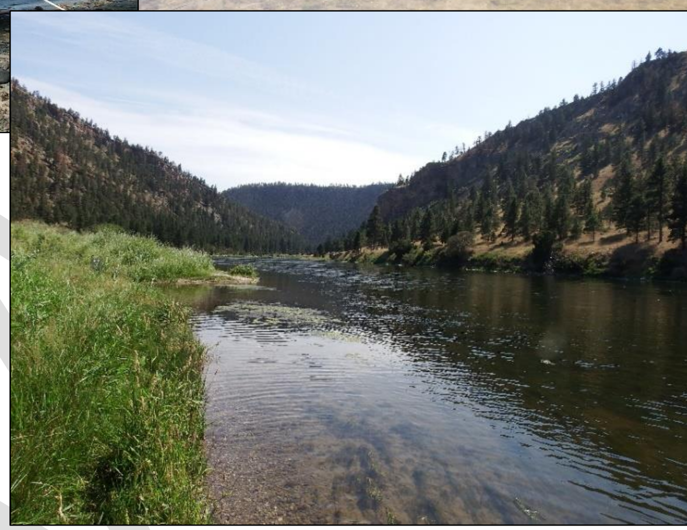
LARGE RIVER EUTROPHICATION ASSESSMENT METHOD



April 2024

Draft Document

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Document Revision and Version History

Revision Date	Version number	Summary of change(s)	Revised sections(s)	Revised by

Suggested Citation

Clift, Troy, Kron, Darrin, Milke, Kyle, Suplee, Michael. 2024. Large River Eutrophication Assessment Method. Draft Document. Helena, MT: Montana Department of Environmental Quality, Water Quality Planning Bureau.

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ACRONYMS

µg/L	microgram per liter
AFDW	Ash-free dry weight
ARM	Administrative Rules of Montana
AU	Assessment unit
CFR	Code of Federal Regulations
chl*a*	chlorophyll-a
CO_2	carbon dioxide
CWAIC	Clean Water Act Information Center
DEQ	Montana Department of Environmental Quality
DO	dissolved oxygen
DO Δ	dissolved oxygen daily fluctuation
DQA	data quality assessment
DQO	data quality objective
MCA	Montana Code Annotated
mg/m^2	milligram per meter squared
MT-eWQX	Montana EQuIS Water Quality Exchange
N	nitrogen
NDS	nutrient diffusing substrate
NO_2	nitrite
NO_3	nitrate
NO_{2+3}	Nitrite-Nitrate
P	phosphorus
QA	quality assurance
QAPP	quality assurance project plan
QC	quality Control
SAP	sampling and analysis plan
SOP	standard operating procedure
S.U.	standard unit
TDG	total dissolved gas
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
WARD	Water Quality Assessment and Reporting Documentation
WQPB	Water Quality Planning Bureau
WOE	weight of evidence

1.0 INTRODUCTION

The purpose of this document is to describe a framework for making beneficial use assessment decisions about eutrophication in large rivers. Specifically, it defines a process by which one can determine if a large river is or is not impaired by eutrophication. Eutrophication is the enrichment of a waterbody, typically by nitrogen (N) and phosphorus (P), leading to increased plant and algae growth and decay, and all the consequential changes to the waterbody and the water quality that occur because of this enrichment (Suplee et al., 2008). This document covers several subjects for assessing eutrophication in large rivers including the appropriate sampling frame, which narrative and numeric standards apply, which parameters are measured and how many samples are needed, how data are to be evaluated statistically, and how disparate data types are to be assembled into a final decision-making matrix.

Large rivers in Montana are defined in Flynn and Suplee (2013) and presented in **Table 1-1**; wadeable streams are not addressed by this methodology. This assessment method comprises a weight-of-evidence (WOE) process for addressing narrative standards, and direct comparison to specific numeric standards that respond to eutrophication (**Figure 1-1**). Direct comparisons can be made to water quality parameters for which numeric water quality standards have been adopted, while WOE is used for parameters that are considered under narrative standards. The WOE approach considers ambient nutrient concentrations in the assessment but gives greater weight to the response of the river, as measured via a set of nutrient-sensitive response variables. As seen in **Figure 1-1**, failure to achieve the narrative standards, the numeric standards, or both may result in listing the waterbody as impaired.

Table 1-1. Large river segments listed by beneficial use classification.

River Name	Assessment Unit Description	Beneficial Use Class*
Big Horn River	Crow Indian Reservation boundary to mouth	B-2
Clark Fork River	Bitterroot River to state-line	B-1
Flathead River	Origin to mouth	B-1
Kootenai River	Libby Dam to state-line	B-1
Madison River	Ennis Lake to mouth	B-1
Missouri River	Origin to Sun River	B-1
Missouri River	Sun River to Rainbow Dam	B-2
Missouri River	Rainbow Dam to Fort Peck Dam	B-3
Missouri River	Fort Peck Dam to Milk River	B-2
Missouri River	Milk River to state-line	C-3
South Fork Flathead River	Hungry Horse Dam to mouth	B-1
Yellowstone River	State-line to Laurel Water Supply Intake	B-1
Yellowstone River	Laurel Water Supply Intake to Billings Water Supply Intake	B-2
Yellowstone River	Billings Water Supply Intake to state-line	B-3

*Beneficial uses taken from ARM 17.30, subchapter 6.

