Phalen Chain of Lakes Strategic Lake Management Plan

Improvement Options and Recommendations

Prepared for:
Ramsey-Washington Metropolitan Watershed District

Prepared by:
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October 2004

Appendix A

Executive Summary

Water quality varies widely throughout the Phalen Chain of Lakes. Gervais and Phalen Lakes typically have good water quality that meets the goals set for them. Kohlman and Keller Lakes, however, typically meet neither the preliminary water quality goals set forth in the Ramsey Washington Metro Watershed District's (District's) Plan nor the Minnesota Pollution Control Agency's Total Maximum Daily Load guideline for phosphorus (expected to be 60 μg/L for shallow lakes), landing them on the MPCA's Impaired Waters List. However, it is not clear that either set of goals is appropriate for Kohlman or Keller Lakes in terms of the District's approach to lake management.

Because of the uncertainty concerning the proper water quality goals for the Phalen Chain of Lakes, the District will be conducting a survey of lake users in 2004, as well as communicating with local agencies with the intention of establishing new water quality goals for the Phalen Chain that reflect current desires. Upon completion of this effort, this SLMP will be finalized.

Regardless of the ultimate goals set for the lakes, all of the lakes in the Phalen Chain would surely benefit from some degree of water quality improvement, as well as improvements in shoreline condition, macrophyte growth and fisheries composition (in terms of a decreased carp population). Therefore, many different structural, in-lake and non-structural (prescriptive practices) are recommended in this draft of the SLMP, at least to the extent that they are evaluated further in feasibility studies. It should be noted that, depending on the results of the feasibility studies, any or all of these recommendations may be changed or discarded in the future for the Phalen Chain of Lakes.

Capital improvement project recommendations (and their feasibility studies) discussed in the SLMP are:

- Shoreline surveys and shoreline management plans for Kohlman, Gervais and Keller Lakes
- Wetland enhancements and retention pond improvements
- Rainwater gardens in drainage areas that currently receive no treatment
- Removal of nuisance benthivorous fish (carp)
- Improvements to Owasso Basin's treatment performance
- Nuisance macrophyte management where needed
- Redirecting Keller Lake outflows through Round Lake
- Inactivation of sediment phosphorus release in Kohlman and Keller Lakes
- Chemical treatment of flows leaving Kohlman Basin
- Several kinds of prescriptive practices

