River Eutrophication Standards Total Maximum Daily Loads Wasteload Allocation Guidance

National Pollutant Discharge Elimination System (NPDES) permit effluent limits and total maximum daily loads (TMDLs) are being developed to protect and restore waterbodies in accordance with Minnesota's river eutrophication standards (RES). Although there are often inconsistencies in the timing of NPDES permit and TMDL development, it is critical that the assumptions and outcomes of these water quality analyses be consistent with each other. The following discussion is intended to promote consistency in the procedures and results used for the development of RES based NPDES permit water quality based effluent limits (WQBELs) and TMDL wasteload allocations (WLAs).

1. Effluent limit development procedures and watershed phosphorus review memos

Minnesota Pollution Control Agency (MPCA) Effluent Limit Unit staff have developed a document titled Procedures for implementing river eutrophication standards in NPDES wastewater permits in Minnesota (November 2015) as an overview of the procedures for assigning total phosphorus (TP) limits and requirements consistent with Minnesota's RES for NPDES wastewater permits. The document specifies that the use of a calibrated water quality model (Hydrological Simulation Program Fortran [HSPF] or equivalent) is the preferred methodology allowing for consideration of multiple complex watershed variables and definition of water quality outcomes during all flow regimes. However, since calibrated water quality models are not always available for permit effluent limit development, the procedures document describes a mass balance equation approach to be used for development of RES based WLAs and WQBELs. An MPCA fact sheet titled Understand your River Eutrophication Standard (RES) Limit (October 2018) provides a concise summary of the RES effluent limit development process.

Based on the techniques defined in the procedures document described above, MPCA Effluent Limits Unit staff are developing HUC8 watershed scale phosphorus effluent limit review memos. The status of each watershed review memo is summarized in this publically available Tableau web page: Status of MPCA watershed phosphorus review memoranda. To date, phosphorus effluent limit review memos have been completed for 41 of the 77 HUC8 watersheds that include wastewater discharges. Note that phosphorus effluent limit review memos are being developed for all HUC8 watersheds that include NPDES permitted wastewater sources, regardless of whether lake or RES impairments are known to exist in the watershed.

Minnesota's 2018 Impaired Waters List includes 50 RES impaired stream reaches located in 18 major watersheds. Table 1 summarizes the watershed phosphorus effluent limit memo status for watersheds that include RES impairments and provides links to the relevant memos. It is the MPCA's recommendation that TMDL developers consult available watershed phosphorus effluent limit memos early in the TMDL development process. The preferred outcome is for TMDL WLAs to be consistent with the WLAs calculated for WQBEL development purposes.

Table 1. 2018 RES impairments and status of watershed phosphorus effluent limit memos.

Basin	Watershed name	HUC 8	RES impaired AUIDs	Completed watershed TP memo	Completed watershed TP memo links[1]
Cedar River	Shell Rock River	07080202	2		in progress
	Winnebago River	07080203	1	ü	07080203 Phosphorus Effluent Limit Review for the Winnebago River Watershed
Des Moines River	Des Moines River - Headwaters	07100001	2	ü	07100001_DesMoinesHeadwaters_TPWatershedReview_v1.1_2017_2-35.pdf
Minnesota River	Blue Earth River	07020009	1	ü	070200XX_BlueEarth_Waton_TPWatershedReview_v1.5_2017_2-31.pdf
	Le Sueur River	07020011	3	ü	07020011_LeSueur_TPWatershedReview_v1.4_2017_2-34.pdf
	Lower Minnesota River	07020012	13	ü	070200XX_MinnRiverBasin_TPWatershedReview_v5.2_2017_2-26.pdf
	Minnesota River - Mankato	07020007	4	ü	
	Minnesota River - Yellow Medicine River	07020004	3	ü	07020004_MinnRYellowMedR_TPWatershedReview_v1.0_2018_2-55.pdf
	Redwood River	07020006	1	ü	07020006_RedwoodRiver_TPWatershedReview_v1.1_2017_2-28.pdf
Missouri River	Lower Big Sioux River	10170203	1		not started
Red River of the North	Bois de Sioux River	09020101	1		in progress
	Clearwater River	09020305	1	ü	09020305_Clearwater_TPWatershedReview_v1.0_2017_2-58.pdf
Upper Mississippi River, Lower Portion	Cannon River	07040002	2	Upstream of Byllesby Reservoir only	07040002_CannonupofByllesby_TPWatershedReview_v1.2_2017_2-54.pdf
	Zumbro River	07040004	1		in progress
Upper Mississippi River, Upper Portion	Mississippi River - Twin Cities	07010206	3	ü	07010206_MissTwinLower_TPWatershedreview_v1.3_2018_2-27.pdf
	Sauk River	07010202	2	Downstream of Horseshoe Chain of Lakes only	Lower Sauk R Watershed Phosphorus Memo_2014
	North Fork Crow River	07010204	4	ü	07010204_GreaterCrow_TPWatershedReview_v1.13_2-32.pdf
	South Fork Crow River	07010205	5	ü	