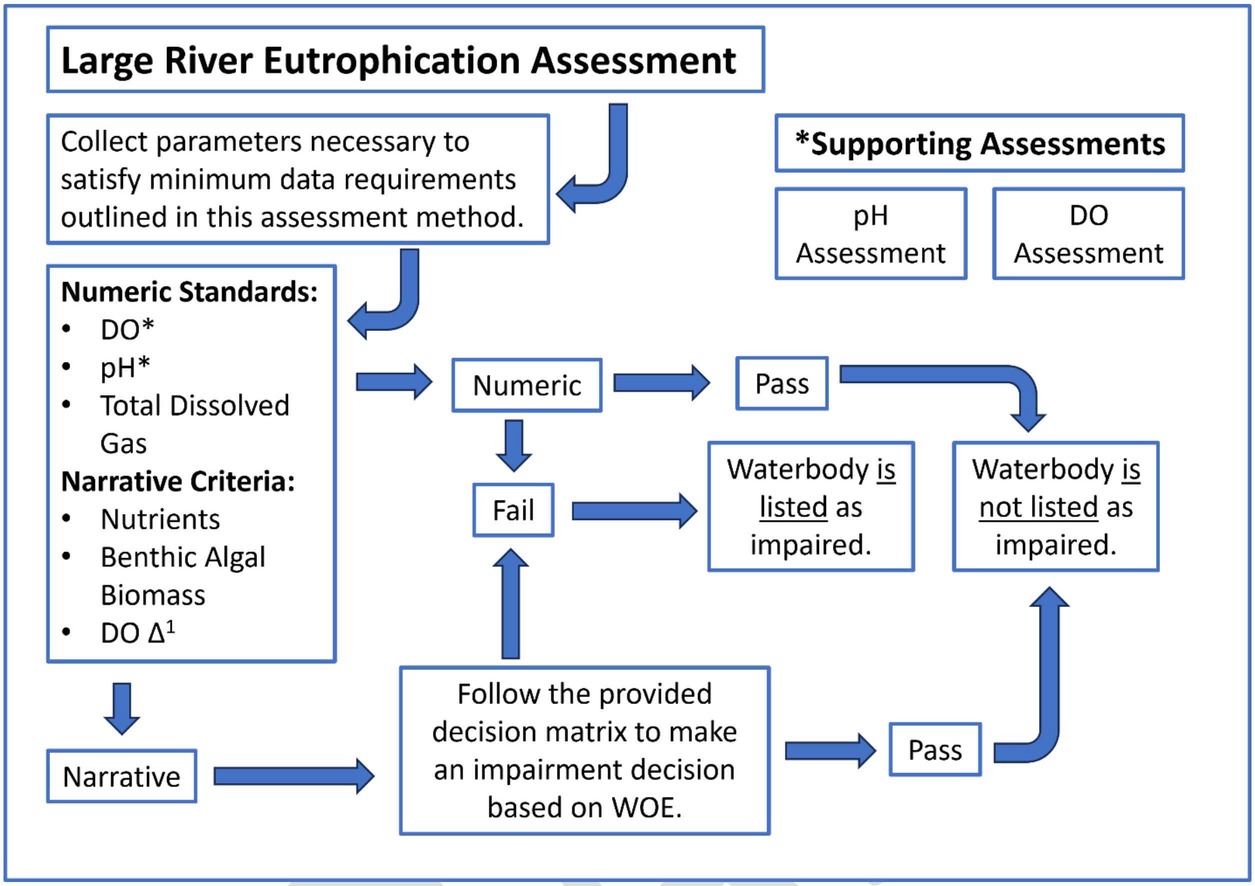

Figure 1-1. A flow diagram demonstrating the suggested order of operations for the Large River Eutrophication Assessment Method.
*DO and pH standards are addressed using techniques provided in other assessment method documents, as indicated in the figure.

[1]DO delta thresholds on portions of the Yellowstone River were the product of DEQ modeling work (Suplee et al., 2015).

1.1 How Eutrophication Affects Large Rivers

Eutrophication causes a variety of water quality problems in flowing waters such as nuisance algal growth, altered aquatic communities, and undesirable water-quality changes that impair beneficial uses (Dodds et al., 1997; Dodds, 2006; Freeman, 1986; Welch, 1992). Undesirable algal levels are among the most common visible effects, and the green algae *Cladophora spp.* has benefited from excess nutrients in lotic systems worldwide (Dodds, 1991; Freeman, 1986; Robinson and Hawkes, 1986; Tomlinson et al., 2010; Whitton, 1970; Wong and Clark, 1975). Many other water quality problems are associated with eutrophication. Commonly experienced eutrophication effects are shown in **Table 1-2** (Smith et al., 1999). They are disruptive to both humans and aquatic inhabitants.

Table 1-2. Water quality problems associated with nutrient enrichment.

Human Impacts[1]	Aquatic impacts[1]
1. Taste and odor problems 2. Reduced water clarity 3. Blockage of intake screens and filters 4. Disruption of flocculation and chlorination processes at water treatment plants 5. Increased numbers of disinfection by-products (which are carcinogenic) 6. Restriction and/or impacts on swimming, boating, and other water-based recreation 7. Fouling of submerged lines and nets 8. Reduced property values and amenity 9. Tourism losses	1. Harmful diel fluctuations in pH and dissolved oxygen 2. Increased algal biomass 3. Changes in species composition of algae 4. Macrophyte over-abundance 5. Reduction in habitat for macroinvertebrates and fish especially in near-shore margins 6. Increased probability of fish kills 7. Toxic algae (more common with reservoir influence) 8. Fishery losses

[1]From Smith et al., (1999) and Dodds et al., (2009). Not all these impacts are directly incorporated into this assessment.

Changes in fish population density or size (Wang et al., 2007), shifts to tolerant species (Hynes, 1966), and a plethora of other long-term chronic or acute ecological effects including loss of key or sensitive species or changed species composition have all been reported as results of eutrophication (Pretty et al., 2003). Altered diel dissolved oxygen (DO) and pH variations are the most common manifestations (Walling and Webb, 1992). If the impact is significant enough (i.e., fluctuations become too severe) fish kills can occur (Welch, 1992). Other health related concerns include taste and odor problems in drinking water.

1.2 Applicability

This assessment method is applicable to large rivers (Flynn and Suplee, 2010; **Table 1-1**) under Montana jurisdiction. Here, large river means a perennial waterbody which has, during the summer and fall baseflow of August 1 to October 31 each year, a wadeability index (product of river depth [in feet] and mean velocity [in ft/sec]) of 7.24 ft^2 /sec or greater, a depth of 3.15 ft or greater, or a baseflow annual discharge of 1,500 ft^3 /sec or greater (Flynn and Suplee, 2013).