Phalen Chain of Lakes Strategic Lake Management Plan
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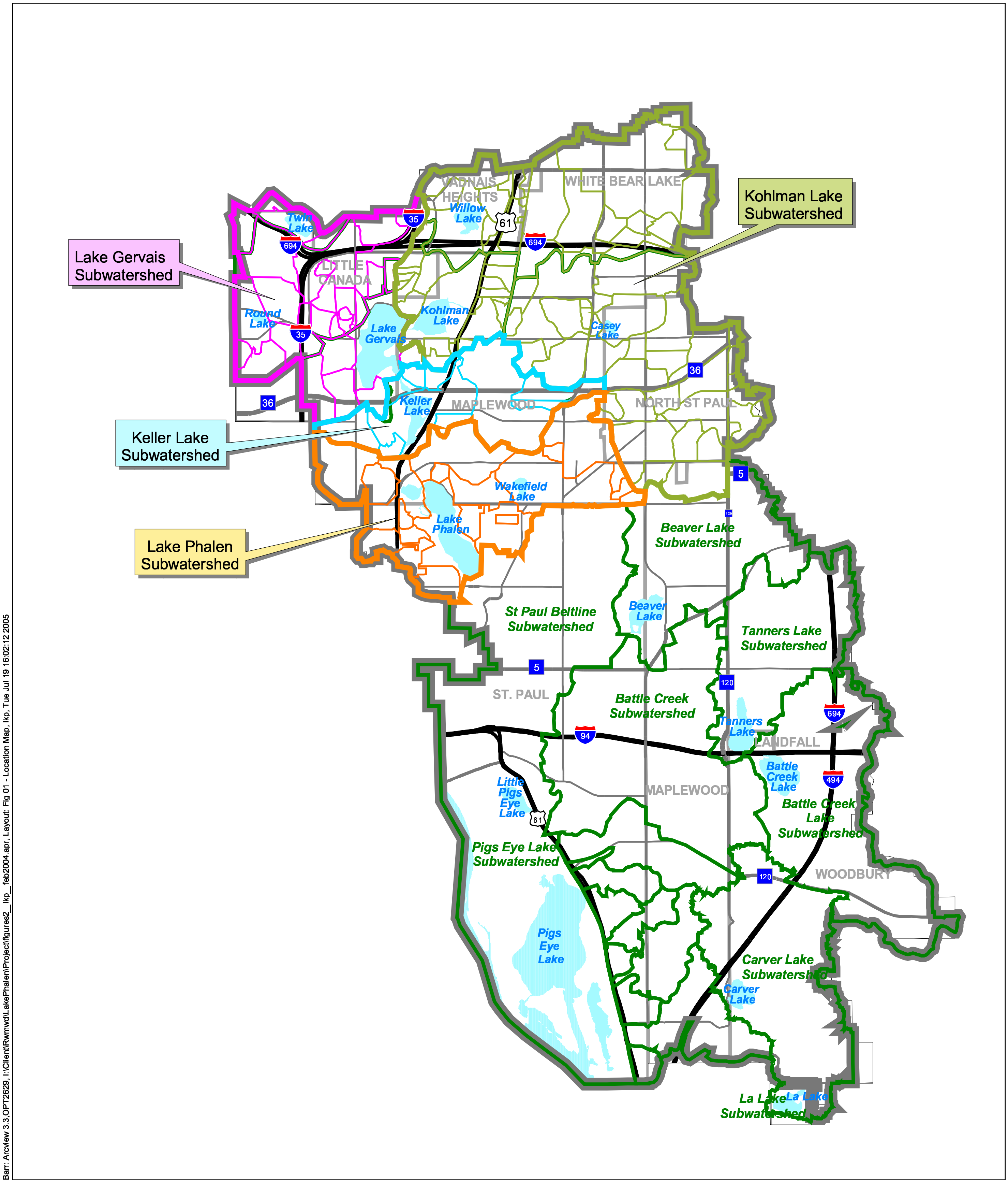
1.0 Introduction

The purpose of this Strategic Lake Management Plan (SLMP) is to establish priorities and provide guidelines for the cities of Maplewood, Little Canada, and St. Paul; Ramsey County; the Ramsey-Washington Metropolitan Watershed District (District); and citizens for meeting water quality goals set for the Phalen Chain of Lakes (Lakes Kohlman, Gervais, Keller and Phalen)—upstream and downstream. These goals were recommended for water bodies within the District in the *Watershed Management Plan* (Barr Engineering Company, 1997). This SLMP identifies watershed best management practices (BMPs) and in-lake management practices that may help achieve the goals for each lake. Estimated costs for the various management practices have been identified, along with recommendations for the most cost-effective improvements and practices. Figure 1 shows the location of the study area in relation to the entire RWMWD watershed.

1.1 Background

In 1997, the Ramsey-Washington Metro Watershed District (District) completed their *Watershed Management Plan* (Plan) (Barr Engineering Company, 1997), which identified preliminary water quality goals for each lake within the District's boundary. These goals were based on the Minnesota Pollution Control Agency's (MPCA's) recreational-use classifications, which are described in Appendix A of this report. Hydrologic and water quality modeling was performed for each lake's subwatershed as part of the Plan. The results of these preliminary hydrologic and nutrient budgets indicated the need for the District to perform more detailed lake water quality studies such as this Strategic Lake Management Plan (SLMP). The Phalen Chain of Lakes was described as having a high priority for SLMP completion.



0.5 0 0.5 1 1.5 2 2.5

Scale in Miles

Ramsey-Washington Metro Watershed District

BARR

Figure 1

SITE LOCATION MAP

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Although a *Phalen Chain of Lakes Surface Water Management Plan* (SWMP) (Barr, 1988) had already been created for the Phalen Chain of Lakes, a SLMP was warranted due to the many changes that had occurred in the watershed and the improved modeling technology that could be used in the SLMP process. The differences between the information used in the 1988 SWMP and this SLMP are:

- Inclusion of Capital Improvement Projects (CIPs) that had been done throughout the Phalen Chain of Lakes subwatershed since the 1988 SWMP (based on the 1988 SWMP's recommendations)
- The use of William Walker's P8 Model (I.E.P., 1990)
- Monitoring data for inflow points and for the lakes themselves
- Survey information for ponds and wetlands throughout the Phalen Chain of Lakes subwatershed
- Updated subwatershed divides
- Updated land use information

1.2 Overview of the Lakes' Recreational-Uses

The lakes in this study area are important recreational water bodies within the District's boundary. Phalen, Gervais and Keller Lakes have public accesses and all four lakes are intensively used during both summer and winter months. Phalen and Gervais lakes have swimming beaches. Large areas of public parkland surround Phalen and Keller Lakes. In addition, the Minnesota Department of Natural Resources' Gateway State Trail passes through the subwatershed for this study area.

Table 1 shows the "existing and desired" recreational uses in each lake according to the District's 1997 Plan. Fishing, boating, swimming, water-skiing and aesthetic viewing are some of the major uses made of these lakes.

Table 1 Recreational Uses of the Phalen Chain of Lakes - Existing and Desired

	Kohlman	Gervais	Keller	Phalen
Swimming		X		X
Scuba Diving				X
Water-Skiing		X	X	
Motorboating	X			
Speedboating		X	X	
Canoeing	X		X	
Fishing	X		X	X
Picnicking	X		X	X
Wildlife Habitat	X (limited)	X (limited)	X	X
Aesthetic Viewing	X	X	X	X

Source: RWMWD *Watershed Management Plan* (Barr Engineering Company, 1997)

To date, it has been assumed that, except for a few complaints outlined below, all four lakes are meeting their desired uses. Also, it is assumed that each lake's desired uses listed in the Plan match the current desired uses for each lake. These are not insignificant assumptions. A public survey of lake residents and users could be a reasonable complement to this study to ensure that all interests have been, or will be, covered. An example of a public survey that could be used is included in Appendix B of this report.

Known complaints are:

- Fishing access to Gervais-Keller Lakes is limited
- Eurasian watermilfoil growth has reached nuisance levels in Gervais Lake
- The shoreline on the southwest side of Gervais Lake is in need of repair or restoration
- The lakes' carp populations have reached nuisance levels

1.3 Water Quality Goals

There are two sets of water quality goals that have been defined for each lake in the Phalen Chain of Lakes. One set is the District's preliminary water quality goals that are described in the District's Plan. The second set is the total phosphorus guideline set forth by the MPCA that determines which lakes should be listed on the Impaired Waters List (List 303(d) MPCA, January, 2004).

Figures 2 through 5 show the historical total phosphorus concentration (summer average) in each of the four lakes in the Phalen Chain of Lakes over the past 22 years. It is important to note that watershed conditions have changed, in some cases significantly, over these years and that only the last 5 or 10 years may really represent today's watershed conditions. It is also important to remember that the past 10 years have been wetter than average. Regardless of these interpretive cautions, these graphs offer a glimpse of the lakes' historical water quality conditions. Trend analysis of the lakes' water quality data do not indicate a downward trend in water quality (degradation) as long as the either the watershed is not significantly changed, or development requirements provide that new developments not significantly change the water quality or quantity of the flows leaving new developments.

