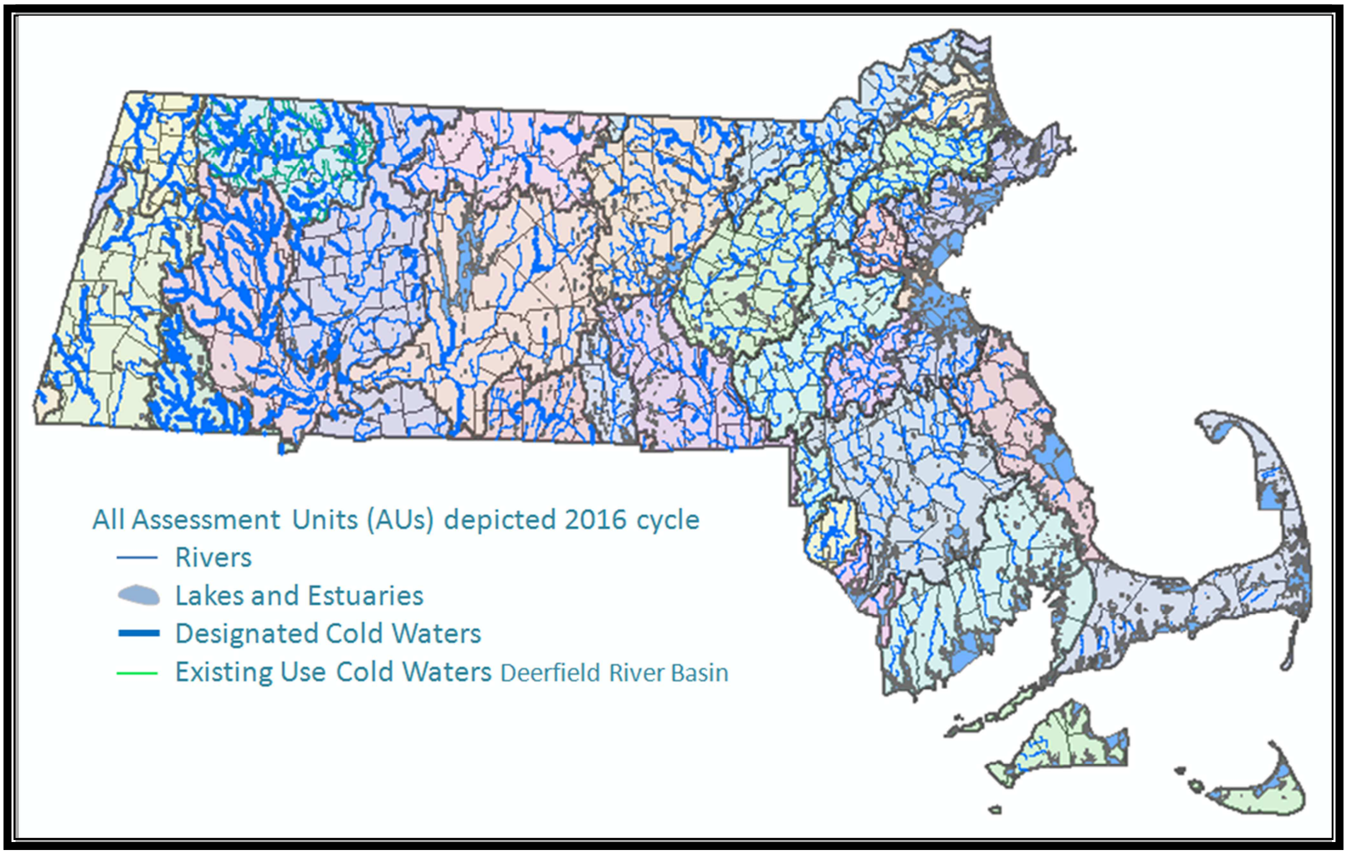
Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2016 Reporting Cycle



Prepared by:

Massachusetts Division of Watershed Management
Watershed Planning Program

12 July 2016

CN 445.0

Notice of Availability

This report is available via the Massachusetts Department of Environmental Protection's (MassDEP) World Wide Web site: http://www.mass.gov/eea/agencies/massdep/water/watersheds/

An electronic record of this document can also be accessed through the State Library of Massachusetts at: http://archives.lib.state.ma.us/handle/2452/35789

A paper copy of this report is available at no cost by request to:

Massachusetts Department of Environmental Protection
Division of Watershed Management
8 New Bond Street
Worcester, MA 01606
508-792-7470

Disclaimer

Table of Contents

List of Appendices

List of Tables

List of Figures

Intentionally left blank

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 consolidated reporting of this information to EPA and the public in the form of an *Integrated List of Waters* report. The *Integrated List of Waters* report 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 2016 CALM Guidance Manual satisfies reporting requirements pursuant to Sections 305(b), 314, and 303(d) of the Federal Clean Water Act (CWA). Included in this CALM manual are: a brief summary of the Massachusetts Surface Water Quality Standards (SWQS) that define the goals for water quality in the state (MassDEP 2006); the requirements for assessing the quality of data to be used for CWA reporting; the methods for evaluating water quality data and information used by the Massachusetts Department of Environmental Protection (MassDEP) Division of Watershed Management's Watershed Planning Program (DWM-WPP) analysts to make designated use-assessment decisions; and a description of the use of the EPA's Assessment Database (ADB) for consolidated reporting and the generation of the *2016 Massachusetts Integrated List of Waters* report (Figure 1).

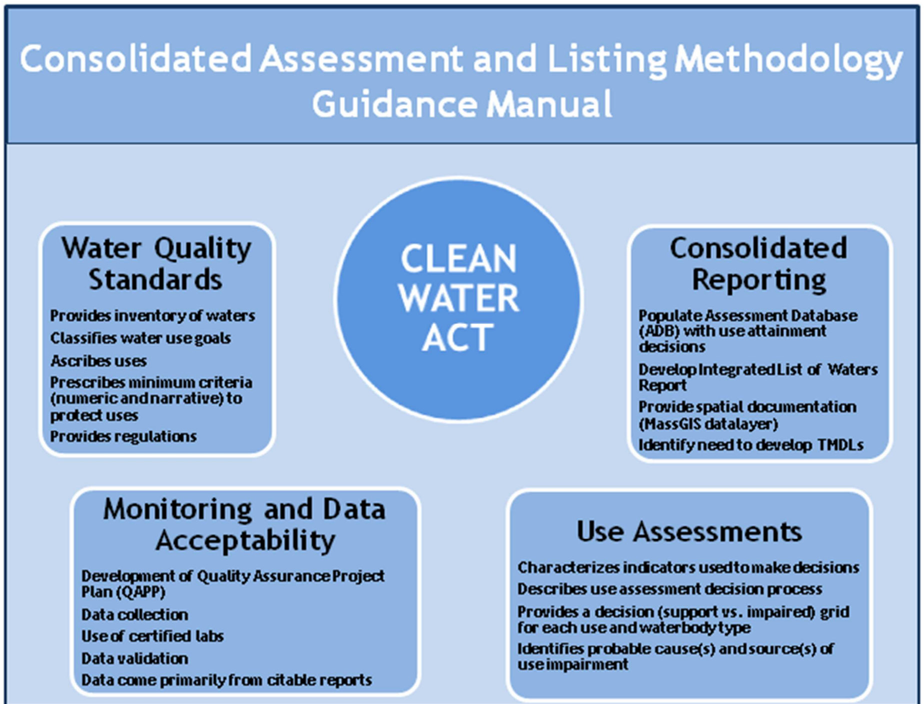


Figure 1. Components of Consolidated Assessment and Listing Methodology Guidance Manual.

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. It is the principal means by which the EPA, Congress, and the public evaluate existing water quality, assess progress made in maintaining and restoring water quality, and determine the extent of remaining problems. The directives of the CWA and the process by which the MassDEP analysts implemented the consolidated reporting for the 2016 cycle are illustrated in Figure 2 and are described in more detail in this document.

Section 305(b) codifies the process whereby waters are evaluated with respect to their capacity to support designated uses as defined in the SWQS. The designated uses include *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 2006). Massachusetts' rivers, lakes and coastal waters are partitioned into discrete segments or assessment units (AUs) that are defined and maintained in the EPA-developed ADB for the purposes of storing and reporting assessment information. The 305(b) assessment process entails evaluating existing water quality conditions in each AU against the applicable criteria established in the SWQS and guidance (details contained in this manual) for each designated use, and identifying wherever possible, causes and sources of use impairment.

Through the 2012 reporting cycle the MassDEP documented assessment decisions and the data used to make them in individual watershed assessment reports (http://www.mass.gov/eea/agencies/massdep/water/watersheds/water-quality-assessments.html). For the 2010 through 2014 reporting cycles the assessment decisions themselves were stored in the ADB V2.3.1. MassDEP uses this tool to produce both the *Integrated List of Waters* report and to provide the electronic data to the EPA. The *Integrated List of Waters* report allows states to provide the status of all their assessed waters in a single, multi-part list -- each AU is listed in one of five categories. Development of Category 5, which is the "List of Impaired Waters" (or "List") mandated in Section 303(d) of the CWA (the 303(d) List), includes a more rigorous public review and comment process than does reporting under the remaining four categories and the final version of this "List" must be formally approved by the EPA. For the 2016 reporting cycle the assessment and listing decisions will be done concurrently and supporting statements for the decisions for each AU (river, lake, or estuarine area) will be stored in the ADB and its use comment fields. A separate "repository" document containing all of the data and the decisions will be kept on file at the MassDEP. Moving forward, the ADB, as well as the MassGIS 2016 Integrated List Data – 305(b)/303(d) geodatabase with its supporting shape and database tables, will be made available to EPA and the public in the form of the 2016 *Integrated List of Waters Report* in fulfillment of the CWA reporting requirements (see Figure 2).

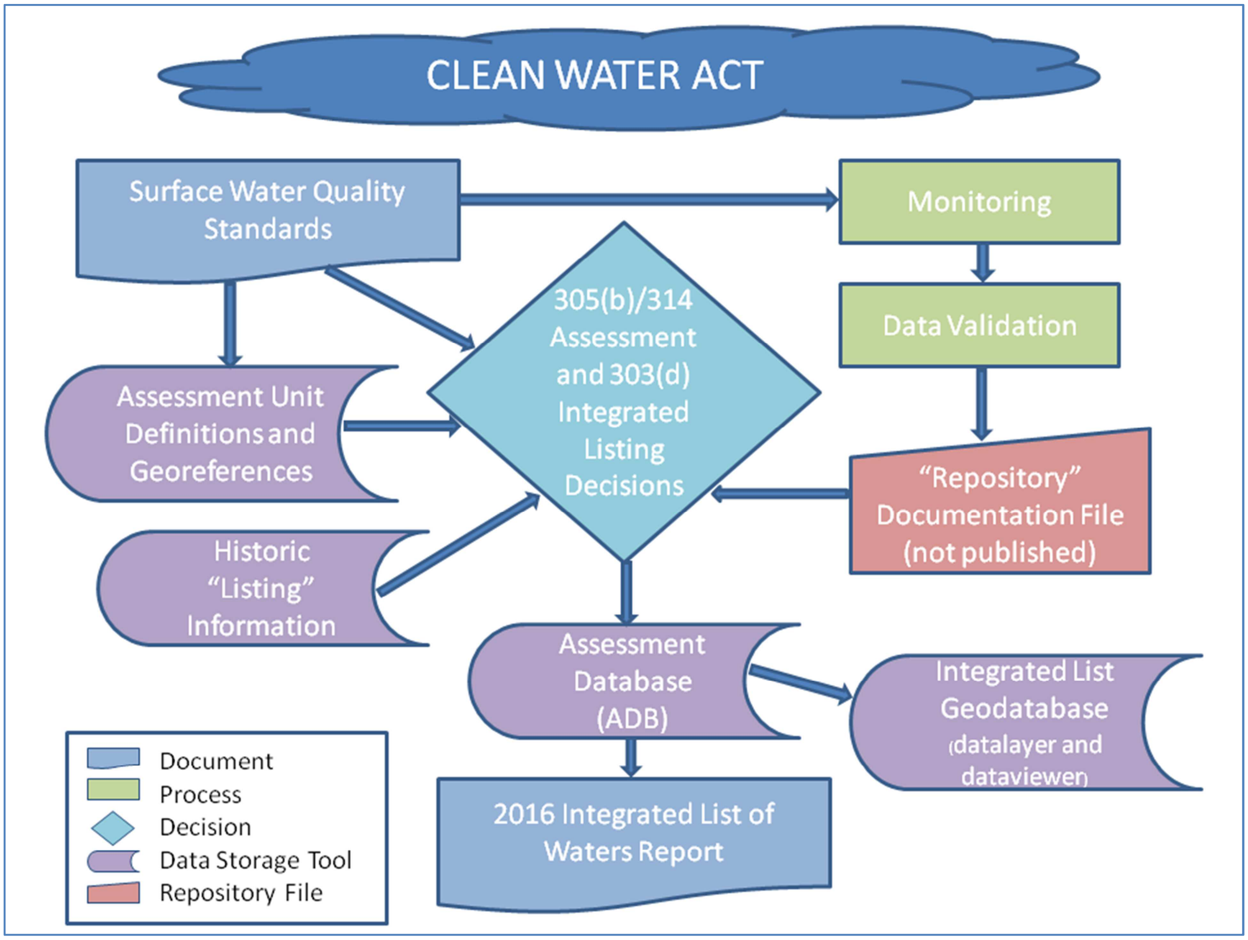


Figure 2. MassDEP, Consolidated Reporting Process Schematic

II. WATER QUALITY STANDARDS

The Massachusetts Surface Water Quality Standards (SWQS - 314 Code of Massachusetts Regulations 4.00) serve as the foundation for the state's water quality management program -- 305(b) water quality assessments, 303(d) lists of impaired waters, Total Maximum Daily Load (TMDL) pollutant calculations, National Pollutant Discharge Elimination System (NPDES) permits, and nonpoint-source management measures. The SWQS are the regulations that : 1) define the *goals* for a waterbody by designating the most sensitive uses for which the surface waters of the Commonwealth shall be enhanced, maintained and protected; 2) prescribe minimum water quality criteria required to sustain the designated uses (both numeric and narrative criteria); and 3) include provisions for the maintenance and protection of existing uses and high quality waters (antidegradation policy), which may include the prohibition of discharges (MassDEP 2006). These regulations should undergo public review every three years.

Water Use Goals

Tables 1 - 27 in the SWQS identify certain surface waters or segments/portions of surface waters (the regulated areas), provide classes to those waterbodies, and describe qualifiers which further refine the uses of those surface waters. Because the SWQS identify, classify, and further refine the uses of these waterbodies, the SWQS tables identify the regulations that apply to them. Each of the six classes are described below (314 CMR 4.05 and 4.06 and in MassDEP 2006). Each class is identified by the most sensitive and, therefore, governing water uses to be achieved and protected. Other waters not specifically designated in 314 CMR 4.06 or listed in the tables to 314 CMR 4.00 (commonly referred to as "unlisted waters" by MassDEP analysts) are Class B for inland waters and Class SA for coastal and marine waters. Inland fisheries designations and coastal and marine shellfishing designations for unlisted waters shall be evaluated on a case-by-case basis as necessary. Surface waters may be suitable for other beneficial uses, but shall be regulated by MassDEP to protect and enhance both existing (attained in waterbody on or after November 28, 1975) 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 Massachusetts SWQS prescribe minimum water quality criteria to sustain the existing and designated uses. These criteria are summarized in Table 1. Furthermore, the standards describe the hydrological conditions at which water quality criteria must be applied (MassDEP 2006). In rivers the lowest flow conditions at and above which aquatic life criteria must be applied are the lowest mean flow for seven consecutive days to be expected once in ten years (7Q10). In waters where flows are regulated by dams or similar structures the lowest flow conditions at which aquatic life criteria must be applied are the flows equal to or exceeded 99% of the time on a yearly basis or another equivalent flow that has been agreed upon (see Mass DEP 2006 for more detail). In coastal and marine waters and for lakes the MassDEP will determine on a case-by-case basis the most severe hydrological condition for which the aquatic life criteria must be applied. Excursions from criteria deemed to be the result of natural background conditions are not evaluated as impairment (guidance provided in Appendix A).

Table 1. Summary of Massachusetts Surface Water Quality Standards (MassDEP 2006, MA DPH 2002, FDA 2003).