1.3 Beneficial Uses Addressed in this Method

State waters are classified in accordance with their present and future beneficial uses per the Montana Water Quality Act (75-5-301(1), Montana Code Annotated [MCA]). In waters classified as A-Closed, A-1, B-1, B-2, B-3, C-1, C-2, and C-3-water quality is to be maintained suitable for bathing, swimming and recreation; growth and propagation of fishes and associated aquatic life, waterfowl, and furbearers; as well as other uses depending upon each classification (Administrative Rules of Montana [ARM] 17.30.621 through 17.30.629). Large river segments and beneficial use classifications are provided above (**Table 1-1**).

1.4 Water Quality Standards

This assessment method implements both narrative and numeric water quality standards to infer the trophic condition of a river and determine support of beneficial uses. The numeric pH and DO standards are a separate analysis and beneficial use assessment decision. Nevertheless, the outcome from those decisions is linked to the narrative eutrophication assessment in this document. DO and pH are used in this assessment because they respond to nutrient enrichment and are adopted water quality standards that tie directly to supporting beneficial uses. Beneficial use linkage from those assessments should be carried forward to eutrophication assessment decisions if exceedances of DO or pH are linked to elevated trophic status.

The standards found at ARM 17.30.637(1)(e) are the narrative standards that apply to this assessment method.

> "State surface waters must be free from substances attributable to municipal, industrial, and agricultural practices or other discharges that will: (e) create conditions which produce undesirable aquatic life."

This statement pertains to casual variables like total nitrogen (TN), total phosphorus (TP), nitrate (NO_3), and nitrite (NO_2) causing measurable in-river responses such as daily DO swings and increased algal growth (chlorophyll-*a* [Chl*a*], ash free dry weight [AFDW], % algae cover) which, when in excess, are undesirable impacts. Thresholds for these response variables are outlined in **Table 1-3**.

Numeric standards define a precise, measurable concentration that if exceeded would harm beneficial uses. As noted earlier, numeric standards that pertain to this assessment method include DO concentration, pH, and total dissolved gas (TDG). And for the Clark Fork River, site-specific nutrient standards have been adopted for TN, TP and Chl*a* (see ARM 17.30.631). Montana's pH numeric water quality standards are broken out by use classification in ARM 17.30.621-658. Dissolved oxygen and TDG numeric standards are prescribed in **Circular DEQ-7**. Montana's numeric water quality standards for DO, pH, and TDG for the applicable beneficial use classes are listed in **Table 1-4.** The numeric pH and dissolved oxygen standards are a separate analysis and beneficial use assessment decision. These supporting assessment methods are used in conjunction with the eutrophication assessment to help identify impairments. When the supporting assessment methods find impairment, the waterbody could be listed as impaired for eutrophication if the underlying cause of DO, or pH problems are due to eutrophic conditions.

Table 1-3. Large river segments and associated dissolved oxygen delta, algae, and nutrient thresholds. An "X" indicates that the parameter applies and is required to be measured at monitoring sites to translate the narrative standards.

Beneficial Use, Applicable River, Reach				Causal Variable and Threshold	Response variable (Threshold)		
Beneficial Use	**River**	**Reach**	**Applicable Time Period**	**TP, TN, Concentration**[1]	**DO Delta**	**Benthic Algal Chl*a*†; AFDW†**	**% filamentous algae bottom cover†**
Recreation	Yellowstone River Mainstem	From the Bighorn River Confluence to the Powder River Confluence	August 1 to October 31	**X** TP: 55 µg/L **X** TN: 655 µg/L	n/a	**X** (150 mg/m^2; 35 g AFDM/m^2)	**X** (30% cover)
Aquatic Life	Yellowstone River Mainstem				**X** (4.1 mg/L)	n/a	n/a
Recreation	Yellowstone River Mainstem	From the Powder River Confluence to the state-line		**X** TP: 95 µg/L **X** TN: 815 µg/L	n/a	**X** (150 mg/m2; 35 g AFDM/m2)	**X** (30% cover)
Recreation	Clark Fork River*	Blackfoot River Confluence to the Flathead River Confluence		**X** TP: 39 µg/L **X** TN:300 µg/L	n/a	**X** ($\bar{x}$ 100 mg/m^2 or 150 mg/m^2; 35 g AFDM/m^2)	**X** (30% cover)
Recreation	Other Large River Reaches (see **Table 1-1**)	Variable		**X** TP‡ **X** TN‡	n/a	X (150 mg/m2; 35 g AFDM/m2)	**X** (30% cover)

[1] The allowable exceedance rate is 20% for reach-specific TP or TN criteria. An allowable 20% exceedance rate will also apply to any site-specific TP or TN concentration identified.

*See ARM 17.30.631(2)(b). The upper reach of the Clark Fork River has numeric chlorophyll *a* standards for a summer mean of 100 mg Chl*a*/m^2 and a maximum of 150 mg Chl*a*/m^2. This reach also has numeric nutrient criteria for TP (39 µg/L) and TN (300 µg/L). These nutrient and chlorophyll *a* standards apply from June 21 to September 21.

†Along shore areas at river transects where approximately 10% or more of the river transect is wadeable.

‡No specific concentrations are provided; site specific criteria will need to be determined case-by-case, generally using mechanistic modeling methods.

DO delta thresholds on portions of the Yellowstone River were the product of DEQ modeling work (Suplee et al., 2015). Mechanistic modeling work may be underway for other parameters, or other large river segments; check DEQ's Water Quality Standards & Modeling Section for status. Field data collected to support model development may be used to assess if the narrative nutrient standards are achieved and a use-support assessment may be completed even before a model is completed. Assessors would need to coordinate with DEQ's Water Quality & Standards Section to determine further refinement of narrative thresholds for any particular assessment unit (AU).

Under the narrative nutrient standards, mechanistic modeling and field data collected to support model development may be used to identify appropriate causal variable and DO delta thresholds for the aquatic life use of large river segments not specified (n/a) in **Table 1-3**. These modeling efforts are subject to department review and are to be documented by DEQ's Water Quality Standards & Modeling Section followed by review and approval by the U.S. Environmental Protection Agency (EPA).

Table 1-4. Montana numeric water quality standards by beneficial use classification.