KOHLMAN LAKE
Growing Season (June through August) Mean Total Phosphorus Concentrations

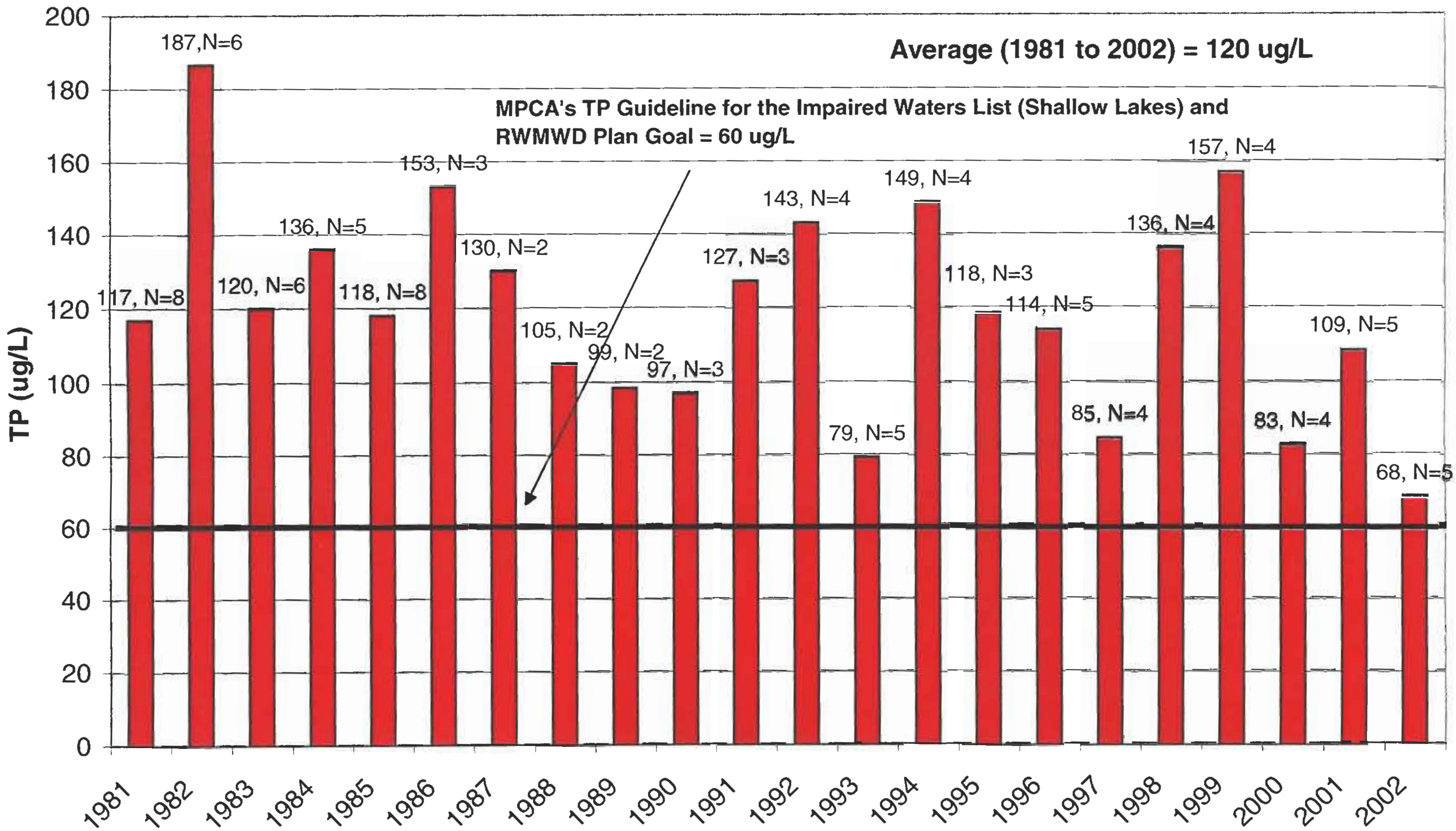


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Figure 2

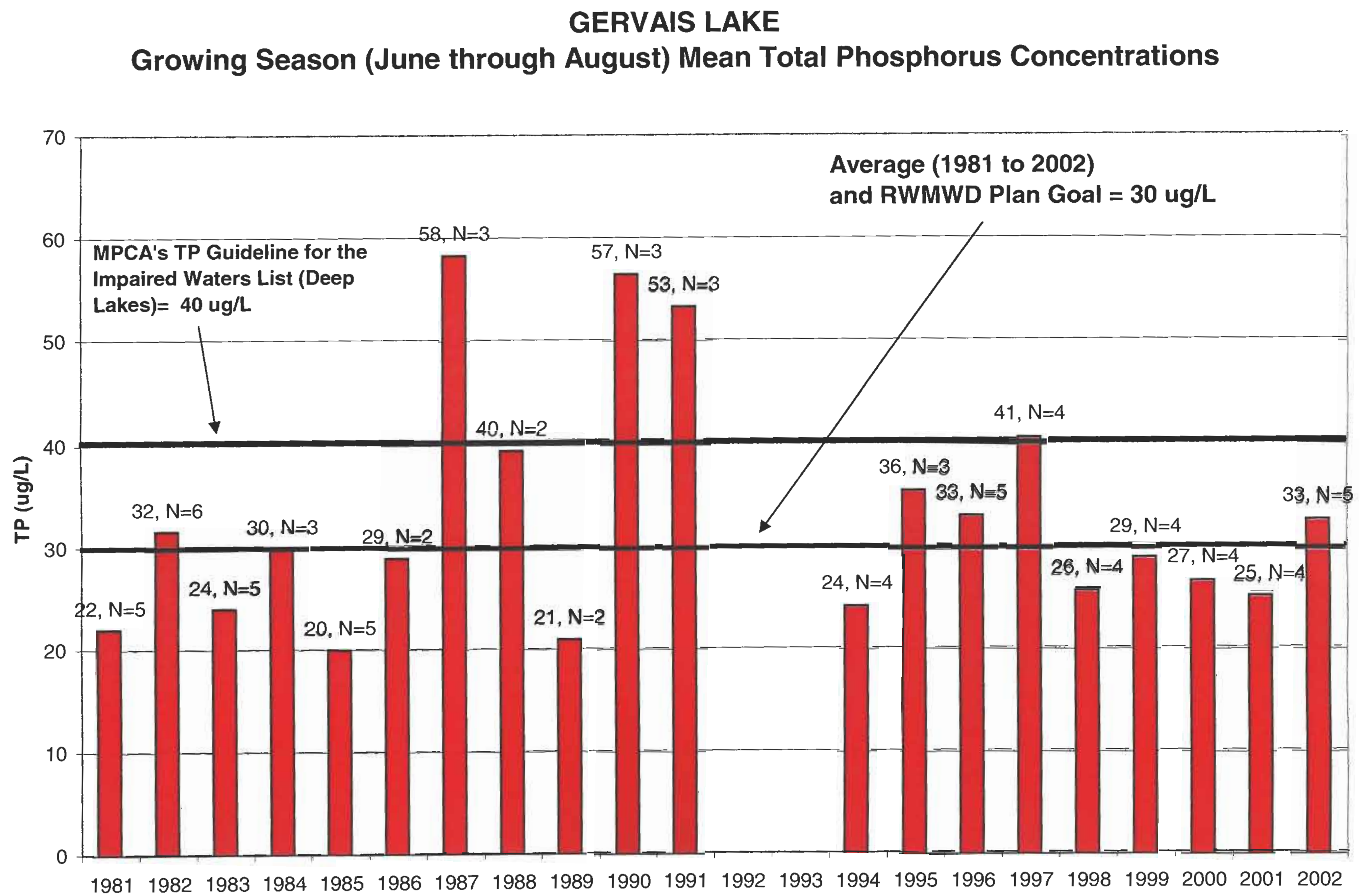

