Narrative Nutrient Standards Assessment Method for Wadeable Streams and Medium Rivers

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REVISION HISTORY

Version Number	Date	Modified By	Sections Modified	Description of Changes
1.0	April 2024	Michael Suplee, PhD	All	Initial document (supersedes Suplee and Sada, 2016)

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ACRONYMS

AFDW	ash free dry weight
ARM	Administrative Rules of Montana
AU	assessment unit
CFR	Code of Federal Regulations
CWA	Clean Water Act
CWAIC	Clean Water Act Information Center
DEQ	Montanan Department of Environmental Quality
DO	Dissolved oxygen
DQA	data quality assessment
EQuIS	MT-eWQX Enterprise database
EPA	U.S. Environmental Protection Agency
MCA	Montana Code Annotated
MPDES	Montana Pollutant Discharge Elimination System
ND	Non-detect
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RPD	relative percent difference
SAP	sampling and analysis plan
SOP	standard operating procedure
TN	total nitrogen
TMDL	total maximum daily load
TP	total phosphorus
WARD	Water Quality Assessment and Reporting Documentation
WQPB	Water Quality Planning Bureau

1.0 INTRODUCTION

This document details the Montana Department of Environmental Quality's (DEQ) narrative nutrient standards assessment method for wadeable streams and medium-sized (medium) rivers. Results from this method will be used to assess the aquatic life and recreation beneficial uses for all wadeable streams and medium rivers for which aquatic life and recreation uses are adopted as surface water quality standards. The DEQ document "Beneficial Use Assessment for Montana's Surface Waters" (Makarowski, 2020) describes the overall process for making a beneficial use assessment for a waterbody.

Users of this assessment method are referred to Part I of Circular DEQ-15 (DEQ, 2024a). Department Circular DEQ-15, herein referred to as "Circular DEQ-15", should be considered a companion document to be used in conjunction with this assessment method. Readers should also review Part I of the circular's supporting guidance document (DEQ 2024b), herein referred to as "DEQ-15 Guidance." Part I of the DEQ-15 Guidance document contains important technical information supporting this assessment method.

1.1 APPLICABILITY

This assessment method only applies to streams and medium rivers; it does not apply to lakes and reservoirs, nor does it apply to large rivers. Definitions for streams and medium rivers are provided below and are consistent with **Circular DEQ-15**. The assessment method for narrative nutrient standards for lakes and reservoirs, and the assessment method for large rivers are addressed in separate documents).

Medium River means a perennial waterbody in which much of the wetted channel is unwadeable by a person during baseflow conditions.

Wadeable Stream means a perennial or intermittent stream in which most of the wetted channel is safely wadeable by a person during baseflow conditions.

1.2 BACKGROUND INFORMATION

In 2021, changes in Montana law[1] required DEQ to transition to narrative nutrient standards. DEQ had been using adopted numeric nutrient standards to assess state surface waters since their adoption in 2014. The 2021 change necessitated the development of a structured translation process to interpret the state's narrative water quality standards applicable to total nitrogen (TN) and total phosphorus (TP) concentrations; these standards are found at Administrative Rules of Montana (ARM) 17.30.637(1)(e). To facilitate the change, DEQ worked with an advisory group, the Nutrient Work Group, to develop the translation process. The translation process relies on weight-of-evidence procedures for determining support/nonsupport of beneficial uses and gives greater weight to biologically based response variables and less weight to measured instream TN and TP concentrations.

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[1] 75-5-321, MCA

1.3 COMMON SOURCES OF TOTAL PHOSPHORUS AND TOTAL NITROGEN

Nutrients are a natural component of stream biological processes but can become over-enriched to the point where undesirable conditions occur. Common sources of excess nitrogen and phosphorus in streams and medium rivers include municipal wastewater treatment plants, home septic system discharges, runoff from fertilized fields used for crop production, soil erosion associated with crop production, mining blasting materials, and livestock production including both rangeland and concentrated animal feeding operations. For information on natural background concentrations of TN and TP in streams and medium rivers around Montana, see Suplee and Watson (2013).

2.0 NARRATIVE NUTRIENT STANDARDS

Narrative nutrient standards are consistent with requirements in Montana state law (75-5-321, MCA) and federal requirements in the 1972 Clean Water Act (CWA, 2002). **Circular DEQ-15** was crafted in accordance with U.S. Environmental Protection Agency guiding principles for a combined criterion approach (EPA, 2013), and is informed by decades of scientific research carried out in Montana and elsewhere.

2.1 TRANSLATION OF MONTANA'S NARRATIVE NUTRIENT STANDARDS FOR WADABLE STREAMS AND MEDIUM RIVERS

As noted in **Section 1.2**, the state's narrative water quality standards applicable to TN and TP concentrations are found in the Administrative Rules of Montana at title 17, chapter 30, subchapter 6.0. The rule at ARM 17.30.637(1)(e) states:

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

NEW RULE I further requires that, for TN and TP, the narrative statement at ARM 17.30.637(1)(e) must be translated as provided in Part I of **Circular DEQ-15**. Translators are structured procedures for consistently converting the narrative requirements into actionable waterbody assessments, MPDES permit limits, and other water quality program actions.

Again, users of this assessment method should review Part I of **Circular DEQ-15** which contains important details relevant to this assessment method. **Circular DEQ-15** Part I should be considered a companion document to be used in conjunction with this document. Readers should also have available **DEQ-15 Guidance**—the document supporting **Circular DEQ-15—**as it contains important technical information supporting this assessment method.

The translator applicable to wadeable streams and medium rivers from **Circular DEQ-15** is reproduced below in **Table 2-1** (and which corresponds to Table 2-1 in the circular). See also, Section 2.0 in Part I of **Circular DEQ-15**. Note in **Table 2-1** below that different beneficial uses are assessed using different biological response variables, and that different geographic zones have different thresholds for the same response variable. The thresholds represent limits beyond which harm to the beneficial use will occur. Thresholds vary by geographic zone because recreation and aquatic life have different sensitivities to TN and TP concentrations depending on if the stream or medium river is (for example) in the mountains or in the intermountain low valleys. Additionally, different regions of the state have variations of beneficial uses (example: cold vs. warm water fishes).

Table 2-1. The Narrative Nutrient Standards Translator as found in Circular DEQ-15. An "X" indicates the parameter applies and is required to be measured at monitoring sites to translate the narrative nutrient standards.

Benefical Use and Applicable Zone			**Causal Variable**	**Response Variable (threshold)**			
Beneficial Use	**Stream Slope Zone***	**Macroinvertebrate Zone***	**TP, TN (*see* ecoregional nutrient concentrations in Table 2-2 of this Assessment Method)**	**DO Delta[†]**	**Benthic Chl*a* ; AFDW**	**% filamentous algae bottom cover**	**Macroinvertebrates**
Recreation	Western and transitional ecoregions, <u>all</u> stream/medium river water surface slopes	n/a	**X**		**X** (150 mg Chla/m^2; 35 g AFDM/m^2)	**X** (30% cover)	
Aquatic Life	Western and transitional ecoregions, streams/medium rivers with >1% water surface slope	Mountains	**X**				**X** Beck's Biotic Index v3 (35.1)
Aquatic Life	Western and transitional ecoregions, streams/medium rivers with ≤1% water surface slope	Low Valleys and Transitional[a]	**X**	**X** (3.0 mg DO/L)			**X** Beck's Biotic Index v3 (18.7)
Aquatic Life	Eastern ecoregions, <u>all</u> streams/medium rivers	Plains	**X**	**X** (6.0 mg DO/L)[b]			

[†] The allowable exceedance rate of a dataset of weekly average DO delta values is 10% in the Low Valleys and Transitional and 15% in the Plains.

[a] With the exception of Big Spring Creek, spring creeks are exempt from this narrative translation. Stream and medium river reaches below dams may be given special consideration. See **Section 2.3** for details and applicable criteria.

[b] Data collected during drought periods may be excluded from analysis. See department guidance for definition of drought.

The following sections provide a brief description of the parameters comprising the **Table 2-1** translator.

2.1.1 Causal Variables: Total Nitrogen and Total Phosphorus

The department compiled and reviewed scientific literature and carried out its own studies (Suplee et al., 2007, 2008, and 2009; Suplee and Watson, 2013; Schulte and Craine, 2023) which demonstrate that TP and TN concentrations protective of recreation aquatic life beneficial uses vary across the state (ecoregion by ecoregion). The upper boundary of TP and TN concentrations that protect these beneficial uses are in **Table 2-2** below (see also, Table 2-3 of Part I of **Circular DEQ-15)**. Harm to beneficial uses (e.g., aquatic life) at lower TN and TP concentrations than shown in **Table 2-2** are documented in the scientific literature (readers should refer to Suplee and Watson (2013) for a compendium of studies). Also, simultaneous realization of paired TN and TP concentrations in **Table 2-2** could affect beneficial uses (i.e., either the TN or the TP value may need to be at a lower concentration than shown in the table to ensure full protection).

DEQ also used stream hydrograph and biological patterns to identify appropriate index periods (i.e., time periods during which parameters should be measured, data collected) applicable to wadeable streams and medium rivers for each ecoregion (Suplee et al., 2009; Suplee and Watson, 2013). Montana streams and rivers are generally most vulnerable to excess nitrogen and phosphorus impacts during the summer and early fall baseflow months. Time periods when TN and TP data should be collected are shown in the two right columns of **Table 2-2**.

Table 2-2. Upper bound of Ecoregional TP and TN Concentrations Protective of Aquatic Life and Recreation Beneficial Uses. The most sensitive beneficial use associated with the ecoregional concentrations is shown. Also shown are the minimum time periods when the concentrations should be applied.

			Upper Threshold		Most Sensitive Beneficial Use Threshold is Associated With	Applicable Time Period	
Region	Ecoregion (Level III)	Ecoregion (Level IV)	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)		Start of Growing Season	End of Growing Season
Western	Northern Rockies (15)	all	40	640	Aquatic Life	July 1	September 30
Western	Canadian Rockies (41)	all	60				
Western	Idaho Batholith (16)	all					
Western	Middle Rockies (17)	all except 17i					
Western	Middle Rockies (17)	Absaroka-Gallatin Volcanic Mountains (17i)	117	Apply concentrations less than Middle Rockies (17) ecoregion threshold above	Aquatic Life	July 1	September 30
Transitional	Northwestern Glaciated Plains (42)	Sweetgrass Upland (42l), Milk River Pothole Upland (42n), Rocky Mountain Front Foothill Potholes (42q), and Foothill Grassland (42r)	226	640	Aquatic Life	July 1	September 30
Transitional	Northwestern Great Plains (43)	Non-calcareous Foothill Grassland (43s), Shields-Smith Valleys (43t), Limy Foothill Grassland (43u), Pryor-Bighorn Foothills (43v), and Unglaciated Montana High Plains (43o)	41	640	Aquatic Life	July 1	September 30
Eastern	Northwestern Glaciated Plains (42)	all except those listed above as transitional for 42	150	1300	Aquatic Life	June 16	September 30
Eastern	Northwestern Great Plains (43) and Wyoming Basin (18)	all except for those listed above as transitional for 43, and 43c below				July 1	September 30
Eastern	Northwestern Great Plains (43)	River Breaks (43c)	Narrative Nutrient Standards Apply	Narrative Nutrient Standards Apply		June 16	September 30

2.1.2 Response Variables: Benthic Algal Chlorophyll *a* and Ash Free Dry Weight

The benthic (bottom-attached) chlorophyll *a* and ash free dry weight (AFDW) thresholds are based on acceptable levels from public opinion surveys in both Montana and Utah (Suplee et al., 2009; Jakus et al., 2017). These parameters should be collected between July 1 and September 30 of each year.

