Procedures for implementing river eutrophication standards in NPDES wastewater permits in Minnesota

(Version 1.0)

Minnesota Pollution Control Agency

November 2015

Table of Contents

Abbreviations used (in alphabetical order)

ADWDF: average dry weather design flow

AUID: assessment unit identification

AWWDF: average wet weather design flow

BATHTUB: lake nutrient model

BOD: biological oxygen demand

BPJ: best professional judgement

Chl-a: chlorophyll-a

DO: dissolved oxygen

DO flux: dissolved oxygen fluctuation

FLUX: river nutrients loading model

EPA: US Environmental Protection Agency

HUC: Hydrologic Unit Code

I/I: infiltration/inflow (analysis)

IBI: index of biological integrity

IWM: intensive watershed monitoring

LES: lake eutrophication standards

MDF: maximum design flow

MnTAP: Minnesota Technical Assistance Program

NPDES: national pollutant discharge elimination system

PMP: phosphorus management plan

RES: river eutrophication standards

RP: reasonable potential

SDR: state discharge restriction

SID: stressor identification

TBEL: technology based effluent limit

TMDL: total maximum daily load

TP: total phosphorus

TSD: technical support document

USGS: U.S. Geological Survey

WLA: wasteload allocation

WQBEL: water quality based effluent limit

WRAPS: watershed restoration and protection strategy

WWTF: wastewater treatment facility

Overview

This document is an overview of the procedures for assigning total phosphorus (TP) limits and requirements consistent with Minnesota's recently adopted river eutrophication standards (RES) for national pollution discharge elimination system (NPDES) wastewater permits. The document will briefly discuss lake eutrophication standards, but the focus is on eutrophication standards for rivers and streams (rivers and streams will be collectively be referred to as "rivers" from this point on). The intent of RES is to protect aquatic life from the negative impacts of elevated suspended algal levels. Minnesota's RES include both a cause criterion (i.e. total phosphorus) and response criteria [i.e. daily dissolved oxygen fluctuation (DO Flux), biological oxygen demand (BOD), and chlorophyll-a (Chl-a)] instead of a single criterion/pollutant like toxics (MPCA 2012, 2013) http://www.pca.state.mn.us/index.php/view-document.html?gid=14947. Phosphorus[1], in itself, is not toxic at levels discharged by wastewater treatment facilities (WWTFs) and is an essential nutrient in aquatic ecosystems. However, when TP exceeds the RES criterion, negative impacts can be observed during summer when water temperatures and other factors such as residence time, shading, depth and transparency are conducive to excessive algal growth. The response criteria provide the linkage to the nuisance condition, excess suspended algae. The inclusions of response criteria with RES requires more monitoring data and a more complicated process for establishing effluent limits, rather than if the RES only included a cause criterion.

RES based effluent limits will be based on river monitoring locations with sufficient data for both the cause criterion and at least one response criterion. A RES effluent limit analysis will be completed for WWTFs upstream of these monitoring locations. When both the cause and a response criteria are exceeded (i.e. exceeds RES), the cause criterion becomes the basis for establishing effluent limits and **reasonable potential (RP) analysis** is completed. When neither the cause nor response criteria are exceeded, the focus is on protecting for the cause criterion, and **protection potential analysis** is completed. The most complicated situation for effluent limit reviewers is when the cause criterion is exceeded and the response criteria are not exceeded. In such cases, effluent limit reviewers will complete **response potential analysis** and consider downstream surface waters (Appendix B).

This document is not intended to provide methods for completing stressor identification (SID). Some of Minnesota's water quality standards are designed to identify water quality problems but do not explicitly identify a causal agent. Impairments of this nature may include; biological impairments as described by fish or invertebrate index of biological integrity (IBI) scores, low DO, which is different than the RES response criterion DO Flux, and periphyton. Phosphorus in each circumstance could, ultimately, be a stressor either by itself or in combination with a suite of other pollutants or physical conditions. Once stressors are identified, one must also determine the pollutant load reduction necessary to meet standards prior to setting wasteload allocations or effluent limits. Development of wasteload allocations and subsequent effluent limits on the basis of these impairments is a complicated and time consuming process that is outside of the scope of the permitting program. Nonetheless, TP limits may be derived from wasteload allocations (WLAs) in total maximum daily load (TMDL) studies or watershed restoration and protection strategies (WRAPS).

[1] Phosphorus is often dosed in drinking water at an order of magnitude higher than the RES TP criterion. Municipalities that add phosphorus at their water treatment plant may be required to remove phosphorus at the wastewater treatment plant.

Unique standard requires specialized staff and watershed based approach

Specialized effluent limit reviewers with experience in limnology and water-quality models will be needed to establish eutrophication based effluent limits. TP effluent limit setters will use best professional judgement (BPJ) to complete watershed based batches of eutrophication limits and requirements. **The procedures outlined in this document are meant to guide TP effluent limit reviewers rather than eliminate flexibility when establishing effluent limits for the unique combination of NPDES permittees and rivers in Minnesota.** For most pollutants, limits are set on the basis of conditions in the immediate receiving water. For eutrophication, limits may be reviewed on the basis of water quality in number of downstream waters. The history of eutrophication standards in Minnesota provides some context to this temporal complexity.

Background

Historical note

Since 2008, MPCA has set effluent limits for WWTFs upstream of lakes and reservoirs consistent with lake eutrophication standards (Figure 1). The experience of setting effluent limits for lakes serves as a template of setting effluent limits for RES. This document will briefly summarize the effluent limit setting process for facilities upstream of lakes in the final section of the main document. The process is similar for both lakes and rivers, but some of the calculations for RP and wasteload allocations are different. In many cases, WWTFs may have rivers and lakes downstream of their outfalls requiring effluent limit reviewers to set limits that are protective of multiple surface waters.

Many facilities in Minnesota have been issued TP water quality based effluent limits (WQBELs) to protect distant lakes such as Lake Pepin. This has resulted in dramatic reductions of TP discharged to Minnesota's rivers. The WWTFs in Minnesota have already reduced TP loads by 70% due to LES, technology based effluent limit (TBELs) and TMDLs. The adoption of RES cannot have the same impact as lake standards in terms of overall reduction of actual point source loads from pre-2002 levels. In some cases, the significant progress from previous efforts achieved in rivers draining to lakes is sufficient to be consistent with RES at local reaches downstream of WWTFs. In other cases, limits set from previous efforts may not be sufficient to protect local rivers and more restrictive limits will be needed. The adoption of RES will insure that rivers without downstream lakes are also evaluated for eutrophication standards.

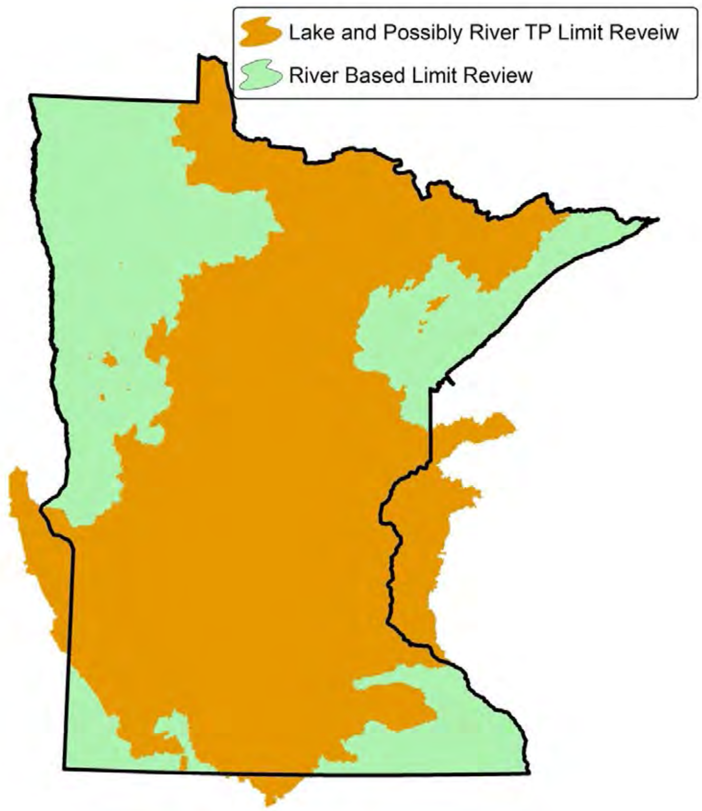


Figure 1. Areas in Minnesota where rivers will be the primary focus of TP effluent limit setting process along with areas upstream of eutrophication impaired lakes that may also be assessed for river eutrophication standards.

Statewide river monitoring network

Minnesota's robust watershed monitoring program along with data from other sources will have sufficient cause and response criterion monitoring at approximately 400 river monitoring stations statewide to assess the eutrophication status of rivers at the writing of this document. Minnesota will monitor all of its 81 watersheds over a 10-yr period. This will include TP and response criteria monitoring at the outlet of the watershed along with additional HUC 11 sized streams with favorable characteristics for growing suspended algae[2]. In a limited number of situations, monitoring will be adjusted to assess the impact of larger WWTFs on the eutrophication status of rivers not captured by the general monitoring network consistent with the 10-yr monitoring cycle of MPCA (Appendix C).

A preliminary analysis of existing TP and Chl-a data for rivers was completed to illustrate the extent of rivers exceeding RES in Minnesota. Minnesota's statewide nutrient reduction strategy has extensive discussion of this analysis (MPCA, 2014a). Figure 2 illustrates the river reaches potentially impaired for RES along with lakesheds of the lakes currently listed on the state's 303(d) list of impaired waters for eutrophication. It is quite obvious that the potential eutrophication statuses of rivers in Minnesota are variable and the lakesheds of impaired lakes cover a large portion of the state. Recent monitoring from

[2] Hydrologic unit code (HUC). United States Geological Survey (USGS) system for cataloging watersheds based on drainage size and relative location. For reference, HUC 8 watersheds drain approximately 1,200 to 1,500 square miles. HUC 11 watersheds drain approximately 150 square miles.

the past three years will add additional data information to this graphic. It is quite apparent that many of the WWTFs in Minnesota are upstream of a current lake impairment or potential river eutrophication impairment.

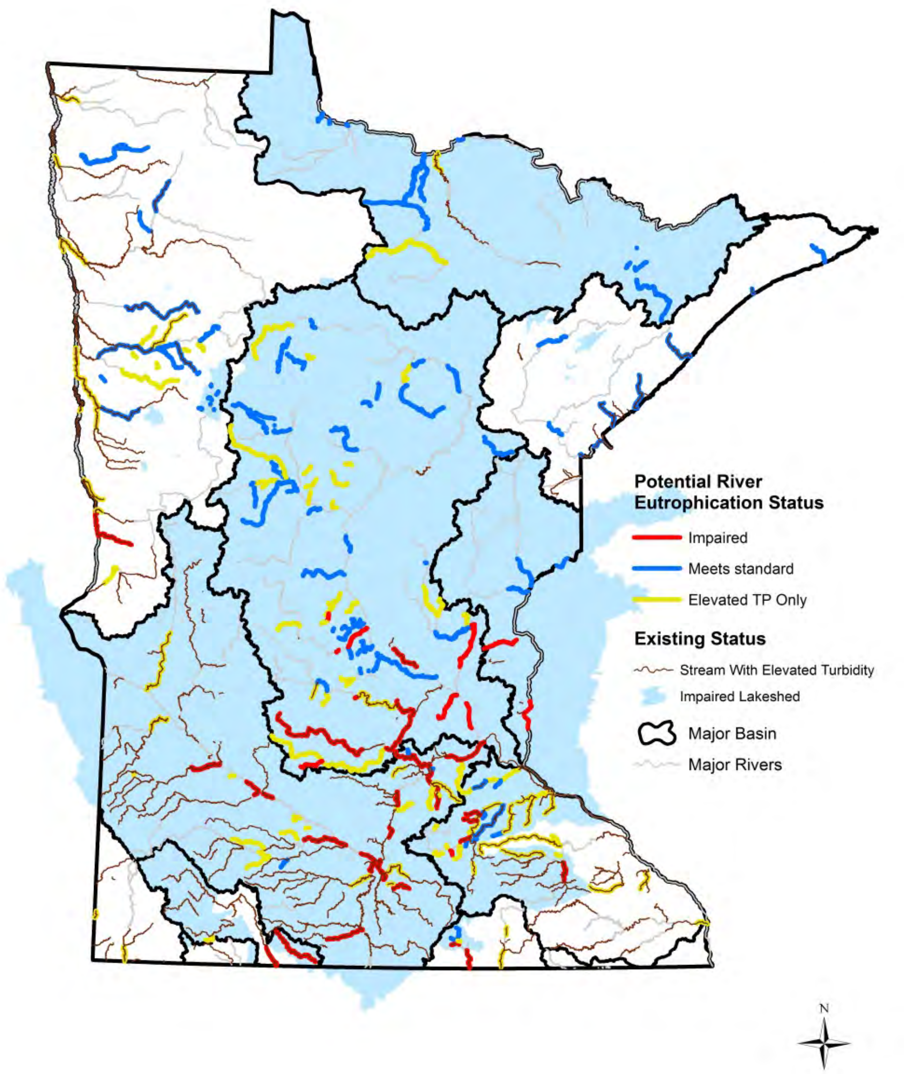


Figure 2. Lakesheds of eutrophication impaired lakes along with potential status of rivers with sufficient data to assess for river eutrophication standards. Data for rivers through 2011. Figure will be updated after statewide assessment for RES in 2015.

Unique frequency and duration of river eutrophication standards

The frequency and duration of RES are unique from most of Minnesota's water quality standards. The RES are based on a long-term summer average concentrations over multiple years instead of a "do not exceed" threshold common with toxic pollutants. When assessing the status of a stream for an impairment using toxic pollutants, the 4-day average concentration of the toxic parameter is only allowed to exceed the standard once in a three year assessment period. US Environmental Protection Agency's (EPA's) "TSD based method" is an expedient method designed to set WQBELs in timely manner for toxic pollutants. The technical support document (TSD) method is simply a dilution equation at a critical flow threshold. This works well for toxic pollutants that are problematic at low flows when dilution is minimal. TP; however, must be linked to a response criterion, and RES are measured as a long-term summer average.

When MPCA promulgated RES, it also adopted some important rule language to guide the implementation of TP WQBELs for eutrophication standards. Minn. Rule 7053.0205 Subpart 7.C. contains the following text:

> *Discharges of total phosphorus in sewage, industrial waste, or other wastes must be controlled so that the eutrophication water quality standard is maintained for the long-term summer concentration of total phosphorus, when averaged over all flows, except where a specific flow is identified in chapter 7050. When setting the effluent limit for total phosphorus, the commissioner shall consider the discharger's efforts to control phosphorus as well as reductions from other sources, including nonpoint and runoff from permitted municipal storm water discharges.*

The intent of this language was to characterize the unique frequency and duration of eutrophication standards and to recognize the impact of other sources of TP to Minnesota's lakes and rivers. The consideration of reductions from other sources is very prevalent in eutrophication TMDLs. This intent of this language has not served as a "free pass" for WWTFs upstream of eutrophication impaired rivers and lakes. In fact, a final monthly limit of 0.070 mg/L TP was issued to Virginia WWTF since it was the primary source of TP to eutrophication impaired Lake Manganika. MPCA has invested considerable effort and funds to collect monitoring data and develop water quality models necessary to calculate defensible WQBELs for eutrophication standards.

