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DRAFT - Description of Nutrient Criteria for Class AA, A, B, and C Fresh Surface Waters (Chapter 583)

Cupsuptic River

MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION
17 State House Station | Augusta, Maine 04333-0017
www.maine.gov/dep

Maine Department of Environmental Protection
17 State House Station
Augusta, ME 04333-0017
http://www.maine.gov/dep/index.shtml
207-287-7688 or 1-800-452-1942 toll free

Author and Grant Manager
Tom Danielson

Nutrient Criteria Team
Linda Bacon, Angela Brewer, Beth Connors, Tom Danielson, Jeremy Deeds, Jeff Dennis, Jeanne DiFranco, Cindy Dionne, Brian Kavanah, Susanne Meidel, Rob Mohlar, Barry Mower, Brandy Piers, Don Witherill, and Gregg Wood

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1 - Introduction

Nutrients are essential to all plant and animal life, however too much nutrient inputs can have a negative impact on water quality. Whereas compounds such as mercury or dioxin are directly toxic to plant and animal life, nutrients such as phosphorus and nitrogen are required by plants and animals for growth through production of proteins and other essential organic compounds. Plants and animals cannot survive without them. People commonly add fertilizers containing phosphorus and nitrogen to gardens to increase plant growth. In a similar way, increasing the amount of phosphorus in a stream or lake can increase the growth of plants and algae. More plants and algae may usually mean more food for some animals that eat plants and algae. Also, it may mean more food for the fish and other predators that eat the plant and algae grazers.

Some nutrients in a lake, stream, or river can be a good thing, however too much nutrients can cause negative environmental impacts. For example, excess nutrients can cause blooms of floating algae or filamentous algae on the bottom of lakes, impoundments, streams, and rivers. Algal blooms, in turn, can cause large swings in the supply of oxygen available to fish and many other aquatic organisms. These large swings in oxygen supply can be accompanied by large swings in how acidic the water is. Blooms of filamentous algae can reduce habitat quality for fish and aquatic macroinvertebrates, which are animals without backbones that can be seen without magnification. In addition, algal blooms can cause fish kills by removing oxygen from the water, thereby suffocating the fish. Severe algal blooms dominated by cyanobacteria (blue-green algae) sometimes produce toxic chemicals called cyanotoxins that damage livers and nervous systems of many animals, including people.

The State of Maine's Water Classification System (38 M.S.R.A. §§ 464 – 470(H)) describes several classes of rivers and streams. Class AA is the most protective and Class AA waters must be "as naturally occurs". Class A waters also must be "as naturally occurs" but more permitted activities are allowed, such as dams and limited effluent discharges. Since AA and A have the same environmental expectations, they will be grouped together for the remainder of the report. More permitted activities are allowed in Class B waters, but no detrimental changes to communities of fish, macroinvertebrates, and other aquatic life are allowed. Class C waters allow the most permitted activities, but Class C waters must still support all fish indigenous to the receiving waters and maintain the structure and function of aquatic life communities.

The Water Classification System also defines water quality standards for each class. Water quality standards include designated uses and criteria. Designated uses are the ecological goals and types of activities that are desired of each class, such as supporting healthy communities of aquatic life, fishing, swimming, boating, supplying drinking water, and generating electricity from hydroelectric plants. The criteria are the measuring sticks for determining if the goals are being attained.

The purpose of most criteria is to maintain healthy communities of aquatic life. For example, there are criteria to maintain sufficient oxygen levels in water so fish and other aquatic life do not suffocate. Other criteria define how much bacteria are allowed, range of acceptable acidity, how green lakes can get from algal blooms, and the composition of biological communities. Some criteria are narrative and consist of written statements, such as "the habitat should be characterized as free flowing and natural." Other criteria are numeric and define specific numbers or concentrations, such as "the dissolved oxygen content shall not be less than 7 parts per million or 75% of saturation." Some designated uses, such as physical habitat, only have narrative statements. Some designated uses, such as bacteria, only have numeric criteria. A few designated uses, such as the support of aquatic life, have both narrative and numeric criteria. Maine Department of Environmental Protection (DEP) staff must use best professional judgment using sound data and ecological theory to interpret narrative criteria and determine when a waterbody no longer supports a designated or existing use. For a numeric criterion, DEP staff must determine if the sampling result is greater than or less than the specified amount by the criterion. For example, the dissolved oxygen concentration in a Class B waterbody must be at least 7 parts per million. If the average concentration from a Class B waterbody was only 4 parts per million, then the waterbody would be impaired.

What do mg/L and µg/L mean?

mg/L means a milligram of a substance in a liter of water. A mg/L is also called a part per million (**ppm**) because a liter of water weighs 1 million micrograms.

µg/L means a microgram of a substance in a liter of water. A µg/L is also called a part per billion (**ppb**) because a liter of water weighs 1 billion micrograms.

1 kilogram = 1 liter of water

1 gram = 1 thousandth of a liter of water

1 mg = 1 millionth of a liter of water

1 µg = 1 billionth of a liter of water

2 - Methods for analyzing data

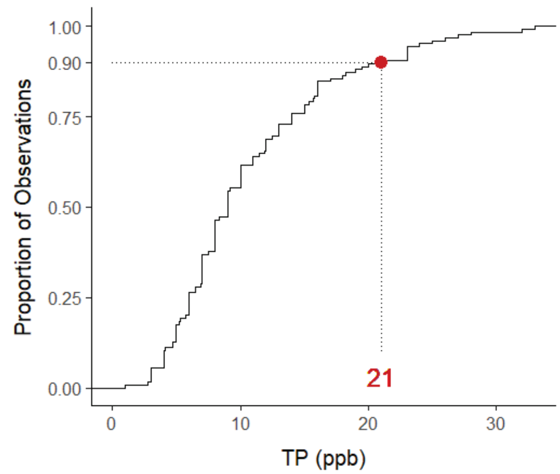
2.1 – Percentiles

Percentiles are statistical measurements that help describe the distribution of a data set. Percentiles define a value at which a certain percent of data points are less than or equal to the value. If the 50th percentile of a set of 100 total phosphorus (TP) samples is 30 ppb, then that means that 50 of the 100 samples (*i.e.*, 50% of samples) have values less than or equal to 30 ppb. Similarly, a 75th percentile of 40 ppb means that 75 of the 100 samples (*i.e.*, 75% of samples) have values less than or equal to 40 ppb. We used two percentile thresholds when examining TP and environmental response variables.

2.2 – Cumulative distribution function

Cumulative distribution functions are graphs that display percentiles (Figure 1). The x-axis has TP concentrations and the y-axis has the percentiles expressed as proportions. A proportion of 0.75 is the same as the 75th percentile. Figure 1 shows that the 90th percentile of TP concentrations collected from reference streams and rivers is 21 µg/L or ppb. In other words, 90% of the samples are less than or equal to 21 µg/L.

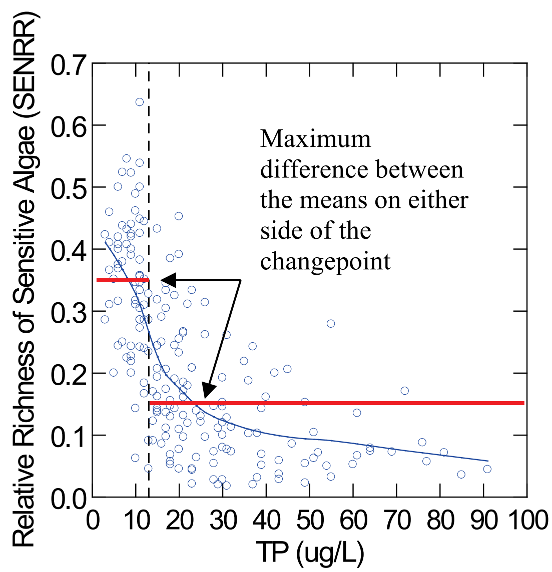
Figure 1. Cumulative distribution function of TP data collected from reference streams and rivers



2.3 - Changepoint analysis

Changepoint analysis uses a statistical procedure called nonparametric deviance reduction, which seeks the value for one variable at which there is the greatest difference in a second variable (Qian et al. 2003, Qian et al. 2004). This method was used by Wisconsin to identify nutrient thresholds (Wang et al. 2007) and was one of the methods recommended by U.S. EPA (Paul and McDonald 2005). Changepoint analysis sequentially 1) selects a TP concentration, 2) splits the data into one group of samples with values less than the TP concentration and another group of samples with values greater than the TP concentration, 3) calculates means of the second variable for both groups of data, and 4) calculates the difference in the two means. The changepoint analysis repeats this process for all TP concentrations. The changepoint is the TP concentration with the greatest difference in the means of the second variable (Figure 2). We estimated uncertainty about the changepoint by calculating the 95% confidence interval using a resampling technique (bootstrap permutations). We also determined if changepoints were ecologically significant by 1) using knowledge of relationships between variables and 2) using a statistical test (approximate χ^2 test) (Qian et al. 2003, Paul and McDonald 2005).

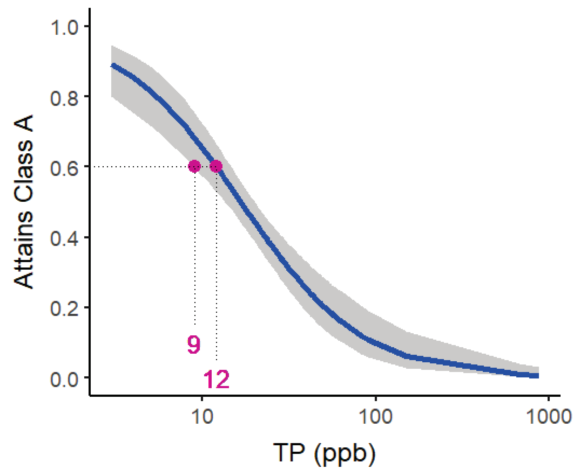
Figure 2. Example of changepoint analysis showing maximum difference between the means of relative richness of sensitive algae on either side of the TP changepoint of 13 ug/L



2.4 – Logistic Regression

Logistic regression computes the probability of an event occurring along a gradient of some kind. For example, Figure 3 shows the probability of attaining Class A aquatic life criteria across a gradient of total phosphorus concentrations. The solid blue curve represents the probabilities. The shaded grey region represents confidence intervals associated with the computed probabilities. One can use the curve to estimate the total phosphorus concentration associated with a particular probability of interest. In this example, the total phosphorus concentration associated with a probability of 0.60 was 12 parts per billion (ppb). The lower confidence interval reached a probability of 0.60 at 9 ppb. Notice that the X-axis has a logarithmic (log_{10}) scale.

Figure 3. Example of probabilities computed by logistic regression of an event occurring (attaining Class A aquatic life criteria) across a gradient (concentrations of total phosphorus(TP))



3 – Process for selecting TP and environmental response values for Classes AA/A, B, and C

We used a weight-of-evidence approach to select TP and environmental response values for Classes AA, A, B, and C. Classes AA and A share the same values because they have the same aquatic life expectations, "as naturally occurs". In most cases, we computed the 90th percentiles for analysis. We did not choose the 75th percentiles because we did not want a quarter of samples that attain a Class to exceed the values. In addition, Montana Department of Environmental Quality found that the threshold where they observed impacts to designated uses was at the 86th percentile of reference sites (Suplee et al. 2007). The exception was when evaluating the relation of TP and attainment of aquatic life criteria based on macroinvertebrates. We computed the 75th percentile because other aquatic life, such as algae, are likely to be more sensitive to nutrient enrichment than macroinvertebrates. When weighing multiple lines of evidence, we attempted to select values that would protect designated uses but not be too overly restrictive.

What is log_{10}?

Log_{10} is a type of data transformation that is commonly used to adjust data for statistical analysis. It adjusts a value to its corresponding value on the logarithmic base 10 scale. Some examples are shown below.

Value	Log_{10} Value
1	0
5	0.7
10	1
50	1.7
100	2
500	2.7
1000	3

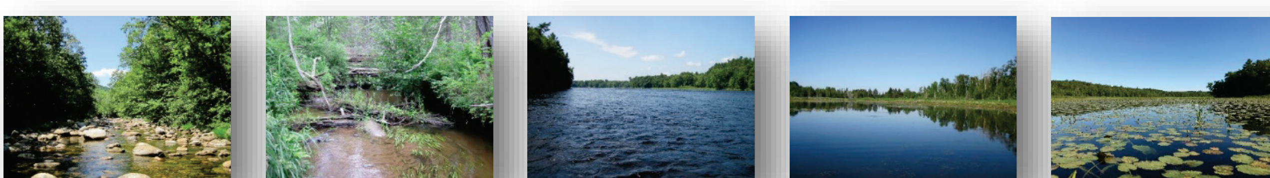
4 – Nutrient Criteria and Decision Framework

The proposed nutrient criteria apply to Class AA, A, B, and C waterbodies and does not apply to Class GPA waters. Class GPA includes natural lakes and ponds, impoundments greater than 30 acres, and impoundments less than 30 acres that were ponds greater than 10 acres in size before being impounded (Table 1). All other fresh surface waters fall into Classes AA, A, B, or C, such as streams, rivers, small impoundments, bogs, marshes, and wetlands (Figure 4). The nutrient criteria combine total phosphorus and seven response indicators to maintain and protect designated uses and antidegradation policies related to 1) habitat, 2) aquatic life support, and 3) recreation in and on the water (38 M.R.S.A. Sections 465).

Table 1. Waterbodies classified as GPA or AA, A, B, or C

Waterbody	**GPA**	**AA, A, B, or C**
Great Ponds, which include • natural lakes or ponds greater than 10 acres in size • impoundments greater than 30 acres in size • impoundments that are less than 30 acres in size by were greater than 10 acres in size before being impounded	X	
Natural lakes and ponds less than 10 acres in size	X	
Wetlands associated with Class GPA waters	X	
Streams and rivers		X
Impoundments less than 30 acres in size that were less than 10 acres in size before being impounded		X
Bogs, marshes and other wetlands that are isolated or associated with Class AA, A, B, or C waters		X

Figure 4. Examples of waterbodies classified as Class AA, A, B, and C.