[1] Currently only available as links to internal MPCA file directories.

2. Unique frequency and duration of river eutrophication standards

The frequency and duration of RES differ from those of other Minnesota's water quality standards. The RES are based on a long-term summer average concentrations over multiple years. When MPCA promulgated RES, it also adopted some important rule language to guide the implementation of TP WQBELs for eutrophication standards. Minn. R. Ch. 7053.0205 Subpart 7.C. contains the following text:

> **7053.0205 GENERAL REQUIREMENTS FOR DISCHARGES TO WATERS OF THE STATE.**
> **Subp. 7. Minimum stream flow**
>
> C. 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 on Minnesota's lakes and rivers. Consideration of reductions from other sources is common in phosphorus TMDLs.

The proportion of TP contributed from different sources varies greatly as river flow conditions are influenced by the variable weather patterns common on any given summer in Minnesota. Point sources, such as wastewater treatment plants (WWTPs), can contribute a much larger proportion of a river's TP load during low flow conditions when algal productivity is greatest. Figure 1 illustrates this concept by showing the allowable WWTP WLA for the Minnesota River, High Island Creek to Carver Creek (AUID 07020012-800), as a percent of the TP load measured at Jordan (based on data from 2005-2015). Flows are shown in terms of exceedance percentiles, with low percentiles representing high flows. The allowable phosphorus load from WWTPs is a very small proportion of the TP load at high flows (low exceedance percentile flows), but represents a much larger proportion of the total load under low flow conditions (high exceedance percentiles). For flows higher than median flow (the 50th percentile flow exceedance) the WWTP WLA is typically less than 10% of the total measured load.

At lower flows (higher percentile flow exceedance) the proportion of the loading capacity represented by the WWTP WLA increases dramatically. Wastewater WLAs represent over 50% of the TP load at low flows (i.e., greater than 80th percentile flow exceedance). For this reason, much consideration is given to the level of TP reduction needed from WWTPs contributing to RES impaired AUIDs. As shown in Figure 2 algal levels, measured as chlorophyll-a concentrations, are highest at low flows (higher flow exceedance percentiles). While WWTPs may be a relatively small source on average over the course of the June-September growing season, the impact of TP loads from WWTPs is significant during low flow conditions when algal concentrations are greatest.[1]

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[1] Adapted from Section 2.2 of Draft Lake Pepin Watershed Phosphorus TMDLs (LimnoTech, MPCA 2018). The TMDL report was later revised to remove Minnesota River RES sections.

Figure 1. WWTP WLA as a percent of TP load for Minnesota River AUID 07020012-800, High Island Creek to Carver Creek, under varying flow conditions.