TMDLs for RES and LES will utilize load duration curves and various models to develop wasteload allocations for WWTFs upstream of eutrophication impaired rivers and lakes. These models cover a wide range of summer flow conditions for several years in most cases. MPCA plans to utilize multiple methods for establishing TP WQBELs for RES including, but not limited to, a modified TSD-based approach, load duration curves and water quality models. Some examples of these methods will be discussed later in the document (Appendix E).

Process Overview

The individual limits and requirements for WWTFs will be contained in watershed (HUC 8 size) memorandums. Within the watershed memorandums, multiple downstream reaches are considered since TP is generally considered conservative in surface waters. This creates considerable possible combinations of receiving waters categories and RES based effluent limit outcomes downstream of a WWTF of interest. Several examples will be discussed later in the document to describe the limit and permit requirements for a WWTF upstream of hypothetical rivers of varying RES categories (Appendix E). The MPCA developed a flow diagram to illustrate the complicated process of assigning RES based TP limits and requirements that are not independent of other limits/requirements impacting TP levels from WWTFs such as annual lake eutrophication based limits (Figure 3). WWTFs will discharge to rivers within the following general categories below. Colors associated with headings correspond to river condition categories (**Error! Reference source not found.**).

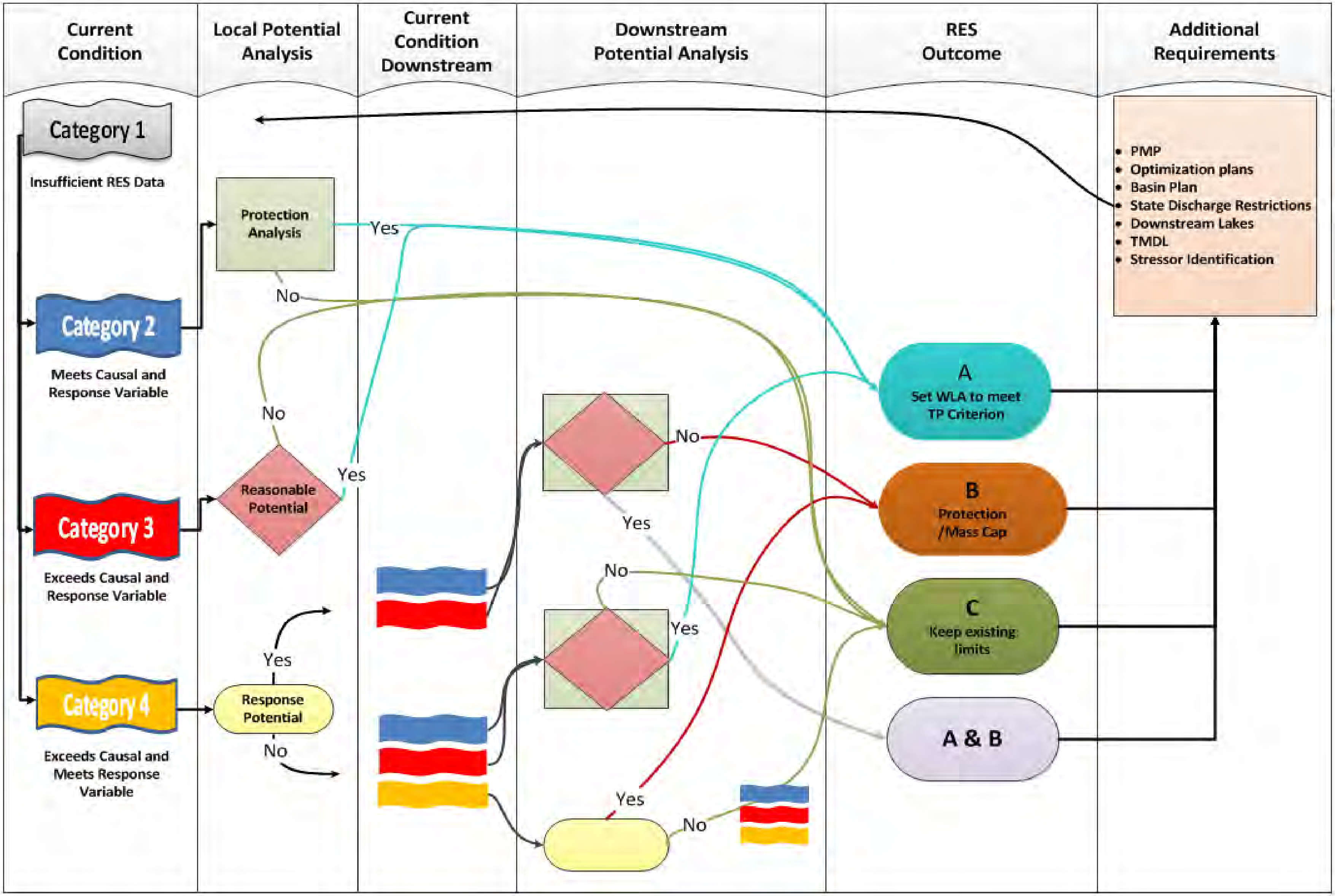


Figure 3. General process for reviewing phosphorus effluent limits for RES in Minnesota.

1. Insufficient data for response criteria
    a. Base limits and strategies on downstream waters
        i. This reach will likely be upstream of one of the other 3 categories listed or a lake
    b. Use BPJ to develop monitoring scheme for receiving waters
    c. Risk of more restrictive limits in the future if response found in current reach with insufficient data
2. Meeting RES (both cause and response below criteria)
    a. Do protection analysis to determine if facility at design flow (70% of AWWDF for municipals) would cause TP to exceed criterion
    b. Protection strategies
        i. When protection analysis indicates TP criterion could be exceeded at design flow calculate WLA based on TP criterion and translate to an effluent limit
        ii. Phosphorus Management Plans (PMP) when protection analysis indicates TP criterion would not be exceeded at design flow (Appendix F).
3. Exceeding RES (both cause and response exceed criteria)
    a. Determine if RP exists
        i. Likely in most river situations if effluent concentration exceeds TP criterion
            a. If facility has RP to contribute, then calculate WLA based on TP criterion with one of the following methods
                i. TMDL (draft or approved)
                ii. Available modeling results
                iii. Mass balance approach at 80 % exceeds flow
            b. Translate WLA into effluent limit
4. Meeting RES (elevated cause with response below criteria)
    a. Stream characteristics are muting response in the river
        i. Evaluate response potential (Appendix B).
    b. When response potential analysis indicates response criteria could be exceeded at design flow, then assign limit to "freeze" discharge at current actual discharge to continue to meet the response criteria at the local reach
    c. Move to downstream water until find a reach in Category 2 or 3

If downstream waters or basin plans require limits, then there will likely be reduced TP from the WWTF to the immediate reach.

There are three general RES based effluent limit outcomes in the RES flow diagram:

A **WQBEL.** RP or protection potential for a local or downstream river exists. A WQBEL for local or distant reach would result in TP meeting the TP criterion at the reach of concern. Examining limits for additional downstream rivers is generally not needed in this situation.
    a. Example: WWTF issued a 0.63 mg/L monthly WQBEL due to response above response criterion in local river. The limit would result in concentration of 0.099 mg/L in a river during the critical 80% exceeds flow. The cause criterion for this example is 0.100 mg/L.
    b. PMPs, state discharge requirements, basin plans and optimization plans may be required for these facilities.

B Mass Cap. Response potential indicates the additional TP loading from the facility may result in a response above the RES criteria at local or downstream reach. Since the existing actual discharge from WWTF does not cause a response above the criterion, a TP mass "freeze" will insure current conditions are maintained.

a. Example: The cause criterion for this example is 0.100 mg/L TP and the response criterion is 18 µg/L Chl-a. The current effluent from the WWTF is 10 kg TP/day which equates to a TP concentration of 0.110 mg/L in a local river during the critical 80% exceeds flow. Existing response of the local river is 16 µg/L Chl-a based on three years of monitoring data. Summer average Chl-a is not exceeding but is certainly near the response criterion, which suggests there is some potential for additional algae growth if phosphorus loading significantly increases. Based on the current design of the WWTF, the WWTF could discharge 60 kg/day which equates to a TP concentration of 0.180 mg/L in a local river during the critical 80% exceeds flow. The TP effluent limit staff examined the existing TP and Chl-a data and concluded based on BPJ that an increase of TP from 0.110 at 0.180 during low flow would likely increase Chl-a (i.e. response potential). The WWTF is issued a 21.0 kg/day (10 kg/day x 2.1 monthly limit multiplier) monthly mass cap due to the potential exceedance of the response criterion in the local river.

b. PMPs, state discharge requirements, basin plans and optimization plans may be required for these facilities.

C. Keep existing limits. The existing discharge from the WWTF at existing limits and design flow (70% of AWWDF for municipals) does not trip RP, protection potential or response potential.

a. Facilities that discharge at or below the TP criterion are often included in this Category. Typically only certain types of industrial facilities can discharge below the TP criterion without additional treatment works.

b. Includes scenarios where all rivers downstream of discharge have elevated TP but no monitored response above criteria and no response potential. Basin strategies may require TP load reduction from WWTFs in these situations.

iii. This sub-category is most common in the Red River Basin.

D. PMPs, state discharge requirements (SDRs), basin plans and optimization plans may be required for these facilities

Additional considerations and requirements

When multiple WWTFs contribute to a river, each WWTF will receive a portion of the overall WLA based on BPJ. Effluent limit staff will combine the RES based TP outcomes or limits which generally apply from June to September with the additional considerations that generally require annual TP management at WWTFs (PMPs, TMDLs, WRAPS, SIDs, SDRs and optimization plans). Optimization plans and PMPs will be considered in the process after the RES based limit analysis is completed.

Limit implementation procedures and examples

The overall process of establishing effluent limits requires five critical steps. The first step requires the effluent limit staff to examine available river water quality data near and downstream of the outfall of the WWTF of concern. This includes the analysis of both TP and response criterion data. The second step requires the effluent limit setter to determine if the WWTF has potential to cause or contribute to a eutrophication impairment. This may include multiple reaches downstream of the WWTF of concern. The third step is the calculation of the WLA for the WWTF. The fourth step is the translation of the WLA into a WQBEL for the WWTF. Finally, the effluent limit setter must compare WQBELs for all applicable downstream surface waters to determine which effluent limits and other requirements should be included in the NPDES permit. The remainder of the document will outline these five steps. If a particular situation for a certain group of WWTFs is not covered in this document, procedures for this unique situation will be developed and added to an updated version.

Rivers: (Steps 1 - 5)

Stabilization Ponds

Steps 2 through 4 require unique considerations for stabilization ponds. The main body of the document will focus on continuous dischargers while specific considerations for controlled discharge stabilization pond facilities will be covered in Appendix A.

New and expanding facilities

The procedures in this section are applicable to new and expanding WWTFs, but the procedures do not specifically address additional permitting considerations such as nondegradation/antidegradation and pollutant trading (Pre-TMDL Phosphorus Trading Permitting Strategy) for new and expanding facilities. TP effluent limit reviews for new and expanding facilities will be evaluated on a case by case basis. The individual reviews for new facilities will need to be compatible with the watershed review for the location of where the new facility is planned.

Step 1: Water quality data review

The first step of the TP effluent limit review is to assess and categorize the current eutrophication status of the receiving waters at and downstream of the WWTF outfall (Figure 3). As discussed earlier, Minnesota's RES include both a cause criterion (i.e. TP) and response criteria (i.e. Chl-a, BOD, and daily DO flux) (Table 1). Effluent limit reviewers will generally examine the past 10[3] years of data for receiving waters upstream and downstream of a given WWTF to determine the long-term summer averages for TP, Chl-a and BOD. The data for DO flux are often collected during continuous water-quality sensor deployments for one or two week periods. The procedures for summarizing RES data will be detailed in an assessment guidance document for RES (MPCA, in draft). The MPCA plans to conduct a statewide assessment of rivers for RES in the fall of 2015. Draft minimum sample numbers for a river reach assessment unit identification code (AUID) for TP, Chl-a, and BOD are two summers with a minimum of 12 samples overall. Stations with fewer samples than the minimum requirements can inform the effluent limiting process, but downstream stations with sufficient datasets will be the basis of the effluent limit calculations.

Table 1. River eutrophication criteria by River Nutrient Region for Minnesota.

	Nutrient	Stressors		
Region	**TP µg/L**	**Chl-a µg/L**	**DO flux mg/L**	**BOD_5 mg/L**
North	≤50	≤7	≤3.0	≤1.5
Central	≤100	≤18	≤3.5	≤2.0
South	≤150	≤35	≤4.5	≤3.0

[3] Recent reductions in point source TP loads from 2006 to the present have resulted in lower TP during low flow conditions in several rivers in Minnesota. This has likely resulted in less algal production during low flow conditions. Effluent limit setters should focus on impact of point source reductions on TP and response criterion data before and after point source TP reductions.

Effluent limit reviewers will need to review available RES data when a recent 303(d) assessment is not available for a river of interest. The water-quality monitoring plans for rivers in Minnesota are variable depending on the goals of the given station and/or monitoring agency. For consistent, equal interval sampling stations, (e.g. 2 times per month) simple averages will be sufficient to assess the status of streams in regards to RES. Calculating simple averages will be the first step for all AUIDs. Many of the monitoring stations in Minnesota have event based sampling schemes to monitor TP concentration and loads during high flow events. For event based stations, monitoring staff collect the majority of samples during rising and falling river levels after storm events in summer. A smaller number of samples are collected during base flow conditions. A straight arithmetic mean of event based sampling will be biased towards high flow sampling. MPCA has considered several techniques to calculate a mean that is more representative of the long-term mean from flow weighted sampling. The effluent limit setter should use BPJ when selecting one of the following averaging techniques (not listed in order of preference):

1. Time weighted average
   a. Samples are given more weight as the gap between samples widens
2. Average by month then by summer
   a. All months with samples receive equal weighting
   b. June often has the most samples
3. Average modeled daily values
   a. HSPF, FLUX and other tools can be calibrated to estimate all summer days
4. Average by flow zone based on load duration curve type analysis
   a. Data are divided into equal flow zone intervals
   b. Take average by flow zone then overall average
   c. This technique is best with a minimum of 10 years of flow monitoring to calculate flow zones
5. Average paired TP and response criterion sampling dates
   a. Response criteria are typically not sampled during all event samples for TP
   b. Removing TP only samples removes bias of event sampling
   c. Additional option of doing simple average on response criteria if based on equal interval sampling and one of first 4 techniques for cause criterion

Less data processing is required when assessing RES response criteria. Chl-a and BOD are typically collected at specified intervals (e.g. 2 times per month) and DO Flux is typically sampled for one or two weeks in late July or early August.

Step 2: Protection analysis, response potential analysis and reasonable potential analysis

Federal regulations require that all discharges with the reasonable potential to cause or contribute to the exceedance of a state water quality standard are required to receive a WQBEL (40 CFR § 122.44). RP is basically a test to determine if a discharge contributes to or has the potential to contribute to an excursion above the applicable RES. This language was developed for a one parameter water quality standard. The MPCA has decided to develop three subcategories of “reasonable potential” for RES. Depending on assessment of local and downstream waters in Step 1, the effluent limit setter will complete one or more of the three following “potential” analyses for downstream reaches with sufficient cause and response monitoring data: protection analysis (when neither the cause nor response criteria are exceeded), response potential analysis (when the cause criterion is exceeded and the response criteria are not exceeded) or response potential analysis (when both the cause and a response criteria are exceeded). Each HUC 8 watershed will likely have a complex set of receiving waters and analyses completed. Watershed review memorandums will summarize the detailed reviews (Appendix E).