Rocky streams | Sandy streams | Deep rivers | Small impoundments | Some wetlands

4.1 - Environmental Response Indicators

The proposed rule includes seven environmental response indicators because of the diversity of waterbody types classified as Class AA, A, B, and C (Figure 4). Also, examining multiple response indicators provides a more holistic approach of evaluating potential effects of nutrient enrichment on aquatic systems. Department staff will select the most appropriate combination of four to six response indicators depending on the type of waterbody being sampled. Table 2 provides examples of combinations of environmental indicators for different kinds of waterbodies.

Table 2. Examples of combinations of environmental indicators for different kinds of waterbodies

Environmental response indicator	Rocky stream	Sandy stream	Low gradient, mucky stream	Deep river	Impoundment	Bog, marsh, or other wetland
Dissolved O_2	✓	✓	✓	✓	✓	✓
pH	✓	✓	✓	✓	✓	✓
Aquatic life[1] (Biocriteria)	✓	✓	✓	✓	✓	✓
"Sewage fungus"	✓	✓	✓	✓	✓	✓
Secchi disk transparency[2]	--	--	--	✓	✓	✓
Chlorophyll *a*[3]	--	✓	✓	✓	✓	✓
% cover of nuisance algae	✓	--	--	--	--	--

1- If conditions such as depth, water velocity, and substrate are suitable for Department sampling methods
2- If the water is still or flowing slowly enough to allow proper use of Department sampling methods
3- If the velocity of flowing water is slow enough to allow the growth of phytoplankton

4.1.1 - Secchi disk transparency

Secchi disk transparency is not suitable when the velocity of flowing water is high enough to prevent the proper use of Department standard operating procedures. Secchi disk transparency should be greater than 2m in waters greater than 2m deep. In waterbodies less than 2 meters deep, water transparency should be clear enough to see the Secchi disk all the way to the bottom of the waterbody. The Secchi disk depths should be accompanied by chlorophyll *a* samples in turbid or colored water to confirm that the limited transparency is due to an algal bloom.

4.1.2 - Water Column Chlorophyll *a*

Algal blooms and poor water clarity in streams, rivers, and impoundments harm recreational opportunities, such as fishing, swimming, and boating. Algal blooms can also harm aquatic life and alter their habitat. DEP follows standard protocols for sampling chlorophyll *a* samples (Potvin and Bacon 2003, Danielson 2006).

Class AA and A waters are supposed to be "as naturally occurs", so we analyzed chlorophyll *a* samples collected from 115 minimally disturbed streams across the state. The watersheds upstream of the sample locations had more than 95% of land cover consisting of forest and wetland. The90th percentile of the chlorophyll *a* values were less than 3.5 µg/L. We noticed that some of the samples with the highest chlorophyll *a* concentrations were low gradient streams with low water velocity. These streams naturally can have higher chlorophyll *a* concentrations because of their slowly flowing water. All 115 sample events were less than or equal to 5.0 µg/L. Therefore, we will give staff the discretion of using 5.0 µg/L as the value for low gradient Class AA and A streams and rivers with water velocity less than 2 centimeters per second.

The limits for Class B, Class C, and all impoundments were set at 8.0 µg/L to be consistent with the way we define algal blooms in lakes. A water sample of 8.0 µg/L chlorophyll *a* will look the same if it is collected from a lake or a flowing water, except for atypical lakes dominated by colonial bluegreen algae such as *Gloeotrichia*. There are some subtle differences about sampling, however. For impoundments, DEP assumes that an impoundment is not as well mixed as a lake because of its linear flow. Therefore, DEP measures chlorophyll *a* in multiple locations starting at the dam and moving upstream. The average chlorophyll *a* concentration in an impoundment should not exceed 8.0 µg/L and no single measurement should exceed 10.0 µg/L. Samples are either collected as epilimnetic cores or euphotic-zone cores, depending on the characteristics of the impoundment.

4.1.3 - Aquatic Life Use Attainment

This variable is an indicator of the condition of aquatic biological communities. A waterbody must attain appropriate narrative aquatic life use criteria as described in 38 M.R.S.A. Section 465 and as well as numeric criteria in *Classification Attainment Evaluation Using Biological Criteria for Rivers and Streams,* 06-096 CMR 579 (Effective May 27, 2003). DEP follows standard protocols for sampling macroinvertebrates in streams and rivers (Davies and Tsomides 2002). Class AA and A waters must support communities of aquatic life that are "as naturally occurs". Class AA and A waters typically have many different kinds of macroinvertebrates and are dominated by taxa that are sensitive to pollution and require cold, clean water, such as mayflies, stoneflies, and caddisflies (Figure 4). Streams that support Class B communities often have a little nutrient enrichment and more organisms (Figure 5). Class B waters may have reduced abundance of some of the most sensitive species, but their communities still have many mayflies, stoneflies, caddisflies, and other sensitive taxa. Waters that support Class C communities often have only a few different kinds of mayflies and stoneflies. The overall abundance can vary from low to very high depending on the type of stressor causing the impact. The community, however, still retains structure and function as well as some sensitive taxa. In contrast, non-attainment waterbodies have most if not all of the sensitive taxa and is dominated by tolerant taxa (Figure 6).

Figure 4. Example of a Class A macroinvertebrate sample

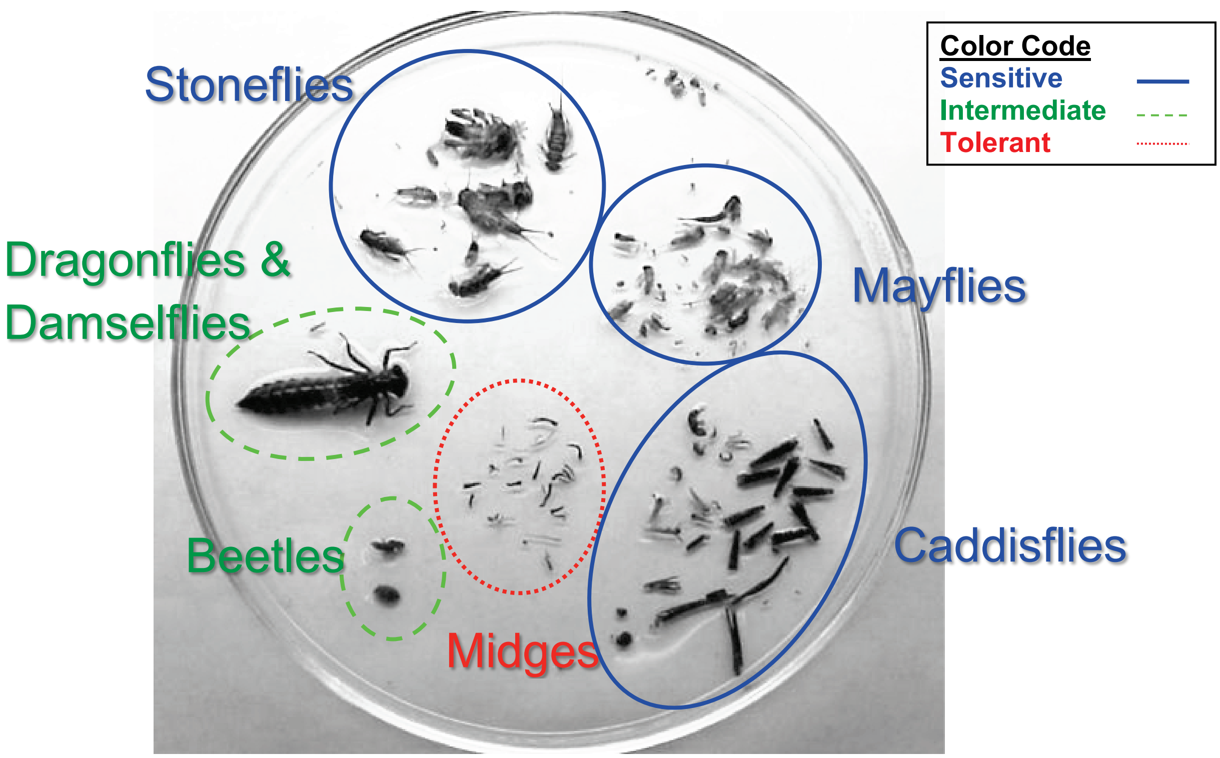


Figure 5. Example of a Class B macroinvertebrate community

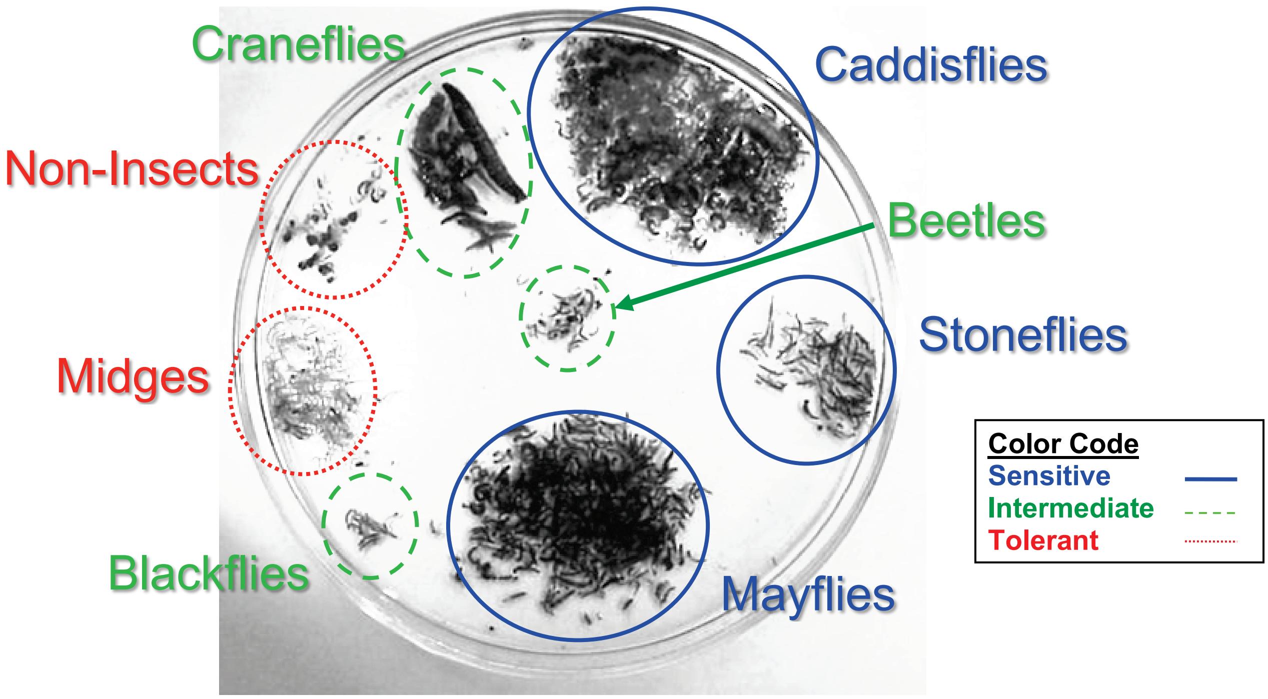
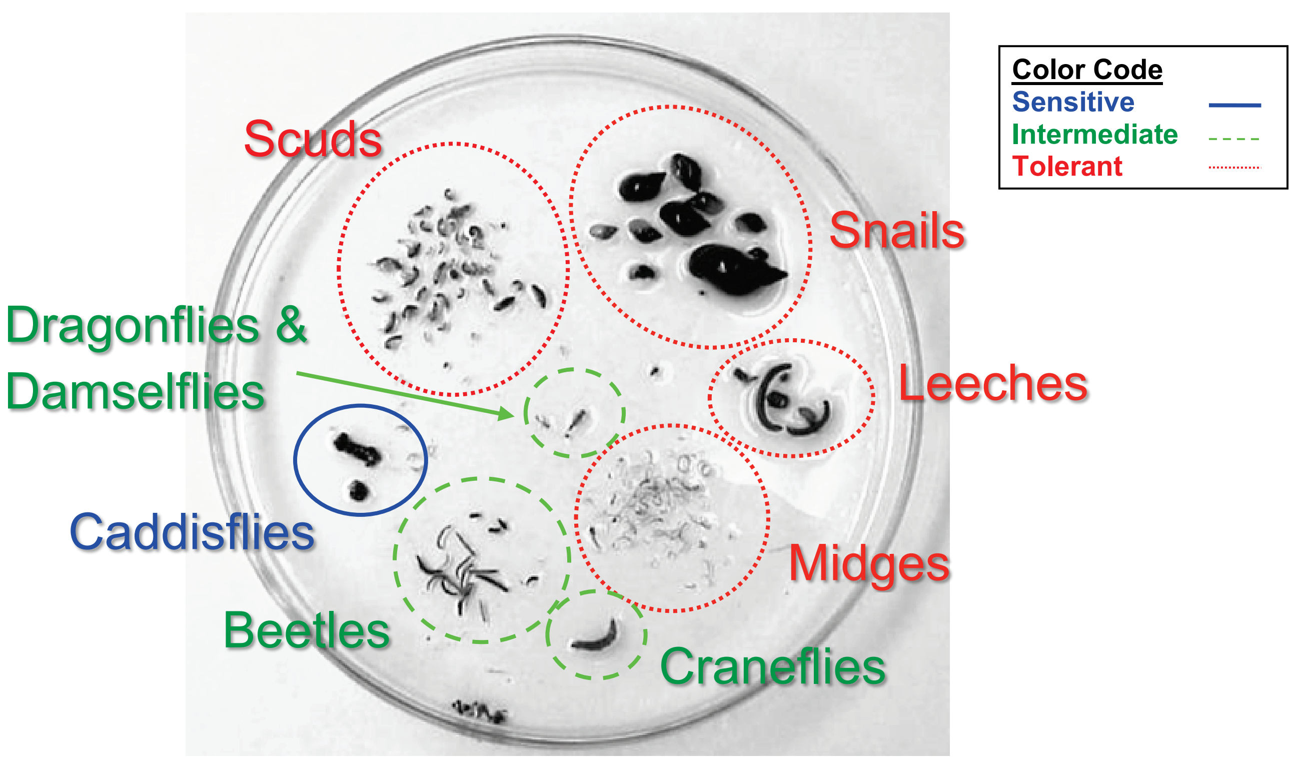


Figure 6. Example of a non-attainment stream that does not meet Class C



4.1.4 - Percent Nuisance Algal cover in Streams and Rivers

Nutrient enrichment can contribute to increased growth and accumulation of filamentous algae or thick mats of algae in streams and rivers. Nutrients are not the only factors influencing the growth of algae attached to the bottom of streams and rivers, but they are important ones. Other factors, such as the availability of sunlight, water temperature, water velocity, and grazing also determine how much algae grow and accumulate. Too much algae attached to the bottom of a stream or river can harm aquatic life by causing problems with dissolved oxygen concentrations. Also, too much algae can reduce habitat quality for some fish and aquatic macroinvertebrates. It also reduces the quality of recreation activities, such as fishing and wading. DEP uses the percent of stream bottom covered by nuisance algae (% nuisance algal cover) as one tool to interpret attainment of the following narrative criteria: recreation in and on the water, aquatic life, and habitat (38 M.R.S.A. Section 465).

Viewing bucket surveys provide a semi-quantitative estimate of algal cover on the stream bottom. The method is less subjective than visual estimates. Viewing bucket surveys complement species composition data by estimating the amount and types of algae (*e.g.*, filamentous algae or thick mats) growing in a stream reach. Species composition data may show signals of nutrient enrichment as some species are replaced by other species that prefer higher nutrient concentrations. In contrast, the viewing bucket surveys may show signals of nutrient enrichment as more filamentous algae or thick mats of algae accumulate in nutrient enriched streams. Most minimally disturbed streams in Maine have little algae growth. Rocks in these streams lack thick mats of algae and extensive growths of filamentous algae. Rocks are typically clean but may have a slippery transparent or semi-opaque layer of algae. Opaque layers of algae thicker than 1 mm are not common. Minimally disturbed streams often have some aquatic moss or plants in them.

Figure 7. Viewing bucket for estimating percent algal cover

Figure 8. Using viewing bucket

DEP has a standard protocol for estimating percent nuisance algal cover using a viewing bucket survey (Danielson 2006), which was slightly modified from the U.S. EPA Rapid Bioassessment Protocols (Stevenson and Bahls 1999). The current method is restricted to shallow streams and river segments (<1.25 meters deep). The viewing bucket is a five-gallon storage container with a Plexiglas bottom. The Plexiglas has a grid of 35 dots that are spaced 4 cm apart (Figure 7). At a sample location, we typically established three transects across the stream reach and used the viewing bucket at three locations along each transect. At each location, one person looked through the viewing bucket and called out the amount and type of algae growth under each of the 35 dots using a qualitative scale (Figure 8). Another person tallied the results on the field sheet. We could not use this method when the water was too deep or too colored to clearly see the substrate. The data were entered into the database and the percent cover of filamentous algae more than 1 cm long or algal mats thicker than 1 mm was calculated for each sample location.

Class AA and A

The limit for Class AA and A streams and rivers was established by examining the percent nuisance algal cover from:

- A set of 36 streams and rivers with >95% of land area within upstream watersheds consisting of forest or wetland, with no dams, and no point source discharges of pollutants. The average % nuisance algae cover was computed for each site with more than one sample. The 90th percentile of the reference streams was **12%** nuisance algal cover (Figure 9).
- A set of 69 paired percent nuisance algal cover samples and macroinvertebrate samples that attain Class AA/A aquatic life criteria. The average % nuisance algae cover was computed for each site with more than one sample. Class AA and A share the same aquatic life criteria. The 90th percentile was **25%** cover (Figure 10).
- A set of 130 sites with a range of % nuisance algal cover. The probability of attaining Class A was computed with logistic regression. The greatest probability of attaining Class A was at 0% nuisance algal cover but the probability was only 0.54. We decided to exclude this analysis because other unidentified stressors must have prevented many streams with little % nuisance algae from attaining Class A (Figure 11).

Based on the weight of evidence, we decided to set the limit for Class AA and A streams and rivers at **18%** nuisance algal cover.

Figure 9. Quantile plot of percent nuisance algal cover from 36 sites with >95% of upstream watershed land cover consisting of forest or wetland

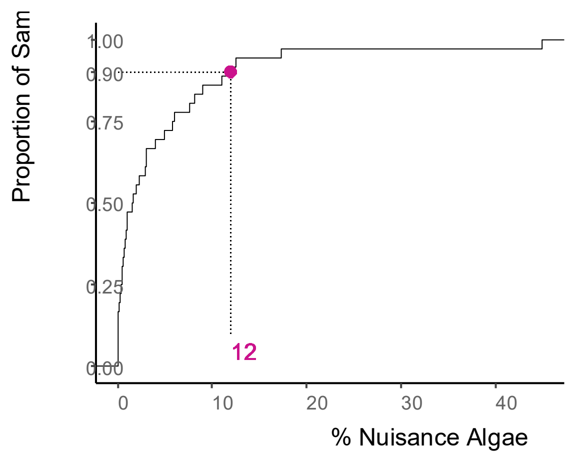


Figure 10. Quantile plot of percent nuisance algal cover from 69 sites that attain Class AA/A aquatic life criteria

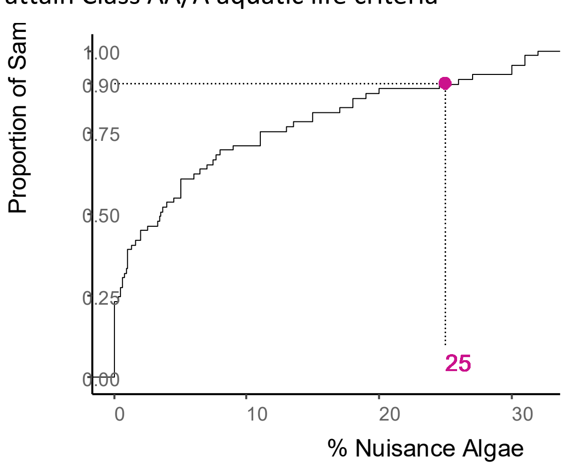
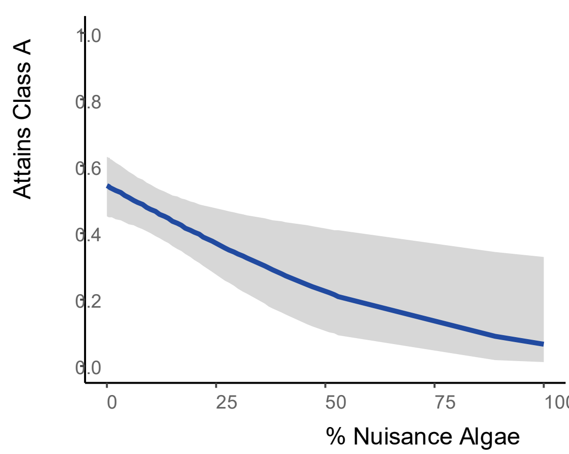


Figure 11. Probability of attaining Class A with % nuisance algal cover (130 sites)



<u>Class B</u>

The limit for Class B streams and rivers was established by examining the percent nuisance algal cover from:

- A set of 37 sites known to attain Class B and do not attain Class A based on macroinvertebrates. The average % nuisance algal cover was computed for sites with more than one sample. The 90th percentile was **24%** nuisance algal cover (Figure 12).
- A set of 130 sites with a range of % nuisance algal cover. The probability of attaining at least Class B was computed with logistic regression. We set the cutoff for Class B at a probability of 0.60. We identified the values of % nuisance algal cover where the lower confidence interval met the cutoff and where blue regression line met the cutoff, which were at **18** and **27%** nuisance algal cover. (Figure 13).

Based on the weight of evidence, we decided to set the limit for Class B streams and rivers at **24%** nuisance algal cover.

Figure 12. Quantile plot of percent nuisance algal cover from 37 sites known to attain Class B and do not attain Class A based on macroinvertebrates

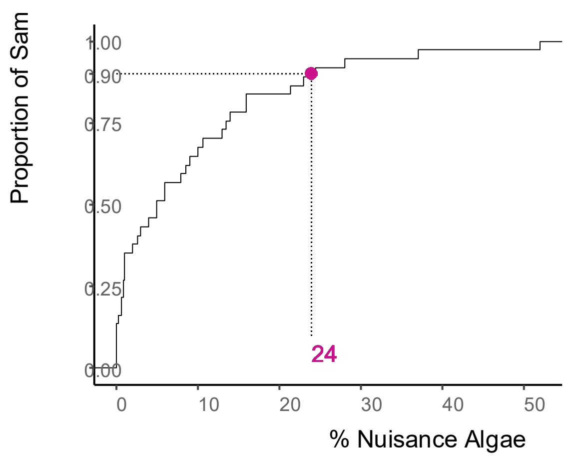
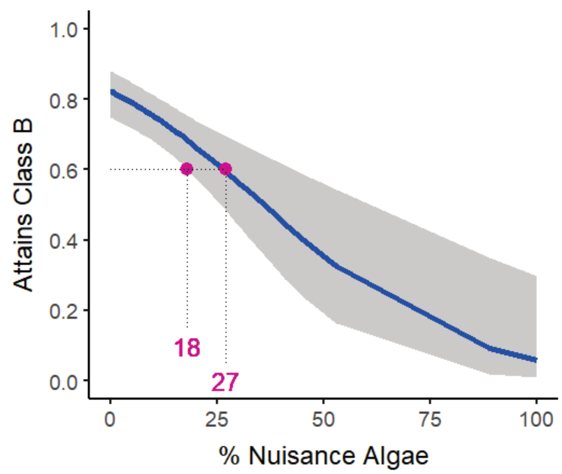


Figure 13. Probability of attaining Class B with % nuisance algal cover (130 sites)



Class C

The limit for Class C streams and rivers was established by examining the percent nuisance algal cover from:

- A set of 17 sites known to attain Class C and do not attain Class A or B based on macroinvertebrates. The average % nuisance algal cover was computed for sites with more than one sample. The 90th percentile was **40%** nuisance algal cover (Figure 14).
- A set of 130 sites with a range of % nuisance algal cover. The probability of attaining at least Class C was computed with logistic regression. We set the cutoff for Class B at a probability of 0.60. We identified the values of % nuisance algal cover where the lower confidence interval met the cutoff and where blue regression line met the cutoff, which were at **36** and **51%** nuisance algal cover. (Figure 15).
- In addition to looking at Maine data, we did a literature search to identify percent algal cover thresholds used to protect aquatic life and recreation (Table 1). Some papers reported thresholds for the amount of chlorophyll *a* collected by scraping rocks in streams and rivers. New Zealand has done the most research on percent algal cover. New Zealand initially set a 40% threshold to protect recreation and aquatic life (Biggs and Price 1987, Quinn 1991, Zuur 1992) and later revised the threshold to **30%** filamentous algal cover to protect aquatic life (Biggs 2000). We also wanted to protect recreational uses. New Zealand produced a series of images of the same stream reach with different amounts of percent algal cover (Figure 16). Montana completed a user perception survey and set a threshold for chlorophyll *a* collected from algae growing on rocks (Figure 17) (Suplee et al. 2009). Montana's threshold for chlorophyll *a* is greater than the corresponding threshold in New Zealand, suggesting that if Montana had a threshold for percent nuisance algal cover it would be somewhat greater than 30%. Utah replicated Montana's study with similar results (Jakus et al. 2017).

Based on the weight of evidence, we set the Class C criterion at **35%**, which was the mean of 40, 36, and 30, to protect both aquatic life and recreation. A value somewhat greater than that used by New Zealand is acceptable because our sampling technique includes thicker periphyton mats in the calculation of percent nuisance algal cover.

Figure 14. Quantile plot of percent nuisance algal cover from 17 sites known to attain Class C and do not attain Class B based on macroinvertebrates

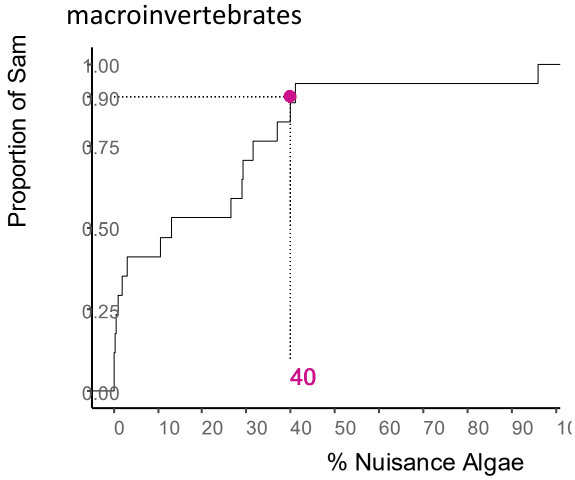


Figure 15. Probability of attaining Class C with % nuisance algal cover (130 sites)

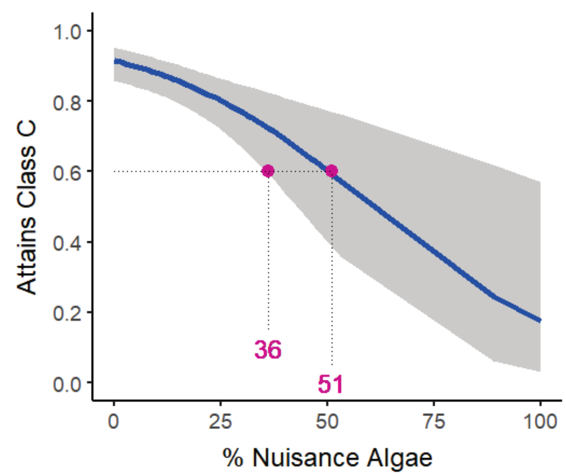
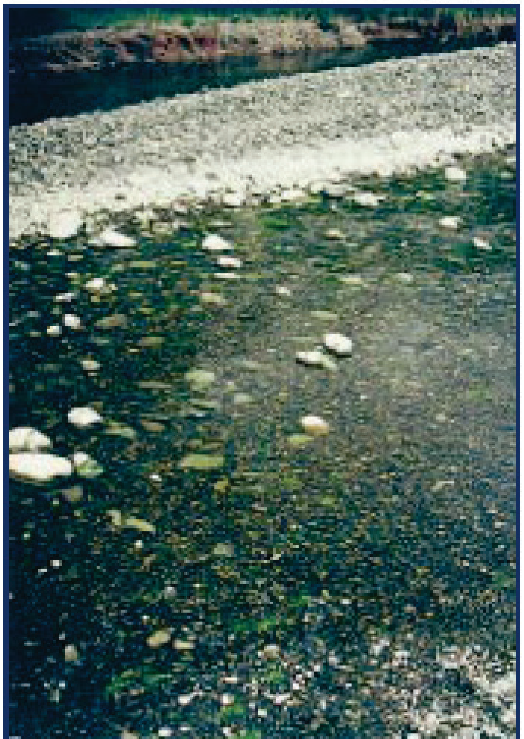


Table 1. Chlorophyll *a* and percent nuisance algal cover criteria found in the scientific literature (table format adapted from Suplee *et al.*, 2009)

Maximum Chlorophyll *a* (mg chlorophyll / m^2)		**Percent nuisance algal cover**		**Use**	**Source**
Diatom	**Filamentous**	**Diatoms**	**Filamentous**		
			40%	40% cover is conspicuous from streambank	Biggs and Price, 1987 (New Zealand)
100-150			20%	Based upon 19 enrichment cases and surveys	Welch et al., 1988 Horner et al., 1983
150-200				Based on perceived impairment	Welch et al., 1989
100			40%	Recreation and aesthetics	Quinn, 1991 Zuur, 1992 (New Zealand)
150					Watson and Gestring, 1996
100-200				Nuisance	Dodds et al., 1997
200				Eutrophy	Dodds et al., 1998
n/a	120	60% (>0.3 cm thick)	30% (>2 cm long)	Contact recreation & aesthetics	Biggs, 2000 (New Zealand)
200	120	n/a	30% (>2 cm long)	Protection of trout habitat	
50	50	n/a	n/a	Protection of benthic biodiversity	
50				Recreation and aesthetics	Nordin, 2001 (British Columbia)
100				Aquatic life	
150					USEPA, 2000
100-150				Coldwater fish and recreation	TetraTech, 2006
150-200				Warmwater fish and recreation	
150			20-60%*	User perception survey, protection of recreation	Suplee et al., 2009 (Montana)

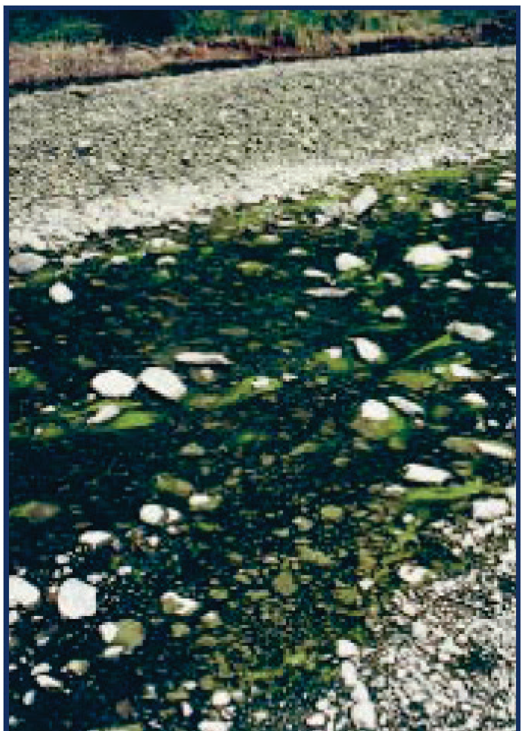
* Montana did not set percent nuisance algal cover criteria, but the first stream to be found unacceptable to the public had patchy growths of filamentous algae with percent cover ranging from 20-60% (Image E in Figure 17).

Figure 16. Percent algal cover photos from New Zealand (Biggs, 2000)

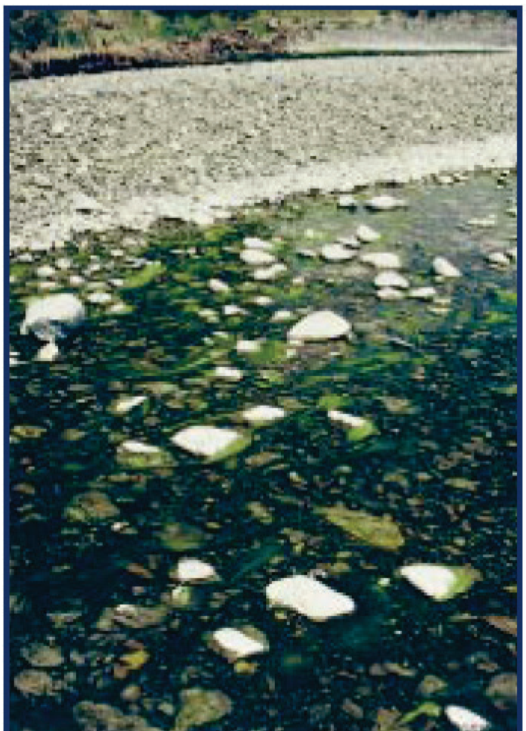


20% cover, 80 mg chl. a/m^2, 25 g AFDM/m^2

30% cover, 120 mg chl. a/m^2, 35 g AFDM/m^2



40% cover, 160 mg chl. a/m^2, 40 g AFDM/m^2



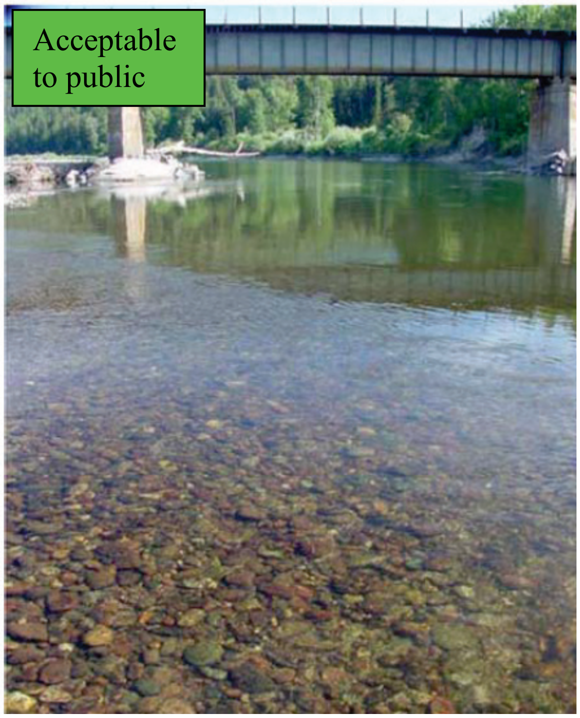
55% cover, 300 mg chl. a/m^2, 50 g AFDM/m^2

Figure 16. Percent algal cover photos from New Zealand (Biggs, 2000) - Continued

70% cover, 900 mg chl. a/m², 200 g AFDM/m²

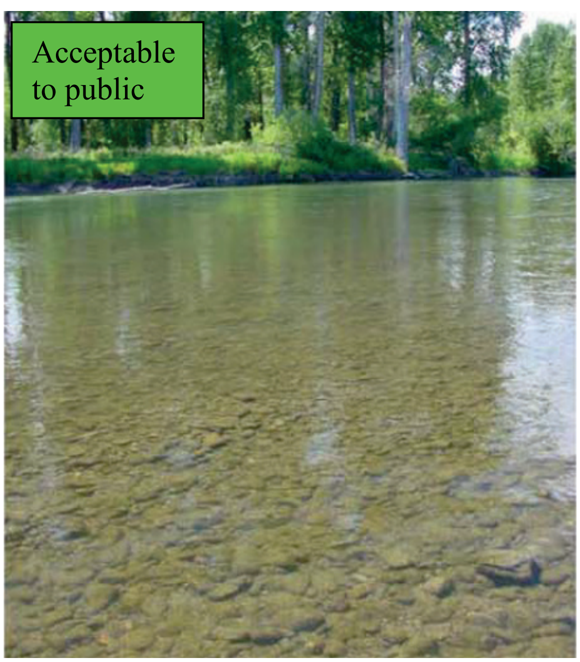
95% cover, 640 mg chl. a/m², 90 g AFDM/m²

Figure 17. Results of Montana's user perception survey (Suplee *et al.* 2009, Jakus *et al.* 2017)



44 mg chlorophyll *a*/m^2,
0% filamentous algal cover

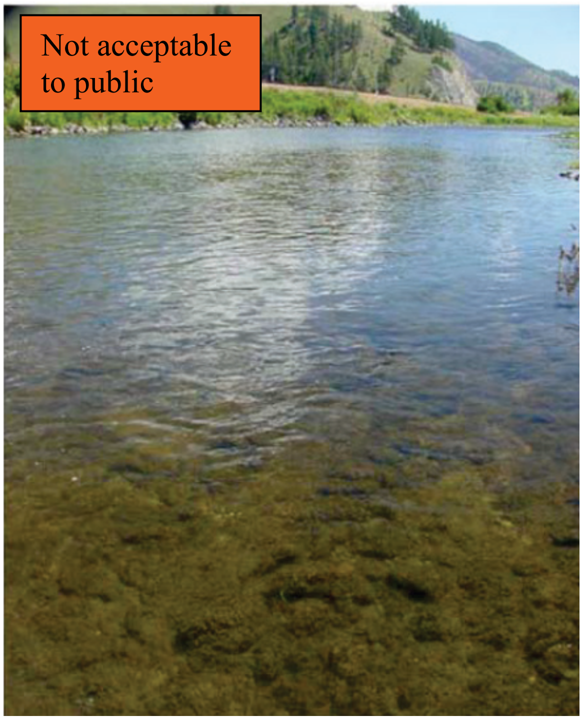
112 mg chlorophyll *a*/m^2,
5-10% filamentous algal cover



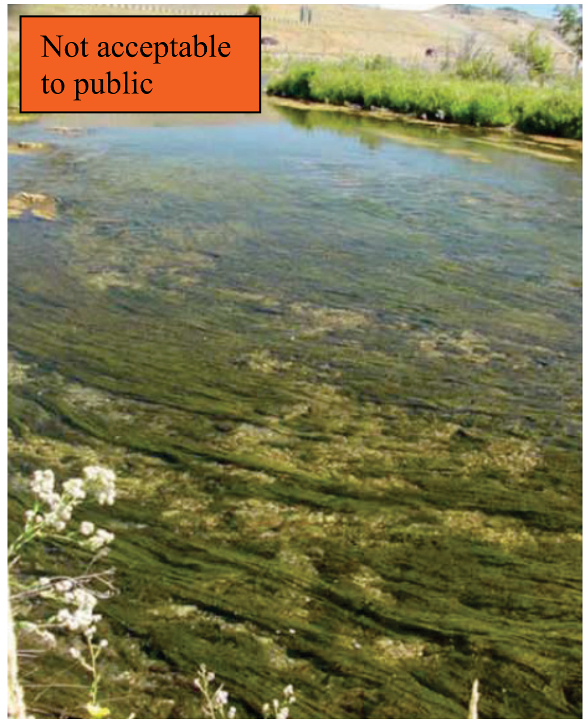
152 mg chlorophyll *a*/m^2,
0% filamentous algal cover but rocks have a "fuzzy" mat of algae

202 mg chlorophyll *a*/m^2,
20-60% filamentous algal cover

Figure 17. Results of Montana's user perception survey (Suplee et al. 2009) - Continued

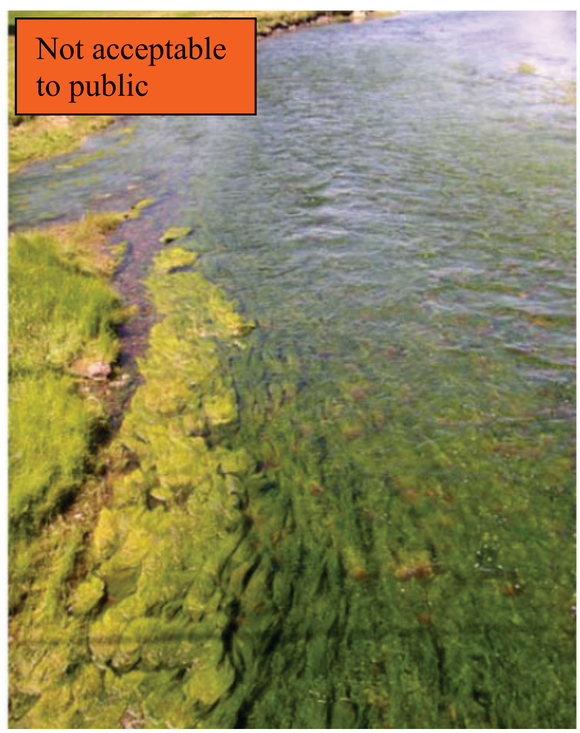


235 mg chlorophyll *a*/m^2,
50% filamentous algal cover



299 mg chlorophyll *a*/m^2,
30-100% filamentous algal cover

404 mg chlorophyll *a*/m^2,
70% filamentous algal cover



1,276 mg chlorophyll *a*/m^2,
90% filamentous algal cover

4.1.5 - Patches of Bacteria and Fungi in Streams and Rivers

This variable indicates major shifts in trophic state and relates to the designated uses and narrative criteria associated with habitat, recreation, and aquatic life in 38 M.R.S.A. §§ 464.4 and 465. Fungi and filamentous bacteria are present in every waterbody in the state. Observable patches of fungi and filamentous bacteria, however, are rare and typically occur in waters receiving large inputs of carbon in the form of sewage, compost, or propylene glycol. Waterbodies with patches of fungi and bacteria typically smell very bad because of the decomposing organic matter. This variable excludes iron and manganese bacteria because they primarily gain energy by converting reduced forms of iron and manganese into oxidized forms instead of decomposing organic matter.

Figure 18 illustrates the shift in biological communities below an untreated discharge of organic pollution. Please note that most licensed discharges in Maine do not cause similar impacts because of the implementation of treatment technology. Panel *a* shows that organic waste increases the biological oxygen demand (BOD) of microorganisms that decompose the waste. The microorganisms use up oxygen and lower the concentration of dissolved oxygen in the water. Panel *b* shows the increase in nutrients, such as nitrate (NO_3^-), ammonia (NH_4^+), and phosphate (PO_4^{3-}). Panel *c* shows the dominance of sewage fungus, which is a type of filamentous bacteria, along with other bacteria and protozoa in the area of greatest pollution. Panel *d* shows the dominance of pollution tolerant organisms in the area of greatest pollution. Figures 19 and 20 show the macroinvertebrate communities of a pair of streams less than a mile apart in southern Maine. The only major difference between the two streams was that one was heavily impacted by untreated, organic waste. The control stream (Figure 19) had a high diversity of macroinvertebrates and is dominated by species that are sensitive to pollution and require cold, clean water to survive. In comparison, the impacted stream was receiving a lot of untreated, organic waste and had substantial growths of filamentous bacteria. The impacted stream (Figure 20) had lower diversity and was dominated pollution tolerant species.

Figure 18. A diagrammatic representation of the longitudinal zonation established downstream of the outfall of a continuous organic effluent discharge. (a) and (b) are physical and chemical changes; (c) changes in microorganisms and plants; (d) changes in larger organisms (Hynes 1960, Giller and Malmqvist 1998)

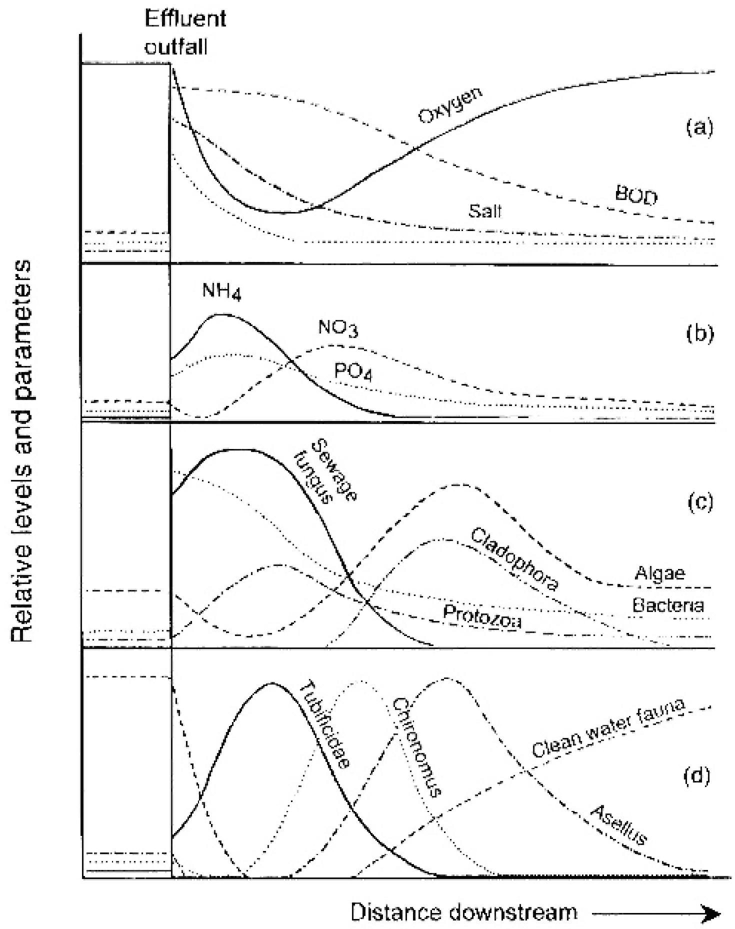


Figure 19. Macroinvertebrate community from the control stream

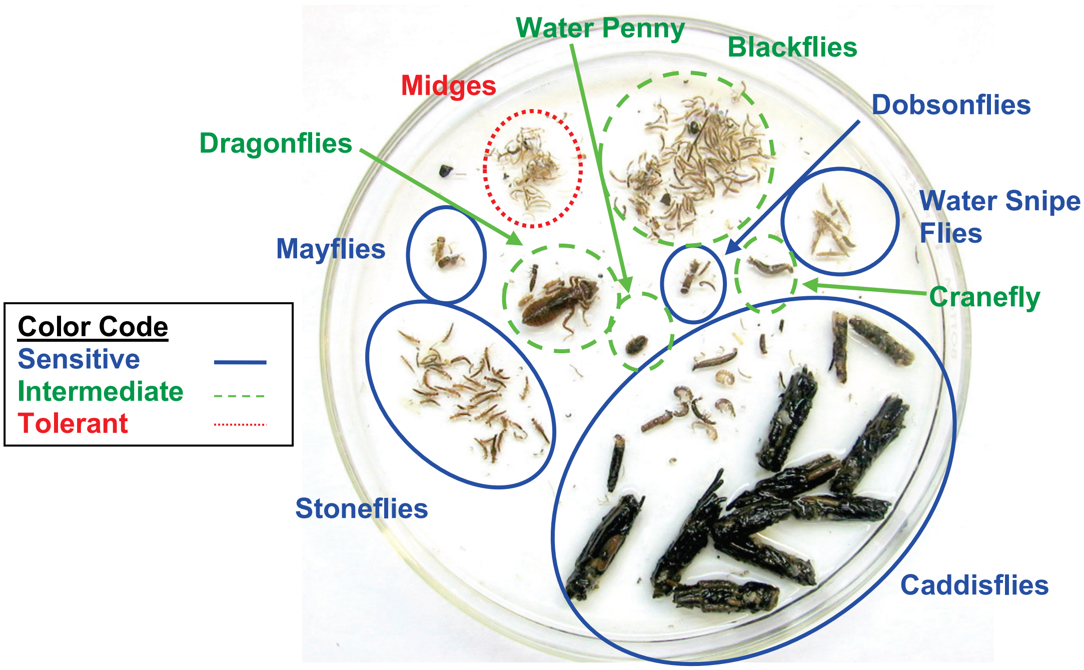
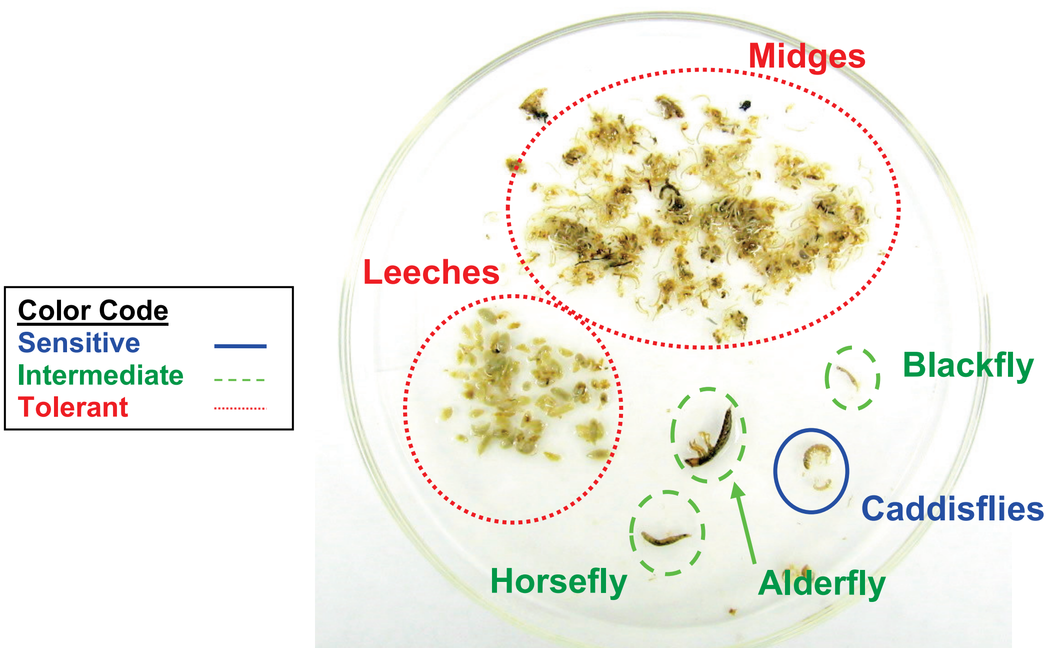


Figure 20. Macroinvertebrate community of the stream impacted by untreated, organic waste



4.1.6 - Dissolved Oxygen Concentrations

This variable protects fish and other aquatic life from suffocation. Waterbodies must attain dissolved oxygen criteria as described in 38 M.R.S.A. §§ 465 and 465-A. Excessive algae growth can alter natural fluctuations in dissolved oxygen. Dissolved oxygen concentrations typically fluctuate because of photosynthesis and respiration. Photosynthesis is a process within the cells of algae and plants that converts energy from sunlight into sugars. Photosynthesis uses up carbon dioxide and water and creates sugars and oxygen. Respiration is the process of converting sugars into the energy to support cellular activities. Respiration uses up sugars and oxygen and creates carbon dioxide and water. Almost all aquatic organisms respire both day and night. During the day, however, there is typically more oxygen created by photosynthesis than is used up by respiration. As a result, dissolved oxygen concentrations typically go up during the day and go down at night when photosynthesis stops. Healthy streams have small daily changes or flux of dissolved oxygen. Healthy streams also have sufficient oxygen, typically more than 7 mg/L, at night to prevent stressful conditions for aquatic organisms. Nutrient enriched streams with excess algae growth can have substantial amounts of photosynthesis during the day and dissolved oxygen levels can get very high. Nutrient enriched streams also have a great amount of respiration at night from all of the organisms and decaying organic matter. Dissolved oxygen levels can plummet at night and cause stress and suffocation of fish and other aquatic life.

Some studies have found that large, daily swings in dissolved oxygen can harm aquatic life. Minnesota found a significant relationship between DO flux and number of different kinds of mayflies, stoneflies, and caddisflies in a study of large rivers (Heiskary and Markus 2003). As DO flux increased from 4 mg/L to around 7 mg/L, the number of different types of mayflies, stoneflies, and caddisflies decreased from 20 to 10. In a follow up study of large rivers, Minnesota found very strong inverse relationships between DO flux and the number of different kinds of fish and macroinvertebrates that are sensitive to pollution (Heiskary 2008). In addition, Minnesota found strong positive relationships between DO flux and the number of different kinds of pollution tolerant macroinvertebrates. High DO flux tended to occur with high water temperature, high nutrient concentrations, low dissolved oxygen concentrations, and high chlorophyll *a* concentrations (Heiskary and Markus 2003, Heiskary 2008), all of which are detrimental to water quality. DEP will consider adding DO flux to the nutrient indicator rule in the future if more information becomes available.

4.1.7 - pH

The pH of fresh waters must be within the range described in 38 M.R.S.A. § 464.4.A.5. pH is a measure of acidity and specifically measures the amount of hydrogen ions in the water. Neutral or "pH balanced" water has a pH of 7.0. Bogs and other acidic waterbodies in Maine sometimes reach pH values of 4.0 or less. Most streams and rivers in Maine have summer pH values between 6.0 and 7.5. Spring or fall pH values can be much lower in streams associated with large wetlands. Waterbodies with a lot of calcium or other minerals have higher pH values. Some streams and rivers in Aroostook County have summer pH values around 8.0.

Nutrients can cause pH values to reach high or low levels that are stressful to aquatic life. In the process of photosynthesis, algae and plants remove carbon dioxide in the water and convert it to sugars. Removing carbon dioxide increases pH and makes the water less acidic (Wetzel 2001). At night, the algae and plants stop photosynthesizing and carbon dioxide levels increase again as bacteria, algae, plants, and other aquatic organisms respire. Even healthy waterbodies see daily changes in pH. In nutrient enriched waters, however, large swings in dissolved oxygen are often accompanied by large swings of pH. The existing pH criteria are in place to protect aquatic life from harmful changes in acidity.

4.2 - Nutrient Indicators

The general rule of thumb is that phosphorus is the primary nutrient that limits the growth of algae and plants in Maine lakes, streams, and rivers (Wetzel 2001). It is well documented, however, that nitrogen can also limit the growth of algae and plants in other parts of the country (Francouer 2001). Nitrogen may in fact limit algae and plant growth by itself or in combination with phosphorus in some Maine lakes, streams, or rivers. In particular, nitrogen may be a limiting nutrient in waters with very low levels of all nutrients or in waters that have already received excessive phosphorus loading.

DEP staff, however, decided to use total phosphorus (TP) as the primary indicator of nutrient enrichment. There are several reasons for choosing TP. First, DEP has a long history of using TP as an indicator of the trophic state of lakes and is familiar with its effects on water quality. We have more phosphorus data than nitrogen data, especially for lakes. Second, concentrations of nitrogen and phosphorus are highly correlated. When one is high, the other is usually high. Finally, it is easier to manage phosphorus inputs into waterbodies than it is to manage nitrogen inputs. Therefore, we decided to use TP as the primary nutrient criterion and use nitrogen and other nutrients on a case by case basis.

TP samples were collected during the summer (June-September) months over a period of several years. Concentrations below the detection limit were given a value one half of the detection limit. Most streams and rivers were represented by single nutrient samples. Average nutrient concentrations were used for locations with multiple samples.

4.2.1 - Class AA and A

The TP value for Class AA and A streams and rivers was established by examining the following data sets (average TP was computed for sites with more than one sample):

- A set of TP samples from 125 sites with >95% of land area within upstream watersheds consisting of forest or wetland, with no dams, and no large discharges of effluent (Figure 21). The 90th percentile of TP was **21 ppb**.
- A set of 135 sites that attain Class A aquatic life criteria based on macroinvertebrates. Class AA and A share the same aquatic life criteria. The 75th percentile was **23 ppb** (Figure 22).
- A set of 246 sites with a range of TP concentrations. The probability of attaining Class A was computed with logistic regression. We set the cutoff for Class A at a probability of 0.60. We identified the TP values where the lower confidence interval met the cutoff and where blue regression line met the cutoff, which were at **9** and **12 ppb**. (Figure 23).

Based on the weight of evidence, we set the TP criterion for Classes AA and A at **18 ppb**, which was the mean of 21, 23, and 9 ppb.

Figure 21. Quantile plot of TP from 125 reference streams across Maine

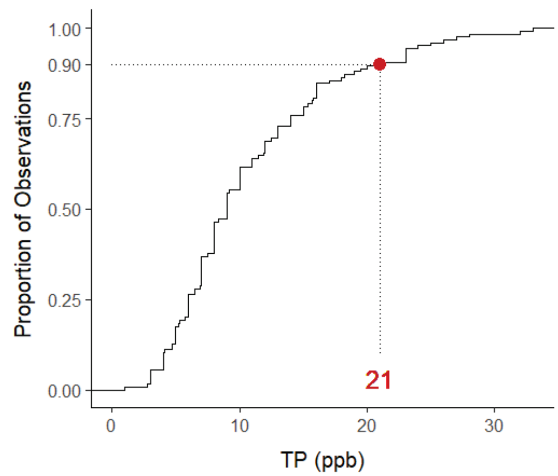


Figure 22. Quantile plot of TP concentrations from 135 streams that attain Class A

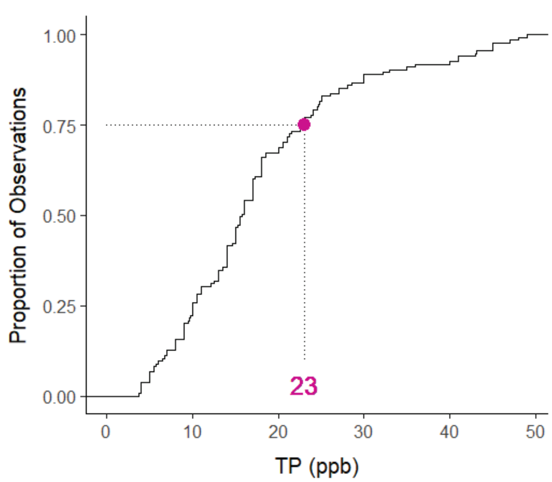
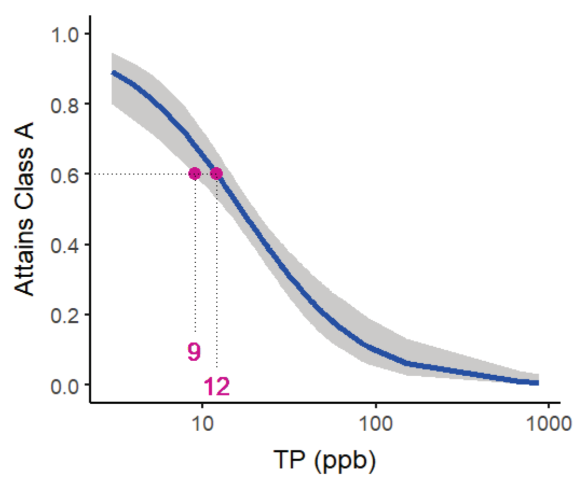


Figure 23. Probability of attaining Class A with TP concentrations



4.2.2 - Class B

The TP value for Class B streams and rivers was established by examining the following data sets (average TP was computed for sites with more than one sample):

- A set of TP samples from 75 sites that attain Class B but not Class A. The 75th percentile of TP was **37 ppb**. (Figure 24)
- A set of 246 sites with a range of TP concentrations. The probability of attaining Class B was computed with logistic regression. We set the cutoff for Class B at a probability of 0.60. We identified the TP values where the lower confidence interval met the cutoff and where blue regression line met the cutoff, which were at **25** and **30 ppb**. (Figure 25).

Based on the weight of evidence, we set the TP criterion for Class B at **30 ppb**, which was one unit less than the mean of 37 and 25 ppb.

Figure 24. Quantile plot of TP from 75 sites that attain Class B but not Class A

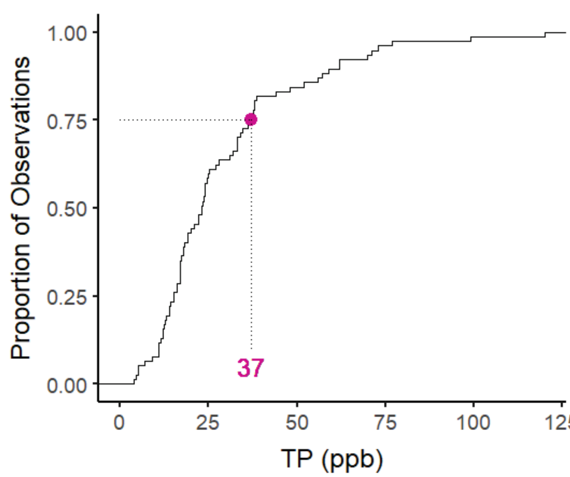
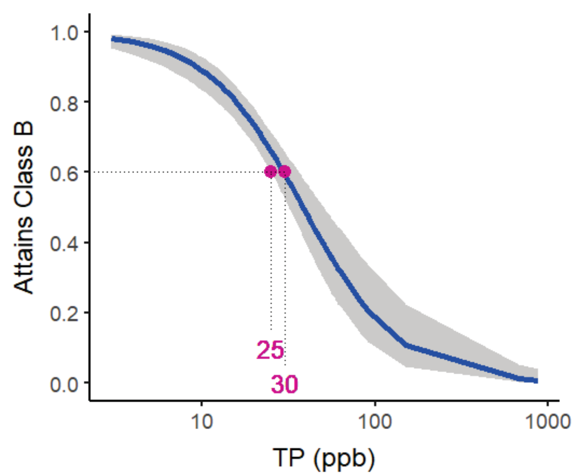


Figure 25. Probability of attaining at least Class B with TP concentrations



4.2.3 - Class C

The TP value for Class C streams and rivers was established by examining the following data sets (average TP was computed for sites with more than one sample):

- A set of TP samples from 50 sites that attain Class C but not Class A or B. The 75th percentile of TP was **54 ppb** (Figure 26).
- A set of 246 sites with a range of TP concentrations. The probability of attaining Class C was computed with logistic regression. We set the cutoff for Class C at a probability of 0.60. We identified the TP values where the lower confidence interval met the cutoff and where blue regression line met the cutoff, which were at **48** and **62 ppb**. (Figure 27).

Figure 26. Quantile plot of TP from 50 sites that attain Class C but not Class A or B

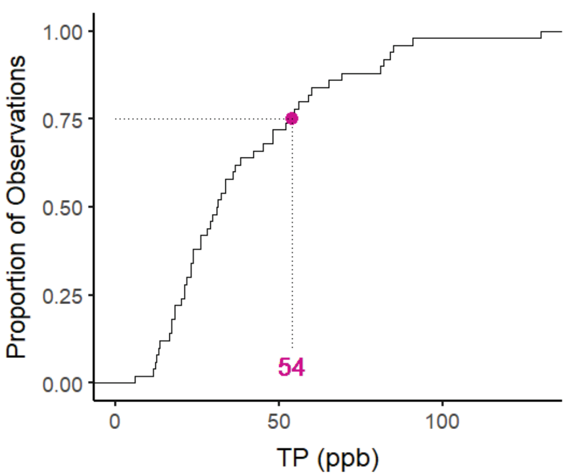
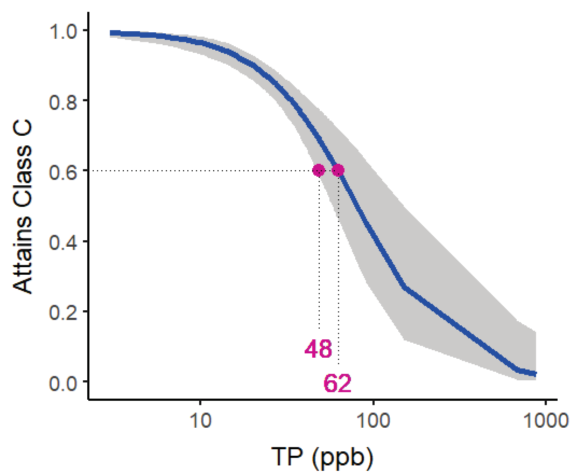


Figure 27. Probability of attaining Class C with TP concentrations



In addition to looking at TP percentiles and probability of attaining Class C at different TP concentrations, we evaluated the relationship of TP with nuisance benthic algae and phytoplankton blooms to protect recreational uses.

- Analyzed a set of 273 samples with TP and % nuisance algal cover observations. Changepoint analysis identified the biggest change of % nuisance algal cover at **37.5 ppb** ($p<0.01$). This is the point where there was the greatest difference of the mean of observations to the right of the changepoint compared to the mean of the observations to the left of the changepoint (Figure 28).
- Regression equation a meta-analysis of concentrations of TP and chlorophyll *a* from planktonic algae floating in the stream and river water(Van Nieuwenhuyse and Jones 1996). The meta-analysis compiled 292 paired samples from 24 studies. The regression line is shown on Figure 38 as a blue curve and the error is shown as light blue shading. The blue regression curve reached 8 ppb chlorophyll a at **47 ppb** TP and upper confidence reached it at **25 ppb** (Figure 29). The equation was:

$$\log_{10} \text{chlorophyll } a = -1.65 + 1.99(\log_{10} \text{TP}) - 0.28 (\log_{10} \text{TP})^2$$
$(s=0.32,\ r^2 = 0.67,\ p<0.001,\ n=292)$

- Regression equation of a study of TP and chlorophyll a concentrations from planktonic algae floating in water of Canadian streams and rivers (Chambers et al. 2012). This dataset included many sites in agricultural settings. The regression line is shown on Figure 28 as a dashed red line. The regression line reached 8 ppb chlorophyll *a* at **79 ppb** TP.

  The equation was:
  - $\log_{10}$ chlorophyll $a = 1.21 (\log_{10} \text{TP}) + 2.22$
    ($r2= 0.38$, $p<0.001$, $n=70$)

Figure 28. Changepoint analysis indicating the TP concentration with the largest change in the % cover of nuisance benthic algae. *Red vertical line is the changepoint. Blue horizontal lines are the means of samples on either side of the changepoint.*

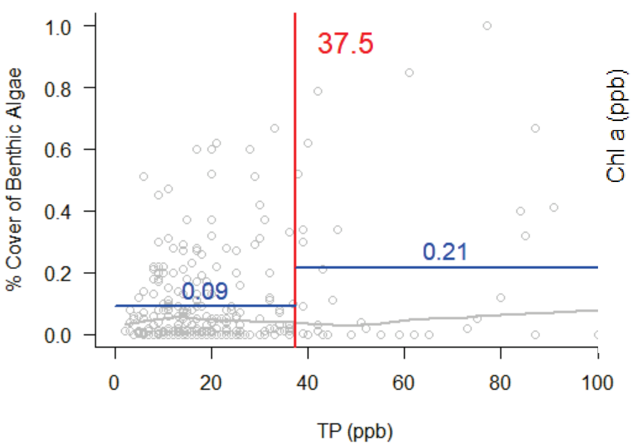
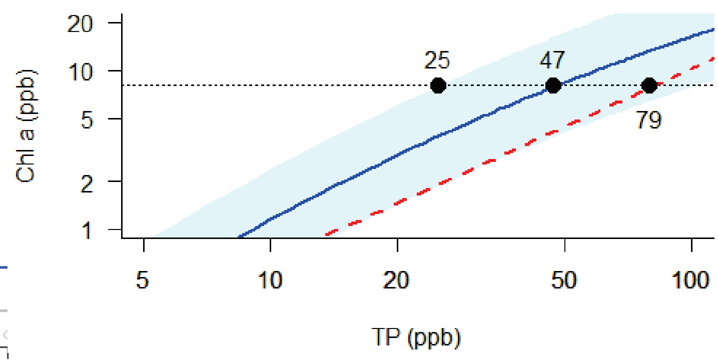


Figure 29. Regression equations of the concentrations of sestonic chlorophyll *a* and TP
Blue curve and associated confidence interval are from Van Nieuwenhuyse and Jones (1996)
Red dashed line is from Chambers et. al (2012)



Based on the weight of evidence, we set the TP value for Class C at **40 ppb**, which was one unit less than the mean of 54, 48, 37.5, and 25 ppb. Our decision was influenced by several factors. First, we wanted the TP value for Class C to protect both aquatic life and recreational uses. We also wanted the TP value to protect downstream uses. The data from Maine included some streams with large TP concentrations but with cold water and shading by trees. We suspect that environmental factors such as shading and cold water could prevent algal blooms and maintain benthic macroinvertebrate assemblages despite having nutrient enrichment. Export of nutrients from these streams to downstream waterbodies, however, is still a concern. In addition, most streams in Maine have low concentrations of orthophosphate, which is a form of dissolved inorganic P that is readily used by plants and algae. Streams with more orthophosphate or organic forms of P would presumably be at greater risk of algal blooms and impaired macroinvertebrate communities. Therefore, we were somewhat conservative when setting the TP value at 40 ppb to help protect against circumstances where the source of P enrichment is organic P or dissolved inorganic P in nature.

5 - Potential for listing new impaired waters

Class AA, A, B, and C waterbodies that do not attain nutrient criteria because of DO, pH, or aquatic life would not be considered "new listings caused by Chapter 583" because those environmental responses are already independent criteria. The potential for "new listings caused by Chapter 583" is restricted to water column chlorophyll *a,* percent nuisance algal cover, and patches of filamentous bacteria and fungi. We estimated the potential for "new impairments" by examining DEP data for the past 5 years.

5.1 - Listing methodology for the Integrated Water Quality Monitoring and Assessment Report

Determination of water quality attainment is based on a water meeting all standards and criteria established for its assigned classification (38 M.R.S.A §§ 465, 465-A, and 465-B). Waters are listed by Assessment Unit (HUC) and/or waterbody segment in one of five categories of attainment (see category descriptions below).

5.1.1 - Category 1: Attaining all designated uses and water quality standards, and no use is threatened.

Highest level of attainment, waters in the assessment unit attains all applicable standards. Assessment is based on combined evaluation of the following information.

1. Current data (collected within five years) indicates attainment, with no trend toward expected non-attainment within the listing period.
2. Old data (greater than five years) indicates attainment and no change in any associated conditions.
3. Water quality models predict attainment under current loading, with no projected change in loading that would predict non-attainment.
4. Qualitative data or information from professional sources indicating attainment of standards and showing no identifiable sources (e.g. detectable points of entry of either licensed or unlicensed wastes) of pollution, low impact land use (e.g. intact riparian buffers, >90% forested watershed, little impervious surface), watershed within state or federal reserve land, park, wilderness area or similar conservation protection, essentially unaltered habitat, and absence of other potential stressors.
5. Determination that the direct drainage area has a human population of <0.1 per square mile according to U.S. Census data obtained in 2000 and watershed conditions as described in item 4, above. For lakes, determinations are based on census data at the town level and consider all towns in the direct drainage of larger (referred to in previous 305(b) reports as "significant") lakes. Populations for the remaining lakes (generally less than ten acres) are determined for the town listed as the point-of-record for the water according to Department of Inland Fisheries and Wildlife Lake Index database.

5.1.2 - Category 2: Attains some of the designated uses; no use is threatened; and insufficient data or no data and information is available to determine if the remaining uses are attained or threatened (with presumption that all uses are attained).

Assessment is based on combined evaluation of the following information.

1. Current data (collected within five years) for some standards indicating attainment, with no trend toward expected non-attainment within the listing period, or an inadequate density of data to evaluate a trend.
2. Old data (greater than five years) for some standards indicating attainment, and no change in associated conditions.
3. Water quality models that predict attainment under current loading for some standards, with no projected change in loading that would predict non-attainment.
4. (For lakes) Probabilistic-based monitoring that indicates a high expectation of use attainment for certain classes of waters based on random monitoring of that class of waters.
5. Insufficient data for some standards, but qualitative data/information from professional sources indicate a low likelihood of impairment from any potential sources (e.g. high dilution, intermittent/seasonal effects, low intensity land use).

5.1.3 - Category 3: Insufficient data and information to determine if designated uses are attained (with presumption that one or more uses may be impaired).

Assessment is based on combined evaluation of the following information. Monitoring schedules are assigned to these waters.

1. Insufficient or conflicting data that does not confirm either attainment or non-attainment of designated uses.
2. Qualitative data or information from professional sources showing the potential presence of stressors that may cause impairment of one or more uses; however, no quantitative water quality information confirms the presence of impairment-causing stressors.
3. Old data, with:
    a. low reliability, no repeat measurements (e.g. one-time synoptic data),
    b. a change of conditions without subsequent re-measurement; or
    c. no evidence of human causes or sources of pollution to account for observed water quality condition (natural conditions that do not attain water quality standards are allowed by 38 M.R.S.A. Section 464.4.C).
4. (For lakes) Current data indicates a return to (or a trend towards) attainment standards over the past few years but requires confirmation; or conversely, that trophic or dissolved oxygen profile evaluation suggests deteriorating conditions requiring further study and verification. (Since lakes respond over a longer period of time and can be highly influenced by weather attributes, it is appropriate to recommend additional monitoring before attainment is determined.)

5.1.4 - Category 4: Impaired or threatened for one or more designated uses, but does not require development of a TMDL.

A water body is listed in Category 4 when impairment is not caused by a pollutant; or, if impairment is caused by a pollutant, but where a TMDL has already been completed, or where other enforceable controls are in place. An impaired waterbody will be listed in Category 5 if both a pollutant and a non-pollutant are involved that would independently cause an impaired or threatened condition. Waters are listed in one of the following Category 4 sub-lists when:

1. Current or old data for a standard indicates either impaired use, or a trend toward expected non-attainment within the listing period, but also where enforceable management changes are expected to correct the condition,
2. Water quality models that predicted impaired use under loading for some standard, also predict attainment when required controls are in place, or,
3. Quantitative or qualitative data/information from professional sources indicates that the cause of impaired use is not from a pollutant(s) (e.g. habitat modification).

4-A: TMDL is completed. A TMDL is complete but insufficient new data exists to determine that attainment has been achieved.
Note: For the 2008 cycle the 4A category now includes all freshwaters in Maine that were listed in previous cycles in a narrative Category 5-C "Impairment caused by atmospheric deposition of mercury" due to the Statewide fish consumption advisory due to mercury. On December 20, 2007 US EPA approved a Regional Mercury TMDL for the Northeast.

4-B: Other pollution control requirements are reasonably expected to result in attainment of standards in the near future. Waterbodies where enforceable controls have a reasonable expectation of attaining standards, but where no new data are available to determine that attainment has been achieved. (Enforceable controls may include: new wastewater discharge licenses issued without preparation of a TMDL, other regulatory orders, contracts for nonpoint source implementation projects, regulatory orders or contracts for hazardous waste remediation projects).

4-C: Impairment is not caused by a pollutant. Waters impaired by habitat modification that is a result of human activity.
Note: Natural conditions that do not attain water quality standards and criteria are allowed by 38 M.R.S.A. Section 464.4.C. Waters that show impairment due to natural phenomena are listed in Categories 1 through 3.

5.1.5 - Category 5: Waters impaired or threatened for one or more designated uses by a pollutant(s) and a TMDL is required.

Waters are listed in one of the Category 5 sub-lists when:

1. Current data (collected within five years) for a standard either indicates impaired use, or a trend toward expected impairment within the listing period, and where quantitative or qualitative data/information from professional sources indicates that the cause of impaired use is from a pollutant(s),

2. Water quality models predict impaired use under current loading for a standard, and where quantitative or qualitative data/information from professional sources indicates that the cause of impaired use is from a pollutant(s), or,
3. Those waters have been previously listed on the State's 303(d) list of impaired waters, based on current or old data that indicated the involvement of a pollutant(s), and where there has been no change in management or conditions that would indicate attainment of use.

5-A: Impairment caused by pollutants (other than those listed in 5-B through 5-D). A Total Maximum Daily Load is required and will be conducted by the State of Maine. TMDL schedules are assigned based on the value of a particular water (considering size, public use, proximity to population centers, and level of public interest for water quality improvement), the nature of the impairment and the source(s) of the problem, available information to complete the TMDL, and availability of staff and contractual resources to acquire information and complete the TMDL study. Projected schedules for TMDL completion are included in Chapter 8 as well as in the Appendices.

*5-B: Impairment is caused solely by bacteria contamination***.** A TMDL is required. Certain waters impaired only by bacteria contamination may be high priority resources, such as shellfish areas, but a low priority for TMDL development if other actions are already in progress that will correct the problem in advance of TMDL development (e.g. better compliance). Certain small streams that are impaired solely by bacteria contamination but where recreation (swimming) is impractical because of their small size are listed in 5-B. Relative to other, more ecologically detrimental causes of impairment these waters are considered a lower priority for TMDL completion. A projected schedule of TMDL completion is included where applicable. Waterbodies impaired only by Combined Sewer Overflows, where current CSO Master Plans (Long-Term Control Plan) are in place, will be monitored to demonstrate that water quality standards are attained and that provisions are in place for both funding and compliance timetables.

*5-C: Impairment caused by atmospheric deposition of mercury and a regional scale TMDL is required***.** Due to EPA approval of a regional scale TMDL for the control of mercury all of Maine's Category 5C waters have been administratively moved to Category 4A.
5-D: Impairment caused by a "legacy" pollutant. This sub-category includes:
1. waters impaired only by PCBs, dioxins, DDT, or other substances already banned from production or use. It includes waters impaired by contaminated sediments where there is no additional extrinsic load occurring. This is a low priority for TMDL development since there is no controllable load.
2. coastal waters that have a consumption advisory for the tomalley (hepato-pancreas organ) of lobsters due to the presence of persistent bioaccumulating toxics found in that organ. This is a low priority for TMDL development since there is no identifiable and controllable load.

5.2 - Chlorophyll a in streams, rivers, and impoundments

In the past 5 years, DEP staff collected chlorophyll *a* in the following samples from streams, rivers, or impoundments that exceeded 8 ppb.

- Swetts Meadow, Limington (33 ppb)
- Littlefield River, Alfred (23 ppb)

In general, implementing this environmental indicator will not greatly increase the number of impaired waterbodies.

5.3 - Percent nuisance algal cover

In the past 5 years, DEP staff observed % nuisance algal cover exceeding the proposed values for Classes AA/A, B, and C in 13 out of 191 samples (Table 2). Most of the streams with abundant nuisance algae are already listed as impaired for other reasons. In general, implementing this environmental indicator will not greatly increase the number of impaired waterbodies.

Table 2. Viewing bucket samples in the past 5 years that exceeded the proposed % nuisance algal cover values proposed in Chapter 583

Waterbody	Class	% Nuisance Algal cover	Impairment Status
Birch Stream, Bangor	B	89	Already listed as impaired
Bond Brook, Augusta	B	63, 52	Already listed as impaired
China Lake Outlet, Winslow	B	31	Already listed as impaired
Fifteenmile Stream, Benton	B	52	
French Stream, Exeter	B	47	Already listed as impaired
Frost Brook, Westfield	B	30	
Kennebunk River, Kennebunk	B	49	Listed as Category 3
Penjajawoc Stream, Bangor	B	60	Already listed as impaired
Riggs Brook, Augusta	B	80	Already listed as impaired
Stetson Brook, Lewiston	B	33	Already listed as impaired
Wesserunsett Stream, Cornville	B	29	Listed as Category 3
Whitney Brook, Augusta	B	63	Already listed as impaired

5.4 - Patches of bacteria and fungi

In the past 5 years, there have been a few documented observations of filamentous bacteria and fungi, such as the following locations:

- Alder Stream, Corinna (cow manure)
- Chickering Creek, Kittery (sewage leak)
- Collyer Brook, Gray (improper disposal of brewery waste)
- Tributary to Swan Pond Brook, Lyman (runoff from composting facility)
- Unnamed Stream, Arundel (leaking septic system)
- Unnamed Stream, Clinton (cow manure)

- Unnamed Stream, Fairfield (cow manure)
- Unnamed Stream, Lyman (malfunctioning leach field)

Sewage fungus is typically associated with low dissolved oxygen concentrations, impaired aquatic life communities, and/or high bacteria counts. As a result, this response indicator would not result in listing waterbodies as impaired that would not be listed as impaired for other reasons.

6 - Potential impacts to permits and licenses

Chapter 583 is a water quality rule designed to add nutrient criteria to Maine's water quality standards for Class AA, A, B, and C waters. Chapter 583 would not directly change other regulatory or non-regulatory programs. However, Chapter 583 could indirectly affect some programs, particularly for licenses to discharge nutrients to receiving waters under the Maine Pollution Discharge Elimination System (MEPDES) and National Pollution Discharge Elimination System (NPDES). First, Chapter 583 could result in a small number of new impaired waters (Sections 5.2-5.4). A permit associated with one of those waterbodies might receive new or more stringent nutrient limits. Table 3 summarizes how the proposed nutrient criteria would be applied to decisions about discharge licenses. Otherwise, the fundamental nature of other regulatory and non-regulatory frameworks would not change (Table 4).

In addition to new impaired waters, Chapter 583 would indirectly affect the evaluation of discharges of nutrients covered under the MEPDES and NPDES. State and federal regulations require permit writers to assess the potential impact of discharges of effluent to downstream water quality. DEP staff do this analysis when issuing or renewing licenses. They gather data about the facility and receiving water and determine if there is a *reasonable potential* of a waterbody failing to attain water quality standards under a worst-case scenario of maximum discharge allowed by the permit at a time when river flows were very low. The nutrient criteria proposed in Chapter 583 are primarily reactive and identify situations where nutrient enrichment has already impacted water quality. In contrast, reasonable potential analysis is proactive and identifies possible water quality problems in worst-case scenarios of maximum discharge of nutrients when there is little water in the river.

