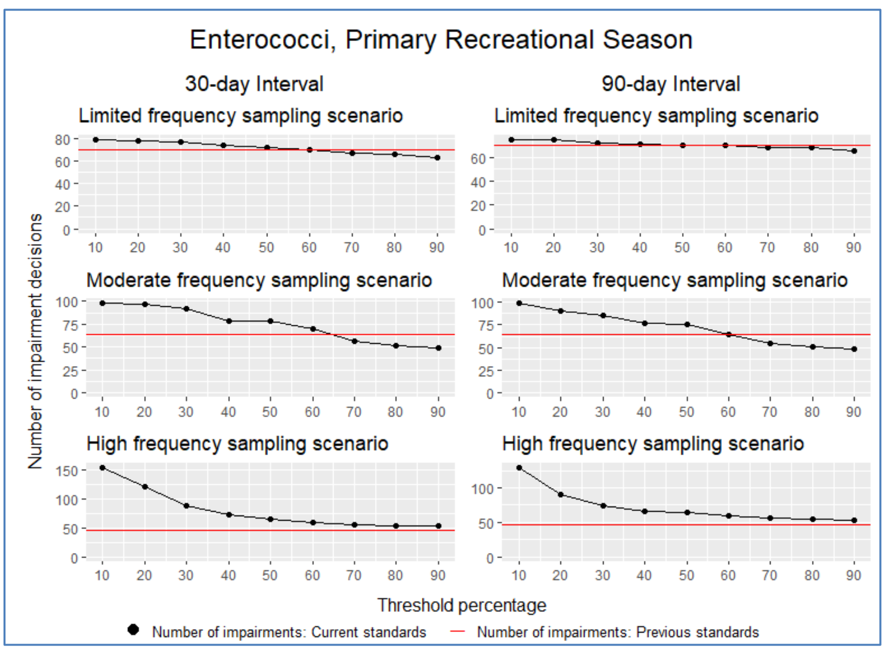


Figure J6. Simulation Exercise Results Used in the Development of Enterococci Threshold Percentages for the Primary Contact Recreation Bacteria Impairment Decision Schema.

The threshold percentages chosen for the impairment decision schema a greater proportion of impairments than the previous guidance (overall GM) for high-frequency, simulated single-year datasets (the magnitude of the difference in the number of impairments differed slightly between *E. coli* and enterococci data). MassDEP analysts have the most confidence in use attainment decisions made with high-frequency datasets, which justifies the use of modified threshold percentages among different sample data frequency scenarios. Incrementally increasing threshold percentages from high- to mid- to low-frequency datasets are imposed in the impairment decision schema to account for reduced statistical confidence as sampling frequency declines. The result was a similar number of impairments and slightly fewer impairments for mid- and low-frequency datasets respectively, compared to previous guidance. Overall, these impairment decision schemas are protective of public health and yield use impairment decisions in which MassDEP has confidence.

References

EPA. 2024. “Adopting Water Quality Criteria for Secondary Contact Recreation: A User Guide.” EPA 820-B-24-001, Available at https://www.epa.gov/system/files/documents/2024-07/scr-user-guide.pdf, Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency, Washington, DC.

MassDEP. 2021. "Massachusetts Surface Water Quality Standards (Revision of 314 CMR 4.00, effective November 12, 2021, corrected December 10, 2021 and January 7, 2022)." Available at https://www.mass.gov/regulations/314-CMR-4-the-massachusetts-surface-water-quality-standards, Massachusetts Department of Environmental Protection, Boston, MA.