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 BCWF: ≤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 BWWF: ≤83°F (28.3°C) and ΔT due to a discharge ≤5°F (2.8°C) in rivers (based on the minimum expected flow for the month) and ΔT due to a discharge ≤3°F (1.7°C) in the epilimnion (based on the monthly average of maximum daily temperatures) in lakes Class C and Class SC: ≤85°F (29.4°C) and ΔT due to a discharge ≤5°F (2.8°C) Class SA: ≤85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°C) and ΔT due to a discharge ≤1.5°F (0.8°C) Class SB: ≤85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°C) and Δ T due to a discharge ≤1.5°F (0.8°C) between July and September and ≤4.0°F (2.2°C) between October and June. *For all classes, natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. There shall be no changes from natural background conditions that would impair any uses assigned to each class, including those conditions necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms.* For CWF waters, where a reproducing cold water aquatic community exists at a naturally higher temperature, the temperature necessary to protect the community shall not be exceeded and natural daily and seasonal temperature fluctuations necessary to protect the community shall be maintained. Class B, C, SA, SB, and SC: See MassDEP 2006 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.*

Table 1. Summary of Massachusetts Surface Water Quality Standards (MassDEP 2006, MA DPH 2002, FDA 2003).

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.*
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 pollutants not otherwise listed in 314 CMR 4.00, the National Recommended Water Quality Criteria: 2002, EPA 822-R-02-047, November 2002 published by EPA pursuant to Section 304(a) of the Federal Water Pollution Control Act, are the allowable receiving water concentrations for the affected waters, unless the Department either establishes a site specific criterion or determines that naturally occurring background concentrations are higher. The Department shall use the water quality criteria for the protection of aquatic life expressed in terms of the dissolved fraction of metals when EPA's 304(a) recommended criteria provide for use of the dissolved fraction* (see Mass DEP 2006 for more detail regarding permit limits, conversion factors, site specific 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.*
Bacteria (MassDEP 2006 and MA DPH 2002) Class A criteria apply to the *Public Water Supply Use*. Class B and SB criteria apply to *Primary Contact Recreational Use* while Class C and SC criteria apply to *Secondary Contact Recreational Use*.	Class A: *At water supply intakes in unfiltered public water supplies:* either fecal coliform shall not exceed 20 organisms/100 ml in all samples taken in any six month period, or total coliform shall not exceed 100 organisms/ 100 ml in 90% of the samples taken in any six month period. If both total and fecal coliform are measured, then only the fecal coliform criterion must be met. Class A other waters, Class B: Where *E.* coli is the chosen indicator at public bathing beaches as defined by MA DPH: The geometric mean of the five most recent *E. coli* samples taken within during the same bathing season shall not exceed 126 colonies/ 100 ml and no single sample taken during the bathing season shall exceed 235 colonies/ 100 ml (these criteria may be applied on a seasonal basis at the Department's discretion). Where Enterococci are the chosen indicators at public bathing beaches*:* The geometric mean of the five most recent samples taken during the same bathing season shall not exceed 33 colonies /100 ml and no single *Enterococci* sample taken during the bathing season shall exceed 61 colonies /100 ml. For other waters and, during the non bathing season, for waters at public bathing beaches: The geometric mean of all *E. coli* samples taken within the most recent six months shall not exceed 126 colonies/ 100 ml typically based on a minimum of five samples and no single sample shall exceed 235 colonies/ 100 ml. These criteria may be applied on a seasonal basis at the Department's discretion. The geometric mean of all *Enterococci* samples taken within the most recent six months shall not exceed 33 colonies/ 100 ml typically based on a minimum of five samples and no single sample shall exceed 61 colonies/ 100 ml. These criteria may be applied on a seasonal basis at the Department's discretion. Class C: *The geometric mean of all E. coli samples taken within the most recent six months shall not exceed 630 E. coli/ 100 ml, typically based on a minimum of five samples and 10% of such samples shall not exceed 1260 E. coli/ 100 ml.* This criterion may be applied on a seasonal basis at the discretion of the Department. Class SA: Waters designated for shellfishing: *Fecal coliform bacteria shall not exceed a geometric mean (Most Probable Number (MPN) method) 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 Areas (more stringent regulations may apply, see 314 CMR 4.06(1)(d)(5)).* Class SB: Waters designated for shellfishing: *Fecal coliform median or geometric mean MPN shall not exceed 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 Areas (more stringent regulations may apply, see 314 CMR 4.06(1)(d)(5)).*

Table 1. Summary of Massachusetts Surface Water Quality Standards (MassDEP 2006, MA DPH 2002, FDA 2003).

	<u>Class SA and Class SB</u>: At public bathing beaches, as defined by MA DPH: No single *Enterococci* sample taken during the bathing season shall exceed 104 colonies /100 ml and the geometric mean of the five most recent *Enterococci* samples taken within the same bathing season shall not exceed 35 colonies /100 ml. At public bathing beaches during the non-bathing season and in non bathing beach waters: No single *Enterococci* sample shall exceed 104 colonies/ 100 ml and the geometric mean of all samples taken within the most recent six months, typically a minimum of five samples, shall not exceed 35 colonies/ 100 ml. These criteria may be applied on a seasonal basis at the discretion of the Department). <u>Class SC:</u> *The geometric mean of all Enterococci samples taken within the most recent six months shall not exceed 175 colonies/ 100 ml, typically based on the five most recent samples, and 10% of such samples shall not exceed 350 colonies/ 100 ml. This criterion may be applied on a seasonal basis at the discretion of the Department.*
Natural Background Conditions	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.

Note: *Italics are direct quotations.* ∆ criterion (referring to a change from natural background conditions) is applied to the effects of a permitted discharge.

It should be noted here that waterbodies affected by combined sewer overflow (CSO) discharges are qualified in the standards; 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).

Antidegradation Policy

The third component of the SWQS is the antidegradation rule that contains provisions designed to preserve and protect the existing beneficial uses and to minimize degradation of the state's water quality. These provisions restrict or prohibit the authorization of wastewater discharges to critical resource waters. Most notable is the Outstanding Resource Water (ORW) designation that applies to all Class A waters and certain Class B, Class SA and Class SB waters. These waters 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 Division 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, State Forests and Parks, or Areas of Critical Environmental Concern (ACECs).

Cold Waters FOCUS TOPIC 2016 Cycle:

The timeliness of several large data sources, combined with reports expressing concern over the loss of *Salvelinus fontinalis* (brook trout) habitat, resulted in a concerted effort by MassDEP to better understand the thermal requirements of our cold water fishes and to then develop an evaluation protocol in order to identify, protect, enhance, and/or restore these waters. For the 2016 reporting cycle all of the designated Cold Water streams in the SWQS in each watershed have been described as AUs and included. 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 <u>generally</u> 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 2006). While many streams were designated as Cold Water during the 2006 revision of the SWQS, it was recognized that additional information (in particular temperature data) were needed to accurately and systematically identify the many other cold water rivers and streams in the state. However, these streams are, in fact, protected under the "Existing Use" clause in the SWQS. These streams, identified by the Massachusetts Department of Fish and Game's (MA DFG) Division of Fisheries and Wildlife as Cold Water Fishery Resources (CFRs), are identified as having an "Existing Use" which also merits protection.

When MassDEP analysts reviewed the definition for Cold Water Fisheries, the thermal criteria, and the definition of "Existing Use" in the SWQS, they 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 fishery "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* assessment 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.

Temperature Datasets for assessing Cold Waters	Designated Cold Waters and Unlisted Waters <u>Tier 1</u> Cold Water Fish Existing Use	Unlisted Waters <u>Tier 2</u> Cold Water Fish Existing Use
Large Thermistor Datasets: Chronic (7-day) Criteria	Apply SWQS standard: 7 day rolling average of the daily maximum temperatures (7-DADM) <u><</u>20.0°C. 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.	Apply EPA 7 day rolling average of the daily average temperatures (7-DADA) <u><</u> 21.0°C. 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.
Deployed Sonde Datasets: Acute (24-hour average) criteria not to be exceeded	23.5°C	24.1°C
Other Datasets: Infrequent measurements	no/infrequent excursions and by no more than 2°C above 20°C	no/infrequent excursions and by no more than 2°C above 20°C

III. DATA ACCEPTABILITY

The availability of appropriate and reliable scientific data and technical information is fundamental to the 305(b) reporting and 303(d) listing process. It is EPA policy (EPA Classification No. CIO 2106.0) that any individual or group performing work for or on behalf of the EPA needs to establish a quality system to support the development, review, approval, implementation, and assessment of data collection operations. 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, 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 Section 305(b) and 303(d) of the CWA.

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 Project Plan (QAPP), including field and laboratory Standard Operating Procedures (SOPs). In addition to MassDEP's Wall Experiment Station laboratory, contract labs may also 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 the use assessment decisions. Ideally these data are five years old or less.

Section B.9 of the DWM-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):

1) Educational/Stewardship-level
2) Screening-level, and
3) Regulatory/Assessment-level

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 this type of data would be used for 305(b)- 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. Screening-level data are typically used to direct future sampling efforts and as supporting evidence only. Assessment-level data have been deemed by MassDEP, based on the external data review procedures, to be directly usable for 305(b) 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.

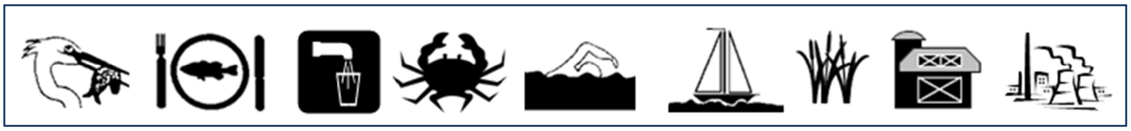
External data can be submitted to MassDEP using guidelines found on the Department's web site here: external-data-submittals. All submitted external data are reviewed using a consistent procedure. Once data are received, a standard data review spreadsheet is used to facilitate and document the MassDEP staff review. Each potential secondary data source is evaluated using the following preliminary criteria: 1) adherence to an acceptable QAPP, including a laboratory Quality Assurance Plan (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 then 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 DWM-WPP's DQOs to look for any large discrepancies that could affect acceptability. In cases where additional information is needed, the external data group is contacted for the information. If available information is deemed insufficient to complete the review, the data are not used. Data can also be considered unusable due to poor or undocumented QAPP implementation, lack of project documentation, incomplete reporting of data or information, poor quality control results and/or project monitoring objectives unsuitable for MassDEP assessment purposes. Best professional judgment is used to make the final determination regarding data validity and usability for assessment purposes. External data are not qualified in any way but considered either acceptable for use or not (as a whole or in part). External data greater than five years old, with few exceptions, are generally considered unusable for assessment decisions.

IV. USE ASSESSMENT 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 2016 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, 2005, 2006, Schwartz 2009, and 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 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* 1993 by D. Persaud, R. Jaagumagi and A. Hayton). Excursions from criteria due solely to "naturally occurring" conditions (e.g., slightly low pH in some areas) do not constitute violations of the SWQS.

The designated uses of Massachusetts surface waters are described below (MassDEP 2006).
As part of the 305(b) reporting process, each designated use (*see exception note below*) of the surface waters in the

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.

state for each waterbody segment (called an assessment unit or AU in the assessment database) is individually assessed as ***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 Integrated List of Waters nor is information on these waters maintained in the ADB. These are considered ***not assessed other waters.***

Exception Note: There are three uses - *Public Water Supply, Agricultural,* and *Industrial* - not assessed for 305(b) reporting purposes by MassDEP analysts. The *Public Water Supply Use* denotes those waters used as a source of public drinking water. These waters may be subject to more stringent regulation in accordance with the Massachusetts Drinking Water Regulations (310 CMR 22.00). They are designated for protection as Outstanding Resource Waters in 314 CMR 4.04(3). 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 (http://water.epa.gov/lawsregs/rulesregs/sdwa/ccr/index.cfm). 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 source protection and finished water quality can/should be obtained at http://www.mass.gov/eea/agencies/massdep/water/drinking 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 assessment decision are provided. Depending on the waterbody type, assessment decision trees for the use assessment 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 (2008/2009)
- Impervious Surface (February 2007)
- Land Use (2005) (June 2009)
- Dams (February 2012)

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 MassGIS Land Use 2005 (40 codes) coverage was grouped into four categories:
   Natural: forest, water, saltwater sandy beach, new ocean, and brushland/successional
   Wetland: wetland, salt water wetland, and forested wetland
   Agriculture: crop land, pasture, cranberry bog, orchard, and nursery
   Developed: mining, open land, participation recreation, spectator recreation, water-based recreation multi-family residential, high density residential, medium density residential, low density residential, commercial, industrial, urban open, transportation, waste disposal, powerline, golf course, marina, urban public, cemetery, very low density residential, and junkyards.
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 et al. 2011).

Aquatic Life Use

Waters supporting the *Aquatic Life Use* should be suitable 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 2006).

Use Assessment Decision-Making Process:
Results from biological (and habitat), toxicological, physico-chemical, sediment, and body burden investigations are all considered in assessing the *Aquatic Life Use*. 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 support 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, in most cases, outweigh all other types 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 those generated by a Rapid Bioassessment Protocol (RBP) III multi-metric analysis (Plafkin et al. 1989) 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. Thus, assuming all data are of equal quality, the weight-of-evidence gradient for data used by the MassDEP 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* assessment decision process are provided below in the order of the weight-of-evidence gradient 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* assessment decisions can be found in Table 3 (see end of this use assessment guidance).

Benthic macroinvertebrate data (rivers) The benthic macroinvertebrate sampling data generated by MassDEP biologists are usually from 100-organism subsamples, which are analyzed by a multimetric approach based on a modification of the RBP III metrics and scoring (Plafkin et al. 1989). [Note: occasionally other sampling regimes are employed (e.g., in deep rivers or where kick sampling is inappropriate or impractical, multi-plate samplers may be used).] Sampling takes place during the months of July through September when baseflows are at their lowest of the year and levels of stress to aquatic organisms are presumed to be at its peak. The sampling index for a specific watershed also approximates historical sampling periods for that watershed, when possible. Metric values for each station are scored based on comparability to a reference station, and scores are totaled. The percent comparability of total metric scores for each study site to those for a pre-selected least impaired reference station (i.e. “best attainable” condition) yields an impairment score for each site. The RBP III analysis separates sites into four categories (% of reference condition): non-impaired (>83%), slightly impaired (54 – 79%), moderately impaired (21 – 50%), and severely impaired (<17%). Reference station sites and sites determined to be non-impaired or slightly impaired based on the RBP III analysis are assessed as supporting the *Aquatic Life Use*. Moderately and severely impaired RBP III sites are assessed as non-support. Occasionally, sample attributes may be noted by MassDEP biologists that influence an assessment decision (e.g., biologists note hyperdominance by a pollution tolerant species even though the RPB III analysis indicated only slight impairment. In this case a determination of “impaired” may be made).

The MassDEP benthic macroinvertebrate monitoring results are typically summarized in a technical memorandum by watershed. These memoranda combine habitat assessment information and the analysis of multi-metric benthic community characteristics for comparison to previously established reference station data (RBPIII analyses). Quality-assured external sources of benthic macroinvertebrate survey reports are occasionally available from outside parties (e.g., other state/federal agencies, consultants, watershed associations, NPDES permittees).

Use is Supported	Use is Impaired
Non-impaired/most slightly impaired (without caveat) RBP III analysis, reference sites	Moderately impaired/severely impaired RBP III analysis, slightly impaired RBP III with special condition (e.g., hyperdominance by pollution tolerant sp.) as noted by MassDEP biologists

Benthic macroinvertebrate data (lakes) – Not currently utilized to evaluate *Aquatic Life Use* of lentic waters.

Benthic macroinvertebrate data (estuaries) MassDEP analysts occasionally utilize external sources of benthic macroinvertebrate data combined with other water quality monitoring data when making *Aquatic Life Use* assessments of 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 et al. 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, shallow dwelling opportunistic species or near absence of benthos, thin feeding zone, as reported from external data sources.

Background/context: MassDEP Benthic Macroinvertebrate Biomonitoring Quality Assurance Project Plan (MassDEP 2005a)

The biological sampling methodology is described in an SOP (MassDEP 2007) and is 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 streams within the watershed by conducting assessments based on aquatic macroinvertebrate communities; and (b) to identify problem stream segments so that efforts can be focused on developing or modifying NPDES and Water Management Act permits, storm water management, and control of other nonpoint source (NPS) pollution.