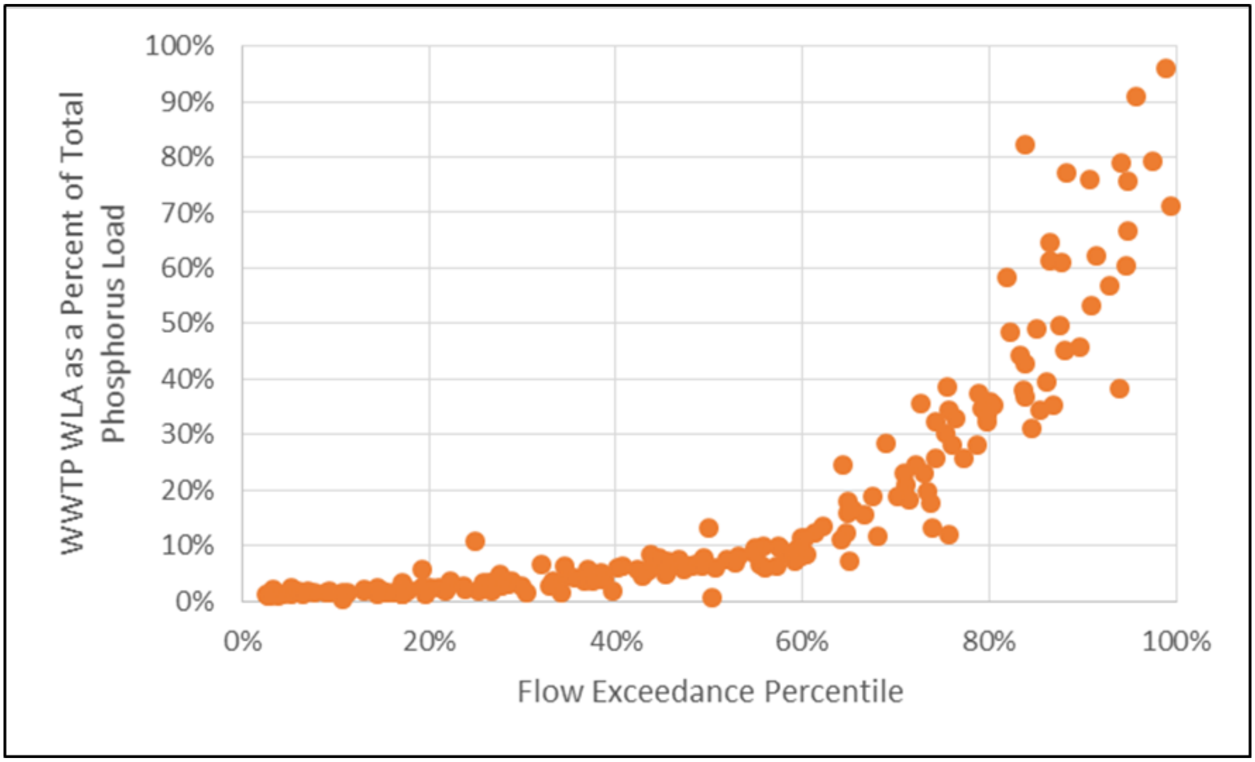
