Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2022 Reporting Cycle

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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 the Massachusetts Department of Environmental Protection (MassDEP) Division of Watershed Management's (DWM) Watershed Planning Program (WPP) analysts to make designated use-attainment decisions; and a description of the use of the federal 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 (Figure 1).

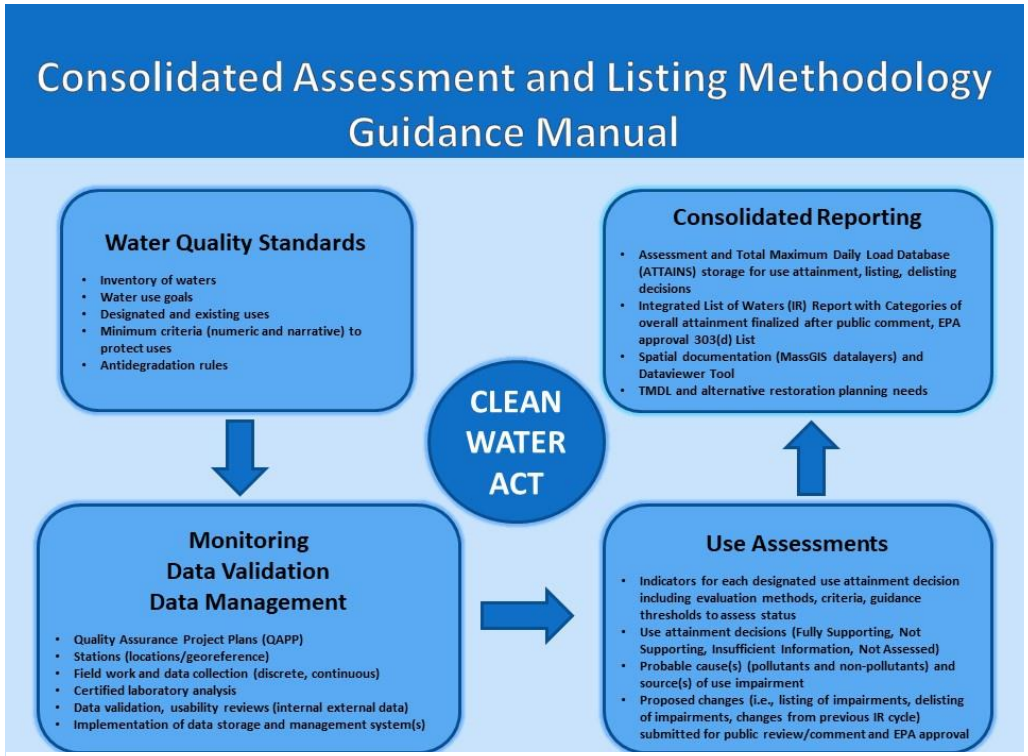

Figure 1. Components of Consolidated Assessment and Listing Methodology Guidance Manual

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 the MassDEP analysts assess and report on the status of Massachusetts' waters are illustrated in Figure 2 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/criteria as defined in the SWQS. The 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 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.

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, the MassDEP documented use attainment decisions and the data used to make them in individual, detailed watershed assessment reports (https://www.mass.gov/service-details/water-quality-assessments). 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 5 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 new How’s My Waterway site (https://mywaterway.epa.gov/state/MA/water-quality-overview) (see Figure 2). 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 a MassDEP data viewer.

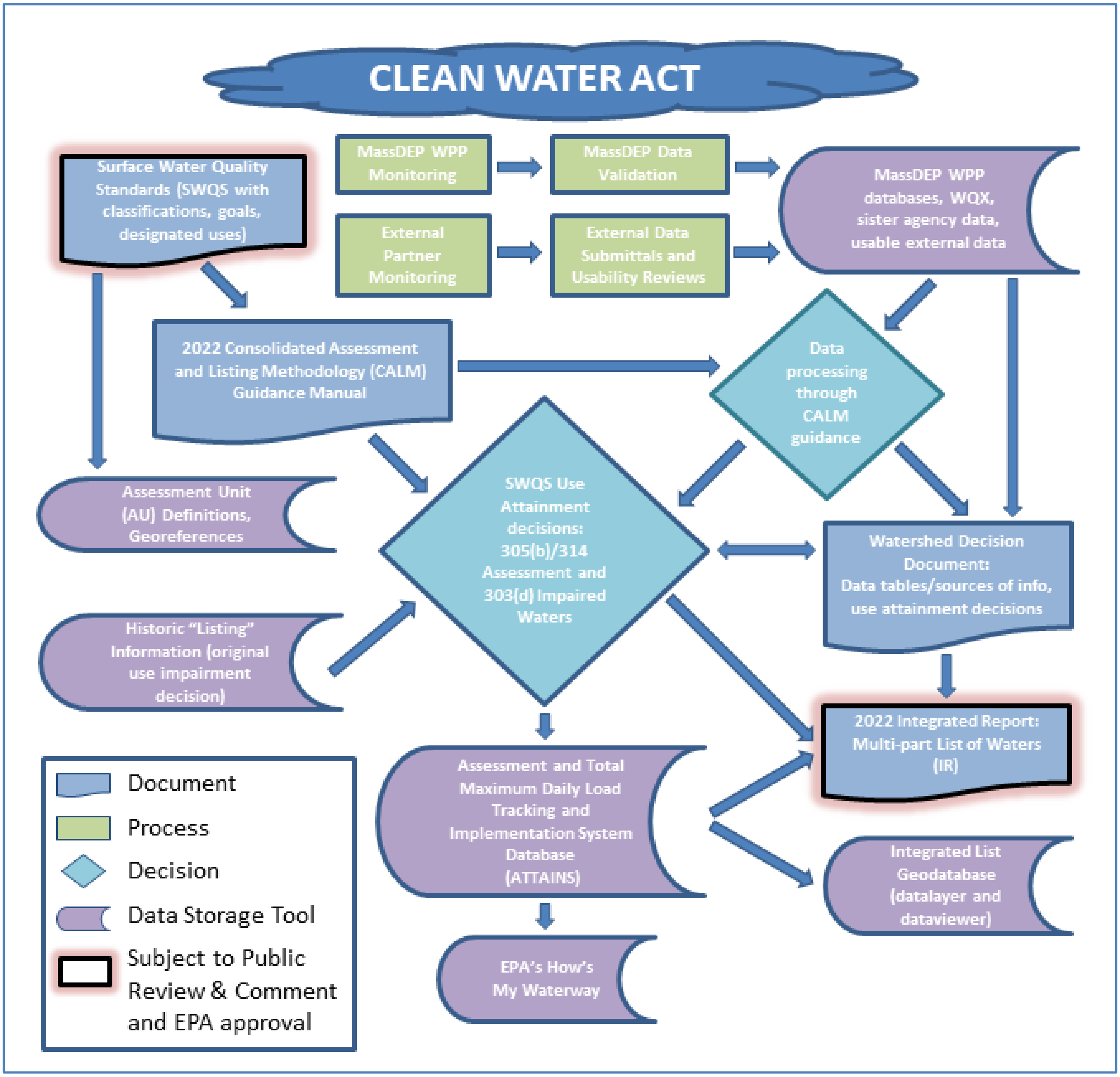

Figure 2. MassDEP, Consolidated Reporting Process Schematic

Notable Guidance Updates for 2022

The first CALM Guidance Manual, published in 2012, provided the methods and rationale for making the use attainment decisions embodied in the IRs up to and including the 2014 report (MassDEP 2012). The CALM Guidance Manual underwent a substantial revision in 2016 that included the development of more comprehensive protocols for identifying, protecting and/or restoring Cold Water Fisheries in Massachusetts and guidance for interpreting longer-term, continuous datasets for dissolved oxygen and temperature (MassDEP 2016a). In 2018 substantial revisions included a new section for Assessment Unit (AU) Definitions; new appendices for a Chloride Estimator and Data Reduction and Analysis Guidance; and guidance updated for: references to the EPA ATTAINS database; clarification for harmful algal blooms as part of recreational and aesthetics uses; clarification for evaluating toxic pollutants; utilization of the mainstem river Target Fish Community model in aquatic life use evaluations; specific inclusion of designated Cold Water AUs and a new temperature evaluation flowchart for Cold Waters; and assessment guidance for evaluation of diadromous fish habitat (MassDEP 2018b). Noteworthy enhancements of the CALM Guidance Manual for 2022 are highlighted below.

Amended Massachusetts Surface Water Quality Standards

- **SWQS amendments promulgated November 12, 2021 (corrected December 10, 2021 and January 7, 2022):** The amendments included adoption of EPA's revised primary contact recreational bacteria criteria (EPA 2012) for surface waters and new and updated toxics criteria. MassDEP adopted all of the current recommended federal 304(a) aquatic life, human health, and organoleptic criteria, with the exception of the more recently published selenium, cyanotoxin, and lake nutrient criteria. The adopted criteria are listed in new Tables 29 and 30 in the amended regulation. The SWQS amendments for aluminum in freshwater require use of the Aluminum Criteria Calculator V.2.0[1] when appropriate input data are available or, if not, use of watershed-based default freshwater aluminum criteria (excluding Cape Cod and the Islands). Additionally, the SWQS amendments require use of the Copper Biotic Ligand Model (BLM) version 2.2.3 software[1] in place of the hardness-based equations to calculate copper criteria when appropriate input data are available (MassDEP 2021b).

Guidance Changes

- **Benthic Macroinvertebrate Data:** The evaluation procedures have been updated from the Rapid Bioassessment Protocol (RBP) III method to the use of regional and gradient-specific Indices of Biotic Integrity (IBI) thresholds.
- **Bacteria data:** The processing and evaluation procedures for *E. coli* and Enterococcus bacteria data have been updated to include adoption of the geometric mean (GM) and statistical threshold value (STV) criteria in the SWQS (MassDEP 2021b). Use Attainment Impairment Decision Schema for the Primary and Secondary Contact Recreational Uses have been developed that provide guidance specific to the bacterial indicator organism, sampling frequency, interval duration, and number of years of available, quality-assured data.
- **Chronic criteria evaluation methods:** An update to Table 4 (toxic pollutant sample scenarios used to evaluate chronic criteria exceedances) has been updated to include methods for larger, moderate frequency and high frequency discrete sampling scenarios ($\geq$6 samples/year).
- **Aluminum:** The exception for not assessing aluminum toxicity has been removed.

Section Updates

- **Data Acceptability:** Additional detail has been provided for data submittals to WPP from external partners and the review of those data for use in regulatory/assessment-level decisions. Also included are details on the age of data (from both MassDEP and external partners) used for the 2022 IR reporting cycle, and the extrapolation of data to an adjacent AU.
- **Use Attainment Decision Process:** Updated MassGIS datalayers in use for the 2022 IR reporting cycle include the new 2016 Land Cover/Land Use layer and the 2019 USGS Color Ortho Imagery (update from 2008/2009).
- **Consolidated Reporting:** This section update includes information on the types of changes made from the prior reporting cycle with more specific detail related to the removal of an impairment (delisting of a pollutant or removal of a non-pollutant) along with the decision documentation process used for the 2022 reporting cycle.
- **Appendix E Metals data comparisons to water quality criteria:** This appendix update includes the addition of the Aluminum Criteria Calculator V.2.0 along with the TOC/DOC translator and the Copper BLM version 2.2.3.

New Appendices

- **Appendix I:** A new appendix entitled "Massachusetts Benthic Macroinvertebrate Indices of Biotic Integrity (IBIs): Additional Regional and Gradient-Dependent IBI Metric Details" has been included. IBIs for high gradient sites in the Western Highlands and Central Hills regions have been developed as well as an IBI for low gradient sites statewide.
- **Appendix J:** In light of MassDEP's adoption of EPA's revised bacteria criteria for primary contact recreation, this appendix provides an overview of the new evaluation procedures for analyzing E. coli and Enterococcus bacteria data, to be included in use attainment decisions.
- **Appendix K:** The rationale for using "Aquatic Plants (Macrophytes)" or APM as a non-pollutant cause of impairment is provided, along with a schematic diagram depicting the data review and delisting process.

For the 2022 reporting cycle, 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

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[1] See the respective information in Table 29a at 314 CMR 4.06(6)(d) for aluminum and copper. See also Appendix D to Table 29a: *Model-Based Software for Calculating Fresh Water Aluminum and Copper Criteria Values*.

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, any remaining rivers and lakes where diadromous fish runs exist but passage is restricted, severely restricted, or has no possible passage will be added as AUs and assessed according to the decision flowchart to address the diadromous fish habitat-related impairments (see Section V. *Aquatic Life Use* – Habitat and flow data section).

II. 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 regulation (40 CFR Part 131.20), requires that state water quality regulations undergo regular public review.

Water Use Goals

314 CMR Sections 4.05 and 4.06 identify and classify certain surface waters or segments of surface waters, and describe and assign qualifiers that further define the designated uses of those surface waters or segments (MassDEP 2021b). The six classes of surface waters (A, B, and C for freshwater and SA, SB, and SC for coastal and marine waters), described below, are identified by the most sensitive, governing water uses to be achieved and protected. Tables 1 through 27 at 314 CMR 4.06(6)(b) of the SWQS list specific waterbodies or groups of waterbodies by classification and/or 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.

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 and their tributaries. 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. These waters are protected as Outstanding Resource Waters.*
***CLASS B** - 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 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 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 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 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 SC** - 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. They shall also be suitable for certain industrial cooling and process uses. These waters shall have good aesthetic value.*

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 (MA DPH 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 an 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 select 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 site-specific copper criteria in Table 28 that have been approved are listed in Appendix E (Table E2).

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, the 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).

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.*

Table 1. Summary of Massachusetts Surface Water Quality Standards.

Parameter	Criteria based on surface water classification*
	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 and 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*.
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 Note: Class A criteria apply to the *Public Water Supply Use*	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):

Table 1. Summary of Massachusetts Surface Water Quality Standards.

Parameter	Criteria based on surface water classification*
and Primary Contact Recreational Use. Class B and SB criteria apply to *Primary Contact Recreational Use* Class C and SC criteria apply to *Secondary Contact Recreational Use*.	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).* <u>Coastal and Marine Waters Class SA and SB ([1, 2]see notes related to applicability below):</u> 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).* <u>Class C ([3]see applicability note below):</u> *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.* <u>Class SC ([3]see applicability note below):</u> *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).* <u>Applicability notes</u>: [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] In lieu of meeting the minimum criteria for bacteria set forth in 314 CMR 4.05(5)(f)1. through 4., concentrations of E.coli bacteria in Class C Surface Waters shall satisfy 314 CMR 4.05(3)(c)4.a. and b., and enterococci bacteria in Class SC Surface Waters shall satisfy 314 CMR 4.05(4)(c)4.a. and b., whenever necessary for the protection of secondary contact recreation.

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).

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 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, the 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 main stem 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 3). 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 the 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.

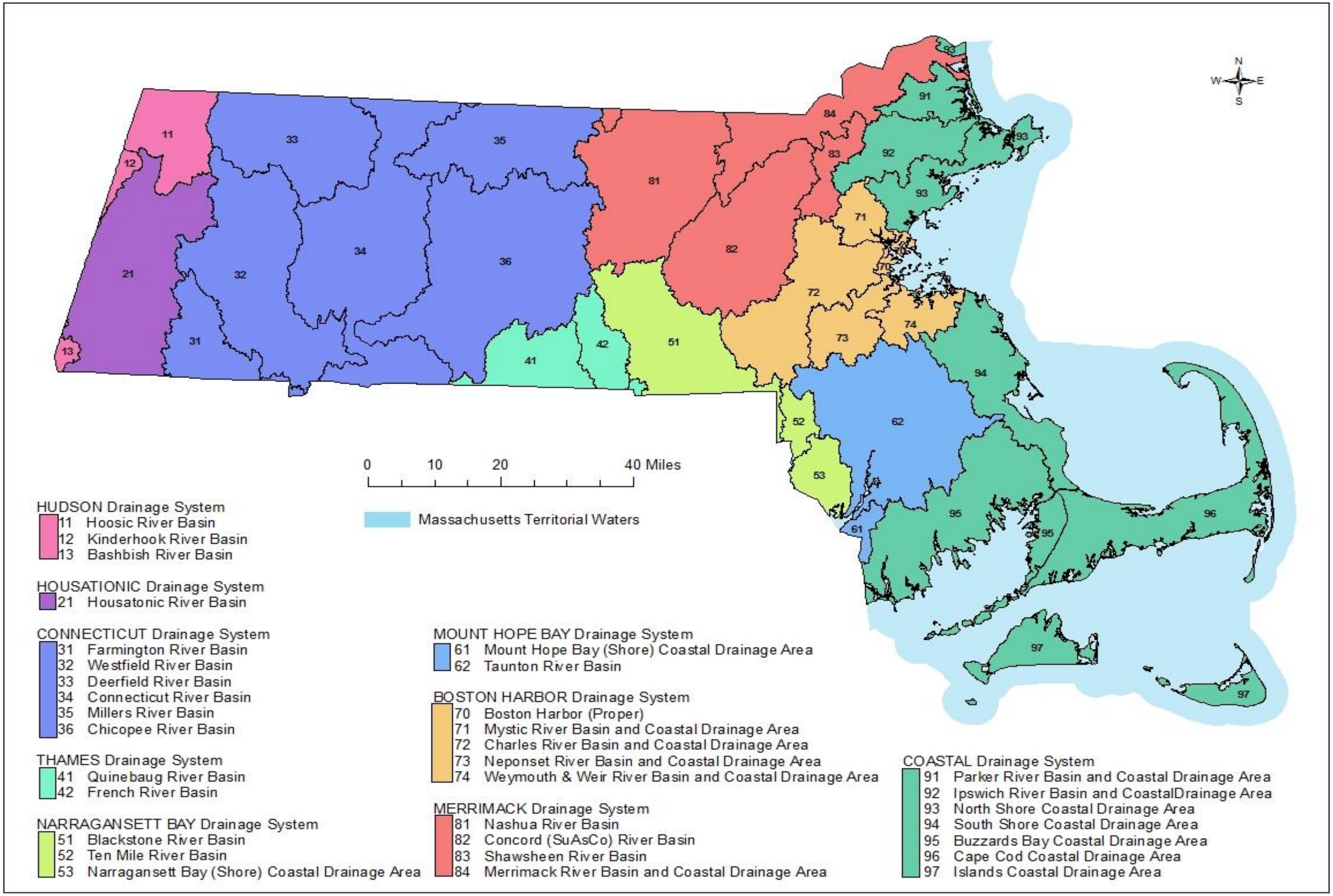
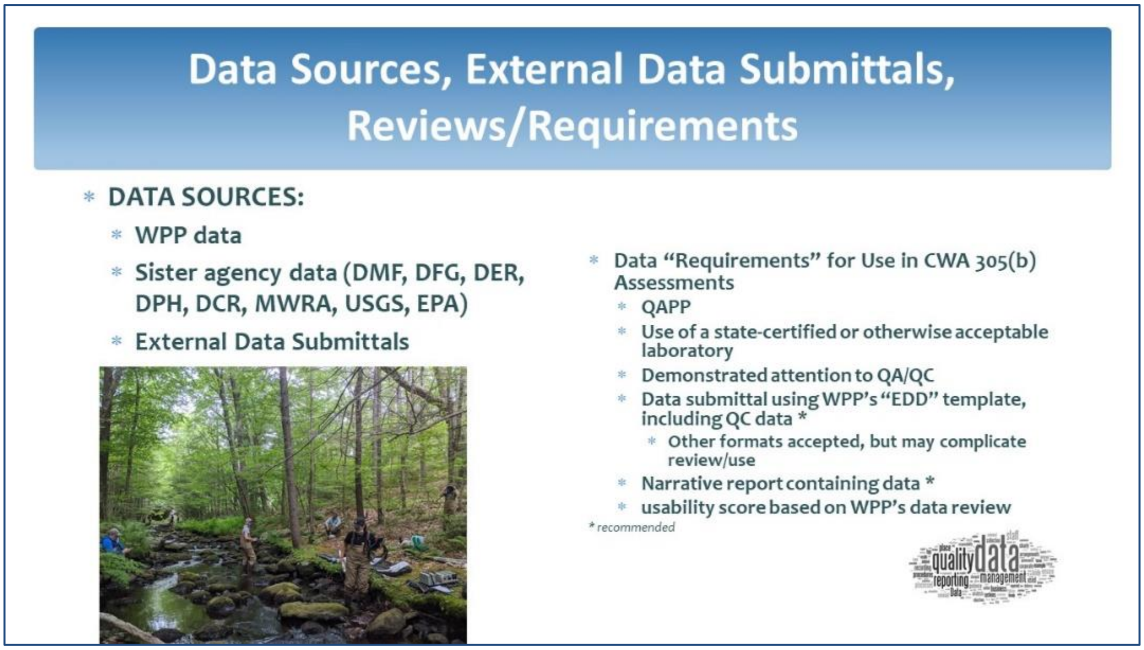


Figure 3. Major drainage systems, river basins (i.e., watersheds) and coastal drainage areas of Massachusetts with their unique Stream and River Inventory System (SARIS) code numbers, as assigned by Halliwell et al. (1982). These river basins and coastal drainage areas serve as the fundamental planning 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. The 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 the 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 the 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 in light of 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. The 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 the 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 water quality standards or is impaired.

External Data Usability Review Process

Data can be submitted to MassDEP using guidelines found on the Department's web site here: external-data-submittals. The data submittal deadline for the 2022 IR was January 15, 2021. All submitted external data are reviewed using consistent procedures. Once data are received, a standard data review process is conducted to facilitate and document the MassDEP staff review (see Table 2 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 the MassDEP WPP's DQOs to look for any large discrepancies that could affect acceptability. In cases where additional information is needed, the external data group is contacted for the information. If available information is deemed insufficient to complete the review, the data are not used. Data can also be considered unusable due to poor or undocumented QAPP implementation, lack of project documentation, incomplete reporting of data or information, poor quality control results and/or project monitoring objectives unsuitable for MassDEP assessment purposes. Best professional judgment is used to make the final determination regarding data validity and usability for assessment purposes. External data are scored and the following guidelines are in place regarding their usability by WPP for assessment purposes:

External Data Level	Data Usability Review Score*
3. Regulatory/Assessment-level*	A+ ASSESS/TMDL: All data should be considered usable by WPP for assessment purposes without caveat
	A- ASSESS/TMDL: All data appear to be usable 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.	

Table 2. Selected evaluation criteria from MassDEP's external data submittal usability review form for CWA 305(b), 314, and 303(d) reporting

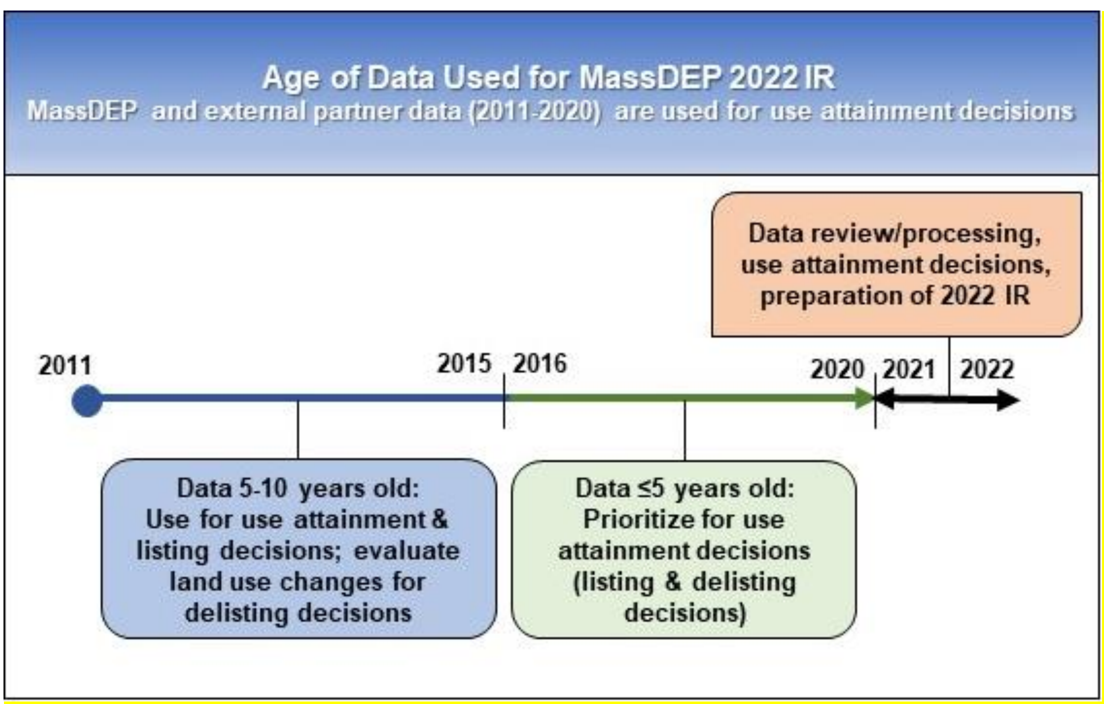
QAPP status for data year(s) and listed parameter(s)
Training provided to samplers?
Lab SOP for parameter provided?
Laboratories used
Lab Certification Status for Parameter
Lab QC data provided?
Other specific issues affecting data quality

Quality Assurance/Quality Control (QA/QC) documentation (in project report or files)?
Addtional 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 2022 reporting cycle, MassDEP WPP data from 2011 through 2018 will be utilized for use attainment decisions. 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 2020 that passed the data usability review will be utilized to the extent possible. Data collected between 2016 and 2020 (≤5 years in age) will be used for the evaluation of use attainment including listing and delisting decisions. Data collected between 2011 and 2015 will also be used to support use attainment and listing decisions; however, in order 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 2022 IR).

Note: 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 extrapolation to adjacent AU

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:

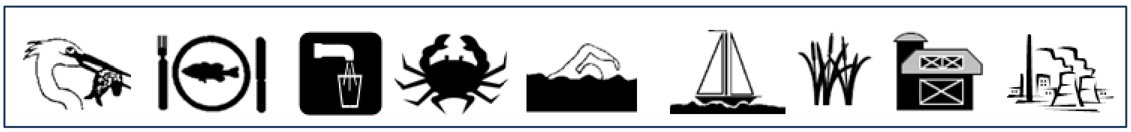
- Water quality data collected downstream of a river AU being evaluated (but upstream of any major discharges, dams, tributaries, etc.) may be used to make assessment decisions, especially if data are lacking from the lower portion of the AU. Data from such a location can provide a good representation 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, so 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 or not a waterbody supports each of the 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 2022 Integrated Reports (IRs) (available at http://www.epa.gov/tmdl/integrated-reporting-guidance) 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 little current data/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", the use is identified with an Alert Status. 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 considerd ***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). The 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. The DWP maintains current drinking supply monitoring data. The suppliers currently report to the MassDEP and the EPA on the status of the supplies on an annual basis in the form of a consumer confidence report (consumer confidence reports). While the 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/should be obtained at MassDEP Drinking Water Program and EEA Online Data Portal for Drinking Water and from 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.

To evaluate whether the *Aquatic Life Use* should be assessed as impaired, the analyst must determine whether or not the condition is natural. Excursions from temperature and DO criteria deemed to be the result of natural background conditions are not evaluated as impairment (see Appendix A guidance). Best professional judgment is always the final arbitrator; however, several GIS datalayers (published date as noted) are typically utilized in some manner:

- USGS Color Ortho Imagery 2019 (MassGIS 2019b)
- Land Cover/Land Use 2016 (including impervious surfaces) (MassGIS 2019a)
- Dams datalayer 2012 (MassGIS 2021a)
- MassDEP Wetlands (2005) (MassGIS 2017)
- MassDEP Wellhead Protection Areas (Zone II, Zone I, IWPA) (MassGIS 2021b)

Google Earth (Google Earth Pro Undated) and Google Maps (Google Maps Undated) information/imagery may also be consulted as needed to provide insight into current and/or historical land use.

The anthropogenic influence can be screened through an ArcMap analysis as follows:

1. The contributing drainage area to each AU is delineated and saved as a shapefile. These shapes as well as further refinements of this spatial scale (described in Appendix A) can then be used to "clip" the land-use, imperious surface polygon coverages, dams or other coverages for each AU's drainage area.
2. The 19 codes of Land Cover from the MassGIS 2016 Land Cover/Land Use coverage were grouped into four categories:

   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).
   Agriculture: cultivated land, pasture/hay
   Developed: impervious, developed open space, bare land (barren land).

3. The percentages of anthropogenic influences can be calculated at the various spatial scales (e.g., impervious cover (IC)>4%, developed <10%). This type of analysis can provide a quantitative evaluation tool to conclude that an exceedance is in fact due to anthropogenic influence(s).

Note: The percent open water in the contributing drainage area, the percent IC in the contributing drainage area, and the percent forest in the contributing drainage area have all been identified as factors affecting brook trout relative abundance (Armstrong, Richards and Levin 2011).

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 the 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. It should be noted that 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 the 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).

Benthic macroinvertebrate data

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 2022 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*.

Use is Supported	Use is Impaired
Exceptional Condition/Satisfactory Condition	Moderately Degraded/Severely Degraded

Lakes

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.

Use is Supported	Use is Impaired
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.

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 loosely 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.*

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 Massachusetts DEP 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.

Fish community data
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 the 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 2019) 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 the 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 when 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. The presence of external anomalies (i.e., deformities, eroded fins, lesions, tumors [DELTS]) are noted and, 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 then an impairment decision will be made.

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.

Use is Supported **Cold Water Fishery**	**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.
Use is Supported **Warm Water Fishery**	**Use is Impaired** **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.

Use is Supported	**Use is Impaired**
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 the 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") HABs (C-HABs), 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, in an effort to determine the degree of enrichment exhibited by these waterbodies, and as another indicator of whether or not 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 (Rivers)

Background/context: Percent Periphyton Cover/Benthic Algae: Micro and 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 exposed to elevated nutrient levels.*

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 the analysts whether or not the taxa indicate nutrient enrichment or some other environmental impact.

Chlorophyll *a* (Rivers, Lakes, Estuaries)

Background/Context: Measures of Biomass (MassDEP 2004)
Chlorophyll is a 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)."*

Either discrete and/or depth-integrated samples are commonly collected by MassDEP staff for chlorophyll and phytoplankton analysis following procedures in MassDEP (2004). Chlorophyll *a* samples from the periphyton (attached algae) can be collected in different ways, 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 $\leq$ 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 (Lakes, Estuaries)

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 Wollfia 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 *Wollfia* 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 wide spread 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 MA DPH 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 (estuaries)

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.

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 MassDEP, Wetlands Conservancy Program (WCP), 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 2022). Data acquisition and image interpretation are detailed in Costello and Kenworthy (2011) and are available online at https://www.mass.gov/guides/eelgrass-mapping-project. 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*	Datalayer Years of Mapping Effort (indicated by X)	
	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

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

Assessment decisions for the 2022 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 (2015-2017) to determine whether or not 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 will no longer be used as the baseline. Rather, the current assessment methods require the eelgrass data evaluations to be made with data generated from the standardized eelgrass mapping protocols (Costello and Kenworthy 2011).]

The following summary provides the Primary Producer Biological Screening Guidelines for the three waterbody types. These are the current biological response indicators used by MassDEP in the nutrient criteria development process (Appendix C). These screening guidelines will likely be refined in the future.

Use is Supported			**Use is Impaired**		
Rivers	***Lakes***	***Estuaries***	***Rivers***	***Lakes***	***Estuaries***
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*	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*	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*	Wadeable rivers: benthic chlorophyll *a* samples >200 mg/m^2*, 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*	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**	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 C-HAB blooms*

*Denotes that an *Aquatic Life Use* attainment decision is not made based on these indicators alone. If exceedances(s) of any threshold indicators are found, an additional evaluation of other water quality monitoring data (see nutrients) is required to make a use attainment decision.

Habitat and 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 absence of visible streamflow and/or dewatered streambed in a perennial stream or dewatered lake due to artificial regulation, extreme deviation from expected flows (e.g., channel status for all but one stream during a survey noted as full but the one stream had little flow), and lack of natural habitat structure (e.g., concrete channel, underground conduit).

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 (http://waterdata.usgs.gov/ma/nwis/current/?type=flow), and the occasional site-specific flow data collected during WPP surveys. Up through the 2016 reporting cycle, information contained in *Marine Fisheries* technical reports on surveys of anadromous fish passage in coastal Massachusetts (https://www.mass.gov/service-details/marine-fisheries-technical-reports) were also utilized.

In November 2016, *MarineFisheries* biologists provided MassDEP staff with their most recent Diadromous Fish Restoration Priority List 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 2020). MassDEP staff use this list to document surface waters with

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. Diadromous fish are important prey for a wide range of fish and wildlife, including important recreational and commercial marine fish such as Atlantic cod, bluefish and striped bass. The migrations and habits of striped bass, one of the most valuable fish in Massachusetts' marine waters, reflect a dependence on diadromous fish for forage. Additionally, river herring, shad, American eel and rainbow smelt historically represented important commercial fisheries of their own.

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). *Declines in the Gulf of Maine have been associated with the collapse of near-shore commercial fishes such as Atlantic cod and pollock and other large predatory marine species that feed on river herring* (Ames and Lichter 2013). *Factors affecting the decline of diadromous fish in the Gulf of Maine are complex; however, the influences of dams on coastal streams (and related losses of inland spawning and nursery habitat), overfishing, and pollution are considered significant across the region. Additional causes include the impingement and entrainment of fish and larvae at power plants and other water intakes, disease, invasive and non-native species infestations, and climate change* (Limburg and Waldman 2009). *Recent declines of river herring in Massachusetts prompted the MarineFisheries 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. MarineFisheries 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. MarineFisheries staff continue to monitor and maintain fish passage structures, where present, and advocate for dam removals or installation of fish passage structures when appropriate.*

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. The process by which the *MarineFisheries* priority list is used to make *Aquatic Life Use* support decisions is illustrated in Figure 4 and described below.

When evaluating the status of the Aquatic Life Use based on diadromous fish habitat, the scoring criteria for two *MarineFisheries* 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 *MarineFisheries* 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 2022 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 at the boundary of two AUs and passage scores are $\geq$4, impairment decisions will be assigned to adjacent/adjoining AUs within the same named stream or to the upstream lake AU and the downstream river AU. Where *MarineFisheries* staff conducted more intensive site-specific habitat assessments, additional stressors identified in their technical reports (available online @ https://www.mass.gov/service-details/marine-fisheries-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”.

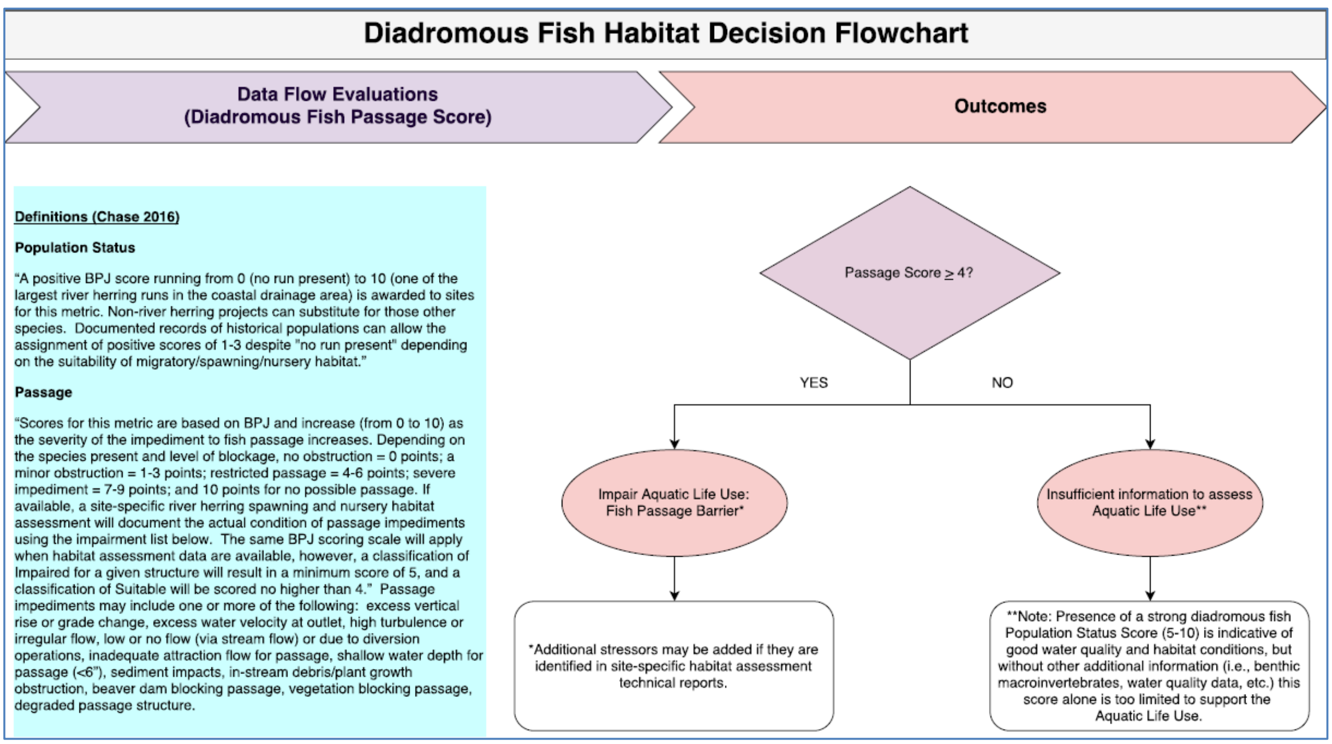


Figure 4. Diadromous fish habitat assessment decision flowchart with population status and passage score definitions.

In the Massachusetts coastal drainage areas, waters listed by *MarineFisheries* 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 exclude these fish from reaching spawning and nursery habitats (Chase 2020) 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.

MassDEP analysts must understand the hydrologic conditions encountered during the surveys and evaluate them 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 the 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

Non-native aquatic species data
Rivers, Lakes, not currently used for Estuaries

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 2022 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

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 the 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.*

Toxicity testing data
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). 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 ($n \leq 10$), 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 included 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.

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 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".

Freshwater 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.

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 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 enterococci 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 the DWM'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.

Water quality data
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 of the 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 the 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.

Assessment guidance is presented below for the following indicators of water quality conditions: dissolved oxygen, pH, temperature, nutrients, and toxic/priority pollutants.

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.

Dissolved oxygen (DO)
National 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). It should be noted here that 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 criteria, DO is considered sufficient to support the *Aquatic Life Use*. When the criterion 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 criterion 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 national 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 criteria 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 (LC) Short-term continuous (SC) Single (S)
30-Day Mean	8.0	NA	6.0	LC[1]
7-Day** Mean (7-Day Avg of Daily Avg or 7DADA)	NA***	6.5	NA	LC, SC [1,2]
7-Day** Mean Minimum (7-Day Avg of Daily Minima or 7DADMin)	6.0	NA	5.0	LC, SC[1,2]
1-Day Minimum***	5.0	5.0	4.0	LC, SC, S
* anadromous fish runs present **Continous monitoring data from sondes deployed between 3 to 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 3-5 day 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 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**.

Use is Supported			Use is Impaired		
Rivers	***Lakes***	***Estuaries***	***Rivers***	***Lakes***	***Estuaries***
Deployed (LC, SC) 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)	No/little depletion (the criterion is met in all depths over ≥90% of the lake surface area during summer season)	No/infrequent (≤10%) prolonged or severe excursions from criteria in surface or bottom waters	Deployed (LC, SC) 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	The criterion is not met at all depths for >10% of the lake surface area during periods of maximum oxygen depletion	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:
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.

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 or not 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.

Use is Supported			**Use is Impaired**		
Rivers	***Lakes***	***Estuaries***	***Rivers***	***Lakes***	***Estuaries***
No or slight pH excursions (<0.5 SU) from criteria (minimum five measurements)	No or slight pH excursions (<0.5 SU) from criteria (minimum one deep-hole profile during summer growing season)	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	Excursion from pH criteria (>0.5 SU) during summer growing season	Frequent (>10%) and/or prolonged or severe pH excursions (>0.5 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). While many streams were designated as Cold Water during the 2006 revision of the SWQS, additional information (in particular temperature data) was needed to accurately and systematically identify other cold-water rivers and streams in the state. 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 or EBT) less than or equal to 140 mm (~5.5"), and/or *Cottus cognatus* (slimy sculpin or SC) of any size during a single sampling event (defined as sampling that took place over a single day) during the months of June through October 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.

Evaluating thermal impairment of cold-water streams: 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 5. 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 (LC) datasets, shorter-term continuous (SC) 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. 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.

Rivers: Waters designated in the Massachusetts SWQS as Cold Water Fisheries (CWF) and unlisted waters for which Tier 1 or Tier 2 Cold Water Existing Uses have been determined, are evaluated using temperature data collected during the summer index period (June through September 15). 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). 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 24-hour rolling average maximum will be compared to the acute criteria.

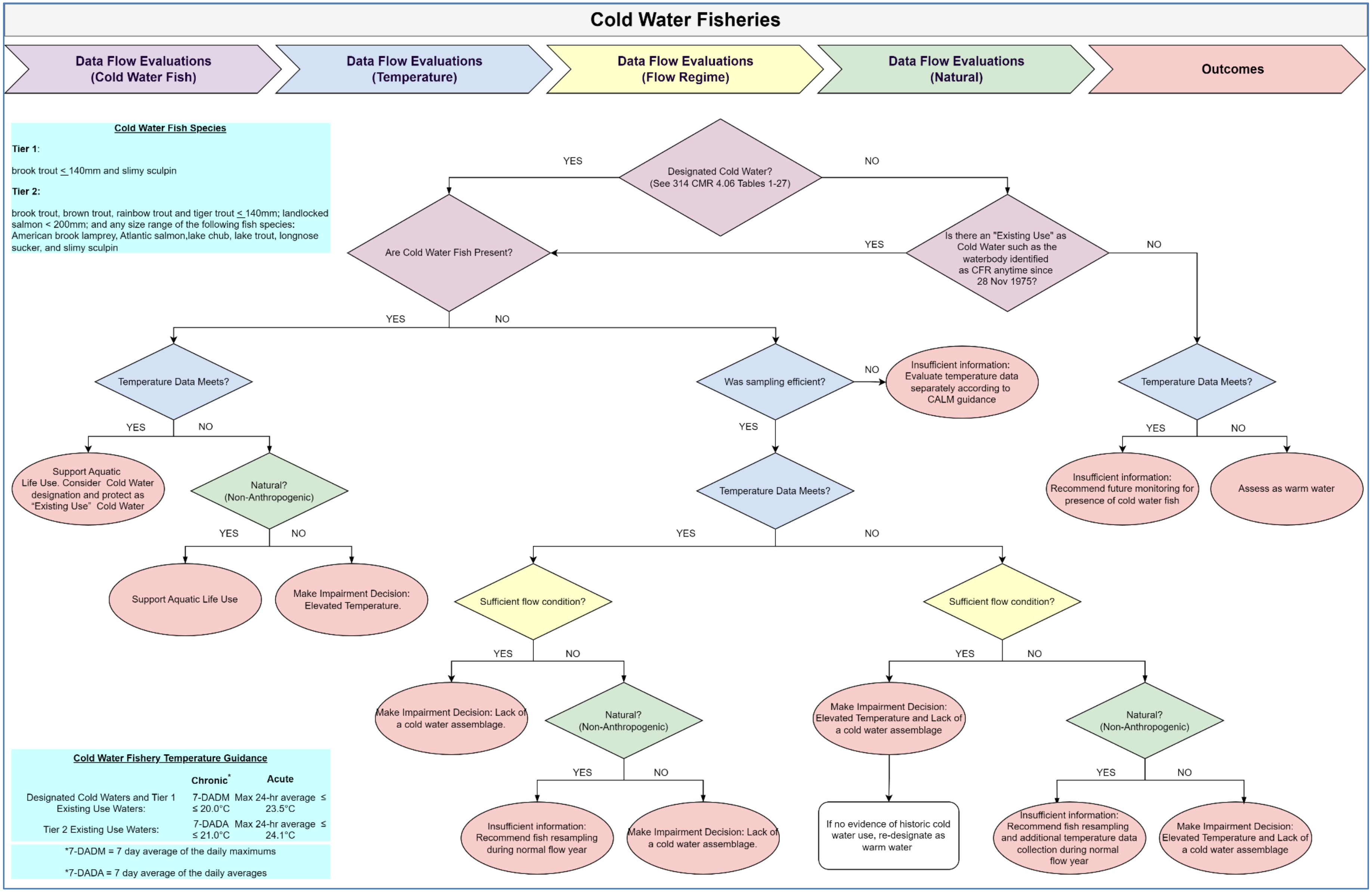


Figure 5. Decision flowchart used to evaluate fish and temperature data for Cold Waters.

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 collected during the summer index period (June through September 15). The long-term datasets are evaluated against the MassDEP-derived 7-DADA criterion (or 3-5 day DADA) and the SWQS warm-water criterion.

Estuaries: The analyst evaluates the temperature measurements against the acute SWQS criteria (shall not exceed 29.4°C nor a maximum daily mean of 26.7°C). Impact of 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.

Data Type	**Use is Supported**			**Use is Impaired***		
	Cold Water Fishery	*Warm Water Fishery*	*Estuarine*	*Cold Water Fishery*	*Warm Water Fishery*	*Estuarine*
Large (>one month usually all summer) Thermistor Datasets (Chronic evaluation):	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)	Designated Warm Waters and Unlisted Class B Waters not Tier 1 or Tier 2: 7-DADM ≤27.7°C (Exceedances ≤11 times)	24-hour average ≤ 26.7°C (Exceedances ≤11 times)	Designated Cold Waters: 7-DADM >20.0°CTier 1 Existing Use Waters: 7-DADM >20.0°C Tier 2 Existing Use Waters: 7-DADA >21.0°C (Exceedances > 11 times)	Designated Warm Waters and Unlisted Class B Waters not Tier 1 or Tier 2: 7-DADM >27.7°C (Exceedances > 11 times)	24-hour average > 26.7°C (Exceedances > 11 times)
Deployed (3-5 day) Sonde Datasets (Chronic evaluations):	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)	3-5-DADM ≤27.7°C (No exceedances)	Not applicable	No impairment decision made but identify exceedance with an Alert Status and recommend followup sampling	No impairment decision made but identify exceedance with an Alert Status and recommend followup sampling	Not applicable
Large Thermistor and Deployed (3-5 day) Sonde Datasets (Acute evaluations):	Acute (Maximum 24-hour average) Tier 1 fish: ≤ 23.5°C Tier 2 fish: ≤ 24.1°C (No exceedances of these these acute thresholds)	Maximum 24-hour average ≤ 28.3°C No exceedances of mean	No more than one day with SWQS criterion exceedance (29.4°C)	Acute (Maximum 24-hour average) Designated Cold Waters: > 23.5°C Tier 1 fish: > 23.5°C Tier 2 fish: > 24.1°C	Maximum 24-hour average > 28.3°C	More than one day above SWQS criterion (29.4°C)
Small (instantaneous/discrete) datasets:	No/infrequent/small excursions (1 to 2°C) above the SWQS criterion (20°C)	No/infrequent excursions above SWQS criterion (28.3°C)	No more than one day with SWQS criterion exceedance (>29.4°C)	SWQS criterion (20°C) frequently exceeded (>10%) or by >2°C (22°C).	SWQS criterion (28.3°C) frequently exceeded (>10% measurements) or by >2°C (30.3°C).	More than one day above SWQS criterion (29.4°C)

*due to anthropogenic influences (see Appendix A for guidance to evaluate if excursions/exceedances from criteria can be considered natural).
**[Note here: MassDEP has adopted a 10% exceedance to reflect the term “generally” in the SWQS. The allowed number of 7-DADM exceedances translates to 11 occurrences during the critical index period June 1st through September 15th. See Appendix D for additional information.

Nutrients 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* [concentrations] *shall not exceed the site-specific criteria developed in a TMDL ….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. It should be noted here that 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 their 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 EPA-approved site-specific criteria, either total phosphorus or total nitrogen is also identified as a cause of impairment. For the 2022 reporting cycle, the summer seasonal (May through September) (n≥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 EPA-approved site-specific criteria. For estuarine waters, a summer seasonal average (n≥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.

> **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.
>
> 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.

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 EPA-approved 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 an EPA-approved 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 or not 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 is intended 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.

Use is Supported			Use is Impaired		
Rivers	***Lakes***	***Estuaries***	***Rivers***	***Lakes***	***Estuaries***
Primary Producer Biological Screening Guidelines					
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*	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*	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*	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*	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*. **These indicators may also be applied to impounded reaches of River AUs**	Substantial decline in AU (= or exceed 10% of eelgrass bed area), Chlorophyll *a* >10 µg/L*, some macroalgae accumulations*
Physico-chemical Screening Guidelines					
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 EPA-approved site-specific criteria	Secchi disk transparency ≥1.2 m, summer seasonal (May through September) average Phosphorus (Total) below EPA Gold Book concentrations ≤0.025 mg/l or EPA-approved site-specific criteria	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*	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 EPA-approved 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 EPA-approved site-specific criteria. **These indicators may also be applied to impounded reaches of River AUs.**	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 unless the Department determines that naturally occurring background concentrations are higher for each pollutant identified in 314CMR 4.06(6)(d): Table 29. Where MassDEP determines that naturally occurring background conditions are higher, these conditions shall not be interpreted as violations of the SWQS and shall not affect the water use classifications adopted by the Department. Table 29a: Aquatic Life Criteria are the concentrations, models, or equations identified for each toxic pollutant (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.

Toxic pollutant data are evaluated against their respective CMC or CCC criteria. 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.

> ***Background/context: Water quality sampling field techniques*** (MassDEP 2016c)***:*** *Discrete instantaneous samples are collected manually at a representative location in the waterbody (wade-in samples preferred for stream sampling or collected off of a bridge or boat in deeper rivers) or collected via a Kemmerer, Van Dorn or other sampling device. Composite samples may be obtained using flow-weighted, time-composited (e.g., 1-hour, 24-hour, four-day, etc.) or other approved/accepted collection techniques.*

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 or not 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 toxicants’ 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 instream metals 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 2022 reporting cycle. In addition, these data will be used to evaluate whether or not historical impairment decisions, based on older metals data not collected using clean sample techniques, were appropriate.

Evaluation of WPP 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 2022 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.

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. It should be noted that 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 are able to 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 exeedances 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).

Chloride

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).

For the 2018 reporting cycle MassDEP analysts developed and validated a linear regression model to estimate chloride concentrations from specific conductance (SC) measurements (see 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:

$$\boldsymbol{Y=0.2753X - 18.987} \ (R^2=0.9445, P<0.001),$$

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 3,193 and 904 µS/cm, respectively. A 10% safety factor is applied to account for uncertainty and best professional judgement used regarding site-specific conditions.

Chlorine 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.

Background/context:
Sediment and tissue chemistry
(CCME 1999b)

Highly persistent, bioaccumulative compounds, such as 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) *"They 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."*

Sediment quality data
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
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: ≤ 500 µg/kg (ppb) wet weight
Total DDT, DDE, DDD: ≤ 1,000 µg/kg (ppb) wet weight
Chlordane and Heptachlor epoxide: ≤ 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] ≤ 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 or not 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 whole body samples do not exceed NAS/NAE guidelines	Residue of contaminants in whole body samples frequently exceed NAS/NAE guidelines, DELTS with abnormal fish histology.

Background/context:
Body Burdens
(CCME 1999a, 1999c, 2000, 2001)

DDT, *a chlorinated hydrocarbon insecticide, was used world-wide 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."*
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).

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)	Excellent Condition/Satisfactory Condition	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 ≥ 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, estuaries) *Note: An *Aquatic Life Use* attainment decision generally not made based on these indicators 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. **Lake impairment indicator levels may also be applied to impounded reaches of river AUs.**	**Benthic Algae** Wadeable rivers: benthic chlorophyll *a* samples ≤200 mg/m^2, filamentous algal cover ≤40% **Chlorophyll a** Deep rivers: phytoplankton Chlorophyll *a* ≤16 µg/L, Lakes: phytoplankton Chlorophyll *a* ≤16 µg/L Estuaries:Chlorophyll *a* ≤5 µg/L **Aquatic Macrophytes** Lakes: ≤25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps Estuaries: little to no macroalgae accumulations **Algal Blooms** Rivers, lakes, estuaries: occasional non-harmful ephemeral algal blooms **Eelgrass bed mapping data** 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	**Benthic Algae** Wadeable rivers: benthic chlorophyll *a* samples >200 mg/m^2, filamentous algal cover >40% **Chlorophyll a** Deep rivers: phytoplankton Chlorophyll *a* >16 ug/L Lakes: phytoplankton Chlorophyll *a* >16 µg/L, Estuaries: Chlorophyll *a* >10 µg/L **Aquatic Macrophytes** Lakes: >25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps Estuaries: some macroalgae accumulations **Algal Blooms** Rivers , lakes, estuaries: recurring and/or prolonged algal and/or C-HAB blooms* **Eelgrass bed mapping data** Estuaries: Substantial decline in AU (= or exceed 10% of eelgrass bed area between 1994 – 1996 and 2010 – 2013 mapping efforts
Habitat and 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, lack of natural habitat structure such as concrete channel, underground conduit), a lack of or restricted fish passage where diadromous fish populations have been documented
Non-native aquatic species data (rivers, lakes)	Non-native aquatic species absent	Non-native aquatic species present

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

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 (LC, SC) 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 (LC, SC) 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 (>0.5 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 followup 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).

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

Indicator for *Aquatic Life Use* Evaluation	Use is Supported	Use is Impaired
	Estuary Chronic evaluation large thermistor dataset: 24-hour average < 26.7°C (Exceedances <11 days) Acute evaluation of large thermistor /deployed sonde (3- 5 day) dataset: No more than one day with exceedance of 29.4°C Small dataset: No more than one day with exceedance of 29.4°C	**Estuary** Chronic evaluation large thermistor dataset: 24-hour average > 26.7°C (Exceedances > 11 times) Acute evaluation of large thermistor/deployed sonde (3- 5 day) dataset: More than one day above criteria 29.4°C Small dataset: More than one day above criteria 29.4°C Other: 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 EPA-approved 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 EPA-approved site-specific criteria
Physico-chemical nutrient screening guidelines (lakes)	Secchi disk transparency >1.2 m, seasonal average Phosphorus (Total) below EPA Gold Book concentrations <0.025 mg/l or below EPA-approved 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 EPA-approved site-specific criteria. **These indicators may also be applied to impounded reaches of river AUs.**
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 whole body samples do not exceed NAS/NAE guidelines	Residue of contaminants in whole body samples frequently exceed NAS/NAE guidelines, DELTS with abnormal fish histology.

Fish Consumption Use

The definition of "Secondary Contact Recreation" in the Massachusetts Surface Water Quality Standards (SWQS) includes the statement that waters supporting the *Secondary Contact Recreational 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 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 Recreational 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)).

Use Attainment Decision-Making Process:
MassDEP biologists have been conducting fish toxics monitoring, mostly in freshwaters, since 1983. As the years passed, 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). Currently, freshwater fish tissue contaminant testing in Massachusetts is conducted by the MassDEP in cooperation with the MA Department of Public Health (MA DPH) 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, through a Memorandum of Understanding (MOU) established in 1994, to facilitate the communication, coordination, and dissemination of information pertaining to contaminants in freshwater fish (MassDEP 2010b, MassDEP 2016b). The collaborative efforts of the MassDEP, the MA DPH, and the 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 the MassDEP provides much of the field and analytical support (refer to background/context inset on next page for the MassDEP WPP Fish Toxics Monitoring Program), all data are submitted to the MA DPH and the MassDEP Office of Research and Standards (ORS) for risk assessment and issuance of advisories, if appropriate. Ultimately, the MA DPH is responsible for decisions regarding the need for and/or implementation of public health advisories.

MA DPH provides a guide to eating fish safely in Massachusetts (MA DPH 2017):

Fish Consumption Advisory for Marine and Fresh Water Bodies (MA DPH 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.
Safe eating guidelines for pregnant women, women who may become pregnant, nursing mothers and children under 12 years old: **(contaminants of concern in parenthetical as noted by MA DPH and MassDEP analysts)**
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.**
Safe eating 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 MA DPH, Bureau of Environmental Health at 617-624-5757.

Background/context
MassDEP DWM Fish Toxics Monitoring Program (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."

In addition to these statewide fish advisories, the MA DPH 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 (see https://www.mass.gov/lists/fish-consumption-advisories).

EPA considers a fish or shellfish consumption advisory to be existing and readily available data and information that demonstrates non-attainment of the "fishable" use when the advisory is based on fish and shellfish tissue data collected from the specific waterbody in question (Grubbs and Wayland III 2000).

The assessment of the *Fish Consumption Use* for the 2022 IR cycle relied on the June 2021 fish consumption advisory list issued by the MA DPH Bureau of Environmental Health (MA DPH 2021). For those waters covered by site-specific MA DPH advisories the *Fish Consumption Use* is assessed as impaired due to the hazard(s) identified (e.g., mercury, PCB, 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 waters in Massachusetts can be considered impaired. However, based on the 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. MA DPH 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. The guidance used to assess the *Fish Consumption Use* is summarized below.

***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 MA DPH Fish Consumption Advisory with hazard (e.g., mercury, PCBs, pesticides, DDT, etc.)

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 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. Final targets will be determined at a later time. Waters for which MA DPH 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.

Shellfish Harvesting Use

The definition of "Secondary Contact Recreation" in the Massachusetts SWQS includes the statement that "*Waters supporting the Secondary Contact Recreational 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 Recreational 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*".

MarineFisheries 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 August 2021 there are 305 growing areas in Massachusetts' coastal waters (Bettencourt August 25, 2021). 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 *MarineFisheries* 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 (*MarineFisheries*), 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 *MarineFisheries* 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), the 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).

***MarineFisheries* 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 - *A conditionally approved area is "…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 – area *"… 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."*

MassDEP analysts assess the *Shellfish Harvesting Use* using the most recent *MarineFisheries* classification of the shellfish growing areas available at the time that the assessments are made. For the 2022 reporting cycle, the Massachusetts Shellfish Classification Areas shapefile, provided by *MarineFisheries* staff on 25 August 2021, 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).

Shellfish Harvesting Use Attainment

Use is Supported	Use is Impaired
SA Waters: Approved SB Waters: Approved, Conditionally Approved, or Restricted	SA Waters: Conditionally Approved, Restricted, Conditionally Restricted SB Waters: Conditionally Restricted

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 *MarineFisheries* reports and information, TMDL reports, and/or BPJ of MassDEP analysts using orthophotos, land-use, and urbanized area MassGIS datalayers.

Note: Information pertaining to whether or not 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 2022 assessment cycle the "Prohibited" classification areas will not be used to make an impairment decision since there is insufficient information available to determine whether or not a particular closure is due to poor water quality conditions.

Aesthetics Use

The narrative aesthetics criterion 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:
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. Therefore, the *Aesthetics Use* is assumed to be supported unless field notes indicated 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. It should be noted that a waterbody will not be assessed as impaired for the occasional presence of litter or debris, but rather for persistent and/or other more serious indicators of aesthetic degradation. External sources of information related to aesthetic quality include volunteer stream team/shoreline surveys and lake reports. Additional guidelines for interpreting aesthetic observations are provided below.

Algal blooms

Rivers, Lakes, and Estuaries The visual presence of planktonic blooms/mats/scums are associated with aesthetically objectionable conditions. Depending on the severity of a bloom, water may appear only slightly colored or it may resemble pea soup or green paint. 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* (and also the recreational uses of the waterbody) is generally considered to be impaired. The *Aesthetics Use* for a waterbody is assessed as impaired as a result of the harmful algal blooms when MA DPH C-HAB advisories exceed 20 days in a year (for more detail see *Primary Contact Recreational Use*). Marine and/or estuarine HABs involving microalgae are addressed on a case-by-case basis.

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 the impounded reaches of river AUs Determining whether recreational uses are impaired due to overabundant (i.e., undesirable or nuisance) growths of aquatic macrophytes or algae 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 with >25% dense/very dense macrophytes are assessed as impaired with Aquatic Plant (Macrophytes), a "non-pollutant" noted as the cause of impairment. There are also cases where algae or certain floating macrophyte species, like *Lemna* sp. or *Wollfia* 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)], Secchi disk transparency < 4 feet at least twice during survey season, MA DPH cyanobacteria advisories for >20 days in a year *Note: Cause identification can be either Aquatic Plant (Macrophyte) non-pollutant or Nutrient/Eutrophication Biological Indicators (pollutant)

Primary Contact Recreational Use

Waters supporting the *Primary Contact Recreational 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 Recreational 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 criterion 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 enterococci bacterial indicators for Class A, B, SA, and SB waters (MassDEP 2021b). *Primary Contact Recreational Use* 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 MA DPH, 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.

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, enterococci, 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 water quality standards (both for fresh waters, enterococci 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).

An overview of the data types and the decision process used by MassDEP analysts to make assessment decisions for the *Primary Contact Recreational Use* is as follows.

Aesthetics
Rivers, Lakes, and Estuaries
It should be emphasized here that because of the narrative aesthetics criteria which are applicable to all surface waters (see *Aesthetics Use* attainment guidance for details), MassDEP analysts assess the *Primary Contact Recreational Use* as impaired when the *Aesthetics Use* of a waterbody is assessed as impaired.

Bacteria data
Rivers, Lakes, and Estuaries
For freshwater AUs (rivers and lakes) the primary source of bacteria data is the results of the MassDEP water quality surveys. 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, can also be utilized for assessment decisions.

E. coli bacteria	*Enterococci* bacteria
GM: ≤126 colonies/100 mL Class A, B STV: ≤410 colonies/100 mL Class A, B	GM: ≤35 colonies/100 mL Class A, B, SA, SB STV: ≤130 colonies/100 mL Class A, B, SA, SB

[Notes: GM calculations use the Method Detection Limit (MDL) and the Upper Quantification Limit (UQL) for "<MDL" and ">UQL" results, respectively. 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. Use Attainment Impairment Decision Schema based on bacteria sampling frequency scenarios during the Primary Contact Recreational 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; 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 exceed 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 exceed 410 (STV) in more than two years [4]
	Enterococci	1) ≥80% of GM intervals >35 OR 2) a. <80% of GM intervals >35 AND b. two or more samples exceed 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 exceed 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 exceed 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 exceed 410 (STV) in more than two years [4]
	Enterococci	1) ≥60% of GM intervals >35 OR 2) a. >10% to <60% of GM intervals >35 AND b. >2 samples exceed 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 exceed 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 exceed 410 (STV)	1) >10% of GM intervals >126 in two or more years 2) >10% of cumulative GM intervals >126 3) >10% of samples exceed 410 (STV) in more than two years [4]
	Enterococci	1) ≥40% of GM intervals >35 OR 2) a. ≥30% to <40% of GM intervals >35 AND b. >10% of samples exceed 130 (STV) OR3) a. >0% to <30% of GM intervals >35 AND b. >20% of samples exceed 130 (STV)	1) >10% of GM intervals >35 in two or more years 2) >10% of cumulative GM intervals >35 3) >10% of samples exceed 130 (STV) in more than two years [4]

[1] The five most recent years of data will be preferentially evaluated, 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.

Presence of active CSO discharges

Rivers, Lakes, and Estuaries Other than in 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; where limited 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 Recreational Use* for *E. coli* (fresh waters) or *Enterococcus* spp. (saline waters).

Secchi disk depth

Lakes The MassDEP analysts apply the 4-foot (1.2 m) Secchi disk transparency guideline as BPJ to indicate when conditions are unsafe for recreational use. When waters fail to meet this guideline it is felt that 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.

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"*.

Harmful algal blooms

Rivers, Lakes, and Estuaries

"Harmful algal blooms, or HABs, occur when colonies of algae — simple plants that live in the sea and freshwater — grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds. The human illnesses caused by HABs, though rare, can be debilitating or even fatal" (noaa.gov/what-is-harmful-algal-bloom). The MA DPH guidelines (Undated) recommend an advisory or closure of a waterbody to avoid contact with the water when a visible scum or mat layer is present, cyanobacteria cell counts exceed 70,000 cells/ml, or when the microcystin level of lysed cells exceeds 14 parts per billion (ppb) in order to protect public health). MA DPH guidelines for evaluating potential health concerns regarding cyanobacteria in fresh waterbodies in Massachusetts and other information can be found online at (https://www.mass.gov/guides/cyanobacterial-harmful-algal-blooms-cyanohabs-water). MassDEP uses MA DPH cyanobacteria advisories when assessing primary, secondary, and aesthetics uses for HAB presence. For the 2022 IR cycle, MassDEP is utilizing MA DPH advisory data from 2015-2019. The issuance of a MA DPH cyanobacteria advisory does not, in and of itself, lead to the decision that a waterbody is impaired because an advisory is posted for a cyanobacteria bloom regardless of its duration. 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

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. Freshwater 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 in order 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* (MA DPH 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 toxin level of approximately 14 ppb which is the current guideline for contact recreational waters. The MA DPH has developed guidelines regarding harmful algal blooms that occur in fresh waterbodies* (https://www.mass.gov/files/documents/2016/07/qk/protocol-cyanobacteria.pdf).

making a use-attainment determination. MassDEP considers HABs to be “frequent” or “prolonged” if they are subject to MA DPH advisories for >20 days in a calendar year. This threshold is based, in part, on the MA DPH *Guidelines For Cyanobacteria In Freshwater Recreational Water Bodies In Massachusetts* (MA DPH Undated) which states that “advisories may be lifted after two successive and representative sampling rounds one week apart demonstrate cell counts or toxin levels below those at which an advisory would be posted”. In light of MA DPH’s policy, waters exhibiting one extended-length advisory or two or more advisories of any duration would be considered by MassDEP to be impaired for HABs. While MA DPH guidelines specifically pertain to freshwater HABs, marine and/or estuarine HABs involving microalgae are addressed on a case-by-case basis.

Beach postings

Estuaries and Freshwater DCR beaches The Beaches Bill monitoring program is a major source of bacteria data and beach posting/closing information. Pursuant to this legislation, the MA DPH 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). MA DPH publishes annual reports of these data (MA DPH 2019a) and, approximately every two years, provides MassDEP analysts with a copy of their database (MA DPH 2019b). It should be noted here that the MA DPH 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 the 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 2022 IR reporting cycle, beach posting data from 2014 through 2019 are being utilized. The pathogen indicator used for marine beach monitoring as well as the DCR fresh water beach monitoring is *enterococci* bacteria (the rare exception being DCR beaches sampled by local municipalities).

The *Primary Contact Recreational Use* is assessed as support 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 Recreational Use* will be 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

> Beaches Bill (MA DPH 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*.”

that may lead to conflicting assessment decisions are handled on a case-by-case basis by the 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 Recreational Use* when the *MarineFisheries* Shellfish Growing Area Classification is "Approved" (Bettencourt August 25, 2021). However, when the shellfish classification is anything less than "approved" no use attainment determination for the *Primary Contact Recreational Use* can be made.

Primary Contact Recreational Use Attainment Decision

Use is Fully Supporting		**Use is Not Supporting**	
Rivers, Lakes	***Estuaries***	***Rivers, Lakes***	***Estuaries***
No aesthetic use impairment; Bacteria do not exceed use attainment impairment decision schema; Secchi disk transparency ≥4 feet; beach postings at DCR freshwater beaches generally ≤10% season	No aesthetic use impairment; Bacteria do not exceed use attainment impairment decision schema; beach postings generally <10% season; MarineFisheries "Approved" Shellfish Growing Area Classification	Aesthetic use impairment; Bacteria exceed use attainment impairment decision schema; risk calculation exceeds hazard threshold for contaminant of concern; MA DPH cyanobacteria advisories for >20 days in a year; Secchi disk transparency <4 feet at least twice during survey season; beach postings at DCR beaches often >10% of season; presence of CSO outfall in waterbody without an approved variance	Aesthetic use impairment; Bacteria exceed use attainment impairment decision schema; beach postings often >10% of season; risk calculation exceeds hazard threshold for contaminant of concern; presence of CSO outfall in waterbody without an approved variance

Secondary Contact Recreational Use

Waters supporting the *Secondary Contact Recreational 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: 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 Recreational Use*.] For purposes of 305(b) reporting the *Secondary Contact Recreational Use* is assumed to occur year-round. Since water quality conditions during the *Primary Contact Recreational* 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 Recreational Use* attainment decisions in addition to data collected under a year-round sampling scheme.

Use Attainment Decision Making Process:
Similar to the *Primary Contact Recreational Use* attainment guidance, the assessment of the *Secondary Contact Recreational Use* is based on sanitary (i.e., bacteria), safety (e.g., Secchi depth) considerations, and/or aesthetic/practical usability of the waters. The bacteria criteria in the SWQS include both a geometric mean (GM) and a statistical threshold value (STV) for Class C/SC waters.The *Secondary Contact Recreational Use* impairment decisions are based on thresholds described in Table 7 for *E. coli* or *enterococci* bacterial indicators in Class C/SC waters, respectively (MassDEP 2021b). Occasionally, site-specific health risk assessments performed by consultants, the MA DPH, 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.

An overview of the data types and the decision process used by MassDEP analysts to make assessment decisions for the *Secondary Contact Recreational Use* is as follows.

Aesthetics
Rivers, Lakes, and Estuaries It should be emphasized here that because of the narrative aesthetics criterion, which is applicable to all surface waters (see *Aesthetics Use* attainment guidance for details), MassDEP analysts assess the *Secondary Contact Recreational Use* as impaired when the *Aesthetics Use* of a waterbody is assessed as impaired.

Bacteria data
Rivers, Lakes, and Estuaries For freshwater AUs (rivers and lakes) the primary source of bacteria data is the results of the WPP’s water quality surveys. The validated (quality-assured) bacteria data from these surveys are usually published by the MassDEP in technical memoranda/reports or 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.

E. coli bacteria	*Enterococci* bacteria
GM: ≤630 colonies/100 mL applies to all inland freshwaters STV: ≤1,260 colonies/100 mL applies to all inland freshwaters	GM: ≤175 colonies/100 mL applies to all coastal/marine waters STV: ≤350 colonies/100 mL applies to all coastal/marine waters

[Notes: 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 Use Attainment 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. Use Attainment Impairment Decision Schema based on bacteria sampling frequency scenarios during Secondary Contact Recreational 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; 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 >630 OR 2) a. <80% of GM intervals >630 AND b. two or more samples exceed 1260 (STV) AND c. the overall GM is >630 [2]	1) >20% of GM intervals >630 in two or more years 2) >20% of cumulative GM intervals >630 3) ≥2 samples each year exceed 1260 (STV) in more than two years [4]
	Enterococci	1) ≥80% of GM intervals >175 OR 2) a. <80% of GM intervals >175 AND b. two or more samples exceed 350 (STV) AND c. the overall GM is >175 [3]	1) >20% of GM intervals >175 in two or more years 2) >20% of cumulative GM intervals >175 3) ≥2 samples each year exceed 350 (STV) in more than two years [4]
Moderate frequency (e.g., monthly) 7 to 14 samples	*E. coli*	1) ≥60% of GM intervals >630 OR 2) a. >10% to <60% of GM intervals >630 AND b. >2 samples exceed 1260 (STV)	1) >20% of GM intervals >630 in two or more years 2) >20% of cumulative GM intervals >630 3) ≥2 samples each year exceed 1260 (STV) in more than two years [4]
	Enterococci	1) ≥60% of GM intervals >175 OR 2) a. >10% to <60% of GM intervals >175 AND b. >2 samples exceed 350 (STV)	1) >20% of GM intervals >175 in two or more years 2) >20% of cumulative GM intervals >175 3) ≥2 samples each year exceed 350 (STV) in more than two years [4]
High frequency (Every two weeks, at minimum) ≥15 samples	*E. coli*	1) ≥40% of GM intervals >630 OR 2) a. ≥30% to <40% of GM intervals >630 AND b. >10% of samples exceed 1260 (STV) OR 3) a. >0% to <30% of GM intervals >630 AND b. >20% of samples exceed 1260 (STV)	1) >10% of GM intervals >630 in two or more years 2) >10% of cumulative GM intervals >630 3) >10% of samples exceed 1260 (STV) in more than two years [4]
	Enterococci	1) ≥40% of GM intervals >175 OR 2) a. ≥30% to <40% of GM intervals >175 AND b. >10% of samples exceed 350 (STV) OR 3) a. >0% to <30% of GM intervals >175 AND b. >20% of samples exceed 350 (STV)	1) >10% of GM intervals >175 in two or more years 2) >10% of cumulative GM intervals >175 3) >10% of samples exceed 350 (STV) in more than two years [4]

[1] The five most recent years of data will be preferentially evaluated, 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 >630 CFU/100mL and any samples are >1260 CFU/100mL (STV) but the overall GM (i.e., January-December) is <630 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 >175 CFU/100mL and any samples are >350 CFU/100mL (STV) but the overall GM (i.e., January-December) is <175 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.

Presence of active CSO discharge

Rivers, Lakes, and Estuaries Other than in Boston Inner Harbor (the Class SB waters described as westerly inside a line from the southern tip of Governors Island to Fort Independence including the Charles, Mystic, Island End and Chelsea (Creek) Rivers, and Reserved, Fort Point and Little Mystic Channels), the Mystic River from the Amelia Earhart Dam to the confluence with the Chelsea River, and the Muddy River in the Charles River Basin, where limited 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 *Secondary Contact Recreational Use.*

Harmful algal blooms
Rivers, Lakes, and Estuaries Waters exhibiting one extended-length advisory (i.e., >20 days) or two or more advisories of any duration would be considered by MassDEP to be impaired for HABs (for more detail see *Primary Contact Recreational Use*). While MA DPH guidelines specifically pertain to freshwater HABs, marine and/or estuarine HABs involving microalgae are addressed on a case-by-case basis.

Beach postings
Estuaries and Freshwater DCR beaches The *Secondary Contact Recreational 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) the *Secondary Contact Recreational Use* is not assessed 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 Recreational Use* when the *MarineFisheries* Shellfish Growing Area Classification is “Approved” (Bettencourt August 25, 2021). However, when the shellfish classification is anything less than “approved” no use attainment determination for the *Secondary Contact Recreational Use* can be made.

Secondary Contact Recreational Use Attainment

Use is Supported		Use is Impaired	
Rivers, Lakes	***Estuaries***	***Rivers, Lakes***	***Estuaries***
No aesthetic use impairment; Bacteria do not exceed use attainment impairment decision schema; beach postings at DCR freshwater beaches generally <u><</u>10% season	No aesthetic use impairment; Bacteria do not exceed use attainment impairment decision schema; beach postings generally <u><</u>10% season; *MarineFisheries* “Approved” Shellfish Growing Area Classification	Aesthetic use impairment; Bacteria exceed use attainment impairment decision schema; presence of CSO outfall in waterbody without an approved variance; MA DPH cyanobacteria advisories for >20 days in a year	Aesthetic use impairment; Bacteria exceed use attainment impairment decision schema; presence of CSO outfall in waterbody without an approved variance

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 cause codes (CAUSE_LUT) and source codes (SOURCE_LUT) used within ATTAINS.

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 6 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 *MarineFisheries* reports (e.g., sanitary surveys) and information and/or BPJ of MassDEP analysts using MassGIS datalayers (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 used by MassDEP analysts can be found in Appendix F.

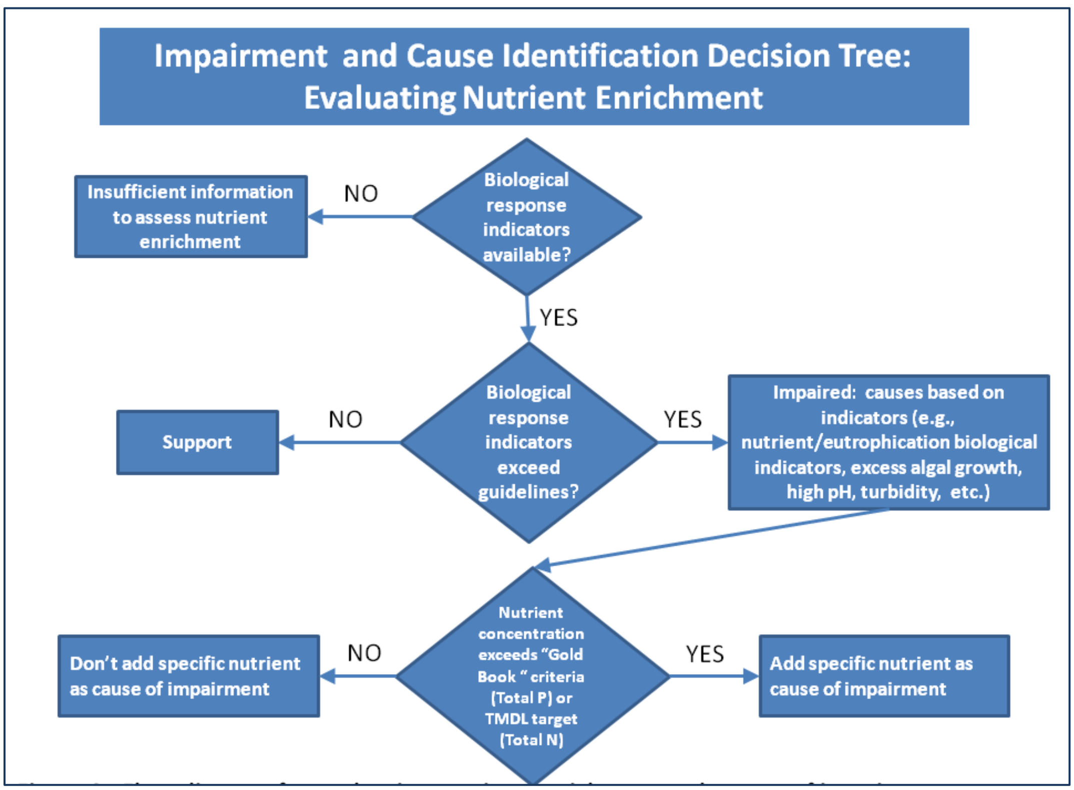


Figure 6. Impairment and cause identification decision tree for evaluating nutrient enrichment in lakes.

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. Similarly, Section 314 of the CWA provides for cooperative agreements between federal, state and local entities to restore publicly-owned freshwater lakes and ponds and protect them against degradation. During the late 1970s through the early 1990s diagnostic and feasibility (D&F) studies were completed for many lakes and ponds throughout Massachusetts and were used in earlier 305(b) assessments and 303(d) listing decisions. Information from these studies continues to carry over into new reporting cycles unless new monitoring information results in a change in their use attainment and listing status. It should also be mentioned that information contained in the nonpoint source assessment report, prepared in 1989 in accordance with the requirements of Section 319, is also reflected in 305(b) and 303(d) reporting elements unless more recent information has resulted in a modification of the original assessment.

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 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 new How's My Waterway site (https://mywaterway.epa.gov/).

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 Massachusetts' surface waters as AUs in ATTAINS. While many of Massachusetts' 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. Brief description of the five list categories of assessed waters used by MassDEP for the IR.

The Integrated List of Waters -- categories of assessed waters	
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 4	Not Supporting one or more uses but not requiring the calculation of a Total Maximum Daily Load (TMDL) because: 1) a TMDL has already been established and approved by the EPA (***Category 4a***); or 2) the impairment is due to "pollution" such as low flow, habitat alterations or non-native species infestations (***Category 4c***).
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. **This category constitutes the 303(d) List.** (Note that 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 until all pollutants are addressed the AU remains in Category 5.) Some pollutant-impaired AUs have an Alternative Restoration Plan (ARP) in place (***Category 5a***).

***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 the 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, the 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 (non-point sources), determining, with a margin of safety, the allowable amount of the pollutant that can be discharged to a specific waterbody while maintaining 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.

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 WQS 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

Good Cause Impairment Removal Reason	Impairment Removal Scenario
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 2022 reporting cycle, MassDEP analysts are completing 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 (as illustrated in Figure 7). 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 color 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

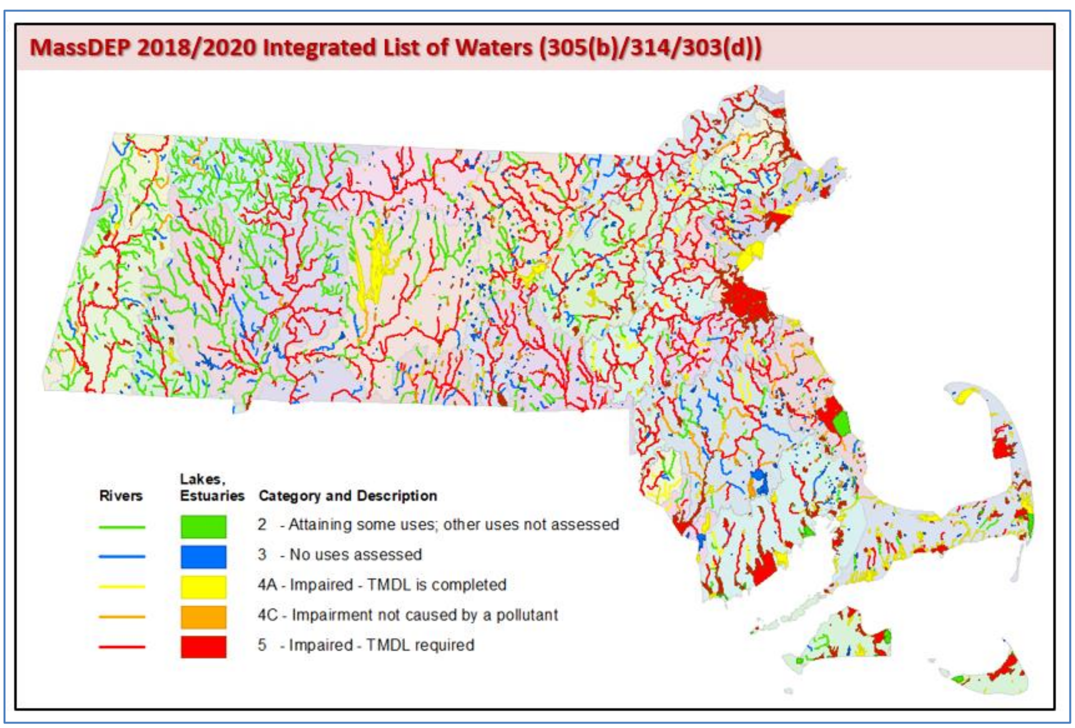


Figure 7. MassDEP geo-referenced waterbody assessment unit (AU) locations and 2018/2020 listing category.

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 (Figure 7) as well as the ability to obtain more detailed information for each AU (Figure 8). 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
https://maps.massgis.digital.mass.gov/MassMapper/MassMapper.html
(e.g., https://www.mass.gov/lists/integrated-lists-of-waters-related-reports).

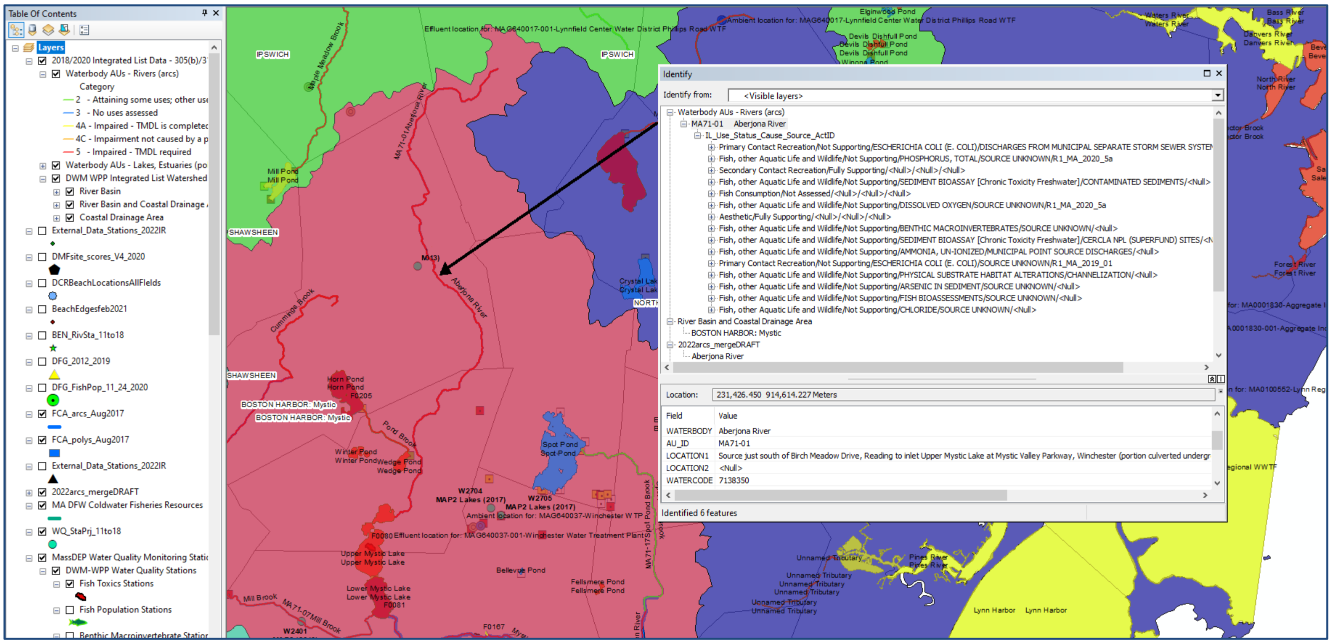


Figure 8. MassDEP Assessment Database (ATTAINS) data associated with geo-referenced waterbody assessment unit (AU) locations.

The Massachusetts 2018/2020 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) website MassGIS 2018/2020 IR datalayer. The datalayers for the 2022 IR will be developed by MassDEP analysts once the 2022 303(d) list (Category 5 waters) is approved by EPA.

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VIII. APPENDICES

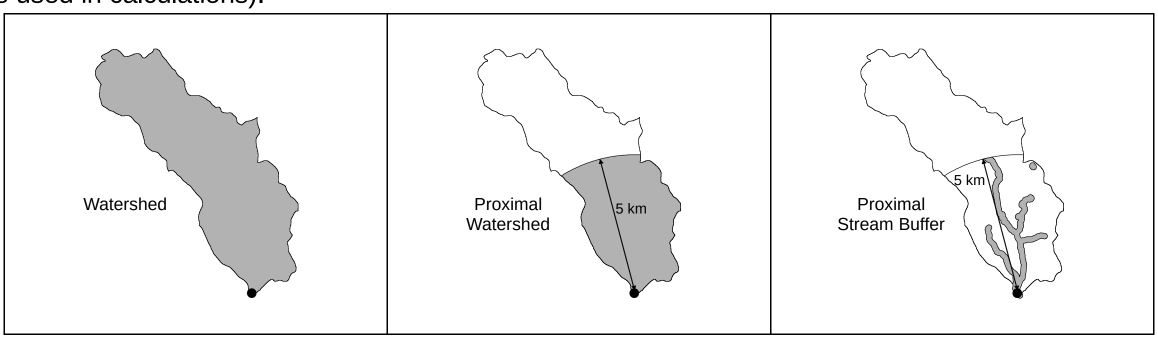
APPENDIX A EVALUATION METHODS FOR NATURAL CONDITION

Temperature

Violations of temperature criteria will NOT be considered natural under any of the following circumstances:

1. Determine which temperature criteria were violated, the warm water or cold water. If the warm-water criteria were violated, the temperature violations will not be considered natural.
2. Determine the general nature of the temperature criteria violations. If the violation is the result of isolated spike(s), the temperature violations will not be considered natural.
3. Delineate a complete watershed, proximal (5 km) watershed, and proximal (5 km) 100 m stream buffer (Figure 1) on either side for the assessment unit (AU) and calculate the percent of natural land, and impervious cover within those delineations (Schiff and Benoit 2007, MassGIS 2019). If the percentages fail to meet the criteria outlined in Table A1, the temperature violations will not be considered natural.
4. Determine the presence of dams along the AU and in its contributing watershed and their potential to be the source of the observed temperature criteria violations. If they cannot be reasonably eliminated as the source of the violations, the temperature violations will not be considered natural.
5. Determine the presence of point source discharges (wastewater treatment plants (WWTP), non-contact cooling water, stormwater, etc.) and/or water withdrawals along the AU and in its contributing watershed and their potential to be the source of the observed temperature criteria violations. If they cannot be reasonably eliminated as the source of the violations, the temperature violations will not be considered natural.
6. Determine the presence of any localized human disturbances within the riparian area of the AU from recorded fieldsheet observations and GIS. If the present localized human disturbances cannot be reasonably eliminated as the source of the violations, the temperature violations will not be considered natural.
7. Determine if there are any other potential sources of the temperature violations not considered above. If there are any other potential sources, the temperature violations will be not be considered natural.

Figure 1. Illustration of the different spatial scales used to evaluate the landscape criteria (grey shaded area clips used in calculations).



If not screened out in any of the above steps, the temperature violations will be considered natural.

Table A1. Landscape thresholds used to evaluate thermal excursions

Land Cover	Complete and Proximal Watersheds	Complete[2] or Proximal Stream Buffer
Natural Land[1]	>80%	>90%[3]
Impervious Cover	<4%	<2%

[1]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
[3]This is best professional judgment of WPP biologists

Dissolved Oxygen (DO)

Violations of the DO criteria may be due to natural conditions, especially in areas where wetlands contribute low DO water to the stream. A study relating natural wetlands and predawn dissolved oxygen in Massachusetts streams reported that wetland areas exceeding 4 percent of the subwatershed within a mile of the sample site was related to a marked drop to 60% dissolved oxygen saturation (Mattson et al., 2007). The study recommended a limit of 7 percent proximal wetland area as a threshold for natural conditions to meet the state's water quality standards. Furthermore the cause and effect is likely confounded by the co-correlation between impervious cover and stream slope (Waite et al., 2006) where the cause of the low dissolved oxygen may be due to the low gradient hydrologic setting.

Violations of DO criteria will NOT be considered natural under any of the following circumstances:

1. Determine the general nature of the DO criteria violations. If the violation is the result of isolated spike(s), the DO violations will not be considered natural.
2. Determine the diurnal shift in DO concentration. If the diurnal shift is ever greater than 3mg/l, the DO violations will not be considered natural.
3. Delineate a complete watershed, proximal (5 km) watershed, 100 m stream buffer on both sides including both the intermittent and perennial streams, and proximal (5 km) 100 m stream buffer (Figure 1) on both sides for the assessment unit (AU) and calculate the percent of natural land, and wetland within those delineations. If the percentages fail to meet the criteria outlined in Table A2, the DO violations will not be considered natural.
4. Determine the presence of dams within the AU and upstream of the AU and their potential to be the source of the observed DO criteria violations. If the present dams cannot be reasonably eliminated as the source of the violations, the DO violations will not be considered natural.
5. Determine the presence of point sources (wastewater treatment plants (WWTP), non-contact cooling water, stormwater, etc.) and water withdrawals to the AU and upstream of the AU and their potential to be the source of the observed DO criteria violations. If the present point sources cannot be reasonably eliminated as the source of the violations, the DO violations will not be considered natural.
6. Determine the presence of any localized human disturbances within the riparian area of the AU from fieldsheets and GIS. If the present localized human disturbances cannot be reasonably eliminated as the source of the violations, the DO violations will not be considered natural.
7. Determine if there are any other potential sources of the DO violations not considered above (e.g., spill). If there are any other potential sources, the DO violations will be not be considered natural.

If not screened out in any of the above steps the DO violations will be considered natural.

Table A2. Landscape thresholds used to evaluate DO excursions.

Land Cover	Complete Watershed	Proximal Watershed	Complete[2] or Proximal Stream Buffer
Natural Land[1]	>80%	>80%	>90%[3]
Wetland	NA	>7%	NA

[1]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
[3]This is best professional judgment of WPP biologists

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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
Esox lucius	Northern pike	NP	Esocidae	MG	I	W
Esox americanus americanus	Redfin pickerel	RP	Esocidae	MG	M	W

Scientific Name	Common Name	Fish Code	Family	Habitat Use Classification[1]	Tolerance Classification[2]	Temperature Classification[3]
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 MEMORANDUM LITERATURE REVIEW OF FRESHWATER NUTRIENT ENRICHMENT INDICATORS

To: DWM-WPP Program Managers
From: Anna Mayor, DWM-WPP Water Quality Standards Committee Member
Date: September 2, 2015
Subject: Literature Review of Freshwater Nutrient Enrichment Indicators

1.0 Introduction

Nutrients, such as total phosphorus (TP) in freshwaters, have been 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.

Massachusetts to date has relied on narrative statements in its water quality standards to regulate unacceptable nutrient impacts on surface waters from anthropogenic sources. To better implement their water use impairment guidelines, MassDEP has increasingly applied quantitative rather than narrative screening guidelines for freshwater nutrient enrichment response indicators, along with TP concentrations, in a weight-of-evidence approach. Because 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, the preferred approach has been to use field measurements of the primary producers' responses as the first indicators for assessing surface waters for impairment in compliance with Section 305(b) of the CWA. Massachusetts currently follows the "Designated Use Approach" (USEPA, 2000a), establishing nutrient enrichment response indicator screening guidelines 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 guidelines used in the 2016 Consolidated Assessment and Listing Methodology (CALM) Guidance Manual.

2.0 Summary of Massachusetts Nutrient Enrichment Indicator Screening Guidelines

To assess nutrient enrichment, Massachusetts has grouped its inland waterbodies into three categories: 1. wadeable rivers and streams; 2. non-wadeable rivers and streams, 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 filamentous algae percent visual coverage,
- benthic algae as chlorophyll-*a*,
- diel changes in and saturation of dissolved oxygen,

- elevated pH, and
- elevated TP.

The indicators used for non-wadeable rivers are:

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

MassDEP has selected its nutrient enrichment indicators and their respective numeric screening guidelines based on historical precedent, best professional judgment (BPJ) and the scientific literature. MassDEP's response indicator guidelines for each waterbody type, the literature reviewed for each indicator, along with the thresholds mentioned or recommended by the literature are provided in Table 1.

Table 1

Recommended Nutrient Enrichment Indicator Screening Guidelines 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	Benthic Filamentous Algae % Visual Coverage	>40%	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/ Recreation/ Aesthetics	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	Δ>3 mg/l	Aquatic Life	Gower, 1980	Δ 2.5 mg/l (generally nutritionally balanced) Δ 10 mg/l (generally nutritionally imbalanced)
				Mathews, 1998	Δ> 3.6 - 6 mg/l
	DO Saturation	≥125%	Aquatic Life	USEPA,1986a	>110-120% (total dissolved gas)
				MassDEP BPJ	≥125% (Oxygen)
	Elevated pH	>8.3 SU	Aquatic Life/ Recreation	USDI, 1968	>8.3 SU (human eye irritation)
				USEPA, 1976	>9 SU (freshwater organisms)
	Elevated TP-seasonal avg: used to confirm nutrient enrichment	>.1 mg/l flowing waters >.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 Rivers	Non-rooted Vegetation % Visual Coverage	>25%	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 μg/l	Aquatic Life	Dodds, et al., 1998	>30 μg/l (mesotrophic-eutrophic rivers)
				USEPA, 2000/2001	0.63 - 3.75 ug/l (rivers + streams)

Waterbody Type	Nutrient Enrichment Indicator	Recommended Indicator Screening Guideline(s)	Water Use Goal Potentially Impacted	Reference	Literature Thresholds
	Diel Changes in DO Concentration	Δ>3 mg/l	Aquatic Life	Gower, 1980	Δ 2.5 mg/l (generally nutritionally balanced) Δ 10 mg/l (generally nutritionally imbalanced)
				Mathews, 1998	Δ> 3.6 - 6 mg/l
	DO Saturation	≥125%	Aquatic Life	USEPA,1986a	>110-120% (total dissolved gas)
				MassDEP BPJ	>125% (DO)
	Elevated pH	>8.3 SU	Aquatic Life/ Recreation	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-Seasonal Average: Used to confirm nutrient enrichment	>.1 mg/l flowing waters >.05 mg/l entering a lake/reservoir (n≥3 samples)	See preceeding indicators for potential impacts	Mackenthun, 1973; USEPA, 1986a	>.1 mg/l flowing waters >.05 mg/l entering a lake/reservoir
				USEPA, 2002	>0.010 mg/l - 0.031 mg/l (range within Massachusetts Ecoregions)
Lakes, Ponds and Impoundments (Generally >2m Depth)	Secchi Disk Transparency	≤ 1.2 m	Aesthetics/ 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 μg/l		USEPA, 2000/2001	>2.43-2.90 ug/l (25th Percentile range within Massachusetts Ecoregions)

Waterbody Type	Nutrient Enrichment Indicator	Recommended Indicator Screening Guideline(s)	Water Use Goal Potentially Impacted	Reference	Literature Thresholds
			Aquatic Life/ Recreation/ Aesthetics	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	USEPA, 1986a	>110-120% (total dissolved gas)
				MassDEP BPJ	>125%
	Elevated pH	>8.3 SU	Aquatic Life/ Recreation	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 Average: 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

These basic nutrient enrichment screening guidelines represent thresholds that shall not be exceeded in more than one site visit (generally visit per month) during the summer index period. If the guidelines are exceeded repeatedly, MassDEP uses a weight-of-evidence approach to assess impairment of the surface water, outlined as follows:

- In the assessment of rivers and streams, MassDEP analysts evaluate both 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 the guidelines will be used to determine whether or not the condition of the surface water supports its designated uses.

- 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 guidelines more than once during the survey season.

- If the surface water is impaired using biological and/or physicochemical indicators, total phosphorus is then included as a cause of impairment if the concentrations exceed EPA's "Gold Book" criteria.

The proposed guidelines apply to freshwaters but exclude darkly colored waters, as well as marine or brackish waters that have salinity greater than 0.5 ppt.
To define appropriate guidelines, MassDEP conducted a detailed literature review of biological and physical characteristics related to nutrient enrichment that support attainment of each surface water's designated uses.

3.0 Literature Summaries

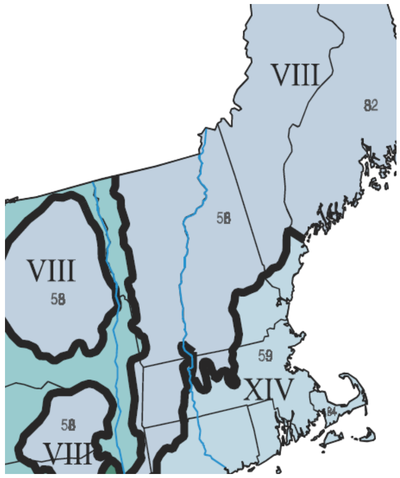
Over the last decade a wealth of research has been generated to help identify appropriate nutrient criteria for protection and restoration of water resources. MassDEP reviewed EPA's technical support and guidance documents, scientific literature and the extensive surface water sampling data collected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

3.1 USEPA General Nutrient-Related Background Information

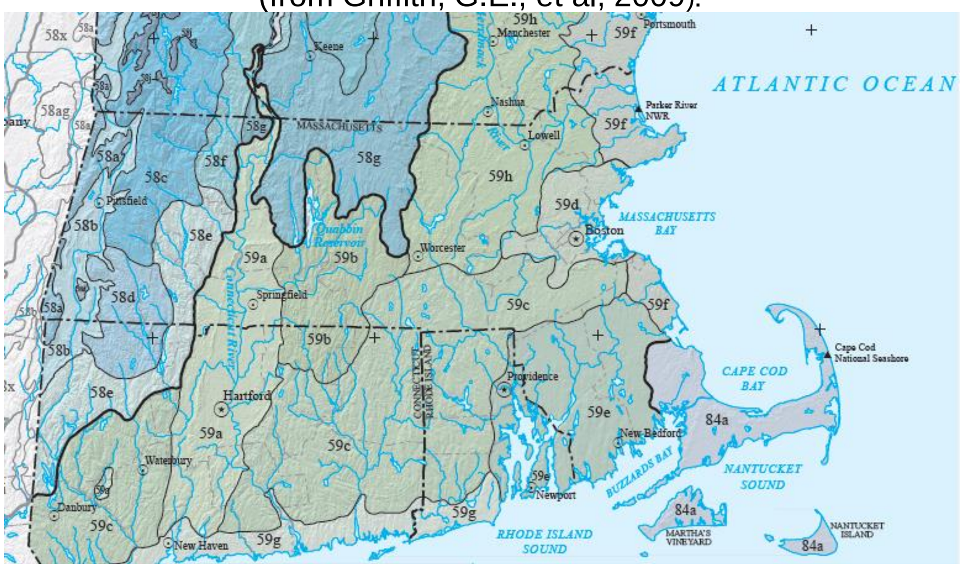
The United States Environmental Protection Agency (USEPA) has published technical support documents to help guide efforts for numeric nutrient criteria development by waterbody type (e.g., estuarine and coastal waters, lakes and reservoirs, rivers and streams and wetlands). In addition USEPA conducted 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 guidelines for freshwater systems. See Figure 1 for the EPA Ecoregions within Region 1, and the Sub-Ecoregions specific to Massachusetts.

<u>Figure 1</u>

EPA Ecoregions for the National Nutrient Strategy



Massachusetts lies within two major Ecoregions: VIII and XIV (see above map), and three Sub-Ecoregions: 58, 59 and 84, as indicated below (from Griffith, G.E., et al, 2009).



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 potential 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.

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 guidelines.

(a) Wadeable Streams and Rivers

(1) Benthic Filamentous Algae % Visual Coverage

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 USEPA rivers nutrient guidance document (USEPA 2000a), the proposed maximum screening guideline for filamentous macroalgae is set at 40 percent coverage in streams.

MassDEP Guideline: 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 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 Guideline: 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 summer growing 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 Guideline: to support the designated use of aquatic life, the diel change in dissolved oxygen greater than 3 mg/l during the summer growing season (April 1 to October 31), 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 Guideline: 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 (April 1 to October 31) 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 Guideline: to support the designated uses of recreation and aquatic life, a pH of >8.3 SU during the summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(6) Elevated Total Phosphorus (TP)

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 .010 mg/l for Ecoregion VIII (Western Mass), and .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 seasonal average (greater than three 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 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).

MassDEP Guideline: When multiple biological and physico-chemical nutrient enrichment indicator screening guidelines are exceeded, the 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 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 guidelines

More information is needed on applicability of benthic and filamentous algae screening guidelines to cold water streams. Future guidance may have to be revised as additional water quality information is 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 the goal of the assessment 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 USEPA 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 the 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 the 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 the 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).

MA Guideline: 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 index period 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 USEPA-derived value of 0.63-3.75 µg/l reported in Table 2 below.

Table 2
Summary of USEPA Statistically-Derived Nutrient Criteria for Massachusetts
By Ecoregion and Waterbody Type (USEPA 2000 a,b,c,d; 2001 a,b).

Parameter	USEPA Ecoregion VIII* Western Massachusetts	USEPA 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 USEPA 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 Guideline: to support the designated uses of recreation and aesthetics, water column chlorophyll-a >16 µg/l in more than one monthly site visit during the growing season from 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 Guideline: to support the designated use of aquatic life, the diel change in dissolved oxygen greater than 3 mg/l during the summer growing season (April 1 to October 31), is considered an indicator of nutrient enrichment.

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

MassDEP Guideline: 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 (April 1 to October 31) is considered an indicator of nutrient enrichment.

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

MassDEP Guideline: to support the designated uses of recreation and aquatic life, a pH of >8.3 SU during the 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 Guideline: When multiple biological and physico-chemical nutrient enrichment indicator screening guidelines are exceeded, the 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 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 Guideline: 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 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 USEPA 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 3 lists the total number of samples for each region.

Table 3
Lake Records for Aggregate Ecoregions VIII and XIV

	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
# 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.

(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 USEPA based on the cumulative transparency frequency of lakes in the Ecoregions (see Table 4).

Table 4
Summary of USEPA Statistically-Derived Secchi Disk Transparency for Massachusetts By Ecoregion and Waterbody Type (USEPA 2000a,b,c,d; 2001a,b).

Parameter	**USEPA Ecoregion VIII* Western Massachusetts**	**USEPA 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 USEPA 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 Antidegredation Implementation Policy (10-21-2009) serves to protect these surface water types.

MassDEP Guideline: 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 index period 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 bluegreen 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 Guideline: 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 index period 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 bluegreen 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 USEPA (see Table 5).

Table 5

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

Parameter	USEPA Ecoregion VIII* Western Massachusetts	USEPA 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.

MA Guideline: to support the designated uses of recreation and aesthetics, if planktonic chlorophyll-a exceeds 16 μg/l in surface waters in more than one site visit within the index period 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 Guideline: 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 (April 1 to October 31) is considered an indicator of nutrient enrichment.

(5) Elevated pH

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

MassDEP Guideline: to support the designated uses of recreation and aquatic life, a pH of >8.3 SU in more than one site visit during the 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 .01-.03 mg/l (Hutchinson, G.E. 1957). More recently, EPA guidance states that there is a general consensus that an ambient TP concentration of greater than 0.01 mg/l is likely to predict blue-green algal bloom problems during the growing season; however, because both soil enrichment and precipitation are variable across the U.S., EPA has taken an Ecoregion frequency approach to the TP criterion (USEPA 2000b). EPA recommends a TP criterion of 0.008 mg/l for lakes in both of the Massachusetts Ecoregions.

However, 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 seasonal average (greater than three 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 lakes, it is recommended that TP be maintained at 0.025 mg/l (EPA 1986a).

MassDEP Guideline: When multiple biological and physico-chemical nutrient enrichment indicator screening guidelines are exceeded, if the seasonal average for TP exceeds 0.025 mg/l for lakes, ponds and impoundments during the 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 Guideline: 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 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 2016 CALM:

MassDEP used in-house data and that collected by the USGS and the Cape Cod Commission (CCC), to generate a lakes and impoundment data set consisting of 211 locations sampled between 1999-2004. Data were collected during the summer index period beginning in mid-June and ending in mid-September. MassDEP is currently undertaking a detailed evaluation of the data, potentially applying it in the future to re-evaluate its water quality nutrient enrichment screening guidelines to increase their specificity to waterbody type (MassDEP 2012a).

Guidelines 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.

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

Memorandum for the Record

By: Gerald M. Szal, Aquatic Ecologist, Surface Water Quality Standards Section, MassDEP, Watershed Planning Program (WPP), Worcester, MA
Date: September 16, 2015
Subject: Derivation of Temperature and Dissolved Oxygen (DO) Assessment Criteria for use in MassDEP/WPP 305b Assessments

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Background: At this point in time 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 305b 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 Criteria 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 criteria are needed to allow for such assessments.

The assessment criteria 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 Methods (CALM) used to conduct 305b assessments. This group consisted of Christine Duerring, Kimberly Groff, Arthur Johnson, Laurie Kennedy, Richard McVoy and me. This group is referred to as the CALM Committee in the discussion below. We were assisted with specific tasks by Dan Davis, Robert Maietta and James Meek.

Cold Water Temperature Criteria

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 Dept. of Fish and Game 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 Cold Water 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 305b Assessments needed to consult:

1. GIS maps provided by Mass Fish and Game 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 305b 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 Criteria 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 MassDFG 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 we had 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 criteria in the category into which they fell.

Acute and chronic assessment criteria, used to evaluate thermal habitat impairment, were developed for the two tiers of cold water fish and are discussed below. To calculate the acute criteria, I used formulae developed by EPA (1977) 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 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 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 criteria below.

Tier 1 Acute Criterion = 23.5°C as a 24-hr. average not to be exceeded: This criterion 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 criterion are expected to be toxic to juvenile brook trout. As a result, even a one-time occurrence of this criterion should result in a judgment of "impairment" to cold water habitat in 305b assessments if the high-temperature event is thought to be due to un-natural (i.e., anthropogenic) sources.

Tier 1 Chronic Criterion = **20°C as a 7-day average of the daily maximum temperatures (allowable exceedances ≤11)**. This criterion 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:

> *Cold Water Fishery. 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". This term 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 Criterion = 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 Fish and Game is controversial for this reason, they have become important to fishermen in MA and are one of the species used by MA Fish and Game to delimit its "cold water fishery resources". The acute criterion 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 occurrence of this criterion should result in a judgment of "impairment" to Tier 2 cold water fish habitat in 305b assessments if the high temperature event is considered to be due to un-natural (i.e., anthropogenic) sources.

Tier 2 Chronic Criterion = 21.0°C as a 7-day average of the daily average temperatures; allowable exceedances ≤11. This criterion 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 criterion was based on the ideas expressed for the Tier 1 Chronic Criterion. As with other criteria, the assessment of "impairment" only applies when the high temperature events are considered to be due to non-natural causes.

Warm Water Temperature Criteria

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 Fish and Game. 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 criteria 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 criteria developed using this species are protective for other fluvial warm-water species in MA.

Acute Criterion = 28.3°C as a 24-hr. average not to be exceeded: This criterion 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 criteria described above, even one-time exposures to temperature/duration combinations above this criterion are expected to result in acute toxicity to adult white suckers and should result in a judgment of "impairment" in 305b assessments of warm-water streams if the high-temperature event is judged to be due to un-natural (i.e., anthropogenic) causes.

Chronic Criterion = 27.7°C as a 7-day average of the daily maximum temperatures (allowable exceedances = <u><</u>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 criterion discussion.

Dissolved Oxygen (DO) Criteria

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 criteria for MA streams. The 2016 CALM assessment criteria for DO are listed below:

	Cold Water Criteria	**Warm Water Criteria**	
	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 and larvae) of fish and from "other life stages" (i.e., juveniles and adults) and developed 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 criteria for “early life stages” were not developed for the cold water DO assessment criteria. In the future, WPP should review egg/larval seasonal presence for other species besides those mentioned to ensure that cold water criteria should not also be considered for early life stages in the summer months. The term “production impairment” used in text below, the studies that were used to develop this term and the DO values associated with it are described fully in EPA 1986a.

Cold Water Criteria

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) criterion **for “other life stages”** (see above) chosen **was 6.0 mg/l**. Invertebrates showed some production impairment at a DO of 5 mg/l and none at DO of 8 mg/l; salmonids were not impaired at a DO near 8 mg/l and showed “moderate production impairment” at a DO 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 criterion 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 Criteria

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

The 7-day mean for early life stages of warmwater fish chosen for a criterion **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 criteria categories should reflect a “no impairment” status.

A 1-day minimum 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 levels around 5 mg/l and below and slight production impairment was found at DO values around 5.5 mg/l. “Some” production impairment to invertebrates was found at DO values near 5 mg/l.

A 30-day mean criterion 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 criterion) which is supported by EPA’s Table 2 (EPA, 1986) recommendation for this category.

A 7-day mean minimum criterion 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 value 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.

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 METALS DATA COMPARISONS TO WATER QUALITY CRITERIA

The following is guidance related to evaluations of Toxic Metals.
EPA usually issues aquatic life criteria recommendations for metals as both 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.

Because 304(a) aquatic life criteria are national guidance, they are intended to be protective of the vast majority of the aquatic communities in the United States.