APPENDIX K
RATIONALE FOR USING AQUATIC PLANT (MACROPHYTES) AS A NON-POLLUTANT CAUSE OF IMPAIRMENT

Rationale for using Aquatic Plant Macrophytes as a non-pollutant cause of impairment

As part of the 2016 reporting cycle MassDEP analysts began an effort to reevaluate waters listed as impaired due to APM. This reevaluation effort was requested by MassDEP staff who developed Total Phosphorus TMDLs, particularly because of their experience developing Total Phosphorus TMDLs for the Selected Millers Basin Lakes (MassDEP 2003c), the Selected French Basin Lakes (MassDEP 2002a), and the Selected Northern Blackstone Lakes (MassDEP 2002b), as well as the site-specific TMDL for White Island Pond (MassDEP 2010). MassDEP currently lacks a lake classification system and, therefore, no differentiation is made between deeper lakes as opposed to more shallow lakes where naturally occurring shallow areas provide ideal habitat for the proliferation of rooted aquatic plants. While several watershed (i.e., Millers, French, and northern Blackstone) lake TMDLs were in development, it was determined, and thereafter approved by EPA, that the original assessment and listing decisions related to the “Noxious Aquatic Plants” impairment evaluations of many lakes in other watersheds of the state were inaccurate or incomplete as documented in the 2002 and 2004 IRs (MassDEP 2003a, 2003b, 2005). While many lakes were delisted during the 2002 and 2004 reporting cycles, those lakes listed as impaired for “Noxious Aquatic Plants” in the Millers, French, and northern Blackstone basins for which TMDLs were already in development were not included as part of that delisting process.

The remaining “Noxious Aquatic Plants” impairments were translated to APM impairments when MassDEP transitioned from using EPA’s Waterbody System (WBS) assessment database to their Assessment Database (ADB) between the 2006 and 2008 reporting cycles. As part of that transition, the APM cause of impairment in the ADB was identified by default as a pollutant, as opposed to a non-pollutant, automatically triggering the development of a nutrient (likely Total Phosphorus) TMDL. As described in Appendix C Section 4.0 of the 2016 CALM Guidance Manual (MassDEP 2016), use of estimated coverages of rooted aquatic plants is not used as a nutrient enrichment indicator. The relationship between nutrients and plant abundance and biomass is influenced by many factors, some of which are natural (e.g., lake bathymetry, light availability). A primary influence on the growth rate of rooted aquatic plants is the nutrient availability in bottom sediments whereas nutrients in the water column are considered a less important, secondary source of nutrients for their growth. As a result, rooted aquatic macrophytes do not respond readily to fluctuation of phosphorus concentrations in the water column, and impairments due to high densities of rooted aquatic plants should not be attributed to a pollutant but rather a non-pollutant (Category 4C). In contrast, non-rooted plants and algae acquire nutrients for growth directly from the water column. In cases of APM due primarily to non-rooted plants, the appropriate cause is thought to be the pollutant phosphorus in the water column (Category 5). It was recommended by TMDL staff during the 2016 IR reporting cycle, that in order to prioritize those lakes best managed through the development of a Total Phosphorus TMDL, as opposed to waterbodies better managed by other in-lake techniques (e.g., mechanical harvesting, winter drawdowns, herbicide applications), that the cause code APM should be mapped as a non-pollutant, resulting in a listing decision which would place the waterbody in Category 4C.

