Guidance Document for the Implementation of Narrative Nutrient Standards

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March 2022	1.0	Initial document	All	Michael Suplee, Rainie DeVaney

Executive Summary

This guidance document has been prepared in support of **Department Circular DEQ-15** and provides guidance for the development and implementation of adaptive management plans under the broader adaptive management program (75-5-321, MCA). An Adaptive Management Plan (AMP) is comprised of an AMP watershed monitoring plan and, if necessary, an AMP implementation plan. This document provides guidance relevant to both components of an AMP. The document has extensive guidance pertaining to the development of mechanistic water quality models and provides links to important department standard operating procedures which will aide users in implementing their AMPs. Two case studies, one for a modeling scenario and one for a non-modeling scenario, have also been provided in the document's appendices.

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Acronyms

AMP	Adaptive Management Plan
ARM	Administrative Rules of Montana
BMP	Best Management Practice(s)
DSS	Decision Support System
EPA	United States Environmental Protection Agency
FWP	Montana Department of Fish, Wildlife & Parks
HBI	Hilsenhoff Biotic Index
LA	Load Allocation
MOS	Margin of Safety
NSC	Normalized Sensitivity Coefficient
NSE	Nash and Sutcliffe Efficiency
PB	Percent Bias
QAPP	Quality Assurance Project Plan
RMSE	Root Mean Squared Error
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USGS	United States Geological Survey
WLA	Wasteload Allocation

1.0 Introduction

In 2021, the 67th Montana Legislature adopted Senate Bill 358 (now 75-5-321, MCA) which described a new process for implementing narrative standards for nutrients in MPDES permits. Nutrients, in this context, refers to total phosphorus (TP) and total nitrogen (TN) concentrations in state surface waters. The narrative standard at ARM 17.30.637(1)(e) — "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" — is the primary narrative standard the department has used to regulate the impacts of excess phosphorus and nitrogen in state waters. However, throughout the Administrative Rules of Montana (ARMs) there are other standards that address unwanted water quality changes which link to excess nutrients and the narrative (e.g., ARM 17.30.623(2)(c), which narratively describes allowable pH changes). This guidance has been developed to provide additional details in support of the rules (ARM 17.30.XXX) and **Department Circular DEQ-15**, which were adopted to conform with the statutory requirements in 75-5-321, MCA.

2.0 Different Data Collection and Evaluation Methods Apply Depending on Waterbody Size

As indicated in **Circular DEQ-15**, for purposes of developing a watershed-specific adaptive management plan (AMP) under the adaptive management program, each point source receiving waterbody must be identified as a large river, medium river, or wadable stream. Please refer to **Section 3.0** for guidance pertaining to modeling (including large river modeling), and **Sections 4.0** for guidance pertaining to medium rivers and wadeable streams.

3.0 Developing and Using Water Quality Models

This section covers water quality modeling. **Sections 3.1** through **3.6** address mathematical (mechanistic) water quality models, while **Section 3.7** covers conceptual water quality models.

3.1 Introduction to Mechanistic Water quality Models

The development of nutrient management AMPs for Montana's large rivers requires an understanding of the individual waterbody response to nutrient loadings including the most limiting nutrient, the magnitude of point and non-point sources at various locations in the watershed, the amount of controllable nutrient load, as well as the fate and transport of nutrients in the receiving water, both upstream and downstream of the point of discharge. As such, this guidance has been prepared should permittees choose or be required to use model-based approaches for demonstrating compliance in meeting narrative nutrient water quality standards, and for watershed-based nutrient management.

Although no single modeling tool is appropriate or useful for every situation, it is recognized that water-quality models may be needed to address nutrient management requirements in large rivers or complex watersheds. This section has been drafted to outline a quasi-standard approach for numerical model selection, development, and application for nutrient AMP implementation purposes. Considerable research has already been devoted to the use of modeling tools for site-specific nutrient management (Bierman et al., 2013), with the premise that properly conducted process-based load-response modeling approaches are effective in accounting for unique water body-specific characteristics along with resolving the effects of multiple confounding factors on ecological responses. Furthermore, simulation models have been increasingly required in water quality planning and management as engineering controls become more costly to implement, and the penalties of judgment errors become more severe (EPA, 1997).

Accordingly, nutrient modeling guidance for Montana's AMP program is contained herein. It is assumed the reader is already familiar with modeling terminology and engineering or natural sciences concepts and processes. For background information see Chapra (1997), Chapra (2003), Shoemaker et al. (2005), Borah et al. (2006), and Bierman et al. (2013). Specifically, the guidance outlines the following topics relative to the nutrient AMP process for large waterbodies: (1) the overall modeling approach including problem specification and definition of appropriate modeling scales and domains and quality planning procedures, (2) indicator/endpoint definition, (3) model selection, (4) model calibration and confirmation, and (5) general guidance and caveats for model application. These are presented in the remaining portions of the guidance section. **Appendix A** provides an applied case study example for the model-based approach.

3.2 Use of Water Quality Models for AMP Implementation – Overall Approach

The primary purpose for models in AMP implementation is to develop a decision support system (DSS) which can be used for regulatory purposes including the following: (1) demonstrating compliance with Montana's narrative nutrient standards, (2) evaluating water quality as a function of nutrient management actions to predict water quality changes in negatively impacted watersheds, (3) using models *vis-à-vis* nutrient trading to manage controllable point and non-point source nutrient contributions (DEQ, 2012; Rutherford and Cox, 2009; Ribaudo and Gottlieb, 2011), and (4) establishing permit limits for point source discharges in the context of AMP planning.

A flowchart for nutrient modeling is found in **Figure 3-1** (reproduced from Bierman et al., 2013). As differentiated in this guidance, both model-based and non-modeling approaches can be applied and regardless of which approach is used, the most important up-front consideration is the water-quality indicators/endpoints upon which nutrient control decisions will be made. Modeling processes are then initiated for the purpose of making management or regulatory decisions. Finally, there is an adaptive management component (circular arrows shown as "monitoring and iterative improvement") that requires the collection of additional data for post-audits or iterative model refinement or improvement.

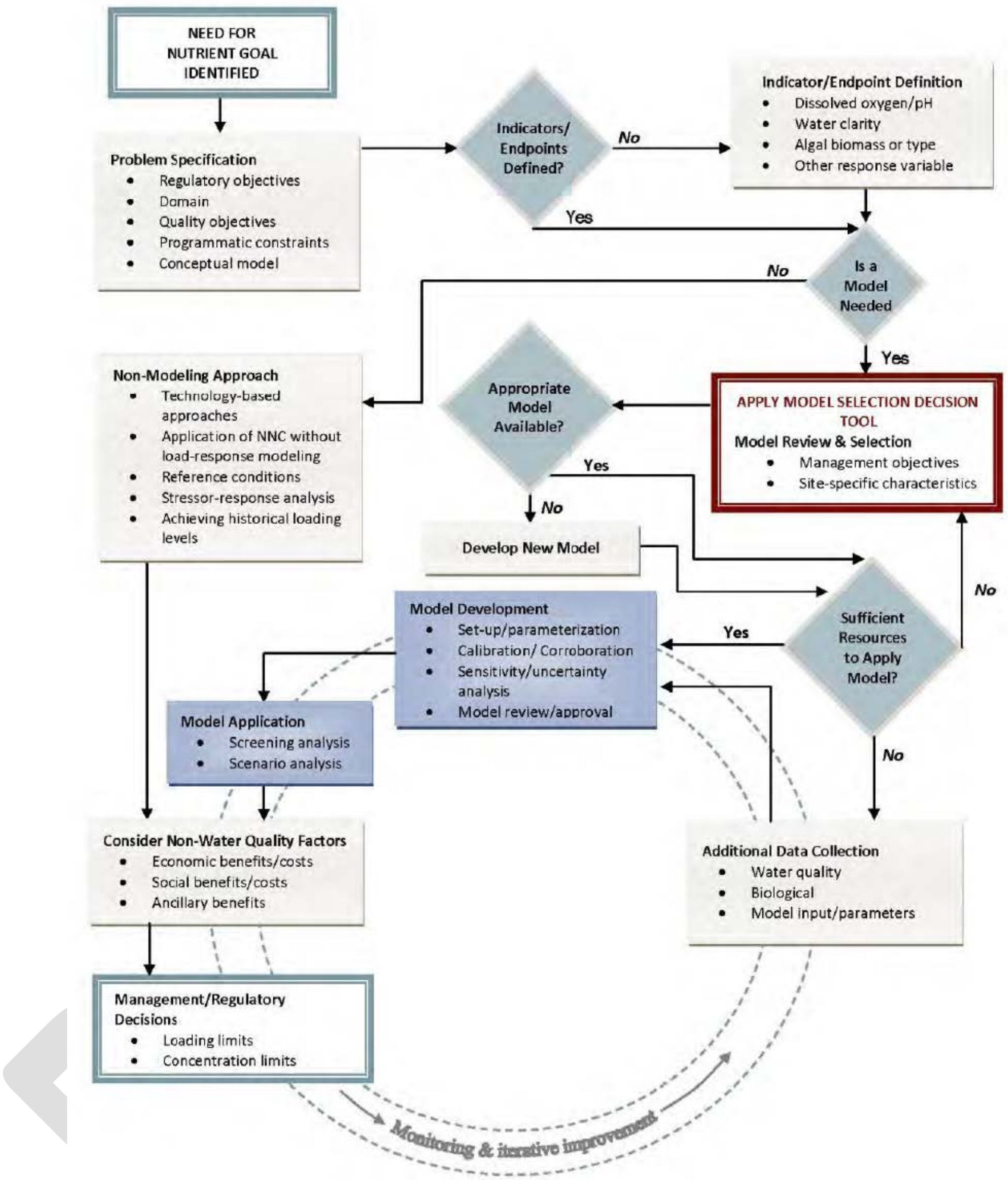


Figure 3-1. Process for Setting Site-specific Nutrient Goals (from Bierman et al., 2013)

3.3 RATIONALE FOR MODELING

The primary impetus for water-quality modeling in an AMP is to build an understanding of water quality problems including where and how they occur. This may include evaluating beneficial use support or compliance with the narrative nutrient standards, understanding the extent and severity of a problem such as a potential impact or the anticipated level of stress from a particular management activity on a response variable of interest, extrapolating from current conditions to potential future conditions, or evaluating the outcome of various management measures and strategies or for evaluating trends or system responses. Anticipated nutrient related AMP questions and actions that can be addressed through modeling will likely include the following:

- Are narrative nutrient standards currently being achieved in the waterbody based on response variables/indicator endpoints of concern?
- Would an increase in wastewater treatment for a particular nutrient (i.e., nitrogen or phosphorus) result in meeting the narrative nutrient standards?
- How can different spatial areas of the watershed be prioritized and managed for water-quality improvement (i.e., hot spot identification)?
- Identifying agricultural or other best management practices (BMPs) that are likely to be the most effective, or most cost-effective in controlling nutrient loads on a watershed basis.
- Determining what combinations of nutrient management options are likely to be most effective in terms of both nutrient load reduction and cost.

More specific discussions about AMP nutrient management modeling are covered in subsequent sections after first discussing types of models and AMP objectives.

3.4 Types of Water Quality Models and AMP Objectives

Widely used water-quality models have been developed by government agencies, universities, and private entities since the advent of modernized computing in the late 1960s. Most of these tools use mathematical (deterministic) and mechanistic relationships that estimate time series of pollutant loads or waterbody responses to pollutants for a variety of spatial or temporal scales. It is important to recognize that models can range in complexity from simple assessments where pollutants are calculated as a function of land use (e.g., export models) to mechanistic simulation models that explicitly describe processes of pollutant export or fate and transport in receiving waters.

For this document, models are broken into two functional categories that reflect overall objectives in the water-quality modeling process. These are: (1) watershed-loading models and (2) receiving-water quality models. The former simulates the export of pollutants from the land surface in some fashion with an emphasis on nutrient loadings from all locations in a watershed, whereas the latter characterize the response of the waterbody to the same pollutant loadings in a very detailed way. Further descriptions of each of these categorical types of water-quality models are provided below.

3.4.1 Watershed-Loading Models

Watershed-loading models simulate the generation and movement of pollutants from the land surface to lakes, rivers, or streams, with simplified in-stream transport (EPA, 1997). They are primarily designed to predict pollutant movement over large watershed scales, thus providing an understanding of the allocation (i.e., where pollution is generated from, and how much) of nutrient sources in a watershed. Such models range in complexity from simple Geographic Information System (GIS) loading estimates to complex simulation tools that explicitly describe the processes of runoff and nutrient transport. Loading models typically operate at the watershed or subbasin scale, although field-scale simulations are possible. Most loading models have been developed for the purpose of nonpoint source estimation with an emphasis on agricultural cropland or forestland, but they have been adapted to other land use categories as well (Donigian and Huber, 1991). For AMP purposes, watershed-loading models would most frequently be used to address the following management questions:

- What spatial areas in the watershed generate the highest nutrient loads?
- What is the overall contribution of point and non-point sources in a watershed?

- How does an agricultural management practice in an upstream location result in a reduction in nutrient loading at a permitted discharge?
- What is the nutrient source loading contribution of an unmonitored tributary?

One caveat is that watershed-loading models incorporate many empirical parameters that cannot be measured directly (e.g., buildup and washoff parameters, soil/chemical characteristics, partition coefficients, and reaction rates). Hence, they require calibration and appreciable data requirements exist for modeling. A general AMP rule of thumb is that the larger the AMP watershed is (spatially), the more likely a watershed-loading model will be needed to understand nutrient management. Such models will subsequently require calibration at multiple spatial locations.

3.4.2 Receiving-Water Models

Receiving-water models explicitly simulate chemical and biological responses of a waterbody to nutrient loadings. In essence, they attempt to reproduce the mechanistic relationship between forcing functions, boundary conditions, and state variables, reflecting the key waterbody response from nutrient stressors. Broad categories of receiving-water models include steady-state (constant flow and loadings) and hydrodynamic (time-variable flow and loadings). Each develop a mass balance for one or more interacting constituents over different spatial domains and temporal scales considering: (1) nutrient inputs to the system, (2) transport through the system, and (3) transformations or reactions within the system. Questions that receiving-water models could be used to answer for AMP purposes include:

- What is the site-specific chemical and biological response (e.g., benthic algal biomass, pH variation, dissolved oxygen minima, or other response variable/endpoint indicators of interest) of the waterbody to nutrient inputs at a variety of spatial locations or temporal scales?
- What is the limiting nutrient, or how does the limiting nutrient change over a given spatial extent given known nutrient sources and loadings?
- How does the waterbody respond to different nutrient inputs at various flow and environmental conditions, and where is the critical response located?
- What is the holistic system response from different actions at different points in the waterbody?

Receiving-water models require considerable site-specific data to calibrate model kinetic processes, and therefore require well thought out data collection and modeling approaches. Receiving-water models can be developed standalone or be used in concert with a watershed-loading model to provide additional insight to dynamic processes, chemical interactions, and biological processes.

3.5 Level of Effort in Modeling

Beyond the type of model being applied, the level of effort in AMP modeling should consider the complexity of the watershed being evaluated and importance of the decision required. Decision-based and data-driven modeling approaches are preferred for AMP planning studies, where robust data and modeling techniques are incorporated into the modeling process to match the rigor and importance of the planning process. This is typically referred to as the graded approach (EPA, 2002). Nutrient AMP modeling efforts can be broken into three levels of detail, each of which will depend on site-specific characteristics of the AMP watershed:

- Simple Methods – Basic techniques or screening/scoping tools require minimal user experience and are adequate for "back of the envelope" modeling computations. They typically are applied with either a hand calculator or spreadsheet and are sufficient in certain circumstances. A simple watershed-loading method is described in DEQ (2005). A good receiving-water example is the Clark Fork River Voluntary Nutrient Reduction Program (VNRP; Tri-State Implementation Council, 1998)[1].
- Moderate Methods – Moderate methods require mid-range user experience and are more data and computer intensive than simple methods. They find a balance between the simplistic and detailed computational methods. A good example of a mid-range watershed model for nutrient evaluation planning is the use of event-mean concentrations in EPA (2006) and DEQ (2008). Flynn et al. (2015) and Suplee et al. (2015) describe a suitable application of a steady-state receiving-water model for nutrient management.
- Detailed Methods – More sophisticated tools are needed for studies having high resource value, socio-political exposure, or controversial/complex nutrient AMP implementation. Detailed methods require a large effort by experienced professionals to simulate the physical processes over large spatial or temporal scales, either in a watershed or river system. Examples include two- or three-dimensional[2] receiving water models, or linked watershed and receiving-water modeling applications such as those described in EPA (2007).