A load duration curve or concentration duration curve is generated to determine the concentration of the receiving stream at low flow (Figure 4). The load duration curve allows for isolating the impact of point sources during critical flow conditions when algae are mostly likely to grow. Details on information gathered from the load duration curves will be covered in Steps 2 and 3.

Downstream considerations

There are some scenarios where achieving the downstream target generally requires local watersheds to achieve the TP criterion at the local reach. In such cases, the local potential analysis should reflect the reductions needed for the downstream reach. For example, a local reach at 0.160 mg/L TP with limited response (Category 4 reach) would be reduced to 0.140 mg/L at critical low flow due to a downstream impairment. The hypothetical TP criterion for the local reach is 0.150 mg/L. A response potential analysis would not be needed at the local reach since requirements for the downstream reach would meet the TP criterion at the local reach at design flow.

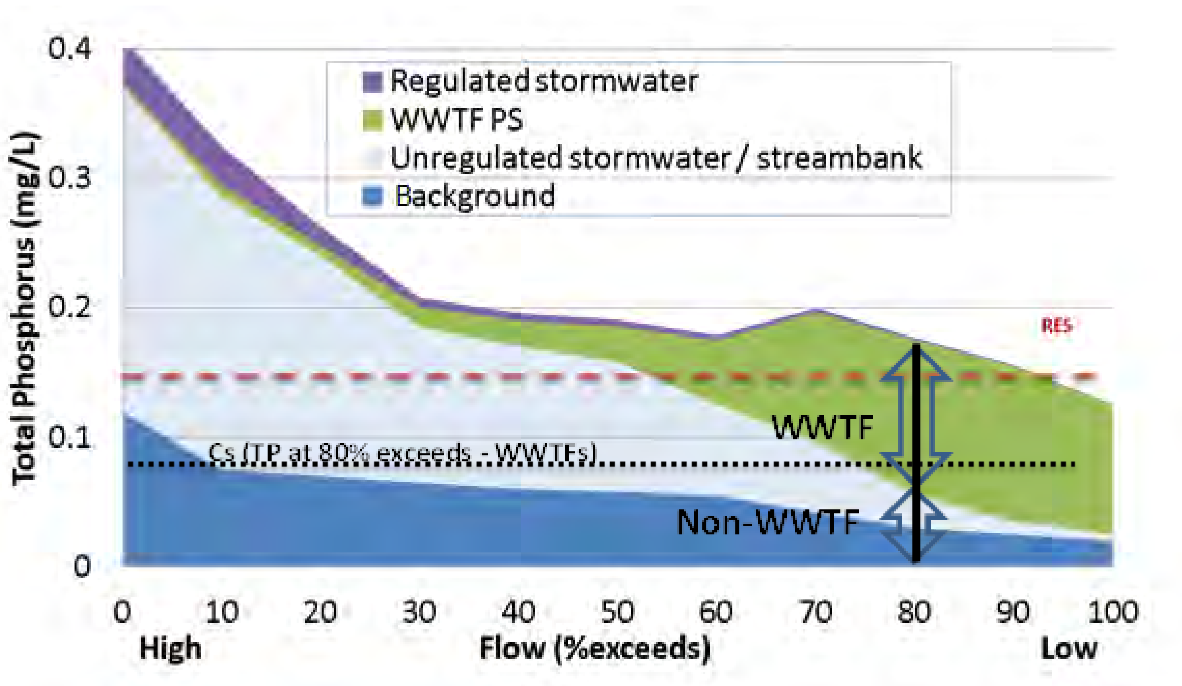


Figure 4. Example concentration duration curve where the concentration of the river is 0.175 mg/L (175 µg/L) at 80% exceeds flow. Solid black line denotes concentration at summer 80 % exceeds flow. Calculated concentration without WWTFs is 0.060 mg/L at 80% exceeds flow.

Reasonable potential analysis (Equation 1)

Identifying the location(s) where a response criterion and cause criterion are both exceeded (Category 3 reach) in a watershed is critical to setting TP effluent limits for RES. TP is generally conservative with some documented transport losses during low flows. **As a general rule, if a facility discharges upstream of a river that exceeds eutrophication standards at an effluent concentration greater than the TP RES criterion of the applicable downstream water, then it contributes to the downstream impairment.** Some TMDLs have included WLAs for facilities discharging below the TP criterion as part of a total accounting system for all sources of TP upstream of an impaired water. In circumstances where the discharge concentration is below the applicable water quality standard, the facility would not have RP, and an additional effluent limit may not be necessary to insure that the discharge is consistent with the assumptions of the TMDL WLA.

There are some aquatic features such as lakes or wetlands that trap TP and may reduce/eliminate the downstream impact of a given discharge. Identifying situations such as this will be done on a case-by-case basis. In most cases where TP is trapped by a lake, the focus of a TP effluent setter will be on the lake rather than a downstream river. Conservative transport of TP to downstream waters is generally assumed unless a large wetland or lake retains TP from the discharger of concern. Computer models like HSPF or select datasets may also be used to estimate transport losses where available.

Protection potential analysis (Equation 1)

Protecting reaches where neither the response criterion nor cause criterion are exceeded (Category 2 reach) in a watershed it is important for maintaining water quality that currently meets RES. In these situations, the current discharge from the facility is acceptable since RES standards are met, but there may be unused capacity at the WWTF that could cause the TP criterion to be exceeded at the critical low flow condition. The TP effluent limit setter will use the protection analysis calculation to determine if the facility has the potential to increase the TP concentration at the critical low flow above the applicable TP criterion (Equation 1). If the calculation yields a result below the applicable TP criterion, then current requirements or downstream requirements are sufficient to protect the local reach. If the calculation yields a result above the applicable TP criterion, then a response potential analysis could be conducted at the local reach. It is very difficult to estimate response potential at Category 2 streams since TP is currently low and modeling would be needed to estimate the impact of increased TP loading to the reach. **As a general rule, if a protection analysis indicates that a facility could increase TP above the RES criterion, MPCA will employ protection strategies to keep TP at the RES criterion at the local reach.**

Equation 1. Reasonable potential and protection analysis calculation

$$C_r = \frac{Q_s C_s + Q_e C_e}{Q_r}$$

If Cr > TP of RES then reasonable potential or protection potential exists

Inputs (details about these inputs are covered in following pages)

$Q_r = Q_s + Q_e$

C_r = Concentration of river at critical flow with WWTF at 70% of average wet weather design flow

Q_s = 80% summer exceeds flow of stream without WWTF(s)

C_s = Concentration of river without WWTF(s)

Q_e = Design flow of WWTF

C_e = Long term effluent concentration, existing concentration limit, proposed concentration WLA for downstream resource, or concentration target of downstream mass WLA.

Note: No multiplier is used to transform C_e to 95^{th} or 99^{th} percentile concentration since RES are long-term summer averages over multiple years. There is no frequency of exceedance specified in Minnesota's RES (e.g. not to exceed once in 10 years).

Receiving water Flow (Qs) = 80% exceeds summer flow

The "Q_s" criterion of the equation is the 80% exceeds summer (June – September) flow of the river reach of concern. If appropriate, the effluent limit setter can subtract out actual flows from all contributing WWTFs. Watershed and TMDL projects will examine all sources and flows while effluent limit reviewers will focus on a relatively low flow period (i.e. 80% exceeds) when contributions from nonpoint sources are minimized and conditions are conducive for algal growth (Figure 4). The 80% exceeds flow was selected based on best professional judgment gained from numerous reservoir TMDLs and is similar to the $30Q_3$ flow option in Wisconsin's NR 217 rule (WI DNR, 2011). The percent exceeds flow approach provides a reliable and reproducible low flow value that is easier to derive than conventional low flow calculations like $30Q_3$ or $7Q_{10}$. Minnesota rules do not require that a minimum flow of $7Q_{10}$ be used when implementing RES (Minn. R. 7053.0205 Subp.7). Flow calculations will be based on available summer flow data from the past 30 years. Streamflow estimates based on land area ratios of nearby gages, models or other techniques may be used when streamflow data is unavailable for the river reach of concern.

Effluent flow volume (Qe)

Multiple facility option: $Q_e = \sum Q_e$ for all contributing WWTFs. The procedures outlined in this document focus on permitted design flow during low flow conditions. Average wet weather design flow (AWWDF) for municipal WWTFs and maximum design flow (MDF) for industrial WWTFs have been traditionally used to calculate TP effluent limits. When MPCA engineers review plans and specifications for WWTFs they focus on the AWWDF as the "design" flow of the facility. To expect AWWDF from facilities at the 80% exceeds summer flow is unrealistic. For municipals WWTFs, "Q_e" is equivalent to 70% of AWWDF which is often similar to average dry weather design flow (ADWDF) for municipal WWTFs. The MPCA initially used 70% of AWWDF to estimate WWTF flow potential during low flow conditions in the Lower Minnesota River low DO TMDL. **In situations where current average summer effluent flow exceeds 70% of AWWDF, the current average flow for the facility will serve as Q_e.** Flow may be considered on a case-by-case basis for municipal stabilization ponds which are prohibited from discharging through much of the summer (Appendix B). For industrial WWTFs, "Q_e" is equivalent to the MDF. Given the complex nature of some industrial facilities, MPCA may use a facility specific approach for some industrial facilities.

Example: Rochester WWTF/ Rochester Water Reclamation Plant
AWWDF: 23.85 mgd
ADWDF: 15.86 mgd
70% of AWWDF: 16.70 mgd

Current background concentration at 80% exceeds flow (Cs)

The TP current background concentration is critical to the RP calculation and the WLA equation. The example C_s in Figure 4 is for a monitoring station downstream of several WWTFs. Many rivers that exceed the response criteria of RES may have multiple discharges upstream of the river reach of concern. Estimating the concentration of the river at the 80% exceeds flow minus any point sources is difficult for several reasons. The following options may be used based on BPJ to estimate upstream concentration:

1. River monitoring data upstream of point sources during low flow conditions. BPJ is needed to insure the upstream station is a representative sampling station. It may not be prudent to use upstream data of a stream with a 5 mi^2 wetland dominated watershed for as background concentration of a large river with a mixed landuse watershed draining 750 mi^2.

2. Assume upstream resource meets applicable RES standard. This is especially important for consideration for river discharges with multiple watersheds upstream and when an upstream lake is major source of water to river.
3. Estimate concentration based on modeling or mass balance calculations.
    a. Model runs with point sources removed to estimate "current background" concentration.
    b. **Equation 2:** Mass balance approach where assume 100% transport of TP from point sources during 80% exceeds flow. The C_s in Figure 4 is 0.060 mg/L once the mass of the WWTFs is removed from the monitored mass at the 80% exceeds flow. There may be some cases where a mass balance approach reveals that the monitored load at a monitoring station is less than monitored effluent load for the contributing WWTFs. In this situation transport losses are occurring during the 80% exceeds flow. If estimated background (C_s) is less than 0.000 mg/L due to transport losses during low flow, then one half of the applicable RES for a given river (North 0.025 mg/L, Central 0.050 mg/L and South 0.075 mg/L) are acceptable values for C_s. In this circumstance, which is somewhat rare, data demonstrate that the river is effluent influenced. However, it may be an unsafe assumption that all measured loading under moderate low flow is due to point sources and that no loading is due to other sources. As such, it is not recommended that 0.000 mg/L be used as C_s, because resulting limits may not be sufficiently protective.
    c. These C_s values can also be used when datasets for the previous two methods are limited and results are inconclusive. TP monitoring data from streams meeting RES are often one half of the RES at the 80% exceeds flow in Minnesota. Nonpoint control is most critical at high flows and less important during low flow unless upstream lakes or wetlands are a source of high TP concentration. During low flow conditions, source water to rivers is dominated by groundwater. Groundwater is well below the TP RES in most cases in Minnesota.

Equation 2.

$$\boldsymbol{C_s}(\textbf{\textit{Background concentration}} \ @\ \mathbf{80}\%\ \textbf{\textit{exceeds flow}}) = \frac{\textbf{\textit{River mass}}\ @\ \mathbf{80}\ \%\ \textbf{\textit{exceeds flow}} - \textbf{\textit{monitored WWTF mass}}\ @\ \mathbf{80}\%\ \textbf{\textit{exceeds flow}}}{\mathbf{80}\%\ \textbf{\textit{excceds flow}}(\textbf{\textit{includes actual WWTF flows}})}$$

Response potential analysis (see Appendix B for more details)

Category 4 streams have an average TP concentration above the TP criterion, but response criteria are not exceeded. If nutrient loading remained stable, then it is logical to assume that response criteria would continue to be suppressed. In many situations there will be downstream limits for Category 2 and 3 reaches that will require TP reductions beyond current actual loading from WWTFs discharging directly to Category 4 reaches. In these situations, response potential analysis would not be needed since TP is going down at the local reach. In other situations, there may be no requirements to reduce the local TP concentration and the facility may have substantial unused capacity. **Response potential evaluates the potential impact of the WWTF(s) going from current loading to loading levels at design capacity and the impact of that shift on response criteria.**

There are two basic types of rivers to evaluate when considering response potential. First, there are rivers with high TP where response monitoring values are well below response criteria. These rivers are typically weak candidates to demonstrate "response potential" since there is basically very minimal response to currently elevated TP (Example A and B in Table 2). If monitoring shows that response data are well below the applicable response criterion at all downstream stations despite TP exceeding the criterion, then response potential does not exist (e.g. main stem of the Red River). The second group of rivers has high TP with response monitoring values near, but still below, response criteria (Example C and D in Table 2). Facilities such as example C have the potential to increase the TP concentration of the river substantially. TP effluent limit reviewers would analyze data from the river and utilize BPJ to determine if the response criterion could be exceeded due to increased TP concentration. If so, "response potential" would exist and a mass freeze would be assigned in the permit to maintain existing TP load which does not result in an exceedance of the response criteria. In example D, the impact of the change from current TP loading from the WWTF to a design load would have minimal impact on river TP or response values.

Table 2. Likely response potential of four example WWTFs at design flow compared to current conditions to a river in the south river nutrient region. Note: Applicable TP criterion is 0.150 mg/L and Chl-a criterion is 35 µg/L for example receiving water.