Beneficial Use Classification	DO (mg/L)		pH (S.U.) [4]	TDG
	Early Life Stages	Other Life Stages		
B1	7 Day Mean: 9.5 (6.5)[1,2] 1 Day Min.: 8.0 (5.0)[1,2,3]	30 Day Mean: 6.5 7 Day Mean Min.: 5.0 1 Day Min.: 4.0	6.5-8.5±0.5	110% of saturation
B2			6.5-9.0±0.5	
B3	7 Day Mean: 6.0[2] 1 Day Min.: 5.0[2,3]	30 Day Mean: 5.5 7 Day Mean Min.: 4.0 1 Day Min.: 3.0		
C3				

[1]These are water column concentrations recommended to achieve the required inter-gravel DO concentrations shown in parentheses. For species that have early life stages exposed directly to the water column, the figures in parentheses apply.
[2]Includes all embryonic and larval stages and all juvenile forms of fish to 30 days following hatching.
[3]All minima should be considered as instantaneous concentrations to be achieved at all times.
[4]Natural pH outside this range must be maintained without change. A natural pH above 7.0 must be maintained above 7.0.

In Montana, conditions resulting from the reasonable operation of dams on July 1, 1971, are natural (§ 75-5-306(2), MCA). Dense macrophyte beds are sometimes found downstream of dams; this is often due to the hydrologic modifications caused by the dam that result in more favorable conditions for macrophyte growth. Check with the Water Quality Standards & Modeling Section to determine if any below-dam site specific DO delta thresholds have been identified. To apply them per this assessment method, they will have had to have been approved by DEQ and submitted to EPA for review and approval under factor 4 of 40 Code of Federal Regulations (CFR) 131(10)(g). 2.0 Monitoring and Data Quality Considerations for Assessment

Waterbody condition will be evaluated based on all credible, existing, and readily available data and information (75-5-702, MCA; 40 CFR 130.7(5)(b)). This section describes several considerations for developing monitoring designs, assessing minimum data requirements, and data quality when performing eutrophication assessments.

2.1 Parameters Required for Assessment

A two-pronged approach is used to determine trophic status; a direct comparison to numeric standards for select variables and a WOE for others. The parameters outlined in **Table 2-1** will be utilized for eutrophication assessment.

Table 2-1. Parameters associated with recreational and aquatic life beneficial uses.

Associated Beneficial Use	Benthic Algae	TDG	pH	DO	DO Delta[+]	Nutrients
Recreation	X					X
Aquatic Life*		X	X	X	X	X

*Aquatic Life beneficial uses are assessed in systems with existing modeling products or numeric standards that demonstrate beneficial use protection.

[+]This parameter applies to specific AUs with completed modeling work.

Table 2-2 presents details on each of the parameters listed in **Table 2-1**, addressing how the parameter is measured, how it links to eutrophication, and the applicable type of water quality standard for each.

Table 2-2. Parameters for large river eutrophication assessment, type of sampling, how they relate to eutrophication, and type of standard associated with them.

Parameter	Sample Type	Linkage to Eutrophication	Standard
DO Assessment	Instantaneous: By hand-held instrument, at dawn and in the late pm. Continuous monitoring: by deployed instrument.	Eutrophication is the stimulation of autotrophic primary productivity and heterotrophic decomposition of organic material. Both affect diel dissolved oxygen patterns in rivers and have been linked to low dissolved oxygen concentrations and aquatic life impacts in large rivers.	Numeric (assessed via separate assessment method; CITE)
pH Assessment	Instantaneous: By hand-held instrument, at dawn and in the late pm. Continuous monitoring: by deployed instrument.	Elevated autotrophic primary production can elevate pH by drawing carbon dioxide (CO_2) out of the water column. Would require some measure of relative change to natural conditions (upstream/downstream monitoring or through modeling).	Numeric (assessed via separate assessment method; CITE)
TDG	Instantaneous: By hand-held instrument, at dawn and in the late pm. Continuous monitoring: by	Eutrophication is the stimulation of autotrophic primary productivity and heterotrophic decomposition. Both of which expel gases into the water column contributing to TDG concentrations. Gas	Numeric

Parameter		Sample Type	Linkage to Eutrophication	Standard
		deployed instrument.	supersaturation in excess of the standard can occur as a result of high DO concentrations.	
DO Δ[+]		Instantaneous: By hand-held instrument, at dawn and in the late pm. Continuous monitoring: by deployed instrument.	Eutrophication is the stimulation of autotrophic primary productivity and heterotrophic decomposition of organic material. Both affect diel dissolved oxygen patterns in rivers and elevated DO Δ has been linked to aquatic life impacts in large rivers.	Narrative
Benthic Algae	Chl*a*	Benthic sampling of river bottom in near-shore areas.	Eutrophic conditions stimulate benthic algal growth in rivers. Benthic algal growth can develop to undesirable levels; the undesirable algae threshold is known. Excess algal growth effects on DO have been documented.	Narrative
	AFDW			
	% Cover			
Nutrients	Nitrogen (TN, NO_2+NO_3)	Grab-sample.	Total instream concentrations are indicative of the level of nutrients that are ultimately biologically available for autotrophic or heterotrophic uptake, which contributes to eutrophication.	Narrative
	TP			

[+] This parameter applies to specific AUs with completed modeling work.

Other parameters may be considered as supporting data for determining eutrophication impairments but are not required. These additional metrics could include primary producer community structure alterations, macroinvertebrate assemblages, biodiversity, aquatic plant diversity, etc.

2.2 Monitoring Methods and Requirements

Eutrophication can be assessed in the field by multiple methods. Currently, Montana utilizes a suite of parameters to develop a WOE approach for assessment. These include AFDW, Chl*a* density, percent algal cover, pH, DO, DO Δ, TDG, and nutrient concentrations. Once collected, these parameters are then applied to the thresholds set forth by **Section 1.4**.