To simplify comparisions, “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 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):

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

[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 Freshwater 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 copper criteria (acute 25.7 µg/L, chronic 18.1 µg/) have been approved by EPA in the SWQS (MassDEP 2021b) for certain waterbody segments (see Table E2). 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 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 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/L, Chronic 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. Freshwater 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

HARDNESS (mg/L as CaCO3) =	2.497*Ca + 4.118*Mg	
	Ca (mg/L)	**Mg (mg/L)**
Example Inputs:	1.9	1.2
HARDNESS (mg/L) =	9.8	

Use best-available hardness data (no lower limit); max=400 mg/L	*italics = not hardness dependent*

Step 1: Enter hardness value		Step 2: Use calculated CMC and CCC values					
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	Notes	
	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	10	**1.54**	**1.25**	*0.960*	*0.960*	Equations based on 2002 Cu Criteria	**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.**
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	10	**16.66**	**16.79**	*0.978*	*0.986*	Equations based on 2002 Zn Criteria	**The hardness-based Zn equations should be used ONLY if there are no site-specific criteria that apply.**
Arsenic (as total)	*NA*	***340***	***150***	*1.000*	*1.000*	From 2002 As Criteria	
Mercury	*NA*	***1.4***	***0.77***	*0.850*	*0.850*	From 2002 Hg Criteria	These are water column criteria for Hg, not fish tissue-based criteria for methyl-Hg.
Chromium VI	*NA*	***16***	***11***	*0.982*	*0.962*	From 2002 Cr VI Criteria	
Selenium (as total)[1]	*NA*	***NA***	***5 (4.61 dissolved)***	*0.996*	*0.922*	From 2002 Se Criteria (2016 EPA criteria have not been adopted by MassDEP)	See Metals Criteria Calculations SOP CN 101.8 for more information (MassDEP 2022).
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] 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.

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

Summary:
For assessment purposes and to better determine the potential for chloride impairments in fresh surface waters, a linear regression model was developed to estimate chloride concentrations from Specific Conductance (SC) measurements. The model development dataset was developed using 2426 paired chloride and SC data points generated by the Massachusetts Department of Environmental Protection (MassDEP) from 1994 to 2012 at 244 inland stream and river stations across Massachusetts (Figure F1). Model validation was conducted using the USEPA Auburn Project study data (N=37) collected during winter of 2013-2014 (Heath 2014), the MassDEP River Meadow Brook study data (N=54) collected between October 2015 and September 2016, and additional data (N = 96) collected by MassDEP staff from streams and rivers in western Massachusetts in 2013-2014.

The equation for estimating chloride concentrations is:

$\boldsymbol{Y=0.2753X - 18.987}$, where Y is chloride concentration and X is specific conductance.

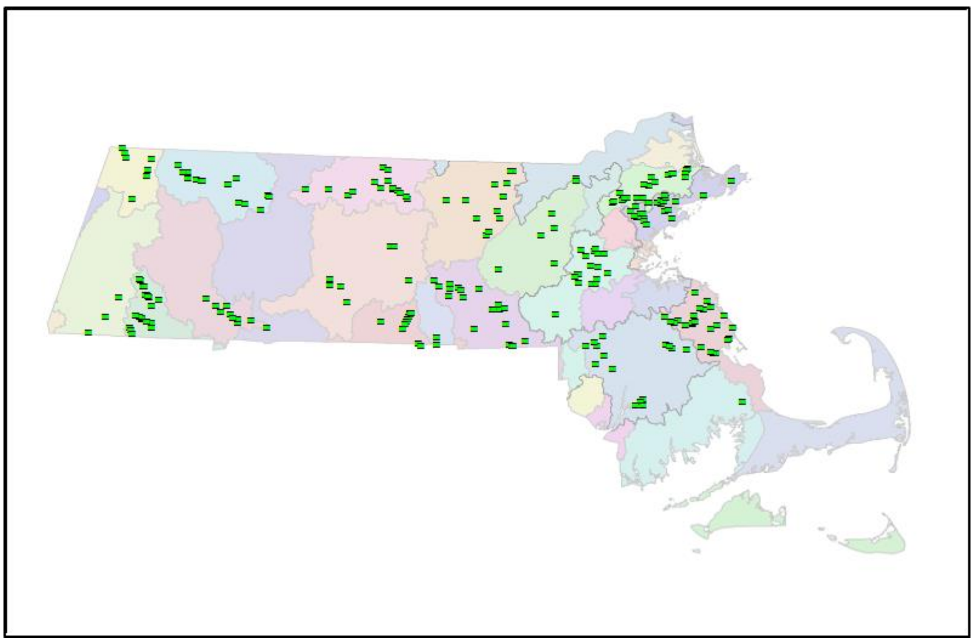

Figure F1. Distribution of the 244 sampling stations where paired chloride-SC data were collected in Massachusetts from 1994 to 2012.

Sample Collection, Chloride Analyses and Specific Conductance Measurements for Model Development
From summer 1994 to fall 2012, water samples for chloride were collected by MassDEP staff at 244 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 2012) (APHA 2005). 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). 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.

Quality Assurance and Control

Chloride and SC data generated by MassDEP generally 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, 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 data used in model development are considered final. Secondary data used in model validation and related analyses were from verified sources.

Regression Analysis

Freshwater samples for both chloride and SC (N=2426) were used to develop a statewide linear model to estimate chloride concentration using SC data. The model for freshwater (Figure F2; R^2=0.9445, P<0.001) shows a strong linear relationship between SC and chloride concentration:

$$\boldsymbol{Y=0.2753X - 18.987}$$, where Y is chloride concentration and X is specific conductance

Development of the freshwater model only included data with SC less than 10,000 µS/cm (n=2426). The lower limit for estimated chloride values using the model is 5 mg/L (i.e., if the model calculates the chloride values <5, these are reported as 5 mg/L for estimation purposes to account for the model error at the extreme lower range. All statistical analysis and model estimation were performed using SAS® (Version 9.4, SAS Institute Inc. Cary, NC).

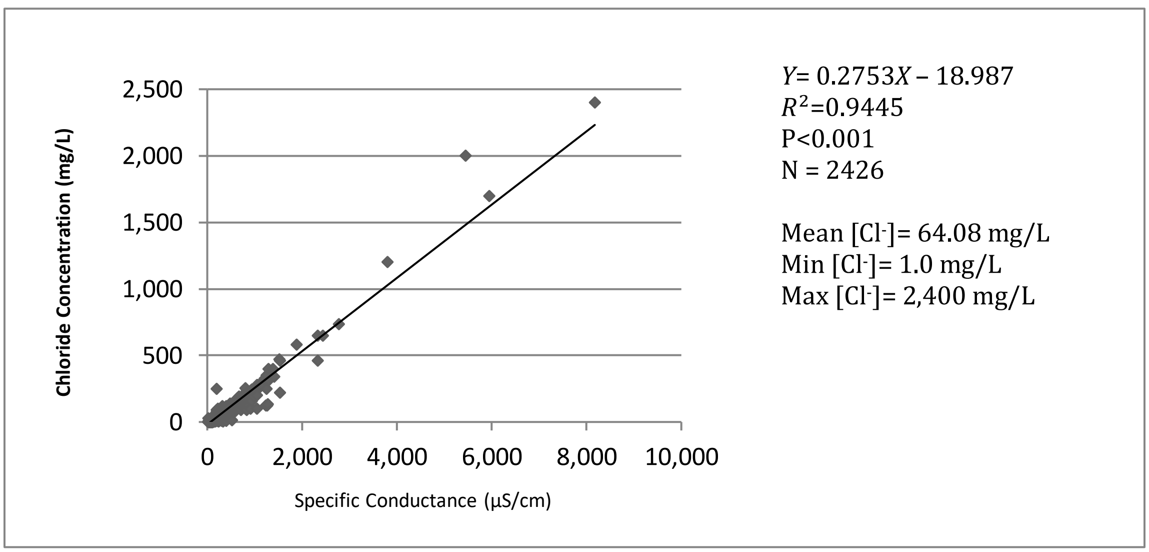

Figure F2. Relationship between chloride and SC for Massachusetts freshwaters.

Model Validations

<u>Initial Model Validation</u>:

The freshwater model was validated using separate data and field observations from the USEPA Auburn Project in Auburn, MA, which was conducted during winter of 2013-2014 (Heath 2014). For the Auburn Project, 37 freshwater samples were collected for SC and chloride by USEPA staff and analyzed for chloride at the USEPA Northeast Regional Laboratory (NERL) in North Chelmsford, MA. Using SC values from the Auburn Project, predicted chloride concentrations generated by the MassDEP freshwater model were compared with actual chloride data collected from the USEPA Auburn Project using a best fit line.

The regression line demonstrates 99% accuracy of the model (Figure F3; R^2=0.9908, P<0.001) with a slope of 0.9709.

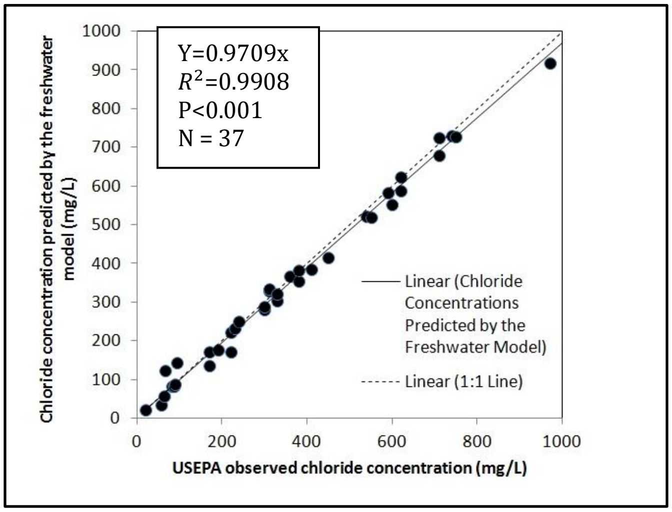

Figure F3. Validation of Freshwater Model using USEPA Data.

<u>Supplemental Validation (River Meadow Brook Study)</u>:
An additional validation of the freshwater model was conducted using MassDEP data collected between October 2015 and September 2016 at a total of six stations in the Concord River Watershed in northeastern Massachusetts. Four stations were located on River Meadow Brook and two stations were located in the Concord River bracketing the confluence of River Meadow Brook. Project details are outlined in a Sampling & Analysis Plan (MassDEP 2015). Onset® probes (HOBO U24 conductivity and temperature loggers) were deployed by MassDEP staff at these six sites to collect continuous conductivity and temperature data and discrete samples for subsequent chloride analysis were also collected periodically (N=9) at each site throughout the deployment period.

Conductivity/temperature loggers (Onset®) were deployed *in-situ* per manufacturer's directions at each of the six stations at a recording interval of every 30 minutes. Prior to deployment, each logger was checked for conductivity and temperature accuracy using a NIST-traceable thermometer and KCl standards in the lab. Each (Onset®) data logger was housed in a protective plastic (ABS) pipe, mounted vertically on a metal post and completely submerged. On a nearly monthly basis site visits (n=9 during the time of deployments) were made to each sampling location where the (Onset®) data logger had been deployed. During these site visits data files were downloaded from each logger and the conductivity sensor faces were cleaned (after side-by-side multiprobe QC readings were taken). To evaluate the accuracy of deployed continuous conductivity data loggers, co-located multiprobe (Hydrolab®) readings, including SC and temperature, were collected using instruments that were calibrated just prior to the survey and were compared to the (Onset®) data logger data. Both pre-survey calibration and post-survey checks were performed on the Hydrolab® multiprobes for each survey. To check deployed logger accuracy, SC (at 25°C) readings from the Hydrolab® multi-probes were compared to conductivities collected by the Onset loggers at ambient temperatures (the co-located SC readings were converted to conductivity and then compared to logger conductivity readings at the nearest 30-minute recording time). Across all stations during the study, relative percent differences (RPD) for conductivities ranged from 0.4% to 13.8%, with a mean RPD of 6.4% for these QC comparisons. To check for drift during deployment, conductivity readings immediately before and after cleaning the sensor were compared for each site. The majority of data align well between a logger that had been recording data for about one month and for a re-deployed logger just after cleaning, with 77% of readings within +/- 3.0% RPD. Because a temperature change may affect the drift (Barron and Ashton 2005) and temperature is a factor in the SC calculation, measured temperature was also compared before and after cleaning, with 76% of readings found to be within +/- 5.0% RPD. At the completion of the study recorded continuous conductivity and temperature data were reviewed and any outliers investigated. All data were reviewed for acceptability, and individual datum qualified or censored as appropriate (e.g., logger data documented or estimated to have been out-of-water for any length of time).

Censored data were excluded from analysis and only accepted and qualified data were used in validating the model.

Discrete chloride samples were collected at each of the six sampling stations approximately once a month using standard WPP procedures for wade-in sampling. Chloride samples were iced following collection and were delivered to the USEPA NERL in North Chelmsford, MA for analysis. Chloride samples were analyzed at EPA NERL using a Dionex ICS-3000 Ion Chromatograph following the EPA Region I SOP, and results were reported in units of mg/L. Ambient field blanks and field duplicate samples for chloride were collected at a minimum of one each per survey trip. Laboratory quality control sampling involved analysis of matrix spikes, duplicates and double-blind KCl standards supplied by MassDEP.

In order to utilize the model, the logger conductivity data (µS/cm) recorded at ambient temperatures were transformed to SC (µS/cm at 25°C) using the following equation:

$$\mathrm{SC} = \frac{\text{Measured conductivity}}{1 + r(T - 25)}$$

where *r* = the temperature coefficient of variation (TCV)
and *T* = temperature of measured conductivity in °C

A Temperature Coefficient of Variation (TCV) of 0.02, which assumes a 2.0% change in conductivity for every degree (°C) change in temperature (Barron and Ashton 2005), was applied for each station to derive continuous SC readings.

Following transformation of the conductivity data, the derived SC data from the loggers were used to estimate chloride concentrations using the regression equation. Then, the estimated chloride data (nearest-in-time to chloride discrete sample collection) were compared to the actual, co-located chloride discrete sample (total of 54) concentrations. Across all stations, RPDs ranged from 0.7% to 30.3%, with an average RPD of 8.3%. Discrete samples at Station 1 in August and September 2016 were excluded from these summaries because the model predicted chloride concentration below 0. More on lower limits of the model is discussed below under Model Uncertainty.

The linear regression equation developed using only the supplemental River Meadow Brook study data was also compared to the statewide freshwater model. The slopes of the two regression lines were found to be identical ($P > 0.05$) and the intercepts between the two show marginally significant difference ($P=0.034$). The regression equations are as follows:

For Massachusetts, $Y=0.2753X – 18.987$
For River Meadow Brook, $Y= 0.2755X – 19.053$

Where Y = modeled chloride concentration and X = lab-measured chloride concentration

<u>Supplemental Validation (applicability to Western MA region):</u>
To address the concern over the need for regional chloride models, additional data collected in 2013-2014 (N = 96) from basins in western Massachusetts were available to compare to the statewide freshwater model using ANCOVA. No significant difference between the western region and the original statewide model was detected ($P=0.6869$). It was concluded that creation of the statewide model accurately predicts chloride concentrations including the western region of the state.

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 70-10,000 uS/cm. The freshwater model can be applied using both instantaneous and continuous SC measurements. The model is less reliable at SC readings <70 uS/cm. Since the linear regression line in the model is not set at a 0,0 intercept SC levels below about 70 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 5 mg/L (SC=87 µS/cm) was established to account for this low-level error. The model has greater accuracy at higher SC levels, including near and above EPA

ambient criteria-based concentrations. For very high SC readings (>5000 uS/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[1] 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 that may have compromised the accuracy of predictions. While not strictly required for assessment purposes, corroboratory sampling and laboratory analysis for chloride should be performed whenever needed to confirm model accuracy.

Calculated chloride values are used for freshwater assessment purposes. The tool is not applicable for coastal areas with salt water influences (e.g., tides, salt water intrusion, etc.).

Note: Predicted chloride values are not maintained in MassDEP's water quality database.

[1] Factors contributing to the cumulative uncertainty of chloride prediction include conductivity probe accuracy (typically 3% of reading), associated temperature probe accuracy (typ. 0.2 ^{o}C), probe drift (typically <3%/year), sensor fouling in-between cleanings, transformation of conductivity readings at ambient temperatures to SC at 25 ^{o}C using an assumed value for temperature coefficient of variation, and regression model error.

References

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Heath D (2014). Data Report Acute Road Salt Contamination of Dark Brook and the Auburn Water District's Church Street Wellfield in Auburn, Massachusetts. Office of Ecosystem Protection, USEPA New England Region 1, Boston, Massachusetts 02109. 14 pages.

MassDEP (2010). Quality Assurance Program Plan for Surface Water Monitoring & Assessment. Massachusetts Department of Environmental Protection Division of Watershed Management 2010-2014. Control Number 365.0, rev. 1. MS-QAPP-27. 136 pages.

MassDEP (2015). Sampling & Analysis Plan DEP Intern Project: Monitoirng and Assessment for Chloride 2015-2016. CN#: 458.0. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA. 7 pages.

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 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 ≥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 occured 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 fieldsheet notes, etc., in order to make decisions on whether to censor all or portion(s) of a continuous record dataset.

Continuous Data --- Notes for assessment summary purposes. WPP qualified data were utilized without caveat. Unattended data for DO: Deleted all records/days that did not include a predawn measurement. Continuous temperature data: Removed records where all statistics were "--" (i.e., daily statistics not calculated due to incomplete days); 24 hour rolling average calculations did not exclude incomplete days and were calculated based on the "previous" 24 hours (not 12 hours on either side); rolling 7DADM statistics (the rolling 7 day averages of the daily maximum results) and 7DADA (the rolling 7 day averages of the daily average results) excluded non-24-hour days that included the probe deploy and pickup days and calculations were based on 3 days on either side.

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.

- Calculating Water Quality Criteria: 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).

- Toxic Unit (TU): The ratio of a toxicant concentration to its criterion. This TU calculation provides the relative magnitude of the exceedance.

- Comparing toxicant data to Water Quality Criteria: 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.

- Geometric Mean Calculation for Bacteria Data: 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 Recreational Use season is 1 April through 31 October while the Secondary Contact Recreational Use season is year-round. For more information, see Appendix J.

Modeled/Estimated Results: 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) Chloride – Specific Conductance regression (freshwater, statewide): Estimates of chloride concentrations are made using a validated regression model between specific conductance (SC) levels and associated chloride concentrations in Massachusetts freshwater streams:

$$\mathbf{\mathit{Cl}=0.2753*(\mathit{SC})-18.987} \quad (R^2=0.9445,\ P<0.001,\ N=2426)$$

   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 bacteria data (see Appendix J). 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 packages used at beginning of a single primary script (i.e., a single code file).
- Separate scripts for separate analyses to organize code blocks.
- Explanatory comments throughout all scripts uses 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.

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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 2022 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	Aquatic Macroinvertebrate 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	Thermal inadequacies Flow reductions Degraded habitat Competition from pond species or generalists Fish Kills Pathogens or contaminants	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 (Streams) Other flow regime alterations Other anthropogenic substrate alterations Physical substrate habitat alterations Sedimentation/Siltation Bottom Deposits Alteration in stream-side or littoral vegetative covers Petroleum Hydrocarbons (Oil Spills) Total Suspended Solids 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
Non-native aquatic species data	**Rivers, Lakes** Non-native aquatic species present	Non-Native Aquatic Plants Non-Native Fish, Shellfish, or 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

***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**
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 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 Bioassays -- Acute Toxicity Freshwater Whole Effluent Toxicity (occasionally used)	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	Oxygen, Dissolved Dissolved oxygen saturation	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
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, water	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	Chlorophyll-a Excess Algal Growth Phosphorus (Total) pH, High Secchi disk transparency	Municipal Point Source Discharges Unspecified Urban Stormwater Internal Nutrient Recycling

***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**
	oxygen/saturation/pH, elevated chlorophyll *a*	Turbidity Dissolved oxygen saturation Nutrient/Eutrophication Biological Indicators	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*	Secchi disk transparency Chlorophyll-a Excess Algal Growth Phosphorus (Total) Turbidity Aquatic Plants (Macrophytes) Secchi disk transparency Dissolved oxygen saturation 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, Sulfide-Hydrogen Sulfide)	Municipal Point Source Discharges Highway/Road/Bridge Runoff (Non-construction Related) Combined Sewer Overflows Contaminated Sediments Source Unknown
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, Zinc 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), Abnormal Fish Histology (Lesions) PCBs (polychlorinated biphenyls), HG, DDT) and it's	Contaminated Sediments Inappropriate Waste Disposal Releases from Waste Sites or Dumps 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**
		metabolites DDD and DDE), Chlordane, PAHs, TCDD in Fish Tissue	

* Asterisk indicates there are many possible contaminants that belong to these classes of pollutants, the cause of impairment however is the individual pollutant (see EPA list of cause codes ((http://iaspub.epa.gov/apex/waters/f?p=ASKWATERS:CAUSE_LUT:0::::P4_OWNER:ATTAINS)) for complete listing.

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 MA DPH 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 it's metabolites DDD and DDE Polycyclic Aromatic Hydrocarbons (PAHs) (Aquatic Ecosystems)	Atmospheric Deposition - Toxics Contaminated Sediments CERCLA NPL (Superfund) Sites Inappropriate Waste Disposal Releases from Waste Sites or Dumps Source Unknown

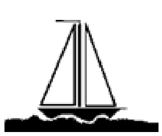
SHELLFISH HARVESTING USE IMPAIRMENT CAUSES AND SOURCES			
Indicator for *Shellfish Harvesting Use* Attainment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	SA Waters: Conditionally Approved, Restricted, Conditionally Restricted, or Prohibited SB Waters: Conditionally Restricted or Prohibited	Fecal Coliform Polychlorinated biphenyls	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,	Excess Algal Growth Debris/Floatables/Trash Foam/Flocs/Scum/Oil Slicks Turbidity	Municipal Point Source Discharges Unspecified Urban Stormwater

	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.)	Total Suspended Solids Nutrient/Eutrophication Biological Indicators Organic Enrichment (Sewage) Biological Indicators Secchi disk transparency Taste and Odor Color Oil and Grease Sedimentation/Siltation	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

PRIMARY CONTACT RECREATIONAL USE IMPAIRMENT CAUSES AND SOURCES			
Indicator for *Primary Contact Recreational 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* Polychlorinated biphenyls** Any applicable aesthetic causes (see list below)	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 RECREATIONAL USE IMPAIRMENT CAUSES AND SOURCES			
Indicator for *Secondary Contact Recreational Use* Attainment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Bacteria concentrations exceed impairment decision schema, aesthetic use impairment	*Enterococcus* *Escherichia coli* Any applicable aesthetic causes (see list below)	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).