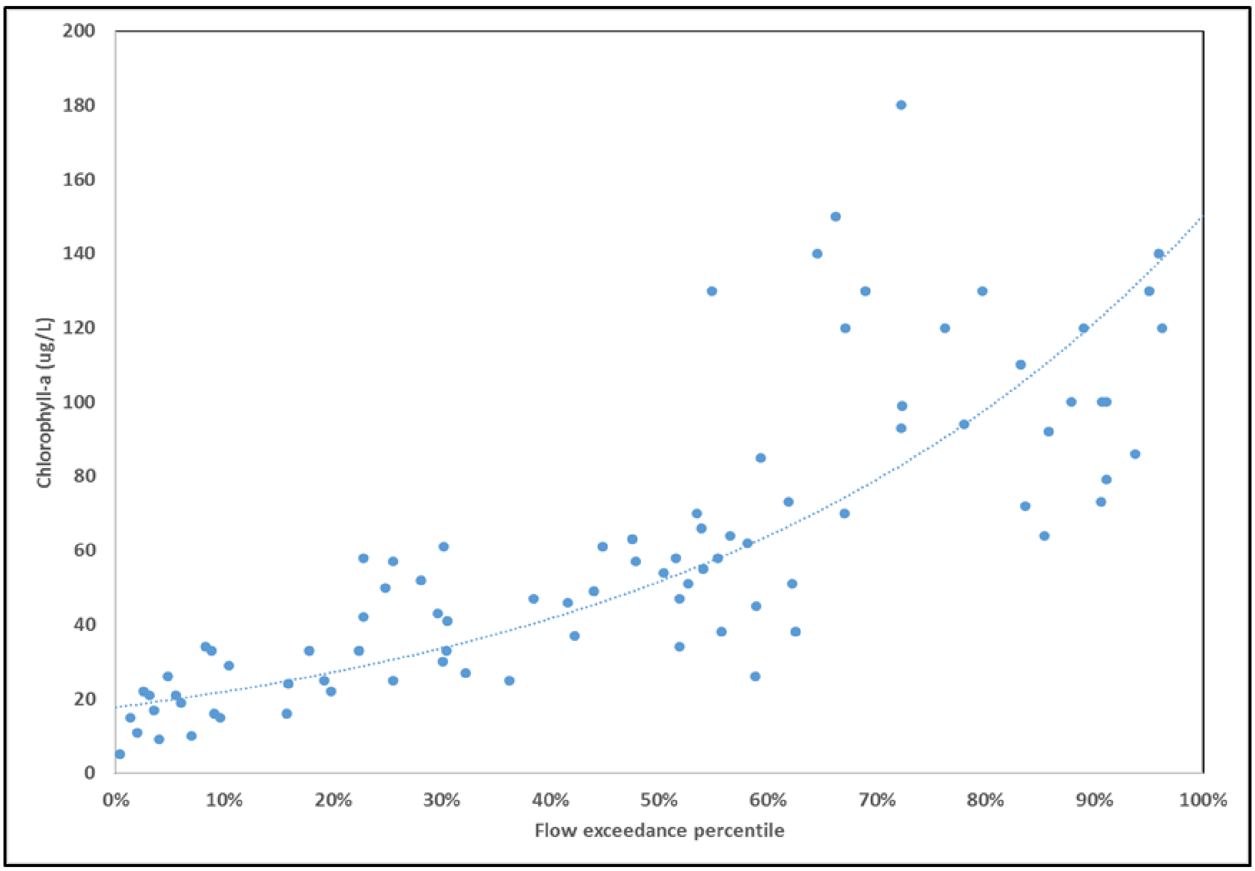