Facility	Current TP (mg/L)	Current Chl-a (µg/L)	Potential TP (mg/L)	Estimated Chl-a	Response potential (Yes or No)	Local limit implications
Example A	0.175	13	0.250	13	No	PMP
Example B	0.350	13	0.400	13	No	PMP
Example C	0.175	32	0.275	>32	Yes	Mass freeze
Example D	0.175	32	0.178	32	No	PMP

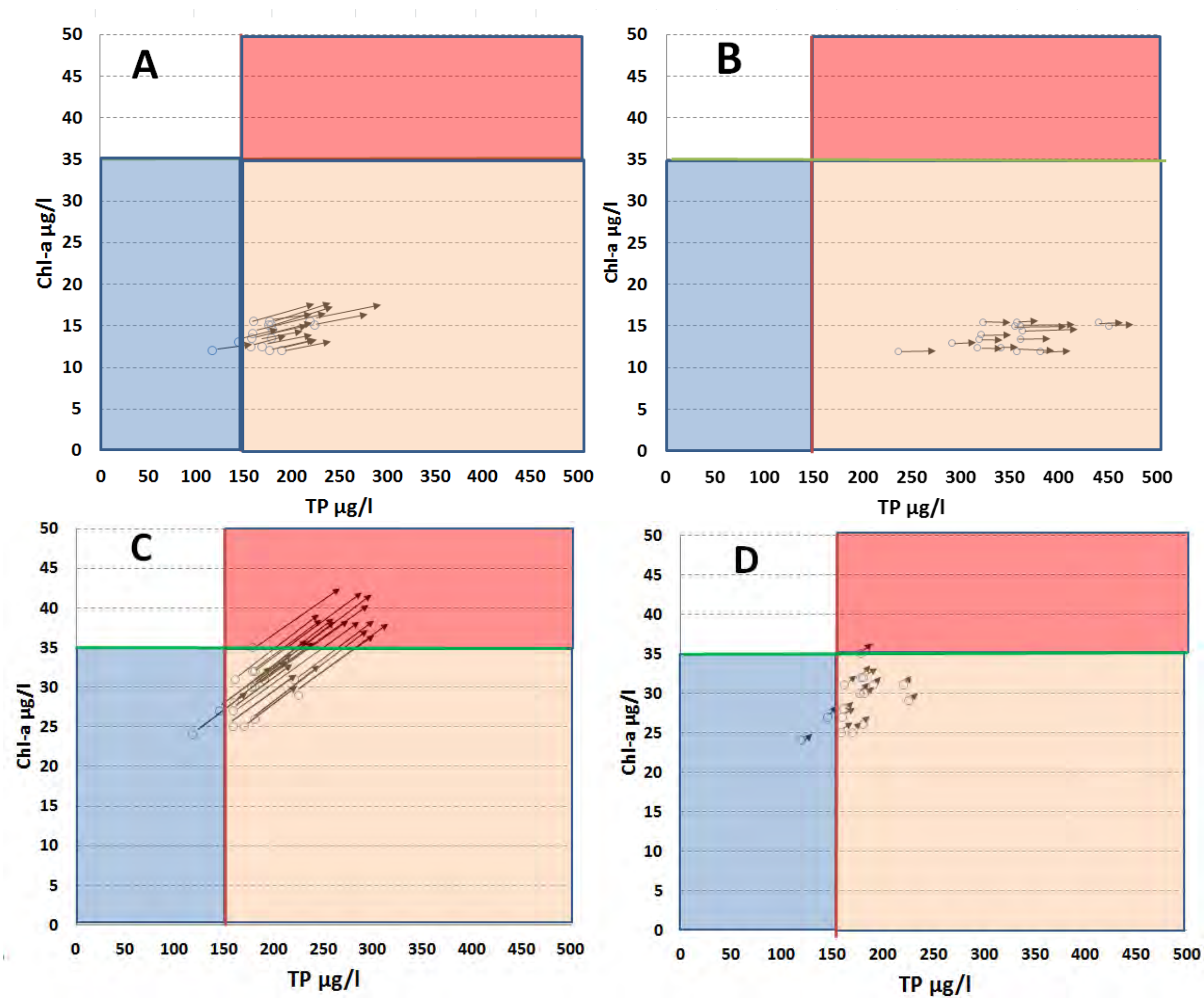


Figure 5. Estimated impact of increased TP on Chl-a for the four examples in Table 2.

Step 3: Wasteload allocation calculation: mass balance approach, water quality model or TMDL/WRAPS

Reasonable potential exists

When a WWTF has RP to cause or contribute to a downstream impairment on a Category 3 stream, a WLA must be established. Like the RP calculation (Equation 1), the WLA calculation (Equation 3) will focus on the TP criterion of RES. This document will focus on a mass balance based equation for calculating WLAs. Water quality models, TMDLs, load duration curves and WRAPS can also be used to establish WLAs. The complexity of these latter techniques is beyond the scope of this document but generally would be favored over the mass balanced equation as they consider more factors in developing the WLA. Examples of completed eutrophication TMDLs for lakes are available on the MPCA webpage (http://www.pca.state.mn.us/index.php/water/index.html; http://www.pca.state.mn.us/index.php/view-document.html?gid=8527).

Protection potential exists

There may be some cases where the immediate or downstream reach meets both the cause and response criteria of RES (Category 2 stream) and protection potential is tripped since the WWTF's actual discharge is well below its potential discharge capacity and/or the stream has limited assimilation capacity. In this situation, the WLA equation is based on meeting the RES at the station where the protection analysis was completed. Equation 3 is used to set the WLA when protection potential exists.

Wasteload allocation calculation: mass balance approach

The mass balance approach is a modified version of the TSD approach for toxics. This section provides sufficient detail for TP effluent limit setting staff to complete mass balance equations for eutrophication standards. Given the great diversity of surface waters in Minnesota, it is anticipated that staff may need to use BPJ to modify or complete the general mass balance equation presented in this document. Nonetheless, this equation serves as a starting point to calculating WLAs.

Equation 3. General mass balance equation for WLA (some terms of equation defined in previous section)

$$WLA_c = \frac{(RES * (Q_s + Q_e)) - (Q_S * C_s)}{Q_e}$$

WLA_c = Wasteload allocation concentration in (mg/L). Can be translated to mass based on Qe and WLA
RES = Total phosphorus river eutrophication standard.

The applicable TP RES criterion varies by river nutrient region. The applicable standards are 0.150, 0.100 and 0.050 mg/L for the south, central and north regions, respectively. In some cases where a river of concern is near region border, a site specific or hybrid number may be used. **The closest downstream river reach with reasonable potential or response potential from Step 2 determines the applicable TP standard.**

Equation 3 example and WQBEL for municipal facility (Note this facility has RP with an existing concentration limit of 1.0 mg/L.)

Total phosphorus RES	RES (mg/L)	0.05	
Receiving water flow rate	Q_s (cfs)	791	
Effluent flow volume	Q_e (cfs)	79.2	
Upstream river TP concentration	C_s (mg/L)	0.025	
	WLA	0.300	mg/L
	Monthly limit	0.629	mg/L
	Mass limit*	174.1	kg/day

***Based on 70 % of AWWDF x monthly limit x conversion factor, conversion of WLA to effluent limits is covered later in the document**

Wasteload allocation calculation: watershed and reach specific models.

The MPCA has extensive experience with watershed, lake and river eutrophication models. In many cases, models are tools used to establish TP WLAs in TMDLs and WRAPS. Models may have the ability to predict outcomes of effluent limits over a range of summer flows, rather than just at the 80% exceeds flow. Given that models will be used in TMDLs to set the ultimate TP allocations for WWTFs that contribute to eutrophication impairments, available models should be used to set allocations prior to final TMDLs when possible. Adjustments can be made to initial allocations from pre-TMDL models in the final TMDL, but MPCA does not anticipate large changes. Effluent limit reviewers have considerable experience with setting WLAs prior to the completion of lake TMDLs. In nearly all cases these allocations have been maintained once the final TMDL has been completed. Given the considerable cost of upgrading WWTFs to meet more restrictive TP limits, effluent limits reviewers strive to set limits compatible with TMDL guidelines.

Mass freeze for response potential

Response potential indicates the additional TP loading from the facility may result in a response above the RES criteria at local or downstream reach. Since the existing actual discharge from WWTF does not cause a response above the criterion, a TP mass "freeze" will insure current conditions are maintained. The current average summer concentration and mass serve as the WLA to establish permit limits that will freeze the WWTF at current TP impact on the river.

> **Example:** The cause criterion for this example is 0.100 mg/L TP and the response criterion is 18 µg/L Chl-a. The current effluent from the WWTF is 10 kg TP/day which equates to a TP concentration of 0.110 mg/L in a local river during the critical 80% exceeds flow. Existing response of the local river is 16 µg/L Chl-a based on three years of monitoring data. Based on the current design of the WWTF, the WWTF could discharge 60 kg/day which equates to a TP concentration of 0.180 mg/L in a local river during the critical 80% exceeds flow. The TP effluent reviewer examined the existing TP and Chl-a data and concluded based on BPJ that an increase of TP from 0.110 at 0.180 during low flow would likely increase Chl-a (i.e. response potential). WWTF issued a 21.0 kg/day (10 kg/day x 2.1 monthly limit multiplier) monthly mass cap due to potential exceedance of response criterion in the local river.

Setting "fair" WLAs and limits for multiple facilities

Many dilution based WLA equations will be based on multiple facilities contributing to a river reach of concern. The MPCA will work with permittees to determine if all facilities' effluent limits should be based on identical concentration WLAs when multiple facilities discharge upstream of a reach of concern. The MPCA has typically assigned more stringent wasteload concentrations for larger facilities, providing modest relief to smaller facilities, which can ultimately limit the need for variances. All facilities generally need to reduce TP concentration when there is RP, but this approach recognizes the "economy of scales" for larger facilities. The WLA can be thought of as a flow weighted WLA when multiple facilities are involved. Past experience has shown that meeting with representatives of WWTFs is an effective technique to finalize TP limits when multiple WWTFs are involved. Various allocation scenarios can be presented and WWTFs can select options that are "fair" for all WWTFs, yet still meets the overall WLA.

The following provides a simplified example of variable WLAs for multiple facilities discharging to the same river reach. An overall concentration WLA of 0.3 mg/L is necessary to achieve the RES criterion. A WLA of 0.2 mg/L is assigned to the largest facility in the watershed, and WLAs of 0.7 mg/L for the smaller facilities in the watershed. The overall flow-weighted WLA would be 0.3 mg/L. TP effluent limit review staff would need to work with engineers and permittees to make decisions on assigning variable WLAs within the example watershed.

Step 4: Converting WLA to permit effluent limit

Reasonable and protection potential based limits

Once the WLA for a particular facility has been calculated, the WLA must be converted into a TP effluent limit. The proposed approach is similar to the approach used to set monthly permit limits for toxics (TSD manual, EPA, 1991). EPA Region V has developed a "2.1" monthly limit multiplier based on major facilities in the state of Minnesota. In the example WLA equation discussed earlier, an annnual WLA of 0.300 mg/L equates to a monthly TP concentration limit of 0.63 mg/L (0.3 mg/L x 2.1 = 0.63 mg/L). By meeting a monthly limit of 0.63 mg/L the facility will average 0.3 mg/L as a long-term summer average which is equivalent to the WLA.

TP effluent data from three WWTFs with the lowest historical monthly effluent limits in Minnesota were examined to verify the validity of the "2.1" monthly limit multiplier for converting WLAs to monthly effluent limits (Table 3). The desired hypothetical WLA based on the procedures in this document of a 0.3 mg/L monthly limit would be equal to 0.143 mg/L. Both Ely and Bemidji have had 0.3 mg/L monthly TP limits for 20 or more years while Princeton's limit is more recent. A "reverse multiplier" was calculated by dividing the monthly effluent limit for each facility by the average effluent concentration. The reverse multipliers for Bemidji and Ely WWTFs both exceeded the "2.1" multiplier indicating performance of these long-term low level treatment facilities is slightly better than expected with a standard 2.1 multiplier. Performance of the Princeton WWTF, based on a smaller dataset than other two facilities, is slightly less than expected based on the standard 2.1 multiplier. Based on the review of these three facilities, it appears that the standard 2.1 monthly limit multiplier will likely achieve the WLA as a long-term summer average.

Table 3. Historical performance of facilities in Minnesota with 0.3 mg/L monthly TP effluent limits.

Facility	Monthly limit (mg/L)	Average concentration (mg/L)	Months sampled	Limit / average
Bemidji WWTF	0.30	0.131	189	2.29
Ely WWTF	0.30	0.136	195	2.21
Princeton WWTF	0.30	0.174	15	1.72
2.1 multiplier	0.30	0.143	NA	2.10

Sensitivity Analysis/Limit type selection: limits based on actual or design flows

A sensitivity analysis should be completed to determine if mass limits alone are sufficient to protect receiving waters (Equation 4-7). The sensitivity analysis is basically multiple runs of Equation 1 with different values for C_e and Q_e. If facilities' flows are near Q_e, sensitivity analysis is of limited value since a facility will need to achieve the WLA_c. Many facilities in Minnesota are discharging well below the Q_e (70% of AWWDF) used in the RP and WLA calculations in Steps 2 and 3. Some of these facilities were overdesigned for various reasons such as projected growth or industrial users that have now gone away. If a facility continues to discharge well below Q_e, then a concentration limit based on the limit setting process outlined in Steps 2 and 3 will result in a limit that is more restrictive than needed to protect the receiving water (Table 4, concentration only sensitivity run). A "sensitivity analysis" can be completed by re-running Steps 2 and 3 with actual average flows instead of 70% of AWWDF. The sensitivity run basically maintains the effluent mass of the WWTF in the original WLA equation.

Equation 4. Concentration of river initial run (C_{ri}):

$$C_{ri} = \frac{Q_s C_s + Q_e WLA_c}{Q_s + Q_e}$$

Re-run reasonable potential (Equation 1) with Q_e at design flow (70% AWWDF for municipals) and WLA_c (result of Equation 3) is substituted for C_e. This initial run should be at the TP criterion since it basis of the WLA_c. Other permit requirements, downstream requirements and margin of safety from TMDLs may result in concentration below the TP criterion at the local reach.

Concentration of river mass sensitivity run (C_{rms}):

Equation 5. Sensitivity analysis -concentration to meet mass at current flow**:**

$$WLA_{cm} = \frac{WLA_m}{Q_{ea}}$$

WLA_{cm}: maximum potential effluent concentration when the mass is fixed at the WLA_m and flow is current actual flow (Q_{ea}) which is less than full capacity (Q_e).

Where:

WLA_m: mass wasteload allocation based on Q_e (70% AWWDF for municipals) and WLA_c from Step 3

Q_{ea}: current actual effluent flow (must be lower than design flow or C_{me} will be equal to the WLA_c)

Equation 6. Maximum concentration of the river if the facility was issued a mass limit only

$$C_{rms} = \frac{Q_s C_s + Q_{ea} WLA_{cm}}{Q_s + Q_{ea}}$$

Re-run RP (Equation 1) with Q_{ea} and C_{em} to determine the maximum concentration of the river if the facility was issued a mass limit only. The C_{rs} will be higher than the initial run since actual facility flow will result in less total flow to dilute the mass of phosphors discharged by the WWTF(s).

Equation 7. Concentration of river concentration sensitivity run (C_{rcs}):

$$C_{rcs} = \frac{Q_s C_s + Q_{ea} WLA_c}{Q_s + Q_{ea}}$$

Optional run: Re-run RP (Equation 1) with Q_{ea} and C_e at WLA_c (result of Equation 3) to illustrate the impact of a concentration limit if WWTF flow remained at current actual flows. The C_{rcs} will be lower than the initial run since actual facility flow and a concentration limit based on design flow will result in less mass discharged than discharged in the C_{Ri} with only slightly less overall dilution flow. This run is useful to illustrate the impact of "excess" flow capacity of WWTFs. The excess flow used in Equation 3 to calculate the WLA_c results in achieving a river concentration well below the RES criterion at the critical 80% exceeds flow if the facility discharges at actual flows.