A regional reference station approach is currently used for comparisons to site data…this is useful in assessing nonpoint source (NPS) pollution impacts (e.g., physical habitat degradation), including NPS pollution at upstream sites as well as suspected impacted sites downstream from known point source stressors…benthic data from some stations are not compared to a regional reference station due to considerable differences in stream morphology, flow regimes, and drainage area, or simply lack of a suitable reference site.

A site-specific sampling approach (downstream study site compared to an upstream reference site) is occasionally employed for an assessment of a known impact site (e.g., point source discharge), provided that the stations being compared share basically similar instream and riparian habitat characteristics…

Background/context:
MassDEP DWM Fish Collection Procedures for Evaluation of Resident Fish Populations Standard Operating Procedures (MassDEP 2011a)

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), and 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 et al. 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"). Two Cold Water species "Existing Use" tiers defined as follows:
Tier 1: brook trout ≤140mm and slimy sculpin
Tier 2: brook trout, brown trout, rainbow trout and 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 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 and Barbour et al. 1999), however, these 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 efficiencies, are used to semi-quantitatively assess the general condition of the resident fish community as a function of the overall abundance (number of species and individuals) and species composition classifications (see inset for more detail) (MassDEP 2011a). MassDEP analysts also utilize fish community sampling data available from the Massachusetts Division of Fisheries & Wildlife (DFW or "MassWildlife") (MassWildlife 2014) as the goals, objectives, and sampling protocols are similar.

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 Class B Cold Water Fishery or for those waters on MA DFG's Coldwater Fishery Resource List, the fish community should contain multiple age classes or young of year (YOY) of any cold water fish (see Appendix B). For waters designated as 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 multiple fluvial specialist/dependent species (see Appendix B) or at least one fluvial specialist/dependent species in moderate abundance. In low gradient streams (glide/pool prevalent streams) the fish community should include at least one fluvial specialist/dependent species or fishes which are intolerant or moderately tolerant to environmental perturbations. 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.

Fish community data are a valuable indicator for assessing the *Aquatic Life Use* and in many cases is all that is needed. In some cases, however, additional data are reviewed prior to making an assessment decision. Sources of information may include historic fisheries, 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 fishes, multiple age classes (indicative of reproducing populations) of any salmonid, presence of YOY salmonids.	Absence of cold water fishes, or dramatic population reductions relative to historical samples, DELTS with abnormal fish histology.
Use is Supported Warm Water Fishery	**Use is Impaired Warm Water Fishery**
In moderate to high gradient streams the fish community should include fluvial specialist/dependents species or at least one fluvial species in moderate abundance. In low gradient streams, at least one fluvial species, or species which are intolerant or moderately tolerant to environmental perturbations should be present	In moderate to high gradient streams fluvial fish are absent. In low gradient streams no fish found or the absence of fish which are intolerant or moderately tolerant to environmental perturbations. DELTS with abnormal fish histology.

Fish community data (lakes, estuaries) – 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 , DELTS with abnormal fish histology

Primary producer data (rivers, lakes, 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 2013). 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 (CyanoHABs), 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 et al. 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 and MassDEP undated):*** *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) "*Algae 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 grab 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 (see CN 60.0, Periphyton SOP).

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 et al. 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 2014) and Aquatic Plant Mapping (MassDEP 2006b): *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 and Lemna sp. are also noted on lake survey fieldsheets during DWM 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 2014). 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 [SOP CN 239.0]). 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 2006b).

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 et al. 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 (personal communication Beskenis 2014).

Algal Blooms (rivers, lakes)

> ***Background/Context: Harmful BlueGreen Blooms (MassDEP 2010a).*** *Blooms of cyanobacteria can be toxic to humans 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. 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 2007) 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 provides guidance on harmful algal blooms in fresh waterbodies (http://www.neiwpcc.org/neiwpcc_docs/protocol_MA_DPH.pdf).*
>
> *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.*

An algal bloom is a rapid increase in the population of algae in response to a surplus of nutrients combined with abundant light and other variables that promote their growth. Counts of the blue-green algae, or cyanobacteria, are used to provide a means of determining if toxins may be present in potentially harmful amounts. The presence of cyanobacteria blooms (CyanoHABs) and the issuance of advisories due to high cyanobacteria cell counts are both considered to be indicative of enriched conditions. Waterbodies experiencing frequent and/or prolonged cyanobacteria blooms are considered to be impaired for the *Aquatic Life Use*.

Eelgrass bed mapping data (estuaries)

The primary biological information used to make assessment decisions for the *Aquatic Life Use* in marine or estuarine waters is obtained from eelgrass bed maps based on surveys conducted by the 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 come 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 is continuing through 2015. Data acquisition and image interpretation are detailed in Costello and Kenworthy (2011) and are available online at http://www.mass.gov/eea/agencies/massdep/water/watersheds/eelgrass-mapping-project.html. The first statewide mapping phase as part of this project was conducted between 1994 and 1996. The most recent data available are from 2010 to 2013 (MassGIS 2014).

> **Background/context: MassDEP Eelgrass Mapping Project (MassGIS 2014 and 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, and 95% in 2012. 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.*

Eelgrass Mapping along Massachusetts River Basins and/or Coastal Drainage Areas*	Datalayer Years of Mapping Effort (indicated by X)	
	1995	2010-2013
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 2016 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 recent available data (2010-2013) 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 2010-2013 [the percent loss is calculated by (50-40)/50 = 0.2 or 20%]. Loss of the deeper water edge of the eelgrass beds is indicative of declining water quality conditions (personal communication 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%*, Deep rivers: phytoplankton Chlorophyll *a* ≤16 µg/L*, occasional non-harmful ephemeral algal blooms*, no HABs (cyanobacterial or non-cyanobacterial 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*, no HABs (cyanobacterial or non-cyanobacterial 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%*, Deep rivers: phytoplankton Chlorophyll *a* >16 ug/L* cyanobacteria blooms that result in advisories (recurring and/or prolonged)	phytoplankton Chlorophyll *a* >16 µg/L*, >25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps*, cyanobacteria blooms that result in advisories (recurring and/or prolonged). **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*

*Denotes that an *Aquatic Life Use* assessment 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 an assessment decision.

Habitat and flow data (rivers, lakes, estuaries)
Most often evaluations of instream habitat support the biological survey results and enhance the interpretation of the biological data. When biological communities are determined to be impaired from RBP analyses 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). Any anadromous fish passage structures that are impassable are considered to be an impairment of the *Aquatic Life Use*. [Note: if impediments to fish passage (such as dams) exist but no structure has ever been built to allow fish passage, 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.

The sources of information that MassDEP analysts utilize to evaluate habitat quality and streamflow conditions include the following: the habitat assessment field sheets and scores (see inset, usually reported in technical memoranda), observations recorded on the water quality monitoring field sheets (water quality technical memoranda or the DWM-WPP's open files) , the United States Geological Survey (USGS) real-time and historical streamflow data (http://waterdata.usgs.gov/ma/nwis/current/?type=flow), and the MA DFG, Division of Marine Fisheries (DMF) technical reports on surveys of anadromous fish passage in coastal Massachusetts (http://www.mass.gov/eea/agencies/dfg/dmf/publications/technical.html). With minor exception MassDEP does not currently have the resources to collect site-specific flow information during water quality surveys.

The Massachusetts SWQS stipulate the most severe hydrologic conditions at which water quality criteria must be applied to prevent adverse impacts of discharges. For rivers, the lowest flow condition at and above which aquatic life criteria must be applied is the lowest flow to be expected for seven consecutive days during a 10-year period; the 7-day, 10-year low flow (7Q10). The 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, functioning anadromous fishways present	Physical habitat structure impacted by anthropogenic stressors (e.g., lack of flow, lack of natural habitat structure -- concrete channel, underground conduit), non-functioning anadromous fishway present

Background/context: MassDEP DWM Benthic Macroinvertebrate Biomonitoring Quality Assurance Project Plan (MassDEP 2005a)

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.

Streamflow Conditions (MassDEP 2005b): "*Historically, river surveys conducted by DWM staff were typically performed 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 discharges. Today, increased attention is given to the identification and control of nonpoint 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 pollutant loadings from stormwater runoff and, when compared with dry-weather survey data, may further distinguish the effects of point and nonpoint pollution sources.*"

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 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 2016 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 2005 or as confirmed/verified by external sources.

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 2006) and Guide to Selected Invasive Non-native Aquatic Species in Massachusetts (MA DCR 2007)

The Massachusetts Surface Water Quality Standards (2006) 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, DWM 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, 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 2011b). 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* assessment 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 assessment decision of support. When survival of test organisms exposed to the river water samples is less than 75% the frequency and magnitude (with respect to temporal patterns) of the low-survival events are considered. The analyst notes any pattern of problems (e.g., seasonal) and reviews associated chemistry data to identify potential cause(s)/source(s). An impairment decision for the *Aquatic Life Use* is typically made when low organism survival (i.e., <75%) occurs in more than 10% of the tests performed since the last assessment was completed. With few data points (n≤10), however, MassDEP analysts will not impair a waterbody unless there is more than one exceedance of the guideline.

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

Other toxicity testing data sources may include EPA investigations or testing carried out as part of waste-site investigations and may also 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 2011)

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 2005b)

One of the DWM'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 2005b, MassDEP 2010c). 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, 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 standards 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 (minimum of five rounds of water quality data during the sampling season augmented with probe deployments) sampling program. 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* assessment 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 2006). 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.

Dissolved oxygen (DO)

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

The Massachusetts SWQS (MassDEP 2006) 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.

National criteria for DO in freshwater (EPA 1986 and 1988a) 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 which 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 dissolved oxygen criteria based on the timing (e.g., presence or absence of early life stages of fish) and frequency of the data measurements (Table 2). 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 2. 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.]

	Coldwater Criteria	Warmwater 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	NA**	6.5	NA	LC, SC [1,2]
7-Day Mean Minimum	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 **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 $\geq$90% of the lake surface area during summer season)	No/infrequent ($\leq$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 (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 excursions (<0.5 SU) from criteria (minimum five measurements)	No or slight excursions (<0.5 SU) from criteria (minimum one deep-hole profile during summer growing season)	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	Excursion from criteria (>0.5 SU) summer growing season	Frequent (>10%) and/or prolonged or severe 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 2006):
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. 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.

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 SWQS as well as MassDEP-derived criteria (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 2006). 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). Long-term datasets are evaluated against either the SWQS criterion (7-day rolling average of the daily maximum temperatures or 7-DADM) or the MassDEP-derived chronic criterion (7-day rolling average of the daily average temperatures or 7-DADA) and either the Tier 1 or Tier 2 MassDEP-derived criteria (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 MassDEP-derived criteria in the table below; however, an impairment decision will not be made with these shorter datasets relative to chronic criteria. Instead, the 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 acute (24-hour rolling average maximum), will be compared to the Acute (Maximum 24-hour average) criteria in the table below.

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).

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.

	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 <u><</u>20.0°C Tier 1 Existing Use Waters: 7-DADM <u><</u>20.0°C Tier 2 Existing Use Waters: 7-DADA <u><</u>21.0°C (Exceedances <u><</u>11 times)	Designated Warm Waters and Unlisted Class B Waters not Tier 1 or Tier 2: 7-DADM <u><</u>27.7°C (Exceedances <u><</u>11 times)	24-hour average <u><</u> 26.7°C (Exceedances <u><</u>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 <u><</u>20.0°C Tier 1 Existing Use Waters: 3-5-DADM <u><</u>20.0°C Tier 2 Existing Use Waters: 3-5-DADA <u><</u>21.0°C (No exceedances)	3-5-DADM <u><</u>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: <u><</u> 23.5°C Tier 2 fish: <u><</u> 24.1°C No exceedances of mean (acute criterion)	Maximum 24-hour average <u><</u> 28.3°C No exceedances of mean (acute criterion)	No more than one day with exceedance of 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 criteria 29.4°C
Small (instantaneous/discrete) datasets:	no/infrequent/small excursions (1 to 2°C) above 20°C	no/infrequent excursions above criteria (28.3°C)	No more than one day with exceedance of 29.4°C	MA SWQS criterion frequently exceeded (>10%) or by >2°C (22°C).	MA SWQS criterion frequently exceeded (>10% measurements) or by >2°C (30.3°C).	More than one day above criteria 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: Allowed (~10%) exceedance up to 11 times June-September (reflects the term “generally” in the SWQS).]

Nutrients The Massachusetts SWQS include both narrative nutrient and aesthetic criteria (see excerpts below) that are applicable to all surface waters (MassDEP 2006).

> *"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 indicators are absent (see 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, the nutrient (total phosphorus or total nitrogen) is also identified as a cause of impairment. For the 2016 reporting cycle, the seasonal average ($n \geq 3$ samples) of the total phosphorus concentration data will be screened against the 1986 EPA recommended "Gold Book" concentrations for rivers (0.1 mg/l flowing waters, 0.05 mg/l for rivers entering a lake/reservoir) and lakes (0.025 mg/l). For estuarine waters, a seasonal average ($n \geq 3$ samples) of the total nitrogen concentration data collected during an ebb tide will be screened against the MEP critical indicator threshold of >0.5 mg/l for waters where eelgrass habitat has not been documented and >0.4 mg/l for waters where eelgrass habitat has been confidently documented at some point in time. According to the MEP critical indicators report, when total nitrogen concentrations are $\leq$ 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 et al. 2003). Higher concentrations (>0.5 mg/l) are typically associated with systems experiencing degraded overall health.

NUTRIENT CRITERIA DEVELOPMENT STATUS FOR MA

It should be noted here that EPA implemented a strategy to develop ambient water quality nutrient criteria by ecoregions for the US (EPA 2000a, 2000b, and 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 2000c, 2000d, 2001a, and 2001b). EPA has not yet published recommended nutrient criteria documents for either the Acadian or Virginian provinces.

Massachusetts 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) 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 considers changes in physico-chemical data, such as: dissolved oxygen (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. 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 assessed primarily with the 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.

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%*, Deep rivers: phytoplankton Chlorophyll *a* ≤16 µg/L*, no HABs *	phytoplankton Chlorophyll *a* ≤16 µg/L*, ≤25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/ clumps*, no HABs*	Eelgrass bed habitat in AU area is increasing or fairly stable (i.e., no or minimal loss), Chlorophyll *a* ≤5 µg/L*, lack of macroalgae accumulations*	Wadeable rivers: benthic chlorophyll *a* samples >200 mg/m^2*, filamentous algal cover >40%*, Deep rivers: phytoplankton Chlorophyll *a* >16 ug/L* cyanobacteria blooms that result in advisories (recurring and/or prolonged)	phytoplankton Chlorophyll *a* >16 µg/L*, >25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps*, cyanobacteria blooms that result in advisories (recurring and/or prolonged). **These indicators may also be applied to impounded reaches of River AUs.**	Substantial decline (more than 10% of eelgrass bed size or total loss of beds no matter their size), 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), seasonal summer average (n≥3)	Secchi disk transparency ≥1.2 m, seasonal average Phosphorus (Total) below EPA Gold Book concentrations ≤0.025 mg/l	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	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	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	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

total phosphorus concentrations below EPA Gold Book concentrations. (<u><</u>0.1 mg/l flowing waters, <u><</u>0.05 mg/l for rivers entering a lake/reservoir)		concentration generally <u><</u>0.4 mg/l*	mg/l flowing waters, >0.05 mg/l for rivers entering a lake/reservoir	mg/l. **These indicators may also be applied to impounded reaches of River AUs.**	concentration generally >0.5 mg/l*

* Denotes that an *Aquatic Life Use* assessment 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 an assessment/listing decision. Site-specific MEP analyses may supersede the screening guidelines above.

Toxic and other pollutants (Rivers, Lakes, Estuaries)
The Massachusetts SWQS include a narrative statement pertaining to toxic pollutants (see excerpt in text box below) that is applicable to all surface waters (MassDEP 2006). To evaluate the potential for observing adverse biological effects, the water quality data for toxic and other pollutants (e.g., metals, ammonia, chlorine, polycyclic aromatic hydrocarbons, chlorinated organics) are compared to their respective current water quality criteria as of August 2014 (EPA 2014 available at http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm). In general, the EPA recommends both acute (typically expressed as one-hour averages) and chronic (typically expressed as four-day averages) criteria to protect against short- and long-term effects. For most toxicants the EPA also recommends that the criteria should not be exceeded more than once every three years.