The primary guiding factors in determining the level of effort in AMP nutrient management include: (1) the number of point source facilities on a large river segment, (2) the complexity of the watershed (i.e., a watershed having multiple nutrient point or non-point sources is considerably more difficult to manage when compared to one that has only a few), and (3) the magnitude of the controllable point and non-point source loads in the watershed, giving deference to the use of reasonable land, soil and water conservation practices.

3.5.1 Preliminary Level of Effort Requirements for Montana Waterbodies

Large river segments for Montana are defined in **Table 3-1** below (from Flynn and Suplee, 2010), shown in conjunction with the number of Montana Pollutant Discharge Elimination System (MPDES) nutrient permits in both the reach of interest, and upstream. Based on inspection, several watersheds are heavily permitted and contain dozens of permits (e.g., Clark Fork, Missouri, and Yellowstone rivers). These will require complex AMP approaches. Several have only a single MPDES permit, however, and will require a lower level of effort. It is important to recognize that the distributed spatial nature of larger watersheds may require careful consideration of the level of modeling detail, effort, and

[1]The VNRP used a steady-state spreadsheet mass balance model for nutrient target setting in the watershed (constant flow and concentration data from point sources, tributary inflows during 30Q10 critical streamflow conditions, and an assumed nutrient gain/loss factor to represent algal uptake of nutrients and groundwater and tributary changes along with a flow increment factor). The primary management goal of the VRNP was to improve water quality and control nuisance algae in the river, noting the nuisance algal goal in that efforts is analogous to the narrative state water quality standard.

[2] Zero-dimensional models reflect completely mixed systems and therefore have no spatial variation. One-dimensional models consider only on spatial representation, typically linear or longitudinal in nature (like a river). Two- and three-dimensional models consider water quality gradients in two- or three- spatial dimensions and are useful in lakes and reservoirs where stratification occurs, or within incompletely mixed rivers.

approach, sometimes involving multi-jurisdictional headwaters extending either into Canada or Wyoming. Moreover, several of the large river segments confluence together such they could potentially be addressed in one master AMP planning effort. Prior to selecting nutrient AMP modeling approach, discussions should be made collectively with the department to select and appropriate methodology for a given watershed.

Table 3-1. Large River Segments of Montana and Anticipated Level of Effort for Water-quality Modeling

River Name	Segment Description	Permitted Nutrient Facilities [a]		Anticipated Water-Quality Modeling Effort
		Within	Up-stream	
Bighorn River	Yellowtail Dam to mouth	0	0	Simple
Clark Fork River	Bitterroot River to state-line	6	13[b]	Detailed
Flathead River	Origin to mouth	8	2	Detailed
Kootenai River	Libby Dam to state-line	2	0	Simple
Madison River	Ennis Lake to mouth	1	5	Moderate
Missouri River	Origin to state-line	26	34	Detailed
SF Flathead River	Hungry Horse Dam to mouth	1	0	Simple
Yellowstone River	State-line to state-line	19	0	Detailed

[a] Nutrient permit only including contributing watersheds; excludes federal NPDES permits
[b] Not including Flathead River

3.6 Technical Guidance and Considerations for Nutrient Modeling in AMP Watersheds

As noted in Bierman et al. (2013), the use of process-based models for nutrient management requires careful consideration of a range of technical and management issues. While the primary technical challenge of water-quality modeling is to develop useful quantitative linkages between nutrients and environmental endpoints of concern, the principal management challenge is to ensure that the model will support the AMP regulatory requirements. To meet each objective, it is recommended that planning and modeling steps identified in **Figure 3-1** and in Figure 3-1 of **Circular DEQ-15** be carefully followed when conducting AMP nutrient modeling. Guidance for key steps are described in the following sections, generalized to any kind of modeling effort. Critical to project success is early engagement and coordination with the department, along with planning agency check points during each phase of the modeling process.

3.6.1 Problem Specification

3.6.1.1 Quality Planning and Modeling Objectives

Prior to AMP modeling, project planning activities should include the development of a Quality Assurance Project Plan (QAPP) that outlines the rationale and objectives for modeling in the context of the AMP. The U.S. Environmental Protection Agency (EPA) addressed environmental models as part of the quality assurance (QA) planning process under Order 5360.1 A2, "Policy and Program Requirements for the Mandatory Agency-wide Quality System" (EPA, 2000), requiring a QAPP for projects where simulation data are used to interpret measured data. The following elements should be included:

- Project management and administration,
- Measurement and data acquisition,

- Assessment and oversight, and
- Data validation and model usability.

The QAPP should outline the project management structure, document the type and quality of data needed to employ an effective modeling approach, establish model setup and calibration methods consistent with the established objectives and project-specific requirements, and ensure that managers and planners make sound and defensible scientific decisions based on modeling results. Further information can be found in EPA (2002). The department also has QAPP templates upon request. Higher planning standards are required for projects that involve multiple point or nonpoint source complexities recognizing that QA activities should be adapted to meet the rigor needed for the project at hand. At a minimum, modeling objectives for the AMP QAPP should incorporate the value of the resource(s) considered, project management details, data needs and monitoring requirements, accuracy required from model output. It is important to recognize in some cases, objectives will best be met by using a combination of models.

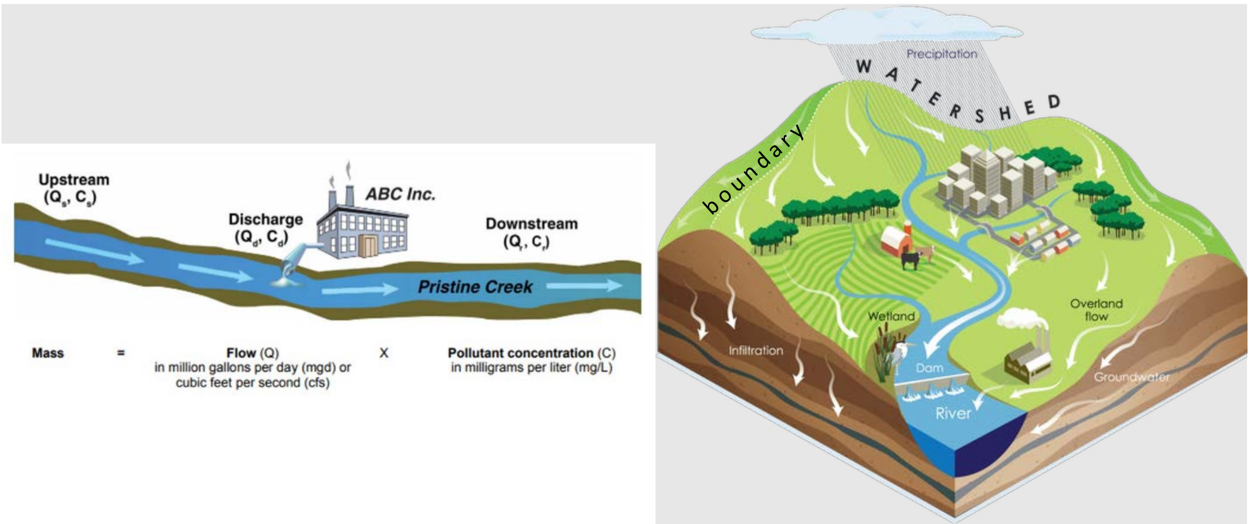
3.6.1.2 Model Extent/Domain

Nutrient AMP modeling will require specification of an appropriate modeling extent or domain. This will depend on site-specific circumstances and hinge on the AMP regulatory question being considered. Only generalized guidance can be offered here, but two generic model domains and types of modeling approaches are envisioned, with flexibility for unique situations. These are as follows:

1. Case 1: Receiving-Water Model. If modeling is solely conducted to demonstrate compliance with the narrative nutrient standards, and one or more MPDES permits are present on the same river segment, and only if point source nutrient management is being considered in the AMP, the model domain can be constrained to MPDES discharge location and downstream extent for a single permit, or alternatively the collective river extent for multiple discharges, in both instances continuing the modeling downstream to the most distal point of waterbody impact.
2. Case 2: Watershed Model/Receiving-Water Model. If both point and non-point source management is being considered as part of the AMP, as would be done in watershed-based nutrient management or nutrient trading, and knowledge of upstream sources and their fate and transport through the watershed are required, the model domain must include the entire contributing watershed of interest, incorporating watershed-loading models, and possibly a linked receiving-water model.

A hypothetical illustration of Case 1 for a single MPDES permit is shown in **Figure 3-2a,** where facility ABC Inc. discharges into a free-flowing river called Pristine Creek (modified from EPA, 2010). In this instance, downstream concentrations are predicted as a function of the upstream load or concentration, noting the model only includes the upstream boundary of the environmental domain of interest (flow and nutrient concentration), the MPDES facility contributions of those same constituents, and computes downstream conditions far enough to observe the most limiting biological response. A similar circumstance is envisioned for multiple MPDES permits on the same river, but over a continuous modeling reach, incorporating multiple permits, with consideration of Montana's use-class boundaries, locations of principal tributaries or irrigation exchanges, groundwater inputs, and other important waterbody features or processes.

For Case 2, it is recognized that near-field sources or management actions closer to an area of interest have a greater influence on localized water quality than far-field sources or management actions because nutrients are not conservative and are subject to transformations such as nutrient spiraling as well as temporary incorporation into fixed and floating algal assemblages along the waterway. Additionally, loading sources are often spatially distributed. Therefore, if permitting or trading were to be done over large spatial scales for AMP nutrient management with multiple source types, the entire watershed will likely have to be evaluated for collective watershed management purposes since nutrient loads could originate from an upstream community or agricultural area (**Figure 3-2b**), or anywhere in between. In this case, watershed-loading and possibly receiving-water models will possibly be needed for AMP nutrient planning over large and complex watershed scales.



(a) **(b)**

Figure 3-2. Example Model Domains for Nutrient AMP Management. (a) Case 1. A single MPDES discharge permit on a segment of a river in a watershed where conditions immediately upstream and then downstream past the point of impact are modeled. (b) Case 2. A watershed-based nutrient AMP domain that must include the hydrologic (watershed) boundary, contributing tributaries, and multiple point and non-point sources.

It important to recognize that the situations above are idealized. Some blending of approaches may be needed. For example, it is unreasonable to expect AMP watershed-loading models to be developed for an entire river basin if only a few distal sources exist upstream and contribute minimally to water quality at a particular location. As such, the model extent or domain should be truncated in these cases and consider only proximal sources to the AMP reach. Lakes and reservoirs may also serve as appropriate breakpoints, depending on nutrient management objectives. For the sake of simplicity, if a particular far-field nutrient source (point or nonpoint) contributes <5% to the overall load of a limiting nutrient at a downstream location when not accounting for instream transport/uptake, its influence is likely minimal and the Case 1 approach would be most relevant.

Moreover, due to the imperfect nature of the approach, and for practicality's sake, preliminary guidance for AMP model domains and breakpoints for Montana's large rivers are provided in **Table 3-2**. Again, the most important considerations are that (1) the upstream study limit is well-understood and extends at least as far upstream as the most upstream permitted discharge in the reach (unless demonstrated that it is not an important contributor) and (2) downstream evaluations should extent far enough so that management actions based on model results do not lead to degradation of downstream waters.

Table 3-2. Large River Segments of Montana and Recommended Modeling Approaches and Domains

River Name	Segment Description	Recommended Model Approach and Domain [a, b]
Bighorn River	Yellowtail Dam to mouth	No model needed
Clark Fork River	Bitterroot River to State-line	Linked watershed-loading and receiving-water model accounting for point and non-point sources for the entire Clark Fork watershed
Flathead River	Origin to mouth	Linked watershed-loading and receiving-water model(s) that account for point and non-point sources upstream to the Glacier National Park Boundary on the NF and MF of the Flathead River and Hungry Horse Dam on the SF
Kootenai River	Libby Dam to state-line	Simple receiving-water model from dam to state-line, recognizing phosphorus additions are being made in this section of the river
Madison River	Ennis Lake to mouth	Include in Missouri River approach
Missouri River	Origin to state-line	Linked watershed-loading and receiving-water model(s) that account for point and non-point sources for the entire Missouri River watershed to Canyon Ferry Reservoir. Downstream from Canyon Ferry Reservoir, the downstream impoundments and river segments should be considered on a case-by-case basis
SF Flathead River	Hungry Horse Dam to mouth	Use Flathead River approach
Yellowstone River	State-line to state-line	Linked watershed-loading and receiving-water model(s) that account for point and non-point sources from Yellowstone National Park Boundary to the state-line, with the possibility to only focus on the lower river downstream of the Stillwater River (e.g., accounting for Clarks Fork and Laurel-Billings urban complex).

[a] AMP model planning consultations should be made with the department early on in a project to select an approach and level of effort that is consistent with watershed complexity and project requirements. Any AMP approach or domain requires final approval by the department, recognizing that model domains can transcend local, state, and national political boundaries (e.g., multi-jurisdictional watersheds).

[b] Some planning tools may already exist that were developed as part of the Total Maximum Daily Load (TMDL) program.

Finally, modeling domains should be of a manageable size to allow for integration and coordination of water quality program data collection activities withing the permitting process, should consider stakeholder involvement or established watershed working groups, and consider funding capabilities and/or requirements.

3.6.1.3 Model Indicator/Endpoint Selection

AMP nutrient modeling applications require *a priori* specification of endpoints affected by nutrients that represent attainment of beneficial uses. These have been defined in **Circular DEQ-15** for large rivers to include: (1) dissolved oxygen concentrations, (2) pH, (3) chlorophyll *a* (as bottom-attached [benthic] biomass), (4) turbidity (as a function of increased phytoplankton biomass), and (5) total dissolved gas. Endpoints must be identified to determine compliance with the narrative nutrient standards prior to the model selection process, to ensure the model includes the correct state-variables representing those responses. Indicators should be framed so that (1) odors, colors, or nuisance conditions, (2) materials that are toxic or harmful to human, animal, plant, or aquatic life; and (3) undesirable aquatic life can all be appropriately represented in the model. To the extent that AMP nutrient concentration and load goals are evaluated, models subsequently provide a site-specific translator relating nutrient inputs to quantitative waterbody responses (Bierman et al., 2013). Endpoints to be used in AMP nutrient modeling should be specified in the modeling QAPP.

3.6.2 Model Selection/Development

Model selection is dependent on AMP project requirements in conjunction with the indicators or endpoints discussed previously. The department advocates using the model selection toolbox (MST) from Bierman et al. (2013) as an initial reference for model selection as it has extensive guidance on types of models available, model selection, and application procedures for nutrient management modeling. It also provides a useful tool in developing a candidate list of models depending on the problem specification and project objectives. Because of this, we only briefly address model selection in this guidance document. Important considerations in the model selection process may include:

- Developing an appropriate conceptual model regarding system processes relative to the problem of interest (regarding conceptual models, see Section 3.1 in **Circular DEQ-15** and **Section 3.7** in this document). This should include determining potential stressors and key state variables that represent the linkage between the stressor and beneficial use indicators/endpoints.
- Determining the appropriate model complexity with respect to spatial, temporal, and processes of interest. This includes choosing appropriate spatial context (0-, 1-, 2-, or 3-dimensional), grid resolution, temporal characteristics (steady-state *vs*. dynamic model), state-variables (i.e., nutrient forms as causal variables and associated response variables), and sediment interactions, growth kinetics, and source/sink terms.

Off-the-shelf public domain models have the following advantages:

- Comprehensive documentation including a user's manual, conceptual representation of the model process, explanation of theory and numerical procedures, data needs, data input format, and description of model output.
- Technical support in the form of training, use-support, and continual development from federal or academic research organizations.
- A proven track record providing validity and defensibility when faced with legal challenges.
- They are readily available to the public (non-proprietary).

An abbreviated list of process-based models that could potentially be used in nutrient AMP planning are shown in **Table 3-3**. The list is not comprehensive, nor well explained, and the reader should consult Shoemaker et al. (2005), Borah et al. (2006), and Bierman et al. (2013) for a complete compendium of modeling tools, including details about selection and application procedures. EPA (1999) also provides useful guidance in terms of selecting potential model endpoints and model selection.

