

Michigan Department of Environmental Quality
Surface Water Quality Division
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Total Maximum Daily Load (TMDL) for Total Phosphorus in Lake Allegan

Location: Lake Allegan is a 1,587-acre impoundment on the Kalamazoo River and is located in Allegan County in southwestern Michigan. The Reach File Location number is 4050003-9-0009. The Section 303(d) list identification number is 083005G. The Lake Allegan watershed has an area of approximately 992,000 acres or 1,550 square miles.

Pollutant: Total phosphorus.

Goal: To achieve an average in-lake total phosphorus concentration of 60 micrograms per liter (ug/l) in Lake Allegan for the period April to September.

Background: Consistent with Rule 100 of Michigan's Water Quality Standards (WQS), Lake Allegan is protected for warmwater fishery, other indigenous aquatic life and wildlife, agriculture, navigation, industrial water supply, partial body contact recreation, and total body contact recreation. Prioritization of the Lake Allegan TMDL was driven by Michigan's five-year rotating watershed assessment approach. Land use in the Lake Allegan watershed consists of agriculture (75 percent), forested land (11 percent), urban areas (7 percent), and wetlands and open water (7 percent).

The United States Environmental Protection Agency (USEPA) conducted a National Eutrophication Survey of Lake Allegan in 1972 (USEPA, 1975), and the lake was classified as hypereutrophic. The results of the survey indicated that the major pollutant contributing to the eutrophication of Lake Allegan was total phosphorus. Additional monitoring data collected by the Michigan Department of Environmental Quality (MDEQ) in 1988, 1994, 1996, and 1997 indicated that the lake had improved since the early 1970s but was still considered extremely nutrient-enriched. The present total phosphorus concentrations in Lake Allegan average 96 ug/l and range from 69 to 125 ug/l. Lake Allegan is still classified as a hypereutrophic lake (Wuycheck, 1998) with extremely high nutrient and chlorophyll a levels, excessive turbidity, periodic nuisance algal blooms, low dissolved oxygen levels, and an unbalanced fish community dominated by carp and channel catfish.

These conditions have caused a violation of Rule 60(2) of the WQS that states..."nutrients shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached, suspended, and floating plants, fungi, or bacteria, which are or may become injurious to the designated uses of the waters of the state." Lake Allegan was formally identified as an impaired waterbody not meeting WQS due to nutrient enrichment in 1996 (Kosek, 1996), 1998 (Wuycheck, 1998), and 2000 (Wuycheck, 2000) and included on the 1996, 1998, and 2000 Section 303(d) TMDL lists.

Rationale: Total phosphorus has been shown to be the limiting nutrient for plant growth in Lake Allegan (USEPA, 1975). Historically, reductions of total phosphorus in the Kalamazoo River upstream of Lake Allegan have resulted in a shift of the aquatic community from a nuisance condition to a more diverse and desirable aquatic community. Therefore, controlling the amount of total phosphorus in Lake Allegan should also result in the improvement of Lake Allegan water quality. In other Michigan lakes, this approach has been found to work extremely well. For example, both the Coldwater Chain of Lakes in Branch County and Kent Lake in Oakland County have responded well to reductions of total phosphorus loads.

In developing the Lake Allegan total phosphorus goal, consideration was given to the available literature regarding total phosphorus in lakes and their responses, goals established for other lakes in Michigan, WQS, and site-specific characteristics of the Kalamazoo River watershed. The total phosphorus goals typically set for lakes in northern Michigan have been in the range of 8 to 10 ug/l for less productive oligotrophic lakes. Goals of 20 to 30 ug/l have been set for more productive lakes classified as eutrophic, which are typically found in southern Michigan.

Perhaps the most predominate factor is the site-specific characteristics of the Kalamazoo River watershed. A review of the Kalamazoo River watershed indicates that it is in a fertile area of the state, with background total phosphorus levels somewhat higher than levels found in other areas of the state (Lundgren, 1994).

As part of the process in evaluating site-specific characteristics, an analysis of the conditions in Morrow Lake, an impoundment on the Kalamazoo River upstream of the city of Kalamazoo, was conducted. Morrow Lake and Lake Allegan share similar land use characteristics with the majority of land use being agriculture and forestlands. Morrow Lake is also of similar size (1,000 acres) and average depth (5-10 foot depth) as Lake Allegan, and appears to have a well-balanced fish community (Bohr and Liston, 1987; MDNR, 1984; and MDNR, 1999) and desirable water quality characteristics. These characteristics, including no reported algae blooms with corresponding low chlorophyll a concentrations, transparency of over three feet, and a balanced non-carp dominated fish community, are the attributes of Morrow Lake that are proposed as the basis for the goals for Lake Allegan. In 1999, the following characteristics were observed in Morrow Lake: average secchi depth was 3.5 feet (with a range of 2.5 to 5.5 feet), average chlorophyll a levels measured 23 ug/l (with a range of 8 to 75 ug/l), and the carp and catfish community was 39 percent (by number). In 1984 and 1985, the percentage of carp in Morrow Lake was less than five percent. A different sampling scheme and effort may account for the higher percentages of carp reported in 1999 than in 1984 and 1985. Based on these site-specific characteristics, the conditions in Morrow Lake were used as the basis to establish the specific desired attributes for Lake Allegan. These are:

<u>Parameter</u>	<u>Desired Attributes</u>	<u>Lake Allegan Present Condition</u>
Chlorophyll a	30 ug/l (Apr-Sept average)	67 ug/l (Apr-Sept 1999 average)
Dissolved Oxygen	5 mg/l (daily minimum)	3.1 mg/l (daily minimum)
Secchi (Transparency)	3.5 feet (Apr-Sept average)	2 feet (Apr-Sept average)
Carp/Catfish	30% (community average)	87% (community average)

mg/l = milligrams per liter

To achieve these attributes, a total phosphorus goal for Lake Allegan was determined through a three-part evaluation of Morrow Lake total phosphorus levels. First, an evaluation of the data available for the intensive monitoring period (April to September 1998) was completed. There were no total phosphorus data measurements directly collected on Morrow Lake in 1998. Therefore, the analysis for 1998 was done using a monitoring station on the Kalamazoo River in Comstock, 1.4 miles downstream of the Morrow Lake outlet. Given the geographic closeness of this station to the outlet of Morrow Lake, the station at Comstock was used as representative of the outlet for Morrow Lake. The average total phosphorus concentration at Comstock in 1998 was 66 ug/l. However, in July 1998, the Battle Creek Wastewater Treatment Plant (WWTP) was exceeding its permitted total phosphorus limit, which resulted in higher than normal total phosphorus concentrations in July. Removing this month as an outlier resulted in an average total phosphorus concentration at Comstock of 64 ug/l. Data from 1999 has shown that a ten percent increase in total phosphorus occurs from Morrow Lake to the Comstock station. Taking this increase into consideration results in an adjusted average total phosphorus concentration for Morrow Lake of 58 ug/l for 1998.

Second, an evaluation of the historical total phosphorus data from 1984 to 1998 was undertaken. This period was chosen since it represents the period starting when the fish community was first found to be balanced to the present. Again, there were no direct measurements on Morrow Lake; therefore, the monitoring station at Comstock was used. The years 1995 to 1997 were omitted because they lacked data at the Comstock station. The remaining years were analyzed to determine which years represented an average condition. Three conditions were determined necessary in the database for a particular year to be considered representative of an average condition: 1) the Battle Creek WWTP total phosphorus loads were between the 10th to 90th percentiles for each month (April to September); 2) the total phosphorus discharge concentrations from the Battle Creek WWTP were less than 1 mg/l; and 3) the flows for the Kalamazoo River at Comstock were between the 10th and 90th percent exceedance flows for the historical period of record (1931 to 1997). Three years were determined to have conditions that were considered to be average (1986, 1991, and 1994). Average total phosphorus concentrations at the Comstock station for the three years was 68 ug/l. Accounting for the ten percent increase discussed above, this resulted in an adjusted total phosphorus concentration for Morrow Lake of 61 ug/l.

Third, the 1999 data for Morrow Lake was considered. The average total phosphorus concentration in Morrow Lake from April to September 1999 was 66 ug/l.

Therefore, based on the site-specific characteristics of the watershed, the similarities between Lake Allegan and Morrow Lake, the total phosphorus concentrations in Morrow Lake, and those representative of Morrow Lake in the Kalamazoo River at Comstock, the total phosphorus goal for Lake Allegan was set at 60 ug/l. The average total phosphorus concentrations in Lake Allegan in 1998 and 1999 were 95 and 96 ug/l, respectively.

Total Phosphorus Load Estimates: Water quality data was collected from Lake Allegan in 1994, 1996, 1997, 1998, and 1999 by the MDEQ to gain a better understanding of the monthly and seasonal variability of the limnological processes controlling the eutrophication of the lake. Extensive sampling was conducted in 1998. Heaton (1999) provides a detailed presentation and analysis of the sampling results and loading estimates. Plant growth in southern Michigan occurs during the spring and summer months of May to September. Due to the short retention time of seven days in Lake Allegan and allowing for time of passage and cycling of total phosphorus through the system, it was determined that the critical period for total phosphorus load to Lake Allegan is from April to September. Therefore, a seasonal approach was used in the development of the TMDL with April to June being the spring season and July to September being the summer season.

The total phosphorus load to Lake Allegan measured in 1998 was 147,887 pounds for April to September. Total phosphorus loading to Lake Allegan in 1998 from nonpoint sources for the six-month period was estimated at 96,224 pounds. Total phosphorus loading from 37 point sources in the Lake Allegan watershed totaled 51,663 pounds. The locations of these 37 point source dischargers in the Kalamazoo River watershed are shown in Figure 1.

The M-89 crossing in the city of Allegan was used as the inlet to Lake Allegan. Based on the Allegan United States Geological Survey topographical quad map, the M-89 crossing in Lake Allegan is upstream of the area designated as Lake Allegan. The total measured loads at M-89 from 1998 were normalized using average flows for the historical period of record (1931 to 1997). The flows for 1998 were about ten percent higher than the average condition. The actual 1998 point source loads for facilities upstream of Lake Allegan were determined from monitoring reported to the MDEQ. The 1998 nonpoint source loads were calculated by subtracting the point source load from the total load. The following loads were used to develop the TMDL load allocations at the M-89 inlet to Lake Allegan:

Month	Normalized 1998 Total Load	Actual 1998 Point Source Loads	Normalized 1998 Nonpoint Source Loads
April	28,500	7,427	21,073
May	25,544	8,565	16,979
June	21,690	9,159	12,531
July	17,763	9,222	8,541
August	16,306	8,303	8,003
September	16,110	8,987	7,123
Total Load (upstream M-89)	125,913	51,663	74,250

TMDL Loading Capacity Development: A comparison of the Lake Allegan average total phosphorus levels to the inlet concentrations at M-89 indicated that there was a decrease in total phosphorus concentrations of approximately 20 percent. The data indicate that the lake functions as a total phosphorus sink due to the slowed water velocities as the Kalamazoo River enters Lake Allegan, resulting in the settling of nutrients and other suspended solids. Therefore, a 20 percent increase in the goal for Lake Allegan of 60 ug/l equates to a concentration goal of 72 ug/l at M-89. The incoming goal of 72 ug/l was translated into monthly average inlet load goals by multiplying the inlet concentration goal of 72 ug/l by the historical monthly average flows at the inlet. These monthly loads were then aggregated into two seasons: spring (April, May, and June) and summer (July, August, and September). Therefore, the monthly average inlet load goals are calculated to be 18,400 pounds per month for the April through June season, and 10,700 pounds per month for the July through September season at the M-89 inlet location. The inlet goal load varies from the total load in Lake Allegan as a result of inputs from the immediate drainage and atmosphere. Adding the additional allocation for immediate drainage and atmospheric input results in a total load in Lake Allegan of 18,600 pounds for April through June and 10,838 pounds for July through September, as shown in the Table 1. The in-lake goal of 60 ug/l will be met with the additional allocation for the immediate drainage and atmospheric input.

Wasteload Allocation (WLA): The actual point source loads measured in 1998 were adjusted to compensate for: 1) Crown Paper not operating at normal capacity; and 2) the Battle Creek WWTP compliance problems in July to represent an expected point source load. Adjusting the 1998 point source load upstream of Lake Allegan resulted in an expected six-month average total phosphorus load from point sources of 8,700 pounds per month.

<u>Month</u>	<u>Expected Point Source Load</u>
April	7,427 pounds
May	8,715 pounds
June	9,717 pounds
July	7,960 pounds
August	8,691 pounds
September	9,250 pounds
Average	8,700 pounds/month

The WLA set for the April to June season was set at the expected load of 8,700 pounds per month for point sources upstream of Lake Allegan. The WLA for the July to September period was set at a load of 6,700 pounds per month for point source discharges upstream of Lake Allegan (see Load Allocation discussion below). This resulted in a 23 percent reduction in total phosphorus from the expected point source discharges for this period. It is during this season that point source load reductions are most important, since during this time, point source loading dominated the total load going to Lake Allegan.

For purposes of establishing a starting point under this TMDL, preliminary individual WLAs are assumed to be at a value that would represent a 23 percent reduction in the expected actual summertime discharge levels for point source discharges, as shown in Table 2. The final WLA may differ from the preliminary WLA values and will be developed under the MDEQ's proposal under the State-EPA Agreement to Pursue Regulatory Innovation: Cooperative Agreement to Meet Total Maximum Daily Load (TMDL) for Phosphorus (Cooperative Agreement). In the Cooperative Agreement, the final WLA will be incorporated into National Pollutant Discharge Elimination System (NPDES) permits as the individual permits are modified or reissued to establish the aggregate and individual WLA as enforceable requirements of the permits, including schedules to achieve the necessary additional reductions.

Load Allocation (LA): The development of the LA included inputs from precipitation, the immediate drainage surrounding Lake Allegan and Dumont Creek, and nonpoint source loads from upstream of the M-89 inlet. Nonpoint sources of total phosphorus in the watershed include: residential lawn fertilizers, septic systems, livestock operations, row cropping activities, construction, transportation, commercial and industrial activities involving storm water, and manipulation of the landscape features. The LA for the April to June period was determined by subtracting the expected point source WLA (8,700 pounds) and the margin of safety (MOS) of 100 pounds (see MOS discussion below) from the inlet goal (18,400 pounds). This resulted in an LA for nonpoint sources upstream of M-89 of 9,600 pounds per month, for a 43 percent reduction from current normalized nonpoint source loads during the April to June period.

Reductions from applications of best management practices target a 50 percent reduction (3,950 pounds per month) in average current nonpoint source loads (7,900 pounds) for the July through September season. Using the LA of 3,950 pounds per month for nonpoint sources upstream of M-89, an MOS of 50 pounds, and the inlet goal of 10,700 pounds per month, the WLA for point sources was then determined to be 6,700 pounds per month.

Additional allocations were made for the immediate drainage of Lake Allegan, atmospheric sources (precipitation), and Dumont Creek. For the immediate drainage and Dumont Creek, a 50 percent reduction was assumed for the six-month period. For atmospheric sources, no reasonable reductions were anticipated; therefore, this load was left at 42 pounds/month. The monthly average seasonal LA for Lake Allegan totaled 9,800 pounds per month for the period April to June and 4,088 pounds per month from July to September, as shown in the attached Table 1.

MOS: An MOS is also required as part of the TMDL process to account for the uncertainties in the WLA and LA calculations. The MOS developed for this TMDL is lower than typically derived because of the low uncertainty involved in estimating the point source and nonpoint source loads to the lake. An extensive amount of information was collected on ambient loadings of total phosphorus entering the lake from the watershed. In addition, point source loadings were intensely investigated so that accurate point source loadings and allocations could be developed. Therefore, an explicit MOS of 100 pounds per month is allocated for the early season from April through June, since loads are greater in the spring season to account for the higher peak flow periods. An explicit MOS of 50 pounds per month is allocated for the summer season, since loads are lower in July to September.

Reasonable Assurance: Since 1999, the MDEQ has been joined by a number of watershed partners to develop the TMDL and an associated reduction plan. The committee consists of representatives and individuals from regulated point sources, environmental groups, local government, agriculture, Michigan State University Extension Service, developers, homeowners, and many others. This core group began intense work in 2000 to gather a larger

group of stakeholders for the purpose of developing a strategy to reduce total phosphorus in the watershed. NPDES permits will play a major role in assuring implementation of the total phosphorus TMDL for Lake Allegan. Nutrient controls will be executed through the use of NPDES permits and the Cooperative Agreement.

In the Cooperative Agreement, point source dischargers would commit to develop a Point Source Reduction Implementation Plan. All point source dischargers accounted for under the Cooperative Agreement are targeted for a collective 23 percent reduction from 1998 loads during the July through September season. A number of point source dischargers have made reductions of total phosphorus in 1998, 1999, and 2000 in anticipation of the TMDL.

Under the Cooperative Agreement, point source dischargers would also agree to facilitate nonpoint source reductions by providing assistance, resources, and coordination of local efforts, and assist in the development of a Nonpoint Source Reduction Implementation Plan (NPSRIP).

Point source dischargers in the watershed have also provided financial assistance to: 1) develop a nonpoint source loading model; 2) initiate monitoring in the Kalamazoo River watershed; 3) initiate efforts to address municipal storm water discharges in their communities; and 4) provide financial assistance for water quality monitoring in the Gun River as part of the Gun River watershed project.

Several communities are proactively planning for regional, cooperative storm water management through the voluntary Michigan storm water permit.

In addition, a two-year water quality trading demonstration project is being conducted in the Kalamazoo River to improve water quality and provide information vital to the design of a statewide water quality trading program. The project will demonstrate and evaluate the environmental and economic implications of watershed-based nutrient (total phosphorus) trading between point and nonpoint sources. It will provide an incentive for implementing voluntary nonpoint source reductions and promote collaborative, community-driven watershed management planning. The reductions envisioned under this TMDL may be achieved, in part, by trading under Michigan's Water Quality Trading Program.

Another integral part of the NPSRIP is the watershed planning and management of targeted sub-basins with significant nonpoint source total phosphorus loading. Federal funding (Section 319 grants) and state funding (Clean Michigan Initiative grants) are being used to implement the efforts of these targeted sub-basins. Specific nonpoint sources that will be targeted are residential lawn fertilizers, septic systems, livestock operations, row cropping activities, construction, commercial, transportation, and industrial activities. Many of these sources are being addressed through existing programs, such as the Davis Creek watershed project, the consolidated drain project in the city of Portage, the multiple farm bill program, and storm water regulation.

Present Conditions: The present condition for each source is described for each season in the Table 1.

Monitoring: River monitoring, at a minimum, will include collecting monthly (April to September) grab samples on the Kalamazoo River at M-118, the inlet to Lake Allegan (M-89), the M-40/M-89 crossing below Lake Allegan, Galesburg, and Comstock, as resources allow. Samples will be analyzed for total phosphorus, ortho-phosphorus, nitrites, nitrates, ammonia, suspended solids, chlorophyll *a*, and total dissolved solids. Lake monitoring will include monthly (April to September) samples collected in Morrow Lake and Lake Allegan for total phosphorus, ortho-phosphorus, nitrites, nitrates, ammonia, suspended solids, and total dissolved solids. Vertical profiles in the lake will be taken for dissolved oxygen, temperature, conductivity, pH,

chlorophyll *a*, and transparency. The fish community in Lake Allegan will also be sampled, at a minimum, during the rotating basin monitoring years in 2004 and 2009 to assess changes. The point source loading to Lake Allegan will be checked through the periodic review of facility discharge monitoring reports.

References:

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Table 1. Total Maximum Daily Load (TMDL) including Waste Load Allocations (WLAs), Load Allocations (LAs), and a Margin of Safety (MOS) for Lake Allegan, April to September. All units as pounds of total phosphorus per month.

	April - June Period		July - September Period	
	<u>Goal</u>	<u>Present Conditions</u>	<u>Goal</u>	<u>Present Conditions</u>
LA:				
Dumont Creek	96	192	34	69
Immediate Drainage	62	123	62	124
Precipitation	42	42	42	42
Kalamazoo River (Inlet)	9,600	16,861	3,950	7,900
Total	9,800	17,218	4,088	8,135
WLA:				
Point Sources	8,700	8,700	6,700	8,700
Total	8,700	8,700	6,700	8,700
MOS:	100	-----	50	-----
Total Load	18,600	25,918	10,838	16,835

Table 2. Expected actual point source total phosphorus loadings (pounds per month) developed from actual loads discharged from April to September 1998.

<u>Facility Name</u>	<u>Expected Actual Total Phosphorus Load (pounds per month)</u>
A M Todd Company	45
Albion Wastewater Treatment Plant (WWTP)	300
Allegan Metal Finishing	5
Allegan WWTP	160
Battle Creek WWTP	1,780
Bellevue WWTP	10
Bostik, Incorporated	1
Charlotte WWTP	150
Checker Motors Corporation	100
Concord Wastewater Sewage Lagoon (WWSL)	80
Crown Vantage	910
Eaton Corporation – Proving Grounds	50
Eaton Corporation – Torque Control Products Division	2
Glassmaster Control – Kalamazoo	20
Gun Lake Sewer Authority	10
Hercules, Incorporated – Kalamazoo Plant	100
Homer WWSL	15
International Paper Company	10
Joseph Campbell Company – Marshall	70
Kalamazoo WWTP	3,330
Kellogg Company	150
Marshall WWTP	130
Mark I Molded Plastics	10
Menasha Corporation	690
Murco Foods, Incorporated	60
Olivet WWSL	110
Otsego WWTP	45
Parker Hannifin Corporation-Brass Products Division	1
Parker Hannifin Corporation-Pump/Motor Division	1
Parma WWSL	2
Perrigo Company-Plant No. 1	25
Perrigo Company-Plant Nos. 4 and 5	1
Pharmacia and Upjohn	35
Plainwell Paper	80
Plainwell WWTP	110
Rock-Tenn Company	90
Springport WWSL	20