2.1.3 Response Variable: Percent Filamentous Algae Bottom Cover

The percent filamentous cover threshold is based on public opinion work in Utah (Ostermiller et al., 2019) and is consistent with cover percentages and preferences documented in Montana's public opinion survey in Suplee et al. (2009). This visual-based parameter should be collected between July 1 and September 30 of each year.

2.1.4 Response Variable: Dissolved Oxygen Delta

The daily curve of dissolved oxygen (DO) change in flowing waters is the response variable with the widest geographic application in the translator. Daily DO change, referred to as DO delta, is the daily maximum DO concentration minus the daily DO minimum concentration, expressed in mg DO/L. When DO delta is excessive, demonstrable impacts to aquatic life can occur as shown by work in Ohio, Minnesota, and Montana (Miltner, 2010; Heiskary et al., 2013; Heiskary and Bouchard, 2015; Suplee et al,. 2019). Thresholds for DO delta for different Montana regions were identified per methods in Suplee (2023). In the western and transitional ecoregions, DO should generally be collected between July 1 and September 30 of each year. For the eastern Montana ecoregions, collection should occur from June 21 to September 30. See also, **Tables 3-2** and **3-3** below and Tables 2-4 and 2-5 in **Circular DEQ-15**.

2.1.5 Response Variable: Beck's Biotic Index (version 3)

Beck's Biotic Index (v3)—computed from aquatic macroinvertebrate samples—was the most consistent macroinvertebrate-based metric across Montana's western and transitional region in terms of correlation with TN and TP concentration gradients (Schulte and Craine, 2023). Thresholds for the index for the Mountains and Low Valleys and Transitional zones were identified per methods detailed in Schulte and Craine (2023). Macroinvertebrate samples should be collected between July 1 and September 30 of each year (DEQ, 2012).

2.2 SITE SPECIFIC SITUATIONS

Please review Section 2.3 in **Circular DEQ-15** for special considerations such as the influence of dams, spring creeks, etc. As a result of site-specific conditions, situations may arise which could warrant modification to the thresholds in **Table 2-1**. These topics are discussed in detail in **Sections 5.6 and 5.7**. **Before they can be applied in an assessment, any criteria modified from what is found in Table 2-1 must be approved by DEQ and submitted to the U.S. Environmental Protection Agency (EPA) for review and approval.**

3.0 SAMPLING AND DATA QUALITY CONSIDERATIONS WHEN APPLYING THE NARRATIVE NUTRIENT STANDARDS

Waterbody condition must be evaluated based on all 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 and assessing data quality when performing assessments. Frequent reference back to sections and tables in **Circular DEQ-15** will be found throughout the remainder of this document. Additional guidance will be found in the **DEQ-15 Guidance** document.

3.1 CAUSAL AND RESPONSE VARIABLE SAMPLE COLLECTION, ANALYSIS, AND UNITS

Table 3-1 below lists parameters, their units, and how single sample and multi-year datasets are to be expressed and reduced. This table corresponds to Table 3-1 in **Circular DEQ-15**.

Table 3-1. Expression of Nutrient Concentration and Response Variables, and Applicable Thresholds.

Applicable Ecoregions	Parameter	How the Parameter is Expressed	How the Parameter is Assessed across Time (2-5 years or longer)	Threshold
Western and Transitional, Eastern	Instream nutrient concentrations	Monthly arithmetic average	Long-term arithmetic average	Applicable ecoregional concentrations in **Table 2-2** in this Assessment Method
Western and Transitional	Benthic algal chlorophyll *a* (Chl*a*)	Weighted average of replicates (normally 11) collected across a reach	One sampling event exceedence is allowed every three years	150 mg Chla/m^2
Western and Transitional	Benthic algal ash free dry weight (AFDW)	Weighted average of replicates (normally 11) collected across a reach	One sampling event exceedence is allowed every three years	35 g AFDW/m^2
Western and Transitional	% Bottom cover by filamentous algae	Arithmetic average of replicates (normally 11) visually assessed across a reach	One sampling event exceedence is allowed every three years	30% bottom coverage
Western and Transitional	Macroinvertebrates	A single metric score generated from a reachwide composite sample	Arithmetic average of sampling-event metric scores	Beck's Biotic Index (v3) Mountains: 35.1 Low Valleys and Transitional: 18.7
Western and Transitional, Eastern	Dissolved Oxygen Delta (daily maximum minus daily minimum)	7-day average of daily DO deltas	All available 7-day average DO deltas compared to the applicable exceedence rates in **Table 2-1** in this Assessment Method.	Western and TransitionaL: 3.0 mg DO/L. Eastern: 6.0 mg DO/L during non-drought periods

3.2 WET WEATHER

Samples should generally be collected during dry weather periods in order to represent steady state conditions during the index period (index periods range from mid-June to the end of September; see **Section 2.1** above as well as Tables 2-3 through 2-5 **in Circular DEQ-15**). TN and TP concentrations are influenced by rain events and collection during or immediately following rain should be avoided. Dissolved oxygen is collected over time via continuous deployed instrument and flow-changing events—from rain, or declining flows as summer progresses—will be a normal part of the recorded DO patterns. Other response variables (e.g., macroinvertebrate samples, benthic algae density) are less influenced by rain events unless an event is intense. Best professional judgement should be used to determine when it is appropriate to incorporate or exclude wet weather data for standards attainment and beneficial use assessment under this assessment method.

3.3 SAMPLING TIMEFRAME AND TEMPORAL INDEPENDENCE

3.3.1 Time of Year, Time of Day

See **Section 2.1** above. Each subsection there provides sample collection timeframes (i.e., index periods) applicable to the causal or response variables addressed. TN and TP and biological samples may be collected any time of day (morning, midday, early evening) for use under this assessment method. Dissolved oxygen is collected via continuous deployed instrument and is discussed in **Section 4.6**.

3.3.2 Temporal Independence

Tables 3-2 and **3-3** below provide temporal spacing requirements for sample collection. Temporal independence does not apply to continuous DO datasets. See also, discussion and analyses related to temporal independence in **Appendix A** and Tables 2-4 and 2-5 in **Circular DEQ-15**.

Table 3-2. Minimum Data Collection Requirements for Monitoring Sites in the Western and Transitional Ecoregions

Parameter	Associated Beneficial Use	Site Type	Annual Index Period	Minimum Annual Sampling Requirements
1. Physical Variables				
Water Surface Slope (%)	Recreation, Aquatic Life	Near-field, far-field, and other monitoring sites	n/a	Determined once, generally at the time the sampling reach is established
2. Response Variables				
Reach average benthic algal chlorophyll *a* (Chl*a*)	Recreation	Near-field, far-field, and other monitoring sites	July 1 to September 30	Twice during the index period, with a minimum of 4 weeks between sampling events
Reach average benthic algal ash free dry weight (AFDW)				
% Bottom cover by filamentous algae, reach average				Monthly during the index period; two of the events must pair with the Chl*a* /AFDW sampling
Dissolved Oxygen Delta (daily maximum minus daily minimum)	Aquatic Life			Instruments deployed annually for at least 14 continuous days which must be in August; longer datasets may include July and September. Logging must occur at least every 15 minutes. Deployment sites must correspond to reaches used to collect other response variable data.
Macroinvertebrates (reach-wide composite)				Once per annual index period, corresponding to one of the other sampling events
3. Nutrient Concentrations				
Total P, Total N	Recreation, Aquatic Life	Near-field, far-field, and other monitoring sites	July 1 to September 30	Twice during the index period, with a minimum of 4 weeks between sampling events

Table 3-3. Minimum Data Collection Requirements for Monitoring Sites in Eastern Ecoregions

Parameter	Associated Beneficial Use	Site Type	Annual Index Period	Minimum Annual Sampling Requirements
1. Response Variables				
Dissolved Oxygen Delta (daily maximum minus daily minimum)	Aquatic Life	Near-field, far-field, and other monitoring sites	Northwestern Glaciated Plains(42): 6/16-9/30 Northwestern Great Plains(43): 7/1-9/30	Instruments deployed annually for at least 14 continuous days which must be in August; longer datasets may include June, July, and September. Logging must occur at least every 15 minutes. Deployment sites must correspond to reaches used to collect causal variable data.
2. Nutrient Concentrations				
Total P, Total N	Aquatic Life	Near-field, far-field, and other monitoring sites	Northwestern Glaciated Plains(42): 6/16-9/30 Northwestern Great Plains(43): 7/1-9/30	Twice during the index period, with a minimum of 4 weeks between sampling events

3.4 SAMPLING LOCATIONS AND SPATIAL INDEPENDENCE

Guidance for selecting sampling locations is provided in this section. The topic of spatial independence of data is also covered. See also, discussion and analyses related to spatial independence in **Appendix A**.

3.4.1 Assessment unit selection

Narrative nutrient standards assessment decisions are made for assessment units (i.e., waterbodies or waterbody segments). DEQ is more likely to prioritize assessment units that may have elevated nutrient concentrations from one or more of the sources listed in **Section 1.3**. DEQ may also prioritize waterbodies that have previously been identified as impaired by TN, TP, benthic algal chlorophyll *a* or AFDW, DO, or pH, due to human activities or other factors.

3.4.2 Assessment Units and Reaches

If an assessment unit exhibits one or more significant longitudinal shifts in type and intensity of potential TN and TP sources such that clear breaks could be made to designate homogenous sub-reaches, then breaking an assessment unit into homogenous reaches may be justified. For example, if a relatively unimpacted upstream reach can be isolated and its condition is likely to be substantially different from other downstream parts of the assessment unit, the assessment unit may be split into two sub-reaches for assessment purposes. The following principals apply:

- If two sub-reaches in an assessment unit are each assessed but only one indicates impairment, the entire assessment unit receives the impairment determination.
- Each sub-reach has the same general data requirements (e.g., dataset minimums) as the parent assessment unit would have had if it hadn't been divided.
- It is better to lump than split reaches to avoid excessive consequential administrative and sampling requirements that result.
- An assessor should, to the best of their ability, decide whether to split an assessment unit into two or more assessment reaches before data collection; this will help ensure that reach breaks are based on considerations of land use and sources.
    - However, if collected data indicate a sub-reach is appropriate, proceed with additional data collection to adequately populate all data needs for both sub-reaches.

3.4.3 Total number of sites

Assessment determinations are made using data pooled for the entire assessment unit or assessment reach per **Section 3.4.2**, not individual sites. Best professional judgement is used to determine how many sites are needed to adequately represent the range of potential human sources influencing the assessment unit. It is best to incorporate data collected at multiple sites to better capture variability throughout the assessment unit.