It is important to point out that pre-existing tools have been developed by the department and others, and these may be useful for nutrient evaluations at the large-watershed scale. For example, the USGS SPARROW (SPAtially Referenced Regressions On Watershed attributes) model provides nutrient load estimates across the conterminous U.S. (Wise, 2019; Robertson and Saad, 2019) under long-term average hydrologic conditions over the period 1999 through 2014, with point source inputs that occurred in 2012. Contributions of municipal wastewater treatment discharge, farm fertilizer, nitrogen fixing crops, urban lands, manure, and atmospheric deposition are estimated at the 8-digit hydrologic unit code (HUC) scale.

Additionally, the implementation of the Hydrologic and Water Quality System (HAWKS, 2020) provides similar functionality in modeling nutrients at the 8-digit HUC level, providing daily, monthly, and annual estimates of water quality across large geographic areas. HAWKS currently is supported by the EPA Office of Water and the Texas A&M University Spatial Sciences Laboratory. None of the above tools (short of those developed by the department) have been verified for Montana's agricultural practices or with site-specific data.

Table 3-3. List of Watershed-loading and Receiving-water Models Useful for Nutrient AMPs

Watershed-Loading Models	Receiving-Water Models
Generalized Watershed Loading Functions (GWLF)	AQUATOX
Hydrologic Simulation Program Fortran (HSPF)	BATHTUB
Loading Simulation Program in C++ (LSPC)	CE-QUAL-RIV1
Pollutant Load–Bank Erosion Hazard Index (PLOAD-BEHI)*	CE-QUAL-W2
Spreadsheet Tool for Estimating Pollutant Loads (STEPL)*	Environmental Fluid Dynamics Code (EFDC)
Soil Water Assessment Tool (SWAT)	Stream Water Quality Model (QUAL2K)
Stormwater Management Model (SWMM)	Water Quality Analysis Simulation Program (WASP)

*Simple method; requires department review and approval.

3.6.3 Data Collection

To accurately calibrate or confirm water-quality models for AMP planning, it is necessary to measure factors that either directly or indirectly influence water quality processes in the river, or that are used in the calibration process. These include forcing functions such as meteorology and hydrology, boundary conditions (i.e., tributary or point source inputs), state-variables for calibration, and rate data (if possible), which are described in subsequent sections. Direct measurement of key parameters will increase the confidence in the model predictions and reduce the uncertainty in calibrated model parameters and coefficients (Barnwell et al., 2004).

3.6.3.1 Data Requirements for AMP Modeling

AMP modeling will typically require a preliminary evaluation of existing data (data compilation) prior to data collection to identify the extent and availability of information to support model development. In most circumstances, complete data will not be available to support AMP modeling; however, in some cases sufficient data may be identified. Even with a considerable number of models available to choose from, many of the basic data requirements will be similar. Input requirements coarsely fall into three general categories: (1) model geometry, (2) forcing functions/boundary conditions, and (3) calibration requirements. These each are described below.

Model Geometry includes the model grid or network representing how the system is subdivided spatially into segments for which water quality predictions will be made. At the heart of the geometry is the computational unit of the model (i.e., elements or cells) over which water and pollutant mass balances are developed. As part of AMP planning, the model network must be defined so that water quality gradients are appropriately described, model stability requirements are met (e.g., Courant condition), and the location of important boundary conditions are adequately delineated. Once the geometry is established, forcing function and boundary condition information must be specified using available data to describe energy, water, and pollutant fluxes into or out of the system.
Forcing Functions quantify major inputs of energy, water, and pollutants into, out of, or along the model boundaries. Types of forcing functions for water-quality models include meteorological data (e.g., solar radiation, air temperature, humidity, wind speed, and atmospheric loadings), hydrologic or hydrodynamic (flow) information, and tributary or point source loadings. Everything outside of, and

crossing, a boundary in a receiving-water model, is treated as an external forcing, meaning the user must know how those boundaries change over time, including changes or variation in flow or loading contributions. As an example, watershed models are driven solely by meteorological data whereas boundaries for lake or river receiving water models would consist of the inflows or upstream and downstream boundary conditions, air-water/water-sediment interfaces, and any tributary or point source inflows. In branched river systems, it may be necessary to decide whether to explicitly model a tributary or consider it as a point input (Bierman et al., 2013).

Calibration Data reflect the real-world data necessary to constrain model coefficients or kinetics to ensure the model reasonably reflects actual watershed or waterbody processes. Data for calibration take the form of observations within the river or system being modeled and will include measured flow and water quality constituents (with an emphasis on nutrients), diurnal state-variable observations that are representative of system biological or chemical responses, and any other observation required to constrain the model. Calibration data are ideally collected in a condition similar to that envisioned for the problem being evaluated and ideally cover multiple spatial locations of importance, as well as temporal conditions of significance.

Dilks et al. (2019) describe procedures for nutrient water-quality model data collection. They consider the following steps, which should be adopted for AMP planning:

- Compiling existing physical description, hydrologic information, climate, external loads, ambient data, and process measurement data.
- Developing and applying a scoping/strawman[3] model as a simple framework that accounts for important spatial and temporal processes.
- Defining sampling parameters, locations, and frequency for the system of interest based on the scoping model evaluation.

Beyond this guidance, monitoring recommendations for larger, deeper rivers and lakes and impoundments are shown in **Table 3-4**. The reader is referred to Dilks et al. (2019) for complete information, noting any data collection efforts should define appropriate spatial sampling locations, monitoring frequency, constituents, and number of monitoring events. Outside of this generalized guidance, it is difficult to specify minimum data requirements given the range and breadth of models considered for AMP planning. The reader is encouraged to consult a model-specific user manual for any model being considered. Generally, a higher level of effort will be required for dynamic models or those that compute mass transport in multiple dimensions beyond steady-state or zero or one-dimensional models. This is because considerably more data is required to calibrate a dynamic water quality model over a range of different flow and water quality loading conditions than a steady state model that represents only the critical waterbody condition.

[3] It is noted that for AMP planning, it is recommended, but not required to develop a scoping model. However, this may be a useful preliminary step to understand data gaps and areas of model sensitivity.

Table 3-4. Nutrient Model Monitoring Guidance by Waterbody Type (from Dilks et al. 2019)

Waterbody Type		Spatial Coverage [a]	Temporal Frequency & Extent	Constituents [b]	Number of Events [c]
Large rivers	Forcing Functions	• Upstream boundary or boundaries for branched systems (flow, chemistry, sonde data) • Each tributary/point source that will change instream concentration by more than 5% • Samples above/below mixing zone of major inputs	• Sufficient frequency to capture variability in forcing functions • Sufficient temporal extent to capture nutrient loads important to condition being modeled • If no watershed model available, wet weather events possibly should be considered	• All nutrient forms and organic carbon in model • Flow • All water quality state variables considered in model that are appropriate to beneficial uses	• Continuous meteorology over modeled period • Boundary conditions as required for specific model approach
	Calibration Data	• Sufficient resolution to capture >10% change in water quality • < 0.5 days travel time apart • Resource areas of concern	• Sufficient frequency to capture variability in forcing functions and nutrient loads important to condition being modeled • Continuous sonde data (DO, pH, etc.)	• All state variables considered by model	• Minimum two years (one near critical preferably)
Lakes or impoundments	Forcing Functions	• At any input that will change in-lake concentration >1% in water quality (flow, chemistry, sonde data) • < 0.5 days travel time apart • Resource areas of concern	• Sufficient frequency to capture variability in forcing functions • Sufficient temporal extent to capture nutrient loads important to condition being modeled • Continuous sonde data (DO, pH, etc.)	• All nutrient forms and organic carbon in model • Flow • All water quality state variables considered in model that are appropriate to beneficial uses	• Continuous meteorology over modeled period • Boundary conditions as required for specific model approach
	Calibration Data	• Sufficient resolution to capture >10% change in water quality • Resource areas of concern	• Sufficient frequency to capture variability in forcing functions and nutrient loads important to condition being modeled • Continuous sonde data (DO, pH, etc.)	• All state variables considered by model • Elevations	• Minimum two years (one near critical preferably)

[a] Model segmentation and boundaries should be discrete enough to capture the water balance, major hydrogeometric features (i.e., changes in flow or geometry), water quality processes, spatial water-quality gradients, areas of water quality concern, characteristics of control structures (e.g., dams, weirs, etc.), and locations of both point and major nonpoint sources.

[b] Nutrient data should include inorganic, organic, and dissolved forms. The same holds true with other water-quality data that influence dissolved oxygen, total carbon, or other response variables related to beneficial uses.

[c] Forcing functions (meteorological data) and deployed instrument data should be collected at high frequency, such as hourly or less to aid in understanding diurnal cycling and for calibration and confirmation of the model.

3.6.3.2 Data Quality

Data of known and documented quality are essential for implementing a successful modeling project. The department recommends that Data Quality Objectives (DQOs) be developed for all AMP modeling projects as part of the planning process to specify the acceptance criteria for model input, calibration, or confirmation. DQOs identify the (1) type and quality of data that will be appropriate for use in modeling, (2) spatial and temporal input data coverage requirements, (3) data quality and currency, and (4) technical soundness of the collection methodology. A bullet list of requirements are shown below:

- All input and calibration data for modeling will be of a known and documented quality,
- Data will be collected from as many sources as are available/practicable, and provide the maximum temporal and spatial coverage for the type of model being used,
- The data will be comparable with respect to previous and future studies, and
- Data will be representative of the parameters being measured with respect to time and space, and the conditions from which the data are obtained.

DQOs can be further refined to define performance criteria that limit the probability of making decision-based errors. They should address the data validity and reliability of the modeling effort and can be described in the context of completeness, representativeness, and comparability. In each AMP effort, the final decision about quality planning will be made in consultation with the department. The higher the risk to the resource value or areal extent, the more comprehensive modeling rigor is required.

3.6.4 Model Calibration

Model calibration is the procedures whereby model parameters are adjusted iteratively to provide a better fit between predicted values and observations. Ideally, calibration is an iterative process where deficiencies in the initial parameterization are reviewed and constrained by refining the calibration through the adjustment of uncertain parameters via a feedback loop with observed data. General information related to model calibration and confirmation can be found in Thomann (1982), Donigian (1982), ASTM (1984), and Wells (2005). Once an acceptable calibration is reached, the model parameterization can then be confirmed on an independent data set to judge the extent to which the model is able to predict water quality conditions over time. Both calibration and confirmation have become increasingly important due to the need for valid and defensible nutrient management models. Water quality model calibration should consider the most important response variables and processes of interest in the AMP watershed. A complete watershed-loading model calibration involves a successive examination of the following characteristics of the watershed hydrology and water quality: (1) annual and seasonal water balance and streamflow, (2) sediment, and (3) nutrients. Simulated and observed values for reach characteristic are examined, and critical parameters are adjusted to attain acceptable levels of agreement. The refinement of calibration parameters should reflect the scientific literature and not exceed reasonability.

Receiving water models are often calibrated globally, although spatially specific kinetics are sometimes used. Calibration should focus on the water balance, temperature, hydrodynamics, and state variables of importance to nutrient management like algal biomass, dissolved oxygen, pH, or other indicators/endpoints deemed critically important in initial AMP planning. A much greater emphasis is placed on the kinetic aspects of biological or chemical processes in the waterbody of interest in a receiving-water model. Appropriate initial conditions or model “warm-up” periods should be used during modeling and decisions made during model calibration and confirmation should be sufficiently documented so that an experienced user could complete the calibration process and obtain similar modeling results.

Ideally, both high and low flow years, and the anticipated range of conditions and scenarios for which the AMP management will be evaluated should be considered in calibration. The deterministic ability to predict conditions over the entire range of observed data is important, along with documenting comparisons of simulated and observed state variables for daily, monthly, and annual values (as appropriate). Calibration should be completed in sequential order, using the most upstream point first and then moving downstream to the next point of calibration, noting important parameters or files associated within the area upstream of a calibrated point should not be changed during subsequent downstream calibration steps.

3.6.4.1 Sensitivity Analysis

Parameter sensitivity has a considerable influence on the uncertainty of the model. As such, a sensitivity analysis is recommended as part of calibration process in AMP modeling. This helps determines the effect of a change in a model input on the model outcome and is of great benefit in guiding the calibration process. Model sensitivity is typically evaluated to identify sensitive parameters that are unknown, are conversely sensitive ones that are known, in order to constrain the calibration. The sensitivity of a given model parameter should be expressed as a normalized sensitivity coefficient (NSC; Brown and Barnwell, 1987), as shown below:

$$NSC = \frac{\Delta Y / Y}{\Delta X / X} \qquad \text{(Eq-1)}$$

where ΔY = change in the output variable Y and ΔX = change in the input variable X. The results of the sensitivity analysis should be documented in final AMP model report documentation. At a minimum, a one-at-a-time sensitivity analysis should be completed with ΔX of ±25% to evaluate the sensitivity of model inputs or calibration coefficients.

3.6.4.2 Performance Metrics

Performance metrics should be used to evaluate the calibration of an AMP nutrient model. Deviations between models and observed data result from: (1) incorrect estimation of model parameters, (2) erroneous observed model input data, (3) deficiencies in model structure or forcing functions, or (4) error of numerical solution methods (Donigian and Huber, 1991). Numerous statistical tests exist for model performance evaluation and a suitable review of error statistics, correlation or model- fit efficiency coefficients, and goodness-of- fit tests is provided by Moriasi et al. (2015). At a minimum, the following performance metrics should be considered in AMP modeling:

Root Mean Squared Error (*RMSE*) is a commonly used objective function for hydrologic or water quality model calibration. It compares the difference between the observed and predicted ordinates and uses the squared differences as the measure of fit. Thus, a difference of 10 between the predicted and observed values is one hundred times worse than a difference of 1. Squaring the differences also treats both overestimates and underestimates by the model as undesirable. These are then summed and divided by the number of observations. The equation for calculation is:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(O_i - P_i)^2} \qquad \text{(Eq-2)}$$

where O_i = observed variable and P_i= predicted variable

Percent Bias (*PB*) measures the average tendency of the simulated data to be larger or smaller than observed data and expresses the value on a percentage basis. It reflects consistent or systematic deviation of results from the "true" value. Percent bias is calculated as the difference between an observed (true) and predicted value as shown below:

$$PB = \frac{\sum_{i=1}^{n}(P_i - O_i)}{\sum_{i=1}^{n} O_i} \times 100 \qquad \text{(Eq-3)}$$

Low-magnitude values indicate an accurate model simulation. Positive values indicate overestimation bias, whereas negative values indicate underestimation bias.

Nash and Sutcliffe Efficiency (*NSE*) is a dimensionless performance measure often used in watershed modeling. It provides a statistical measure of the variability between measured and predicted model values. It is calculated as below:

$$NSE = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i - \overline{O})^2} \qquad \text{(Eq-4)}$$

A *NSE* value of one indicates a perfect fit between measured and predicted values for all events. *NSE* values between zero and one suggest a positive relationship between observed and predicted values, thus allowing for the use of predicted values in lieu of observed data. A value of zero indicates that the fit is as good as using the average value of all the measured data.

Graphical comparisons of model performance can also be made through time series plots of observed and simulated variables, residual scatter plots (observed versus simulated values), or spatially oriented plots. When observed data are adequate, or uncertainty estimates are available, confidence intervals should be provided so they can be considered in the model performance evaluation. For water quality data, model performance may at times rely primarily on visual and graphical presentations because the frequency of observed data is often inadequate for computing accurate statistical measures.

3.6.4.3 Acceptance Criteria for AMP Models

Acceptance criteria should be defined as part of the initial project planning and should be considered in the calibration process. Thomann (1982) and Arhonditsis and Brett (2004) provide suitable guidance for defining model acceptance criterion and general recommendations applied in this guidance are provided in **Table 3-5**. Final criteria for AMP modeling acceptance criteria will be project specific and should be discussed with the department before finalizing.

Table 3-5. Candidate Acceptance Criteria for AMP Nutrient Models

State-variable	Relative Error (±%)[a, b]	Units
Temperature	10	°C
Dissolved oxygen	15	mg/L
Nutrients	25	µg/L
Benthic Algae	35	mg/m^2
Phytoplankton	35	µg/L

[a]Arhonditsis and Brett (2004), 153 aquatic modeling studies in lakes, oceans, estuaries, and rivers.

[b]Thomann (1982), studies on 15 different waterbodies (rivers and estuaries).