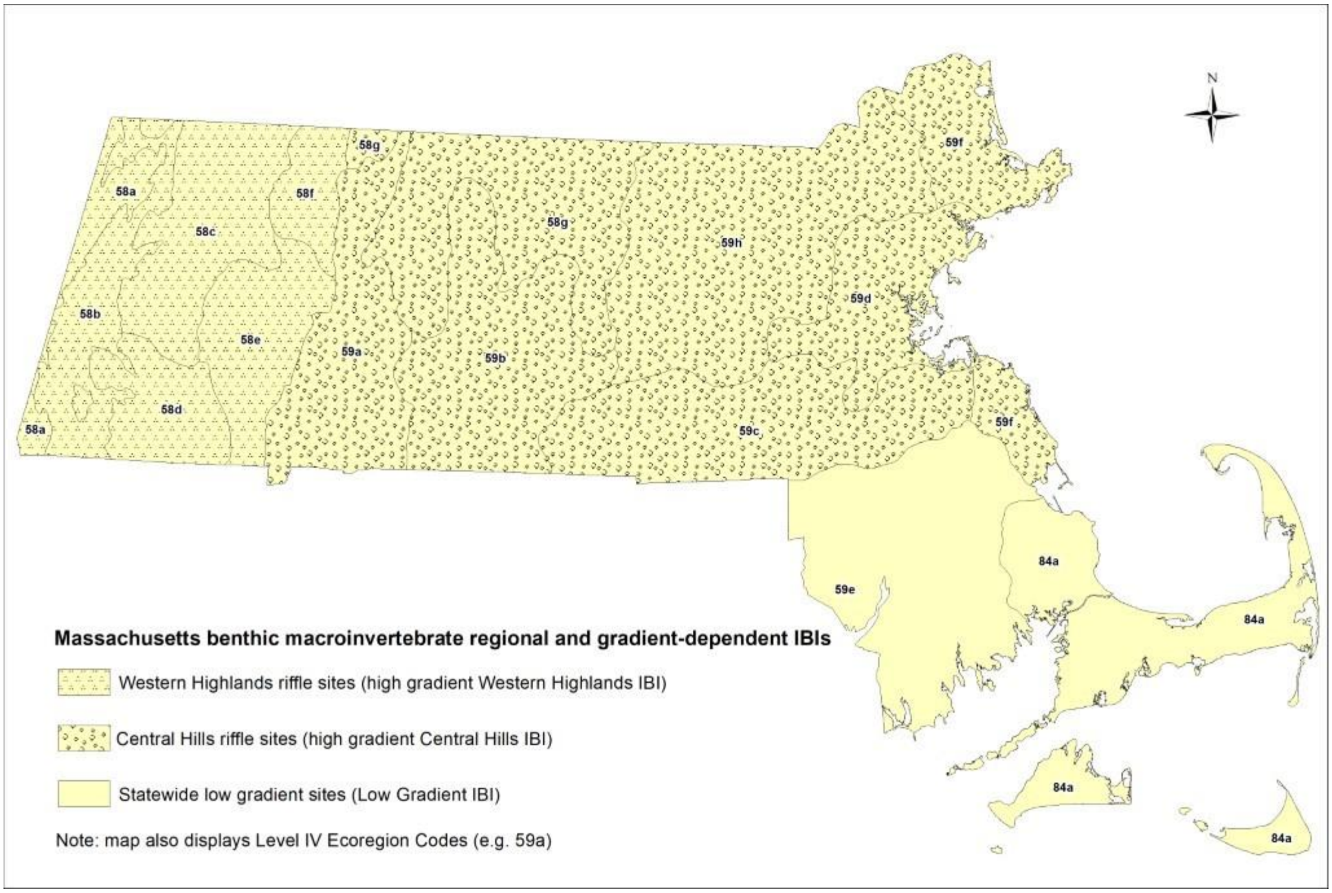


Figure I1. For IBI development, Omernik Level IV ecoregions were grouped into two regions for high gradient streams: Western Highlands and Central Hills. An IBI for each of these high gradient regions was developed. The southeastern portion of the state was grouped exclusively under the jurisdiction 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.

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APPENDIX J OVERVIEW OF THE PROCESSING AND EVALUATION PROCEDURES USING *E. COLI* AND ENTEROCOCCUS BACTERIA DATA FOR RECREATIONAL USE ATTAINMENT DECISIONS BASED ON THE MASSACHUSETTS SURFACE WATER QUALITY STANDARDS

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 Waters		Applicable Classes	Coastal and Marine Waters		Applicable Classes
	GM[a] (CFU[b]/100 mL)	STV[c] (CFU[b]/100 mL)		GM[a] (CFU[b]/100 mL)	STV[c] (CFU[b]/100 mL)	
E. coli	126	410	Class A, B	-- [d]	--[d]	Class SA, SB
Enterococci	35	130	Class A, B	35	130	Class SA, SB

[a] Geometric Mean
[b] 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). Note: for simplicity in IR related material, all references to CFU/100mL results may also refer to MPN/100mL results.
[c] Statistical Threshold Value (a value not to be exceeded by more than 10% of samples)
[d] *E. coli* is not a marine indicator bacterium
Note: The SWQS define Primary Contact 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 updated 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.

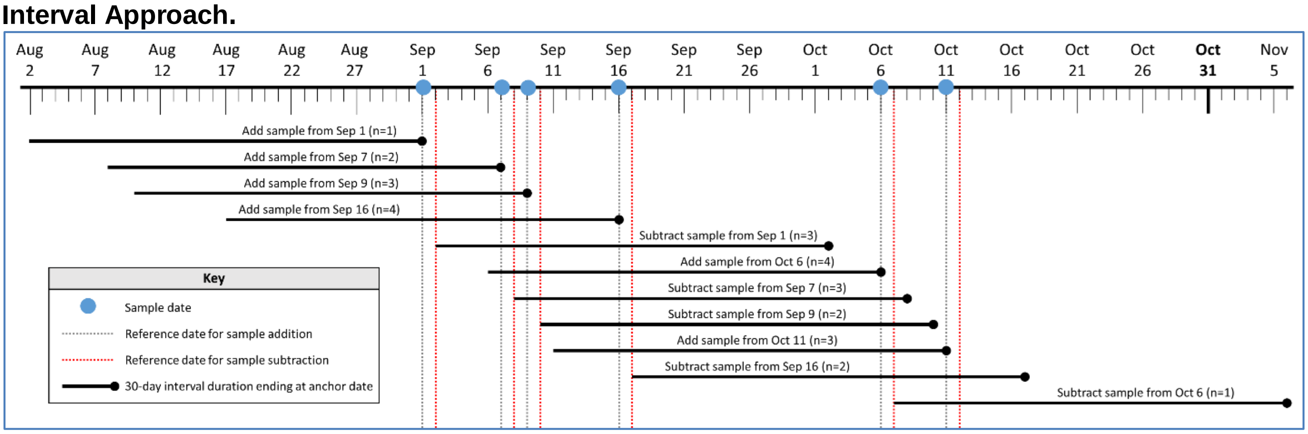
For beach closure decisions, MDPH has communicated to EPA that their approach using GMs and Beach Notification Thresholds (BNTs) is as protective as the 2014 National Beach Guidance and Required Performance Criteria for Grants, as demonstrated by a comprehensive analysis of local water quality data. 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 Recreational Criteria and Use Attainment Decisions
MassDEP analysts developed new bacteria data assessment methods for making use attainment evaluations of the Primary Contact Recreational 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”. MassDEP removed the minimum sample requirement from the SWQS to be consistent with EPA’s criteria recommendations but use attainment evaluations require a minimum of either two or three samples for 30- or 90-day interval GM calculations, respectively. For STV evaluations, the individual (discrete) bacteria concentrations are compared directly to the STV criterion. Evaluations of the STV are made using either the number or percentage of samples exceeding the threshold depending on the sampling frequency.

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 recreational season, even though all samples used for GM calculations are collected from April 1 to October 31 (the primary contact recreational 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 considered in the data evaluations.

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. 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.

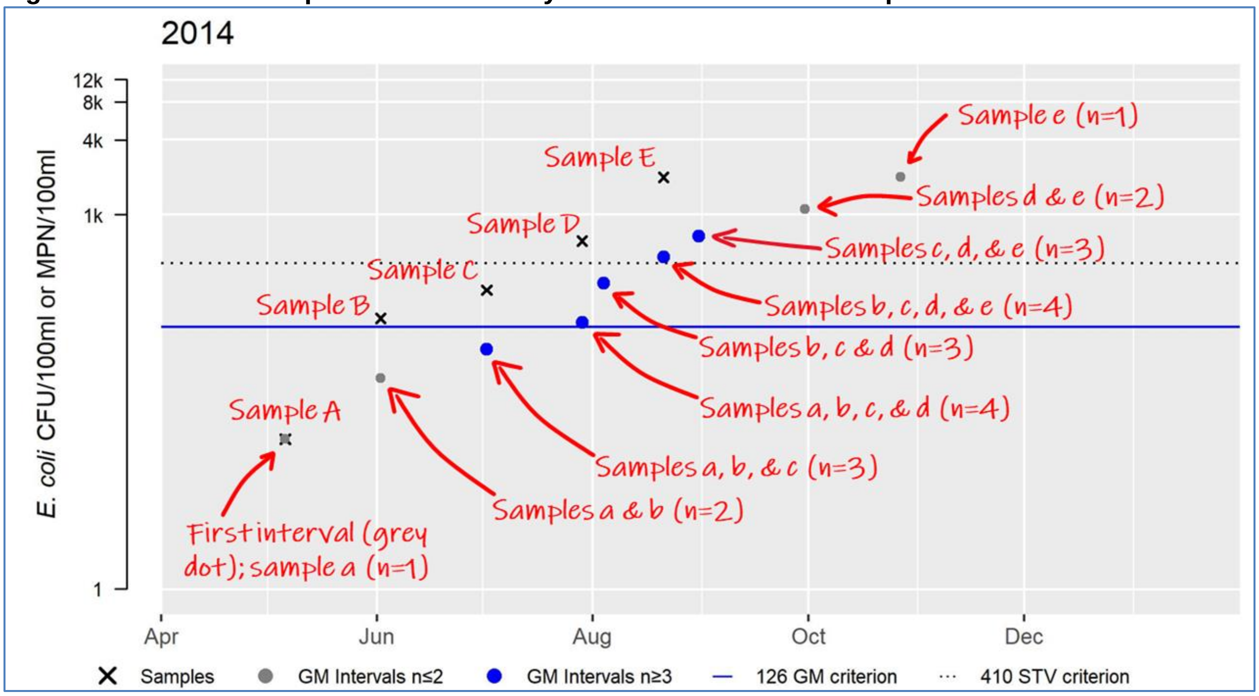
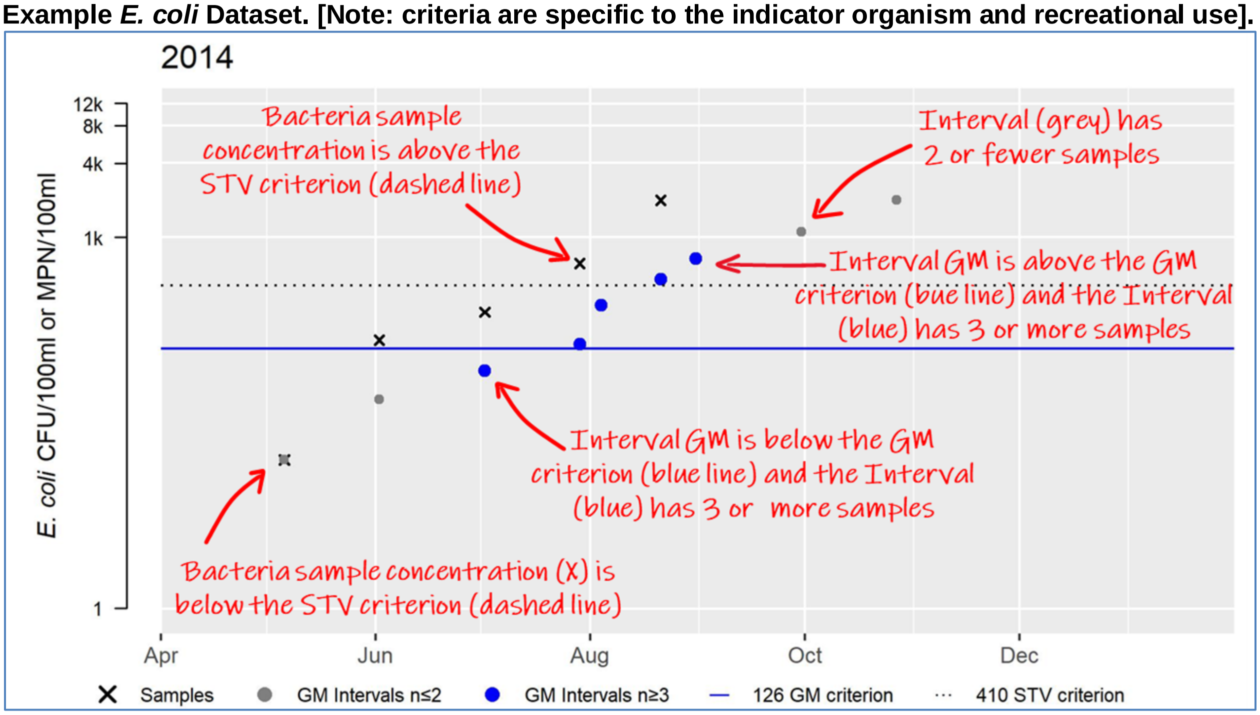


Figure J3. Comparison of Interval GMs and Bacteria Sample Concentrations to GM and STV Criteria for an Example *E. coli* Dataset. [Note: criteria are specific to the indicator organism and recreational use].



Summary statistics for the primary contact recreational 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, the cumulative %GMI Ex is calculated over the entire dataset and separately for the last five years of data for those datasets including six or more years of data (See Figure J4b). [Note: the ‘last five years of data’ may include non-consecutive years of data and years that do not meet the minimum sample requirement for GM calculations]. These summary statistics are used in conjunction with the graphical representations to evaluate data according to the Use Attainment Impairment Decision Schema (Table J2).

Figure J4a. Bacteria Sample Data, 90-Day Interval GMs, and Summary Statistics for Single-Year Datasets.

Var	Res
Samples	5
SeasGM	235
#GMI	5
#GMI Ex	4
%GMI Ex	80
n>STV	2
%n>STV	40

Table of summary statistics for the individual year represented in the plot below

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

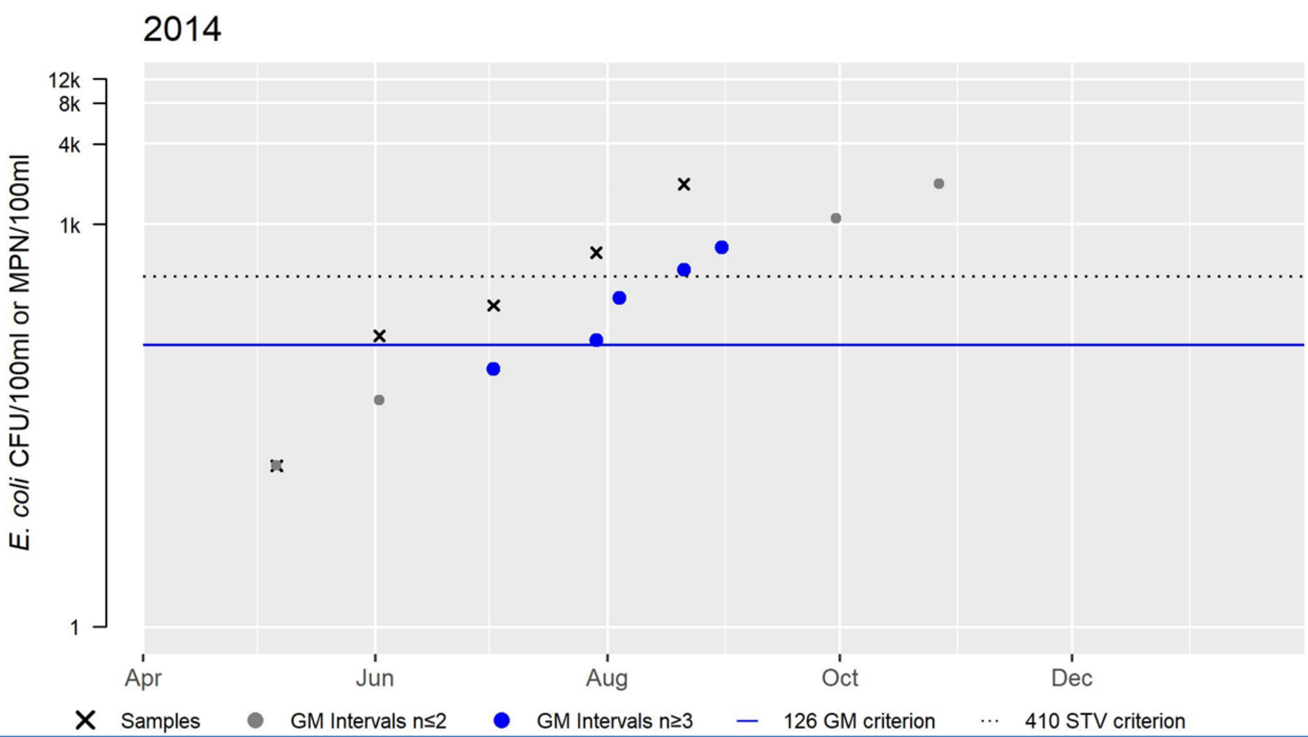


Figure J4b. Bacteria Sample Data, 90-Day Interval GMs, and Summary Statistics for Multi-Year Datasets.

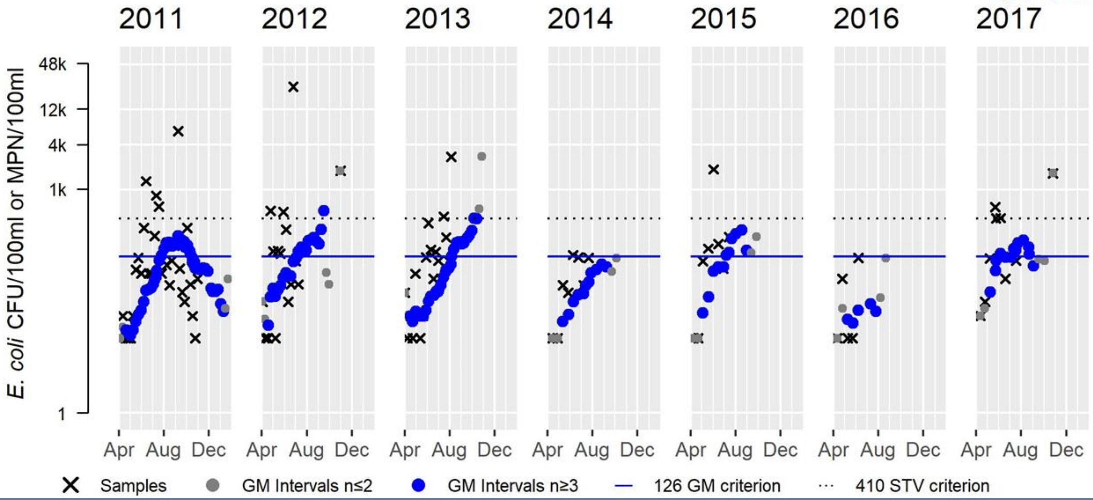
Var	Res	Var	Res	Var	Res	Var	Res	Var	Res	Var	Res	Var	Res
Samples	30	Samples	16	Samples	19	Samples	8	Samples	8	Samples	5	Samples	10
SeasGM	79	SeasGM	123	SeasGM	74	SeasGM	46	SeasGM	102	SeasGM	24	SeasGM	159
#GMI	52	#GMI	25	#GMI	31	#GMI	11	#GMI	11	#GMI	5	#GMI	13
#GMI Ex	21	#GMI Ex	12	#GMI Ex	11	#GMI Ex	0	#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 Exceedances; %GMI Ex = percent GMI Exceedances; 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



Derivation of the Primary Contact Recreational Use Attainment Impairment Decision Schema.
MassDEP analysts developed an impairment decision schema for the Primary Contact Recreational Use (Table J2) 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.

Table J2. Use Attainment Impairment Decision Schema based on bacteria sampling frequency scenarios during the Primary Contact Recreational 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; 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 exceed 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 exceed 410 (STV) in more than two years [4]
	Enterococci	1) ≥80% of GM intervals >35 OR 2) a. <80% of GM intervals >35 AND b. two or more samples exceed 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 exceed 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 exceed 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 exceed 410 (STV) in more than two years [4]
	Enterococci	1) ≥60% of GM intervals >35 OR 2) a. >10% to <60% of GM intervals >35 AND b. >2 samples exceed 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 exceed 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 exceed 410 (STV)	1) >10% of GM intervals >126 in two or more years 2) >10% of cumulative GM intervals >126 3) >10% of samples exceed 410 (STV) in more than two years [4]
	Enterococci	1) ≥40% of GM intervals >35 OR 2) a. ≥30% to <40% of GM intervals >35 AND b. >10% of samples exceed 130 (STV) OR 3) a. >0% to <30% of GM intervals >35 AND b. >20% of samples exceed 130 (STV)	1) >10% of GM intervals >35 in two or more years 2) >10% of cumulative GM intervals >35 3) >10% of samples exceed 130 (STV) in more than two years [4]

[1] The five most recent years of data will be preferentially evaluated, 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.

Bacteria Data Processing and Evaluation Procedures for Secondary Contact Recreational Use Attainment Decisions.

The SWQS regulation designates Class C and SC waters only for secondary contact recreation and, therefore, these waters are not subject to the primary contact recreation bacteria criteria. The bacteria criteria for Class C and SC waters are used to assess the Secondary Contact Recreational Use which is assumed to occur year-round [Note: 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 criteria magnitudes are unchanged in the amended SWQS; however, the evaluation interval was revised from 6 months to 90-days to be consistent with criteria applicable to primary contact recreation. The amended bacteria criteria for Class C and SC waters are summarized as follows:

Class C: [C]oncentrations of *Escherichia coli* (*E. coli*) bacteria in Class C Surface Waters shall satisfy 314 CMR 4.05(3)(c)4.a. and b. whenever necessary for protection of secondary contact recreation.

a. Concentrations of *E. coli* bacteria in Class C surface waters shall not exceed 630 colony-forming-units per 100 mL (CFU/100 mL), calculated as the geometric mean of all samples collected within any 90-day or smaller interval.
b. No more than 10% of all such samples described in 314 CMR 4.05(3)(c)4.a. shall exceed 1260 CFU/100 mL.