Also, as resources allow, it is preferable to collect multiple samples from each monitoring site selected so long as temporal spacing requirements are met (see **Section 3.3.2**). This enables a multifaceted approach to data analysis; for example, in addition to pooling data from the entire assessment unit to make impairment determinations, an assessor may also strive for enough data to analyze individual sites to perform a thorough source assessment to assist in determining probable sources. Increased monitoring efforts will also provide better information for TMDL development. However, assessment decisions can be based on data collected from just a single sampling location <u>if</u> that single sampling location can reasonably be considered representative of portions of the assessment unit. The assessor will determine if sufficient spatial representation justifies progression to a full narrative nutrient assessment.

3.4.4 Site selection

Data must be collected from the assessment unit. Generally, sampling should target sites that are most likely influenced by sources of concern rather than random sampling designs intended to represent all potential impairment and non-impairment conditions throughout the assessment unit or reach. Sampling locations that may be prioritized for monitoring include:

1. Up- and downstream of point sources.
2. Up- and downstream of known or likely nonpoint sources.
3. Up- and downstream of incoming tributaries that may, themselves, have human-caused nutrient sources.

Other site locations that may be useful for source assessment purposes include sites that represent natural background conditions (e.g., upstream from human sources), sites that bracket tributary confluences or source areas, and sites on waters that are hydrologically connected to the assessment unit (e.g., ditches, point source discharges, wetlands, reservoirs).

3.4.5 Spatial independence

The following guidance for achieving spatial independence aligns with similar guidance found in other DEQ assessment methods, and is consistent with discussion and analyses presented in **Appendix A**:

- Select sites that are at least one stream mile apart unless there is a flowing tributary that confluences with the segment or a discrete source is located between the two sites.
- Consider land use and landform changes to help identify potential sources of excess nutrients as well as sites representative of natural background conditions.

3.5 SAMPLE SIZE

See **Tables 3-2** and **3-3** for minimum annual data requirements. In the circular, DEQ states its preference that a 3–5-year long dataset be used to accurately determine achievement/non-achievement of the narrative nutrient standards. However, per this assessment method, a minimum of <u>two</u> calendar years of data may be used by DEQ to carry out an assessment on an assessment unit or assessment reach. In areas with complex sources, or higher use waters, it is preferred that at least three years be sampled.

Given the shorter temporal data-collection period (2 years), minimum sample sizes for any given AU or reach are shown in **Table 3-4** below. Note in **Table 3-4** that DEQ prefers (but is not requiring) 12-13 nutrient samples for an AU or assessment reach, if feasible.

Table 3-4. Minimum Parameter Sample Sizes to Carry out an Assessment on an Assessment Unit or Reach

Parameter	Associated Beneficial Use	Minimum Total Sample Size for an Assessment Unit or Reach
1. Response Variables		
Average benthic algal chlorophyll *a* (Chl*a*)	Recreation	Six (6) site averages, each comprising (normally) 11 replicates from an assessment site
Average benthic algal ash free dry weight (AFDW)		
Average % bottom cover by filamentous algae		Six (6) site averages, each comprising (normally) 11 visual assessment points at an assessment site
Dissolved Oxygen Delta (daily maximum minus daily minimum)	Aquatic Life	See requirements in **Tables 3-2** and **3-3** of this Assessment Method
Macroinvertebrates (reach-wide composite)		Three (3) discrete samples
1. Nutrient Concentrations		
Total P, Total N*	Recreation, Aquatic Life	Six (6) discrete samples*

*DEQ prefers that 12-13 discrete samples be collected, if possible.

3.5.1 Number of Replicate Samples Used to Represent Each Site

Normally one sample (e.g., one TP sample, one composite macroinvertebrate sample) will be collected per site visit. Additional replicates (i.e., two or more samples collected for a parameter during a single site visit) may be acquired if heightened accuracy for that parameter is desired. Normally, during the analysis phase, results from replicate samples are averaged to best represent the parameter-by-site-date value.

3.6 DATA CURRENCY

Normally only data collected within ten years of when the assessment is started should be used to carry out the assessment. Assessors should evaluate the data to determine how well it represents current conditions; if conditions have changed substantially at a site or within a reach that could affect TN and TP loads (e.g., a wastewater facility upgrade), it may be appropriate to exclude data collected prior to the change even if the data are <10 years old. See also, Section 3.3 in Part I of **Circular DEQ-15**; any decisions that are made regarding exclusion of data <10 years old must be consistent with that section of the circular.

3.7 PARAMETERS REQUIRED FOR NARRATIVE NUTRIENT STANDARDS ASSESSMENT

All parameters with an **X** in **Table 2-1** are required in order to use the translator and complete the narrative nutrient standards assessment for the beneficial use and geographic zone indicated in the table. If only a partial dataset of these parameters is available, the narrative nutrient standards cannot be assessed unless via overwhelming evident (**Section 5.5**). Refer to **Sections 2.1.1 through 2.1.5** for a brief description of each parameter in the **Table 2-1** translator.

3.8 QUALITY CONTROL SAMPLES: FIELD DUPLICATES AND FIELD BLANKS

Field duplicates are samples collected as close as possible to the same point in space and time; duplicates should be collected by the same person and using the same collection method, though they are stored in separate containers and analyzed independently. For some (not all) parameters in **Table 2-1** the sampling design should incorporate field duplicates and the frequency of duplicate sampling must be documented in a quality assurance project plan (QAPP) or sampling and analysis plan (SAP). Field duplicates are usually collected at a minimum frequency of 10% of total samples. Field duplicates collected for data quality control differ from replicates which are intentionally collected from the same site to better represent variability within a site.

Narrative nutrient standards translators require water chemistry as well as biological samples, and duplicates may be undertaken for any of these. However, the requirement to collect duplicates on 10% of samples only applies to TN and TP water samples; biologically based samples (e.g., macroinvertebrates) are reach-average composites by design, and therefore duplication is not required.

Field blanks are samples collected and handled following the same methods as routine samples except laboratory-grade deionized or distilled water is used rather than ambient water. Field blanks represent total ambient conditions during sampling and laboratory sources of contamination (EPA, 2009). Any sampling design intended for assessing water quality standards attainment should incorporate field blanks and the frequency should be documented in a QAPP or SAP. Typically, field blanks are prepared at the end of each sampling event or data collection loop, and at least one field blank is analyzed along with each batch of routine TN and TP samples.

4.0 DATA QUALITY

Established policies and procedures in DEQ's Water Quality Division for quality assurance and quality control, beneficial use assessment, and data management apply to this assessment method. Data quality requirements apply to all data incorporated into making assessment decisions, whether collected internally or externally.

4.1 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, 2002a, 2002b). 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 must 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 must accompany this override with adequate justification.

Additional data quality screening may be necessary before the data set is ready to support attainment decisions (EPA, 2002a), for example:

- handling non-detects,
- evaluating database flags,
- evaluating QC samples (i.e., field duplicates and field blanks),
- verifying applicable holding times were adhered to,
- reviewing QA/QC reports,
- investigating errors in collection or analysis,
- addressing missing data, and
- reviewing deviations from SOPs and SAPs.

Once DEQ determines that data meet basic documentation requirements, the data are ready to be analyzed to support water quality standards attainment decisions (EPA, 2002b).

4.2 TOTAL KJELDAHL NITROGEN (TKN) AND TOTAL PERSULFATE NITROGEN (TPN)

Total Kjeldahl nitrogen (TKN) detection limits are poorer than those for TPN (225 µg N/L vs. 70 µg N/L, respectively). For their nitrogen samples, assessors should use TPN whenever possible. However, please note that TKN is required for MPDES permit compliance and therefore sampling at sites downstream of an MPDES permitted facility—particularly if the facility is under an Adaptive Management Plan—may require TKN. Please check with the Adaptive Management Program Lead to determine status and use of TKN and nitrate +nitrite (NO_{2+3}) to measure TN, as necessary.

4.3 EVALUATING FIELD DUPLICATES

Relative percent difference (RPD) is used to evaluate results between two duplicate samples:

$$RPD = \frac{|(result\ 1 - result\ 2)|}{(result\ 1 + result\ 2)/2} \text{ X } 100$$

Field duplicates (**Section 3.8**) for TN and TP should generally be within 25% RPD of one another. If greater than 25% RPD is found among these field duplicates, the assessor should verify data quality to confirm that the routine result values are valid for inclusion in assessment.

4.4 EVALUATING FIELD BLANKS

Assessors may decide to reject TN or TP samples collected during a sampling event for which a field blank returns detectable levels of these nutrients. If field blank detections are found, assessors should attempt to identify the probable source of contamination, and (for subsequent sampling) provide additional training or adjust collection, handling, storage, or analysis processes, as necessary.

4.5 BENTHIC ALGAL CHLOROPHYLL A AND ASH FREE DRY WEIGHT

All data collection and analysis must follow DEQ's applicable SOP (DEQ, 2024c) and be consistent with this assessment method and requirements in section 2.4 of Part I of **Circular DEQ-15**.

4.6 VISUAL ASSESSMENT OF PERCENT BOTTOM COVER BY FILAMENTOUS ALGAE

All data collection and analysis must follow DEQ's applicable SOP (DEQ, 2024c) and be consistent with this assessment method and requirements in section 2.4 of Part I of **Circular DEQ-15**.

4.7 DISSOLVED OXYGEN DATASETS AND DISSOLVED OXYGEN DELTA

All data collection and analysis must follow DEQ's applicable SOP (McWilliams and Nixon, 2020) and be consistent with requirements in section 2.4 of Part I of **Circular DEQ-15**. DO delta can only be accurately determined from continuous datasets from deployed instruments. Therefore, deployed instruments (e.g., PME MiniDOT, YSI EXO2) are, per this assessment method, required for this parameter. Continuous DO datasets should be processed to derive the daily DO delta values and, in turn, average 7-day DO delta values in accordance with procedures provided in Section 2.4.4 of Part I of **DEQ-15 Guidance**.

4.8 MACROINVERTEBRATE SAMPLES AND METRICS CALCULATION

All macroinvertebrate collection and identification must follow DEQ's SOP (DEQ, 2012) and be consistent with requirements in section 2.4 of Part I of **Circular DEQ-15**. Beck's Biotic Index (version 3) must be calculated per Section 2.4.5 of Part I of the **DEQ-15 Guidance**. Macroinvertebrate taxa tolerance values are in Appendix A of DEQ (2012).

5.0 DATA ANALYSIS TO SUPPORT NARRATIVE NUTRIENT STANDARDS ACHIEVEMENT DECISIONS

All applicable data parameters in **Table 2-1** must be available in order to complete a beneficial use assessment for the indicated use and geographic zone.

5.1 HANDLING NON-DETECTS

Required reporting limits for TN and TP should be documented in the project QAPP, SAP, or similar. For TN and TP data points reported below the required reporting limit, the non-detect (ND) values should be replaced with numeric values which are ½ the required reporting limit so long as the NDs do not represent more than about 15% of the total assessment reach dataset (EPA, 2006).

5.2 OVERVIEW OF THE ASSESSMENT DECISION FRAMEWORK

The same process and decision framework is applied whether or not a waterbody was previously listed on the 303(d) list as impaired by TN, TP, other nutrients, benthic algal chlorophyll *a*/AFDW, macroinvertebrates, DO, or pH. Parameters required per the **Table 2-1** translator (e.g., TP and TN concentrations, Beck's Biotic Index (v3) scores, 7-day average DO deltas) are assembled, allowable exceedance rates are applied, and conclusions are reached as to whether or not each parameter meets or exceeds its threshold in accordance with **Tables 2-2** and **3-1** above. Each "meets or "exceeds" outcome for each parameter is then compiled and compared to the applicable weight-of-evidence decision tables in Section 3.2 of Part I of **Circular DEQ-15** (see Tables 3-2 through 3-5 there). Each combination of results leads to a decision of achievement or non-achievement of the narrative nutrient standards.