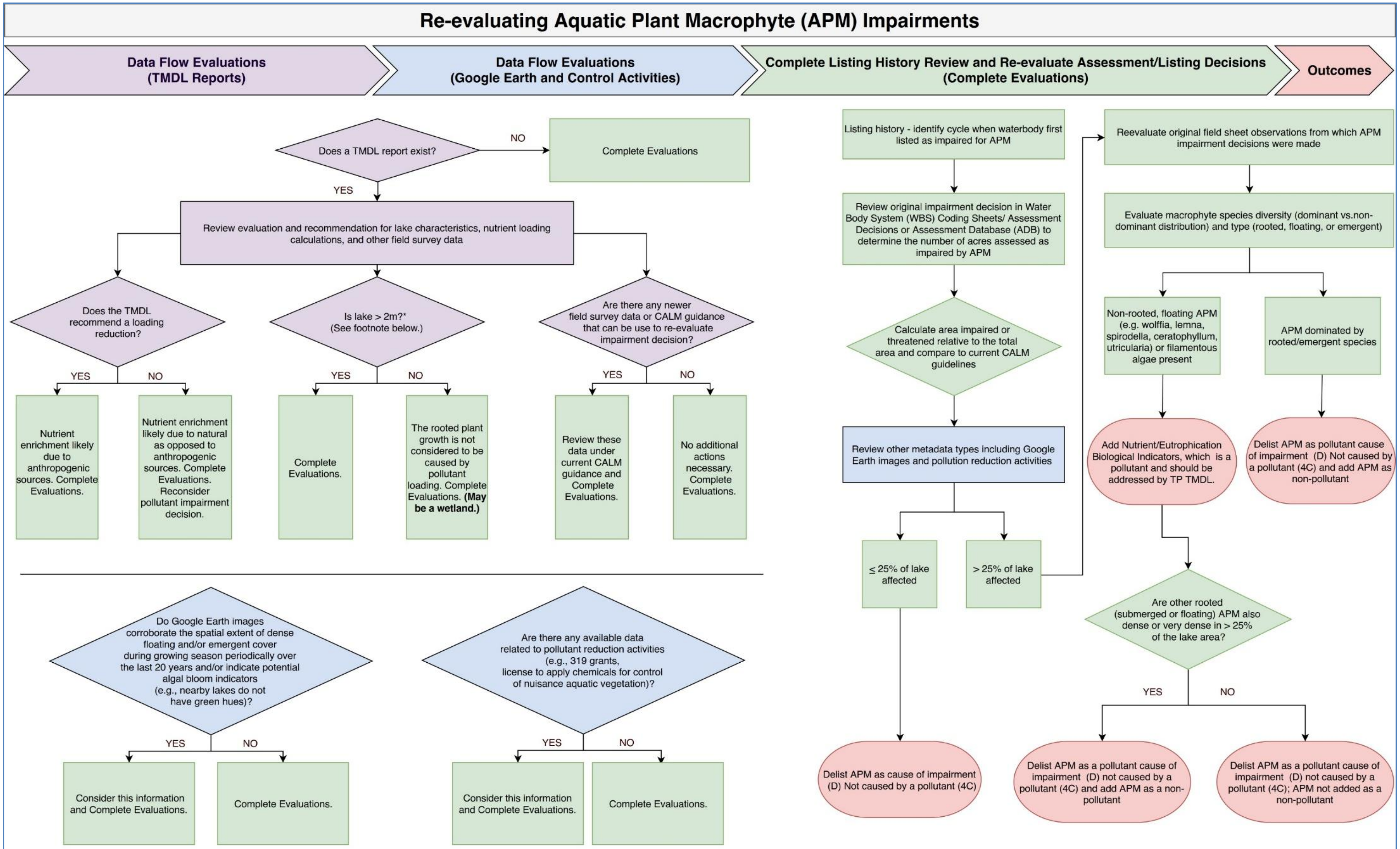
A stepwise review process for the APM reevaluation (see Figure J1) was developed by WPP analysts to consider multiple sources of information, including but not limited to Google Earth satellite imagery (often available for various months/years ranging from the mid-1990s through current time), herbicide application records, historical information on maximum lake depth, DEP water quality monitoring data, and 319 grant activities, leading to an outcome of

1) APM being delisted as a pollutant and relisted as a non-pollutant,
2) APM being delisted due to historical errors in the original listing or reapplication of current assessment methodology on whatever data are available (including original data utilized for an impairment listing if they are the only data available), or
3) APM being delisted as a pollutant to be replaced with a listing of impaired due to Nutrient/Eutrophication Biological Indicators (a pollutant).

As part of the reevaluation process, those lakes experiencing dense/very dense plant coverage >25% of the lake area by filamentous algae, or aquatic macrophyte species that utilize nutrients directly from the water column (e.g,. non-rooted floating species including *Lemna*, *Wolfia*, *Spirodella*, *Ceratophyllum*, *Utricularia*) should be reassessed as impaired using the pollutant code “Nutrient/Eutrophication Biological Indicators”. This reclassification would place these lakes in Category 5 until a Total Phosphorus TMDL is developed and allow MassDEP to better prioritize TMDL development for lakes based on core indicators (e.g., TP, Chl a) where nutrient reduction efforts should result in restoration, as opposed to requiring TMDLs for waterbodies (solely or also with with the pollutant code “Nutrient/Eutrophication Biological Indicators”) where naturally occurring shallow areas are conducive to both rooted and non-rooted aquatic plant growth and attached algae.