Algae levels and nutrient concentrations will be assessed through grab samples, while instantaneous measurements, or continuous monitoring, is necessary for monitoring fluctuations in pH, DO, and TDG. Algal and nutrient sampling methods are outlined in Water Quality Planning Bureau (WQPB) Standard Operating Procedures (SOPs): Sample Collection and Laboratory Analysis of Algal Chlorophyll-a, and Ash Free Dry Weight, and Aquatic Plant Visual Assessment Standard Operation Procedure, Guidelines for the use of sondes and instruments capable of continuous monitoring can be found in DEQ's SOPs for Multiparameter Water Quality Sondes or for Instantaneous Field Meters.

2.2.1 Nutrients: Nitrogen (TN, NO_{2+3}) and Total Phosphorus

Nutrient samples should not be used for beneficial use assessment from outside of the period to which nutrient thresholds apply (Aug. 1 – Oct. 31). The summer and early fall period of August 1 – October 31 is generally the time of maximum growth potential. Monitoring outside of this timeframe may be useful for other objectives such as determining sources.

A minimum of 6 independent nutrient samples should be collected over two years within the same assessment unit or reach over multiple years; however, collecting 12-13 nutrient samples over three years is recommended. The assessor should disperse sampling effort across sites as much as possible. Compliance/non-compliance with the applicable exceedance rate for nutrients (20%; **Table 1-3**) is determined as a function of sample size via Table 2-1 in DEQ (2024).

2.2.2 Benthic Algae

Chlorophyll-*a* is measured as a means of estimating algae (periphyton or phytoplankton) biomass in a body of water. It is expressed as mass per unit area for periphyton (milligrams per meter squared [mg/m^2]) and mass per unit volume (mg/L) for phytoplankton. Heavy growths of attached or free-living algae generally indicate inferior water quality.

Periphyton growth is controlled by season, nutrient concentrations, velocity of the current, days of accrual, shading, water temperature, and other factors. Because of this, sampling designs using Chl*a* should include times when stable flows have been achieved, as well as times when standing crop is generally peaking. Intensive sampling may include multiple visits to capture the waterbody's peak algal growth. The summer and early fall period of August 1 – October 31 is generally the time of maximum growth potential. Periphyton standing crops are quantified by measuring the amount of accrual on natural substrates at the study site. There are three methods for collecting attached algae (periphyton)– the hoop, the core, and the template.

A water depth of about 0.75 m can be used to separate wadeable from non-wadeable zones. Wadeable samples should be equitably distributed out from the R and L banks to the degree possible, and equally spaced. If feasible, non-wadeable samples may be collected via boat using an Ekman grab or similar device and should be equitably spaced. If non-wadable zone data collection is infeasible—which is common—just collect the wadeable zone samples. See the Sample Collection and Laboratory Analysis of Algal Chlorophyll-a, Ash Free Dry Weight, and Aquatic Plant Visual Assessment Standard Operation Procedure (v9) for subsequent details.

Algae samples should be collected at the most at risk location within the AU or assessment reach once during the growing season for at least two years. However, it is preferred to monitor two separate sites over two separate years to meet the minimum data requirement for response variable assessment for each AU or assessment reach. For impairment delisting, three consecutive years of beneficial use attainment should be demonstrated by response variables to indicate recreation use attainment.

If modeling is being pursued to refine nutrient thresholds, the 11 samples collected at a site in the wadeable zones should be analyzed without being composited, and five samples in the non-wadeable zone are preferred (if possible) but not required. A water depth of about 0.75 m can be used to separate wadeable from non-wadeable zones and a boat will be necessary to collect the non-wadable samples. Wadeable samples should be equitably distributed out from the R and L banks to the degree possible, and equally spaced. If feasible, the five non-wadeable samples can be collected via boat using an Ekman grab or similar device and should be equitably spaced. If infeasible, just collect the wadeable zone samples.

2.2.3 DO Δ

DO Δ should be measured using in-river deployed logging instruments that have been properly calibrated in accordance with the manufacturer's instructions. Consider any current guidance developed by DEQ when selecting instruments and evaluating different instrument deployment options. Instruments are to be deployed for at least 14 continuous days which should be in August; longer datasets may include September. Logging should occur at least hourly; 15 minutes is preferred. DO Δ values should be expressed as a 7-day moving average however, for datasets ≥30 days long, DO Δ values may—alternatively—be expressed as a calendar weekly average (n=4 weekly averages, minimum). Daily DO Δ can be calculated using the "DeltaCalculator_v1" tool.

Sampling to Determine DO Δ: Continuous DO data are needed for DO Δ assessment. Logging must occur at least every 15 minutes. DO Δ values should be expressed as a 7-day moving average however, for datasets ≥30 days long, DO Δ values may be expressed as a calendar weekly average (n=4 weekly average, minimum). If more than one site is established in the assessment reach, disperse sampling effort across the different sites. **Dissolved oxygen deltas fluctuate rapidly, and therefore you do not need to wait 30 days to collect subsequent DO data at a site.** The longer the DO Δ that can be collected in the assessment reach, the better. These same continuous DO datasets may be used to assess the DO standards directly (**Section 2.5.4** below). Instruments are to be deployed for at least 14 continuous days in August; longer datasets may include September.

2.2.4 Total Dissolved Gas

Total dissolved gas (TDG) is measured as a percent saturation and will be measured with an instantaneous field meter, or continuous monitoring. DEQ will assess TDG using continuous monitoring data. Continuous monitoring provides a better representation of the waterbody condition. In general, TDG single sample measurements are rarely collected. Therefore, this assessment method will not assess single sample datasets.

DEQ will consider datasets that include at least one sample value per hour to be continuous monitoring, whereas measurements performed less frequently than once per hour to be single sample data. The one-hour average concentration of TDG in surface waters may not exceed 110% more than once in any three-year period. In comparing results to the TDG standard, DEQ will account for the fact that dissolved oxygen is only a fraction of TDG. Exceedances of the criteria generally occur below dams during critical operational conditions, such as powerhouse shut down or start up. Total dissolved gas levels must be ≤ 110% of saturation to protect aquatic life (DEQ, 2019).

2.2.5 DO and pH Assessment

Other assessment method SOPs will be used in conjunction with the parameters described above to help corroborate eutrophic conditions. If the standards set forth in the DO or pH assessment methods are exceeded, then the assessor could use those impairments as additional lines of evidence to list the waterbody as impaired. This additional information should only be used if the DO or pH impairment listings are attributed to algal response variables.

The minimum data requirements listed under those assessment methods should be adhered to when making impairment decisions.

2.2.6 Additional Methods

Additional methods, such as the use of nutrient diffusing substrates (NDS), may also be warranted. These additional methods may be necessary to quantify nutrient thresholds or identify limiting nutrients. Nutrient thresholds and limiting nutrients are necessary for Total Maximum Daily Load (TMDL) development. Guidelines for conducting NDS studies are outlined in **DEQ's Standard operating Procedure for Nutrient Diffusing Substrates**.

2.3 Monitoring Timeframe and Temporal Independence

Eutrophication monitoring should be conducted during the period when the state's large rivers are most vulnerable to eutrophication impacts. They are most sensitive to eutrophication in the August 1 – October 31 period (Flynn et al., 2015), as this is after spring runoff has ended and during the time when there are high light levels, warmer air and water temperatures, and lower flows. All parameters should be sampled during these sensitive seasonal periods (August 1 – October 31) and during the same monitoring events.

2.4 Monitoring Locations and Spatial Independence

The guidance outlined in this section for selecting sampling locations is intended to help ensure spatial independence of data.

2.4.1 Assessment Unit Selection

Eutrophication assessment decisions are made by assessment unit (AU). An AU may be an entire waterbody or segment of a waterbody (e.g., dam to a tributary). The Montana DEQ may prioritize monitoring of waters that have been previously identified as impaired, waters at higher risk of eutrophication impairment due to human activities, agricultural use, areas where watershed restoration or engineering solutions have been implemented, or other factors.

2.4.2 Assessment Reaches

The assessment analyses may take place over the entire AU or over an assessment reach. An assessment reach is a sub-segmented portion of an AU. Sub-segmenting an AU may be justified if an AU exhibits one or more significant shifts in type and intensity of potential eutrophication sources such that clear breaks could be made to designate homogenous sub-reaches (Suplee and Sada, 2016). For example, if a relatively unimpacted upstream reach can be isolated, and its condition is substantially different from other downstream parts of the AU, the AU may be split into two reaches for assessment purposes. The following guidelines should be used when sub-segmenting an AU:

- If one reach indicates impairment, the entire AU receives the impairment determination.
- Each reach has the same general data requirements (e.g., dataset minimums) as the parent AU would have had if it hadn't been divided.
- It is better to lump than split reaches to avoid excessive sub-segmentation and the consequential administrative and sampling requirements that result.
- An assessor should decide whether to sample potential reach breaks in an AU before data collection; this will help ensure that reach breaks are based on considerations of land use and sources.
- Sub-segmenting AUs should ensure that beneficial uses are met in all parts of the AU that are outside of mixing zones.

2.4.3 Total Number of Sites and Site Locations

Each sampling site needs to be selected and sampled in a manner that minimizes bias caused by the collection process and that best represents the intended study objectives (USGS, 2006). Selection of sampling locations depends largely on the data quality objectives (DQOs) of the water quality study.

Sites should be spatially independent of each other. Spatial independence relies on the assessor's best professional judgment, particularly when combining data from multiple sources and projects. The following guidance for achieving spatial independence for eutrophication monitoring is an adaptation of other assessment methods (Drygas, 2012; Suplee and Sada, 2016):

- Select sites that are representative of conditions throughout the AU at least 5 km (Suplee et al, 2015) apart unless there is a flowing tributary that confluences with the segment, or a discrete source is located between the two sites.
- Consider that tributaries and point sources take significantly longer to assimilate into the water column in large rivers.
- Do not sample in mixing zones.
- Monitor below areas where tributaries or ditches sufficiently mix with the AU.
- Consider land use to help identify potential impacts on nutrient concentrations.

2.4.4 Additional Site Considerations

Reaches immediately downstream of dams may have elevated or depressed DO and TDG. Dam design and discharge operation greatly influences the saturation potential of surface waters. Water released from the top of a dam may contain elevated levels of DO and TDG due to increased turbulence which enhances aeration as the water falls. Bottom release dams may cause DO and TGD deficits, as the water moves more slowly and is subject to lower levels of turbulence. Check with the Water Quality Standards & Modeling Section to determine if any below-dam site specific DO delta thresholds have been identified. To apply them per this SOP, they will have had to have been approved by DEQ and submitted to EPA for review and approval under factor 4 of 40 Code of Federal Regulations (CFR) 131(10)(g).

2.5 Data Currency

Data collected within the past ten years are considered current and may be used in making assessment decisions (Makarowski, 2020). If during this period significant changes in sources have been documented, the assessor may use their best professional judgment when determining which data are appropriate to include in the assessment. The assessor should document the specific changes, identify data currency alternatives, and determine which years of data are appropriate to include in the assessment process.

2.6 Quality Control Samples

The appropriate quality control (QC) samples to assess field collection activities should be designated in the project planning documents (Quality Assurance Project Plan [QAPP], Sampling and Analysis Plan [SAP]). Because the designated sampling frame is a multi–transect sampling frame, information about the variability among measurements is inherent to the collection design. Therefore, duplicate samples do not generally need to be collected unless project DQOs require a high degree of defensibility. Documentation of the approach intended to be used to evaluate the results should be described in the quality control section of the project planning document(s).

3.0 Data Quality

This assessment method is subject to DEQ Water Quality Division's established policies and procedures for quality assurance (QA)/QC, beneficial use assessment, and data management. Data quality requirements apply to all data used for making assessment decisions, whether collected internally or externally.

3.1 Data Quality Assessment Overview

Data quality assessment (DQA) is the scientific and statistical evaluation of data to determine whether data obtained from monitoring operations are of the right type, quality, and quantity to support water quality assessments (EPA, 2002). Assessors use DEQ's Water Quality Assessment and Reporting Documentation (WARD) System to document the DQA outcome (pass or fail) for each parameter group being assessed per beneficial use. All data quality indicators should be met to pass the DQA; if a single indicator is not met, the DQA fails for that parameter group. An assessor may override pass or override fail a DQA, but they should accompany this override with adequate justification.