One additional scenario may be encountered, namely, overwhelming evidence indicating severe exceedance of specific parameters in the dataset. Overwhelming evidence is addressed in **Section 5.5**.

5.3 PREPARING THE DATA FOR ASSESSMENT

1. Compile all data types (e.g., TN, TP samples, 7-day average DO delta values, Beck's Biotic Index (v3) results) required for carrying out an assessment for a specific beneficial use in a specified geographic zone (**Table 2-1**) for the assessment unit or reach in question.
2. Perform data quality assessment to identify the usable dataset (**Section 4.0**).
3. Organize data and reduce the data in accordance with requirements in Table 3-1 in **Circular DEQ-15**. Apply allowable exceedance rates which are provided as footnotes in Table 2-1, and also as found in the "How the Parameter is Assessed across Time" column in **Table 3-1**. Refer to **Table 2-1** to determine the number of exceedances allowed for a given response variable dataset. In the case of nutrient samples, an AU, reach, or site average should be compared to the applicable **Table 2-2** threshold and a determination of "meets" or "exceeds" is then made.
4. If assessing a plains (eastern Montana) wadeable stream or medium river, identify which of your weekly average DO delta values were collected during drought vs. non-drought periods. See Section 3.0, Part I of the **DEQ-15 Guidance** for instructions on using the National Drought Monitoring Center website to derive this information. Weekly average DO delta values collected during drought may be excluded from analyses undertaken per this assessment methods (see Table 3-5 in Part I of **Circular DEQ-15**).5.4 Assessment Decision Framework

The decision framework for achievement/non-achievement of narrative nutrient standards is provided Section 3.2 of Part I of **Circular DEQ-15**. Tables 3-2 through 3-5 in the circular provide outcomes specific to the beneficial use and geographic zone indicated. Each combination of results leads to a decision of achievement or non-achievement of the narrative nutrient standards for the beneficial use in the assessment reach under investigation.

5.5 OVERWHELMING EVIDENCE OF NUTRIENT IMPAIRMENT-ALL REGIONS

Some circumstances related to excess nutrient pollution are severe enough that a rigorous data collection effort for multiple data parameters is not required; the narrative nutrient standard at ARM 17.30.637(1)(e) can be assessed with limited information. Photo documentation with associated lat/long and field description of location will suffice. Below are conditions that can be considered overwhelming evidence; these apply equally to all wadeable streams and medium rivers across the state. These conditions are likely to be intertwined with organic pollution problems which impact DO concentrations.

- Fish kills involving massive growths of senescing algae mats. These mats may be attached to the bottom or floating. Dissolved oxygen levels at dawn (if measured) may at times be <1 mg/L.

- Filamentous algal growth covering the entire bottom from bank to bank and extending continuously for a substantial longitudinal distance (>150m). Use the photographs below (**Figures 5-1** and **5-2**) as guides. Don't confuse these conditions with sporadic, longitudinallypatchy growths of heavy filamentous growth, in between which there is lighter algal growth. The latter scenario is not extreme enough to warrant overwhelming evidence and should be sampled/assessed per methods in this assessment method.

Figure 5-1. Photographs of heavy, bank-to-bank and longitudinally continuous *Cladophora* growth Left photo is from Sandgren et al. (2004).

Figure 5-2. Massive *Cladophora* growth in the Clark Fork River, MT, 1984.This nuisance alga is aptly named "blanket weed". *Photo courtesy of Dr. Vicki Watson, University of Montana.*

5.6 SPRING CREEKS

Spring creeks in western and transitional ecoregions of Montana are excluded from the narrative nutrient standards translator in **Table 2-1**. Note, however, that spring creeks in eastern Montana ecoregions are subject to the **Table 2-1** translator. The narrative nutrient standards (ARM 17.30.637(1)(e) apply to western spring creeks but will require development of site-specific causal and response variable criteria on a case-by-case basis. Such criteria must be approved by the department and submitted to EPA for review and approval. Note also that Big Spring Creek (from its headwaters at 46.999211, -109.33704, to its mouth at the Judith River) is not included among the spring creeks described in this section (Big Spring Creek is influenced by 23 non-spring tributaries). **Instead, use the translator in Table 2-1 for Big Spring Creek.**

Montana spring creeks are inventoried (Decker-Hess, 1989), making it clear which waterbodies the different criteria in **Circular DEQ-15** should be applied to. Use Decker-Hess (1989) to determine if your AU or reach is a spring creek. **Circular DEQ-15** allows for unlisted (i.e., those not found in Decker-Hess 1989) but verified spring creeks to be evaluated and assessed on a case-by-case basis. **If you suspect you are working in an unlisted spring creek, discuss next steps with your supervisor.**

5.6.1 Overwhelming Evidence of Nutrient Impairment in Spring Creeks

Healthy spring creeks will naturally have high densities of macrophytes (aquatic vascular plants), but usually only limited densities of benthic filamentous algae or filamentous algae attached or entangled with the macrophytes. If conditions in a spring creek resemble those shown in the figures in **Section 5.5** above, the spring creek may be listed as impaired for narrative nutrient standards based on overwhelming evidence.

5.7 CONSIDERATION OF SITE-SPECIFIC CONDITIONS

Although ecoregion boundaries are clearly mapped, until a site visit has occurred there may remain a certain degree of uncertainty as to whether a western Montana waterbody is better viewed as a mountain stream/medium river or a low valley stream/medium river. Also, biologically based criteria in the translator in **Table 2-1** are influenced by environmental factors besides TN and TP concentrations. DEQ has analyzed confounding environmental factors that influence the response variables (see Schulte and Craine, 2023; Suplee, 2023a) and DEQ's goal is that the most reasonable and accurate causal and response variables and thresholds be applied when assessing a waterbody. Towards this end, DEQ outlined considerations in **Circular DEQ-15** for site-specific conditions. As an assessor using this assessment method you may, through your data collection, encounter situations that may warrant site specific criteria. Bring such situations to the attention of your supervisor. **If any criteria changes are to occur, however, they must first be approved by the department and submitted to EPA for review and approval as site-specific criteria.** Once approved, they may then be used for assessment purposes.

5.7.1 Stream Gradient in Western and Transitional Streams and Medium Rivers

If your waterbody is near the boundary of one of the Mountains Macroinvertebrate Zone ecoregions in Table 2-2 of Part I of **Circular DEQ-15**, and its water surface slope is ≤1%, the Low Valley and Transitional parameters and thresholds might be more appropriate. **Bring the situation to the attention of your supervisor.** However, please note that translator parameters and thresholds in **Table 2-1** of the assessment method do apply and must be used for assessment until a waterbody has had criteria changes approved by the department and submitted to EPA for review and approval as site specific standards.

The following are characteristics commonly observed in a Low Valley and Transitional stream, and which might be observed in a low-gradient Mountains stream:

> Low gradient (≤1% water surface slope), somewhat sinuous, cobble-to-gravel-bottomed but with substantial proportions of finer substrates (sand or finer) along its length, a longitudinal pool-riffle-run series but also including longer, quiescent glides, and a sparse macrophyte population.

5.7.2 Influence of Dams

See Section 2.3.1 in Part I of **Circular DEQ-15**. If your assessment unit or reach is downstream of a dam and the conditions described in the circular apply, determine if there are any known concerns about how the dam is being operated. For information on this, consult DEQ's Water Quality Standards & Modeling Section, DEQ's Enforcement unit, and DEQ staff who undertake 401 certification of hydroelectric dam permits. If there are concerns, this will likely preclude the development of any site-specific criteria. **If there are no known concerns about the operation of the dam, consult your supervisor about your data and findings**. The next step may involve the setting of site-specific water quality standards. This will involve DEQ's Water Quality Standards & Modeling Section and review and approval of the modified criteria by EPA.

5.7.3 Influence of Salinity on Beck's Biotic Index (version 3) in Low Valley and Transitional Regions

See Section 2.3.3 in Part I of **Circular DEQ-15**. If your assessment reach has elevated specific conductance, and Beck's Biotic Index (but not DO delta) has not attained its threshold, refer to Section 2.3 in Part I of the **DEQ-15 Guidance** and Appendix B in that document. Would a specific conductivity adjustment to your Beck's Biotic Index score result in achieving the narrative nutrient standards (i.e., is this a borderline situation)? **If yes, consult your supervisor about your data and findings.** The next step will involve determining if the elevated salinity is nonanthropogenic. This will most certainly involve some type of GIS analysis which could become complicated. If the GIS (or equivalent) work is carried out and ambient salinity is found to be nonanthropogenic, the next step is the setting of site-specific water quality standards (i.e., an adjusted Becks Biotic Index score for the site, assessment unit, or reach). This will involve the Water Quality Standards & Modeling Section and review and approval by EPA. If the elevated salinity is not natural (it is anthropogenically elevated), then proceed to assess the waterbody using the Beck's Biotic Index threshold (and other applicable parameters) in **Table 2-1**, and complete the assessment.

5.8 DOCUMENT ASSESSMENT DECISIONS AND REVIEW WITH MANAGEMENT

The assessor must document all data and decisions made pertaining to narrative nutrient standards achievement/non-achievement and beneficial use support determinations for assessment units. Assessment outcomes for individual assessment units, including data summaries, impairment determinations and beneficial use support determinations are documented in DEQ's Clean Water Act Information Center (CWAIC) available at:
https://clean-water-act-information-center-mtdeq.hub.arcgis.com/

Waterbodies for which the narrative nutrient standards are shown to be impaired are included on Montana's biennial Water Quality Integrated Report and list of impaired waters. The listing will normally include identification of whether TN, TP, or both as the likely cause; these are pollutants for which total maximum daily loads (TMDLs) are developed. 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.

6.0 SOURCE ASSESSMENT AND SUPPLEMENTAL INFORMATION

6.1 PROBABLE 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 the most commonly associated with TN and TP impairment listings in Montana; additional selections are available in the Water Quality Assessment and Reporting Documentation (WARD) system if needed:

- Row crop (fertilized) agriculture
- Livestock (Grazing or Feeding Operations)
- On-site Treatment Systems (Septic Systems and Similar Decentralized Systems)
- Find a mining option (TNT or other nitro explosives)
- Urban runoff
- Industrial site runoff or discharge
- Municipal Point Source Discharges
- Combined Sewer Overflows
- Septage Disposal
- Impacts from Land Application of Wastes
- Accidental release/Spill
- Natural Sources

If water quality data is available that proves a probable source is contributing loads or increasing concentrations, 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. The assessor may also include a brief description of sources in the overall condition of the waterbody summary in WARD.

6.2 SUPPLEMENTAL INFORMATION

Additional data types and information that may supplement or further support an assessment decision made per this document are provided below.

Flow

Discharge data collected concurrently with TN and TP samples can be used to calculate loads:
Load = Concentration x Flow x Unit conversion factor. This data will be helpful, later, if a TMDL is developed for the assessment unit.