> *"All surface waters shall be free from pollutants in concentrations or combinations that are toxic to humans, aquatic life or wildlife. For pollutants not otherwise listed in 314 CMR 4.00, the National Recommended Water Quality Criteria: 2002, EPA 822-R-02-047, November 2002 published by the EPA pursuant to Section 304(a) of the Federal Water Pollution Control Act, are the allowable receiving water concentrations for the affected waters, unless the Department either establishes a site specific criterion or determines that naturally occurring background concentrations are higher. The Department shall use the water quality criteria for the protection of aquatic life expressed in terms of the dissolved fraction of metals when the EPA's 304(a) recommended criteria provide for use of the dissolved fraction."* (See Mass DEP 2006 for more detail regarding permit limits, conversion factors, site specific criteria).

For those toxic and other pollutants measured in the water column, a matrix of the analytes concentrations and their respective acute and chronic criteria values is developed. When the ratio of the pollutant to the criterion (a "Toxic Unit" or TU calculation) is greater than 1.0 it is considered an exceedance of the criterion. The TU calculation also provides the relative magnitude of the exceedance. A minimum of two exceedances (TU>1.0) of the acute criterion must be found prior to making an impairment decision. The same method (TU calculation) is applied to evaluate chronic criteria exceedances; however, more intensive data collection/evaluations prior to an impairment decision are needed. The reasoning for this is as follows: MassDEP analysts consider grab samples to be directly comparable to the acute criteria whose duration and frequency is typically expressed as a "one-hour average concentration not to be exceeded more than once every three years". However, since the chronic criteria duration-frequency is typically expressed as a "four-day [or longer] average concentration not to be exceeded more than once every three years" the comparability of (typically monthly) grab sample data to these criteria is not considered appropriate at this time. Therefore, exceedances of the chronic criteria will be flagged as needing additional, intensive data collection/evaluations prior to making an impairment decision. In developing ambient water quality criteria for toxic pollutants, EPA either conducted its own tests or relied upon toxicity test information from the literature. Many of these tests were done with well water or other waters that were low in organic carbon or other constituents that can bind toxicants and make them less "bioavailable". When pollutants are released into more natural waters than those used by EPA in their tests, the toxicity of some pollutants can be less than that expected from the EPA criterion for that pollutant. This is not always the case, of course, and certain properties (e.g., low pH) of water can increase the toxicity of certain pollutants. EPA has recognized this and allows states to develop "site-specific" criteria. However, this can be an expensive and time-intensive undertaking. Since concentrations above criteria often do not result in toxicity, the weight-of-evidence approach/gradient is followed by MassDEP analysts. Therefore, when other biological data (e.g., benthic macroinvertebrates, fish, toxicity testing data) are available and of at least equal data quality, the analysts rely more heavily on those than on the chemical concentration data.

Metals. Historically, instream metals data were collected by MassDEP field staff during water quality monitoring surveys. In addition, NPDES facilities still report metals data as part of their whole effluent toxicity (WET) testing requirements. Some of these data were utilized in the past to make *Aquatic Life Use* assessment decisions. However, none of these historical data were collected using clean sampling techniques and the validity of using these data in use-impairment decisions came into question in the late 1990s. Since the late 1990s, MassDEP analysts have not been utilizing metals data as part of the water quality assessment reporting. In 2007 an effort was initiated by the MassDEP to develop clean sampling techniques for gathering instream dissolved metal data. While this dataset is very limited, validated data collected using clean sampling techniques will be used in the *Aquatic Life Use* assessment decisions for the 2016 reporting cycle. In particular, these data will be used to evaluate whether or not historical impairment decisions, based on older metals data, were appropriate.

Evaluation of dissolved metals data that were collected using grab samples and clean sampling techniques is conducted according to the Toxic Unit (TU) method described above. For hardness-dependent criteria the actual instream hardness (calculated from the calcium and magnesium concentration data when available) is used to calculate the criteria. Each individual metal concentration is compared to its acute criterion and TUs above 1 indicate an exceedance. However, a minimum of two exceedances of any metal (each metal is evaluated separately) must be found prior to making an impairment decision. The criteria and hardness-dependent formulas can be found in Appendix E. The metals evaluated include cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), silver

(Ag), zinc (Zn), and arsenic (As). No evaluations will be made for aluminum (Al) for several reasons: 1) the Al criteria are currently under review by EPA; 2), Al data collected by DWM-WPP's monitoring program using clean sampling techniques were for dissolved Al rather than for total Al (on which the criteria are based); and 3) MassDEP has collected information demonstrating that natural background concentrations of Al may be much higher than the chronic ambient water quality criterion (87 ug/l) (see Appendix E). As described above, Massachusetts' SWQS state that the 2002 compendium of EPA Ambient Water Quality Criteria shall be used "*unless the Department either establishes a site specific criterion or determines that naturally occurring background concentrations are higher."* Lastly site-specific criteria for Cu were adopted in the state's SWQS for certain waterbodies. Where appropriate (i.e., as identified in the state's SWQS) the Cu data were compared to the site-specific acute and chronic criteria of 25.7 and 18.1 µg/L, respectively.

Ammonia

According to the EPA (2013) the freshwater acute and chronic criteria for ammonia are dependent on pH and temperature. At lower temperatures (<15.7^{o} C) 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 should *screen* results by using the highest pH and temperature measurements taken at each site during the course of the surveys to determine the conservative acute and chronic ammonia criteria. The concentration data can then be compared to these site-specific conservative ammonia criteria values. In the absence of site-specific temperature and pH data, the analyst should utilize a watershed-specific maximum pH and temperature to calculate an acute "screening" criterion; however, if an exceedance is found an impairment decision should not be made. Rather, more data, including pH and temperature at the time of sample collection, will need to be collected prior to making an impairment decision. As previously described, impairments will be made only based on acute criteria exceedance. This is because the chronic criteria duration-frequency is typically expressed as a "four-day (and in the case of ammonia a 30-day) average concentration not to be exceeded more than once every three years" and the comparability of (typically monthly) grab sample data to these criteria is not considered appropriate at this time. Therefore, exceedances of the chronic criteria will be identified as needing additional, intensive data collection/evaluations, but an impairment decision will not be made.

> EPA (1999) *"regarding the dependence of the toxicity of ammonia to aquatic organisms on various physicochemical properties of the test water, especially temperature, pH, and ionic composition… in aqueous solution, ammonia primarily exists in two forms, un-ionized ammonia (NH3) and ammonium ion (NH4 +)…the individual fractions vary markedly with temperature and pH…ammonia speciation also depends on ionic strength, but in fresh water this effect is much smaller… These speciation relationships are important to ammonia toxicity because un-ionized ammonia is much more toxic than ammonium ion…it was observed that increased pH caused total ammonia to appear to be much more toxic… because it is a neutral molecule and thus is able to diffuse across the epithelial membranes of aquatic organisms much more readily than the charged ammonium ion…ammonia is unique among regulated pollutants because it is an endogenously produced toxicant that organisms have developed various strategies to excrete, which is in large part by passive diffusion of un-ionized ammonia from the gills…high external un-ionized ammonia concentrations reduce or reverse diffusive gradients and cause the buildup of ammonia in gill tissue and blood".*

EPA's chronic ammonia criteria are 30-day average criteria which present some difficulties for analyzing grab-sample information. EPA presents a matrix of these criteria that vary with pH and temperature. MassDEP decided not to attempt to compare its 2005-2010 ammonia data to the chronic ammonia criteria for the following reasons: for any particular temperature, the chronic ammonia criterion varies more than an order of magnitude through the range of allowable pH values defined in the SWQS for Massachusetts' waters (i.e. 6.5-9.0). For example, in a coldwater stream with a mean temperature of 18°C, the criterion varies by about 13-fold [from 2.4 to 0.18 mg/l] over this pH range. For a typical warmwater stream, with a mean temperature of 25°C, the criterion varies by about the same factor over the same pH range. By comparison, for a stream with a pH of 6.5, the criterion varies by only a factor of 4.5 across the entire range of yearly temperatures that might be encountered (0-30°C) in any stream in Massachusetts. The chronic criterion for a stream with a much higher pH (e.g., 7.8) varies by about the same factor across the same temperature range. From this, one can see that, of the two principal variables that determine chronic ammonia toxicity, pH plays a larger role than does temperature.

Although the MassDEP water quality monitoring program staff collected continuous temperature information at many sites, the pH data represent instantaneous measurements taken when the grab ammonia samples were collected (~5 samples sometime between April and October). Because we are unable to approximate the central tendency for pH at any of our sampling sites, and because this variable has such a strong influence on ammonia toxicity, the program analysts decided it was not appropriate to evaluate chronic ammonia toxicity especially considering the paucity of the ammonia data at each site. Based on our evaluation of these data, we recommend that in order to assess chronic ammonia toxicity in the future, monitoring information will need to include both long-term temperature as well as long-term pH information.

Chloride While chloride occurs naturally in aquatic environments, elevated levels of chloride that often result from anthropogenic sources are known to be toxic to aquatic life. 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 1988b). The EPA-recommended acute criterion for chloride when associated with sodium is 860 mg/l (one-hour average) and the chronic criterion is 230 mg/l (four-day average). Neither value is to be exceeded more than once every three years. According to the EPA, these criteria will not be sufficiently protective of aquatic life when the chloride is associated with potassium, calcium, or magnesium which is generally more acutely toxic than sodium chloride when compared on the basis of mg of chloride per liter (EPA 1988b). At the time of the criteria development there were insufficient data to develop criteria that could account for these differences. EPA anticipated releasing new recommended chloride criteria in 2014 but, as yet, these have not been published. When evaluating chloride data the analyst should note the number, as well as the magnitude, frequency, and duration of exceedances.

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 EPA-recommended 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). Neither criterion is to be exceeded more than once every three years. 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.

In summary, MassDEP analysts evaluate whether or not there are exceedances of toxic and other pollutants by comparing the data to their respective acute and chronic water quality criteria. Infrequent excursions (no more than a single exceedance of an acute criterion) are not considered impairments. More than one acute exceedance of criteria is considered an impairment unless a weight-of-evidence based decision suggests otherwise. With the exception of ammonia, the evaluation of chronic criteria exceedances will be flagged for requiring additional, more intensive data collection/evaluations prior to making an impairment decision given the incompatibility of comparing the results of grab samples to the longer averaging period associated with those criteria. In order to assess chronic ammonia toxicity in the future, both long-term temperature and pH data will be needed.

Use is Supported	Use is Impaired
For each toxic and other pollutant there is no more than a single exceedance of the acute criterion (i.e., analyte specific TU>1 in no more than one sample).	For each toxic and other pollutant there is more than one exceedance of the acute criterion (i.e., at least two samples contain a specific analyte with a TU > 1). Chronic TU exceedances will not result in an impairment decision, but will trigger a recommendation for additional data collection.

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

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 1999a).

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, 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, estuaries)

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

Total PCBs: $\leq$ 500 µg/kg (ppb) wet weight
Total DDT, DDE, DDD: $\leq$ 1,000 µg/kg (ppb) wet weight
Chlordane and Heptachlor epoxide: $\leq$ 200µg/kg (ppb) wet weight (also applies to total residues of aldrin, benzene hexachloride (BHC), chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, and toxaphene either singly or in combination).

Residues of contaminants in whole body samples of fish are compared to the NAS/NAE recommended guidelines based on whole fish for the protection of fish-eating wildlife. If the concentration of contaminants is below the guideline(s) (e.g., [total PCB] $\leq$ 500 µg/kg (ppb) wet weight) then no impairment decision for the *Aquatic Life Use* is made. However, if whole body burden residue(s) exceed the recommended guideline(s), best professional judgment is used by the analyst to evaluate whether 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 1999b, 1999c, 2000 and 2001)

DDT, *a chlorinated hydrocarbon insecticide, was used world-wide since the 1940s to control insects (CCME1999b). "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 Assessment

Table 3. *Aquatic Life Use* assessment decision indicator summary by weight-of-evidence gradient.

Indicator for *Aquatic Life Use* Assessment	Use is Supported	Use is Impaired
BIOLOGICAL MONITORING INFORMATION		
Benthic macroinvertebrate data (rivers)	Non-impaired/most slightly impaired RBP III analysis, reference sites	Moderately impaired/severely impaired RBP III analysis, slightly impaired with special condition (e.g., hyperdominance by pollution tolerant species), as noted by MassDEP biologists
Benthic macroinvertebrate data (estuaries)	Relatively high no. species, high no. individuals, good diversity and evenness, moderate to deep burrowing, tube dwelling organisms present, as reported from external data sources	Relatively low no. species, low no. individuals, poor diversity and evenness, 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 streams the fish community should include fluvial specialist/dependents species or at least one fluvial species in moderate abundance. In low gradient streams, at least one fluvial species, or species which are intolerant or moderately tolerant to environmental perturbations should be present	**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 streams fluvial fish are absent. In low gradient streams no fish found or the absence of fish which are intolerant or moderately tolerant to environmental perturbations. DELTS with abnormal fish histology.
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* assessment 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 an assessment decision. **Lake impairment indicator levels may also be applied to impounded reaches of river AUs.**	**<u>Benthic Algae</u>** Wadeable rivers: benthic chlorophyll *a* samples ≤200 mg/m^2, filamentous algal cover ≤40% **<u>Chlorophyll a</u>** Deep rivers: phytoplankton Chlorophyll *a* ≤16 µg/L, Lakes: phytoplankton Chlorophyll *a* ≤16 µg/L Estuaries:Chlorophyll *a* ≤5 µg/L **<u>Aquatic Macrophytes</u>** Lakes: ≤25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps Estuaries: little to no macroalgae accumulations **<u>Algal Blooms</u>** Rivers and lakes: occasional non-harmful ephemeral algal blooms, no HABs (cyanobacterial or non-cyanobacterial blooms) **<u>Eelgrass bed mapping data</u>** Estuaries: Eelgrass bed habitat in AU area is increasing or fairly stable (i.e., no or minimal loss) between 1994 – 1996 and 2010 – 2013 mapping efforts	**<u>Benthic Algae</u>** Wadeable rivers: benthic chlorophyll *a* samples >200 mg/m^2, filamentous algal cover >40% **<u>Chlorophyll a</u>** Deep rivers: phytoplankton Chlorophyll *a* >16 ug/L Lakes: phytoplankton Chlorophyll *a* >16 µg/L, Estuaries: Chlorophyll *a* >10 µg/L **<u>Aquatic Macrophytes</u>** Lakes: >25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps Estuaries: some macroalgae accumulations **<u>Algal Blooms</u>** Rivers and lakes: cyanobacteria blooms that result in advisories (recurring and/or prolonged) **<u>Eelgrass bed mapping data</u>** Estuaries: Substantial decline in AU (= or exceed 10% of eelgrass bed area between 1994 – 1996 and 2010 – 2013 mapping efforts
Habitat and flow data (rivers, lakes, estuaries)	No direct evidence of severe physical habitat or stream flow regime alterations, functioning anadromous fishways present	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
Non-native aquatic species data (rivers, lakes)	Non-native aquatic species absent	Non-native aquatic species present
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.

Indicator for *Aquatic Life Use* Assessment	Use is Supported	Use is Impaired
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) **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	**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: MA SWQS criterion frequently exceeded (>10% measurements) or by >2°C (30.3°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

Indicator for *Aquatic Life Use* Assessment	Use is Supported	Use is Impaired
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	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
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 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. **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 each toxic and other pollutants there is no more than a single exceedance of the acute criterion (i.e., analyte specific TU>1 in no more than one sample).	For each toxic and other pollutants there is more than one exceedance of the acute criterion (i.e., at least two samples contain a specific analyte with a TU > 1). No impairment decision will be made with chronic TU exceedances but will trigger a recommendation for additional data collection.
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 2006). For the purpose of assessment and 305(b)/303(d) Integrated List 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 CMR4.05(5)(e)3b in MassDEP 2006).

Use Assessment 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 2010c). 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 2010c). 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 DWM-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 2012):

Fish Consumption Advisory for Marine and Fresh Water Bodies (MA DPH 2012)

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: *Swordfish, shark, king mackerel, tilefish, and tuna steak* **(Hg)**

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 and shellfish from the closed areas of New Bedford Harbor* **(PCB)**

Do Not Eat: *Lobster tomalley* **(PCB)**

*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 Massachusetts Department of Public Health, Bureau of Environmental Health at 617-624-5757.

In addition to these statewide fish advisories, the MA DPH periodically (every one to three years) updates their **Freshwater Fish Consumption Advisory List**. The most recent list was made available in August 2013 (MA DPH 2013). This list provides specific consumption advice for individual water bodies that is to be considered in addition to the statewide advisories (MA DPH 2009). This list identifies the waterbody, the town(s), the fish consumption advisory language, and the hazard (see http://www.mass.gov/dph/fishadvisories). MassDEP analysts assess waterbodies that have site-specific fish consumption advisories as impaired due to the hazard identified on the MA DPH list.