Figure 2. Summer (June-September) monitored chlorophyll-a concentration of Minnesota River from 2011-2015, AUID 07020012-800, High Island Creek to Carver Creek, under varying flow conditions.



3. Long term average summer flow and loading capacity determination

The draft RES TMDL documents that have been developed so far use different approaches for long term summer average flow and loading capacity determination.

Draft Lake Pepin Watershed Phosphorus TMDLs (LimnoTech, August 2018)[2]

The individual loading capacities (LCs) for the impaired stream AUIDs were determined through an analysis of historical flows from 1985-2015 and the applicable RES criteria. Flow data from U.S. Geological Survey (USGS) gauge stations along the Minnesota River and Mississippi River closest to the impaired AUIDs were used to calculate average June-September flow. Drainage area ratios were applied to estimate flows when USGS gauge station locations did not match an AUID drainage area. The estimated average June-September flow was multiplied by the applicable TP RES criterion for each AUID to determine the daily LC. The LCs for the RES TMDLs are summarized in Table 2.

Table 2. Lake Pepin TMDL Watershed Phosphorus TMDLs - Calculation of loading capacity for RES impaired AUIDs.

Listed waterbody name	Reach (AUID)	Applicable total phosphorus criterion (µg/L)	Average June-September flow (cfs)	Loading capacity (kg/day TP)
Mississippi River: Crow River to Upper St. Anthony Falls	07010206-805	100	10,175	2,490
Minnesota River: River Mile 22 to Mississippi River	07020012-505	150	8,226	3,019
Minnesota River: Carver Creek to River Mile 22	07020012-506	150	8,087	2,968
Minnesota River: High Island Creek to Carver Creek	07020012-800	150	7,830	2,874
Minnesota River: Cherry Creek to High Island Creek	07020012-799	150	7,482	2,746
Minnesota River: Blue Earth River to Cherry Creek	07020007-723	150	6,792	2,493
Minnesota River: Cottonwood River to Blue Earth River	07020007-722	150	5,112	1,876
Minnesota River: Little Rock Creek to Cottonwood River	07020007-721	150	4,309	1,581
Minnesota River Beaver Creek to Little Rock Creek	07020007-720	150	4,251	1,560
Minnesota River: Echo Creek to Beaver Creek	07020004-750	150	4,021	1,476
Minnesota River: Yellow Medicine River to Echo Creek	07020004-749	150	3,538	1,299
Minnesota River: Granite Falls Dam to Yellow Medicine River	07020004-748	150	3,452	1,267

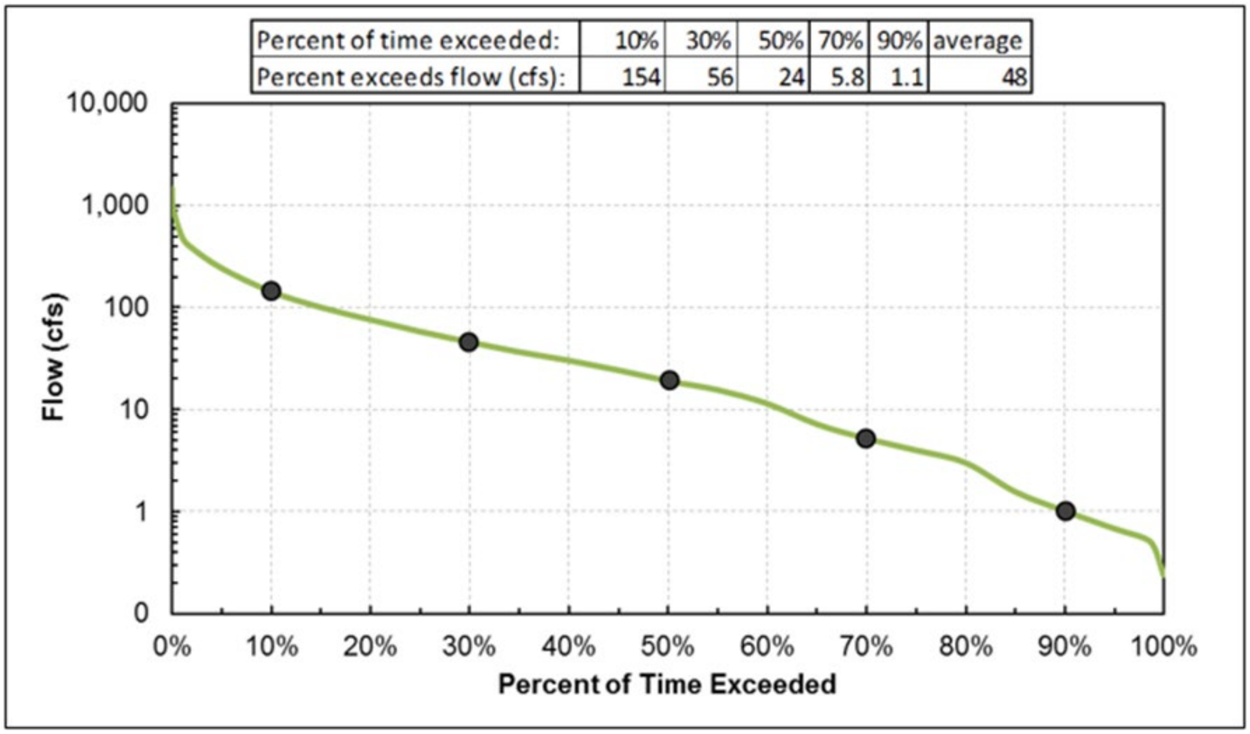
Draft Lower Minnesota River Watershed TMDLs (Tetra Tech, October 2018)