Data quality requirements that apply universally:

- Data is representative of current conditions; generally, this means data is less than 10 years old, although data greater than 10 years old may be considered if conditions are known not to have changed or, alternately, data may be excluded even if it is less than 10 years old if conditions are known to have changed.
- Data is linked to a documented location (i.e., latitude and longitude).
- Data is submitted to DEQ in the specific Montana EQuIS Water Quality Exchange (MT-eWQX) format using the data submittal process described in “MT-eWQX Guidance Manual - Call for Data” (DEQ, 2010).
- Data includes written documentation (such as a QAPP and/or SAP) which describes monitoring objectives, DQOs, QA/QC measures, study design, field sample collection and laboratory analytical methods.
- Data includes field notes, laboratory notations, or summaries that indicate deviations from the QAPP or SAP and their potential impact on the data quality and objective outcome.

Once DEQ determines the data meet basic documentation requirements, the data are ready to be analyzed to support water quality standards attainment decisions. Additional DQA information can be found in DEQ’s Beneficial Use Assessment Method.

4.0 Data Analysis to Support Water Quality Standards Attainment Decisions

4.1 Overview of the Assessment Decision Framework

To thoroughly assess the eutrophication status of large rivers, this assessment method evaluates physical, chemical, and biological measurements. Parameters identified in **Table 1-3** need to be evaluated individually against thresholds and then applied to the decision-making framework **in Figure 1-1 and Table 2-1** to produce consistent decision outcomes (i.e., the river is impaired by eutrophic conditions, or is not impaired by eutrophic conditions).

Once the applicable data has been collected, they should be assessed as outlined in **Section 4.3**. After the proper statistical analysis has been performed, the assessor should determine whether the parameters have passed or failed. These pass/fail metrics should then be used within the assessment decision framework. If the waterbody fails a numeric water quality standard, the waterbody is listed as impaired for those. For the narrative standards, a WOE approach uses key water quality parameters. The different combinations of results from parameters included in the WOE approach have been assembled in **Appendix A** and an Excel spreadsheet tool for assessors (**XXXXXAssessFramework.xlsx**). This table allows the user to find their unique combination of results from their assessment analysis to derive impairment conclusions. For each combination of results, the table provides an outcome (i.e., impaired, not impaired, unclear), and an explanation as to what is likely going on in the system's ecology.

If the waterbody fails any applicable numeric standard (DO or pH) or narrative criteria as provided in **Circular DEQ-15**, then the waterbody is listed as impaired. Some of the impacts that eutrophication exhibits on rivers are captured by other assessment methods (DO and pH). These supporting assessment methods are used in conjunction with the eutrophication assessment to help identify impairments. When the supporting assessment methods find impairment, the waterbody could be listed as impaired for eutrophication if the underlying cause of DO, or pH problems are due to eutrophic conditions.

4.2 Preparing the Data for Assessment

Preparing data for assessment will take the requirements outlined in **Section 2.0** and **Section 3.0** into consideration. It is important to validate each data point and document any data that gets rejected for failing data quality protocols.

4.3 Assessment Decision Framework

This assessment method comprises a WOE process for addressing narrative standards, and a direct comparison to numeric standards for addressing those. Numeric standards evaluated via other assessment methods, i.e. DO and pH, and those evaluated in this assessment method can be used to list a waterbody if any of the numeric water quality standards outlined in **Table 1-4** are exceeded. The decision framework which incorporates evaluations of both narrative and numeric criteria is provided in **Appendix A** and is used by the assessor to help make impairment determinations.

Due to complex nutrient dynamics in lotic systems, additional considerations should be made when making impairment decisions. Eutrophic conditions are caused by excess nutrients, and as most excess nutrients are anthropogenic in origin, a nutrient listing should be placed on systems to manage eutrophication and facilitate TMDL development. The nutrient data should be compared to the criteria in **Table 1-3** and used to identify causal nutrients. A nutrient that substantially exceeds the criteria should be used for impairment listings. In instances where TN and TP in **Table 1-3** exceed their respective criterion and response variables indicate eutrophic conditions, TN and TP nutrient ratios, prior modeling and/or diffuser studies should be used to further investigate nutrient limitation.

In these instances, the waterbody should be listed as impaired for the limiting nutrient, or for both if the system is co-limited. The ratio of TN to TP, as expressed by the Redfield Ratio (Redfield, 1958), of water samples can be used to determine the limiting nutrient in the watershed. By mass, the Redfield ratio is 7.2:1. However, to be indicative of P limitation, the ratio will be considerably higher than 7.2 (Dodds, 2003). Generally, when the TN:TP ratio is greater than 10 the system is likely P limited, when the ratio is between 6-10 it suggests N and P co-limitation, and a ratio below 6 indicates N limitation is likely (Hillebrand and Sommer, 1999). However, note that the TN:TP ratio of the two Yellowstone River criteria in **Table 1-3** are 11.9:1 and 8.6:1, respectively, which is not at Redfield; consider this fact when determining nutrient limitation for those river reaches.

Under DEQ's combined criterion approach for narrative nutrient standards, nutrient impairments can be delisted once response variables show beneficial use attainment for 3 consecutive growing seasons.

4.4 Document Assessment Decisions and Review with Management

The assessor should document all data and decisions made pertaining to eutrophication impairment and beneficial use support determinations for AUs. Assessment outcomes for individual AUs, including data summaries, impairment determinations, and beneficial use support determinations are documented via Montana DEQ's Clean Water Act Information Center (CWAIC) (available at www.cwaic.mt.gov). Waterbodies identified as impaired due to trophic status are included in Montana's biennial Water Quality Integrated Report and list of impaired waters as a pollutant. Assessment decisions are reviewed by the Monitoring and Assessment Section Supervisor and may be reviewed by the QA Officer and managers or staff from other DEQ programs.