Land Use Information

Land use information related to nutrient sources (e.g., septic density, land application, animal feeding operations, stormwater outfalls, and presence of wastewater treatment plants) supports monitoring designs and source assessment.

Reconnaissance, Photos, and Visual Observations

Visual observations and photos can help to substantiate assessment decisions and source assessments, such as observations of heavy filamentous algae growth, septic leakage, very heavy cattle grazing in and along the stream, etc.

Natural background information

Information that helps distinguish between natural and human nutrient sources supports source assessment and load allocations.

Data from connected waters

TN and TP concentration and load data from tributaries, ditches, point source discharges, wetlands, reservoirs, etc., that are hydrologically connected to the assessment unit is useful when evaluating location and magnitude of sources and seasonal variability.

Precipitation/weather data

Information about timing of precipitation will assist with best professional judgements regarding inclusion of wet-weather samples collected during assessment.

7.0 PUBLIC INFORMATION

All data parameters collected by DEQ in support of a narrative nutrient standards assessment are stored in DEQ's MT-eWQX Enterprise (EQuIS) database and uploaded weekly to the Water Quality Portal (EPA et al., 2018). Some datasets (i.e., continuous DO datasets, macroinvertebrates) will be stored as raw measurements or raw taxa counts, not as final metrics. Assessment outcomes for individual assessment units, 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).

8.0 REFERENCES

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APPENDIX A. DETERMINING SAMPLE INDEPENDENCE

According to definitions in Hurlbert (1984), much sampling carried out by DEQ on individual streams tends to violate spatial and temporal independence assumptions and results in pseudoreplication. For example, samples collected over time at a site can be serially correlated, which precludes temporal independence (Hurlbert 1984). However, the statistical views advocated by Hurlbert are not universally supported; contrary opinions on the matter can be found in the literature (Stewart-Oaten and Murdock 1986; Stewart-Oaten et al. 1992; Osenberg et al. 1994) and have led to what one journal referred to as a “healthy debate” (*Ecological Applications*, volume 4, No. 1, 1994). In general, more needs to be known about detection of non-independence and the frequency with which temporally independent samples can be collected (Underwood 1994).

A.1 TEMPORAL INDEPENDENCE

Time-series collected samples from a site may be used in inferential statistical testing, if used cautiously; this requires that one assumes that actual trends in time are identical in magnitude and direction for all the sites across the study (Norris and Georges, 1993). Osenberg et al. (1994) examine time-series serial correlation of physical and biological measurements in a BACI (Before-After-Control-Impact) study and conclude that, in the marine environment they study, sampling can occur at a site every 60 days without yielding substantial serial correlation.

DEQ recognizes the issue of temporal pseudoreplication, but also needs to be practical about the reality of sampling streams which, by their very nature, make collection of independent samples difficult. In DEQ’s reference project (Suplee et al., 2005), 30 days has generally been used as a minimum time span between sampling events at a site to infer temporal independence of water samples. This time span was based on the experiential observation that, during the brief Montana summer, substantial changes in flow, temperature, and vegetation (both riparian and instream) occur from month to month, changes that would likely affect water quality. But Stewart-Oaten et al. (1986) recommend that the assumption of temporal independence be tested, rather than assumed. The Durbin-Watson test statistic is widely used to check for time-series serial correlation. Stream sites with monthly nutrient sampling during the summer were available in Montana, and some of these sites were tested using the Durbin-Watson statistic Results are shown in **Table A-1** below.

Table A-1. Durbin-Watson Values for Time-series Collected Nutrient Samples at Selected Sites. All Samples were Collected Approximately 30 Days apart. Nutrients Showing Probable Time-series Serial Correlation (95% Confidence Level) are Highlighted.

					Nutrient	
Stream Site	**Months Sampled**	**Time Range**	**n**	**Total N**	**Total P**	**NO_{2+3}**
Rock Creek Site 2	June, July, Aug, Sept	2001-2004	12	1.18	1.43	2.3
Clark Fork R. at Deer Lodge (site 9)	July, Aug, Sept	1998-2006	25	1.81	1.78	1.68
Clark Fork R. above Little Blackfoot R. (site 10)	July, Aug, Sept	1998-2006	26	2.01	1.57	1.46
Clark Fork R. above Flathead R. (site 25)	July, Aug, Sept	1998-2006	26	1.76	1.21	2.08

In general, Durbin-Watson values around 2 mean there is no serial correlation, whereas values greater than approximately 2.5 or less than about 1.5 lead one to suspect negative or positive serial correlation, respectively (Neter, et al., 1989; Ott, 1993). What can be concluded from this limited analysis? Most nutrients did not show serial correlation, and one of the three that did is borderline cases (statistic =1.43, but power of test very low). Overall, it appears that serial correlation is present in nutrient samples collected a month apart, but the effect is very weak. It is evident that 30-day separated water samples can provide a fairly high degree of independence for nutrients.

2016 Update:

Methods. In 2016 we made an in-depth analysis of temporal sample independence patterns as manifested by Montana stream nutrient datasets. Historic nutrient data (1968-2012) from legacy STORET and MT-eWQX were queried to find contiguous daily, weekly, or biweekly datasets (or close approximations thereof). TP, TKN, and NO_{2+3} data were queried (little TN data exists in older datasets). Time-series datasets were located for 87 different wadeable streams, from eastern and western MT, representing both heavily polluted and relatively un-impacted sites (**Table A-2**). Datasets with >16.6% non-detects (U.S. Environmental Protection Agency 2006) or with other flagged data were eliminated. Durbin-Watson significance tables from Savin and White (1977) were used. The critical bound for decisions (dU, the upper bound[2]) on each side of the ideal score of 2 was used to determine if a given dataset demonstrated serial correlation or not (95% confidence level). We incorporated the previously-completed monthly dataset results (**Table A-1** above), with updated dU decision thresholds as necessary, per Savin and White (1977). Time-series datasets were then categorized as representing 3-day (i.e., sampling occurred about every three days), weekly, or biweekly sampling intervals. If a dataset did not exactly match one of these categorical intervals, it was placed in the closest category.

Table A-2. Sites with Nutrient Datasets Regularly Sampled (every 3-days, weekly, biweekly).

Station ID	Site Name	Nutrient	Interval
3732PR02	PRICKLY PEAR CK JUST ABOVE KAISER CEMENT	TKN	3-day
5614AS03	ASHLEY CR JUST ABV KALISPELL WWTP OUTFALL	TP, TKN	3-day, weekly
CBM-SW-1	0.25 MI UPSTREAM OF CONFLUENCE WITH DAISY CREEK	NO3	weekly
5514AS01	ASHLEY CR @ BRIDGE ABV CONFL WITH FLATHD	TP, NO3	weekly
5613AS02	ASHLEY CR @ BRIDGE ABV FOREST PROD CO.	TP, TKN, NO3	weekly
5613AS03	ASHLEY CR @ BRIDGE BEL FOREST PROD CO.	TP, TKN, NO3	weekly
5614AS08	ASHLEY CR @ BRIDGE NR DEMERSVILLE SCHOOL	TP, NO3	weekly
5614AS01	ASHLEY CR @ GAUGE STAT ABV STORM SEWER	TP, TKN	weekly
5513AS01	ASHLEY CR AT BRIDGE ABOVE SMITH LAKE	TP, TKN	weekly
5613AS01	ASHLEY CR AT BRIDGE BEL SMITH LAKE	TP, TKN	weekly
5512AS01	ASHLEY CR AT BRIDGE ON ROGERS LAKE ROAD	TP	weekly
3127BL01	BLACKTAIL CREEK ABOVE SILVER BOW	TP, TKN, NO3	weekly
5317BO01	BOND CREEK-UPPER	NO3	weekly
SEELEY1	CLEARWATER RIV AB RAINY LK	NO3	weekly
SEELEY4	CLEARWATER RIV BL LK ALVA	NO3	weekly
SEELEY8	CLEARWATER RIV BL SEELEY LK	NO3	weekly
SEELEY9	DEER CREEK NR SEELEY LAKE	NO3	weekly
3125GE05	GERMAN GULCH CREEK ABV CONF W SILVERBOW C	TP, TKN, NO3	weekly
5317HA01	HALL CREEK-UPPER	NO3	weekly
3326MI02	MILL-WILLOW BYPASS NR WARMSPRINGS POND	NO3	weekly
SEELEY10	SEELEY CRK AT SEELEY LAKE TOWN	NO3	weekly

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[2] The procedure tests the null hypothesis of zero autocorrelation in the residuals *vs.* the alternative that residuals are positively autocorrelated. If a test result is greater than dU, the null is not rejected (i.e., no serial correlation exists). Between dU and dL is the test's gray zone (result is inconclusive). If the result is lower than dL, the null is always rejected (there is serial correlation). Either boundary (dU or dL) can be used as the critical threshold. The dU boundary, which we used, is more conservative as more cases will be found with serial correlation.