Background/context
MassDEP DWM Fish Toxics Monitoring Program (MassDEP 2010c)

"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."

According to Grubbs and Wayland (2000) "For purposes of determining whether a waterbody is impaired and should be included on a section 303(d) list, EPA considers a fish or shellfish consumption advisory…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."

The assessment of the *Fish Consumption Use* is made using the most recent fish consumption advisory lists issued by the MA DPH Bureau of Environmental Health Assessment (MA DPH 2012, MA DPH 2013). Because of the statewide advisories that affect both fresh and estuarine waters in Massachusetts no surface waters can be assessed as support for the *Fish Consumption Use*. Where a site-specific advisory is in place (i.e., the waterbody is on the MA DPH Freshwater Fish Consumption Advisory List) the *Fish Consumption Use* is assessed as impaired. If no site-specific advisory is in place the *Fish Consumption Use* is not assessed. In the few waterbodies where fishing is not allowed but fish have tested high for mercury, MA DPH has removed them from their list. MassDEP analysts will continue to assess these waters as impaired until such a time as the concentration of mercury in the fish tissue meets standards (0.3 ppm or less). The guidance used to assess the *Fish Consumption Use* is summarized below.

Fish Consumption Use Assessment

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 2006). For the purpose of assessment and 305(b)/303(d) Integrated List 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*. In 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 2006).

Use Assessment 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*".

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 2006), 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 Sanitation and Management Overview (MA DFG undated)

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 all 1,745,723 acres 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 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. Each year water samples are collected at 2,320 stations in 294 growing areas in Massachusetts' coastal waters at a minimum frequency of five times while open to harvesting. 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.

***MarineFisheries* Shellfish Growing Area Classifications (USFDA 2009)**

Approved - *"...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."*

Conditionally Approved - *"...subject to intermittent microbiological pollution..." During the time the area is open, it is "...for harvest of shellfish for direct human consumption subject to local rules and regulations…" A conditionally approved area is closed some of the time due to runoff from rainfall or seasonally poor water quality. When open, shellfish harvested are treated as from an approved area."*

Restricted – *"…area contains a "limited degree of pollution." It is open for "harvest of shellfish with depuration subject to local rules and state regulations" or for the relay of shellfish. A restricted area is used by DMF for the relay of shellfish to a less contaminated area."*

Conditionally Restricted - *"...subject to intermittent microbiological pollution..." During the time area is restricted, it is only open for "the harvest of shellfish with depuration subject to local rules and state regulations." A conditionally restricted area is closed some of the time due to runoff from rainfall or seasonally poor water quality. When open, only soft-shell clams may be harvested by specially licensed diggers (Master/Subordinate Diggers) and transported to the DMF Shellfish Purification Plant for depuration (purification)."*

Prohibited – "*Closed for harvest of shellfish*."

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 2016 reporting cycle the Shellfish Growing Areas GIS datalayer was dated 8 January 2014. The guidance used by MassDEP analysts to assess the *Shellfish Harvesting Use* is summarized below. Shellfish growing areas under administrative or management closures are not assessed (see note below).

Shellfish Harvesting Use Assessment

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 2016 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 2006). 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 Assessment Decision Making Process:

Aesthetic observations (Rivers, Lakes, 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) The visual presence of planktonic blooms/mats/scums (particularly bluegreens) are associated with aesthetically objectionable conditions. Depending on the severity of a bloom, water could range from appearing slightly colored to resembling pea soup or green paint. Additionally, the MA DPH (undated) also recommends 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 can be found online at (http://www.mass.gov/eohhs/docs/dph/environmental/exposure/protocol-cyanobacteria.pdf). Waterbodies with greater than 40% percent cover of algae (filamentous green) may 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 green 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 use of the waterbody) is generally considered to be impaired (i.e., excess algae growth).

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, but they are part of a diverse, naturally-occurring community. These cases do not represent 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.

Macroalgae (Estuaries) No current guidelines developed.

Aesthetics Use Assessment

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), Secchi disk transparency < 4 feet at least twice during survey season.

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 2006). For purposes of 305(b) reporting the "bathing season" each year is defined as 1 April to 15 October.

Use Assessment Decision Making Process:
The assessment of the *Primary Contact Recreational Use* is based on sanitary (i.e., bacteria), safety (e.g., Secchi depth) considerations, and/or aesthetics of the waters. MassDEP analysts assess this use as support when sanitary, safety, and aesthetic (i.e., desirability) conditions are suitable (e.g., low bacteria densities, low turbidity, infrequent beach closures/postings) and when aesthetics are good (e.g., narrative aesthetics criteria are met – see *Aesthetics Use* assessment guidance for details). While the current bacteria criteria for Massachusetts surface waters include both a geometric mean and a single sample maximum, the assessment decisions are based on whether or not the geometric mean of bacteria samples collected within the "bathing season" meet the criterion for primary contact recreation (i.e., *E. coli* and/or *Enterococci* bacterial indicators for Class A, B, SA, SB waters) (MassDEP 2006).

Bacteria Standards for Recreation (EPA 2003)

"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 in the 1986 Ambient Water Quality Criteria for Bacteria document (both for fresh waters, enterococci for marine waters). The standards are defined as a concentration of the indicator above which the health risk from waterborne disease is unacceptably high".

E. coli bacteria	*Enterococci* bacteria
Geo mean ≤126 colonies/100 ml Class A, B	Geo mean ≤33 colonies/100 ml Class A, B Geo mean ≤35 colonies/100 ml Class SA, SB

[Note: Single sample maximum bacteria criteria are also in the SWQS, however, the geometric mean criterion is considered by MassDEP analysts to be a more robust and appropriate measure for making the *Primary Contact Recreational Use* assessment decision, while the single sample maximum value is more appropriate for determining the need to close beaches because of an immediate risk.]

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, Estuaries)
It should be emphasized here that, because of the narrative aesthetics criteria, which are applicable to all surface waters (see *Aesthetics Use* assessment 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, 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. 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 DWM-WPP's external data validation procedures and, when approved, can also be utilized for assessment decisions.

The geometric mean of either *E. coli* and/or *Enterococci* data (minimum of five or more samples) during each "bathing season" (1 April through 15 October) is calculated for each sampling station/site by year. The geometric mean is then compared directly to the SWQS (provided above). Geometric mean calculation used the Method Detection Limit (MDL) and the Upper Quantification Limit (UQL) for "<MDL" and ">UQL" results, respectively; however, the geometric mean is flagged when an MDL or UQL is used. It should be noted here that if a UQL is used to calculate the geometric mean, the result can be utilized to make a decision of impairment but not a decision of support since the actual count is not known. [Note: An occasional exception will be made that allows for an assessment decision to be based on a geometric mean of only four samples.]

NEW FOR 2016 – Presence of Active CSO discharges (Rivers, Lakes, 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 *Primary Contact Recreational Use.*

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"*.

Risk Assessment (Rivers, Lakes, Estuaries) 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 respiration. 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.

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 2014a) and, approximately every two years, provides MassDEP analysts with a copy of their database (MA DPH 2014b). 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 current exception for the 2016 reporting cycle 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 purposes of the analysis for the 2016 reporting cycle, which included beach posting data from 2005 through 2013, postings due to the 2011 tropical cyclones "Bob" and "Irene" were excluded from the calculations because they were preemptive severe weather postings and not based on bacteria sampling. The pathogen indicator used for marine beach monitoring as well as the DCR fresh water beach monitoring (the rare exception being DCR beaches sampled by local municipalities) is *Enterococci* bacteria.

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 to the more recent years of posting data by the MassDEP analyst when an improvement or decline in posting at a beach occurred. Data for multiple beaches located along the shoreline of an AU that may lead to conflicting assessment decisions are handled on a case-by-case basis by 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 DMF Shellfish Growing Area Classification is "Approved" (MA DFG 2014). However, when the shellfish classification is anything less than "approved" no use assessment determination for the *Primary Contact Recreational Use* can be made.

Beaches Bill (MA DPH 2014a): *"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 a 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."*

Primary Contact Recreational Use Assessment

Use is Supported		Use is Impaired	
Rivers, Lakes	***Estuaries***	***Rivers, Lakes***	***Estuaries***
No aesthetic use impairment, Geo mean bacteria meets criterion, Secchi disk transparency ≥4 feet, Beach Postings at DCR freshwater beaches generally ≤10% season	No aesthetic use impairment, Geo mean bacteria meets criterion, Beach Postings generally ≤10% season, DMF "Approved" Shellfish Growing Area Classification	Aesthetic use impairment, Geo mean bacteria exceeds criterion, risk calculation exceeds hazard threshold for contaminant of concern, Secchi disk transparency < 4 feet at least twice during survey season, Beach Postings at DCR beaches often >10% season Presence of CSO outfall in waterbody without an approved variance	Aesthetic use impairment, Geo mean bacteria exceeds criterion , Beach Postings often >10% 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* assessment decisions.

Use Assessment Decision Making Process:
Similar to the *Primary Contact Recreational Use* assessment 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. While the current bacteria criteria for Massachusetts surface waters include both a geometric mean and a single sample maximum, the assessment decisions are based on whether or not the geometric mean of bacteria samples collected meet the following criteria for *Secondary Contact Recreation* (i.e., *E. coli* and/or *Enterococci* bacterial indicators for Class C, SC waters) (MassDEP 2006):

E. coli bacteria	*Enterococci* bacteria
Geo mean ≤630 colonies/100 ml applies to all inland freshwaters	Geo mean ≤175 colonies/100 ml applies to all coastal/marine waters

[Note: While single sample maximum bacteria criteria are also ascribed in the SWQS, they are utilized for making short-term closure/posting decisions. The geometric mean criterion is considered by MassDEP analysts to be a more robust and appropriate measure for making the *Secondary Contact Recreational Use* assessment decision.]

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, Estuaries) It should be emphasized here that because of the narrative aesthetics criterion, which is applicable to all surface waters (see *Aesthetics Use* assessment 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, Estuaries) For freshwater AUs (rivers and lakes) the primary source of bacteria data is the results of the DWM-WPP's water quality surveys. The validated (quality-assured) bacteria data from these surveys are usually published by the MassDEP in technical memoranda/reports. 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.

The geometric mean of either *E. coli* and/or *Enterococci* data (minimum of five sampling events) each year is calculated for each sampling station by year. The results are then compared directly to standards (provided above). [Note: Geometric mean calculations included the Method Detection Limit (MDL) and the Upper Quantification Limit (UQL) for "<MDL" and ">UQL" results, respectively; however, the geometric mean is flagged when an MDL or UQL is used. It should be noted here that if a UQL is used to calculate the geometric mean, the result can be utilized to make an impairment decision but not a decision of support since the actual count is not known.]

Presence of Active CSO discharge (Rivers, Lakes, 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.*

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 DMF Shellfish Growing Area Classification is "Approved" (MA DFG 2014). However, when the shellfish classification is anything less than "approved" no use assessment determination for the *Secondary Contact Recreational Use* can be made.

Secondary Contact Recreational Use Assessment

Use is Supported		Use is Impaired	
Rivers, Lakes	***Estuaries***	***Rivers, Lakes***	***Estuaries***
No aesthetic use impairment, Geo mean bacteria meets criterion, Beach Postings at DCR freshwater beaches generally <u><</u>10% season	No aesthetic use impairment ,Geo mean bacteria meets criterion, Beach Postings generally <u><</u>10% season, DMF "Approved" Shellfish Growing Area Classification	Aesthetic use impairment, Geo mean bacteria exceeds criterion, Presence of CSO outfall in waterbody without an approved variance	Aesthetic use impairment, Geo mean bacteria exceeds criterion , 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. The EPA maintains lists of available cause codes (http://iaspub.epa.gov/apex/waters/f?p=ASKWATERS:CAUSE_LUT:0::::P4_OWNER:ATTAINS) and source codes (http://iaspub.epa.gov/apex/waters/f?p=ASKWATERS:SOURCE_LUT:16678150255726::::P4_OWNER:ATTAINS) which are available to states choosing to store assessments in the ADB.

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 assessment guidance. As an example, Figure 3 illustrates the decision process for identifying whether nutrient enrichment is present in lakes and, if so, the causes of impairment.

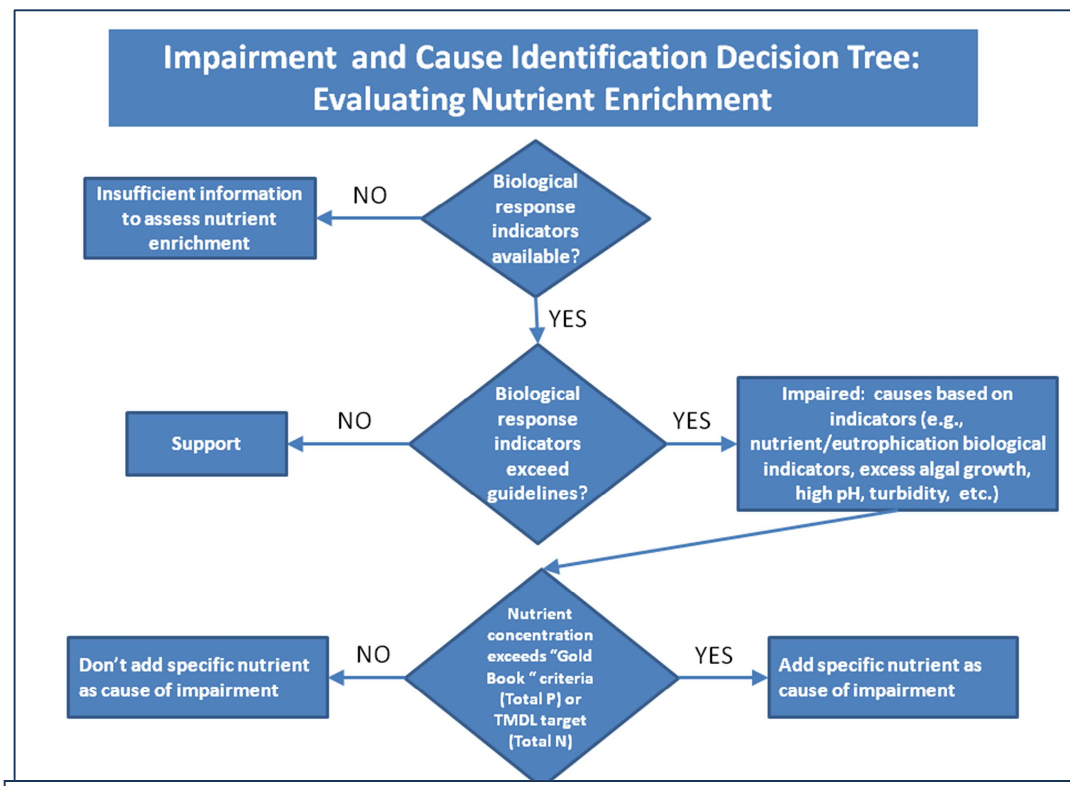


Figure 3. Impairment and cause identification decision tree for evaluating nutrient enrichment in lakes.

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.

V. 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 *Integrated List of Waters* report. The *Integrated List of Waters* report 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 assessment 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 assessment 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 assessment and listing cycles unless new monitoring information results in a change in their assessment 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. These are 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. 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 list must be formally approved by the EPA.

The Assessment Database (ADB)

The EPA-developed Access database, the ADB (Version 2.3.1), is a relational database designed for tracking water quality assessment decision data, including use attainment status and causes and sources of impairment. The ADB was designed to make the assessment and listing process accurate, straightforward and user-friendly for states, tribes and other water quality reporting agencies. Finally, the ADB automates the production of reports required by the CWA, which states submit to the EPA, thus reducing the burden of reporting under sections 305(b), 314 and 303(d). Massachusetts implemented the ADB for the 2010 listing cycle.

Currently in Massachusetts the ADB has been populated with basic AU information, use attainment decisions, causes and sources of impairment, and the TMDL status for the final 2014 *Integrated List of Waters* (303(d) list approved in February 2016) available at: http://www.mass.gov/eea/docs/dep/water/resources/07v5/14list2.pdf.