Google Earth satellite imagery are readily available for recent years as well as many historical dates going back to the mid-1990s by using the historical imagery button (Google Earth Pro Undated). Comparing images provides a means to capture plant/algal cover on most lakes/ponds during multiple summer growing seasons and to evaluate whether coverage changes or remains the same over time. These data provide a qualitative tool that can be utilized by MassDEP analysts to aid in the IR reporting process and they help to fill in gaps related to timing and frequency of other data collection efforts.

An additional, major effort was undertaken between the 2008 and 2016 reporting cycles, and completed during the 2016 reporting cycle, to eliminate cases where AU overlap occurred. To avoid “double counting” in future IRs, MassDEP analysts reviewed morphometric and hydrological data from impoundments as part of this process to determine whether the AU should continue to be defined and assessed as a lake AU or incorporated into a river AU. As a general rule, those impoundments formerly identified as lake AUs, but exhibiting unidirectional flow and estimated average retention times of less than fourteen days, were eliminated and merged with their respective river AU, whether or not they were named lakes depicted on USGS topographic quadrangle maps and/or had been assigned Pond and Lake Information System (PALIS) numbers. As new AUs are added in the future, impoundments along streams will continue to be evaluated to avoid any “double counting” going forward. In a few cases lake AUs with APM (formerly “Noxious Aquatic Plants”) impairments listed in either Category 4a (with an approved TMDL) or 5 may have been incorporated into a river AU. The impairments were transferred to the river AU. An effort is currently being undertaken to calculate the portion of the former lake reach within the total river AU. It is our BPJ that where the impounded portion of the river AU comprises <10% of the total AU river length, the APM impairment should be delisted because it is not considered to well-represent the AU. This analysis will need to be completed for all APM impairments where applicable during the APM reevaluation process.



*(FROM 314 CMR 4.0 Definition for Lakes and Ponds--waterbodies having open water, situated in a topographical depression, generally with a maximum depth of >2m.) The topic of lakes, wetlands, and perhaps more detailed lake habitat classification (deep vs.shallow) will require a structured evaluation procedure likely to be developed as part of the 2018 CALM guidance manual.

Figure K1. Flowchart depicting data review process related to reevaluation of Aquatic Plant Macrophyte (APM) Impairments.

References

Google Earth Pro. Undated. Satellite Imagery of selected stream and lake/pond segments, Massachusetts.

MassDEP. 2002a. Total Maximum Daily Loads of Phosphorus for Selected French Basin Lakes. TMDL Report Number: MA42003-2002-28, CN 110.0 Approved by EPA 12 July 2002, Massachusetts Department of Environmental Protection. Worcester, MA.

MassDEP. 2002b. Total Maximum Daily Loads of Phosphorus for Selected Northern Blackstone Lakes. TMDL Report Number: MA51004-2002-3, CN 70.1 Approved by EPA 2 May 2002, Massachusetts Department of Environmental Protection. Worcester, MA.

MassDEP. 2003a. Massachusetts Year 2002 Integrated List of Waters, Part 1 – Context and Rationale for Assessing and Reporting the Quality of Massachusetts Surface Waters. CN 125.1 Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA.

MassDEP. 2003b. Massachusetts Year 2002 Integrated List of Waters, Part 2 – Final Listing of Individual Categories of Waters. CN 125.2 Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA.

MassDEP. 2003c. Total Maximum Daily Loads of Phosphorus for Selected Millers Basin Lakes DEP, DWM TMDL Final Report MA35005-2002-1. CN 123.2 Approved by EPA 5 February 2003, Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA.

MassDEP. 2005. Massachusetts Year 2004 Integrated List of Waters – Final Listing of the condition of Massachusetts' waters pursuant to Sections 303(d) and 305(b) of the Clean Water Act. CN 175.0 Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA

MassDEP. 2010. Final Total Maximum Daily Load of Phosphorus for White Island Pond Plymouth/Wareham, MA DEP, DWM TMDL Report MA95166-201009-1. CN 330.2 Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA.

MassDEP. 2016. Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2016 Reporting Cycle. CN 445.0 Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA