

Missouri Clean Water Commission Meeting
Department of Natural Resources
Lewis and Clark State Office Building
LaCharrette/Nightingale Creek Conference Rooms
1101 Riverside Drive
Jefferson City, Missouri

May 4, 2011

Nutrient Criteria Implementation Procedure

Issue: The Water Protection Program has drafted a procedure for the implementation of nutrient criteria for lakes (10 CSR 20-7.031(4)(N)). The nutrient criteria for lakes and reservoirs become effective on September 30, 2009. In order to ensure consistent application of this procedure, its requirements will be proposed for inclusion in the effluent regulation (10CSR 20-7.015) during the next rule making period.

Background: The last Water Quality Standards revision was promulgated limits for total nitrogen, total phosphorus, and chlorophyll in the State's lakes and reservoirs. The complex regulation reflects that regional and hydrologic variations affect the normal background nutrient concentrations that would occur in a lake or reservoir, even without human disturbance. For point sources that may contribute to nutrient loading, the appropriate degree of regulation is highly dependent not only on the magnitude of the discharge, but also on its location within the lake's watershed.

The Implementation Procedure is intended to specifically address permitted point source dischargers that are within the watersheds of lakes affected by the rule. It is recognized that, in many cases, substantial contributors to nutrient impairment are non-point sources, both in rural and urban settings. The Programs will seek remediation of such impacts with incentives for Best Management Practices and other tools, in cooperation with other agencies, and the eventual development of a water quality trading program.

The documents in your packet are specifically focused on how the Program will work with point source dischargers. Nutrient monitoring for all facilities that are within lake watersheds will be added as a condition at the time of renewal. Small, non-commercial facilities with design flows of less than 100,000 gallons per day may choose default values to represent their contribution. New or expanding facilities will have specified options following antidegradation review, depending on whether the lake in question is listed as impaired for nutrients.

For lakes that are listed as impaired, facilities within their watersheds may be required to meet nutrient limits in their discharges. What these limits are will depend on the discharge size and location, and will be based on the waste load allocation that is calculated as a part of the lake's total maximum daily load.

There are some lakes in which nutrient impairment is suspected from available data, but not sufficient data from which to perform an assessment that would be in compliance with the rule. In these cases, the Program will strive to collect additional data to reach a decision.

It is imperative that the nutrient rule be implemented in a consistent manner. Therefore, we are proposing to include the guidelines described in the implementation document as a part of the effluent regulation when that rule is open for revision.

This document is a draft, and we will welcome comments for further revision and improvement.

Recommended Action: Information only.

Suggested Motion Language: None.

List of Attachments:

- a) Nutrient and Chlorophyll Criteria for Lakes: Implementation Procedure for Permitted Facilities
- b) Flowchart: Nutrients and Chlorophyll Criteria Implementation Strategy and Procedure for NPDES Permitting
- c) Tables A1-A4. Predictive Values for Phosphorus from Formulas Found on Table L, 10 CSR 20-7.031
- d) Tables B1-B11. Permits Affected by the Nutrient Criteria in Selected Watershed can be found at [Clean Water Commission Web page](#)

Nutrient and Chlorophyll Criteria for Lakes Implementation Procedure for Permitted Facilities

Missouri Department of Natural Resources
Water Protection Program

May, 2011

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Attachments:

Flowchart: Nutrients and Chlorophyll Criteria Implementation Strategy and Procedure for NPDES Permitting

Tables A1-A4. Predictive Values for Phosphorus from Formulas Found on Table L, 10 CSR 20-7.031

Tables B1-B11. Permits Affected by the Nutrient Criteria in *Selected* Watershed (Note: *List does not include all affected permits*)

Facts, History and Background

The Missouri Department of Natural Resources' (department) most recent triennial revision of the Water Quality Standards (WQS) regulation (10 CSR 20-7.031) became effective October 30, 2009. A major revision was the establishment of nutrient and chlorophyll standards for lakes and reservoirs (here after, "lakes"). Nutrients and chlorophyll standards include criteria values for total phosphorus (TP), total nitrogen (TN) and chlorophyll (Chl).

The effects of nutrients on designated water uses are complex and variable. Nutrients constitute an essential element of aquatic life, and are not generally toxic. Ammonia is the exception and has toxicity criteria in the rule at 10 CSR 20-7.031, Tables B1 – B3. However, in high concentrations, nutrients in waters have been linked to drinking water-related concerns that include methemoglobinemia, disinfection by-products, cyanotoxins from cyanobacteria, and aesthetic impacts on taste and odor.¹

General water quality concerns from excess nutrient levels in waters include reduced water clarity potentially affecting recreational use, eutrophication of waters that can lead to low dissolved oxygen from excess algae production and noxious plants. Excess algae and plant production can also affect sensitive aquatic organisms by altering the type and quality of food available.²

The department developed a plan for nutrient criteria development that EPA approved in July 2005. The plan calls for development of nutrient criteria for lakes first, to be followed by criteria for streams and rivers, and later, the development of criteria for wetlands and the Missouri and Mississippi Rivers. The 2009 additions to the rule (10 CSR 20-7.031(4)(N) and Tables L, M and N) represent the first stage of nutrient criteria development in Missouri.

The nutrient criteria for lakes are based primarily on hydrological factors, including lake depth (as approximated by dam height), hydraulic residence time, and watershed characteristics. These factors are further modified by consideration of the eco-region in which a lake is located. Specifics of how these factors are applied are described in the rule at 10 CSR 20-7.031(4)(N) and Tables L, M, and N. Numeric values for these factors for most classified lakes are available for distribution (see *Determining Nutrient Criteria*).

Consequently, these hydrological factors produce a range of expected concentrations for TN, TP, and Chl among different lakes. Achievement of compliance with criteria in lakes requires consideration of the entire watershed areas in which they are located. The trophic condition of a lake may be impacted by direct or indirect discharges from point source facilities, and it is also largely a function of overland runoff. Almost all lakes in Missouri are actually reservoirs, meaning there is no real "natural" condition to protect; however, for the protection of water quality for designated uses, an excessive nutrient level is considered an impairment of beneficial uses due to algal growth, lack of water clarity and other values inconsistent with water quality standards. The rule is designed to estimate the threshold between naturally-occurring and cultural eutrophication, which is the progression and aging of a lake from nutrient poor to more nutrient rich conditions.

^{1,2} *An Urgent Call to Action – Report of the State – EPA Nutrient Innovation Task Force, August 27, 2009*

Intent of the Procedure

Because Missouri's new nutrient and chlorophyll WQS for lakes at 10 CSR 20-7.031(4)(N) have become effective, point-source discharges into lakes (considered "waters of the state") or within the watersheds of lakes may be affected. The intent of this procedure is to ensure consistent implementation and gathering of sufficient water quality data to manage discharges to those lakes or into the watersheds of those lakes. This guidance will include procedures to implement Missouri's nutrient and chlorophyll standards for: 1) existing point sources regulated under the Missouri State Operating Permit program (MSOP), or 2) new or expanding point sources. An expanding point source is defined as discharge from a facility that is increasing its dry-weather design flow or organic loading or both. A new point source is defined as the construction of a facility that does not currently possess a MSOP or the introduction of TP or TN in the discharge as a new pollutant of concern in a current MSOP.

The determination of a water body as a "water of the state" is the initial application of the WQS and all surface waters of the state will be addressed in this guidance. This guidance is not intended to address the control of nutrient sources not regulated under the MSOP program. For lakes that have nutrient concentrations higher than the corresponding criteria, modeling will establish the contribution of point and non-point sources within the lake's watershed. Missouri mitigates these nonpoint source contributions through the Best Management Practices (BMP) approach as well as public education and incentive programs. Finally, these new standards will likely lead to the development of a nutrient trading program that would achieve overall nutrient reduction in an efficient and cost-effective manner.

Tables B1 through B11 list permitted point sources that are located within the watersheds of affected lakes (or lakes having nutrient concentration greater than their corresponding criteria. The lists include approximately 2,000 affected permitted facilities, among which 25% are storm water, 25% are general and 50% are site-specific permits. Nearly 85% of these permits are within the watersheds of the 10 largest lakes in the state.

Evaluation of Lakes

Applicability Determination Process

Nutrient criteria (TN, TP and Chl) apply to 1) classified lakes greater than 10 acres in size [10 CSR 20-7.031, Table G], and 2) unclassified lakes as waters of the state that are greater than 10 acres in size and outside the Big River Floodplain eco-region. Waters of the state are defined as (Missouri Statutes Chapter 644, Section 644.016): "[A]ll rivers, streams, lakes and other bodies of surface and subsurface water lying within or forming a part of the boundaries of the state which are not entirely confined and located completely upon lands owned, leased or otherwise controlled by a single person or by two or more persons jointly or as tenants in common and includes waters of the United States lying within the state." The department will consider every such lake as a water of the state unless the applicant demonstrates that the lake owner has complete ownership control of the lake drainage area. For determination of waters of the state, a geographic information systems (GIS) layer or plat map showing land ownership within the county of the facility discharge may be used. For the implementation of this rule, GIS will be a vital tool in the applicability determination process. See the department's interactive map viewer at: <http://www.dnr.mo.gov/internetmapviewer/> for additional information.

This implementation procedure addresses qualifying lakes and the watersheds of these lakes. Achievement of compliance with criteria in lakes requires consideration of the entire lake watershed area. Thus, this implementation procedure and the requirements of the WQS apply to discharges that drain into streams within the watershed of an applicable lake. Losing streams that are in the watershed of qualifying lakes are given the same consideration as gaining streams, unless the applicant can demonstrate through dye tracing that water of said stream is losing to a watershed outside of the qualifying lake (a quality assurance project plan is required for dye tracing). To ascertain watershed boundaries of the lake, GIS will be a vital tool in the applicability determination process. For larger lakes, the 8-digit or 12-digit USGS Hydrologic Unit Codes (HUC) watershed boundaries can be used. For smaller lakes, the first consideration may be the 12-digit HUC, but the use of digital 1:24,000 scale topographic maps combined with digital aerial photography or digital elevation model (DEM) layers may be necessary.

Determining Nutrient Criteria

As mentioned in the "Background" section, nutrient criteria for lakes are based primarily on hydrological factors, including lake depth (as approximated by dam height), hydraulic residence time, and watershed characteristics. For the Plains eco-region, the predictive value for TP requires dam height, hydraulic residence time, and percentage of watershed historically covered in prairie. For the Ozark Border and Ozark Highlands eco-regions, dam height is the only factor needed to calculate the predictive value. Records of dam height may be available from the department's Dam and Reservoir Safety Program at <http://dnr.mo.gov/env/wrc/damsft/statemap.htm>. The Dam and Reservoir System Rules and Regulations provide definitions of terms used in administration of the Missouri Dam Safety Law. The proper method of measuring the height of a dam is based on these definitions. See <http://dnr.mo.gov/env/wrc/damsft/damhgt.htm> for additional information. The Natural Resources Conservation Service (NRCS) should have records on dams built under the Watershed Protection and Flood Prevention Act (PL-566).

Actual values for nutrients and chlorophyll are determined by direct monitoring of the receiving water body. Information on lake water quality is available from the department for existing water quality data or sampling as described in the WQS at 10 CSR 20-7.031(4)(N)4, and existing data are available on the department's website. As a part of nutrient criteria implementation, the department will be sampling lakes with wastewater discharges that could be affecting its nutrient concentrations. A lake owner, lake association, citizen group, permittee or more than one permittee may sample a lake at his or her own expense if all lake sampling has a Quality Assurance Project Plan (QAPP) that is approved by the department's Water Protection Program. Water quality data that were collected without a department-approved QAPP and the quality assurance protocol may be submitted to the department for review. However, such data may not be used to determine nutrient or chlorophyll levels unless there is sufficient evidence for their reliability.

Note: Predictive criteria values for many lakes using the formulas on Table L of 10 CSR 20-7.031 are provided in the attached Tables A1-4.

Nutrient Criteria Implementation Procedure for Point Source Discharges

Regulated Existing Point Source Discharges to Lakes

All existing permitted discharges within the watersheds of lakes that are affected by the rule will be monitored for nutrient concentrations, as a part of their normal discharge monitoring reports for a defined period. Until a wasteload allocation is developed, the following exemptions from effluent monitoring only may be considered if circumstances warrant:

- The permitted low-flow design flow of a domestic wastewater treatment facility is less than 100,000 gallons per day. For the wasteload allocation development process, the extent of nutrient loading from the facility may be assumed using default concentration values. These default values must assume that these facilities do not have tertiary treatment for nutrients. Typically, untreated municipal waste water contains 4 to 8 mg/L TP and 25 to 35 mg/L TN.³ Default values will be drawn from within these ranges.
- The facility operates with waste water treatment processes that are clearly demonstrated through existing effluent monitoring data to result in a discharge that does not include any nutrient concentration that is greater than non-impaired natural background levels.

The generalized goal for existing dischargers seeking renewal of their state operating permit within watersheds of or directly to lakes (here after, "affected waters") that have nutrient values in excess of criteria is to have effluent limits for TP and TN based on the calculation of a waste load allocation (WLA). The Water Protection Program develops, or reviews and approves, WLAs prior to implementation into the permitting process. During implementation, adjustment to the loading may be realized from nonpoint source reductions. Water quality trading may also be an option for these facilities.

Depending on the location of a given permitted facility, there are three (3) alternative implementation actions:

- For lakes that are known to exceed their nutrient criteria, DNR staff will develop Total Maximum Daily Loads (TMDL) from which WLAs will be calculated. Appropriate nutrient limits will be derived for each of the permitted facilities of the watershed.
- Lakes for which there are not sufficient data to determine whether nutrient criteria are exceeded, but for which available data indicate that exceedence is likely, DNR will require that all facilities that are located within the watersheds of these lakes to monitor for nutrients as a part of their discharge monitoring reports (DMR). The Department will review the data. If there is a significant probability of impairment because of nutrient loading, the Department will request the affected facilities to develop WLAs that would be applicable to their discharges. Production of these WLAs will require submission of QAPPs and will be subject to approval by the Department.
- Wastewater facilities that are located within the watersheds of lakes for which data indicate that nutrient criteria are not exceeded will only include nutrient monitoring as a part of their DMR if there are insufficient data to determine treatment performance.

Following the development of a WLA, whether or not it is associated with a TMDL, watershed protection staff will work with the permitting staff to develop appropriate and achievable limits

³ US EPA, 2010. Nutrient Control Design Manual. EPA/600/R-10/100.
<http://www.epa.gov/nrmrl/pubs/600r10100/600r10100.pdf>

for point sources, taking into consideration the limit of technology (LOT). The implementation plan (IP) will also include a compliance schedule for possible facility modifications to meet these limitations. At the time of permit renewal, if the LOT has been revised downward because of advances in technology that are practicable for the facility, and if the affected water still exceeds criteria, permitting staff will modify the permit accordingly.

If the impairment is caused by a combination of point source discharges, each discharger may be allocated a percentage of the total allocation corresponding to their relative load contribution, their location within the watershed, and the LOT.

Existing dischargers to affected waters with nutrient effluent limitations that seek renewal of their state operating permit will continue to meet these limitations until lake sampling indicates that the use of those effluent limitations is known or expected to produce an effluent that will not endanger or violate water quality. In these cases, an adjusted WLA may be applied to the permit.

Existing dischargers to affected waters without nutrient effluent limitations that seek renewal of their state operating permit and discharging within affected waters that exceed TN, TP and/or Chl criteria will be required to monitor their effluent discharge (see *Follow-up Evaluation of Lakes*) for TP and TN until the TMDL or WLA is developed. After the WLA development process, the WLA and/or appropriate nutrient limits will be imposed (or water quality trading pursued) as permits are renewed.

Existing dischargers without nutrient effluent limitations that seek renewal of their state operating permit and discharging within watersheds of lakes that do not exceed TN, TP and/or Chl criteria or do not have data to show exceedences will have effluent monitoring requirements for TP and TN added to the permit at permit renewal for at least one permit cycle. The frequency of monitoring will be at least quarterly. The department may eliminate nutrient monitoring, or reduce its frequency to suit the water quality situation. Those non-expanding discharges without effluent limitations that have collected sufficient data prior to renewal may be excluded from the required monitoring provided a minimum of 20 samples have been collected over at least a five (5) year period. The department may also not require nutrient monitoring if sufficient data are available for the similar types of treatment facilities or nutrient point sources. These data should allow the department to determine discharge concentration with reliability.

Antidegradation Review of New or Expanded Source Discharges to Lakes

In accordance with the *Missouri Antidegradation Rule and Implementation Procedure* (AIP), all new or expanded regulated discharges are subject to antidegradation review requirements. The AIP is available on the web at <http://dnr.mo.gov/env/wpp/docs/aip-cwc-appr-050708.pdf>.

New or expanding regulated discharges of nutrients within watersheds of affected lakes that exceed nutrient criteria are prohibited if the discharge would cause or contribute to the impairment. An application may be accepted before the completion of the WLA calculation, if the permittee accepts one of the following available options: 1) wait, meaning no permit will be issued until the WLA is developed by the department (Watershed Protection Section) and approved by EPA; or 2) maintain loading of nutrients, if sufficient effluent data is available to characterize the nutrient concentrations discharged; or 3) conduct an analysis of practicable control technology⁴ for the purpose of selecting the LOT that will address nutrient concentrations in the effluent. If options 1-3 are eliminated from consideration, water quality trading when

⁴ Affordable and effective in removing nutrients

developed may be considered. Please refer to the Antidegradation Implementation web link for more information on antidegradation review submittal requirements at <http://www.dnr.mo.gov/env/wpp/permits/antideg-implementation.htm>.

For any new or expanding regulated discharges that would discharge toward affected lakes *not exceeding nutrient criteria or not having data to be evaluated*, the available options include: 1) assuming degradation from TP, TN and Chl and conducting alternative analysis of non-degrading, less-degrading and degrading alternatives for TP and TN as described in the AIP Section II. B for selecting the LOT that will address nutrient concentrations in the effluent; 2) demonstrating that an analysis for an alternative to the proposed discharge analysis is unnecessary as described within the AIP; or 3) conducting water quality trading. To use option #2, the amount of resources that would be required to gather the necessary data to accurately model the lake for minimal degradation will likely be extremely prohibitive for some facilities. Therefore, the department believes that in some cases the most viable approach is Option #1 as described in the AIP Section II.B. Alternatives analysis is the structured evaluation of the reasonableness of less- and non-degrading alternatives to a new or expanded discharge likely to cause significant degradation. Additionally, for significant degradation, an analysis of the social and economic benefits to the community that will occur from any activity involving a new or expanded discharge is required by the AIP. By default, those lakes without existing water quality data also receive this Tier 2 review.

For option #1, in accordance with the AIP, the base case of pollution control is the control required to protect existing uses and to achieve the highest statutory and regulatory requirements. Without the data to accurately model the lake to show the effects of this new or expanded discharge, an assumption of the base case may be made. The department already has shown success in protecting lake water quality and facilities are meeting effluent limitations using phosphorus through the use of effluent regulations for discharge to Lake Taneycomo and Table Rock Lake watersheds. Effluent regulations in 10 CSR 20-7.015(3)(F) and (G) set limits of 0.5 mg/L total phosphorus as a monthly average. Because of the success of this effluent regulation, the department is proposing to use this value for the base case of pollution control for discharge to all lakes in Missouri. However, Missouri's regulatory effluent limitation for TP is not the LOT based on more recent advancements in effluent.

Thus, for the base case treatment (see *Municipal Nutrient Removal Technologies Reference Document*, September 2008), proposed treatment alternatives must have the capacity to attain an effluent discharge for TP of 0.5 mg/L and TN of 10 mg/L as a monthly average. In addition, the applicant may demonstrate that these base-case treatment capacities are not achievable. The department selected the current regulatory effluent limitation for TP discharges as mentioned above because of the lack of appropriate methodology to derive water quality-based effluent limits for the base case that comply with water quality standards at the lake outflow. The TN monthly average follows the rationale that a TN-to-TP ratio of 20:1 is protective of water quality standards.

Setting Effluent Limits Following a Water Quality Analysis

If the WLA for impaired lakes or data for non-impaired lakes reveal that additional TP and/or TN reduction is needed by the permittee, more protective effluent limits would be imposed in a permit modification with a schedule of compliance to bring the facility into compliance with the new effluent limitation. Facilities may accomplish additional nutrient reduction through facility upgrades, elimination of nutrient discharge or through water quality trading, when developed and if available. The Missouri Department of Natural Resources' Effluent Regulations at 10 CSR 20-

7.015(3)(B)4 indicates that “where the use of effluent limitations set forth in section (3) is known or expected to produce an effluent that will endanger or violate water quality, the department may either—conduct waste load allocation studies in order to arrive at a limitation which protects the water quality of the state or set specific effluent limitations for individual dischargers to protect the water quality of the receiving streams. When a waste load allocation study is conducted for a stream or stream segment [within a lake’s watershed], all permits for discharges in the study area shall be modified to reflect the limits established in the waste load allocation study.”

Key Issues of Water Quality Trading

Water quality goals for nutrients may be achieved through coordination and cooperation among those responsible for point and nonpoint discharges of nutrients to affected waters. Trading of effluent limits between affected parties can be useful in achieving water quality standards effectively and economically.

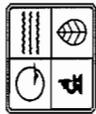
Currently, there is no water quality trading program in Missouri. Implementation of such a program will require rulemaking and adequate staffing. The Water Protection Program intends to develop the regulations for a trading program during a future rulemaking.

Note: The establishment of a nutrient trading agreement does not, by itself, create sufficient cause for removing a water body from a 303(d) list.

Follow-up Evaluation of Lakes

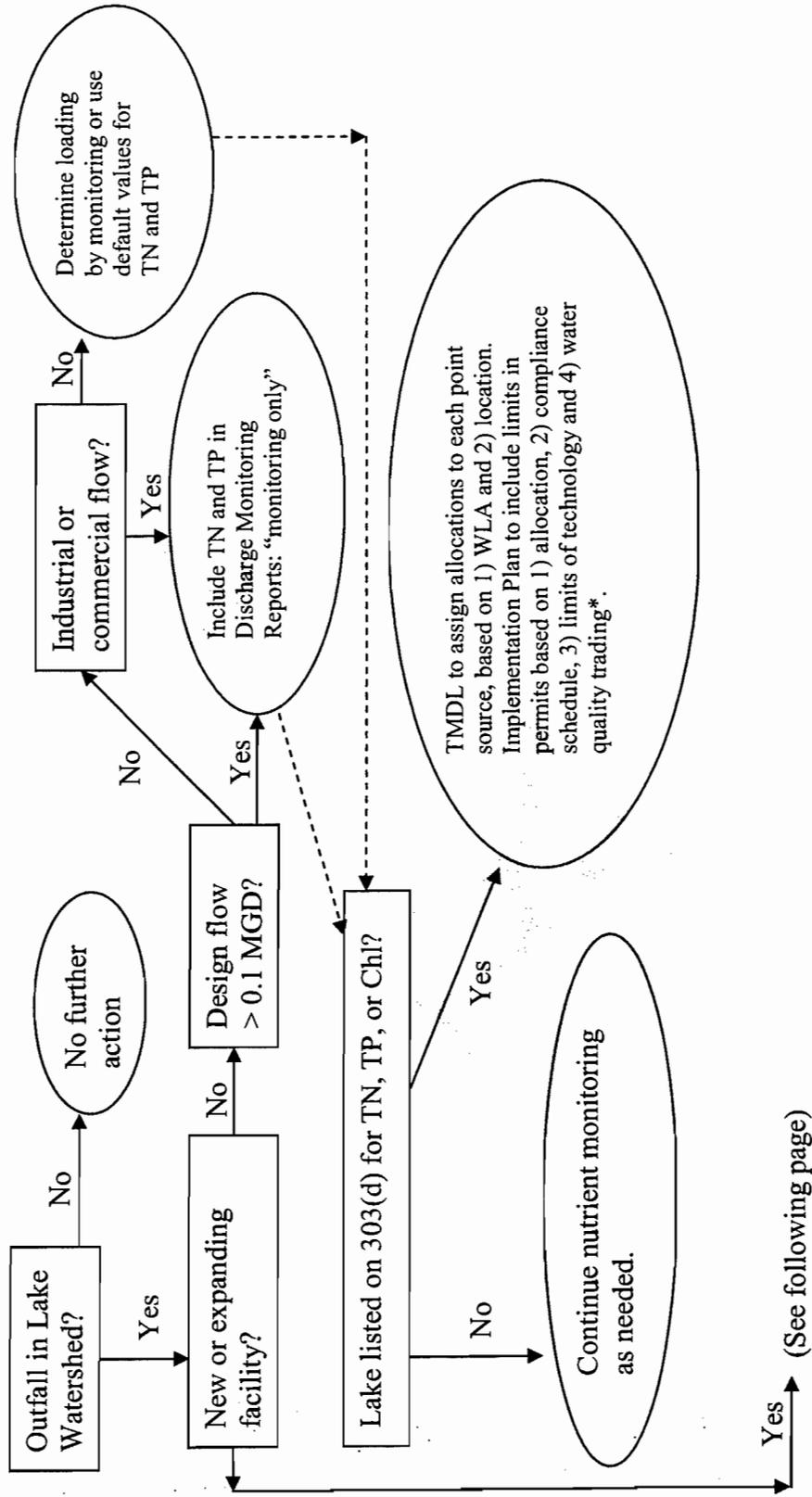
A reasonable potential analysis (RPA) of effluent monitoring data as described in EPA’s *Technical Support Document for Water Quality-Based Toxics Control*; 505/2-90-001 (TSD) is not possible for any effluent limitation developed under the TMDL process or through alternative analysis. The primary reason is that compliance with water quality standards is near the outflow of the lake. The TSD’s RPA methodology does not account for several natural phenomena including seasonal (summer) sequestration of nutrients in the hypolimnion, long-term storage of nutrients in lake sediments, decay of nutrients from discharges in the watersheds before reaching the lake or the dilution process from lake discharge to the lake outflow. Thus, the evaluation of compliance with nutrient and chlorophyll criteria for existing or newly imposed effluent limitations is near the outflow of the lake. See the *Regulated Existing Nutrient Point Sources to Lakes* above for additional procedures.

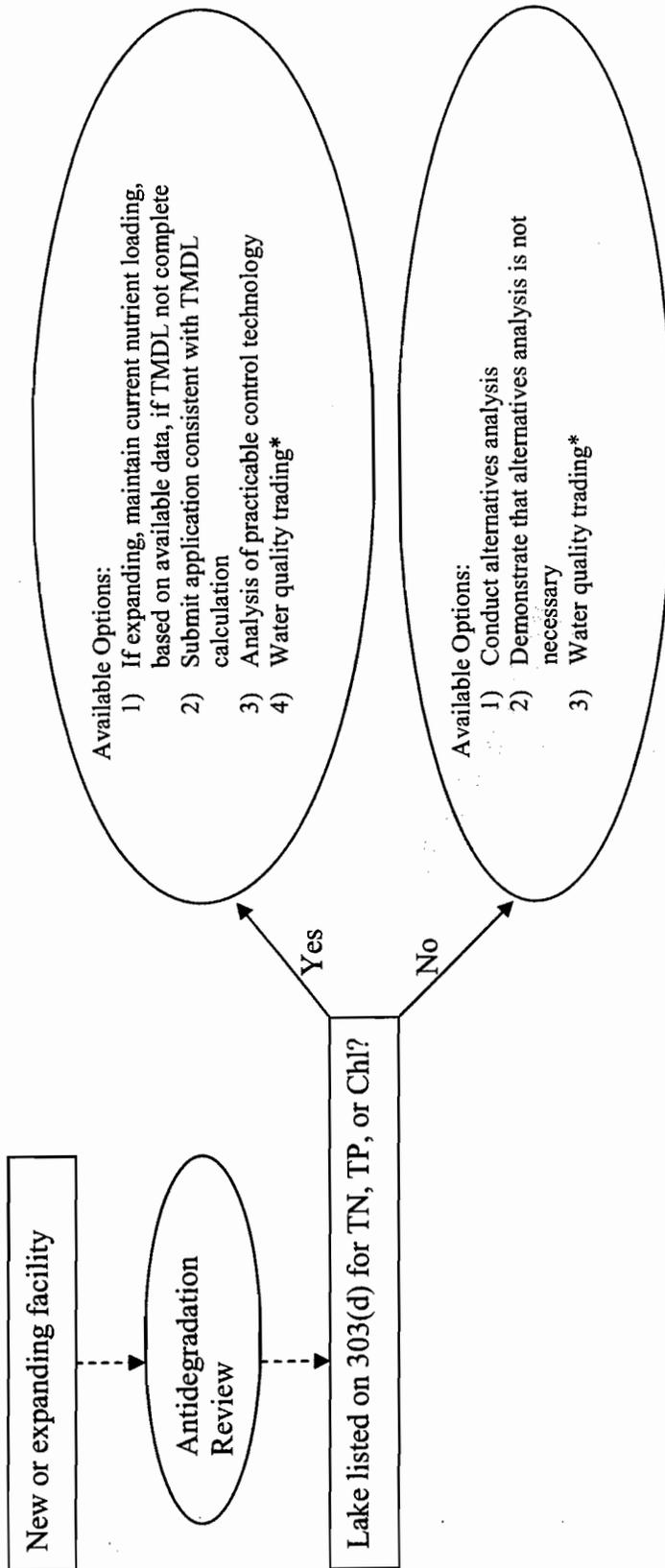
Nutrient and chlorophyll concentrations within individual lakes are seasonal and vary yearly due to climatic conditions as well as changes in land use within watersheds. Evaluation of lake nutrients requires sufficient data to account for natural nutrient and chlorophyll concentration variability. As specified in 10 CSR 20-7.031(4)(N)4, a valid determination of a lake’s nutrient status requires at least four years of data collected near the outflow of the lake, with a minimum of four samples taken each year and uniformly spaced between May 1 and August 31. Evaluation is based on a comparison of the criterion with the geometric mean of all samples taken within this period. However, for the purpose of this procedure and to proactively reduce any threat to lake water quality, lake nutrient status will be based on a moving geometric mean of at least three consecutive records. Equally spaced samples of any one of the three parameters may be used to calculate the geometric mean and evaluate the likelihood of criteria exceedence. As data become available, the moving geometric mean may include up to four years worth of data.



Missouri Department of Natural Resources

Nutrients and Chlorophyll Lake Criteria Implementation Strategy and Procedure for NPDES Permitting





*Pending development of water quality trading policy for Missouri

Table A1. Predictive values for total phosphorus from formulas found on Table L, 10 CSR 20-7.031 for lakes that have been assessed
 Note - Lakes listed in **bold** have been included in the 2010 303(d) list.

Region	Lake Name	Historic		Hydraulic Retention years	Dam Height feet	Predictive Value µg/L	Reference Value µg/L	Assessed Value µg/L	Criteria Value µg/L
		Prairie % watershed							
Ozark Border	Binder	0.0		1.038	48	30	41	53	41
Ozark Border	Manito	74.9		0.806	43	32	41	97	41
Ozark Highland	Bismark	0.0		0.137	24	36	26	23	26
Ozark Highland	Capri*	0.0		4.388	97	13	26	5	6
Ozark Highland	Clearwater	0.4		0.286	154	10	26	14	26
Ozark Highland	Council Bluff*	0.0		1.222	110	12	26	7	7
Ozark Highland	Fellows	3.3		2.014	100	12	26	14	26
Ozark Highland	Little Prairie	0.0		0.846	48	20	26	21	26
Ozark Highland	LOTO-Dam	41.9		0.392	148	10	26	26	26
Ozark Highland	McDaniel	8.7		0.179	48	20	26	32	26
Ozark Highland	Pomme de Terre	20.1		0.708	155	10	26	22	26
Ozark Highland	Springfield	7.2		0.015	45	21	26	49	26
Ozark Highland	Stockton	22.3		1.324	161	10	26	9	10
Ozark Highland	Table Rock*	4.1		2.080	252	8	26	9	9
Ozark Highland	Taneycomo	3.5		0.013	58	18	26	21	26
Ozark Highland	Wappapello	0.8		0.052	114	11	26	38	26
Plains	Atkinson	98.8		0.836	28	64	58	70	64
Plains	Bilby Ranch	100.0		2.060	54	43	58	48	58
Plains	Blue Springs	65.7		0.916	53	45	58	30	45
Plains	Bowling Green-New*	9.3		0.869	61	30	58	49	31
Plains	Bowling Green-Old*	12.4		1.568	73	21	58	19	21
Plains	Brookfield	95.1		5.269	43	40	58	21	40
Plains	Butler City	94.4		0.349	30	88	58	68	88

Table A1. (Cont.)

Region	Lake Name	Historic		Hydraulic Retention years	Dam Height feet	Predictive Value µg/L	Reference Value µg/L	Assessed Value µg/L	Criteria Value µg/L
		Prairie % watershed							
Plains	Deer Ridge	10.1		1.810	38	26	58	27	58
Plains	Forest*	7.2		2.671	66	16	58	26	21
Plains	Fox Valley*	0.0		3.057	52	17	58	18	17
Plains	Grindstone	94.0		0.516	53	65	58	127	65
Plains	Harrison County	72.3		0.727	49	52	58	68	58
Plains	Hazel Creek*	37.6		3.857	65	22	58	22	27
Plains	Hazel Hill	100.0		0.499	38	72	58	48	58
Plains	Henry Sever	61.7		2.052	41	37	58	50	58
Plains	Higginsville	67.8		0.774	34	54	58	89	58
Plains	Hunnewell	53.6		1.478	36	40	58	33	40
Plains	Jacomo	74.8		2.836	74	32	58	31	32
Plains	Kraut Run	22.1		0.301	22	85	58	102	85
Plains	LaBelle	100.0		1.222	33	55	58	73	58
Plains	Lake St. Louis	40.4		0.217	47	96	58	63	96
Plains	Lake Ste. Louise	42.4		2.070	52	29	58	31	58
Plains	Lamar City***	86.2		0.408	26	83	58	79	83
Plains	LaPlata	100.0		1.762	43	47	58	25	47
Plains	Lincoln*	0.0		2.097	69	16	58	13	16
Plains	Little Dixie	36.8		2.236	42	30	58	55	58
Plains	Long Branch	49.3		0.914	71	38	58	41	58
Plains	Longview	91.2		1.274	110	41	58	26	41
Plains	Macon	26.7		0.983	42	37	58	56	58
Plains	Marceline (new)	70.2		1.836	49	38	58	74	58
Plains	Mark Twain	57.9		0.532	112	50	58	44	50

Table A1. (Cont.)

Region	Lake Name	Historic Prairie % watershed	Hydraulic Retention years	Dam Height feet	Predictive Value µg/L	Reference Value µg/L	Assessed Value µg/L	Criteria Value µg/L
Plains	Mozingo	93.4	5.725	77	34	58	34	58
Plains	Nodaway	100.0	2.075	55	43	58	42	43
Plains	North Lake	100.0	0.299	28	99	58	114	99
Plains	Odessa	47.1	0.954	47	41	58	38	41
Plains	PrairieLee	90.1	0.534	69	61	58	43	58
Plains	Raintree	97.1	1.281	55	47	58	40	47
Plains	Smithville	61.1	2.229	105	28	58	32	58
Plains	SpringFork***	94.7	0.310	43	88	58	147	88
Plains	Sugar Creek	41.8	0.586	49	49	58	43	49
Plains	Thomas Hill	37.9	1.298	70	30	58	48	58
Plains	Truman	54.7	0.353	126	64	58	41	58
Plains	Unionville	84.9	0.534	30	70	58	89	70
Plains	Viking*	62.3	5.951	85	25	58	23	25
Plains	Watkins Mill	43.3	2.704	52	28	58	36	58
Plains	Waukomis*	0.0	3.820	68	13	58	19	25
Plains	Weatherby Lake*	0.9	7.230	85	9	58	16	16

Table A2. Predictive values for total phosphorus for auxiliary sites of major lakes that have been assessed.

Region	Lake Segment Name	Maximum Depth feet	Depth Coefficient	Depth at Sample Site Feet	Predictive Value µg/L	Reference Value µg/L	Assessed Value µg/L	Criteria Value µg/L
Ozark Highland	LOTO-Niangua Arm	90	1.6	50	14	26	33	26
Ozark Highland	Table Rock-James R Arm	180	1.4	64	13	26	11	16**

Table A3. Predictive values for total phosphorus from formulas found on Table L, 10 CSR 20-7.031 for lakes that have not been assessed

Region	Lake Name	Historic		Dam Height feet	Predictive		Reference Value µg/L	Criteria	
		Prairie % watershed	Hydraulic Retention years		Predictive Value µg/L	Estimated Value µg/L		Value µg/L	Value µg/L
Ozark Border	Bella Vista	0.0	2.121	48	30	41	22	30	
Ozark Border	Boutin	0.0	3.697	46	31	41	21	31	
Ozark Border	D.C.Rogers	0.0	1.504	45	31	41	31	31	
Ozark Border	Fayette	0.0	1.232	33	37	41	43	41	
Ozark Border	Forest (Ann)	0.0	0.346	47	31	41	39	41	
Ozark Border	Girardeau	0.0	1.044	39	34	41	47	41	
Ozark Border	Glover	0.0	0.132	33	37	41	58	41	
Ozark Border	Goose Creek*	0.0	2.672	139	20	26	13	12	
Ozark Border	Perry Co. Comm.	0.0	0.538	47	31	41	75	41	
Ozark Border	Pinnacle	0.0	0.669	49	30	41	18	30	
Ozark Border	Tishomingo	0.0	1.311	68	26	41	21	26	
Ozark Border	Tywappity	0.0	1.305	36	36	41	50	41	
Ozark Border	Wanda Lee	0.9	0.110	47	31	41	43	41	
Ozark Border	Wauwanoka*	0.0	1.810	50	30	41	12	12	
Ozark Highland	Austin	0.0	0.559	27	32	26	20	26	
Ozark Highland	Carmel	0.0	1.279	65	16	26	8	8	
Ozark Highland	Crane*	0.0	0.147	46	21	26	13	9	
Ozark Highland	Fourche Creek*	0.0	0.068	60	17	26	9	9	
Ozark Highland	Fredricktown City	0.0	0.024	24	36	26	60	36	
Ozark Highland	Indian Hills	7.5	0.911	50	20	26	32	26	
Ozark Highland	Killarney	0.0	0.028	29	31	26	54	31	
Ozark Highland	Loggers*	0.0	0.118	34	27	26	9	9	
Ozark Highland	Lower Taum Sauk*	0.0	0.088	75	15	26	12	9	

Table A3. (Cont.)

Region	Lake Name	Historic		Hydraulic Retention years	Dam Height feet	Predictive		Reference Value µg/L	Estimated		Criteria Value µg/L
		Prairie % watershed	Retention			Value µg/L	Value µg/L		Value µg/L	Value µg/L	
Ozark Highland	Marseilles*	0.0	4.206	69	16	26	9	9	9	9	
Ozark Highland	Miller Community	0.0	0.533	27	32	26	21	26	21	26	
Ozark Highland	Monsanto*	0.0	0.380	30	30	26	9	26	9	9	
Ozark Highland	Noblet*	0.0	0.011	30	30	26	11	26	11	9	
Ozark Highland	Northwoods	0.0	1.394	50	20	26	20	26	20	20	
Ozark Highland	Peaceful Valley	6.9	1.462	64	17	26	30	26	30	26	
Ozark Highland	Pinewoods	0.0	0.718	25	35	26	26	26	26	26	
Ozark Highland	Ripley	0.0	0.715	27	32	26	22	26	22	26	
Ozark Highland	Roby	0.0	0.355	15	54	26	15	26	15	26	
Ozark Highland	Shayne	0.0	4.123	72	15	26	6	26	6	15	
Ozark Highland	Sims Valley	0.0	0.492	33	27	26	24	26	24	26	
Ozark Highland	Sunnen*	0.0	0.133	48	20	26	12	26	12	9	
Ozark Highland	Timberline*	0.0	0.776	73	15	26	8	26	8	8	
Ozark Highland	Turner	0.0	0.321	32	28	26	17	26	17	26	
Ozark Highland	Ziske	0.0	0.457	24	36	26	27	26	27	36	
Plains	Allaman	39.6	0.590	20	66	58	39	58	39	58	
Plains	Amarugia Highlands	62.8	1.270	31	47	58	44	58	44	47	
Plains	Baring Country Club	91.8	3.044	35	44	58	27	58	27	44	
Plains	Belcher Branch	0.2	1.330	47	24	58	35	58	35	58	
Plains	Bethany	38.4	8.956	60	21	58	29	58	29	58	
Plains	Blind Pony	45.0	0.849	35	46	58	82	58	82	58	
Plains	Bushwacker	95.3	0.747	40	59	58	32	58	32	58	
Plains	Cameron #1	94.3	0.300	33	94	58	172	58	172	94	
Plains	Cameron #2	88.8	0.493	38	70	58	55	58	55	58	

Table A3. (Cont.)

Region	Lake Name	Historic		Hydraulic Retention years	Dam Height feet	Predictive Value µg/L	Reference Value µg/L	Estimated Value µg/L	Criteria Value µg/L
		Prairie % watershed	Retention						
Plains	Cameron #3	46.4	0.502	33	61	58	95	61	
Plains	Cottontail	100.0	0.225	25	119	58	102	119	
Plains	Edina City	100.0	0.622	39	65	58	62	65	
Plains	Ella Ewing	96.9	0.517	22	81	58	81	81	
Plains	Elmwood	23.1	1.597	47	28	58	51	58	
Plains	Gopher	100.0	0.272	28	104	58	78	104	
Plains	Green City	96.2	1.324	20	65	58	75	65	
Plains	Hamilton City	93.2	1.687	40	47	58	52	58	
Plains	Harmony Mission	99.9	0.882	42	57	58	47	57	
Plains	Harrisonville	88.3	1.973	55	41	58	48	58	
Plains	Holden City	78.6	2.026	58	37	58	40	58	
Plains	Indian Creek	46.9	1.618	56	32	58	21	32	
Plains	King	91.3	0.249	40	101	58	173	101	
Plains	Lancaster	100.0	1.044	30	59	58	76	59	
Plains	Lotawana	74.8	2.320	58	35	58	31	35	
Plains	Maple Leaf	100.0	1.451	50	47	58	37	47	
Plains	Marie*	0.0	5.793	50	14	58	14	14	
Plains	Maysville	99.1	0.239	20	120	58	179	120	
Plains	Memphis City	60.8	0.193	28	119	58	76	119	
Plains	Monroe City	90.2	0.544	31	70	58	72	70	
Plains	Montrose	84.1	0.167	33	134	58	142	134	
Plains	NehaiTonkeia*	24.3	9.274	65	17	58	14	15	
Plains	Nell	100.0	1.335	30	56	58	78	58	
Plains	New Milan	1.2	1.305	36	28	58	39	58	

Table A3. (Cont.)

Region	Lake Name	Historic		Hydraulic Retention	Dam Height	Predictive		Reference Value	Estimated Value	Criteria Value
		Prairie	% watershed			Value	Value			
Plains	Paho	75.2	2.578	40	39	58	49	58	58	
Plains	Pape (Concordia)	81.9	0.529	40	65	58	75	65	65	
Plains	Pony Express	94.8	1.748	40	47	58	62	58	58	
Plains	Rocky Fork	20.8	0.101	15	202	58	21	58	58	
Plains	Shelbina	70.6	0.444	28	74	58	95	74	74	
Plains	Spring	0.0	0.776	25	43	58	25	43	43	
Plains	Sterling Price	95.6	0.683	21	74	58	90	74	74	
Plains	Tapawingo	52.7	1.962	55	32	58	33	58	58	
Plains	Thunderhead	69.6	1.702	54	37	58	43	58	58	
Plains	TriCity	35.5	0.908	25	49	58	55	58	58	
Plains	Vandalia	100.0	0.631	21	77	58	54	77	77	
Plains	Westmoreland	79.7	0.244	34	102	58	21	58	58	
Plains	Williams (RockyHollow)	36.0	0.557	46	50	58	72	58	58	
Plains	Willow Brook	90.1	0.687	48	58	58	75	58	58	
Plains	Winnebago	92.6	0.621	64	58	58	44	58	58	

Table A4. Predictive values for total phosphorus for auxiliary sites of major lakes that have not been assessed.

Region	Lake Segment Name	Maximum Depth feet	Depth Coefficient	Depth at Sample Site feet	Predictive Value µg/L	Reference Value µg/L	Estimated Value µg/L	Criteria Value µg/L
Ozark Highland	LOTO-Gravois Arm	90	1.6	70	12	26	27	26
Ozark Highland	LOTO-Grand Glaize Arm	90	1.6	50	14	26		26
Ozark Highland	Table Rock-Kings River Arm	180	1.4	44	17	26	19	18**
Ozark Highland	Table Rock-Long Creek Arm	180	1.4	104	10	26		12**

Formulas for Primary Sites

Plains TP(µg/L) = % Watershed historically prairie/4+16/hydraulic residence time+570/dam height

Ozark Border TP(µg/L) = 15+740/dam height

Ozark Highland TP(µg/L) = 5+740/dam height

Formulas for Auxiliary Sites

Depth Coefficient = Max Depth/Dam Height

Ozark Highland TP(µg/L) = (5+740/(Depth Coefficient*Depth at Sampling Site))

* Table M Lakes with Site-Specific Criteria

**Criteria Subject to Revision

***TMDL has been written for this waterbody.