The Integrated List of Waters

The ADB is used to generate output files, which are then assembled into an *Integrated List of Waters* in a single, multi-part list. Each waterbody, or AU thereof, is listed in one of five categories (see Table 4 for brief description of each List Category). It should be reiterated here that the ADB and its precursor databases never contained an entry for every surface water or AU thereof in Massachusetts. Rather, waters represented are only those for which assessments of one or more designated uses were actually completed at some time in the past. As assessments are carried out in new waters they are added to the ADB, resulting in greater representation of Massachusetts' surface waters in future versions of the *Integrated List of Waters*. The MassDEP acknowledges that with the new multi-part listing format, all surface waters could be categorized whether or not they have ever been assessed. However, the time and resources are currently not available to add all of the surface waters in Massachusetts to the ADB. Therefore, it is acknowledged that many of the Massachusetts surface waters that have never been assessed are missing from the *Massachusetts Integrated List of Waters* report. By definition, they would all be listed as Category 3 (Not Assessed).

Table 4. Brief description of the five list categories of assessed waters used by MassDEP for the *Integrated List of Waters*.

The Integrated List of Waters -- categories of assessed waters	
Category 1	Support and not threatened for all designated uses
Category 2	Support for some uses and not assessed for others
Category 3	Insufficient information to make assessments for any uses
Category 4	Impaired for one or more uses, but not requiring the calculation of a Total Maximum Daily Load (TMDL); (impairment due to "pollution" such as low flow, habitat alterations or non-native species infestations).
Category 5	Impaired for one or more uses and requiring a TMDL (impairment due to pollutant(s) such as nutrients, metals, pesticides, solids and pathogens). This constitutes **the 303(d) List.**

List Categories 1 - 3
Integrated List categories 1-3 include those waters that are either unimpaired or not assessed with respect to their attainment of designated uses. Often insufficient data and information exist to assess all designated uses of any particular waterbody or AU. Furthermore, 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 described previously in the use assessment decision process. Waters listed in Category 2 were found to support the uses for which they were assessed, but other uses were not assessed. Finally, Category 3 contains those waters for which insufficient or no information was available to assess any uses. Waters for which assessments were determined to be insufficient for 303(d) listing were also included in Category 3.

List Category 4
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, since the MassDEP chooses to list 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. The CWA distinguishes between "pollutants" such as nutrients, metals, pesticides, solids and pathogens that all require TMDLs and "pollution" such as low flow, habitat alterations or non-native species infestations that do not require TMDLs. Non-pollutant stressors are marked with an asterisk in the *Integrated List of Water* report to distinguish them from pollutants requiring TMDLs. Waterbodies impaired solely by "pollution" 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 remains subject to the prevailing regulation governing the implementation of 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. On some occasions biological impairment is found but the cause of the impairment is unclear or unknown. In these cases the waterbody AU is placed, by default, into Category 5 until further evidence can better define the cause.

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, based on Section 303(d) of the CWA and the implementing regulations at 40 CFR 130.7, to develop a pollutant budget designed to restore the health of the impaired waterbody. The process of developing this pollutant budget, generally referred to as a Total Maximum Daily Load (TMDL), includes: identifying the cause (type of pollutant) and source (where the pollutant comes from), determining how much of the pollutant is from direct discharges (point sources) or indirect discharges (non-point sources), determining the maximum amount of the pollutant that can be discharged to a specific waterbody to meet water quality standards, and developing a 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 its Assessment and Total Maximum Daily Load Tracking and Implementation System (ATTAINS), which can be accessed at http://ofmpub.epa.gov/waters10/attains_state.control?p_state=MA. This system assigns a unique identification number to each approved TMDL. This number is included for reference in categories 4a and 5 of the *Massachusetts Integrated List of Waters* reports.

Waterbodies, or AUs thereof, can be removed from Category 5, or delisted, when a TMDL is approved by the EPA for that waterbody or AU. Waters with approved TMDLs move into Category 4a until it is determined that they are no longer impaired. In addition, there are some instances when a previously listed waterbody can be removed from the 303(d) List without calculating a TMDL; for example, when a new assessment reveals that the waterbody is now meeting all applicable water quality standards.

Spatial Documentation

Another component of consolidated reporting is the spatial georeferencing of the river, lake, and estuary AUs (as illustrated in Figure 4). MassDEP analysts maintain geospatial information for each waterbody AU stored in the ADB. 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 MassGIS1:25,000 hydrography based on USGS topographic maps. Additional on-screen editing was performed as needed using USGS topographic quadrangles and/or MassGIS color orthophotos as a base map for all river AUs. Occasionally National Oceanic and Atmospheric Administration nautical charts at several scales and the "Planimetry of Harbors for the 1984 305(b) Report" were utilized. Where definitions were still ambiguous after using these references, DWM-WPP staff members were consulted to define and geo-reference individual waterbody 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 the ADB can be related to each shape and spatially displayed. This allows mapping to display the *Massachusetts Integrated List of Waters* by their category (Figure 4) as well as the ability to obtain more detailed information for each AU (Figure 5). A table generated from the ADB 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. An additional tool was also developed to access this information without the need for ArcMap. The link to this interactive map can be found here: http://www.mass.gov/eea/agencies/massdep/water/watersheds/integrated-list-of-waters.html.

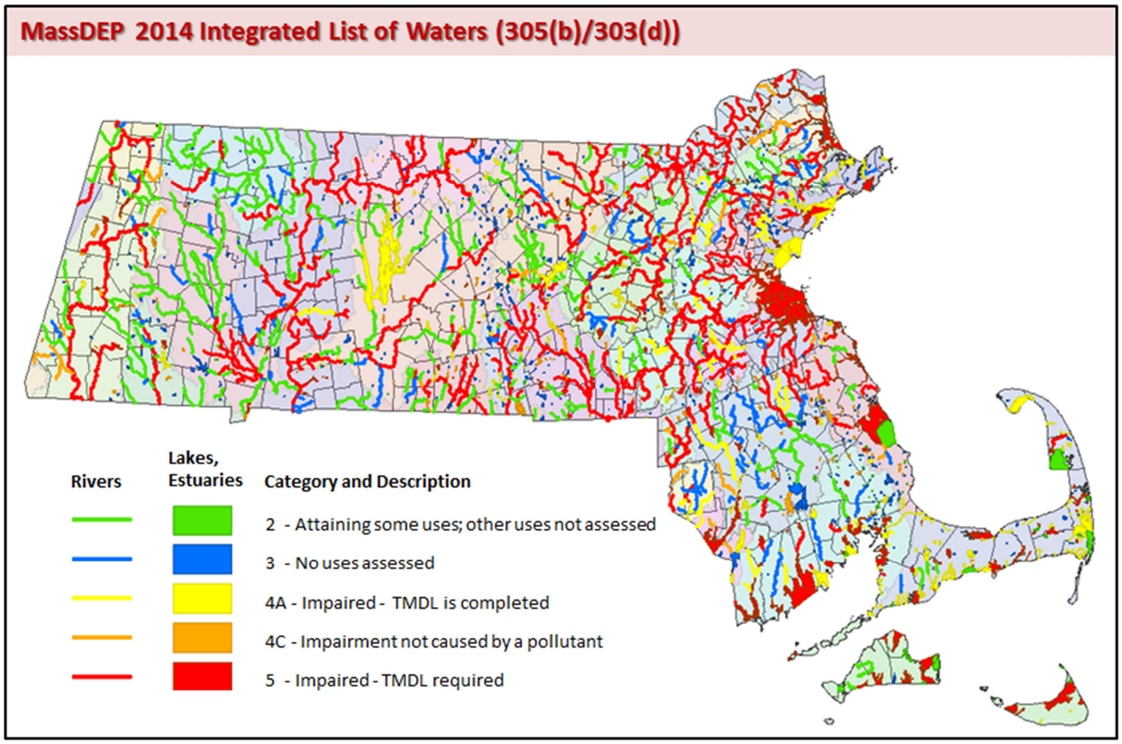


Figure 4. MassDEP geo-referenced waterbody assessment unit (AU) locations and 2014 listing category.

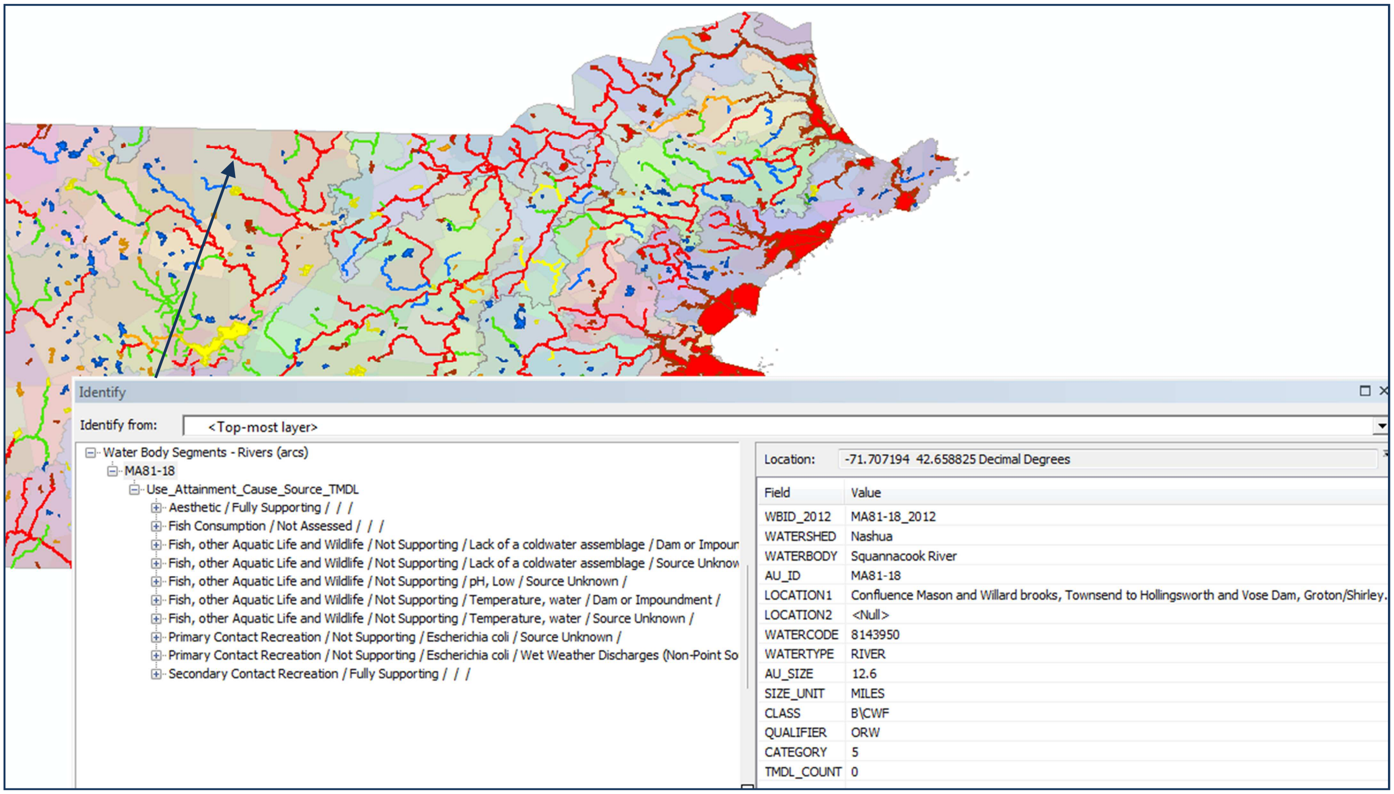


Figure 5. MassDEP Assessment Database (ADB) data associated with geo-referenced waterbody assessment unit (AU) locations.

The Massachusetts 2014 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 (http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/wbs2014.html). The datalayers for the 2016 Integrated List of Waters will be developed by MassDEP analysts once the 2016 303(d) list (Category 5 waters) is approved by EPA.

VI. REFERENCES

Armstrong, D.S., Richards[1], T.A., and Levin, S.B. 2011. *Factors influencing riverine fish assemblages in Massachusetts*. U.S. Geological Scientific Investigations Report 2011-5193. Reston, VA. (also available at http://pubs.usgs.gov/sir/2011/5193) Prepared in cooperation with the Massachusetts Department of Conservation and Recreation, the Massachusetts Department of Environmental Protection and the Massachusetts Department of Fish and Game[1].

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid bioassessment protocols for use in wadeable streams and rivers: periphyton, benthic macroinvertebrates, and fish,* second edition. EPA 841-B-99-002U.S. Environmental Protection Agency. Washington, DC.

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

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

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

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

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

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

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

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

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

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

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

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

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

EPA 1999. *1999 Update of Ambient Water Quality Criteria for Ammonia.* EPA-822-R-99-014. EPA Office of Water, Washington, D.C.

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

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

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

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

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

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

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

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

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

EPA. 2011. [Online]. *NPDES System Whole Effluent Toxicity*. U.S. Environmental Protection Agency. Retrieved 14 July 2011 from http://cfpub.epa.gov/npdes/wqbasedpermitting/wet.cfm

EPA 2013. *Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater 2013.* EPA-822-R-13-001. EPA Office of Water, Washington, D.C.

EPA. 2014. [Online]. *Compilation of EPA's Current National Recommended Water Quality Criteria*. U.S. Environmental Protection Agency retrieved 25 August 2014 from http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm [site last updated 1 August 2014].

FDA. 2003. G*uide for the Control of Molluscan Shellfish 2003 Revision.* [Online]. Updated 12 November 2004. United States Food and Drug Administration, Department of Health and Human Services, National Shellfish Sanitation Program. http://www.cfsan.fda.gov/~ear/nss2-toc.html. Accessed 2005 December 5.

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

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

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

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

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

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

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

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

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

MA DFG. 2014. *Designated Shellfish Growing Areas Datalayer – January 2014.* Published by MassGIS in October 2009. Massachusetts Department of Fish and Game, Division of Marine Fisheries, Boston, MA.

MA DFG. undated. [Online]. *Shellfish Sanitation and Management*. Retrieved 27 October 2011 from http://www.mass.gov/dfwele/dmf/programsandprojects/shelsani.htm

MA DPH. 2002. *105 CMR 445.000: Minimum Standards For Bathing Beaches, State Sanitary Code, Chapter VII* [Online]. Massachusetts Department of Public Health, Division of Community Sanitation Regulations and Statutes, Boston, MA. Retrieved 19 September 2002 http://www.mass.gov/eohhs/docs/dph/regs/105cmr445.pdf

MA DPH. 2007. *MDPH Guidelines for Cyanobacteria in Freshwater Recreational Waterbodies in Massachusetts*. Massachusetts Department of Public Health. Boston, MA [as cited in MassDEP 2010]

MA DPH. 2012. *A Guide to Eating Fish Safely in Massachusetts Revised May 2012.* Massachusetts Department of Public Health, Bureau of Environmental Health Assessment, Boston, MA. (guide available online @ http://www.mass.gov/eohhs/docs/dph/environmental/exposure/fish-eating-guide.pdf.)

MA DPH. 2013. *Freshwater Fish Consumption Advisory List – August 2013.* Massachusetts Department of Public Health, Bureau of Environmental Health Assessment, Boston, MA. (List available online @ http://www.mass.gov/eohhs/docs/dph/environmental/exposure/fish-consumption-advisory-list.pdf

MA DPH. 2014a. *Marine and Freshwater Beach Testing in Massachusetts Annual Report: 2013 Season*. Massachusetts Department of Public Health Bureau of Environmental Health Environmental Toxicology Program, Boston, MA.

MA DPH. 2014b. *Beaches Bill Reporting Database 2002 - 2013.* Massachusetts Department of Public Health, Environmental Toxicology Program, Boston, MA.

MA DPH. Undated. *Freshwater Algae Blooms: Contributing Factors and Health Concerns.* Poster [Online at http://www.mass.gov/eohhs/docs/dph/environmental/exposure/algae/ccnhc-poster.ppt] Massachusetts Department of Public Health, Bureau of Environmental Health, Boston, MA.

MassDEP. Undated. *Draft Sampling Plan for Year 2010 Periphyton Percent Cover and Biomass Monitoring in the Northeast Region Watersheds.* CN370.0. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

MassDEP. Unpublished. *Draft Phase I Phosphorus Guidance for the Restoration of Massachusetts Lakes, Rivers, and Streams* dated August 18, 2015. CN407.0. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

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

MassDEP. 2004. *Standard Operating Procedure Extracted Chlorophyll a (SM-10200 H) (USEPA Flourometric Method 445 and 445 with the Welschmeyer modification)*. CN 003.4. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

MassDEP. 2005a. *Quality Assurance Project Plan Benthic Macroinvertebrate Biomonitoring and Habitat Assessment*. CN226.0. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

MassDEP. 2005b. *A Water Quality Monitoring Strategy for the Commonwealth of Massachusetts*. CN203.0. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

MassDEP. 2005c. *Quality Assurance Program Plan Surface Water Monitoring & Assessment MADEP-Division of Watershed Management 2005-2009*. CN225.0, MS-QAPP-25 (Rev. #1). Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

MassDEP. 2006. *Massachusetts Surface Water Quality Standards (Revision of 314 CMR 4.00, effective December 29, 2006).* Massachusetts Department of Environmental Protection, Boston, MA.