Interpretation of sensitivity analysis results

Once the sensitivity analysis has been completed, determine whether there is any biologically significant or measureable change in C_r from a mass only limit. Based on the change in C_r select one of the following options for limit types in the permit:

1. If modified C_{rms} results in measurable C_r differences consider implementing a monthly average concentration limit. Multiply non-modified WLA_c by 2.1. Implement as monthly average concentration limit. In the South Fork Crow River Watershed, the watershed outlet went from a C_{ri} of 0.150 mg/L to a C_{rms} of 0.210 mg/L in the sensitivity analysis (Table 4). Concentration limits for the summer season are needed for facilities discharging in the South Fork Crow River Watershed.

Concentration and mass limits option:

Monthly concentration WQBEL (mg/L) = WLA_c (mg/L) * 2.1

Concentration limits apply as monthly averages from June through September.

Sensitivity analysis indicates river concentration could potentially increase significantly with mass only limits.

Table 4: South Fork Crow River Watershed sensitivity analysis. TP criterion is 0.150 mg/L.

Variables	Initial run (C_{ri})	Mass only sensitivity run (C_{rms})	*Concentration sensitivity run (C_{rcs})*
Q_s	13.91 mgd	13.91 mgd	13.91 mgd
C_s	0.075 mg/L	0.075 mg/L	0.075 mg/L
Q_e	**13.32 mgd**	**5.47 mgd**	**5.47 mgd**
C_e	**0.228 mg/L**	**0.56 mg/L**	**0.228 mg/L**
Q_r	27.23 mgd	19.38 mgd	19.38 mgd
C_r	0.150 mg/L	**0.210 mg/L**	*0.118 mg/L*

2. If there is no change in C_r outside of the margins typically associated with field sampling and laboratory uncertainty, apply monthly average mass limit. Multiply C_e by 70% of AWWDF and the 2.1 multiplier. Implement in permit as kg/day monthly average TP limit. In the Le Sueur River Watershed, the estimated watershed outlet concentration went from a C_{ri} of 0.149 mg/L to a C_{rms} of 0.152 mg/L in the sensitivity analysis (Table 5). Concentration limits are not needed for facilities discharging in the Le Sueur River Watershed since mass only limits would not result in a biological significant change in C_r.

Mass limits only option:

Mechanical facilities: Monthly mass WQBEL (kg/day) = WLA (mg/L) * **70% of AWWDF** * 2.1 * 3.785

Mass limits apply as monthly averages from June through September.

Table 5. Le Sueur River watershed sensitivity analysis. TP criterion is 0.150 mg/L.

Variables	Initial run (WLA)	Mass only sensitivity run	Concentration sensitivity run
Q_s	34.9 mgd	34.9 mgd	34.9 mgd
C_s	0.041 mg/L	0.041 mg/L	0.041 mg/L
Q_e	**4.95 mgd**	**4.01 mgd**	**4.01 mgd**
C_e	**0.91 mg/L**	**1.12 mg/L**	**0.91 mg/L**
Q_r	39.8 mgd	38.9 mgd	39.8 mgd
C_r	0.149 mg/L	**0.152 mg/L**	0.128 mg/L

Protection potential limits

The goal of the mass freeze when protection potential exists is maintain the current impact of the WWTF on the receiving water of concern. The intent of these limits is not to result in new treatment works unless the WWTF expects actual increases in effluent flows. TP effluent limit reviewers will use

BPJ to establish mass and/or concentration limits that maintain existing “average” loading from the WWTFs.

Step 5: Verify final limits (multiple downstream endpoints and seasonal considerations)

The final step of the limit setting process requires the effluent limit reviewer to evaluate all applicable regulations and requirements for local and downstream resources to determine the TP limits to be included in the NPDES permit of a given WWTF. The limit reviewer will strive to make the permit as simple as possible, yet be mindful of multiple downstream resources, antidegradation, antibacksliding, seasonal considerations and TBELs. In this step, the effluent limit reviewer will also determine if it is necessary to include concentration and/or mass limits. After the final limits and requirements are determined by the TP effluent limit reviewer, compliance schedules and optimization plans will be included if needed in the NPDES permit by MPCA permitting staff (Appendix F).

RES based limits apply June-September

Since RES were specifically developed for June to September, the majority of limits based on RES will be applied from June to September only, since rivers generally do not retain annual TP loads like many lakes. The TP requirements for any given discharge may vary by season if there are multiple eutrophication impaired waters downstream. It is quite possible that some facilities will have a monthly mass or concentration limit to protect local resources from June to September, an annual mass limit to protect downstream resources and a SDR limit from a historical permit reissuance. The effluent limit reviewer will examine the limits to determine which limit is most restrictive throughout the calendar year. The most restrictive limit will be applied for each “season”. To simplify permits, some limits may be eliminated if less restrictive than another limit(s) throughout the year. Multiple limits to protect a single waterbody are generally avoided to reduce redundancy and unnecessary complexity in permits.

Seasonal example: Mechanical facility with AWWDF = 2.0 mgd

- Maintains 1.0 mg/L TBEL applicable as 12 month moving average from January to December
- Assigned 0.4 mg/L monthly limit from June to September to protect local river
- Assigned annual mass based limit to protect Lake Pepin of 2210 kg/yr (based on AWWDF*0.8mg/L*conversion factor)

Outcome: all three limits are included in the permit

Seasonal consideration for state discharge requirements (new and expanding facilities)

SDRs allow for seasonal limits (Minn. R. 7053.0255 Subp. 4), but few if any permittees have requested seasonal limits since 2008 when the rule allowing seasonal limits was adopted. This rule was geared towards new and expanding facilities meeting TBELs and was not tailored for facilities with WQBELs for lakes and rivers. Since 2010, many annual mass WQBELs have been assigned for existing WWTFs that were not expanding.

Compliance schedules and optimization plans (see Appendix F)

The MPCA has flexibility with permit language to protect rivers from eutrophication. This document has focused primarily on calculating TP effluent limits. PMPs or optimization plans may also be required. These plans will encourage permittees to reduce pollutant source loading and better utilize existing treatment works to remove phosphorus.

Alternatives to treatment for permittees

There are multiple options for municipalities and industries to consider if treatment to meet proposed RES based effluent limits are not the most prudent option. Some options include spray irrigation, large land based systems or other potential treatment types that do not discharge to surface waters during summer. When possible, permit language for stabilization ponds to avoid the summer eutrophication window is an example of a permit requirement that is not tied to a numeric effluent limit. Given the unique nature of some industrial facilities, permit flexibility may be examined where reasonable and appropriate.

Additional Monitoring Considerations (see Appendix C)

Sufficient water quality data, outlined in *Minnesota Nutrient Criteria Development for River* (MPCA, 2013), is required for RP analysis. In areas where potential impacts from WWTFs are unclear due to a lack of data, RP analysis is not completed. In these situations, MPCA can evaluate the need for additional RES based monitoring in select locations. A number of factors need to be taken into consideration when determining what, if any, reaches need additional monitoring. Below is a list of those factors and how they will be considered.

Lakes: (Steps 1-5)

TP WQBELs for lakes have been issued since 2008 when LES were adopted. Simple mass balance equations have not been used to calculate WQBELs for WWTFs upstream of lakes. The BATHTUB model has been the primary tool for calculating WLAs for lakes. In some cases, such as Lake Pepin, more complicated models have been used to calculate WLAs. The five steps for assigning river eutrophication WQBELs are similar for lakes, but several key differences will be highlighted for each step consideration.

Step 1: Data assessment

Data for lakes is almost universally collected on an equal interval basis. Summer samples are averaged by year, then the most recent 10-yr period to compare to the applicable LES (MPCA 2014b, http://www.pca.state.mn.us/index.php/view-document.html?gid=16988).

Step 2: Reasonable potential

RP for facilities that discharge at a concentration of TP above the LES are done on a case by case basis. A model such as BATHTUB is used to determine if a given facility has RP to contribute to a lake eutrophication impairment or cause a lake meeting LES to exceed LES. The process is similar to that for rivers except that the equation(s) are contained within the model. Multiple model runs may be needed for facilities discharging well below design flows.

Step 3: Wasteload allocations

The WLA for facilities with RP is calculated within a lake model. MPCA has considerable experience with this process since 2008. The typical averaging period for a lake model is one year, and weather conditions range from dry to average years depending on the specific lake. Predictive tools range from BATHTUB models based on runoff coefficients to 3-dimensional water-quality models such as the model used for Lake Pepin. Models incorporate TP from multiple sources including: stormwater, rural nonpoint, atmospheric deposition, WWTFs and other sources if data exists. In general, models are used to determine the pollutant load reduction necessary to meet standards or the assimilative capacity in the waterbody. Permitted loading from facilities upstream of the resource are adjusted accordingly to achieve a protection or restoration goal.

Step 4: Conversion of WLA to effluent limits

There have been two primary practices for assigning TP effluent limits for facilities with RP. The first method is simply assigning the WLA as an annual mass limit. No multipliers are applied to the annual mass limit. An annual limit is issued since lakes have long residence times, and the averaging period for most lake models is one year. Limits are typically expressed as 12 month moving totals. No concentration based WQBEL is assigned to these facilities.

For lakes where the facility is a major source of TP, multiple model runs are completed to verify that an annual mass is protective. This is another example of sensitivity analysis where the model is run with the multiple WWTF flows and effluent concentrations. If these scenarios reveal that an annual mass limit is not sufficient to protect the given lake, then monthly concentration limits are assigned. These limits may be seasonal, and a variability of treatment multiplier can be used. Generally monthly average concentration limits are only assigned where point sources are the primary pollutant load source.

Step 5: Verify final effluent limits

Determine whether limits designed to support LES in the nearest lake or reservoir are also sufficiently protective of the next downstream water. In general, because LES are lower than RES, most limits to meet the first downstream lake will also be protective of other downstream rivers. However, there is the potential that a limit set to meet a shallow lake may need additional restrictions to be protective of a deep lake farther downstream.

References

MPCA, 2014a. The Minnesota Nutrient Reduction Strategy. 44 pp. http://www.pca.state.mn.us/index.php/view-document.html?gid=20213.

MPCA, 2014b. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List: 2014 Assessment and Listing Cycle. 54 pp. http://www.pca.state.mn.us/index.php/view-document.html?gid=16988.

MPCA, 2013. Minnesota Nutrient Criteria Development for Rivers. 176pp. http://www.pca.state.mn.us/index.php/view-document.html?gid=14947.

MPCA, 2012. Mississippi River Pools 1 through 8: Developing River, Pool, and Lake Pepin Eutrophication Criteria. 83 pp. http://www.pca.state.mn.us/index.php/view-document.html?gid=14927.

MPCA (2015). Assessment procedures for river eutrophication standards.

Tetra Tech. (2009). Minnesota River Basin Turbidity TMDL Scenario Report. Prepared for Minnesota Pollution Control Agency by Tetra Tech, Inc., Research Triangle Park, NC.

Wisconsin Department of Natural Resources (2011). Wisconsin administrative code NR 217.6. Register January 2011 No. 661, pages 149 - 150-6.

U.S. EPA, 1991. Technical support document for water quality-based toxics control. EPA/505/2-90-001, PB91-127415, 335 pp.

Appendices

Additional strategies are considered when implementing RES based TP limits. These additional strategies are important when determining the most effective way of protecting RES by means of implementing RES based limits. Appendices A – F outline these strategies which include, but are not limited to, WWTF discharge window, river response criterion exceedance potential, additional watershed ambient monitoring, and PMPs and optimization plans.

Appendix A. Special considerations for municipal pond facilities.

Many smaller communities in Minnesota have stabilization pond WWTFs. These facilities are allowed to discharge seasonally which partially overlaps with the summer season of RES. There are two basic categories when establishing RES based TP limits for stabilization ponds. Considerations for downstream waters and basin plans are not independent of local RES based limits and will, in many cases, overlap. This will be addressed in Step 5 of the RES implementation procedures.

1. **Reasonable potential or protection potential exists for RES in immediate HUC 8 watershed.**

    a. **Avoid discharging from June to September; Q_e = 0 in Equation 1.** A facility can change operations to avoid summer discharge. This allows a facility to be removed for RES WLA calculations. Stabilization ponds are already prohibited from discharging in July and August. If existing records indicate that a facility has not routinely discharged during June and September, and has adequate storage capacity to avoid a summer discharge, the following items will be considered.

        i. Language in permit to prohibit summer discharge. Exceptions may include discharge under extreme high flow conditions. The facility will be required to notify MPCA of intention to discharge from June to September.

        ii. Facility may still have annual limits depending on downstream waters and basin strategies.

        iii. Facility may have to construct to provide additional storage to avoid summer window.

        This strategy is effective for new and expanded pond facilities.

    b. **If a facility needs to discharge in June and September.** For the WLA calculation, flow will be equivalent to 70% of AWWDF. Assume that this flow is spread over the entire summer period even though ponds can only discharge during a portion of the summer. This technique is possible since the standard is a long term average over multiple summers rather than a “do not exceed” standard averaged over a short duration such as a 4-day average.

        i. For the sensitivity analysis (Equations 4-7), Q_{ea} is equivalent to average summer flow during recent summers (five years). To calculate this flow take the total volume discharged during June and September divided by 122 days. The intent of the conversion is to represent the long-term average flow of the facility during the summer. These calculations will determine if going from existing flows to design flows will significantly impact the receiving water. For facilities with limited growth potential, consider language about maintaining current flows during summer to minimize impacts from discharge. Significant new sources of flow will require new calculations.

        ii. RES based limits will only apply from June through September, while downstream resources or basin strategies may require annual limits.

2. **Response potential exists for RES in immediate HUC 8 watershed.** In these watersheds current performance of the stabilization facilities is adequate, but increased loads may increase response in the river. Slight adjustments in permit language or a mass freeze will minimize the impact of ponds during summer. Downstream resources or basin strategies may require annual limits.

   a. Pond facilities have the potential to avoid RES based limits if:

      - Existing records indicate that the facility has not routinely discharged during June and September.
      - They can change operations, to avoid summer discharge.
      - The facility agrees to permit language to prohibit summer discharge in the future. Exceptions may include discharge under extreme high flow conditions. The facility will be required to notify MPCA of intention to discharge from June through September.
      - Facilities may still have annual limits depending on downstream waters and basin strategies.

   b. Keep the option to discharge in June and September and assign mass freeze.

      - Develop mass or concentration limits to maintain “average” discharge of the facility.
        - Consider intervention limits due to extremely variable flows of some pond facilities from year to year.
      - If feasible based on past performance, insert language to reduce June and September discharges when possible. Focus on reducing discharges in September since points sources generally have a greater impact on TP loads during September than June.
      - Require PMP
      - Apply annual limits if needed for downstream resources and basin strategies.

Appendix B. Response potential for facilities discharging to rivers with elevated TP and response criteria that meet RES

The current monitored water quality condition is acceptable at current actual WWTF loads since the response criteria do not exceed standards. Use BPJ to determine if increase from current loads to permitted load will cause an elevated response. An extensive modeling effort is not needed for an efficient use of agency time for response potential. A weight of evidence approach will be needed since the most restrictive requirement of response potential is a mass freeze.

Table 6. General considerations when evaluating response potential.

Consideration	Response potential more likely	Response potential less likely
Response criteria within 75% of RES	Yes, some evidence that river has potential to respond to TP additions	No, evidence that river does not respond currently elevated TP levels
Current TP levels in river near TP criterion	Yes, depending on other factors more TP may increase response	No, existing high TP levels well above TP criterion do not cause response, it is unlikely additional TP will cause a response
Current TP is well below criterion at low flows	Yes, this may be a nonpoint source dominated river where TP could increase during low flows due to WWTFs discharging at design flow	No, there is already sufficient TP at low flow at actual WWTF loads
Ortho phosphorus levels during low to moderate flows	Existing ortho phosphorus levels are low suggesting possibility of phosphorus limitation	Existing ortho phosphorus levels are above detection limit suggesting algae are not phosphorus limited
Existing sample data is from high flow years	Yes, higher flow summers tend to increase TP and decrease Chl-a	No, existing data from moderate to low flow summers indicate that river is not conducive for algal production
TP & Chl-a relationship indicates response potential	Yes, graph indicates additional TP will likely lead to exceedance of Chl-a criterion (Figure 5C)	No, graph indicates additional TP will likely not lead to Chl-a criterion exceedance (Figure 5A, 5B and 5D)
Similar nearby rivers with higher TP exceed response criteria	Yes, be mindful of how “similar” the rivers are	No, be mindful of how “similar” the rivers are
WWTF has considerable unused capacity	Yes, design loads will be much higher than current loads	No, design loads will be similar to current loads
River has low baseflows in summer	Yes, WWTF will have more impact on TP concentration in the river	No, WTTF will have less impact on TP concentration in the river

General outcomes of response potential

1. Limits from downstream response or basin plan result in similar or lower loads than current actual discharge.
    a. Basically, current discharges are frozen at existing levels.
2. Response variable close to criterion. Actual loading could increase with downstream based limits. BPJ that response could increase.
    a. Optimization plan or mass freeze to maintain current loading which equates to meeting response criterion.

3. Red River mainstem or similar river station: BPJ that TP will not cause a response even at highest possible loading rates.
    a. Consider basin plans and require optimization plan or PMP

Appendix C. Additional ambient monitoring considerations for river eutrophication standards

Justification for additional monitoring

Much of the implementation procedures focus on river reaches where receiving water monitoring data for both cause and response criteria of RES are available. This approach is both defensible and efficient since the effluent limit reviewer has actual data of the impact of TP on a given river. For streams with limited response data (e.g. < 10 Chl-a samples in 10 years), estimating the impact of TP above the cause criterion would require some of the following: additional river monitoring, modeling, peer review and BPJ. The additional time requirements for effluent limit staff for this type of analysis would result in a large backlog of expired permits and there would still be considerable uncertainty about the likelihood of response above RES criteria due to maximum allowable discharge of TP from a WWTF. The MPCA is committed to assessing the impacts of TP on rivers through its extensive water quality and biological monitoring program. The data generated through the monitoring programs will be analyzed fully in the WRAPS process and subsequent permit reissuances. If a response to TP above the response criteria is monitored after the initial RES based reissuance or TP is identified in the WRAPS process as direct link to impaired biology or elevated periphyton, then limits will be set to meet the TP criterion/target needed to reduce the response to the applicable criterion.

There is some risk that a facility that builds for a downstream response based TP limit in the first permit cycle may have to install additional treatment due to a local response based on updated monitoring and analysis in subsequent permit reissuances. This is an inherent risk of a response driven standard and the procedures outlined in this document.

Future monitoring

Typically, MPCA will collect additional water quality for those locations downstream of existing WWTFs, whereas individual WWTFs may be required to collect appropriate water quality data for those areas downstream of new or expanded WWTFs. These data will then be used to calculate appropriate WQBELs for the respective WWTFs upstream of the collection sites.

What parameters will be collected?

Additional water quality collected for RES based TP limit determination will primarily use TP and Chl-a samples; however, DO flux and BOD_5 may also be considered.

When will sample collection occur?

Additional water quality data collected by MPCA is expected to be incorporated with the statewide IWM plan. Minnesota’s 81 watersheds are on a 10-year extensive monitoring cycle completed over a consecutive 2-year period. Incorporating additional monitoring with the on-going IWM work will provide consistency and certainty.

Where will sample collection occur?

Where additional monitoring is being considered in a given watershed, a range of factors will guide the location of such monitoring. Below is a list of the primary factors and how they will be considered.

- River size: While adopting the standard, MPCA found that Chl-a is generally less abundant per unit of TP in wadeable streams than nonwadeable streams (Figure 6).

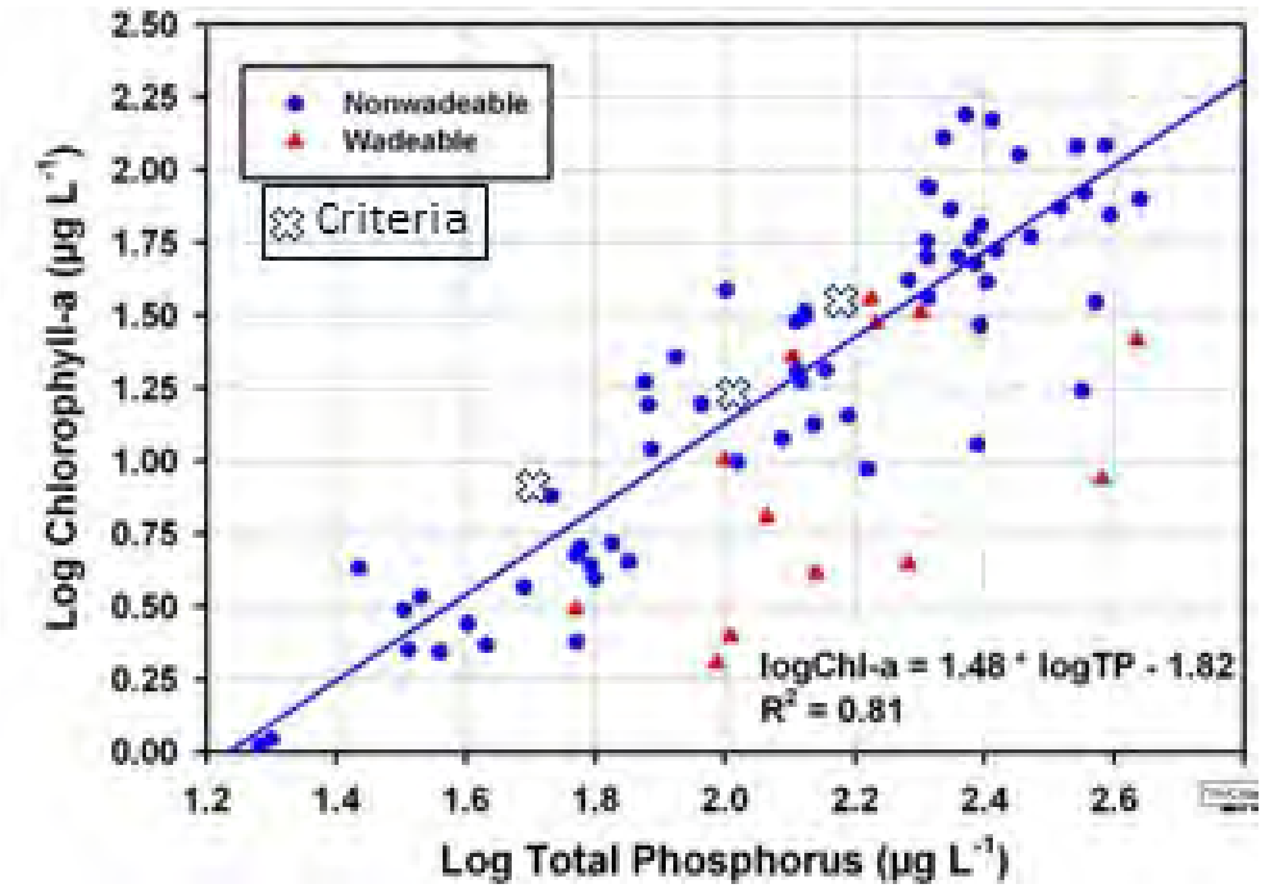


Figure 6. Comparison of the summer average response of suspended algae (chlorophyll-a) to summer average TP in wadeable streams and nonwadeable river in Minnesota. River eutrophication criteria for the three river nutrient regions were included as a point of reference.

- Water classification: additional monitoring will be completed for waters of interest that are Class 2 waters, those designated to protect for aquatic life and recreation. Additional sampling will not be completed for those waters not designated as Class 2 waters (see location D in example below).
- High priority waters: extra effort will be made to monitor high priority waters (e.g. outstanding resource value waters) where appropriate in addition to any other applicable nondegradation review requirements.
- Distance: samples collected should be representative of water quality impacts from WWTFs of interest. Samples collected too far downstream may include additional dilution from tributaries (see locations C, D, and E in example below).
- Geographic region: certain geographic regions have a higher or lower tendency to grow excess algae. Those areas that have a higher tendency to grow algae (i.e. south river nutrient region) are of higher concern compared to areas that have a lower tendency to grow algae (i.e. north river

nutrient region). Data provided by the statewide river assessment will provide additional support characterizing streams as higher or lower potential for growing algae.

- Physical conditions: A number of physical conditions can influence a river's ability to grow algae, including shading, impoundments, lakes and wetlands. Monitoring locations selected should represent the area of interest with minimal influence from unnatural geomorphology (see location A in example below).
- Residence time: allowing sufficient time for algae to grow is important when determining how far downstream from a WWTF a sample is collected. Typically a 1-2 day residence time is considered the minimum time needed for algae to grow if present in the right conditions (see location E in example below).
- Relative contribution: WWTFs that contribute a significant load contribution relative to the receiving water of interest are of higher concerns than those WWTFs that contribute a relatively insignificant amount of loading to the receiving water where additional sampling is considered (see locations B and C in example below).

How many sample locations will be selected?

The number of sample locations within a watershed will vary. Coordinating efforts within MPCA can lead to more sampling locations available for additional RES based monitoring. In general, about three to seven sample locations will be identified throughout the watershed for all IWM work. This includes one sample location at the watershed outlet and the remaining six throughout the watershed typically located at HUC 11 outlets (Figure 7). When possible, one or more of these locations may be strategically located for additional RES monitoring for assessing the impact of larger WWTFs.

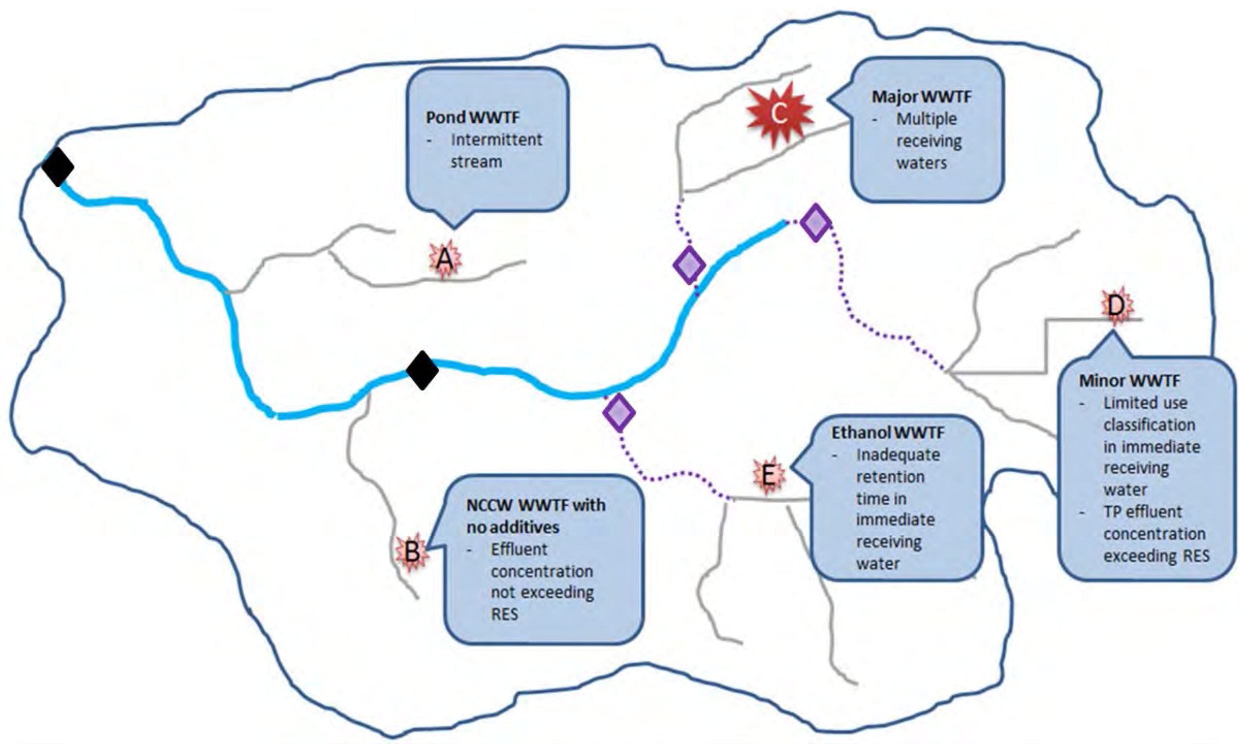


Figure 7. Example watershed with three stream locations (purple diamonds and dotted line, HUC 11) where additional RES monitoring would be recommended. Blue line identifies sufficient water quality data for RES analysis based on two existing monitoring locations.

Appendix D. Examples of current background TP concentration at 80% exceeds flow (C_S)

This brief appendix provides two examples of the variable C_S (current background at 80% exceeds flow) referenced in Equations 1 through 7 in the main document. Typically, C_S is calculated by averaging TP samples from 75 to 85% exceeds when no point sources are present. When a monitoring station is impacted by WWTFs, the contributions from WWTFs are removed in Equation 2 of the main document. The C_S of the Straight River upstream of Owatonna is near the TP criterion at the 80% exceeds flow so there is limited dilution for WWTFs (Figure 8). There are essentially no point sources upstream of the Straight River (S003-015) station. In the Kettle River, C_S is below the TP criterion and some dilution is available for point sources (Figure 8. Upstream river has limited dilution at 80% exceeds flow. Summer TP of Straight River (S003-015) from 2000-2014. Average TP concentration at 80% exceeds flow (75% - 85% shaded area) is 0.145 mg/L. Blue line represents daily load at RES criterion of 0.150 mg/L. Flow at station E39101001 (Straight River near Faribault, Minnesota) was selected for illustration purposes. Flow was not adjusted to represent expected lower flows at upstream water-quality site (S003-015). Daily loads are likely elevated, but flow exceedance percentile should be representative surrogate for S003-015.

).

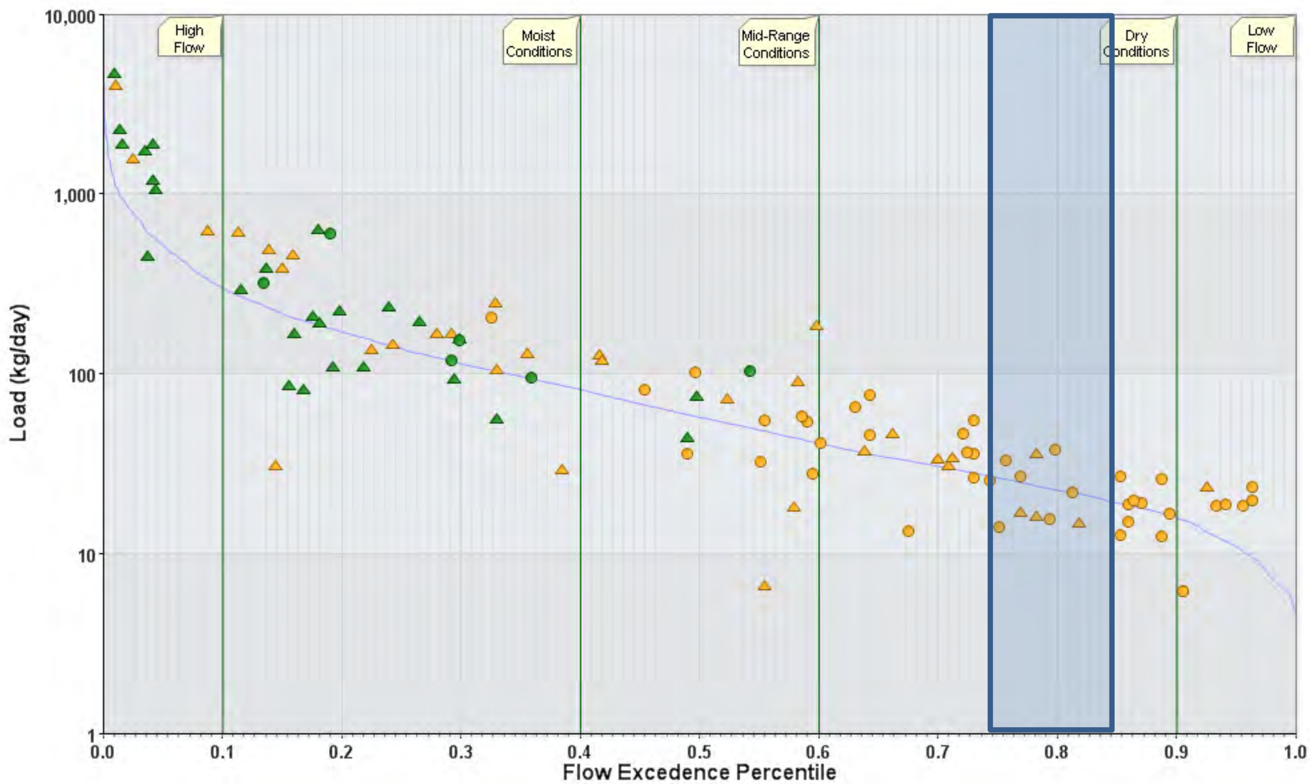


Figure 8. Upstream river has limited dilution at 80% exceeds flow. Summer TP of Straight River (S003-015) from 2000-2014. Average TP concentration at 80% exceeds flow (75% - 85% shaded area) is 0.145 mg/L. Blue line represents daily load at RES criterion of 0.150 mg/L. Flow at station E39101001 (Straight River near Faribault, Minnesota) was selected for illustration purposes. Flow was not adjusted to represent expected lower flows at upstream water-quality site (S003-015). Daily loads are likely elevated, but flow exceedance percentile should be representative surrogate for S003-015.

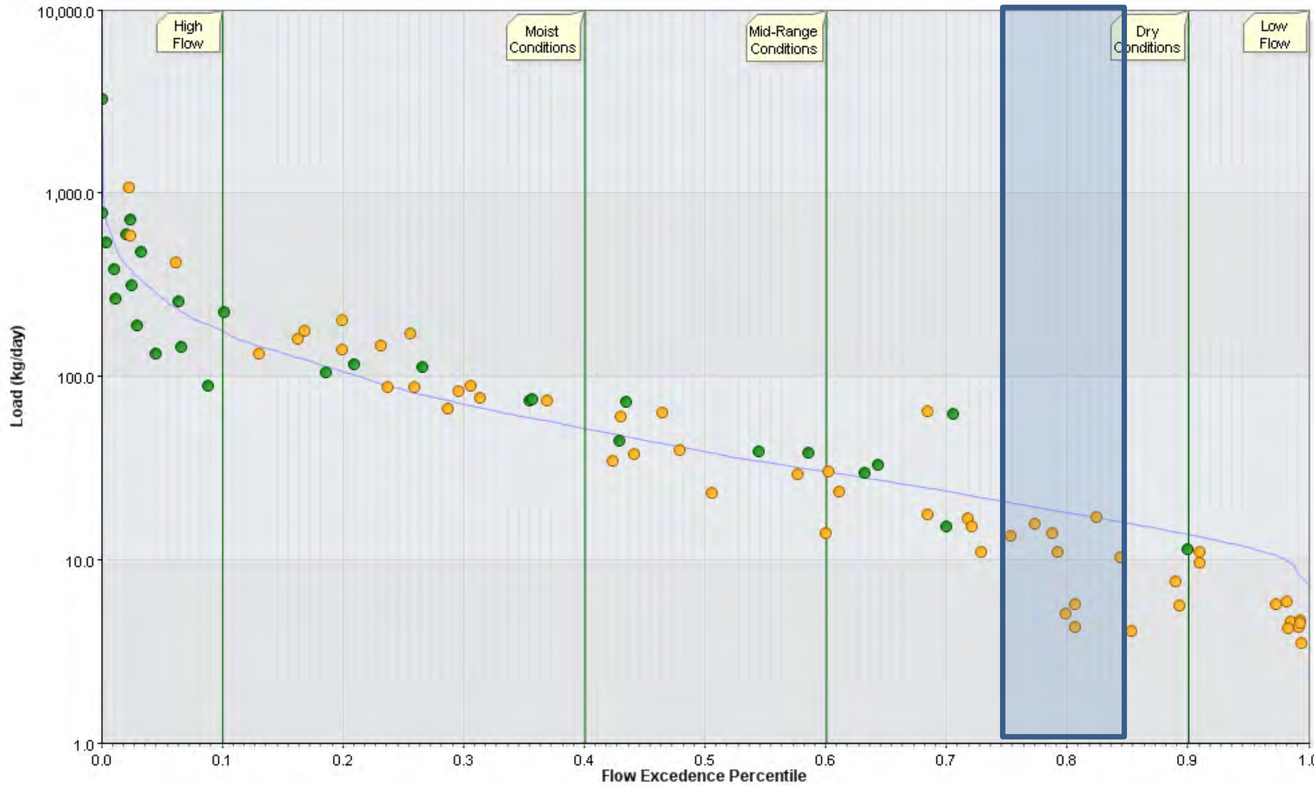


Figure 9. Summer TP load duration for the Kettle River (S000-121) from 2004 – 2013. Colors: green = June, yellow = July - September. Flow exceedance percentile based on Kettle River at Sandstone from 1984-2013. Existing average concentration at 80% exceeds flow and actual historical WWTF discharges is 0.038 mg/L. Concentration without WWTFs is 0.037 mg/L.

Appendix E. Simplified river examples

Seven simplified RES analysis examples are shown below. In each situation, sufficient water quality allow for RES analysis in local and downstream waters. These examples demonstrate various situations where one or more of the following management strategies may be appropriate: RES and LES based limits, TP mass cap limits, PMPs and optimizations plans, and basin plans. The examples are not intended to provide an exhaustive list of every situation found in Minnesota; however, they cover the majority.

Current Condition Categories

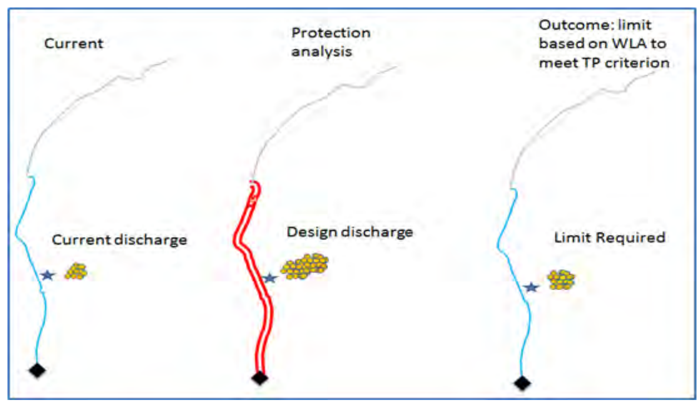
- Category 1 - Insufficient RES data
- Category 2 - TP and response meeting
- Category 3 - TP exceeds and response exceeds
- Category 4 - TP exceeds and response meeting

Potential analysis (response potential, protection potential analysis or reasonable potential)

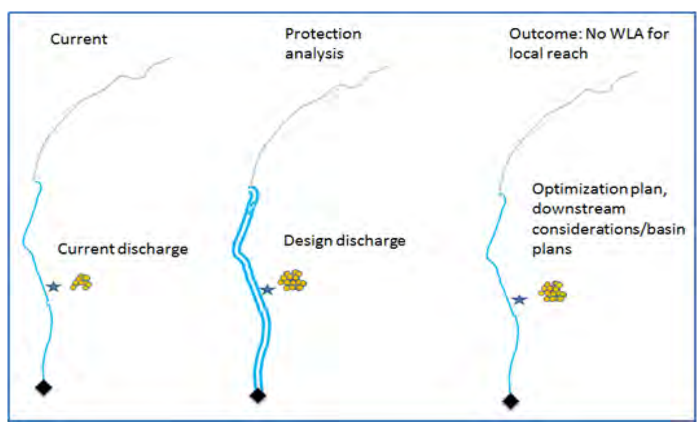
- **Potential does not exist**
- **Potential exists**

WWTF TP load (local and delivered)
WWTF location
Potential future monitoring
Current river monitoring location

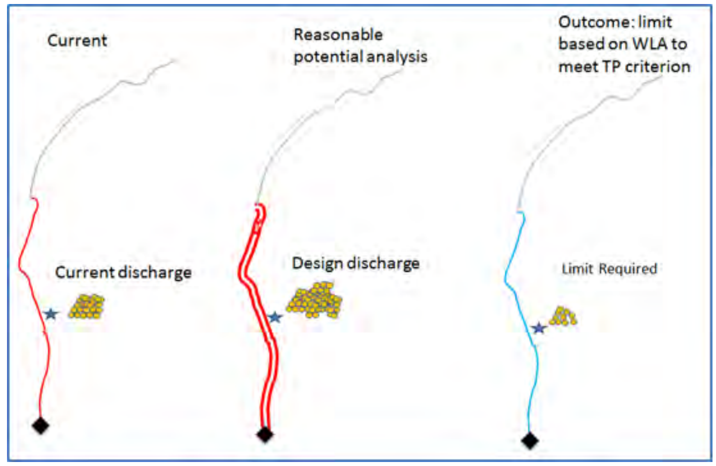
Example 1. Simplified RES analysis example where a RES based limit is necessary to meet the TP causal criterion in the local reach. The current condition (left figure) indicates the local reach is meeting RES. Further protection analysis (middle figure) indicates that under low flow and WWTF design conditions, there is the potential for the river to exceed RES. Therefore, a limit based on the WLA to meet applicable RES TP criterion, under low flow conditions, is set for the WWTF (right figure). The WLA is slightly larger than the current discharge amount.



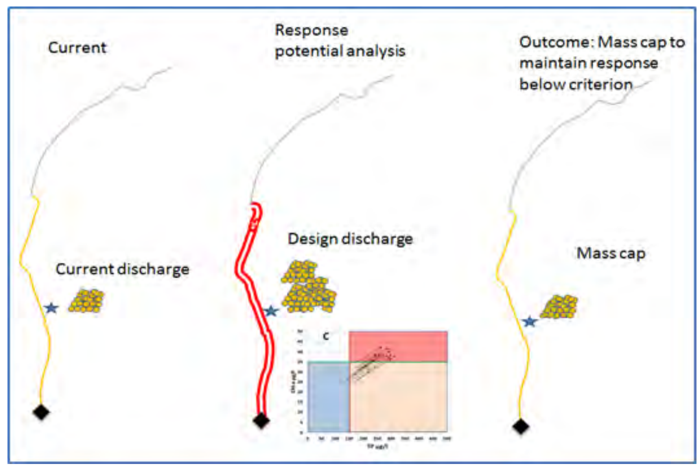
Example 2. Simplified RES analysis example where no WLA is necessary to meet the TP causal criterion in the local reach. The current condition (left figure) indicates the receiving water is meeting RES. Further protection analysis (middle figure) indicates that under low flow and WWTF design conditions, the local reach is still anticipated to meet RES. Therefore, no WLA is required to meet the RES TP criterion in the local reach, under low flow conditions (right figure). Alternatively, optimization plans and downstream considerations, including basin plans, are implemented as necessary. These will likely maintain loading at or below the WWTF design discharge capacity.



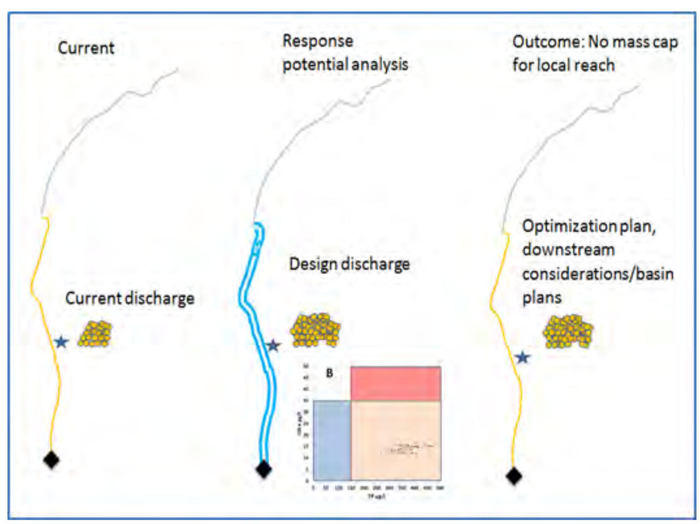
Example 3. Simplified RES analysis example where a RES based limit in the local reach is necessary to meet the TP causal criterion. The current condition (left figure) indicates the receiving water is exceeding RES (both cause and response criteria). The RP analysis (middle figure) indicates that under low flow and WWTF design conditions, the local reach is still anticipated to exceed RES. Therefore, a limit based on the WLA to meet the RES TP criterion in the local reach, under low flow conditions, is required (right figure). The WLA is less than what is currently being discharged.