3225SI03	SILVER BOW CR AT STUART ST BRIDGE OPPORT	TP,TKN, NO3	weekly
3127SI07	SILVER BOW CR BEL COLO TAILS & SLTR HOUSE	TKN, NO3	weekly
3126SI01	SILVER BOW CREEK 1 MILE BELOW RAMSAY	TP, TKN, NO3	weekly
3125SI02	SILVER BOW CREEK AT ROAD TO FAIRMONT	TP, TKN, NO3	weekly
3326SI01	SILVER BOW CR-LOWER PH SHACK NR WARM SPRG	TP, NO3	weekly
3127SI01	SILVERBOW CR ABV CONFL OF BLACKTAIL CREEK	TP, TKN, NO3	weekly
3324WA01	WARM SPRINGS CR 1 MILE BELOW MYERS DAM	TP, NO3	weekly
FL1003	BOHANNON CR 11 MI SSE BIG FORK, MT.	NO3	weekly, biweekly
3326WA01	WARM SPRINGS CR AT MOUTH NR SILVER BOW CR	TKN, NO3	weekly, biweekly
FL8008	ALDER CR 20 MI. WNW WHITEFISH MT	NO3	biweekly
2529BI01	BIGHOLE RIVER NEAR TWIN BRIDGES	TP	biweekly
2354BU01	BUTCHER CR - NR COONEY DAM RD	TP, TKN,NO3	biweekly
2453BU01	BUTCHER CR-NR MOUTH	TP, TKN,NO3	biweekly
2253BU01	BUTCHER CR-NR SH78	TP, TKN,NO3	biweekly
3555CA01	CARELESS CREEK AT MOUTH NR RYEGATE	TP	biweekly
3526CL01	CLARK FORK R -BRIDGE JUST ABV DEER LODGE	TP, NO3	biweekly
SEELEY7	CLEARWATER RIV AB SEELEY LK	NO3	biweekly
4814CR02	CROW CR BLW LOWER CROW RES NR RONAN	TP,TKN	biweekly
4815CR02	CROW CREEK ABOVE LOWER CROW RES NR RONAN	TP,TKN	biweekly
4714DU01	DUBLIN GULCH AT MOUTH NR MOIESE	TP,TKN	biweekly
4415FI01	FINLEY CK AT MOUTH NR ARLEE	TP, TKN	biweekly
2738GO04	GODFREY CK EAST FORK MOUTH	TP, NO3	biweekly
2738GO02	GODFREY CR - EAST FORK MOUTH	TP	biweekly
2738GO05	GODFREY CR - NEAR CHURCHILL	TP, NO3	biweekly
FL8014	GRIFFIN C, LOWER 20 MI WSW WHITEFISH MT	NO3	biweekly
FL8015	HAND C LOWER 21 MI WSW WHITEFISH, MT	NO3	biweekly
FL8016	HAND C, UPPER 23 MI WSW WHITEFISH,MT	NO3	biweekly
4515JO01	JOCKO R ABOVE VALLEY CK NR ARLEE	TP	biweekly
4416JO01	JOCKO RIVER ABOVE FINLEY CK NR ARLEE	TP,TKN	biweekly
4614JO01	JOCKO RIVER NEAR MOUTH AT HW 212 BRIDGE	TP,TKN	biweekly
4814LI01	LITTLE BITTERROOT R NEAR MOUTH AT SLOAN	TP,TKN	biweekly
FL8011	LOGAN C, LOWER 14 MI W WHITEFISH, MT	NO3	biweekly
FL8012	LOGAN C, MIDDLE 15 MI. SW WHITEFISH MT	NO3	biweekly
FL8013	LOGAN C, UPPER 16 MI SW WHITEFISH, M T.	NO3	biweekly
4615MI02	MISSION CK ABOVE SABINE CK NR ST IGNATIUS	TP,TKN	biweekly
4714MI01	MISSION CK AT HWY 212 NR MOIESE	TP,TKN	biweekly
4616MI03	MISSION CK BLW MISSION RES ABV DRY CR	TP,TKN	biweekly
4916MU01	MUD CK (UPPER) NR PABLO	TP	biweekly
4815MU01	MUD CREEK AT HWY 211 NR RONAN	TP,TKN	biweekly
5034MU01	MUDDY CREEK ABOVE DRAIN E	TP, NO3	biweekly
5034MU03	MUDDY CREEK ABOVE DRAIN M	TP, NO3	biweekly
5134MU02	MUDDY CREEK ABOVE EAST AND WEST FORKS	TP, NO3	biweekly
5034MU02	MUDDY CREEK ABOVE SPRING COULEE	TP, NO3	biweekly
5134MU03	MUDDY CREEK AT BRIDGE IN CORDOVA-WEST OF	TP, NO3	biweekly
3866MU01	MUSSELSHELL R AT HWY BRIDGE E OF MELSTONE	TP, NO3	biweekly
3455MU01	MUSSELSHELL RIVER AT BRIDGE IN RYEGATE	TP	biweekly
3650MU01	MUSSELSHELL RIVER AT HARLOWTON UPSTREAM	TP	biweekly
3457MU01	MUSSELSHELL RIVER NEAR LAVINA	TP	biweekly
3553MU01	MUSSELSHELL RIVER SOUTH OF SHAWMUT	TP	biweekly
3660MU01	MUSSLSHELL RIVER AT USGS STATION ROUNDUP	TP	biweekly
4815NI01	NINEPIPE RES OUTLET NR CHARLO	TP,TKN	biweekly
FL1001	NO FK LOST CR 3 MI. SE SWAN LAKE, MONTANA	NO3	biweekly
4916NO01	NORTH CROW CK ABOVE RONAN	TP	biweekly
4816NO02	NORTH CROW CK AT MOUTH NR RONAN	TP,TKN	biweekly
3646NO01	NORTH FORK MUSSELSHELL @ HWY 12	TP	biweekly
FL1002	PORCUPINE CR 5 MI. SW SWAN LAKE, MT	NO3	biweekly
4716PO01	POST CK ABOVE KICKING HORSE RES NR RONAN	TP,TKN	biweekly
4715PO01	POST CK AT HIGHWAY 93 BRIDGE	TP,TKN	biweekly
4715PO04	POST CK NR MOUTH AT CO.RD BRIDGE NR ST IG	TP,TKN	biweekly
4615SA01	SABINE CK AT MOUTH NR ST IGNATIUS	TP,TKN	biweekly
HUN103	SF FLATHEAD RIV 500FT BL H-H DAM	NO3	biweekly

4916SP01	SPRING CK NR RONAN	TP	biweekly
4815SP01	SPRING CREEK NEAR MOUTH NEAR RONAN	TP,TKN	biweekly
5231TE03	TETON R BELOW PRIEST BUTTE LAKE DISCH	NO3	biweekly
FL8021	TRIB TO SQUAW MEADOWS C 23 MI SW WHITEFISH MT	TP	biweekly
4815WE01	WEST FORK MUD CK AT HWY 211 NR RONAN	TP,TKN	biweekly

Results. The most common dataset time interval was biweekly (n=78), followed by weekly (n=55) and 3-day (n=3). The most common dataset size was n=7 samples (55 cases), the largest was n=20 (a 3-day interval dataset). Results are plotted in **Figure A-1.** This is the best fit relationship (natural log) and is curvilinear, with an R^2 of 0.84. **Figure A-2** is the same data but includes one assumed data point; it was assumed that if streams were sampled every minute (i.e., high frequency), all case studies would have serial correlation (think of TSS being sampled minutely on the rising limb of a hydrograph). The assumed data point provides a reasonable anchor point on the Y-intercept when deriving a best-fit curvilinear relationship using an algorithm (Gauss-Newton in this case). The relationship in **Figure A-2** is the best fit (i.e., lowest error sum of squares), but a 2nd order polynomial also reasonably fits these data ($R^2 = 0.81$; $y = 0.0016x^2 – 0.0764x +1$). The weekly and biweekly results do not plot exactly where one would expect, but the overall pattern of a curvilinear relationship with increasing serial correlation with fewer days between sampling events is clearly evident in **Figures A-1** and **A-2**.

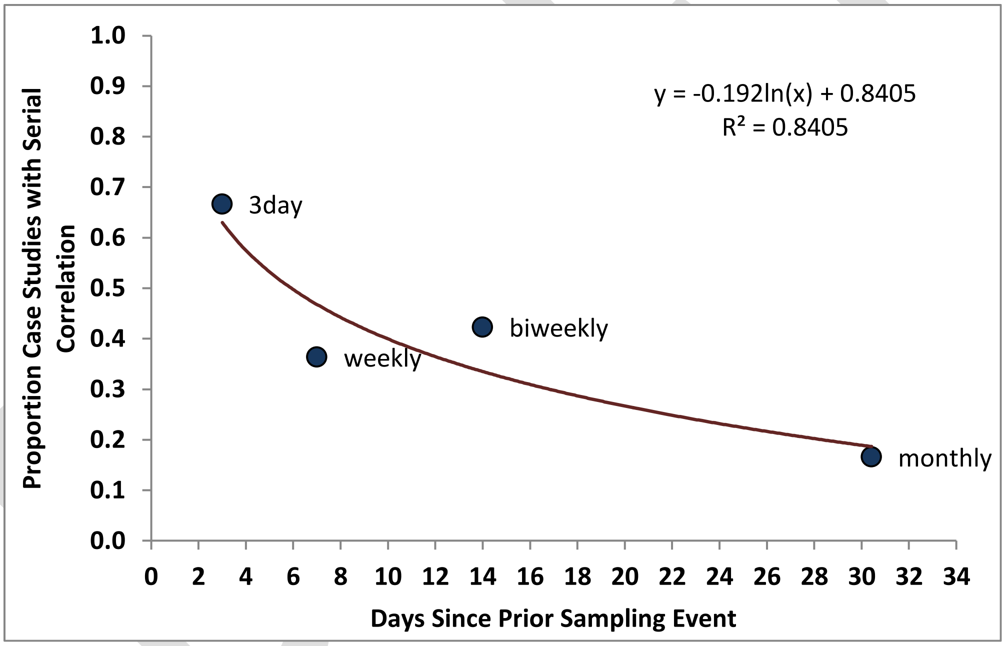


Figure A-1. Best-fit curvilinear relationship (natural log) between days since prior samping event (X) *vs.* the proportion of nutrient sampling case studies with serial correlation (Y).

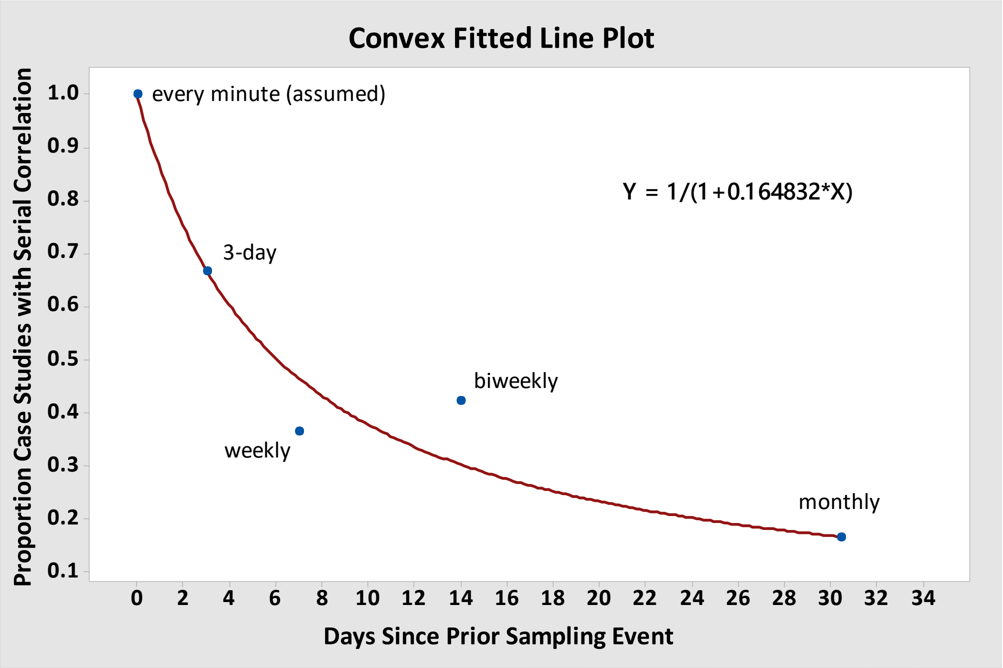


Figure A-2. Best-fit curvilinear relationship between days since prior sampling event (X) *vs.* the proportion of nutrient sampling case studies with serial correlation (Y). The line was fit using the Gauss-Newton algorithm in MiniTab 17 and includes an assumed data point at the Y-intercept.

Discussion and Conclusion. Based on the earlier work (**Table A-1**), DEQ has accepted—per this assessment method—that 17% of nutrient-sampling events would have serial correlation at the monthly interval sampling frequency. This was considered a tolerable level. This updated, more in-depth analysis was reviewed by **DEQ Standards Modeling staff and management in March 2016 and we concluded that the sampling interval could be reduced to two weeks.** The relationship between days since the prior sampling event and percentage serial correlation in dataset case studies is clearly curvilinear (**Figures A-1, A-2**). In **Figure A-2** the curve's apex is about 7 days, and at two weeks the curve is into the flattening part of the curved relationship. In both figures, at two-week sampling intervals, the percent of sampling events with serial correlation would be about 30%—below a critical concern level of 50%. Based on experience using this document's assessment method over the past 5 years, allowing sampling to occur at two-week intervals provides big advantages for completing field work and assembling adequately sized nutrient datasets during the short Montana field season. Given our better understanding of the sampling interval/serial correlation relationship, we believed the pros of allowing two-weeks between events greatly outweigh the cons of somewhat more cases with serial correlation.

A.2 SPATIAL INDEPENDENCE

DEQ is aware that spatial independence is also a concern. Water flows from upstream to downstream, consequently influencing the spatial independence of downstream sampling sites. No generally applicable spatial minimums were found as of this writing. U.S.EPA guidance (USEPA, 2002) generally glosses over the topic of spatial independence in streams.

To address spatial independence, we tested a Montana dataset. We used the pre-dosing baseline data collected as part of the Box Elder Creek nutrient dosing study (Suplee et al. 2016). We found that total nutrient samples collected within hours of one another at two sites located 0.73 stream miles apart were not spatially correlated. We compared nutrient samples collected from the Low Dose site to those collected on the same day at the High Dose site which is 0.73 miles downstream. Box Elder Creek is perennial and was flowing during all sampling events. No tributary intervenes between the sites. Samples were collected within 1-2 hours of one another, during the summer index period. We only considered samples collected *prior to* nutrient dosing, as these are comparable to what one would encounter during routine stream sampling/assessment. Using the Rank von Neumann test (U.S.Environmental Protection Agency 2006), we found that there was no serial correlation for total N or total P (i.e., we could not reject the null hypothesis "no serial correlation"), at an alpha of 0.05. There was serial correlation for Soluble Reactive Phosphate (SRP). We were unable to assess soluble N as there were too many non-detects in the datasets, which led to too many rank-ties; too many rank-ties precludes proper statistical evaluation (Gilbert, 1987).

Spatial independence can therefore be established (albeit as rules of thumb) for total nutrients as a minimum of about 1 mile between two sites. Other factors leading to spatial independence include a tributary confluencing on a stream between two sampling sites, or if major land form or land use changes occur along the reach (Montana Department of Environmental Quality 2007; Montana Department of Environmental Quality 2011a).

Giving consideration to our findings, below are guidelines for establishing independence of samples collected within an assessment reach:

- Sites (or short reaches equivalent to sites) should be located a minimum of 1 stream mile apart.
- Sites may be placed < 1 mile apart along the assessment reach if there is a flowing tributary confluencing with the segment between the two sites.
- Try to collect water samples starting at the downstream end of the assessment reach moving upstream, to avoid re-sampling the same water.
- Land use changes and land form changes should be considered and can be used to help define (1) breaks between assessment reaches and/or (2) additional sampling sites within an assessment reach.
- And, per **Section A.1**, nutrient samples collected at the same site (or short reach) should be collected at least 14 days apart.

Total nutrient samples that meet the above conditions may generally be considered both spatially and temporally independent for the purposes of determining compliance with the nutrient criteria. As such, they may be used in inferential statistical analyses and to make conclusions about the assessment reach in question.

Precautionary Considerations: The last bullet above (temporal independence resulting from approximate 14-day time spans) is not applicable for some bioassemblage samples (e.g., macroinvertebrates, fish). These organism populations operate on different (longer) time scales from water samples and diatoms and may show considerable year-to-year stability. Please see **Section 9.0** of Suplee (2004) and Bramblett *et al.* (2005) for more details on temporal patterns of these biological assemblages. Diatom populations tend to shift quickly, within 1-5 weeks, in response to environmental changes (LaVoie et al. 2008). Thus, this rate of change is sufficient to be able to consider diatom sampling events spaced 30 days apart as being largely independent of one another.

APPENDIX B. CRITICAL EXCEEDANCE RATE ANALYSIS FOR TN, TP IN A MT MEDIUM RIVER

Critical Exceedance Rate: *An estimate of the actual proportion of samples that exceed an applicable water quality criterion. When more than this proportion exceeds the criterion, the standard is not attained (i.e., stream is not in compliance with standard).*

An exceedance rate can be estimated using lines of reasoning, empirical evidence, and literature values. The considerations used to estimate an exceedance rate for numeric nutrient standards were (1) recommended exceedance rates from EPA (U.S. Environmental Protection Agency 2002) and (2) long-term benthic algae and nutrient relationships on the Clark Fork River, MT. Detailed consideration of (1) and (2) are provided below). We recommend:

- A critical exceedance rate for compliance with numeric nutrient standards be set at 0.2 (20%)

Below are our two major considerations leading to the selection of the 20% exceedance rate.

(1) EPA recommends that, for a number of different polluting substances (e.g., fecal bacteria, conventional pollutants, toxic trace metals, etc.), criteria exceedance rates be set between 0.1 and 0.25 (10 to 25%) to protect beneficial uses (Environmental Research Laboratory-Duluth 1997; U.S. Environmental Protection Agency 2002).

(2) The analytical approach described in **Section B.1** below was undertaken in June 2008, and only considered Clark Fork River data through 2006. Subsequent data collection (through 2009) and a somewhat different approach to ascertaining an acceptable exceedance rate allowed DEQ to update this analysis, as provided in **Section B.2.** Both analyses (that from 2008, in **Section B.1**, and the work done in 2011, in **Section B.2**) arrive at the same basic conclusion, and both are presented here.

B.1 2008 ANALYSIS OF THE CLARK FORK RIVER ALGAE AND NUTRIENT STANDARDS

Introduction: Numeric nutrient (TN and TP) and benthic algae (mg Chl *a*/m^2) standards have been in place on most of the Clark Fork River in Montana for about 6 years. A systematic collection of nutrient and algae data has been ongoing since 1998. At a number of sites both algae and nutrient data have been collected multiple times each year for nearly 10 years. These data lent themselves well to empirically deriving a numeric nutrient exceedance rate because some river sites almost always exceed the algae standards, while others do not. The question became:

> *Do sites on the Clark Fork River that routinely exceed the numeric algae standards exceed the river's established numeric nutrient (TN and TP) standards more frequently than sites that do not exceed the numeric algae standards?*

Benthic algae levels >150 mg Chl *a*/m^2 (maximum) are not to be exceeded during the summer (ARM 17.30.631). Maximum in this case does not refer to a single stone from a Clark Fork River site; it refers to the mean value of a series of repeat measures (n = 15 to 20) that are collected at a site *during a particular sampling event.* Clark Fork River sites are usually sampled several times throughout the summer. It has been noted for some years that, during the summer, some sites are usually above the algae standards, while others are not. TN and TP standards were established on the Clark Fork River (ARM 17.30.631) in 2002 and, if ultimately met, should keep benthic algae below the nuisance threshold described above. However, an exceedance rate was never explicitly established in the regulations. In carrying out the exceedance rate determination described herein, it is assumed that the magnitude of the TN and TP criteria on the Clark Fork River were accurately determined, and therefore any exceedance rate drawn from this analysis is meaningful.

Methods: Benthic algae and TN and TP concentration data where concurrently available for seven Clark Fork River sites from 1998-2006. Data were restricted to the time period June 30th to October 1st to generally comply with the summer growing season for this ecoregion (Suplee et al. 2007) and the regulatory timeframe in ARM 17.30.631. Every benthic Chl *a* measurement from a site (n = 15-20 per sampling event) collected over time was treated as a repeat measure. This resulted in a grand total of 285 to 333 repeat measures of Chl *a* at each site for the period 1998-2006. A grand benthic Chl *a* mean was calculated for a site by averaging all the repeat measures collected between June 30th and Oct 1st for all available years. Nutrient data collected at the corresponding sites during the same time frames where similarly compiled. At each site nutrients were collected as a single grab sample and, as a consequence, there were fewer data (43 to 78 N or P samples per site). Total N data were not collected; however, Total Kjeldahl Nitrogen (TKN) and NO_{2+3} were. Therefore, for each site, individual Total N concentrations were calculated by summing the TKN and NO_{2+3} sample results collected simultaneously during a sampling event.

Next, the Clark Fork River TN and TP criteria concentrations were matched to their corresponding values in the nutrient cumulative frequency distributions for each site, and the associated percentile was recorded. For example, the TN criterion for the Clark Fork River is 0.3 mg/L, and it resulted that at site 9.0 (Clark Fork at Deer Lodge) 0.3 mg TN/L corresponded to the 23rd percentile of site 9.0's cumulative TN frequency distribution. This process was carried out for all 7 sites for both TN and TP. There is a break at the Blackfoot River confluence where the Clark Fork's upstream TP criterion (0.02 mg/L) differs from that below (0.039 mg/L); each TP criterion was applied as appropriate for a site's location along the river.

Results: Table B-1 shows the results for 3 sites that, over the 1998-2006 time period, did not exceed the Clark Fork River's benthic algal biomass criteria. For this group of sites the nutrient criteria exceedance rate (both TN and TP) was, on average, about 8%. That is, nutrient samples whose concentrations exceed the standards occur only about 8% of the time at these sites. **Table B-2** shows three sites that *did* exceed the benthic algae standard; for this group of sites, the nutrient criteria exceedance rate was, on average, about 58%. Sites in **Table B-1** (did not exceed algae standard) had a range of exceedance rates (TN and TP) from 0.1%-24%, and sites in **Table B-2** (exceed algae standard) had a range of exceedance rates from 27.7% to 88%. The remaining site examined (Site 12; Clark Fork River at Bonita), which is not presented in **Table B-1** or **B-2**, had a mean algae density (144 mg Chl *a*/m^2) so close to the algae standard it was considered borderline. Site 12's exceedance rate was 30.8% for TN, 68% for TP.

Table B-1. Sites on the Clark Fork River (CFR) Not Exceeding the Maximum Benthic Algae Standard (Growing Season, 1998-2006).

			Percentile in Site's Nutrient Frequency Distribution Matching CFR Standard		**Criteria Exceedance Rate (%)**	
Clark Fork River Site #	**Site Name**	**Long-term Benthic Algal Biomass (mg Chl *a*/m², growing season) Mean [median]**	**TN**	**TP**	**TN**	**TP**
15.5	Clark Fork above Missoula	96 [80]	90th	95th	10.2%	5.4%
22	Clark Fork at Huson	72 [52]	76th	96th	24.0%	3.8%
25	Clark Fork above Flathead	35 [20]	100th	99th	0.1%	1.5%
					Grand Mean:	**7.5%**
					Grand Median:	**4.6%**
					Maximum:	**24.0%**
					Minimum:	**0.1%**

Table B-2. Sites on the Clark Fork River (CFR) Consistently Exceeding the Maximum Benthic Algae Standard (Growing Season, 1998-2006).