Class SC: [C]oncentrations of enterococci bacteria in Class SC Surface Waters shall satisfy 314 CMR 4.05(4)(c)4.a. and b., whenever necessary for the protection of secondary contact recreation.

a. Concentrations shall not exceed 175 colony forming units (CFU) per 100 mL, calculated as a geometric mean of all samples collected within any 90-day or smaller interval.
b. No more than 10% of all such samples described in 314 CMR 4.05(4)(c)4.a. shall exceed 350 CFU per 100 mL.

MassDEP analysts, using the Class C and SC criteria, updated evaluation procedures for the Secondary Contact Recreational Use for closer alignment with new procedures for the Primary Contact Recreational 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 Recreational 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. 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 Recreational 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 Recreational Use criteria (see Figures J2, J3, J4a, J4b; Table J3).

Table J3. Class C and SC Bacteria Criteria in the Massachusetts Surface Water Quality Standards (314 CMR 4.00; MassDEP 2021).

Bacteria Indicator Organism	Applicable Class	Criterion	
		GM[a] (CFU[b]/100 mL)	STV[c] (CFU[b]/100 mL)
E. coli	C (Freshwaters)	630	1260
Enterococci	SC (Coastal and Marine Waters)	175	350

[a] Geometric Mean
[b] colony forming units (or some results may be reported as MPN Most Probable Number)
[c] Statistical Threshold Value (a value not to be exceeded by more than 10% of samples)
[Note: 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.*"*]*

Summary statistics for the Secondary Contact Recreational 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, the cumulative %GMI Ex is calculated over the entire dataset and separately for the last five years of data for those datasets including six or more years of data (See Figure J4b). [Note: the ‘last five years of data’ may include non-consecutive years of data and years that do not meet the minimum sample requirement for GM calculations].

The summary statistics are used in conjunction with the graphical representations to evaluate year-round data according to the Use Attainment Impairment Decision Schema for the Secondary Contact Recreational Use (Table J4). The same threshold percentages are applied as those described in “Derivation of the Primary Contact Recreational Use Attainment Impairment Decision Schema.”

Table J4. Use Attainment Impairment Decision Schema based on bacteria sampling frequency scenarios during Secondary Contact Recreational 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; 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]: <u>TWO OF THE THREE CONDITIONS MUST BE MET</u>
Limited frequency (e.g., less than monthly) <7 samples	*E. coli*	1) ≥80% of GM intervals >630 OR 2) a. <80% of GM intervals >630 AND b. two or more samples exceed 1260 (STV) AND c. the overall GM is >630 [2]	1) >20% of GM intervals >630 in two or more years 2) >20% of cumulative GM intervals >630 3) ≥2 samples each year exceed 1260 (STV) in more than two years [4]
	Enterococci	1) ≥80% of GM intervals >175 OR 2) a. <80% of GM intervals >175 AND b. two or more samples exceed 350 (STV) AND c. the overall GM is >175 [3]	1) >20% of GM intervals >175 in two or more years 2) >20% of cumulative GM intervals >175 3) ≥2 samples each year exceed 350 (STV) in more than two years [4]
Moderate frequency (e.g., monthly) 7 to 14 samples	*E. coli*	1) ≥60% of GM intervals >630 OR 2) a. >10% to <60% of GM intervals >630 AND b. >2 samples exceed 1260 (STV)	1) >20% of GM intervals >630 in two or more years 2) >20% of cumulative GM intervals >630 3) ≥2 samples each year exceed 1260 (STV) in more than two years [4]
	Enterococci	1) ≥60% of GM intervals >175 OR 2) a. >10% to <60% of GM intervals >175 AND b. >2 samples exceed 350 (STV)	1) >20% of GM intervals >175 in two or more years 2) >20% of cumulative GM intervals >175 3) ≥2 samples each year exceed 350 (STV) in more than two years [4]
High frequency (Every two weeks, at minimum) <u>></u>15 samples	*E. coli*	1) ≥40% of GM intervals >630 OR 2) a. ≥30% to <40% of GM intervals >630 AND b. >10% of samples exceed 1260 (STV) OR 3) a. >0% to <30% of GM intervals >630 AND b. >20% of samples exceed 1260 (STV)	1) >10% of GM intervals >630 in two or more years 2) >10% of cumulative GM intervals >630 3) >10% of samples exceed 1260 (STV) in more than two years [4]
	Enterococci	1) ≥40% of GM intervals >175 OR 2) a. ≥30% to <40% of GM intervals >175 AND b. >10% of samples exceed 350 (STV) OR 3) a. >0% to <30% of GM intervals >175 AND b. >20% of samples exceed 350 (STV)	1) >10% of GM intervals >175 in two or more years 2) >10% of cumulative GM intervals >175 3) >10% of samples exceed 350 (STV) in more than two years [4]

[1] The five most recent years of data will be preferentially evaluated, 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 >630 CFU/100mL and any samples are >1260 CFU/100mL (STV) but the overall GM (i.e., January-December) is <630 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 >175 CFU/100mL and any samples are >350 CFU/100mL (STV) but the overall GM (i.e., January-December) is <175 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.

<u>Technical Information Related to Threshold Development (Justification)</u>

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.

Derivation of Minimum Sample Requirements

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.

Selection of the Rolling Backwards Unique Interval Approach

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.

Use Impairment Threshold Development

The specific structure of the Use Attainment 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) preserved at least the same or greater number of impairments overall compared to previous guidance,
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, and,
d) were readily understandable and practical.

Figures J5, J6, and J7 illustrate the results of the *E. coli* and/or enterococci data simulation exercises used to derive GM and STV threshold percentages for the Primary and Secondary Contact Recreational Use Attainment Impairment Decision Schemas. Single-year datasets were evaluated for the number of impairment decisions using the structure of the Use Attainment Impairment Decision Schema (Tables J2 and J4) 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 Recreational Use Attainment Impairment Decision Schema.

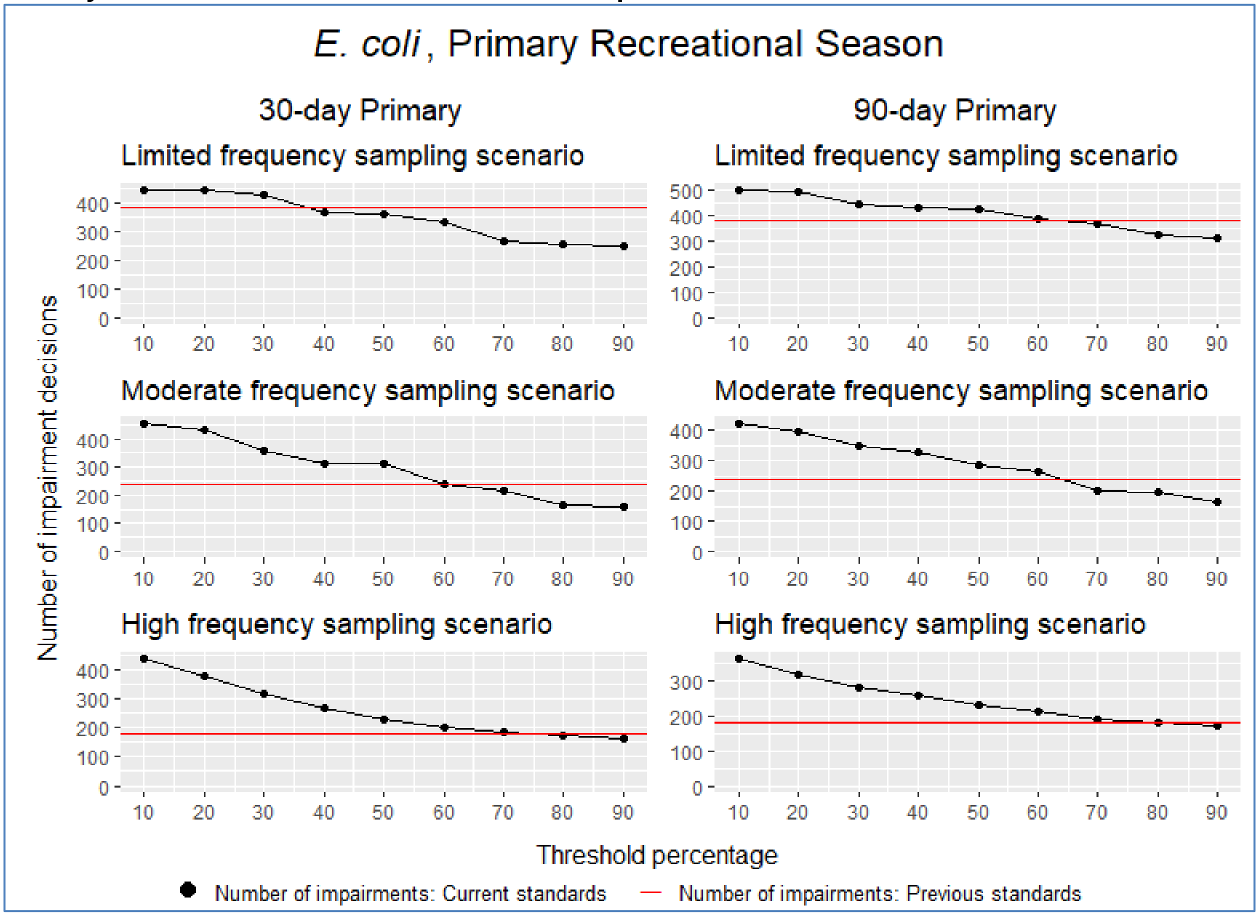


Figure J6. Simulation Exercise Results Used in the Development of Enterococci Threshold Percentages for the Primary Contact Recreational Use Attainment Impairment Decision Schema.

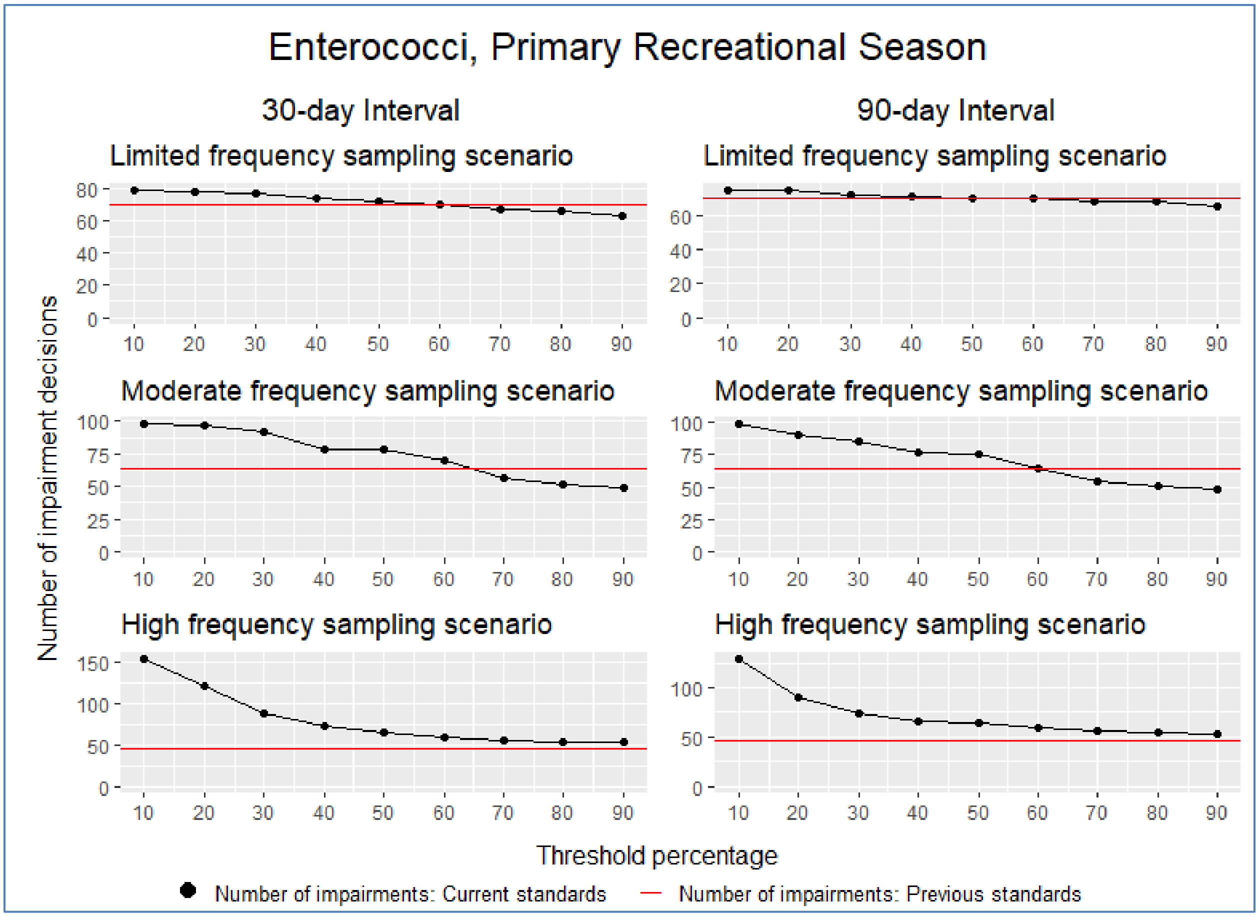
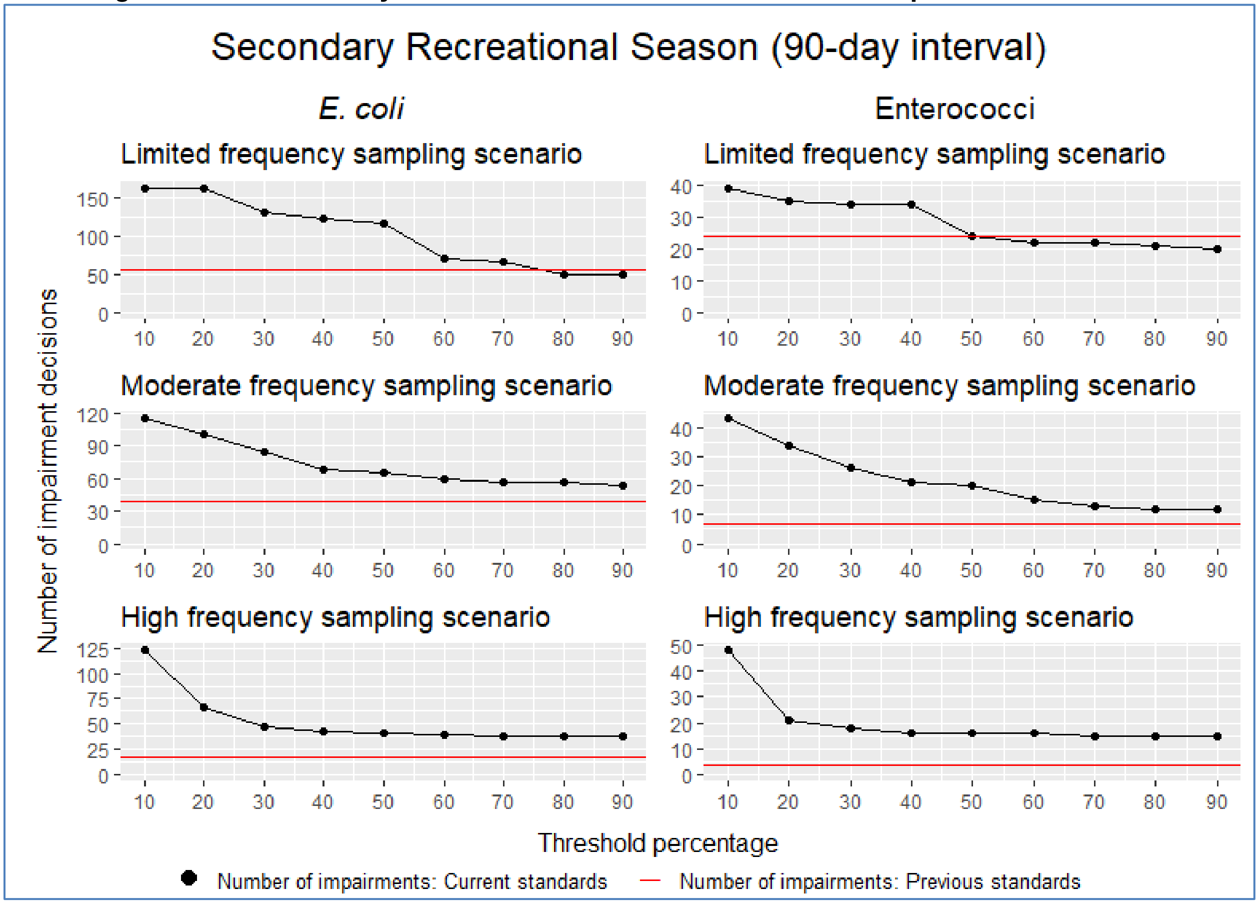

Enterococci, Primary Recreational Season
30-day Interval
90-day Interval
Limited frequency sampling scenario
Moderate frequency sampling scenario
High frequency sampling scenario
Number of impairment decisions
Threshold percentage
Number of impairments: Current standards
Number of impairments: Previous standards

Figure J7. Simulation Exercise Results Used in the Development of *E. coli* and Enterococci Threshold Percentages for the Secondary Contact Recreational Use Attainment Impairment Decision Schema.



The threshold percentages chosen for the impairment decision schema (Tables J2 and J4) yield 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.

APPENDIX K RATIONALE FOR USING AQUATIC PLANT (MACROPHYTES) AS A NON-POLLUTANT CAUSE OF IMPAIRMENT

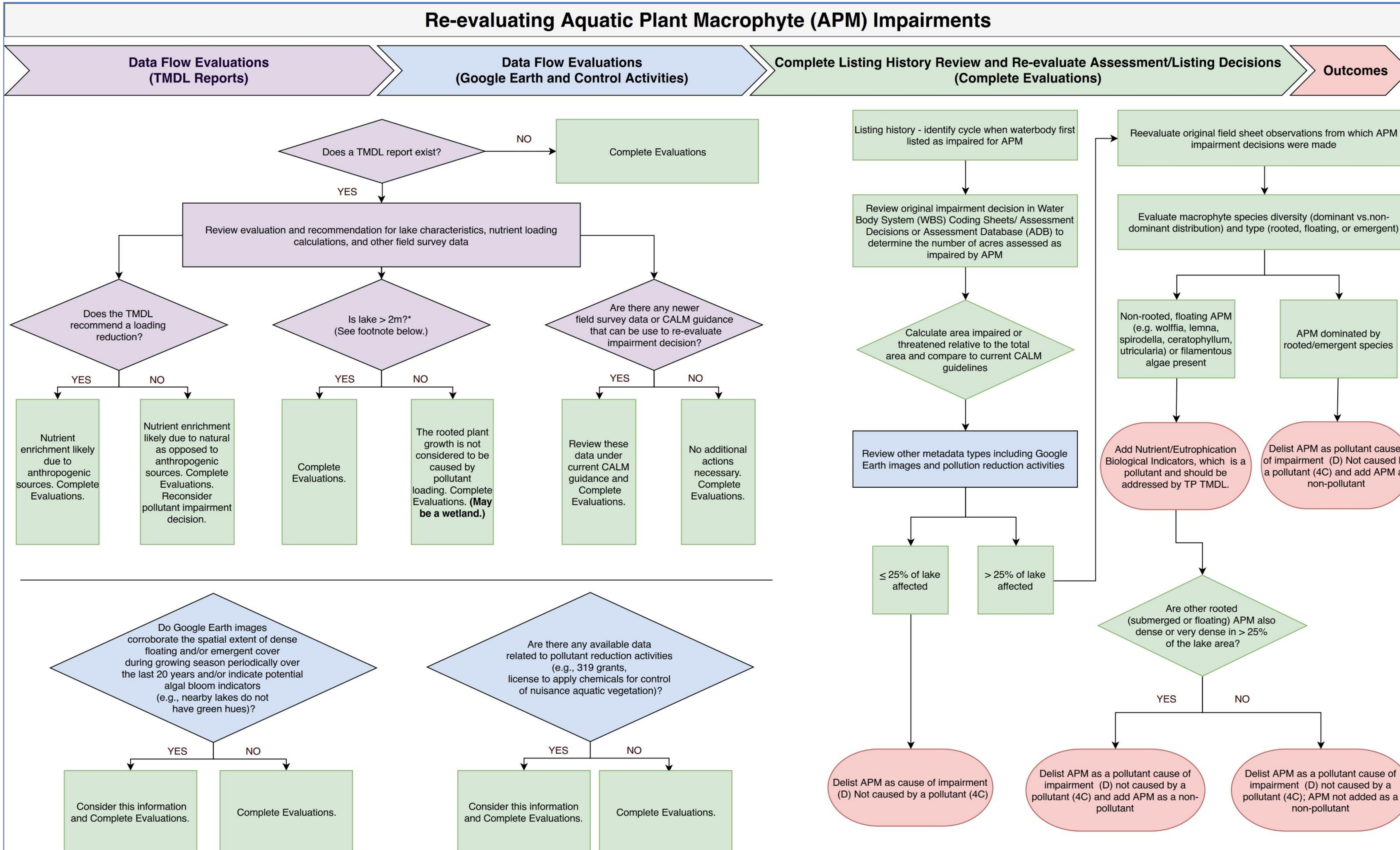
Rationale for using Aquatic Plant Macrophytes as a non-pollutant cause of impairment
As part of the 2016 reporting cycle MassDEP analysts began an effort to reevaluate waters listed as impaired due to APM. This reevaluation effort was requested by MassDEP staff who developed Total Phosphorus TMDLs, particularly 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 river watersheds 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 inlake 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, algal blooms, 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 where nutrient reduction efforts should result in restoration, as opposed to requiring TMDLs for waterbodies where naturally occurring shallow areas are conducive to aquatic macrophyte growth.

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.

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Google Earth Pro. Undated. Satellite Imagery of selected stream and lake/pond segments, Massachusetts.

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