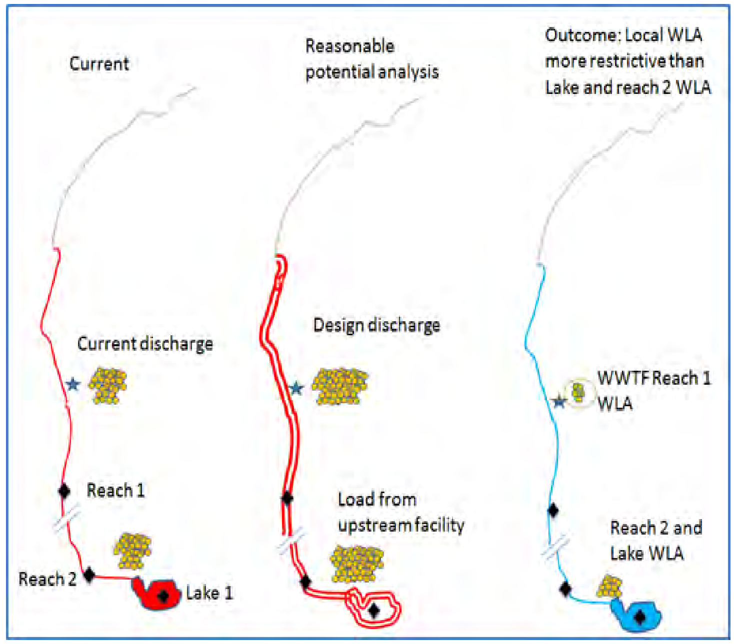
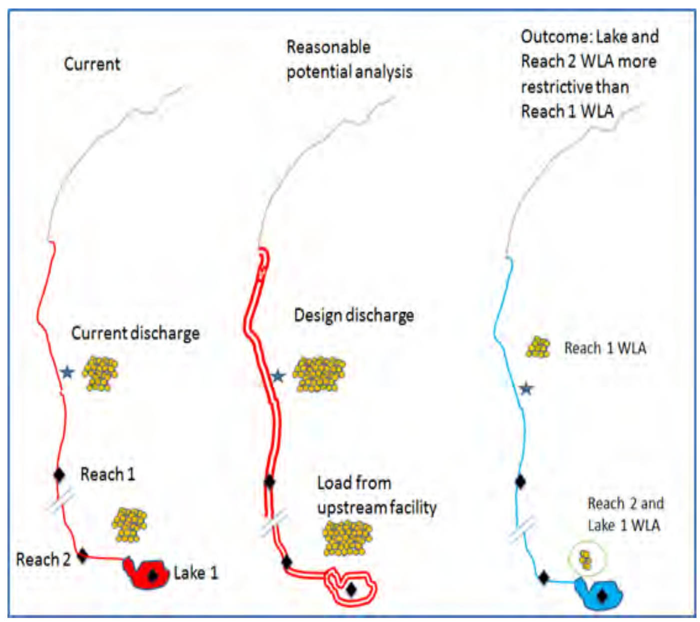


Example 4. Simplified RES analysis where a WWTF TP mass cap is needed in order to protect the local reach. The current condition (left figure) indicates the local reach has elevated TP, but not Chl-a concentrations. A response potential analysis (middle figure) shows the WWTF at design conditions could increase the response at the local reach water above a RES response criterion. TP and Chl-a concentrations in the local reach indicate a positive linear relationship. As TP concentrations increase, Chl-a concentrations also increase. As such, a TP mass cap is applicable for the WWTF to maintain loading at the current condition in order to maintain the response concentration below the criterion.



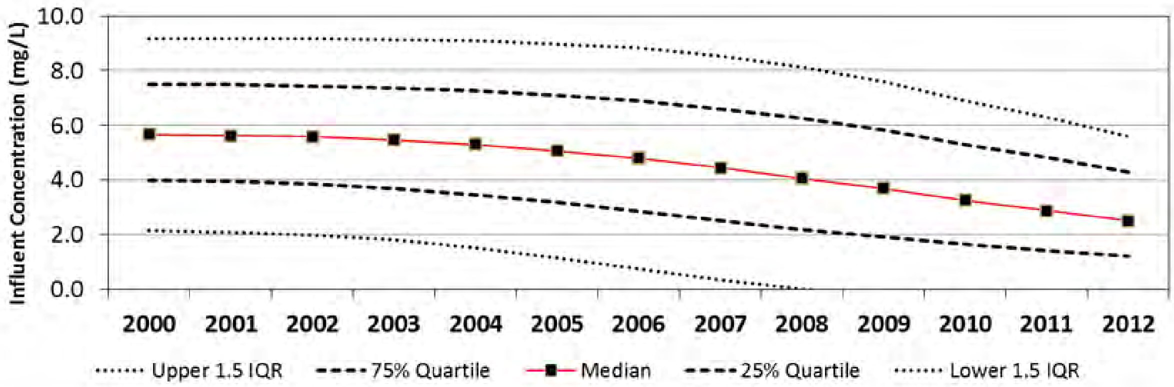
Example 5. Simplified RES analysis where a WWTF TP mass cap is not needed to protect the local reach. The current conditions (left figure) indicates the local reach has elevated TP, but not Chl-a concentrations. A response potential analysis (middle figure) shows under WWTF design conditions, the local reach water quality is anticipated to meet RES criteria. TP and Chl-a concentrations indicate a nonlinear relationship. As TP concentrations increase, Chl-a concentrations tend to remain relatively stable. As such, a TP mass cap for the WWTF is not necessary to maintain the response concentration below the response criteria (right figure). Alternatively, optimization plans and downstream considerations, including basin plans, are implemented as necessary. These will likely maintain loading at or below the WWTF design discharge capacity.



Example 6. Simplified example of RES analysis where RES and LES based TP limits are necessary. The current condition (left figure) indicates Reach 1 and 2, and Lake 1 all exceed their eutrophication criteria. It also shows the current WWTF discharge going into Reach 1 is also making it to Lake 1 based on conservative transport assumptions. RP analysis (middle figure) indicates the WWTF has the potential to cause or contribute to a downstream impairment for both rivers and lakes. Under low flow and WWTF design conditions, RES criteria are expected to be exceeded from Reach 1 down through Lake 1. As such, a specific WLA is derived for the WWTF (right figure) so that under low flow conditions, the local reach and downstream river and lake are anticipated to meet applicable eutrophication standards. The RES based WLA for Reach 1 is more restrictive than the WLA for Reach 2 and Lake 1. The RES and LES WLAs are less than what is currently being discharged.	
Example 7. Simplified example of RES analysis where RES and LES based TP limits are necessary. The current condition (left figure) indicates Reach 1 and 2, and Lake 1 are all exceeding their eutrophication criteria. It also shows the current WWTF discharge going into Reach 1 is also making it to Lake 1 based on conservative transport assumptions. RP analysis (middle figure) indicates the WWTF has the potential to cause or contribute to a downstream impairment for both rivers and lakes. Under low flow and WWTF design conditions, RES criteria are expected to be exceeded from Reach 1 down through Lake 1. As such, a specific WLA is derived for the WWTF (right figure) so that under low flow conditions, the local and downstream river reach are anticipated to meet RES and the downstream lake is expected to meet LES. The RES based WLA for Reach 1 is less restrictive than the WLA for Reach 2 and Lake 1. The RES and LES WLAs are less than what is currently being discharged.	

Appendix F. Phosphorus Management Plan/WWTF optimization

The PMP concept has been incorporated in NPDES permits in Minnesota for the last 15 years. It was originally developed as a set of permit requirements designed to ensure the optimization of phosphorus removal at municipal WWTFs, primarily through the management and reduction of upstream sources. Relatively successful efforts in this regard are demonstrated by a 3.2 mg/L median influent concentration reduction from 5.7 mg/L in 2000 to 2.5 mg/L in 2012 (Figure 10).



Influent	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Upper 1.5 IQR	9.2	9.2	9.2	9.1	9.1	9.0	8.9	8.5	8.1	7.6	6.9	6.3	5.6
75% Quartile	7.5	7.5	7.4	7.4	7.3	7.1	6.9	6.6	6.3	5.8	5.3	4.8	4.3
Median	5.7	5.6	5.6	5.5	5.3	5.1	4.8	4.4	4.1	3.7	3.3	2.9	2.5
25% Quartile	4.0	3.9	3.8	3.7	3.5	3.2	2.9	2.5	2.2	1.9	1.7	1.4	1.2
Lower 1.5 IQR	2.2	2.1	2.0	1.8	1.5	1.1	0.7	0.3	0.0	-0.2	-0.4	-0.5	-0.6
IQR	3.5	3.6	3.6	3.7	3.8	3.9	4.1	4.1	4.1	3.9	3.7	3.4	3.1
1.5 IQR	5.3	5.3	5.4	5.5	5.7	5.9	6.1	6.2	6.1	5.9	5.5	5.1	4.6
Max	12000	12000	12000	12000	12000	12000	12000	931	931	931	931	887	887
Mean	7.8	7.8	7.7	7.5	7.3	7.1	6.8	6.1	5.7	5.2	4.6	4.1	3.6
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

IQR = Inter quartile range (25-75%). Median value +/- IQR represents non-outlier values in normally distributed data (Tukey, J. 1977).

Figure 10. Influent municipal wastewater concentration trends for WWTFs whose permits do not contain effluent total phosphorus limits.

The MPCA's original PMP resources in 2000 were subsequently updated to include materials that focused more closely on data analysis, industrial pretreatment and WWTF operational optimization. The MPCA's PMP web page[4] was developed in collaboration with the Minnesota Technical Assistance Program (MnTAP), a University of Minnesota outreach and assistance program dedicated to help Minnesota businesses develop and implement industry-tailored solutions that prevent pollution at the source, maximize efficient use of resources, and reduce energy use and costs to improve public health and the environment. The webpage, intended as a phosphorus management resource for Minnesota's wastewater sector, is a compendium of fact sheets and guidance documents designed to assist in the development of PMPs. Available resources include:

- PMP development templates
- Phosphorus removal benchmarking guidance by WWTF type
- Phosphorus reduction tips
- Industrial pretreatment local limit development guidance
- Phosphorus influent, effluent and percent removal spreadsheet and chart templates
- Industry specific pollutant reduction fact sheets
- WWTF optimization for phosphorus removal fact sheet

[4] MPCA Phosphorus Management Plans - http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/water-quality-and-pollutants/phosphorus/phosphorus-management-plans.html

PMPs have an important role in the implementation of RES based effluent limits. Historically, PMPs were requirements for facilities whose permits did not otherwise contain effluent phosphorus limits to optimize phosphorus management through minimization of influent phosphorus concentrations and optimization of WWTF operations. RES implementation will result in the application of new or enhanced phosphorus effluent limits for many more WWTFs. In some cases, WWTF upgrades will be required to provide the advanced treatment necessary to meet the new limits. In some cases with mass only limits, facilities will be able to meet new RES based phosphorus limits under current actual conditions, but would have difficulty meeting them in the future as they grow into their design conditions. Others may not be able to meet new RES based limits based on past performance, but WWTF optimization might allow for the WWTF to meet limits or realize significant cost savings compared to a full WWTF upgrade. Phosphorus management planning and WWTF optimization for phosphorus removal can help WWTF operators develop low cost alternatives for achieving water quality objectives.

The MPCA intends to utilize three alternate sets of PMP requirements in permits depending on the WWTF's phosphorus optimization potential and the progress demonstrated in the past.

1. **Enhanced PMP requirements** – will be incorporated in permits for facilities that have a greater potential for source reduction and WWTF optimization.
2. **Streamlined PMP requirements** – will be incorporated in permits for facilities that have already achieved significant phosphorus reductions and demonstrated an ability to maintain and build on those gains in the future.
3. **No PMP requirements** – will be incorporated in permits on a case by case basis when MPCA staff determines there is no benefit to including a PMP. The following list includes some of the possible situations where PMPs most likely will not be required.
   - WWTF will need a major upgrade to meet new TP limits. The design engineer will be optimizing the WWTF to remove TP when he or she is designing the upgraded WWTF. The WWTF would have completed PMPs in past permit cycles to reduce influent TP.
   - Existing concentration from the WWTF is lower than the applicable RES criterion. Some industrial facilities discharge at very low TP concentrations. Average effluent concentration is less than 0.8 mg/L for municipal facilities and previous PMPs or upgrade included WWTF optimization.
   - Previous PMP included WWTF optimization and MPCA staff determine that additional PMPs would have limited impact on effluent TP concentration.

Sample PMP Permit Conditions:

Enhanced PMP Permit Language

Within 180 days of permit issuance the permittee shall prepare and submit to the MPCA, a PMP for review and comment. The PMP must identify specific actions that the permittee will take to reduce or minimize influent phosphorus sources by working with the influent contributors, and the expected reduction to phosphorus in the effluent from that action, when implemented.

The PMP should include, but not necessarily be limited to:

A. A summary of recent influent and effluent phosphorus concentrations and mass loadings.

B. An identification of sources of high phosphorus loading to the WWTF and development of a plan for reducing phosphorus loading. This plan shall include an evaluation of phosphorus reduction opportunities for users or classes of users with high phosphorus loading. When necessary, require high phosphorus loading users to submit PMPs that include identification of user specific opportunities to reduce phosphorus loads to the WWTF. In some cases, the development and implementation of local limits may be appropriate.

C. An evaluation of past and present WWTF operations to determine those operating procedures that result in phosphorus removal to the fullest practicable extent. The evaluation should include, but not necessarily be limited to, the following:

   i. Analysis of the phosphorus loads associated with return flows (digester supernatant, etc.), and evaluation of the benefits of side stream treatment of return flows with significant phosphorus loads or concentration or minimizing the impact on recycle streams by improving aeration within holding tanks.

   ii. Infiltration and inflow (I/I) analysis and evaluation of the effect of I/I on the WWTF's effluent pollutant loads. This is especially important for WWTFs with monthly or annual mass limits.

   iii. For controlled discharge WWTFs, analysis of the effect of I/I on stabilization pond residence time and the WWTF's ability to avoid or minimize discharges in June and September.

   iv. WWTF process optimization alternatives

   v. Optimization of biological phosphorus removal (if applicable)

A. Information and data related to potential WWTF expansions or significant modifications, population growth, and potential phosphorus removal plans that will help to evaluate the current and potential effects of the WWTF on the receiving water.

B. An evaluation of source reduction strategies and WWTF optimization alternatives aimed at achieving (Permit Team should select the appropriate option):

   i. an effluent phosphorus concentration goal of (WWTF specific effluent concentration assumption) milligram per liter (annual average[5]).
   OR

   ii. compliance with the (WWTF specific value) kg/year effluent limit as the WWTF approaches its design flow[6].

PMP guidance can be found on the MPCA internet at http://www.pca.state.mn.us/enzq8fa or by contacting the compliance staff listed on the cover page of this permit. Immediately upon submittal, the Permittee shall implement the PMP for the remainder of the permit.

Streamlined PMP Permit Language

Within 180 days of permit issuance the Permittee shall prepare and submit to the MPCA, a PMP. The intent of the PMP is to help maintain previous improvements and conduct ongoing evaluations to

---

[5] Effluent concentration goals can be evaluated by calculating the influent concentration necessary to achieve the effluent concentration goal based on the WWTF's total phosphorus removal efficiency (% removal).The resulting influent concentration goal can be evaluated in comparison to historical influent data and typical values (available from MPCA). Note that the WWTF's removal efficiency is likely to decrease as a function of decreasing influent concentrations.

[6] Predicting future growth and future wastewater flows and evaluating effluent concentrations necessary to meet limits during those flow conditions.

determine possible source reduction measures, operational improvements, and minor WWTF modifications that will reduce phosphorus loadings at a reasonable cost. Immediately upon submittal, the permittee shall implement the PMP for the remainder of the permit.

The PMP should include, but not necessarily be limited to, an evaluation of the following and a plan to implement the necessary changes:

1. WWTF influent reduction measures
    a. Re-evaluation of the phosphorus reduction potential of users
    b. Determine which sources have the opportunity for further reduction of phosphorus (e.g., industrial, commercial, institutional, municipal, and others)
    c. Determine whether known sources (e.g., restaurant and food preparation) have adopted or can adopt phosphorus minimization and water conservation plans
    d. Re-evaluation of whether or not local limits on influent sources of excessive phosphorus are needed. This includes an evaluation of whether any existing local limits are appropriate.
2. WWTF effluent reduction measures
    a. Continued optimization of existing treatment processes
    b. An assessment of side stream loading and reductions options