Model performance evaluations should consist of comparison of model results with observed historical data, and general evaluation of model behavior. At the end of the calibration, AMP managers and project stakeholders should be able to assess the ability of the model to simulate water quality responses based on the following criteria:

- Modeling input and output validity,
- Model calibration and validation performance determination,
- Sensitivity and uncertainty analysis assessment, and
- Parameter deviation and post-simulation validation.

This will ensure that model predictions are reasonable, and that all work is consistent with the requirements of the project.

3.6.4.4 Modeling Journal

A modeling journal is recommended for calibration of nutrient AMP models to keep a log of the internal parameters that were adjusted during the calibration process. Each time that changes are made to the model, or a model calibration run is completed, adjustments should be documented to provide a record of the modeling process. The level of detail in the model calibration journal should be sufficient that another modeler could duplicate the calibration given the same data and model. The modeling journal should include complete recordkeeping of each step of the modeling process. Documentation should consist of the following information:

- Model assumptions.
- Parameter values and sources.
- Input file notations.
- Output file notations and model runs.
- Calibration and validation procedures and results from the model.
- Intermediate results from iterative calibration runs.
- Changes and verification of changes made in code.

These files should be retained over the long term for post-auditing or project reuse. The credibility of a modeling approach hinges on the ability to provide this information.

3.6.5 Model Confirmation

Following calibration, the AMP model should be confirmed using an independent data set to ensure that it is sufficiently credible for decision making. The purpose of model confirmation is to assure that the calibrated model properly assesses the range of variables and conditions expected within the simulation. Although there are several approaches to confirming a model, perhaps the most effective is to use only a portion of the available observations for calibration. The remaining portion of the dataset is then used for confirmation. Once final calibration parameters are developed, a simulation is performed, and the same performance metrics used in the calibration are reassessed for the confirmation data. This type of split-sample approach should be used when possible. However, it is important to recognize that confirmation is, in reality, an extension of the calibration process (Reckow, 2003; Wells, 2005). In this regard, if the confirmation is not initially successful, the AMP should not be abandoned. Rather the remaining data should be used for recalibration of the model and then the utility of the model should be evaluated in consultation with the department for decision-making purposes.

3.6.6 Uncertainty Analysis

Research has shown that uncertainty analysis should be completed to examine how the lack of knowledge in model parameters, variables, and processes propagates through the model structure as model output or forecast error. Uncertainty stems from our limited ability accurately describe complex processes. As such, an uncertainty analysis should be considered for AMP modeling. Potential sources of model uncertainty include:

- Estimated model parameter values.
- Observed model input data.
- Model structure and forcing functions.
- Numerical solution algorithms.

It is recommended, although not required, that AMP modeling projects include an uncertainty analysis. This decision should be made jointly with the department during project planning.

3.6.7 Decision Support and Simulating AMP Objectives

Objectives envisioned for AMP nutrient management modeling include: (1) assessing support of beneficial uses and water quality impacts in the modeled watershed and (2) using the model(s) to simulate potential changes in phosphorus and/or nitrogen management to best manage water quality through BMPs, permitting, and nutrient trading. General guidance for completing these decision support activities is provided below for flowing waters and lentic waterbodies, each which necessitate different approaches.

To assess whether narrative nutrient standards are being achieved in large rivers (i.e., if beneficial uses are being supported), the models developed using the approach described in this guidance document should be used to simulate water quality during critical low flow conditions. For nutrients, this corresponds to the summer growing season when algal growth is at its peak and water quality impacts are maximal. Selection of a critical condition should consider a low-flow duration and frequency corresponding to the 14Q5 (14-day 5-year) in the receiving water for steady-state models (representing the time it takes to grow nuisance algal biomass, with an excursion frequency that allows for the waterbody to recover from impacts) along with critical meteorological and boundary conditions expected during the same time. For dynamic models[4], selection of a year corresponding to a critical flow condition hydrograph is required. Both are envisioned to be done under maximum MPDES permit load limits for any facility in the modeled reach, or perhaps under current load limits.

Predefined water-quality indicators/endpoints are then assessed through the model output to ascertain whether narrative nutrient standards are being achieved. This would include examining algal biomass, dissolved oxygen, pH, and other model response endpoints that reflect beneficial use support as defined in Montana's water quality standards (e.g., ARM 17.30.627(1)(e); ARM 17.30.623(2)(c)), the AMP, and the modeling QAPP) over the entire spatial domain of the AMP planning area. When appropriate, diurnal indicators should be evaluated at the same time (e.g., DO minima, pH maxima), with the most limiting indicator being used as the decision-point of whether the waterbody is compliant with the narrative nutrient standards. In essence, the model is used as a translator between the nutrient stressor and waterbody response to determine beneficial use attainment under critical conditions.

In lakes or impoundments, a slightly different approach is required as the response during critical conditions (again during summer growing season when the lake is stratified and surface temperatures are warm), is contingent mainly on the nutrient loading during spring runoff rather than summer months. In this case, AMP modeling will need to account for loadings over the entire year, necessitating watershed-loading and time-variable receiving-water modeling. Critical loads could be developed with the watershed model to simulate loadings to the lake from all tributary sources and groundwater during a high flow year, in conjunction with loadings at maximum MPDES permit limit levels over the simulation period. The lake/reservoir receiving-water model would then be used to evaluate how the waterbody processes those loadings over the summertime period in terms of algal response, Secchi depth, harmful algal bloom (HAB) frequency or other indicators of importance.

AMP modeling of complex watersheds may require the use of linked models to simulate integrated effects of various management practices at the basin scale. One model may be necessary to predict loading to a waterbody from nonpoint sources and a second to predict fate and transport of pollutants in the waterbody. This combination of linked models may be useful for:

- Characterizing runoff quantity and quality including the temporal and spatial detail of concentrations or load ranges from non-point sources.
- Estimating load reductions needed to meet a water quality standard.
- Providing input or boundary conditions to a receiving water quality analysis, e.g., drive a receiving water quality model.
- Distinguishing between the effects of different management strategies, including the magnitude and most effective combinations of BMPs.
- Determining if management criteria can be met by a proposed strategy.

[4] Specific guidance has not been developed to determine at what condition a dynamic flow model should be used. Generally, if streamflow in the receiving water is not varying by more than 10% over the critical condition period, a steady-state model should suffice provided loadings are also not varying in time considerably.

- Performing frequency analysis on quality parameters to determine the return periods of concentrations and loads for a given site.
- Providing input to cost-benefit analyses.
- Nutrient trading.

Two scenarios are envisioned for nutrient AMP modeling: (1) simulating baseline conditions which reflect existing conditions for the waterbody and (2) one or more scenarios in which nutrient management is contemplated. By comparing simulated results between the existing modeled condition and proposed BMPs, or future growth scenarios, changes in water quality can be evaluated to guide stakeholder decisions and assist in the development of AMPs. This may include consideration of management techniques to regulate the most limiting nutrient, or BMPs that will have the greatest impact on pollutant reduction and potential for reaching desired nutrient levels to attain beneficial uses. A final factor in AMP modeling is that a margin of safety (MOS) should be considered. The MOS could be addressed through an uncertainty analysis discussed previously, or by directly specifying a value based on conservative analytical assumptions. Should protective assumptions be relied on to provide an MOS, they should be appropriately described and documented. From a regulatory perspective, the allowable pollutant load to a specific waterbody would consist of the sum of: (1) waste load allocations from point sources, (2) load allocations for nonpoint sources, and (3) the MOS sufficient to account for uncertainty and lack of knowledge (EPA, 1999).

3.6.8 Best Practices for Modeling

A summary of best practices for modeling are provided below as outlined in Donigian and Huber (1991). They are expounded upon with specificity to AMP planning.

- Have a clear statement of project objectives. Verify the need for water quality modeling. Can objectives be satisfied without water quality modeling? Define the following:
    - Will the department require a water quality model for my AMP watershed?
    - How can a model help address the questions and problems relevant to AMP decisions?
    - How can a model be used to link stressors or management actions to quantitative measures (endpoints) of waterbody condition?
    - Is modeling appropriate for examination of the stressors of concern in this situation?
- Use the simplest model that will satisfy the project objectives. Often a screening model, e.g., regression or statistical, can determine whether more complex simulation models are needed. Consider the spatial and temporal scale and resolution of the application in defining model complexity, recognizing it may be necessary to use multiple models or link models to address nutrient management problems. Because of this consideration, it is important to choose models with compatible input and output data.
- To the extent possible, utilize a quality prediction method consistent with available data. Data availability should be evaluated before beginning the model selection process.

- Only predict the quality parameters of interest and only over a suitable time scale. For AMP planning, this will primarily be the water-quality indicators/endpoint of interest. It is important to define carefully which model state-variables correspond to those indicators.
- Perform a sensitivity analysis on the selected model and familiarize yourself with the model characteristics.
- Calibrate and confirm the model results. Use one set of data for calibration and another independent set for confirm. If no such data exist for the application site, formulate data collection plans that meet modeling objectives.
- Use the linkage between model input and output to support management/decision-making for AMP decision making.

The above practices essentially reiterate the workflow described at the beginning of this guidance document, outlining a framework for systematic application of water-quality modeling for nutrient AMP support. It is important to recognize models are tools and should be used in combination with other assessment techniques, when possible, to reflect our understanding of watershed systems. It is useful to recognize the AMP modeling approach in a large way parallels the EPA NPDES watershed strategy initiative developed in the early 1990s (EPA, 1994). That framework provided a basis for management decisions using an ecosystems approach through watershed-based permitting where NPDES permits are issued to point sources on a geographic or watershed basis to enhance permitting efficiency, improve coordination among programs, and provide greater consistency and responsiveness[5]. This would enable a greater focus on watershed goals and allow consideration of multiple pollutant sources and stressors, including the level of nonpoint source control that is practicable (EPA, 2015).

3.7 Guidance Related to the Development of a Conceptual Model

Permittees intending to build a conceptual water quality model should refer to EPA's Stressor Identification Guidance Document (2000). The stressor identification process—which is at the heart of the conceptual model—consists of five basic steps: (1) define the case, (2) list candidate causes, (3) evaluate data from the case, (4) evaluate data from elsewhere, and (5) identify probably cause. Additional information pertaining to the development of a conceptual model is found in Cormier and Suter (2008) and Cormier et al. (2010).

4.0 Data Collection for Watershed Monitoring in Medium Rivers and Wadeable Streams

Section 4.0 describes guidance related to response variable data collection. Situations where other response variables and thresholds may be appropriate are addressed in **Section 4.8**.

[5] The most common watershed-based permitting approach is to re-issue NPDES permits according to a five-year rotating basin schedule. Each source receives an individual permit, and the permits are issued based on basin or watershed management areas. This process allows permittees to compare their permits with other dischargers in the same area and facilitates sharing data to arrive at the most appropriate limits.

4.1 Response Variable Data Collection Differs Across the State

Ecoregions are mapped regions of relative homogeneity in ecological systems derived from perceived patterns of a combination of causal and integrative factors including land use, land surface form, potential natural vegetation, soils, and geology. The department uses ecoregions to describe regions of relative ecological uniformity for data collection and application of stream macroinvertebrate populations, diatom algae populations, and ambient stream nutrient concentrations (Teply, 2007, 2010a, 2010b; DEQ, 2012; Suplee et al., 2008; Suplee and Watson, 2013). Ecoregions are based on the 2002 version (version 2) of the U.S. Environmental Protection Agency map, found at: https://www.epa.gov/eco-research/ecoregion-download-files-state-region-8#pane-24 .

For purposes of this guidance, two broad ecoregional zones are identified (**Figure 4-1**). Per **Figure 4-1,** the western and transitional ecoregions (green and dark gray areas) comprise a single "western" ecoregional zone, and the eastern ecoregional zone (in orange) comprises the second. Different data collection requirements apply to each of these two zones.

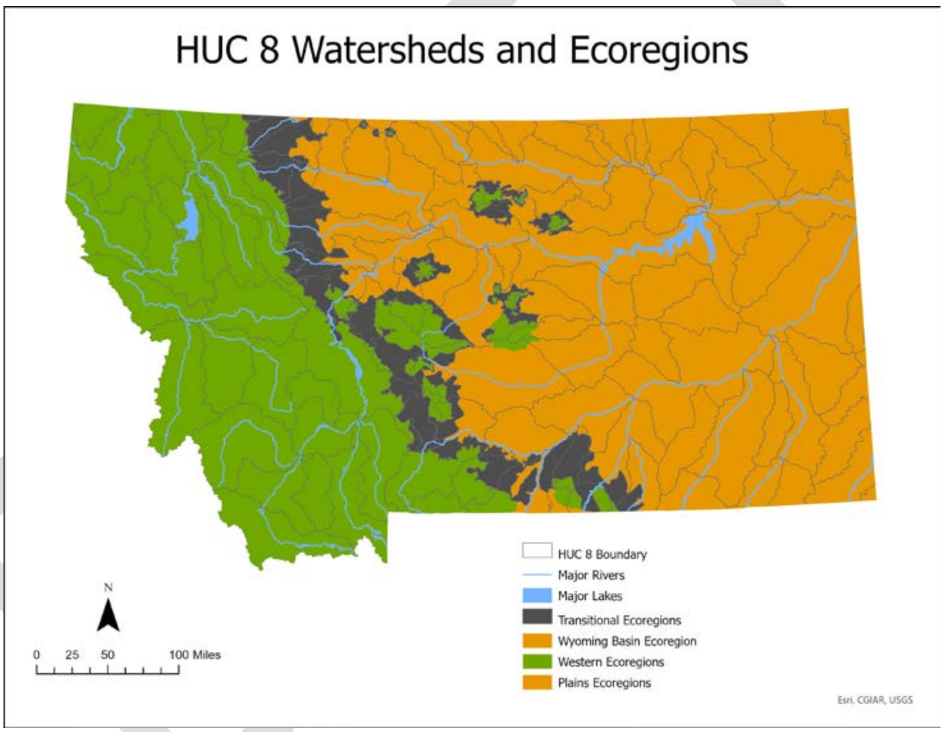


Figure 4-1. Ecoregional Zones in Montana, along with 8-digit Hydrologic Unit Codes (HUCs). The green and dark gray areas comprise the western ecoregional zone, the dark orange area the eastern ecoregional zone.

4.1.1 Identifying which Response Variables and Thresholds Best Applies in a Mixed-ecoregion AMP Watershed

Adaptive management plans are based on watersheds however data collection requirements are based on ecoregions (**Circular DEQ-15**). This can result in cases where data collection methods for both the western and the eastern ecoregional zones apply in the same watershed. In such cases, upon submittal, An AMP must describe which ecoregion zone (western or eastern) will apply to the watershed, along with a justification.

Permittees should carry out a geospatial information system (GIS) analysis and establish which ecoregional zone (eastern, western, or western transitional) covers the majority of the area in their AMP watershed. The location of the point source in the watershed in relation to the ecoregional zone boundaries in the watershed should also be closely considered. This work should then be coupled with an on-the-ground reconnaissance in the AMP watershed to ensure that the point source receiving stream generally reflects the underlaying expectation of the ecoregion. Typical regional stream patterns are:

Western Ecoregional Zone streams are those that are usually perennial and generally clear during base flow, have moderate gradient, are mostly gravel- to cobble-bottomed, comprise a pool-riffle-run series longitudinally, have limited macrophyte populations, and generally support a salmonid fish population.

Eastern Ecoregional Zone streams are those that are low-gradient and which may become intermittent during summer baseflow, often haves deep pools even when intermittent, commonly have a mud bottom, may be quite turbid, are often very sinuous, frequently have substantial macrophyte populations, often have filamentous algae but sometimes only phytoplankton algae (i.e., a green color to the stream water), and generally support warm-water fish species (e.g., green sunfish, black bullheads, silvery minnows, etc.).

Field reconnaissance can consist largely of site visits documented by a longitudinal series of stream photos. Additional data (e.g., stream substrate D_{50}, Rosgen and Silvey 1996; rapid visual assessments per the department's Aquatic Plant Visual Assessment Form in the standard operating procedure at https://deq.mt.gov/files/Water/WQPB/QAProgram/Documents/WQPBWQM-011v8.pdf) will also be helpful. These data, along with the geospatial analysis described above, will greatly aid the department's review of the submitted justification. Note in particular: does the waterbody tend to develop long algal streamers (filaments) but has only very few macrophytes? If so, the response variables for the western ecoregional zone may be the best fit. Some transitional ecoregions are known, based on reference sites, to have naturally higher benthic algae density than is typically found in the ecoregion (e.g., the Rocky Mountain Front Foothill Potholes [42q]; Suplee and Watson, 2013). In such cases, if benthic algae measurements are the most appropriate response variables for the AMP watershed, a higher benthic chlorophyll *a* (Chl*a*) threshold is probably justified.