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

MassDEP. 2007. *STANDARD OPERATING PROCEDURE Water Quality Monitoring In Streams Using Aquatic Macroinvertebrates* Revised November 2007. CN 039.2. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

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

MassDEP. 2010b. *Quality Assurance Program Plan Surface Water Monitoring & Assessment MassDEP-Division of Watershed Management 2010-2014*. CN365.0, MS-QAPP-27 (Rev. #1). Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

MassDEP. 2010c. *Quality Assurance Project Plan Fish Toxics Program*. CN096.0. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

MassDEP. 2011a. *Standard Operating Procedure Fish Collection Procedures for Evaluation of Resident Fish Populations (Method 003/11.20.95)*. CN75.1. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

MassDEP. 2011b. *Open files – ToxTD database retrievals*. Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA.

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

MassGIS. 2014. *DEP Eelgrass – 2013* [Online]. *MassDEP Eelgrass Mapping Project.* MassGIS (MA Office of Geographic and Environmental Information System, Executive Office of Energy and Environmental Affairs, Boston, MA). *Retrieved 7 July 2015 from* http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/massdep-eelgrass-project.html. Site last updated updated 23 September 2014 .

MassWildlife. 2014. *MDFW Fisheries Survey Database_29July2014.* Massachusetts Department of Fish and Game, Division of Fisheries & Wildlife, Westborough, MA.

Mattson, M.D., P.J. Godfrey, M.F. Walk, P.A. Kerr, and O.T. Zajicek. 1992. *Regional Chemistry of Lakes in Massachusetts.* (Paper No. 92059). Water Resources Bulletin, American Water Resources Association, Vol. 28, No. 6, December 1992.

Mattson, M.D., P.J Godfrey, R.A. Barletta, and A.Aiello. 2004 *Eutrophication and Aquatic Plant Management in Massachusetts. Final Generic Environmental Impact Report.* Edited by Kenneth J. Wagner. Massachusetts

Department of Environmental Protection, Division of Watershed Management, Worcester, MA and Massachusetts Department of Conservation and Recreation, Boston, MA.

NEIWPCC. 2007. *Northeast Regional Mercury TMDL Fact Sheet October 2007.* [Online]. New England Interstate Water Pollution Control Commission, Lowell, MA. Retrieved 23 January 2008 from http://www.neiwpcc.org/mercury/mercury-docs/FINAL%20Northeast%20Regional%20Mercury%20TMDL%20Fact%20Sheet.pdf.

Northeast States. 2007. *Northeast Regional Mercury Total Maximum Daily Load.* Connecticut Department of Environmental Protection, Maine Department of Environmental Protection, Massachusetts Department of Environmental Protection, New Hampshire Department of Environmental Services, New York State Department of Environmental Conservation, Rhode Island Department of Environmental Management, Vermont Department of Environmental Conservation, New England Interstate Water Pollution Control Commission. October 24, 2007.

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

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

Portnoy, J.W., M.G. Winkler, P.R. Sanford & C.N. Farris. 2001. *Kettle Pond Data Atlas: Paleoecology and Modern Water Quality.* Cape Cod National Seashore, National Park Service, U.S. Department of Interior. 119p.

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

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

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

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

US National Office for Harmful Algal Blooms. 2013. *Harmful Algae*. NOAA's Center for Sponsored Coastal Ocean Research website http://www.whoi.edu/redtide/. Accessed on June 25, 2015.

USFDA. 2009. [Online]. *National Shellfish Sanitation Program Guide for the Control of Molluscan Shellfish 2009, Section IV. Guidance Documents, Chapter 11. Growing Areas .03 Sanitary Survey and the Classification of Growing Waters.* Retrieved 28 October 2011 from http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/Seafood/FederalStatePrograms/NationalShellfishSanitationProgram/ucm053724.htm Page last updated 26 April 2011.

Walk, M.I., P.J. Godfrey, A. Ruby III, O.T. Zajicek, and M. Mattson. 1991. *Acidity Status of Surface Waters in Massachusetts*. (revised May 13, 1991). University of Massachusetts, Water Resources Research Center, Blaisdell House, and Department of Chemistry, Amherst, MA.

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

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

Zen, E., 1983. *Bedrock Geologic Map of Massachusetts*. Massachusetts Department of Public Works, Boston, MA 2 sheets, scale 2:25,000 [as cited in Mattson et al. 1992.]

APPENDIX A

Evaluation methods for natural condition

Temperature

Violations of temperature criteria will NOT be considered natural under 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). If the percentages fail to meet the criteria outlined in Table D1, 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).

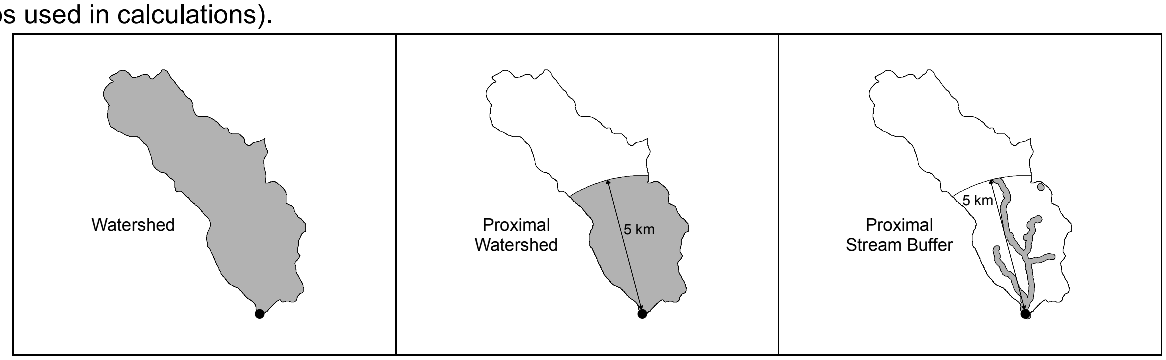


Table D1. Landscape criteria used to evaluate thermal excursions		
Land Cover	**Complete and Proximal Watersheds**	**Complete[2] or Proximal Stream Buffer**
Natural Land[1]	>80%	>90%[3]
Impervious Cover	<4%	<2%

[1]Includes forest, brushland/successional, wetland, and water.
[2]Watersheds <25 mi^2
[3]This is best professional judgment of DWM-WPP biologists

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

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 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 D2, 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 D2. Landscape criteria 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 forest, brushland/successional, wetland, and water.
[2]Watersheds <25 mi^2
[3]This is best professional judgment of DWM-WPP biologists

References

Mattson, M.D. A. Haque and R. Isaac. 2007. *Nutrient criteria: The Influence of wetlands on Dissolved Oxygen and other water quality variables in Massachusetts streams*. CN 264.0 MassDEP Division of Watershed Management, Worcester, MA

Schiff, R., and G. Benoit. 2007. *Effects of Impervious Cover at Multiple Spatial Scales on Coastal Watershed Streams*. Journal of the American Water Resources Association (JAWRA) 43(3):712-730. DOI: 10.1111/j.1752-1688.2007.0057.x

Waite, I.R., S. Sobieszczyk, K.D. Carpenter, A.J. Arnsberg, H.M. Johnson, C.A. Hughes, M.J. Sarantou and F.A Rinella. 2006. *Effects of Urbanization on stream ecosystems in the Willamette River Basin and surrounding area, Oregon and Washington*. USGS Scientific Invest. Report. 2006-5101-D.

Weiskel, P.K., Brandt, S.L., DeSimone, L.A., Ostiguy, L.J., and Archfield, S.A., 2010, *Indicators of streamflow alteration, habitat fragmentation, impervious cover, and water quality for Massachusetts stream basins*: U.S. Geological Survey Scientific Investigations Report 2009–5272, 70 p., plus CD–ROM. (Also available at http://pubs.usgs.gov/sir/2009/5272

APPENDIX B

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
Umbra limi	Central Mudminnow	CM	Umbridae		T	W
Osmerus mordax	Rainbow smelt	RS	Osmeridae		I	C

Scientific Name	Common Name	Fish Code	Family	Habitat Use Classification[1]	Tolerance Classification[2]	Temperature Classification[3]
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	Aquatic Life/ Recreation/	USEPA, 2000/2001	>2.43-2.90 ug/l (25^{th} Percentile range within Massachusetts Ecoregions)

Waterbody Type	Nutrient Enrichment Indicator	Recommended Indicator Screening Guideline(s)	Water Use Goal Potentially Impacted	Reference	Literature Thresholds
			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

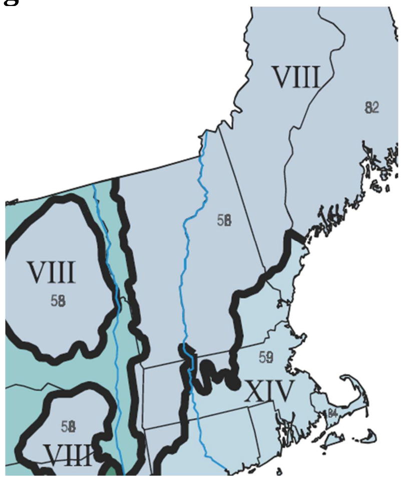
Over the last decade a wealth of research has been generated to help identify appropriate nutrient criteria for protection and restoration of water resources. MassDEP reviewed EPA's technical support and guidance documents, scientific literature and the extensive surface water sampling data collected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

3.1 USEPA General Nutrient-Related Background Information

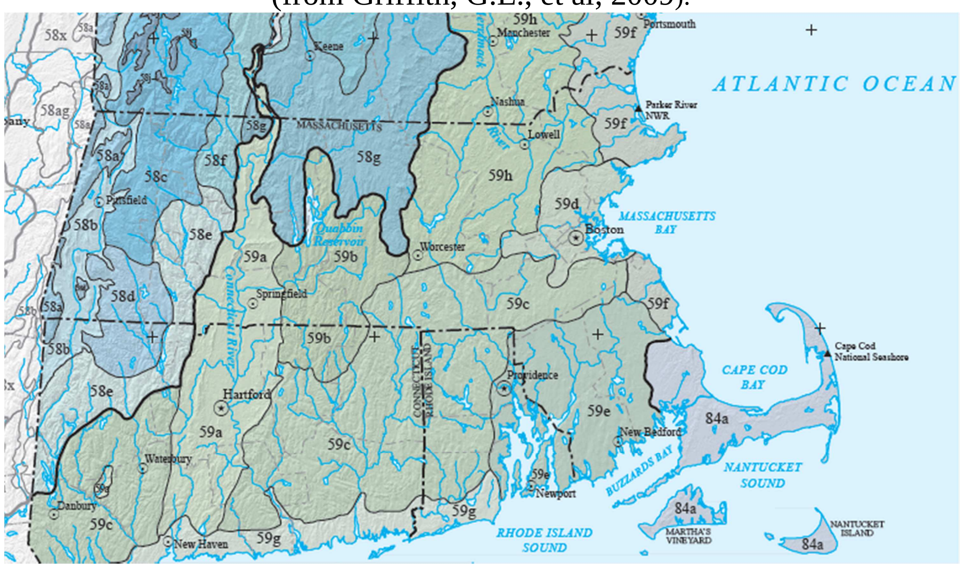
The United States Environmental Protection Agency (USEPA) has published technical support documents to help guide efforts for numeric nutrient criteria development by waterbody type (e.g., estuarine and coastal waters, lakes and reservoirs, rivers and streams and wetlands). In addition USEPA conducted 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.

Figure 1

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: $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$. 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.

(5) **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.

References

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

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

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

Biggs, B. J. F. 2012. Personal communication e-mail dated November 4, 2012. B.J.F. Biggs to J. Beskenis.
Dodds, W. K., V. H. Smith, and B. Zander. 1997. Developing nutrient targets to control benthic chlorophyll levels in streams: a case study of the Clark Fork River. *Wat. Res*. Vol. 31 No 7. pp. 1738-1750.

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

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

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

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

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

Hutchinson, G.E. 1957. *A Treatise on Limnology*, v. 1. Geography, Physics and Chemistry. Wiley. 1015p.
Jones, Bill. 2011. *Oxygen—The Most Important Water Quality Parameter? The Water Column*, a Technical Publication of the Indiana Department of Environmental Management (IADEM). Vol. 23, No 1. Spring 2011.

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

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

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

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

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

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

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

MassGIS. 2012. *MassGIS Data-Dams.* Database Compiled by the Massachusetts Office of Dam Safety (ODS), February 2012. www.mass.gov/mgis/.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

APPENDIX D

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

---

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 $\leq$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 MA SWQS uses the following phrase to define the temperature regime for Cold Water:

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

Note the term "generally". 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 = ≤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

There are a few notes to keep in mind related to the Toxic Metals.

1. *The following definitions are given by EPA for their Criteria Maximum Concentration and Criterion Continuous Concentration: The Criteria Maximum Concentration (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 Criterion Continuous Concentration (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 are the 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.*
2. *According to EPA's website there was a "*Notice of Intent to Revise Aquatic Life Criteria for Copper, Silver, Lead, Cadmium, Iron*.*

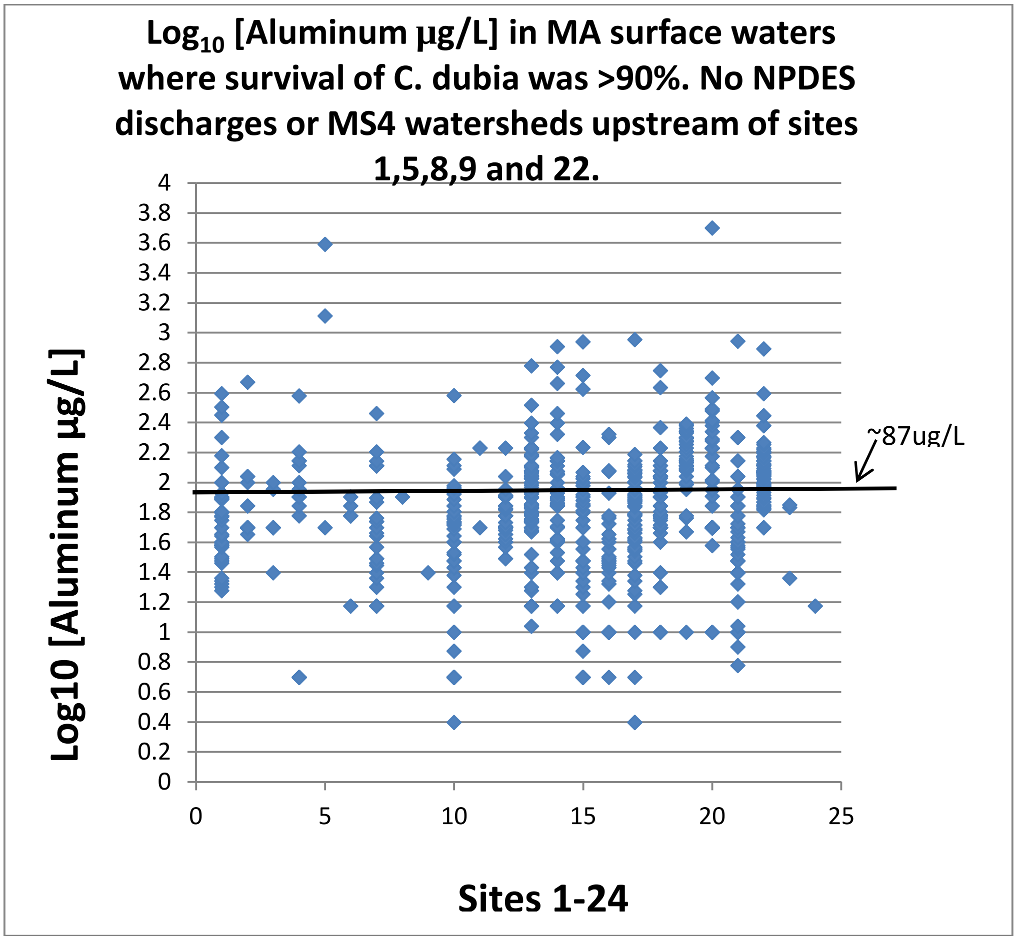
The assumption that the concentration associated with a grab sample is representative of a 4-day chronic condition is extremely conservative. While MassDEP analysts are comfortable using grab samples for the assessment of acute metals toxicity, we are not comfortable making an impairment decision on chronic metals toxicity but rather use these data as a screening measure to identify the need for more detailed investigations. Some of the reasons for this approach are outlined below using Aluminum as an example.