In order to align with the RES, the LC is based on the seasonal (June through September) average of the midpoint flows of five equally spaced flow zones: 0–20, 20–40, 40–60, 60–80, and 80–100 percent exceeds flows. In other words, the average seasonal flow for each impaired reach is the average of the 10, 30, 50, 70, and 90 percent exceeds flows (Figure 3). This type of averaging was used over a simple average of all flows in order to limit the bias of very high flows on phosphorus loading, recognizing that the effects of phosphorus (i.e., algal growth) are most problematic at lower flows.

[2] The Lake Pepin Watershed Phosphorus TMDLs report was later revised to remove Minnesota River RES sections.

The existing concentration of each impaired reach was calculated as the average of the seasonal (June through September) average phosphorus concentrations of the years of available data. The overall estimated concentration-based percent reduction needed to meet each TMDL was calculated as the existing concentration minus the TP standard (150 µg/L) divided by the existing concentration.

Figure 3. Lower Minnesota River Watershed TMDL sample flow duration curve from Sand Creek (AUID 840) to illustrate calculation of average seasonal flow.



4. Wasteload allocation assumptions

RES based wastewater WLAs depend on the facility type and watershed specific effluent flow and concentration assumptions.

A. Design flow:

- Municipal WWTPs - 70% of WWTP average wet weather design flow used to calculate WWTP WLAs as a surrogate for dry weather design flow.
- Industrial discharges – 100% of the maximum daily permitted flow is used to calculate industrial WLAs.
- Stabilization pond WWTPs - controlled discharge pond WWTPs are only authorized to discharge during a portion of the June – September RES applicability period. While discharge events are infrequent, daily effluent flow volumes can be significant. Minnesota River RES TMDLs assume that stabilization pond WWTPs may discharge a maximum of 16 days during summer.

B. Concentration assumptions:

- WLA concentration assumptions vary depending on watershed specific analysis. In general the MPCA's phosphorus WLA concentration assumptions recognize the principle that larger and more advanced treatment facilities are capable of achieving lower effluent concentration targets more efficiently than smaller and less technologically advanced systems. The fact that large phosphorus loading reductions cannot be obtained from small facilities further justifies the use of lower concentration assumptions for the computation of WLAs for larger WWTPs.
- Major municipal WWTP phosphorus WLA concentration assumptions range from 0.15 mg/L (SF Crow River) to 1.0 mg/L (Des Moines River Headwaters) depending on the reduction needed and the degree of point source dominance (ratio of wastewater flow to stream flow).

- Industrial wastewater concentration assumptions can be as low as the RES TP criterion for uncontaminated noncontact cooling water discharges.
- Concentration assumptions for smaller municipal and industrial WWTP WLAs vary from 5 mg/L for very small recirculating sand filter or constructed wetland WWTPs with minimal phosphorus removal capabilities to 0.3 mg/L for significant minor facilities (design flow 0.2 to 1.0 mgd).
- Draft Minnesota River RES WLAs for stabilization pond WWTPs were expressed as daily values calculated as seasonal loads based on 16 days of discharge at each pond's maximum permitted daily flow rate, multiplied by a 1 or 2 mg/L effluent concentration assumption (depending on applicable effluent limits) divided by 122 summer days. The draft TMDL document specified that local watershed reviews will include examination of these facilities in greater detail and that permit effluent limits for stabilization ponds will generally be implemented as 12 month moving total mass limits.

Table 3. Summary of wastewater WLA flow and concentration assumptions.

	Des Moines River	Blue Earth River	Le Sueur River	Minnesota Basin	Yellow Medicine River	Redwood River	NF Crow River	SF Crow River	Winnebago River
Model	HSPF	Mass balance	Mass balance	HSPF	HSPF	HSPF	Mass balance	Mass balance	HSPF
Municipal WWTP % of average wet weather design flow assumption		70%	70%	70%	70%	70%	70%	70%	70%
Industrial discharge % of maximum daily flow assumption		100%	100%	100%	100%	100%	100%	100%	
Major municipal & large industrial WWTPs	1 mg/L	0.626 mg/L	0.7 mg/L	0.53 mg/L	0.53 mg/L	0.53 mg/L	0.2 - 0.38 mg/L	0.15 - 0.3 mg/L	
Significant minor municipal WWTPs		0.626 mg/L	1 mg/L	0.9 mg/L	0.9 mg/L		0.3 – 0.48 mg/L	0.3 mg/L	
Small industrial high concentration				1.0 mg/L	1.0 mg/L				
Small municipal WWTPs				2.5 mg/L	2.5 mg/L		0.48 – 1.67 mg/L	0.5 mg/L	3.5 mg/L
Small municipal septic/sand filter WWTP					5.0 mg/L				
Stabilization pond WWTPs		Annual LES WLA	Annual LES WLA	Annual LES WLA	Annual LES WLA	Annual LES WLA	Annual LES WLA†	Annual LES WLA†	

†Controlled discharge stabilization pond WWTPs in the North and South Fork Crow River watersheds have also been assigned 2 mg/L phosphorus effluent limits.

5. Boundary condition delineation

Defining watershed specific boundary conditions can help limit the size of RES TMDL watersheds and the number of required individual WLAs (wastewater and stormwater). The Des Moines River Headwaters HUC8 provides a good example. The watershed includes two RES impairments:

Table 4. Des Moines River – Headwater RES impairments.

Waterbody name	Waterbody description	AUID	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year
Des Moines River	Windom Dam to Jackson Dam	07100001-501	07100001	Des Moines River Headwaters	Nutrient/eutrophication biological indicators	2018
Heron Lake Outlet	Heron Lake (32-0057-01) to Des Moines R	07100001-527	07100001	Des Moines River - Headwaters	Nutrient/eutrophication biological indicators	2018

The watershed contains 17 NPDES permitted wastewater facilities and one MS4 however, due to the fact that most facilities are located upstream of impaired lakes, only four wastewater treatment facility permits will require RES TMDL WLAs. RES TMDL boundaries can be set at the outlets of Heron Lake and Talcot Lake because the phosphorus water quality criteria (90 µg/L) for those waterbodies are more restrictive than the phosphorus criteria (150 µg/L) for the downstream RES TMDLs (Figure 4). The Heron Lake TMDL was approved in 2008 and the Talcot Lake TMDL is currently in development. Both TMDLs establish WLAs calculated to ensure that lake outflow phosphorus concentrations will be consistent with achieving downstream RES targets. As a result it is not necessary to reallocate summer phosphors loads to watershed areas and point sources upstream of those boundaries.

TMDL watershed boundaries could also be established on the basis of upstream water quality that is known to be consistent with TMDL objectives. For example, the draft Lake Pepin Watershed Phosphorus TMDLs excludes the Rum River watershed and the Mississippi River upstream of the Crow River confluence because both rivers meet RES criteria. While no WLAs were calculated and included in the TMDLs, the TP loads from upstream areas must still be considered in the downstream TMDLs. Loadings from these boundaries were calculated using the long-term daily average flow rate from 1985-2015 at the outlet of the boundary area and a TP concentration representative of the boundary condition.

Figure 4. Des Moines River Headwaters RES Boundary Conditions.