Additional data, for example the receiving waterbody's fisheries population from Montana Fish, Wildlife, and Parks online databases, will be very helpful and the department highly recommends that they be reviewed. Please see their searchable database at https://myfwp.mt.gov/fishMT/reports/surveyreport to determine the type of fish which have been document in the stream. See **Appendix B** for a case study example of this process.

4.2 Nutrient Data Collection in an AMP Watershed

Collection of total phosphorus (TP), total nitrogen (TN), and other nutrient data (e.g., nitrate) should follow the standard operating procedure (SOP) in the document found at the following link: https://deq.mt.gov/files/Water/WQPB/QAProgram/Documents/SOP_ChemistrySampling_WQDWQPBFM-02_2019_Final.pdf

Readers should also refer to the latest version of the Water Quality Planning Bureau's sample parameter requirements list to ensure they are using the most up-to-date reporting values etc. for nutrients. This can be requested from the department (see also **Section 4.6**).

4.3 AMP WATERSHED MONITORING PLAN SAMPLE COLLECTION: ADJUSTMENTS TO THE INDEX PERIOD

The index period (aka growing season) during which AMP response variable data are to be collected is from July 1 to September 30 annually. This index period applies across the entire state (**Circular DEQ-15**). Per **Circular DEQ-15**, the index period may be modified to include earlier or later dates on a case-by-case basis, subject to department review and approval.

Index period start- and end dates were based on average regional biological and hydrograph patterns as described in Suplee et al. (2007), but individual streams may depart somewhat from the average. If a permittee believe it may be necessary to adjust the data collection index period for their receiving waterbody, the department recommends using flow from a stream gage as close to and on the same waterbody as the point source. Data should reflect conditions over the past 10 years. The data can be used to estimate what the best—on average—sampling period may be for the waterbody. For example, as can be seen from the 10-year hydrograph from the East Gallatin River in **Table 4-1**, the first two weeks of July have higher flows (about 2.5 times higher) compared to later in July, August, and September (see dark gray days in **Table 4-1**). In this case, commencing July sampling sometime after July 14 would exclude the higher flows and lead to better baseflow data collection more consistent with the bulk of the index period. (Note that for this example no departmental approval would be required to alter the initiation of sampling, as sampling would still fall within the annual index period of July 1 to September 30.) To move the sampling season earlier than July 1, the department would need to be presented with a site-specific hydrograph similar to that in **Table 4-1** but showing that stable and representative base flows are already achieved in June. Further, if the request included an extension into the first half of June, water temperature data would also need to be provided to confirm that water temperatures were not unusually low at that time (due to it being early in the season) compared to later in the index period.

Sampling might also extend into the first two weeks of October, if temperatures remain moderate and base flow conditions remain reasonably stable (Suplee and Sada de Suplee, 2016). Local flow and water temperature data, and nearby weather station data would be needed to support such a change, subject to department review and approval per **Circular DEQ-15**.

Table 4-1. Discharge (ft3/sec) for USGS gage 06048700 "East Gallatin River at Bozeman, Mont." Values shown are the average daily flows over the 2001 to 2011 period. Darker gray areas show time periods within the index period when flows are still elevated relative to the rest of the sampling index period.

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	42	47	45	118	283	433	164	52	43	40	55	47
2	44	43	44	128	267	441	155	51	42	41	55	47
3	44	42	46	124	268	453	147	53	39	42	57	47
4	41	43	48	112	297	433	142	53	37	44	56	47
5	43	44	47	121	295	418	141	51	39	48	55	47
6	43	47	46	148	328	425	130	52	42	50	53	47
7	41	44	46	139	364	479	124	51	43	51	55	46
8	46	44	52	140	379	461	118	52	41	51	62	43
9	44	42	54	149	376	440	108	54	43	52	60	43
10	42	42	56	157	380	443	102	52	50	52	56	44
11	41	42	58	155	373	513	101	49	45	52	56	46
12	42	42	70	164	373	501	97	46	41	53	56	46
13	43	42	88	182	377	465	94	45	42	52	57	45
14	44	42	88	218	404	436	90	45	42	52	56	45
15	43	41	80	232	439	420	84	47	43	55	52	45
16	42	41	80	212	442	404	81	44	42	59	55	43
17	44	41	81	229	464	390	78	44	44	61	54	42
18	46	41	86	239	484	359	75	47	45	59	53	41
19	51	42	89	235	509	335	73	46	44	59	53	43
20	48	40	88	231	528	310	68	42	44	66	52	44
21	47	41	93	254	523	299	66	41	46	63	49	45
22	44	41	94	279	505	277	66	41	47	58	47	44
23	44	41	94	324	495	264	67	45	48	56	48	46
24	44	41	90	315	500	247	62	43	49	56	46	44
25	43	41	89	290	615	237	63	41	46	57	48	45
26	43	42	95	293	540	228	64	41	43	55	50	46
27	47	43	93	270	502	209	63	39	42	55	48	44
28	46	43	95	266	475	195	61	39	42	55	47	44
29	44	41	91	274	490	183	55	41	42	57	46	46
30	45		97	295	466	175	51	41	44	57	47	44
31	43		104		444		50	43		56		43

4.4 Guidance for AMP Watersheds that Include a Lake or Reservoir

Guidance is provided below for scenarios which are likely to be encountered in AMP watersheds.

4.4.1 Permittees Discharging Directly to a Lake or Reservoir

Per **Circular DEQ-15**, permittees discharging directly to a lake or reservoir are required to determine their proportion of the total annual nutrient load (TP, TN, or possibly both) to the lentic waterbody. In northern temperate regions like Montana, the majority of nutrient loading to a lake or reservoir typically occurs during spring runoff. As such, data collection should focus on that period. A stream hydrograph gage (maintained by the United States Geological Survey [USGS] or others) on the principal tributary flowing into the lake or reservoir of concern should be reviewed to determine the period of greatest inflow. Select a gage as near to the lake/reservoir inlet as possible. Nutrient data collection (at a minimum, TP and TN) should then be undertaken in the principal inflowing waterbody (or waterbodies) to the lake/reservoir. Equal depth- and width-integrated (EWI) sampling is highly recommended, although mid-stream grab samples may be adequate. Nutrient data collection should target the rising and falling limb of the hydrograph, as well as the peak. Approximately two weeks to a month prior to the commencement of spring runoff, data collection at lower intensity (e.g., bi-weekly) should commence. With the rising limb of the hydrograph, sampling intensity should increase, to weekly if possible, until the falling limb has come down in early summer. Minimal sampling can then occur for the remainder of the year (monthly or every 6 weeks).

At the same time, the permittee will need to have records of their discharge volume and nutrient concentrations throughout this entire period. These data can then be compiled with the inflow data described above to determine the relative load contribution of the point source to the lake/reservoir.

If, as a result of the loading calculations, a permittee is required to monitor in-lake response variables like phytoplankton chlorophyll *a*, the department recommends establishing a monitoring site near mid lake. If a reservoir, consult with the department on the most appropriate location. Data should be routinely collected throughout the summer (the time period of greatest concern for algae blooms, etc.). A deployed sonde that continuously measures chlorophyll *a* is a good option if a buoy or other deployment platform can be arranged.

4.4.2 Permittees Discharging to a Flowing Waterbody which May Affect a Downstream Lake or Reservoir

Determining when a point source discharge to a flowing waterbody is affecting a downstream lake or reservoir can be complicated. The potential for an effect varies depending on distance between the lentic waterbody and the point source, the size of the discharge and the lake/reservoir, etc. The department will carry out this analysis at a statewide scale, as indicated in Circular DEQ-15, however that work may not cover all situations. Permittees should also determine if there is an existing TMDL load allocation (LA) in the watershed assigned to the lake or reservoir.

4.5 Locating the Different Types of Sites in an AMP Watershed Monitoring Plan

There may be several types of sampling/monitoring sites in an AMP watershed monitoring plan (**Figure 4-2**). The location of the downstream near field site(s) located downstream of the point source should be identified by first carrying out nutrient spiraling calculations (Mulholland et al., 2002; Ensign and Doyle, 2006; Kohler et al., 2008). **The department has a spreadsheet available called "SpiralingCalcs_DistanceEstimates_v2.xls" to provide the distance estimates.** The spreadsheet requires input of average stream water velocity and stream depth to compute a series of approximate downstream distances for emplacing the site or sites. Bear in mind that the computed distances may be a well downstream from the point source discharge and well beyond the normal mixing zone used for other pollutants. Average stream velocity can be computed from average index period base flow data and average channel cross sectional area, if such data are available from a nearby gage on the receiving waterbody. If no gage data are available, index period flow and width and depth measurements will have to made, and (in turn) cross-sectional area and water velocity computed. **Please see the example provided in the spreadsheet** starting in column J.

Once the average index period stream velocity and depth are known, the department recommends computing the minimum, maximum, median, and average downstream distance estimates using the spreadsheet. Enter your velocity (meters/sec) and depth (meters) data into cells C8 through D24 and then look at the **Summary of Computations** applicable to your facility starting in row 50 of the spreadsheet. The department recommends that reconnaissance be carried out at the locations

indicated (min, max, median, and average distance downstream from the discharge), as well as at locations in between.
Photographs should be taken and later provided to the department to support the justification for the site(s) selected; photos will allow the department to evaluate the suitability of the selected site(s). Monitoring at the near field sites is expected to remain relatively consistent in perpetuity, therefore site access now and into the future is a critical consideration. Use of public land (if possible) helps ensure access, or if private land access is necessary the landowner should be aware of the long-term nature of the data collection. If the land owner is not comfortable with this type of arrangement another site should be selected.

Far field and tributary sites should be adaptive to the needs of the AMP. For example, potential nutrient sources identified during a watershed inventory may prompt the selection of new or additional monitoring sites to quantify nutrient loads or isolate potential nutrient reduction projects. Initial characterization at tributary sites may clarify which tributaries contribute greater or lesser nutrient loads to the receiving waterbody and therefore may lead to tributary sites being added or discontinued. Additional or different monitoring sites may also be necessary to demonstrate effectiveness of nonpoint source reduction projects or to affirm compliance with narrative nutrient standards. Downstream far field sites should generally be located near the end of the AMP watershed so that nutrient loads exiting the watershed can be documented. Please see the case study in **Appendix B** for an example of locating far field and tributary sites.

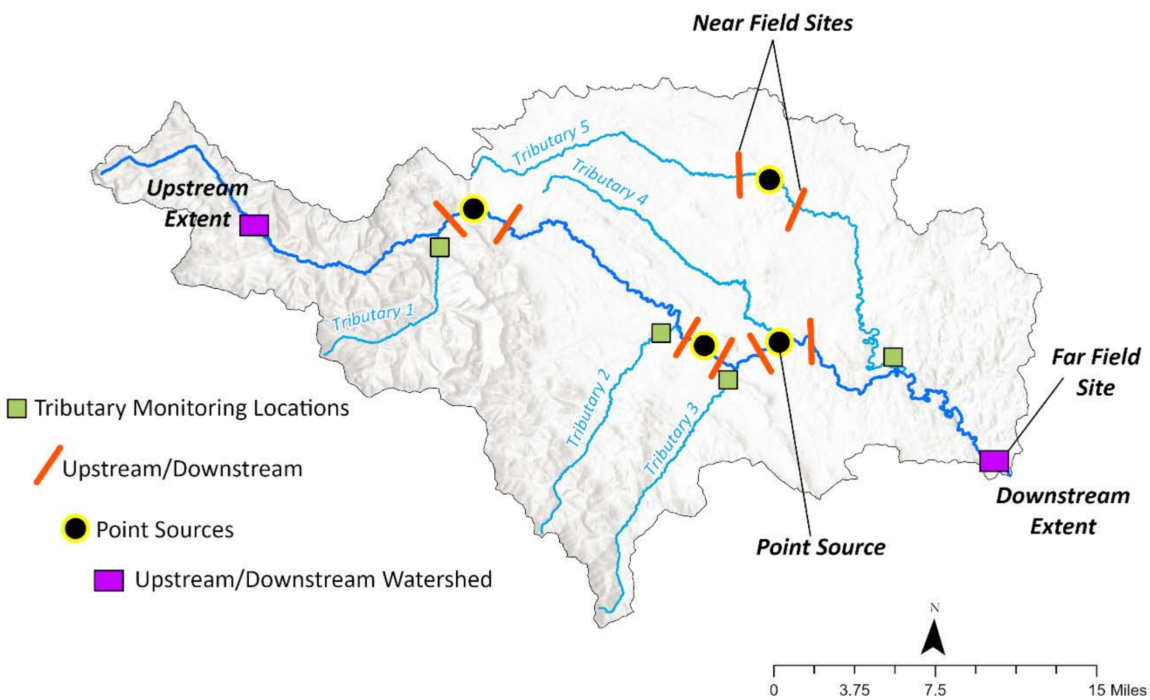


Figure 4-2. Example AMP Watershed, Showing Different Types of Monitoring Sites. This is an example of a large, complex watershed with multiple point sources.

4.6 Monitoring Data: Western and Eastern Ecoregional Zones

Table 4-2 provides links to department standard operating procedure (SOP) documents associated with the collection and evaluation of response variable data. The SOPs provide detailed instructions on all aspects of collecting data associated with each response variable and should be followed in their entirety.

The department recommends the PME MiniDOT dissolved oxygen and temperature logger for monitoring dissolved oxygen delta. Other instruments (e.g., YSI EXO2 or EXO3 sondes) are also excellent for this work, but they are larger and more expensive because they collect many more water quality variables than is necessary for this application.

In addition, the department's Water Quality Planning Bureau maintains a list of water quality sample parameters (e.g. nutrients, metals, common ions, etc.) and their associated sample bottle type, preservation, allowable holding times, analytical reporting limits, etc. This list is periodically updated as reporting limits change, etc. Users of this guidance document should contact the department to get the latest version of this list to ensure their data-collection work corresponds to the current department protocols.

Table 4-2. Hyperlinks to Department Standard Operating Procedures which Address each of the Response Variables Shown

Response Variable	Annual Index Period	Standard Operating Procedure (SOP) Hyperlink
Western Ecoregional Zone		
Benthic chlorophyll *a* (Chl*a*)	7/1 to 9/30	https://deq.mt.gov/files/Water/WQPB/QAProgram/Documents/WQPBWQM-011v8.pdf
Benthic ash free dry weight (AFDW)	7/1 to 9/30	https://deq.mt.gov/files/Water/WQPB/QAProgram/Documents/WQPBWQM-011v8.pdf
% bottom cover by filamentous algae	7/1 to 9/30	https://deq.mt.gov/files/Water/WQPB/QAProgram/Documents/WQPBWQM-011v8.pdf
Macroinvertebrates	7/1 to 9/30	https://deq.mt.gov/files/Water/WQPB/QAProgram/Documents/WQPBWQM-009_rev3_Final.pdf
Eastern Ecoregional Zone		
Dissolved Oxygen Delta (daily maximum minus daily minimum)	7/1 to 9/30	https://deq.mt.gov/files/Water/WQPB/QAProgram/Documents/SOP_SmallDataLoggers_WQDWQPBFM-07_Final.pdf
5-day Biochemical Oxygen Demand (BOD_5)	7/1 to 9/30	https://deq.mt.gov/files/Water/WQPB/QAProgram/Documents/SOP_ChemistrySampling_WQDWQPBFM-02_2019_Final.pdf
Dissolved Oxygen Concentrations (per Circular DEQ-7)	7/1 to 9/30	*Placeholder for final department dissolved oxygen assessment SOP*

4.7 Identifying Response Variables for Waterbodies that are Atypical of the Ecoregional Zone

Section 4.1.1 addressed situations where an AMP watershed contains land area from both the western and eastern ecoregional zones. Beyond these situations, however, uncommon cases may arise where a waterbody is within the main body of an ecoregional zone but does not fit the general stream characteristics outlined in **Section 4.1.1** of this document or Section 4.1 of **Circular DEQ-15**. If this is the case, it will be necessary to identify more appropriate response variables and thresholds. If the waterbody retains most of the characteristics of the ecoregional zone opposite from where it is located (i.e., the site is in the Western Ecoregional Zone but has the characteristics of the Eastern Zone streams), it may be appropriate to apply the response variables from the other zone. Response variable thresholds may need to be adjusted accordingly. A good option is to develop a conceptual model to better describe the ecological functions of the particular stream, identify its stressors, and define better-suited response variables and thresholds as needed. Please see **Section 3.7** for additional information on conceptual models.

4.8 Data Collection for Watersheds with a New Point Source

Data collection for response variables and TP and TN must be collected for at least one index period in advance of the time that the new discharge commences in order to establish baseline conditions of the receiving waterbody.

5.0 Guidance on Determining Compliance with Permit Limits for Medium Rivers and Wadeable Streams

Circular DEQ-15 contains a flowchart (Figure 5-1 in that document) to guide permittees to the appropriate compliance determination process. Additional guidance is provided here for the Exact Binomial Test Method as it is the most complex.

5.1 Response Variables and Thresholds

Response variables and thresholds from **Circular DEQ-15** are summarized in **Table 5-1** below.

Table 5-1. Summary of Response Variables, and Associated Thresholds (Where Applicable), For Medium Rivers and Wadeable Streams in the Western and Eastern Montana Ecoregional Zones

Applicable Ecoregional Zone	Parameter	Threshold	Minimum Locations where Data are Collected
Western	Benthic chlorophyll *a* (Chl*a*)	125 mg Chla/m^2	At upstream near field site(s), at downstream near field site(s)
Western	Benthic ash free dry weight (AFDW)	35 g AFDW/m^2	
Western	% Bottom cover by filamentous algae	30% bottom coverage	
Western	Macroinvertebrates	No threshold specified. Examine relative upstream/downstream change.	
Eastern	Dissolved Oxygen Delta (daily maximum minus daily minimum)	5.3 mg DO/L, computed as a weekly average	
Eastern	5-day Biochemical Oxygen Demand (BOD_5)	No threshold specified. Examine relative upstream/downstream change of Hilsenhoff Biotic Index (HBI)	

5.2. Guidance for the Exact Binomial Test Method

The department has available an Excel spreadsheet tool by which the number of allowable exceedences of a response variable threshold can be calculated for any given sample size. **The Excel file name is "MT-NonComplianceTool_test1" and it has two tabs; users only need to use the tab labelled "BTNonCompliance."** In the upper left-hand corner, ensure that cell B5 = 0.27, cell B6 = 0.1, and cell B7 = 0.25, then push the large gray square button located near cell G23. The spreadsheet will then provide the number of exceedences for each sample size, in columns D and C, that indicate that the allowable exceedance rate has been surpassed. So long as the number of exceedences is less than that indicated in column D, the allowable exceedance rate has been attained and, as described in Table 5-2 of **Circular DEQ-15**, the conclusion is "pass." (In contrast, if the number of exceedences is greater than or equal to the value in column D, the conclusion is "fail.") Evaluation should be carried out independently for each response variable dataset (e.g., in the western ecoregional zone that would be for Chl*a*, AFDW, and % bottom cover by filamentous algae).

For response variable data that do not have thresholds (e.g., the macroinvertebrate HBI metric), users should compute an arithmetic average for all the data available up to that time. For example, if four years of sampling has been completed and there are four HBI scores of 3.0, 4.5, 5.2, and 3.5, the arithmetic average would be 4.05.

The results from the Exact Binomial Test spreadsheet can then be combined with the averaged results from the non-threshold based response variables per the tables in Section 5.3 of **Circular DEQ-15**. Those tables and the conditions of the MPDES permit will inform permit compliance.

6.0 WATERSHED INFORMATION PROVIDED BY RELATIVE CHANGES UPSTREAM AND DOWNSTREAM OF A POINT SOURCE

Insights into the status of a watershed in regards to excess nutrients can be obtained by considering the combination of results from near field sites up- and downstream of a point source. Potential outcomes are shown below in **Table 6-1**. Once permit compliance determination has been completed via the MPDES permit, next-step actions for the AMP watershed monitoring plan or AMP implementation plan can be guided by the "Implications/Actions" column in **Table 6-1** below.

Table 6-1. Potential Scenarios Resulting from Monitoring of Near Field Sites Up- and Downstream of a Point Source. "Achieving" means the sites indicated are achieving the narrative nutrient standards.

Scenario	Upstream Near Field Site(s)	Downstream Near Field Site(s)	Implication/Action
A	Achieving	Achieving	Watershed is achieving the narrative nutrient standards; continue to monitor; evaluate downstream use impacts (via far field site[s]) if nutrients are elevated d/s of point source
B	Achieving	Not Achieving	Watershed is not achieving the narrative nutrient standards; nutrient reduction work should focus on point source improvements; evaluate downstream use impacts via far field site(s)
C	Not Achieving	Achieving	Watershed is not achieving the narrative nutrient standards; point source may be having a dampening effect on the response variables or water quality conditions below the point source are improved. Investigate if near field sites are sufficiently comparable, investigate if the point source discharge is dampening response variables (e.g., chlorination effect on algal growth). Evaluate downstream use impacts (via far field site[s]) if nutrients are elevated d/s of point source.
D	Not Achieving	Not Achieving	Watershed is not achieving the narrative nutrient standards; suggests that nutrient reduction work could begin upstream of point source, at point source, or both; evaluate downstream use impacts via far field site(s)

7.0 Integration of the Adaptive Management Program with the Total Maximum Daily Load Program

Circular DEQ-15 includes a flowchart which shows where in the AMP process the TMDL program interfaces. This figure is reproduced below (**Figure 7-1**).

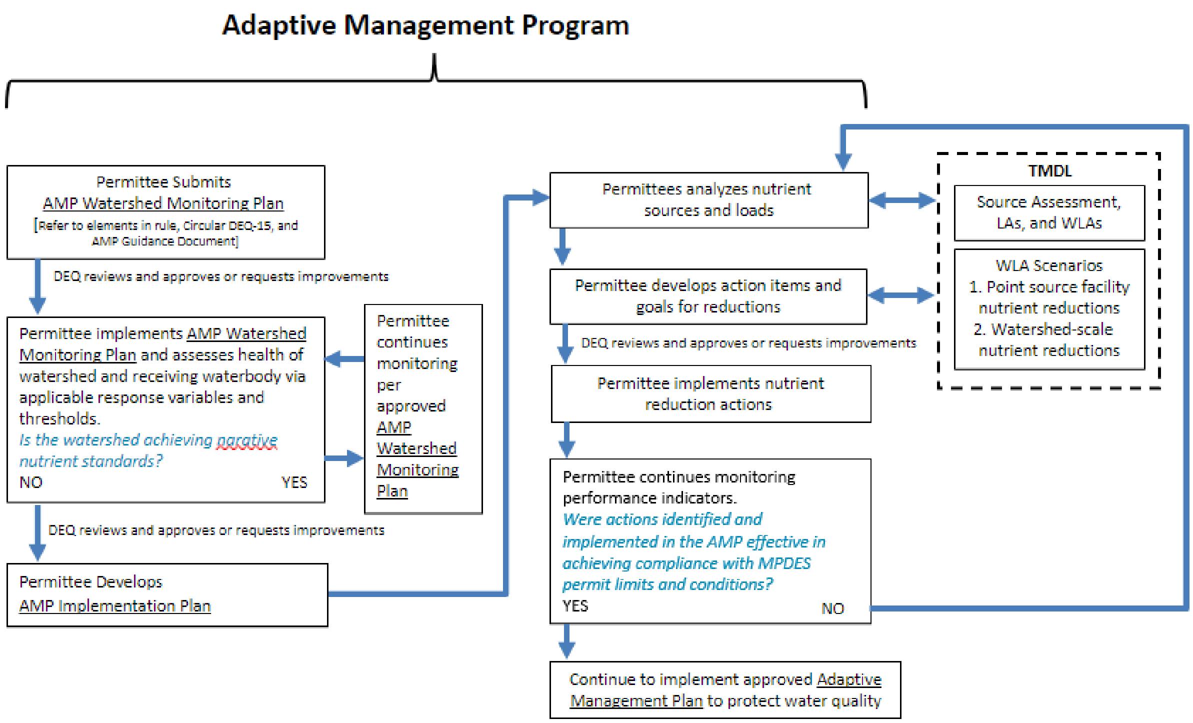


Figure 7-1. Flowchart Indicating the Point where the TMDL Process Interfaces with the Adaptive Management Program

A total maximum daily load (TMDL) is the maximum amount of a pollutant a waterbody can receive and still meet water quality standards. A TMDL calculation is the sum of the load allocations (LAs), wasteload allocations (WLAs), and an implicit or explicit margin of safety. Once the TMDL is determined, reductions are allocated to each identified significant source in order to meet the TMDL.

Point source WLAs may incorporate strategies from a DEQ-approved AMP implementation plan. This may include strategies to reduce nonpoint source load contributions of the pollutant (nitrogen or phosphorus). However, this should not be in lieu of the required WLA. The sum of the required load reductions (LA + WLA) must equal the TMDL.

8.0 Activities to be Carried out in Watersheds not Achieving the Narrative Nutrient Standards

This section provides guidance pertaining to activities to be carried out in watershed once it has been determined that the watershed is not achieving the narrative nutrient standards and an AMP implementation plan is required.

8.1 Quantification and Characterization of All Sources of Nutrient Contributions

If a watershed is determined to be negatively impacted by nutrients, existing scientific information concerning algal growth dynamics, applicable scientific data specific to the region, locally collected data from the waterbody, and features of the point source effluent(s) and the nonpoint sources may all be used to quantify and characterize the nutrient sources and loads in the watershed. Consideration should be given to the magnitude and extent of nonpoint source nutrients already in the receiving waterbody and the degree to which the point source(s) alone can reduce concentrations below algal pgrowth saturation concentrations. Saturating phosphorus concentrations in rivers and streams are low (5-30 µg/L) and considerable reduction in TP may be necessary to achieve controlling concentrations.

Phosphorus is very commonly associated with suspended sediment in flowing waters (Grayson et al., 1996; Uusitalo et al., 2000). Therefore, control actions which limit soil erosion from developed lands (e.g., row crops) can be very effective in lowering P loading to rivers and streams. Often the greatest sediment and P loading occurs during spring runoff and controlling such loads in spring may not necessarily have a large bearing on riverine algal growth during the summer index period. However, reduction of soil erosion potential can be equally effective during summer rain events, and thus aide in reducing P loading at that critical time. Not all phosphorus associated with suspended sediment is necessarily bioavailable, however analytical methods are available to distinguish bioavailable from non-bioavailable P if necessary (Suplee, 2021).

8.1.1 Identifying when Nitrogen Will be the Target Nutrient

Per 75-5-321, MCA, priority is given to the minimization of phosphorus in a watershed; however, site-specific conditions must be accounted for. Circumstances may occur where nitrogen is the primary limiting nutrient. In such cases, nitrogen limitation may need to be given priority and/or in addition to phosphorus limitation.

Nutrient diffusing substrates provide a mechanism to determine if phosphorus, nitrogen, or both control algae growth and primary productivity in a river or stream. Nutrient diffusing substrates can be deployed in flowing waterbodies for the purpose of determining the limiting nutrient(s). Users of this guidance document should refer to the department’s SOP for making, deploying, and analyzing nutrient diffusing substrates, found at:

PUT WEB HYPERLINK HERE WHEN DOCUMENT IS AVAILABLE

Some examples of results from nutrient diffusing substrates deployed in Montana rivers and streams are shown below (**Figure 8-1**). If results from such a study were to show that the +N and +NP treatments had similar Chl*a* magnitudes and were significantly higher in Chl*a* than the Control and +P treatments, this would constitute a demonstration of N limitation. Bear in mind that nutrient limitation can vary spatially and temporally and therefore the goals of the AMP implementation plan should be carefully considered when selecting sites for deploying nutrient diffusers.

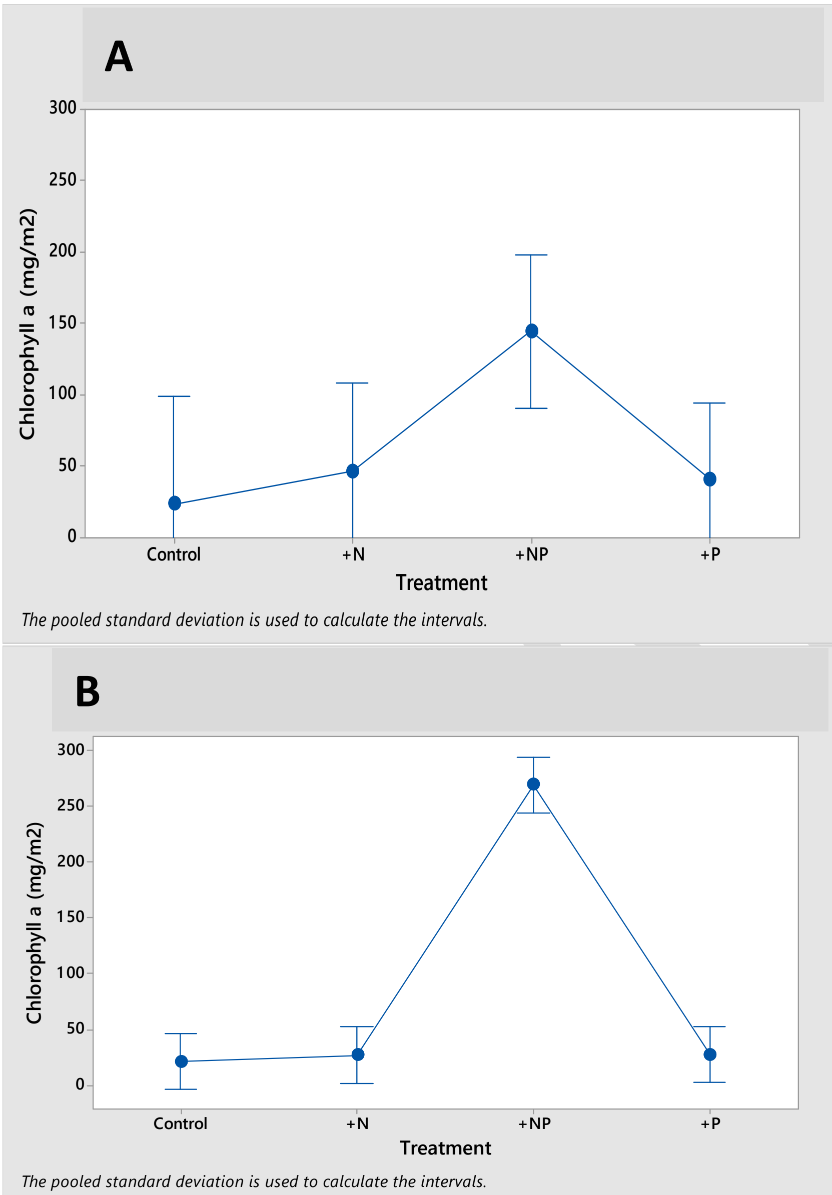


Figure 8-1. Examples of Different Nutrient Diffusing Substrate Results (n = 4 Replicates per Treatment; "Control" Means no Nutrients were Added to the Diffusing Replicates). A. A scenario in which no clear indication of nutrient limitation is indicated in the waterbody. B. An example where strong N- and P- co-limitation is indicated.

The ratio of TN to TP (i.e., the Redfield Ratio; Redfield [1958]) may also be used to inform the analysis of the limiting nutrient in the watershed. The Redfield Ratio is 7.2:1 by mass. Water TN:TP ratios are to be used in conjunction with (not as an exclusive alternative to) nutrient diffusing substrates (**Circular DEQ-**

15). In general, studies of benthic algae show that it is necessary to move some distance above or below the Redfield ratio in order to be strongly convinced that a lotic waterbody is P or N limited (Dodds, 2003). When a benthic algal Redfield ratio (by mass) is 10, P limitation is indicated (Hillebrand and Sommer, 1999). Thus, there is a range of N:P values between about 6 and 10 where one can state, for practical purposes, that algal growth is co-limited by N and P.

8.2 Identifying All Partners that will Assist in Implementing Nutrient Reductions

Facilities that discharge nutrients should identify partners to work with to target point and nonpoint sources of nutrients which minimizes their overall fiscal outlays while working to achieving compliance with the narrative nutrient standards.

Permittees should consult with the department on whether an established stakeholder group exists for the watershed and obtain assistance identifying stakeholders. Specifically, the department may have created a TMDL watershed advisory group if TMDLs have been completed, or are under development, for the watershed, per 75-5-704, MCA.

Individuals and organizations from which to solicit participation may include, if applicable:

- Landowners
- Local irrigation districts
- Conservation or environmental organizations
- Watershed groups
- Water quality districts
- Municipalities
- Counties (planning department, sanitarian/environmental health)
- USDA Natural Resources Conservation Service (district conservationist)
- Federal land management agencies (U.S. Forest Service, Bureau of Land Management, U.S. Fish and Wildlife Service wildlife refuges, etc.)
- State land management agencies (MT Department of Natural Resources and Conservation; MT Fish, Wildlife & Parks)
- Timber companies
- Hydroelectric industry
- Other point source dischargers of nutrients in the watershed
- Tribal nations

8.3 Developing Action Items for the Reduction of Nutrients in the Watershed

If the watershed is not achieving narrative nutrient standards, permittees will develop an AMP implementation plan. Within the implementation plan, permittees will develop action items and goals to achieve nutrient reductions. The permittee may choose to improve their individual facility, through optimization or capital improvements, and/or proceed with a watershed scale approach, including controlling phosphorus or offsetting point and nonpoint sources in order to meet necessary nutrient reductions to achieve compliance.

8.3.1 Implementing Facility Improvements

A permittee may achieve nutrient reductions through conventional capital improvements or through Montana's optimization program. Montana offers technical support and training to municipal wastewater treatment plant operators to achieve nutrient reductions through operational optimization.

8.3.2 Implementing Nonpoint Source Projects

A permittee may achieve nutrient reductions in the watershed through nonpoint source project implementation. The TMDL WLA requires reasonable assurance that the load reduction expected will be achieved. All significant pollutant sources, including natural background, permitted point sources, and nonpoint sources, need to be quantified at the watershed scale so that the relative pollutant contributions and reductions can be determined. Because the effects of pollutants on water quality can vary throughout the year, assessing pollutant sources must include an evaluation of the seasonal variability of the pollutant loading. This loading and reduction analysis will be done using a department approved watershed-loading model (**GD 3.4.1**).

Once necessary reductions have been calculated and allocated to sources, the permittee needs to select nonpoint source projects that will reduce nutrients to a level that will meet the narrative standard in the waterbody and demonstrate reasonable assurance by having secured funding and landowner/partner agreements to implement nonpoint source projects either individually, or in conjunction with other permittees and nonpoint sources, or other partners, including municipal and county governments, in the watershed must be included in the plan. Plans should include any contracts/landowner agreements reflecting commitments by partners to implement applicable actions.

8.3.3 Nutrient Trading

A permittee may achieve nutrient reductions through nutrient trading. Trading is a market-based approach to achieving water quality standards in which a point source purchases pollutant reduction credits from another point source or a nonpoint source in the applicable trading region that are then used to meet the source's pollutant discharge obligations. **Circular DEQ-13**, Montana's Policy for Nutrient Trading, should be followed if trading is pursued, which states all trades that involve point source discharges will be monitored and enforced under a MPDES permit.

8.4. Demonstrate the Ability to Fund and Implement the AMP Implementation Plan

8.5 Continued Data Collection for Response Variables as Performance Indicators

Data collection at the near field sites must remain relatively consistent in perpetuity. However, data collection that best supports an AMP implementation plan needs to be adaptive. Each watershed will be different and case-by-case customization of tributary and far field monitoring sites will be necessary. The department has a sampling and analysis plan (SAP) template which can be used to describe expansions of an AMP watershed monitoring plan beyond the basic near field sites. This document can be request from the department. In addition, the department has completed numerous SAPs for projects across the entire state; these describe specific sampling projects, their objectives, and the corresponding sampling sites and data types. Examples can be provided upon request.

9.0 ACKNOWLEDGEMENTS

Thanks to the members of the Nutrient Work Group for their contributions and suggestions on this document, and on **Circular DEQ-15** and the rules adopted into the Administrate Rules of Montana.

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APPENDIX A: MECHANISTIC MODELING CASE STUDY

A hypothetical mechanistic modeling case study is provided below to better illustrate the approach proposed in this guidance document. For real world examples, the reader is referred to Bierman et al. (2013) who detail the use of nutrient models for setting site-specific nutrient goals. Included in that work is a demonstration of the application of all modeling concepts discussed in this document, along with judgement decisions made along the way for the development of nutrient decision support.

Pristine River Case Study. The Pristine River is in a large multi-HUC watershed that has three large tributaries entering it (**Figure A-1**). Tributary 1 (T1) enters from the northeast and contains a small, single MPDES nutrient permit (City 1). Tributary T2 enters from the southeast and is pristine. Along the path of the Pristine River and downstream of the confluence of T1 and T2 enters a single nutrient point source discharge at midpoint of the watershed at City 2. Downstream of this location, Tributary 3 (T3) enters and is primarily agriculturally dominated. A third MPDES nutrient permit (City 3) is located downstream of T3. To characterize water quality, each city was bracketed by appropriately placed near-field sampling sites both upstream and downstream of each point of discharge, as well far-field sites near the upper and at the lower end of the watershed, along with tributary confluences and key mainstem monitoring locations. The overall load (*W*, in kg/day) of the most limiting nutrient during the most recent synoptic sampling is detailed in the figure.

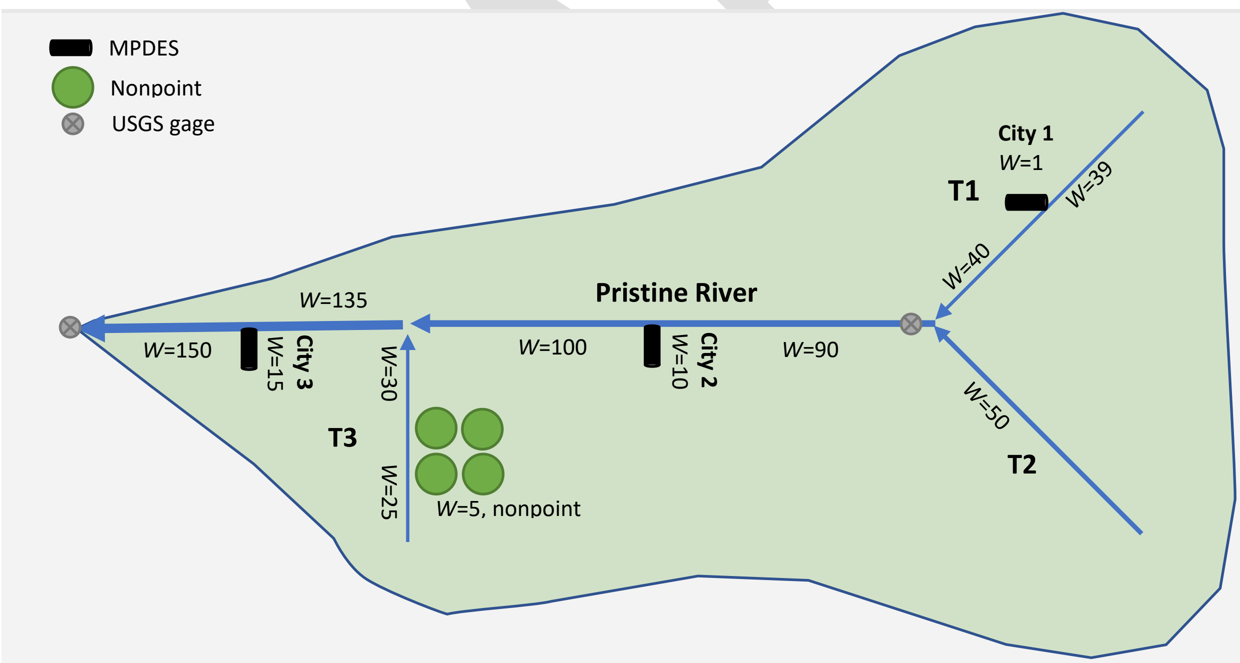

Figure A-1. Schematic of Pristine River Associated with the Hypothetical Case Study.

To complete watershed nutrient management, an AMP stakeholder group has formed in the lower, more urbanized part of the Pristine River consisting of City 2 and 3, and several of the agricultural producers. They have agreed to share costs to model the river to assess whether narrative nutrient standards are currently being achieved. Primary questions the group has is whether beneficial uses are being supported and to understand whether agricultural BMPs in T3 will have any benefit to watershed management during the next permitting cycle. At the same time, City 1 has decided to conduct their own independent effort. Both stakeholder groups have hired independent consultants that will follow the AMP modeling guidance.

Based on the problem specification, the consultant for City 1 concludes that a simple receiving-water model could be used on T1. Modeling would require knowledge of the upstream boundary condition above City 1, the City 1 load contribution, and then several calibration points downstream to evaluate the water-quality response, extending downstream as far as impacts from the point source are observed. All nutrient-related state variables, response variables, and applicable information such meteorological data should be monitored for the modeling.

The consultant for the lower watershed has concluded that nutrient management activities are only feasible in the lower portion of the watershed. However, they also recognize that City 1 is an upstream nutrient loading source. From review of available loading data, it is identified that City 1 contributes approximately 1% of the overall nutrient load upstream of City 2, not accounting for instream processing. Because of this, and following the AMP guidance, the effect of nutrients from this location can be ignored, and the lower river can be examined on its own.

To define the model domain in the lower river, the consultant for the lower Pristine River stakeholder group decided that the Pristine River water-quality model would begin immediately upstream of City 2, extending downstream to include T3 and all downstream sources. However, a more complex approach is required since multiple point sources and influent tributaries exist, and agricultural practices are widespread in T3. Two potential modeling approaches were conceived by the consultant for AMP water-quality modeling. They comprised:

- A receiving-water model of Pristine River extending from just upstream of City 2 to the most downstream point in the watershed where nutrient planning is desired, recognizing the following:
    - In this case, boundary conditions would need to be established upstream of City 2, and at the mouth of T3 and the City 2 and City 3 MPDES discharge.
    - Just as was proposed for City 1 further upstream, locations for model calibration should be established periodically along the river, upstream of the City 3 point of discharge, and downstream of the points of discharge near the estimated critical impact point (e.g., near field sites), and extending downstream to the project terminus (far field).
    - The relationship between agricultural practices in T3 and the T3 boundary condition are not understood. Therefore, empirical estimation of how agricultural BMPs would affect water quality at the T3 boundary condition is required.
- A second and more detailed approach was also considered by the consultant which was to develop a watershed-loading model to aid in BMP calculations and to better understand nutrient processes within the modeled reach. In deliberating, the watershed model could be constructed to encompass one of the following:
    - The entire watershed, integrating the point source in T1 and associated fate and transport of nutrients downstream. This would enable holistic watershed-wide planning and decision making; or

- For T3 only, for the sole purpose of understanding the relationship between agricultural BMPs and the T3 boundary condition. This information would then be integrated into the lower river's receiving water model to evaluate nutrient AMP scenarios.

In this case, the decision was made to conduct a sensitivity analysis on the influence of the T3 tributary, including the presumed influence of BMPs on the tributary's loadings, to determine if its nutrient contribution has any meaningful influence on the overall model response (i.e., using a strawman model). Based on this outcome it was decided that due to the small size of the agricultural loadings relative to the rest of the loadings in the reach, and minimal in-stream responses from changes in those loadings, watershed modeling would not be required, and empirical estimates would be sufficient. However, it was also recognized that if the agricultural contribution in this watershed were to become large in the context that it was impacting water quality in the Pristine River, T3 would likely need to be modeled using a watershed model. The project approach was discussed with the department and agreed upon. Once formulated and vetted, modeling tool(s) were then chosen by both consultants for the work and the required steps of model calibration, confirmation, and ultimately decision support analysis for AMP purposes was completed. This allowed appropriate AMP decision making for each of the watersheds by modeling nutrient endpoints to assess beneficial use support, as well as using modeling tools to best manage nutrients in the watershed.

As is evident in this case study example, each AMP watershed and modeling approach will be site-specific, and will require up-front discussions with the department about project methodology, recognizing that activities might span multiple HUCs and requiring coordination between multiple municipalities or stakeholder groups. The case study should be used for illustrative purposes only.

APPENDIX B: CASE STUDY: USING A NON-MODELED APPROACH TO DATA COLLECTION IN A SIMPLE AMP WATERSHED

Introduction

Data collection in the point source receiving waterbody is a required component of each Adaptive Management Plan (AMP). Data collection is conducted to represent the extent to which permitted dischargers are affecting beneficial uses of their receiving waters, to evaluate compliance with permit limits, and to identify opportunities for water quality improvements. This case study presents a hypothetical example of how an AMP watershed monitoring plan could be developed without using a water quality model in a less complex watershed which has a limited number (probably no more than three) permitted facilities discharging to a receiving water.

Watershed Overview

The Redwater River watershed (4th code, 8-digit HUC 10060002) (**Figure B-1**) is in northeastern Montana, in McCone, Dawson, Prairie, and Richland counties. The watershed is in the Northwestern Great Plains ecoregion and the waters within are classified as C-3, meaning they are "to be maintained suitable for bathing, swimming, and recreation, and growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl, and furbearers," and their "quality is naturally marginal for drinking, culinary, and food processing purposes, agriculture, and industrial water supply" (ARM 17.30.629).

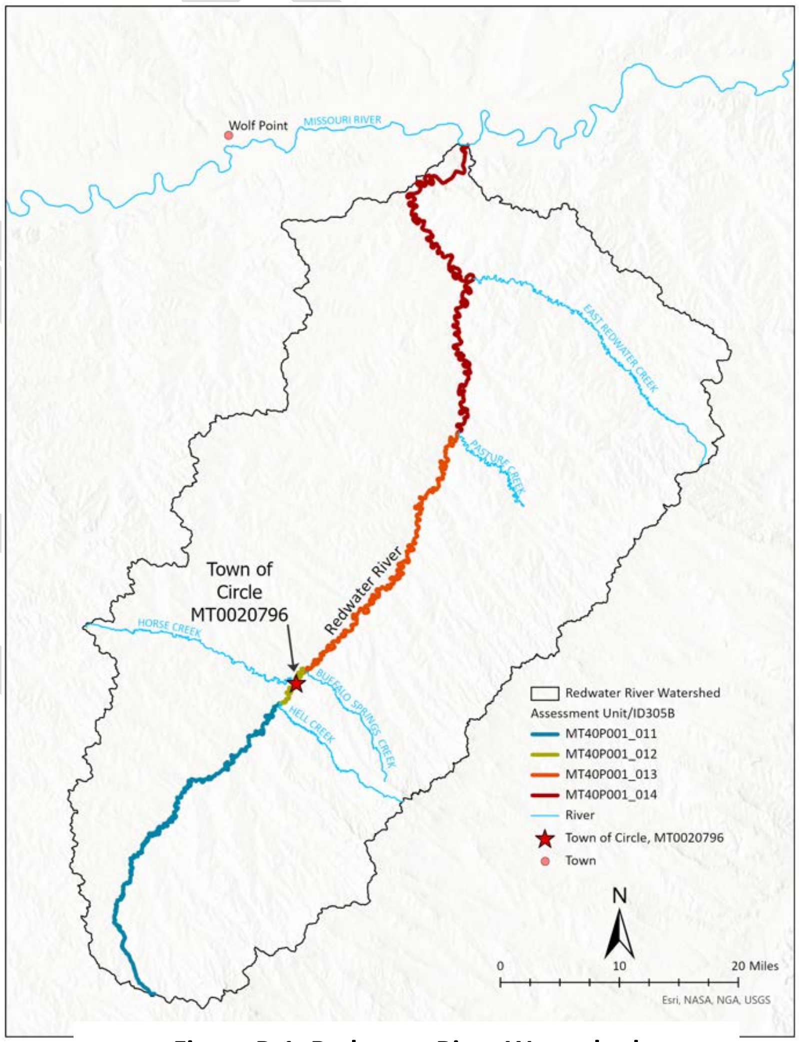

Figure B-1: Redwater River Watershed

The Redwater River, for the purposes of this case study, is the receiving water for the Town of Circle domestic wastewater treatment facility per the facility's MPDES individual permit. The Redwater River flows 170 miles northeast from its headwaters to its confluence with the Missouri River downstream from Wolf Point. It is a low gradient, mostly wadeable medium river in the eastern prairie region. Tributaries to the Redwater River include Hell, Buffalo Springs, Horse, Pasture, and East Redwater creeks. The Redwater River consists of four assessment units which are unique segments used by the department for administrative and assessment purposes.

AMP Monitoring Plan: Evaluating Relative Change Upstream and Downstream

In this case study, the basic AMP data collection effort focuses on response variables and nutrient concentrations at near field sites upstream and downstream from the point source discharge. The primary objective of this work is to evaluate whether the watershed is negatively impacted by nutrients. The data are compared against thresholds, and relative change between upstream and downstream near field sites is also examined (see Section 5.0 in **Circular DEQ-15**).

If evaluation of the data concludes that the watershed is not negatively impacted by nutrients (scenario A in **Table 6-1** of this guidance), the department may agree that it is sufficient to continue implementing a sampling plan to meet minimum annual monitoring requirements until change occurs. Alternately, if evaluation of the data determines the watershed is negatively impacted by nutrients, the permittee would implement an AMP implementation plan (see "**AMP Implementation Plan**" below), which entails an expanded monitoring strategy, and would initiate a watershed inventory to quantify and characterize nutrient sources and identify partners to assist in implementing nutrient reductions.

Site Selection

Near field monitoring sites should be located on the mainstem of the receiving waterbody. Efforts will be made to select sites that are adequately comparable in character in terms of slope, water volume, depth, substrate, and shading.

The upstream near field site will be located upstream from the point of discharge at a location that is as near as possible to the discharge point without water quality being influenced by the discharge itself. This site is intended to capture water quality conditions immediately prior to the input of the permitted facility's discharge (**Figure B-3**) and should have physical characteristics similar to the downstream site.

The downstream near field site is selected after carrying out nutrient spiraling calculations. Nutrient spiraling calculations use water velocity and channel depth data plus literature values for uptake velocity (v_i) to estimate the distance that nutrients travel before being taken up by organisms (e.g., algae). The downstream near field site is selected within this uptake distance so that data collection for response variables occurs where nutrient impacts are likely to manifest. Downstream near field sites should also be downstream from the permit-defined mixing zone.

Nutrient spiraling calculations using the recommended Nutrient Spiraling Spreadsheet yield a range of uptake distance estimates for nitrate and phosphate. When selecting the downstream near field site, both the mean and the median of the downstream distance estimates, plus the stream or river segment between these distances, as well as the minimum and maximum, should be visited for reconnaissance purposes to identify the most appropriate sampling location. Once a candidate downstream near field site is located, confirm that its basic characteristics match those of the upstream near field site. If they do not reasonably correspond, then it will be necessary to reposition one or both sites until site characteristics are reasonably comparable.

Data from the United States Geological Survey (USGS) gage station on the Redwater River at Circle, MT (USGS 06177500) is used in nutrient spiraling calculations. Uptake distances are based on mean channel depth (calculated from area and width) and mean water velocity measurements (n = 35) collected during the summer growing season (July 1 through September 30) from 1986 to 2021. In this case study, the downstream near field site should be located approximately 800 to 2400 meters downstream from the point source discharge (**Table B-1**; **Figure B-3**).

Table B-1: Nutrient Uptake Distance Estimates for the Redwater River

Summary Statistic	Uptake Distance* (S_w) (meters)	
	Nitrate	Phosphate
Minimum	756	545
Mean	878	813
Median	2368	1472
Maximum	6562	3631

*Based on 139 studies (Ensign and Doyle, 2006) with an additional correction factor

Note: if a tributary confluences with the receiving waterbody between the point source discharge and the near field downstream site location identified via nutrient spiraling calculations, a monitoring site near the mouth of this tributary should be included in the monitoring plan. Nutrient concentration data should be collected at this site so that tributary loads can be considered when evaluating upstream/downstream change.

Ecoregion Zone

GIS analysis confirms that the Redwater River watershed lies wholly within the Northwestern Great Plains level III ecoregion. Observations of waterbody characteristics during on-the-ground reconnaissance confirm that the Redwater River reflects the underlaying expectation of the eastern ecoregion zone. Further, a search of fish survey and inventory data in the Montana Department of Fish, Wildlife and Parks (FWP) MFISH database for the Redwater River yields a list of 34 fish species which are indicative of a warm-water fishery expected in this eastern ecoregion zone; the ten most common species are shown in **Table B-2**. These factors confirm that the ecological characteristics and monitoring requirements that correspond to the eastern ecoregional zone (see **Section 4.0**, this guidance) are appropriate to apply in this watershed.

Table B-2: Ten Most Common Fish Species Inventoried in the Redwater River since 2000

Species	Count
Fathead Minnow	10,451
Sand Shiner	8,857
White Sucker	2,845
Flathead Chub	1,570
Emerald Shiner	984
Longnose Dace	909
River Carpsucker	341
Common Carp	322
Brassy Minnow	293
Green Sunfish	258

Data Collection Strategy

Grab samples of ambient water will be collected from each upstream and downstream near field site and submitted to an analytical laboratory for analysis of nutrient (TN and TP) concentrations twice between July 1 and September 30 with at least 30 days between sampling events.

Response variables appropriate for the eastern ecoregion zone, dissolved oxygen (DO) delta and 5-day Biochemical Oxygen Demand (BOD_5) (**Table 5-1**, this guidance), will be monitored at each near field site.

Continuous DO will be measured via deployment of MiniDOT data logger instruments deployed for at least 30 days between July 1 and September 30, with at least 21 of those days in August. Given the prevalence of fine sediment substrate and intermittent pools, a fencepost or rebar is expected to be the best deployment platform (pending review of site-specific conditions) (**Figure B-2**). The instrument will be attached using zip-ties to a metal fencepost or rebar that has been pounded securely into the substrate of the channel in a location near a bank where the instrument is likely to remain submerged. To limit interference of the instrument's DO sensors, copper wire mesh will be secured over the sensor face to limit fouling, and the deployment location will be free from macrophytes (removed manually as needed). The DO delta (daily maximum minus daily minimum) will be calculated for each day of deployment and weekly average DO delta will also be calculated.

Grab samples will be collected and submitted to an analytical laboratory for 5-day BOD analysis twice between July 1 and September 30 with at least 30 days between sampling events. Note: these samples have a very short holding time and extra care must be taken to ensure they are delivered quickly to the lab.

Figure B-2. Dissolved Oxygen Sonde Deployment

Data will be compared against thresholds (**Table 5-1**, this guidance) and relative change between upstream and downstream near field sites will also be examined and incorporated into the compliance decision.

AMP Implementation Plan: Characterizing Nutrient Sources and Identifying Water Quality Improvement Opportunities

In this case study, if evaluation of the initial monitoring data from near field sites indicates the watershed is negatively impacted by nutrients, the permittee would initiate an AMP implementation plan. The primary objectives of this plan are:

- To quantify nutrient loads throughout the watershed to understand the magnitude and extent of nutrient sources in the watershed and identify opportunities for implementing nutrient reductions.
- To continue collecting data for response variables as performance indicators of the effectiveness of implemented AMP actions in achieving compliance with narrative nutrient water quality standards.

Site Selection

The near field sites monitored during the AMP implementation plan will be the same sites as those monitored during the initial data collection effort (see "**AMP Monitoring Plan**" above) (**Figure B-3**).

The far field sites will be selected to characterize the upstream and downstream extents of the watershed. The Redwater River is the mainstem waterbody draining the watershed and is the point source receiving waterbody. The far field site representing the furthermost upstream extent of the watershed will be as near to the headwaters of the Redwater River as is practical, in a reach of the river that is accessible for sampling purposes and is upstream of any substantial tributary inflows and other nutrient contributions.

The purpose of the far field downstream extent site is to quantify nutrient loads from the receiving waterbody to the waterbody it confluences with downstream, and to characterize water quality conditions (including response variables) at a point that represents the cumulative impacts of all watershed activities upstream. This site should be downstream from tributary inflows that may contribute nutrient loads to the mainstem and downstream from substantial nutrient sources along the mainstem. The site should be located downstream from areas where nutrient reduction actions may be implemented so that the data can be useful while evaluating effectiveness of water quality improvement activities throughout the AMP process.

In this case study, the far field downstream extent site will be as near to the Redwater River's confluence with the Missouri River as is accessible and avoids backwater influence from the Missouri River (**Figure B-3**).

Tributaries

One monitoring site should be selected near the mouth of each principal tributary to the receiving waterbody. Data from tributary sites can be used to quantify and compare nutrient loads among tributaries for consideration when developing and prioritizing action items for the reduction of nutrients in the watershed. Tributary sites are also useful when monitoring how effective water quality improvement projects that are implemented in the tributary's watershed were at reducing nutrient loads. In this case study, one site is selected near the mouth of Hell, Buffalo Springs, Horse, Pasture, and East Redwater creeks (**Figure B-3**).

Ecoregion Zone

The same eastern ecoregion zone applies (See "**AMP Watershed Monitoring Plan Ecoregion Zone**").

Data Collection Strategy

At each site (near field, far field, and tributaries), grab samples of ambient water will be collected and submitted to an analytical laboratory for analysis of nutrient (TN and TP) concentrations twice between July 1 and September 30 with at least 30 days between sampling events.

Response variables appropriate for the eastern ecoregion zone, dissolved oxygen (DO) delta and 5-day Biochemical Oxygen Demand (BOD) (**Table 5-1**, this guidance), will be monitored at each site:

Continuous DO will be measured via deployment of MiniDOT data logger instruments deployed for at least 30 days between July 1 and September 30, with at least 21 of those days in August. The DO delta (daily maximum minus daily minimum) will be calculated for each day of deployment and the weekly average DO delta will be compared against the weekly average threshold in **Table 5-1**, this guidance.

Grab samples will be collected and submitted to an analytical laboratory for 5-day BOD analysis twice between July 1 and September 30 with at least 30 days between sampling events. Note: these samples have a very short holding time and extra care must be taken to ensure they are delivered quickly to the lab.

Discharge (flow) measurements will be paired with each nutrient concentration sampling event to enable loading calculations. Calculating nutrient loads will allow for relative comparisons of nutrient contributions between tributary inflows to the Redwater River, thereby informing action items in the AMP implementation plan. Tributaries in this watershed may be intermittent and periodically not flowing or dry during sampling events; efforts will be made to capture tributary flow events during the index period to represent tributary nutrient sources to the Redwater River. Alternatively, and if found to be necessary, flow can be measured up- and downstream of intermittent tributaries to determine any flow additions that are occurring below the surface.

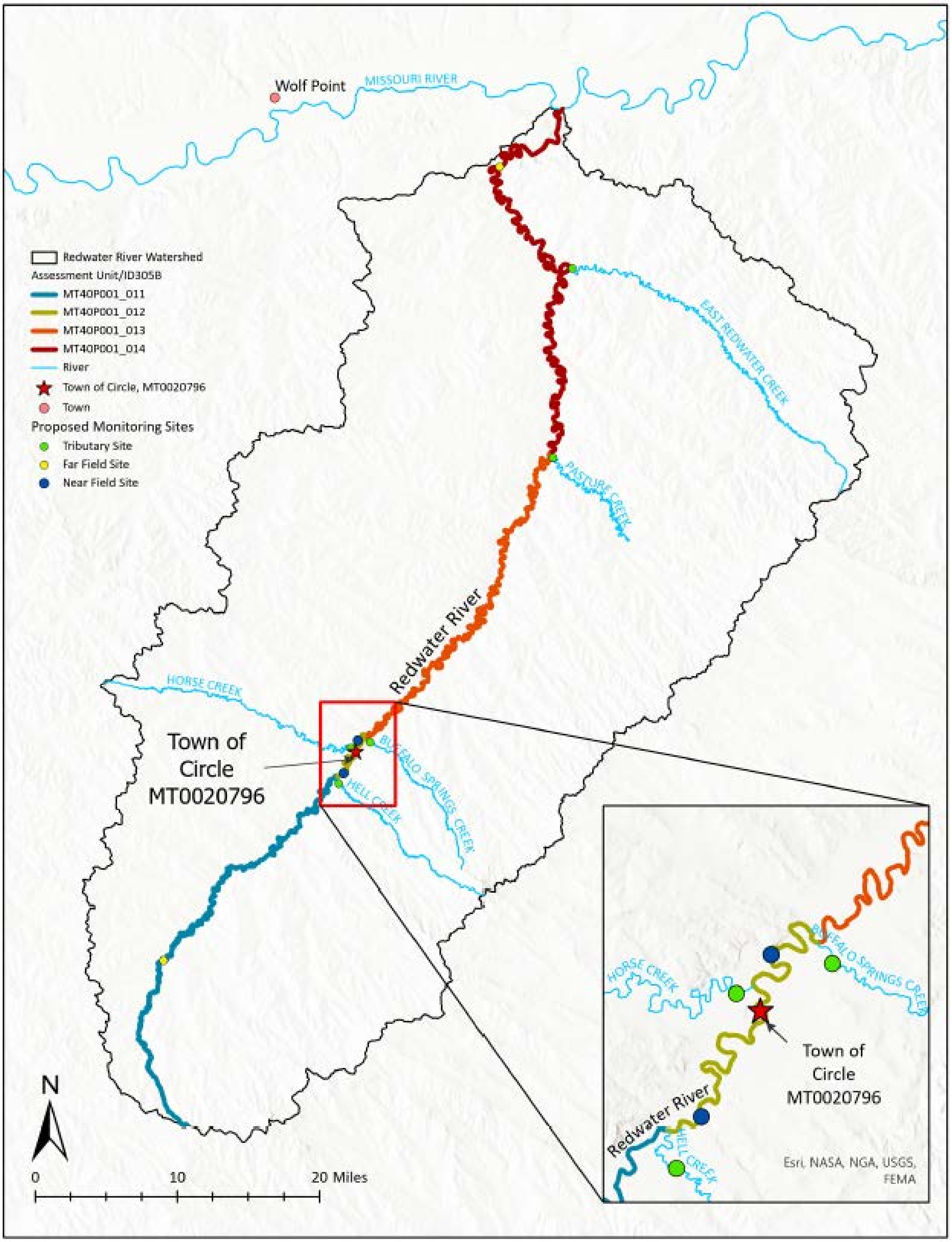

Figure B-3: Proposed Monitoring Sites Under the AMP Implementation Plan

Implementation

Adaptive Monitoring Plans

Monitoring planning is often an iterative process in which the results of the data collection efforts are compiled, analyzed, and used to refine the monitoring strategy. The basic monitoring plan will help to establish future monitoring needs throughout the AMP process. Monitoring at the near field sites is expected to remain relatively consistent in perpetuity. However, monitoring planning during the AMP Implementation Plan phase also needs to be adaptive. For example, potential nutrient sources identified during a watershed inventory may prompt the selection of new or additional monitoring sites to quantify nutrient loads or isolate potential nutrient reduction projects. Initial characterization at tributary sites may clarify which tributaries contribute greater or lesser nutrient loads to the receiving waterbody and therefore may lead to tributary sites being added or discontinued. Additional or different monitoring sites may also be necessary to demonstrate effectiveness of nonpoint source reduction projects or to affirm compliance with narrative nutrient standards.

Watershed Inventory

To develop and implement a watershed-specific AMP, a permittee will need to inventory the point and nonpoint source contributions of nutrients throughout the watershed. The watershed inventory may entail geospatial analysis or other desktop exercises, coordination with partners in the watershed, and data collection. Quantifying these sources may entail collecting data for nutrient concentrations and discharge to calculate loads. The watershed inventory, including relative comparisons of nutrient loads from each, will help to identify and prioritize opportunities for nutrient reductions.

Partnerships

The AMP process highlights the benefits of forming partnerships to achieve cumulative water quality improvements in a watershed. Partnerships will be necessary to facilitate the implementation of best management practices or other watershed improvement projects aimed at reducing nonpoint nutrient sources. Decreasing nutrient loads from nonpoint sources upstream from the point source could help to increase the assimilative capacity of the receiving waterbody, while reducing nonpoint nutrient sources downstream from the point source discharge may present pollutant credit trading opportunities. All improvement actions will lead to cumulative improvements in water quality in the receiving waterbody. To identify partners that will assist in implementing AMP action items, the permittee may contact, for example, counties and municipalities, conservation districts, watershed groups, conservation organizations, and landowners.

Monitoring partnerships may also be possible to reduce or leverage resources to meet water quality monitoring requirements through time. Point source dischargers may be able to identify entities that already have proficiency in similar water quality monitoring methods who may be willing to partner to achieve data collection. For example, entities that administer monitoring programs include watershed groups, conservation districts, water quality districts, and non-governmental organizations, some of which enlist community volunteers to become trained and participate in data collection.