1. Aluminum concentrations are higher than EPA chronic criteria in many waters and sensitive organisms in certain of these waters appear to be unaffected. EPA developed its aluminum criteria from evaluations including toxicity tests of a large number of aquatic species. Of all the warmwater species evaluated, largemouth bass (eggs and larvae) was the obligate freshwater species with representation in the northeast region that was most sensitive to aluminum. The reader should be aware that EPA performed a large number of analyseis of aluminum toxicity, and collated information on aluminum toxicity from the literature and published that information in the 1988 "White Book" for aluminum (Ambient Water Quality Criteria for Aluminum, 1988). In this 1988 document, EPA developed its recommendations for aluminum criteria and those same criteria have been used in subsequent criteria documents published by EPA. Based on the data EPA presented in the 1988 criteria document for largemouth bass eggs and larvae, these life stages are expected to have a "NOEC" (No-Observable Effect Concentration) for aluminum very near, or even lower than, the EPA chronic criterion of 87 ug/L as a 4-day average. The 8-day average EC50 (measured as 50% death and deformity to the exposed organisms) concentration for largemouth bass eggs and larvae is reported as 170 ug/L. Based on the fact that No-Effect concentrations must be lower than the no-effect concentration, and best professional judgment, MassDEP estimates that the No-Effect concentration for this exposure was 1/3rd to ½ the LC50 value (i.e., ~57-85 ug/L). Thus, the largemouth bass should be useful as a sensitive "indicator organism" for aluminum toxicity in warmwater streams.

Using the logic presented above, one would expect that if the EPA chronic criterion, which is most probably close to the NOEC for largemouth bass eggs and larvae, were useful as a tool to predict impairment of aquatic life use, regular exceedances of this criterion would effectively remove largemouth bass from waterbodies where this took place because the eggs and larvae of this species would have been exposed to levels much higher than the no-effect concentration. Largemouth bass are lentic spawners and are expected to spawn within impoundments of any rivers where they are found. However, largemouth bass are common in the Ten Mile River in southeastern MA where the aluminum concentrations often exceed the 87 ug/L chronic criterion.

2. The background concentrations of aluminum in MA waters are often higher than the EPA chronic criterion. MassDEP collated information from the MassDEP DWM-WPPs Toxicity Testing Database (ToxTD). The state of MA has been requiring NPDES permittees that are conducting effluent toxicity tests to analyze a number of constituents in water (the "upstream diluents") that is collected upstream of the discharge and later used in developing the effluent dilution series in the toxicity test. These upstream diluents are collected as grab samples. We compared these data to EPA's chronic criterion (87 ug/L) to better understand background concentrations of aluminum in MA waters.

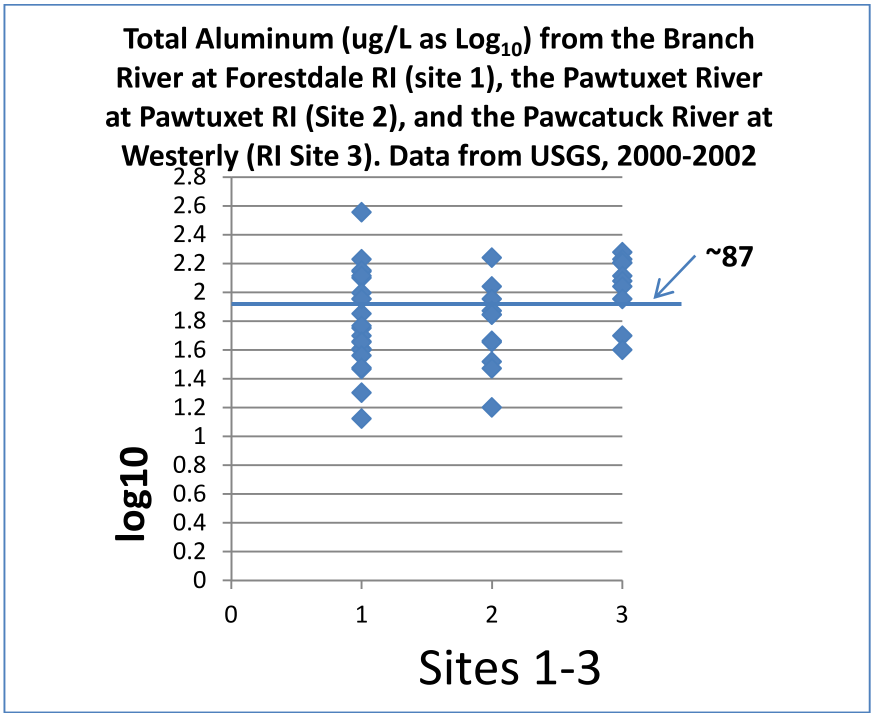
In the figure below, we present total aluminum concentrations from sites for which survival of *Ceriodaphnia dubia* was 90% or greater (the EPA test acceptability criterion for test validity based on survival of test organisms used for dilution water in a 48-hr test) at the end of 48-hr. exposures to these waters. Please note that none of these samples was collected with "clean" techniques.[1] We selected sites that had few or no NPDES discharges upstream. Many of the sites also had contributing watershed areas upstream that included MS4 communities. Note that sites 1, 5, 8, 9 and 22 in the graphic below had neither NPDES discharges nor MS4 contributing watersheds upstream.



Note that the range of aluminum concentrations in the five "clean" sites is not that different from the range of concentrations at other sites. We conclude from these data that background levels of total aluminum in MA waterbodies often exceed 87 µg/L.

---

[1] Although *Ceriodaphnia dubia* used in these chronic toxicity test evaluations were not significantly affected by the "upstream waters" characterized below, we do not mean to suggest that *C. dubia* is especially sensitive to aluminum (see the toxicity test results for this species in the 1988 EPA Aluminum Criteria document). However, we did not want to confuse the aluminum issue by presenting data from waters that were found to be toxic to this commonly-used test species. The reader should also know that data were retrieved from chronic tests that may last 7-9 days. Unfortunately for the purposes of evaluating aluminum levels in upstream diluents, the chronic test methods require changes in the test medium over the course of the test; each of these changes requires the collection of both a new effluent sample and a new diluent sample. MassDEP requires that permittees only conduct chemical analyses on the first effluent and diluents (upstream) water samples collected in the chronic test. Thus, we have no knowledge of the chemical concentrations in waters collected and used as "renewals" (two such renewals occur) of effluent and diluent during the chronic test. As a result, the 48-hr. survival information is pertinent only to the constituent concentrations found in the first effluent and diluents samples used in these tests and report. As such, we report below only on data from the 1st sample collection used in the toxicity tests.



3. There are complex and synergistic interactions among chemical constituents of waters that alter the toxicity of aluminum but have not been accounted for in EPA's ambient water quality criteria for aluminum. While there are certain factors which are now known to alter the toxicity of aluminum in surface waters, many of the studies to support this contention were not available to EPA when they developed the 1988 aluminum criteria document. Aluminum toxicity is influenced by at least four variables: temperature, DOC, hardness and pH. Gensemer and Playel (1999; see these author's 137-pg. document on aluminum chemistry and toxicology at: http://www.tandfonline.com/doi/pdf/10.1080/10643389991259245) provide a review of the complex chemical interactions between aluminum and these four variables, as well as a review of aluminum toxicology with regard to these four variables. Although Gensemer and Playel's paper is over ten years old, it clearly demonstrates why, in many cases, exceedances of the EPA chronic criterion would not result in impairment to aquatic life. It is clear from this review that aluminum toxicology is complex and that the reduction of the complexity to a single "safe" number to fit all situations is not justified.

4.Other states do not use the EPA chronic aluminum criterion. EPA has recognized that there are problems with the chronic criteria for aluminum and has allowed at least two states (West Virginia and New Mexico) to alter their chronic criteria for certain waterbodies.

Based on the facts that: 1) largemouth bass, shown by EPA to be sensitive to aluminum at levels near or below the 87 ug/l chronic value are found in waters where aluminum levels greatly exceed that value; 2) natural background levels of aluminum in MA waters are sometimes well above the chronic EPA criterion; 3) temperature, pH and organic carbon are all known to interact with aluminum and change its toxicity to aquatic organisms but hese were not factored into the ambient water quality criteria for aluminum; 4) EPA has already allowed other states to alter their chronic criteria for aluminum, MassDEP concludes that to use the EPA chronic criterion for aluminum in making impairment decisions will result in poor decisions on the use of public funding to restore aquatic life uses.

MassDEP notes that EPA is also considering revising criteria for several other metals including copper, silver, lead cadmium and iron. Because of this, and because of the fact that MassDEP only collects "grab" samples for its metal analyses, we feel that we are unable to make well-informed impairment decisions relative to the chronic water quality criteria for metals at this point in time.

WPP uses an Excel spreadsheet (CN101.5 SOP_MetalsCriteriaCalculations.xls July 2013) with hardness-dependent formulas for certain metals embedded to calculate criteria. Toxic Units are developed using results from these calculations. Table 1 below is an example spreadsheet showing criteria at a hardness of 10 mg/l.

Table 1. Freshwater Metals Aquatic Life Criteria (as dissolved fraction, unless otherwise stated) (for illustrative purposes only criteria shown at a hardness of 10 mg/l as $CaCO_3$)				Use best-available hardness data (no lower limit)	HARDNESS (mg/l as CaCO3)=	2.497*Ca + 4.118*Mg	
Jul-13				HARDNESS max=400	*Example:*	**Ca (mg/l)**	**Mg (mg/l)**
italics = not hardness dependent						1.9	1.2
via USEPA "National Recommended Water Quality Criteria--Correction (EPA 822-Z-99-001), April, 1999; and subsequent updates					**HARDNESS=**	9.8	
Step1: 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) necessary for total-to-dissolved criterion	CCC Conversion Factor (CF) necessary for total-to-dissolved criterion	notes	
	mg/l as CaCO3	*Acute (1 hour average not to be exceeded more than once in three years unless otherwise noted)*	*Chronic (4-day average not to be exceeded more than once in three years unless otherwise noted)*	*acute*	*chronic*		
Cadmium	10	**0.21 (24 hour average)**	**0.05**	1.040	1.005		
Chromium III	10	**86.44**	**11.24**	0.316	0.860		
Copper	10	**1.54**	**1.25**	0.960	0.960	based on 1995 updated copper criteria, not 2007 revision	http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/pollutants/copper/upload/2009_04_27_criteria_copper_2007_criteria-full.pdf
Lead	10	**4.91**	**0.19**	1.127	1.127		
Nickel	10	**66.75**	**7.41**	0.998	0.997	CMC=470 @100hardness (EPA)	
Silver	10	**0.06**	**NA**	0.850	--		
Zinc	10	**16.66**	**16.79**	0.978	0.986	CMC and CCC=120 @100hardness (EPA)	
Arsenic (as total)	*NA*	***340***	***150***	*1.000*	*1.000*	as total arsenic (use CF to derive diss. criterion)	
Mercury (as total)	*NA*	***1.4***	***0.77***	*0.850*	*0.850*	as total mercury (use CF to derive diss. criterion)	
Chromium VI	*NA*	***16***	***11***	*0.982*	*0.962*	as dissolved metal	
Selenium (as total)	*NA*	***see note 7***	***5 (4.61 dissolved)***	*0.996*	*0.922*	as total selenium; CFs from GLI (not current); see Note 7	
Aluminum (as total)	*NA*	***750***	***87***	--	--	pH 6.5-9.0; as total metal	

L There are three major reasons why the use of Water-Effect Ratios might be appropriate.
The value of 87 µg/l is based on a toxicity test with the striped bass in water with pH = 6.5–6.6 and hardness <10 mg/l. Data in "Aluminum Water-Effect Ratio for the 3M Plant Effluent Discharge, Middleway, WestVirginia" (May 1994) indicate that aluminum is substantially less toxic at higher pH and hardness, but the effects of pH and hardness are not well quantified at this time.
In tests with the brook trout at low pH and hardness, effects increased with increasing concentrations of total aluminum even though the concentration of dissolved aluminum was constant, indicating that total recoverable is a more appropriate measurement than dissolved, at least when particulate aluminum is primarily aluminum hydroxide particles. In surface waters, however, the total recoverable procedure might measure aluminum associated with clay particles, which might be less toxic than aluminum associated with aluminum hydroxide.
EPA is aware of field data indicating that many high quality waters in the U.S. contain more than 87 g aluminum/L, when either total recoverable or dissolved is measured.

Intentionally left blank

APPENDIX F

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 and 2014 integrated reporting cycles.

AQUATIC LIFE USE IMPAIRMENT CAUSES AND SOURCES			
Aquatic Life Use **Assessment Indicators**	**Use is Impaired**	**Typical Cause(s) of Impairment**	**Typical Source(s) of Impairment**
BIOLOGICAL MONITORING INFORMATION			
Benthic macroinvertebrate data	**Rivers** Moderately impaired/severely impaired RBP III analysis, slightly impaired with special conditions (e.g., hyperdominance by pollution tolerant sp.) as noted by DWM-WPP biologists **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*** No fish found or fluvial fish were absent or relatively scarce (few in number), 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 Eurasian Water Milfoil, *Myriophyllum spicatum* Zebra mussel, *Dreissena polymorph*	Introduction of Non-native Organisms (Accidental or Intentional) Source Unknown
Periphyton/algal blooms	**Rivers, Lakes, Estuaries** Frequent and/or prolonged algal blooms or growths of periphyton, cyanobacteria blooms result in advisories (recurring and/or prolonged), >25% cover noxious aquatic plants (e.g. *Lemna* sp.),	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)

AQUATIC LIFE USE IMPAIRMENT CAUSES AND SOURCES			
***Aquatic Life Use* Assessment Indicators**	**Use is Impaired**	**Typical Cause(s) of Impairment**	**Typical Source(s) of Impairment**
	periphyton cover within stream AU >40%		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 oxygen/saturation/pH, elevated chlorophyll *a*	Chlorophyll-a Excess Algal Growth Phosphorus (Total) pH, High Secchi disk transparency Turbidity 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
	Lakes Combination of indicators present: excessive visible nuisance algal blooms or macrophytes, low Secchi	Secchi disk transparency Chlorophyll-a Excess Algal Growth Phosphorus (Total)	Municipal Point Source Discharges Unspecified Urban Stormwater Internal Nutrient Recycling

AQUATIC LIFE USE IMPAIRMENT CAUSES AND SOURCES			
***Aquatic Life Use* Assessment Indicators**	**Use is Impaired**	**Typical Cause(s) of Impairment**	**Typical Source(s) of Impairment**
	disk transparency, high oxygen super-saturation, elevated pH elevated chlorophyll <u>a</u>	Turbidity Aquatic Plants (Macrophytes) Secchi disk transparency Dissolved oxygen saturation Nutrient/Eutrophication Biological Indicators	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 metabolites DDD and DDE), Chlordane, PAHs, TCDD in Fish Tissue	Contaminated Sediments Inappropriate Waste Disposal Releases from Waste Sites or Dumps Source Unknown

* Asterisk indicates there are many possible contaminants that belong to these classes of pollutants, the cause of impairment however is the individual pollutant (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* Assessment	**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* Assessment	**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* Assessment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Aesthetically objectionable conditions frequently observed (e.g., blooms, scums, water odors, discoloration, taste, visual turbidity highly cloudy/murky, excess algal growth (>40% filamentous cover in rivers, nuisance growths >25% dense/very dense macrophytes or blooms in lakes), Secchi disk transparency < 4 feet at least twice during survey season.)	Excess Algal Growth Debris/Floatables/Trash Foam/Flocs/Scum/Oil Slicks Turbidity 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 Point Source Discharges Unspecified Urban Stormwater Municipal (Urbanized High Density Area) Combined Sewer Overflows Internal Nutrient Recycling Discharges from Municipal Separate Storm Sewer Systems (MS4) Introduction of Non-native Organisms (Accidental or Intentional) Source Unknown

PRIMARY CONTACT RECREATIONAL USE IMPAIRMENT CAUSES AND SOURCES			
Indicator for *Primary Contact Recreational Use* Assessment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Geometric mean bacteria above criterion, 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* Assessment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Geometric mean bacteria above criterion, 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