Reasonable potential analysis involves calculating the TP concentration in the river at a point downstream of a discharge ($TP_{downstream}$) based on the upstream flow at a critical flow level ($Q_{upstream}$), maximum upstream TP concentration ($TP_{upstream}$), maximum flow of the discharge allowed by the permit ($Q_{discharge}$), and average TP concentration of the discharge ($TP_{discharge}$) (Figure 30). For the critical river flow ($Q_{upstream}$), the Department uses calculates the 7Q10, which is the lowest average flow over a 7-day period that occurs, on average, once every 10 years. The Department created a website with an interactive tool to calculate $TP_{downstream}$ based on model inputs that can be adjusted by the user (https://streamdoctor.shinyapps.io/Reasonable_potential_calculator_for_stream_TP/). After calculating the $TP_{downstream}$, Department staff compare the $TP_{downstream}$ to a numeric threshold. Before 2012, the Department used a TP threshold of 35 ppb along with 7Q10 as the background

Table 3. Implementation of the proposed nutrient criteria in the process of issuing discharge licenses (Adapted from Vermont Department of Environmental Conservation, 2014)

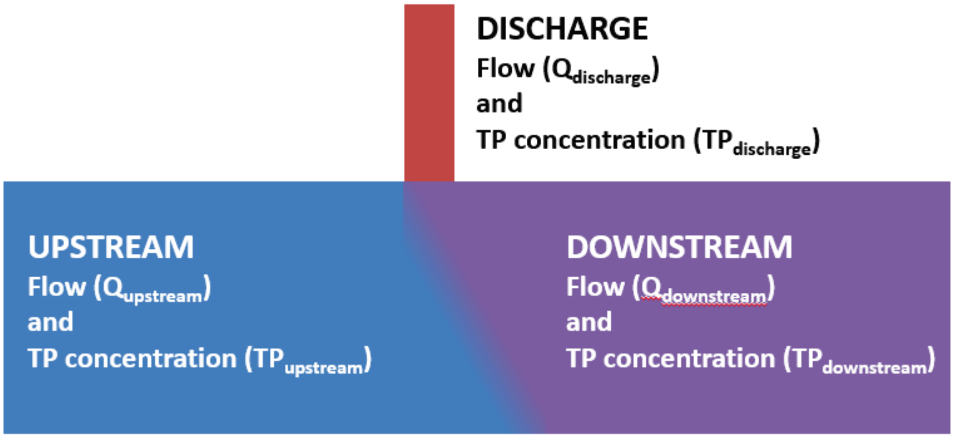
	Seasonal mean TP concentration is less than or equal to the applicable value in Chapter 583 or an established site-specific value ***AND*** **If the waterbody has a site-specific value for a non-TP nutrient, the seasonal mean concentration of the non-TP nutrient is less than or equal to the site-specific value for the non-TP nutrient**	**Seasonal mean TP concentration is greater than the applicable value in Chapter 583 or an established site-specific value** ***AND/OR*** **If the waterbody has a site-specific value for a non-TP nutrient, the seasonal mean concentration of the non-TP nutrient is greater than the site-specific value for the non-TP nutrient**
All applicable response indicators meet the values in Chapter 583	If a new or increased discharge is proposed, the permit will limit the phosphorus concentration increase according to the anti-degradation policy. No new or increased phosphorus discharge would be permitted that would cause the phosphorus concentration to be greater than the applicable value. If a current discharge has reasonable potential to produce a phosphorus concentration above the applicable value, then annual monitoring will be conducted at the site for phosphorus concentration and all nutrient response conditions. If response conditions are worsening or indicate a likelihood that an impairment will develop, more stringent permit limits will be applied in order to prevent the impairment.	If a new or increased discharge is proposed, the permit will limit the effluent phosphorus concentrations and loads to the existing amounts or less. If response conditions are worsening or indicate a likelihood that an impairment will develop, more stringent permit limits will be applied in order to prevent the impairment.
One or more of the applicable response indicators do not meet the values in Chapter 583	If the site is determined not to be impaired by nutrients but a new or increased discharge is proposed, the permit will limit the nutrient increase according to the anti-degradation policy. In no case will amounts be permitted that would cause the phosphorus value to be exceeded. If the site is determined to be impaired by nutrients, then more stringent permit limits will be applied in order to correct the impairment.	More stringent permit limits will be applied in order to correct the impairment. A Total Maximum Daily Load (TMDL) designed to achieve the applicable phosphorus concentration may be required.

Table 4. Aspects of water quality management before and after adopting Chapter 583

	Without Chapter 583	After adopting Chapter 583
WATER QUALITY STANDARDS (nutrient response indicators)		
Dissolved oxygen	✓	✓ **Same**
pH	✓	✓ **Same**
Aquatic life (biomonitoring)	✓	✓ **Same**
Sewage fungus	✓	✓ **Same**
Secchi disk transparency		✓ New
Chlorophyll *a* concentration		✓ New
% nuisance algal cover		✓ New
REGULATORY REQUIREMENTS * Maine Pollution Discharge Elimination System (MEPDES) * National Pollution Discharge Elimination System (NPDES) * Municipal Separate Stormwater Systems (MS4) permits * Nutrient management plans	✓	✓ **Same framework** Individual permits might have new or more stringent nutrient limits if a waterbody does not attain nutrient criteria.
NON-REGULATORY PROGRAMS * Incentives restoration, buffer strips, etc.	✓	✓ **Same framework**

stream flow ($Q_{upstream}$) (Table 5). If the calculated $TP_{downstream}$ was greater than 35 ppb, then there was reasonable potential that the waterbody would not attain water quality standards under worst-case conditions and a P limit would be added to the permit (Table 6). In 2012, the Department switched to using a TP threshold of 100 ppb for reasonable potential analysis. If Chapter 583 were adopted, the U.S. EPA would require the Department use the TP values of 18, 30, and 40 ppb as the new thresholds for Classes AA/A, B, and C, respectively. This change could increase the number of facilities with reasonable potential issues.

Figure 30. Equation for calculating the TP concentration of the receiving water, downstream of a discharge.



$$\frac{Q_{discharge}TP_{discharge} + Q_{upstream}TP_{upstream}}{Q_{discharge} + Q_{upstream}} = TP_{downstream}$$

$Q_{discharge}$ = Maximum flow of the discharge allowed by permit

$TP_{discharge}$ = Average TP concentration of the discharge

$Q_{upstream}$ = Background stream flow (at critical flow)

$TP_{upstream}$ = Maximum background in-stream TP concentration

$TP_{downstream}$ = Resultant downstream TP concentration

Table 5. History of TP thresholds and critical flows used by the Department in analysis of reasonable potential.

Component of RP Analysis	Before 2012	2012 – current	If Chapter 583 was adopted
TP threshold	35 ppb	100 ppb	18 ppb for AA/A 30 ppb for B 40 ppb for C
Critical Flow (cubic feet per second)	7Q10[1]	7Q10[1]	August median flow[2]

1 – 7Q10 is the lowest average flow over a 7-day period that occurs, on average, once every 10 years.
2 – August median flow approximately 3-5 times more water than 7Q10, depending on the river.

Table 6: Example of different scenarios after reasonable potential analysis for a Class B stream

Downstream Computed TP	TP value for Class B	Response Indicators	Action
20 ppb	30 ppb	All are OK	Nothing or monitor TP
40 ppb	30 ppb	All are OK	Reasonable potential exists and a permit must have an effluent TP limit[1] *(Could consider a study to determine if a site-specific TP value is appropriate)*
40 ppb	30 ppb	One or more response variables do not meet values in Chapter 583 or was not measured	Reasonable potential exists and a permit must have an effluent TP limit[1]

1 – Various approaches could be employed to potentially avoid reasonable potential and a TP limit. For example, one could try to reduce the maximum flow allowed by the permit and/or reduce the average TP concentration of the discharge.

If Chapter 583 were adopted, the Department would switch from using 7Q10 to August median flow (as $Q_{upstream}$) when analyzing the reasonable potential of TP causing a waterbody to no longer attain water quality standards. This transition is not part of Chapter 583 but is based on existing statutory authority in 38 M.R.S. Section 464.4.D. The August median flow is computed by sorting available August flow data from lowest to highest and finding the value with approximately half of the data above that value and half of the data below that value. Depending on the river, August median flow typically equates to 3-5 times more water than 7Q10. The Department is considering the change because of the following reasons:

- phosphorus is not toxic at concentrations observed in Maine waters,
- adding nutrients will not always lead to water quality problems because of other factors that may limit the growth of algae, and
- it typically takes 10-21 days to form a bloom of algae floating in the water (phytoplankton) or filamentous algae growing on rocks.

Switching from 7Q10 to August median flow would decrease the number of facilities with reasonable potential issues. The combined effect of using both the new TP thresholds and switching to August median flow would lead to a small increase in the number of facilities with discharges that trigger reasonable potential, when compared to the current approach. Approximately 8% of the 163 public operated wastewater treatment plants and several other commercial, state, and federal facilities would have issues with reasonable potential under those conditions. Various approaches could be employed to reduce the $TP_{downstream}$ and potentially avoid reasonable potential and a TP limit. For example, a facility could take steps to reduce the average TP concentration of the discharge ($TP_{discharge}$). Alternatively, a facility could agree to reduce the maximum discharge allowed under the permit ($Q_{discharge}$). Finally, a watershed-based approach could be used to reduce TP pollution from upstream ($TP_{upstream}$). If none of those approaches reduced $TP_{downstream}$ enough, then the Department would need to add a TP limit to the license the next time it came up for renewal. The Department would work with impacted facilities to establish a compliance schedule, determine an appropriate course of action, and help obtain funding through grants and the Statewide Revolving Fund (SRF) program. If a facility triggers reasonable potential but all environmental response indicators meet the values in Chapter 583, then there is the potential of conducting a multi-year study to determine if a high site-specific TP value could still maintain water quality of the receiving water and attainment of water quality standards (Chapter 583 Section . Any site-specific TP values would need to be approved by the U.S. EPA and appended to Chapter 583 through a public rulemaking process.

The Department held public meetings on December 11, 2020 and January 22, 2021 to get feedback about the draft nutrient rule. Many people supported the use of August median flow in reasonable potential calculations. Some people commented that using August median flow would be less protective than using 7Q10 in RP calculations, which is true. DEP previously debated between using 7Q10 and August median flow and decided to use August median flow because P is not toxic, it takes several weeks for nutrient enrichment to create algal blooms, and environmental factors may limit the growth of algae, such as shade and unstable substrate. While not the deciding factor, the choice of August median or 7Q10 flows would influence the Department's ability to conduct water quality studies to determine if site-specific values for TP or another nutrient are appropriate. With 7Q10, staff could only collect data, on average, once every 10 years. In contrast, staff could collect data every couple of years, on average, with August median flow.

7 – Studies for site-specific TP values

Section 5(2)(a) of the draft Chapter 583 describes a study to determine if a site-specific TP value is appropriate for a waterbody that has high TP concentrations but still has good environmental response indicators. The studies consist of at least three years of sampling, including at least one year with critical ambient conditions, such as low flow and warm temperature. The Department estimates that it would cost \$2,000 - \$5,000 to complete one season of monthly sampling for a wadeable stream with rocky substrate (Table 7). The lowest estimate includes just lab costs. The higher estimate includes the lab costs plus hiring a contractor to do the sampling. The Department estimates that sampling an impoundment or deep river for one season with monthly sampling (Table 8) would cost \$1,700 (just lab costs) to \$4,800 (lab plus hiring contractor to collect samples). The Department may determine that more frequent sampling is required in some circumstances.

Table 7. Example of a sample plan with monthly samples for a wadeable stream with rocky substrate

Parameter	June	July	August	September
Water samples (TP, O-PO_4)	✓	✓	✓	✓
Dissolved oxygen	✓	✓	✓	✓
pH	✓	✓	✓	✓
Sewage fungus	✓	✓	✓	✓
% nuisance algal cover	✓	✓	✓	✓
Aquatic life (biomonitoring)				
macroinvertebrates	--	--	✓	--
algae	--	✓	--	--
Chlorophyll *a* concentration	--	--	--	--
Secchi-disk transparency	--	--	--	--

Table 8. Example of a sample plan with monthly samples for an impoundment or deep river

Parameter	June	July	August	September
Water samples (TP, O-PO_4)	✓	✓	✓	✓
Dissolved oxygen	✓	✓	✓	✓
pH	✓	✓	✓	✓
Sewage fungus	✓	✓	✓	✓
% nuisance algal cover	--	--	--	--
Aquatic life (biomonitoring)				
macroinvertebrates	--	--	✓	--
algae	--	--	--	--
Chlorophyll *a* concentration	✓	✓	✓	✓
Secchi-disk transparency	✓	✓	✓	✓

8 – Definitions and acronyms related to the draft nutrient rule

- "303d list" is a list of impaired waters, referring to Section 303d of the Clean Water Act.
- "7Q10" is the lowest 7-day average stream/river flow that occurs (on average) once every 10 years.
- "Algal bloom" means a growth of suspended algae in the water column that causes Secchi disk transparency to be less than 2.0 meters.
- "BPJ" means Best Professional Judgment, often used in context related to the analysis on samples collected for aquatic life attainment assessments.
- "Chlorophyll a" means a particular kind of photosynthetic pigment of algae and plants
- "Class" means the statutory goal (i.e., AA, A, B, C, GPA) assigned to a waterbody as established in Water Classification Program, 38 M.R.S.A. §§ 464(4), 465, 465-A, 467, and 468 for the purpose of protecting designated and existing uses.
- "Colored" means water having a mean apparent color >25 standard platinum units or equivalent value of true color or dissolved organic carbon.
- "CWA" is the Federal Clean Water Act.
- "DACF" is the Maine Department of Agriculture, Conservation and Forestry.
- "DEP" is the Maine Department of Environmental Protection.
- "DO" is dissolved oxygen.
- "Impounded waters" means riverine waters upstream of a dam and not classified as GPA where the surface elevation is essentially the same as found at the dam.
- "MEPDES" is the Maine Pollutant Discharge Elimination System.
- "M.R.S." is the Maine Revised Statutes.
- "MS4" is the municipal separate stormwater sewer systems.
- "NPDES" is the National Pollutant Discharge Elimination System.
- "Nutrient" means any chemical which an organism requires to live and grow. Nitrogen and phosphorus are important nutrients that frequently limit growth of aquatic organisms, especially primary producers, but the term includes many other essential and trace elements.
- "O-PO4" is a measurement of ortho phosphate measurements.
- "POTW" means Publicly Owned Treatment Works.
- "Patches of fungi and filamentous bacteria" means visible growths of aquatic fungi or filamentous bacteria (e.g., sewage fungus), excluding iron and manganese bacteria.
- "Percent algal cover" means the amount of stream and river substrate covered by filamentous algae greater than 1 centimeter long or periphyton mats greater than 1 millimeter thick.
- "Periphyton" means a layer of microscopic algae, bacteria, and fungi growing on a substrate within a waterbody.
- "pH" means a measure of water acidity.
- "Phaeophytin" means a byproduct of chlorophyll degradation formed when chlorophyll loses its central magnesium molecule.

- "Phytoplankton" means algae suspended in the water column.
- "ppb" means parts per billion, which is equivalent to micrograms per liter (µg/L).
- "ppm" means parts per million, which is equivalent to milligrams per liter (mg/L).
- "Q" is a variable for stream/river flow, typically measured in cubic feet per second (cfs).
- "Secchi-disk depth" means a measurement of water clarity using a Secchi disk.
- "TMDL" means Total Maximum Daily Load.
- "TP" means total phosphorus.
- "Turbid" means that the water is not clear or transparent due to small organic and inorganic particles suspended in the water.
- "Type" means a kind of waterbody based on size, geomorphology, movement of water, and substrate type, such as pond, lake, wadable stream with rocky bottom, wadable stream with unconsolidated substrate, impoundment, and non-wadable river.
- "Water column chlorophyll *a*" means a measurement of the concentration of chlorophyll a in a water sample. It is an indicator of phytoplankton or algal blooms.

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