			Percentile in Site's Nutrient Frequency Distribution Matching CFR Standards		**Criteria Exceedance Rate (%)**	
Clark Fork River Site #	**Site Name**	**Long-term Benthic Algal Biomass (mg Chl *a*/m^2, growing season) Mean [median]**	**TN**	**TP**	**TN**	**TP**
9	Clark Fork at Deer Lodge	180 [147]	23rd	50th	77.0%	50.0%
10	Clark Fork above Little Blackfoot River	163 [117]	48th	12th	52.0%	88.0%
18	Cark Fork at Shuffields	197 [181]	50th	72nd	50.4%	27.7%
					Grand Mean:	**57.5%**
					Grand Median:	**51.2%**
					Maximum:	**88.0%**
					Minimum:	**27.7%**

Discussion: The main assumption of this analysis was that the magnitudes of the Clark Fork River nutrient criteria, which were established as standards for the river, are correct. That is, if the nutrient standards are achieved, then summertime algae levels should be kept below the established nuisance thresholds. It was assumed that, as has previously been shown, both N and P co-limit in the Clark Fork River (Lohman and Priscu 1992; Dodds et al. 1997). It was further assumed that the algae standard (150 mg Chl *a*/m^2, site mean per sampling event) will protect beneficial uses. Regarding the later, research completed since the Clark Fork River standards were adopted in 2002 show that 150 mg Chl *a*/m^2 (site mean) is identified as a nuisance threshold by the Montana public majority (Suplee et al. 2009). If all these assumptions hold true, then reasonable exceedance rates for the 9 year dataset can be derived and used as a case study. It would have been ideal to have a true population of data (rather than a subset of data for a single river over a specific time period) with which to carry out this analysis. But such data are not readily available, and the long-term dataset examined here will have to serve as a proxy.

Comparison of Clark Fork River sites 15.5, 22, and 25 (don't exceed algae standard; **Table B-1**) *vs.* 9, 10, and 18 (do exceed algae standard; **Table B-2**) show a clear separation in the consistency of compliance with the river's numeric nutrient standards. It is clear from **Table B-2** that if the exceedance rate is about 50% then nuisance algae growth will almost certainly occur. But when the exceedance rate is ca. 5-10%, nuisance algae is unlikely to occur (**Table B-1.**) For purposes of estimating a protective nutrient criteria exceedance rate, the range of exceedance rates from these site groups needs to be considered as well. Note that an exceedance rate *of as much as* 24% does not result in excess benthic algae in some cases (site 22; **Table B-1**). On the other hand, notice that an exceedance rate *of as little as* 27.7% can result in non-compliance with the algae standard (site 18; **Table B-2**). Thus, an exceedance rate around 25% probably represents a threshold; if about 25% of the dataset exceeds the nutrient criteria, then there are roughly equal odds that the site could have nuisance algae (or not). This is partially supported by the fact that the single site with borderline algae conditions (site 12, Clark Fork River at Bonita; 144 mg Chl *a*/m^2) had a TN exceedance rate of 30.8%.

Conclusion: These analyses show that over a 9 year period (1998-2006) sites on the Clark Fork River that have consistently exceeded the nuisance algae standard (150 mg Chl *a*/m^2, summertime max) have TN and TP exceedance rates with a central tendency around 54%. On the other hand, sites that did not exceed the benthic algae standards had TP and TN exceedance rates with a central tendency around 6%. Within each group (sites that do not exceed algae standards, those that do; **Tables B-1** and **B-2**), individual sites had exceedance rates as high as or as low as about 25%. This suggests that 25% may be an exceedance rate threshold where the ability to assure compliance with the algae standard becomes tenuous. Given that about 50% is certainly too high of an exceedance rate and will not protect beneficial uses, approximately 10% is probably too restrictive, and 25% is borderline, it is recommended that a nutrient exceedance rate be set to 20%.

B.2 2011 ANALYSIS OF THE CLARK FORK RIVER ALGAE AND NUTRIENT STANDARDS

The 12-year (1998-2009) nutrient and algae dataset for the Clark Fork River was very large, and was first reduced prior to statistical analyses. Data reduction followed the following general pattern: At any given site (e.g., CFRPO-12), for any given year (e.g., 2005), and for any given parameter (e.g., TP concentration), the data were reduced to a monthly mean for each summer month (June, July, August, or September). First, quality control duplicates collected on the same day were reduced to a mean (TN data was not analyzed directly until 2009 and so, for 1998-2008 data, TN is the sum of TKN and NO_{2+3} samples collected simultaneously during a sampling event). Next, the mean of all individual days when sampling occurred within a month was calculated, resulting in a monthly mean. Nutrient sampling effort varied considerably from site-to-site and from year-to-year, and we did not want heavily sampled months or years to be over-represented in the dataset in the final analysis. In the manner we reduced the data, therefore, each monthly value carries equivalent weight, with some summer months being better characterized (i.e., sampled more days) than others.

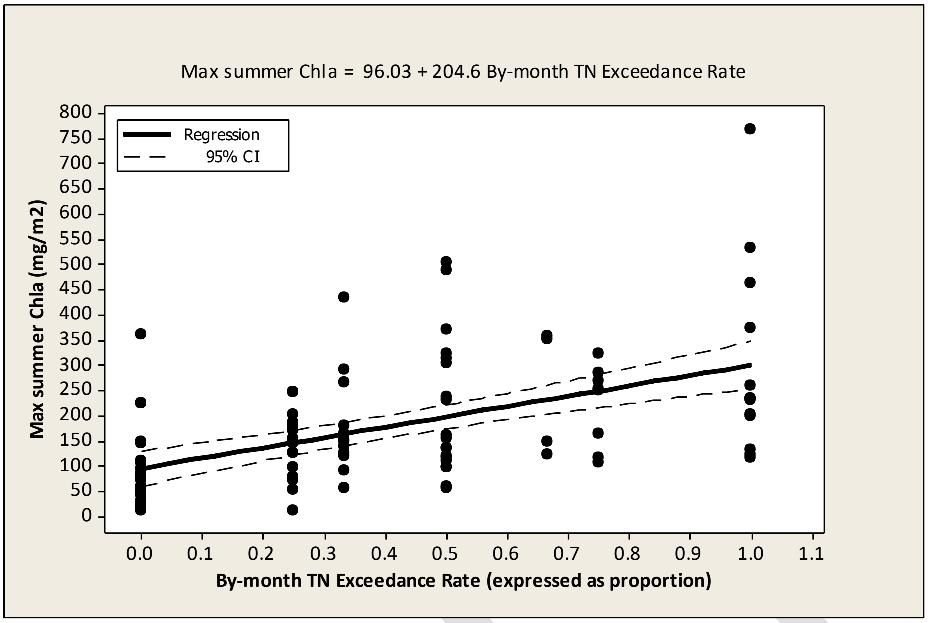
For benthic algae samples, up to 20 spatially-dispersed replicates were collected at a site during any given sampling event. Algae sampling events occurred only once a month. Thus, for a given site/year/month, the benthic algae mean calculated was the value used.

We next determined if each mean nutrient concentration, computed on a month-by-month basis, was above or below the Clark Fork River's applicable standards (TP or TN). This was only carried out for sites and times which had corresponding benthic algae samples. Then, we determined the proportion of months during a summer, at a site, that exceeded the river's nutrient criteria. For example, if a site in 2008 was sampled in June, July, August, and September, and June and August exceeded the TN standard, the TN exceedance rate for summer '08 would be 0.5 (50%). Each exceedance rate was then associated with its corresponding "Max Summer Chl*a*" value (nutrient exceedance rate as X, Max Summer Chl*a* as Y). Max Summer Chl*a* is the highest mean monthly Chl*a* value encountered during the summer at a site, per ARM 17.30.631. TN or TP data that were collected *after* the Max Summer Chl*a* event occurred were not included (e.g., if the Max Summer Chl*a* occurred in August, we did not include in the analysis the September TN or TP data for that site/year). Finally, least squares regressions (with 95% confidence intervals) were run for TN exceedance rate vs. Max Summer Chl*a* and TP exceedance rate vs. Max Summer Chl*a,* combining all sites and years together. The results are shown on the next page in **Figure B-1.**

Regression statistics for both regressions were significant ($p << 0.01$). Using the line equations shown in **Figure B-1**, 150 mg Chl *a*/m^2 (i.e., the maximum allowable benthic Chl *a* level for a summer; ARM 17.30.631) equates to a 26% exceedance rate of the TN standard and a 31% exceedance of the TP standard. The equivalent exceedance rates corresponding to the upper 95% confidence intervals (which are more conservative) are about 11% and about 5% for TN and TP, respectively.

These Clark Fork River data demonstrate that, across 10 sites with 12 years' worth of monitoring, there is a significant, definable relationship between benthic algal growth and the frequency of exceedance of the river's nutrient standards. That is, sites which frequently exceed the nutrient standards have higher levels of benthic algae. Sites that experience greater than about 25-30% exceedance of the nutrient standards will develop nuisance benthic algal growth, i.e., growth equal to or greater than 150 mg Chl*a*/m^2.

The analytical approach taken in 2008 (**B.1** above) was more coarse than what we have done here, in that it lumped all data by site and then looked to see how often that site—over the long haul—exceeded the nutrient standards. This analysis, in contrast, looks at each site and each summer as an individual event, and then collectively evaluates all the data together, regardless of location along the river (**Figure B-1**). Interestingly, the overall results between the earlier analysis and the current one are largely the same, in spite of the different analytical approaches. If we continue to assume that the nutrient standards on the Clark Fork River are largely correct in magnitude, then this latest analysis indicates we would want to keep exceedance rates of the applicable nutrient standards between 5-31%, if we want to keep benthic algae below nuisance levels. Since these results correspond nicely to the earlier analysis, we continue to recommend that nutrient criteria exceedance rates be set at 20%.



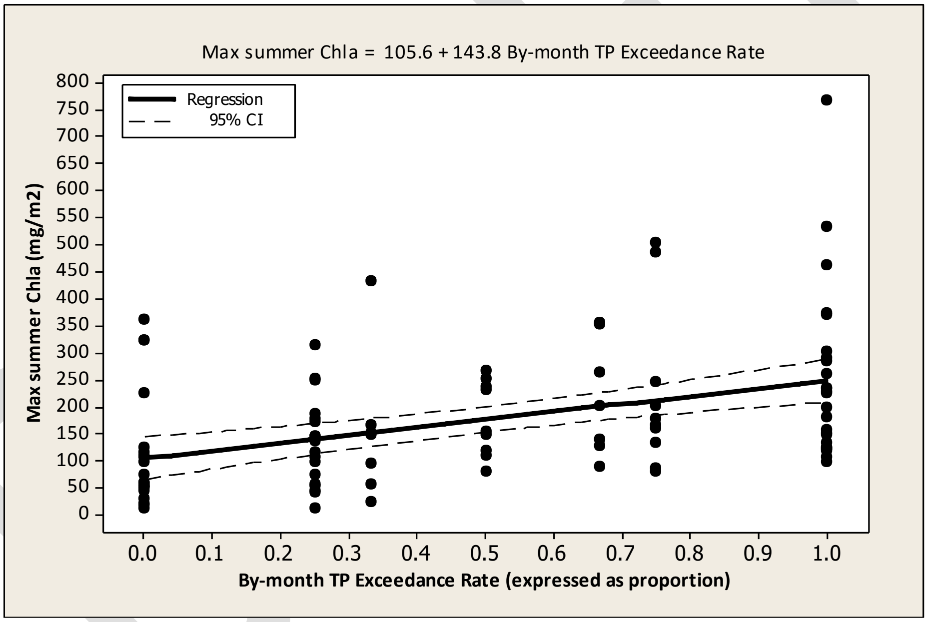


Figure B-1. Least squares regression for TN exceedance rate vs. Max Summer Chl*a* (upper panel) and TP exceedance rate vs. Max Summer Chl*a* (lower panel), for ten Clark Fork River monitoring sites (1998-2009). Dotted lines are the 95% confidence intervals. Both regressions are significant ($p << 0.01$).