5.0 Potential Sources

Probable sources of impairment are the activities, facilities, or conditions that generate the pollutants that prevent waters from meeting water quality standards. The following sources are commonly associated with conditions that lead to eutrophication impairment listings in Montana; additional selections are available in the WARD system if needed:

- Dam or Impoundment
- Industrial Point Source Discharge
- Loss of Riparian Habitat
- Agriculture
- Municipal Point Source Discharges
- On-site Treatment Systems (Septic Systems and Similar Decentralized Systems)
- Urban Runoff/Storm Sewers
- Mining
- Natural Sources
- Golf Courses
- Erosion and Sedimentation
- Accidental Release/Spill

If water quality data are available that proves that a probable source is likely contributing to eutrophication, the assessor should check the Source Confirmed box in WARD, whereas if probable sources are present in the watershed but are not confirmed, the assessor should check the Source Not Confirmed box. If source data exists, it should be incorporated into the data analysis and data matrix within WARD. The assessor may also include a brief description of sources in the overall condition of the waterbody summary in WARD.

6.0 PUBLIC INFORMATION

Ammonia data collected by DEQ is stored in DEQ's MT-eWQX database and is uploaded weekly to the Water Quality Portal (EPA, USGS and NWQMC, 2018). Assessment outcomes for individual assessment units, including data summaries, impairment determinations, and beneficial use support determinations, are documented via Montana DEQ's CWAIC (available at www.cwaic.mt.gov).

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APPENDIX A – EUTROPHICATION ASSESSMENT DECISION FRAMEWORK

Impairment listings are designed to protect the most sensitive beneficial uses. The most sensitive beneficial uses in Montana's large rivers are recreational and aquatic life uses. For this reason, assessment decisions matrices are broken into two separate frameworks based on each beneficial use. **Table A-1** outlines the decision framework for aquatic life listings, while **Table A-2** outlines the decision framework for recreational uses.

Table A-1. Assessment decision framework for aquatic life beneficial use.

This table outlines the **aquatic life** assessment decision framework for aquatic life beneficial use scenarios by listing possible WOE parameter scenarios. Based on the implications of each parameter, the decisions outlined are designed to be protective of the established beneficial uses of large rivers in Montana.

Scenario	*DOΔ*	*Nutrients**	*Resulting Decision*	*Listing*	*Other Considerations*
1	Pass	Pass	Waterbody is not impaired.	Fully Supporting	
3	Pass	Fail	Waterbody is not impaired.	Fully Supporting*	
4	Fail	Fail	Waterbody is impaired.	Not Fully Supporting	
6	Fail	Pass	Waterbody is impaired	Waterbody is not fully supporting beneficial uses for aquatic life. DO Δ	Macrophytes or algae could be assimilating the nutrients, leading to low limnetic nutrient concentrations.

*For reaches only under the narrative nutrient standards. Reaches with numeric nutrient standards are held to those numeric standards, and therefore, if those standards are exceeded the waterbody is not fully supporting its beneficial uses. When making impairment decisions within this two-tiered framework, it is important to consider ecological function and the interaction between these parameters. If several parameters indicate elevated levels of primary productivity, the river system is likely experiencing the effects of eutrophication. Using multiple parameters and indicators of trophic status allows the assessor to perform a WOE approach to determine the likely sources of impairment and allows for flexibility when making impairment decisions.

Table A-2. Assessment decision framework for recreation beneficial use.

This table outlines the **recreation** assessment decision framework by listing possible WOE parameter scenarios. Based on the implications of each parameter the decisions outlined are designed to be protective of the established beneficial uses of Large Rivers in Montana.

Scenario	*Benthic Chla**	*% Cover*	*Nutrients**	*Resulting Decision*	*Listing*	*Other Considerations*
1	Pass	Pass	Pass	Waterbody is not impaired.	Fully Supporting	
2	Pass	Pass	Fail	Waterbody is not impaired.	Fully Supporting	Under narrative criteria, response variables must exceed to be listed as impaired*
3	Pass	Fail	Fail	Waterbody is impaired.	Though aquatic life uses are supported, the waterbody is not fully supporting recreational beneficial uses. Listing cause Nutrients and Algae.	Not all undesirable algae produce large volumes of Chl*a* (e.g., Didymo on the Kootenai River)
4	Fail	Fail	Fail	Waterbody is impaired. Indicators show the waterbody is not in compliance.	Not Fully Supporting. Listing cause of TN, TP, Algae, and elevated ΔDO	
5	Fail	Fail	Pass	Waterbody is impaired	Not Fully Supporting. Listing cause of excess algae and ΔDO	Narrative criteria are exceeded when response variables indicate that there are excess nutrients in the system. Nutrients could be assimilated into macrophytes or algae.

Scenario	*Benthic Chla**	*% Cover*	*Nutrients**	*Resulting Decision*	*Listing*	*Other Considerations*
6	Fail	Pass	Pass	Waterbody is impaired	Waterbody is not fully supporting beneficial uses for aquatic life. ΔDO	Large volumes of attached algae could be present. These algae could be assimilating nutrients from the water column, leading to low nutrient concentrations.
7	Fail	Pass	Fail	Waterbody is impaired.	Not fully supporting. List causes of nutrients and ΔDO for aquatic life	Large volumes of attached algae could be present.
8	Pass	Fail	Pass	The waterbody is impaired.		Filamentous algae could be outcompeting attached algae and assimilating nutrients from the water column.

* For reaches only under the narrative nutrient standards. Reaches with numeric nutrient standards are held to those numeric standards, and therefore, if those standards are exceeded the waterbody is not fully supporting its beneficial uses. When making impairment decisions within this two-tiered framework, it is important to consider ecological function and the interaction between these parameters. If several parameters indicate elevated levels of primary productivity, the river system is likely experiencing the effects of eutrophication. Using multiple parameters and indicators of trophic status allows the assessor to perform a WOE approach to determine the likely sources of impairment and allows for flexibility when making impairment decisions.

APPENDIX B – LONGITUDINAL DATA VISUAL REVIEW

Table Error! No text of specified style in document.**-1. Monitoring locations showing significant impairment.**

This table is designed to help project managers identify "hot spots" or monitoring locations that show significant impairments compared to other sites within the river segment.

River Name	Assessment Unit	Station ID	Parameter Exceedance (y,n)						
			Nitrogen		Total Phosphorus	Dissolved Oxygen	Total Dissolved Gas	pH	Δ Dissolved
			TN	NOx					