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Figure 3

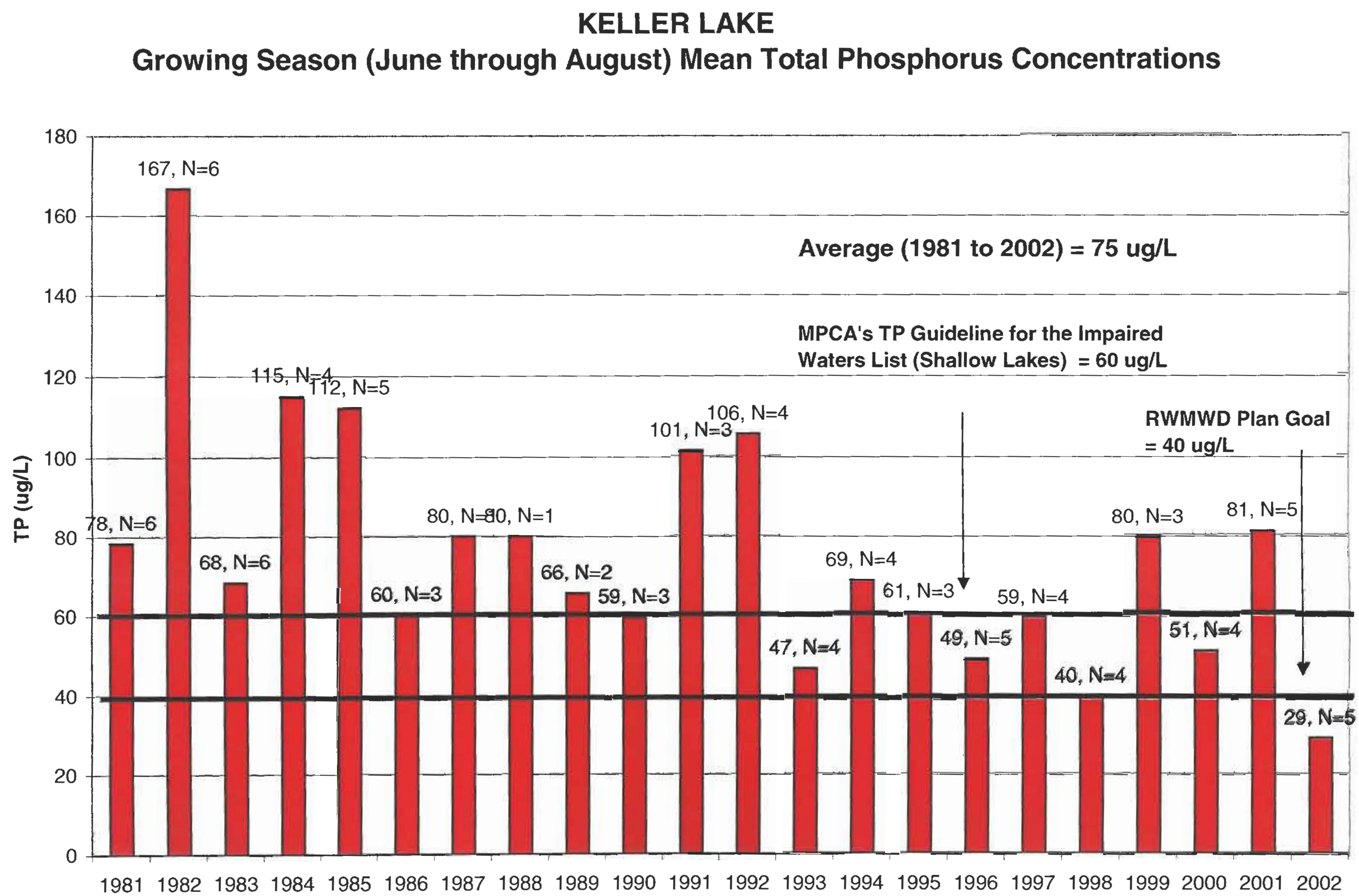

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Figure 4

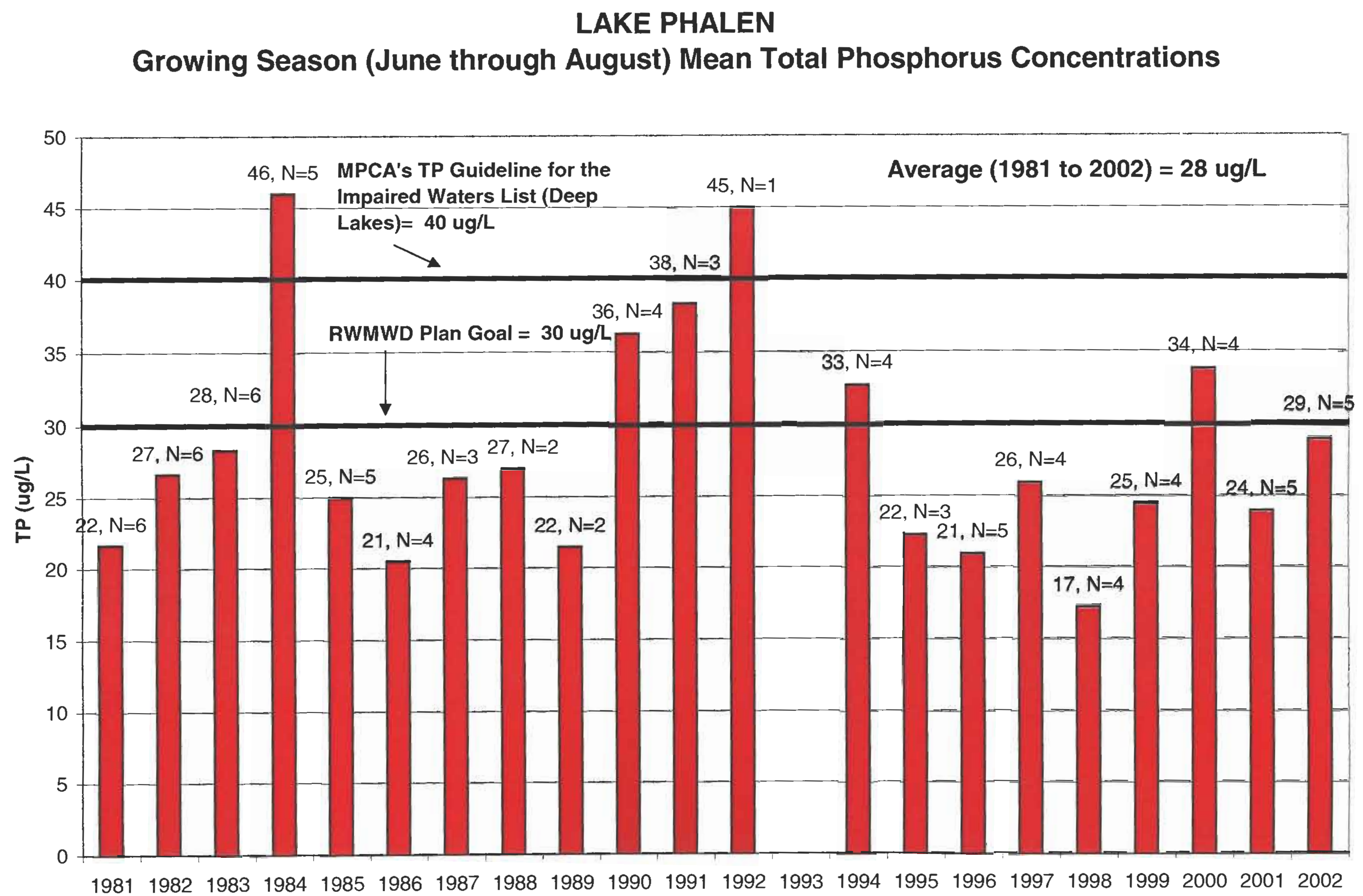

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Figure 5

On each lake's graph, there is a line that indicates the preliminary total phosphorus goal described in the Plan (labeled "RWMWD Plan Goal"). Another line indicates the MPCA's TP guideline for the Impaired Waters List (described below). The 20-year average total phosphorus concentration for each lake is also written on the graph. As shown on Figures 2 and 4, Kohlman and Keller Lakes have typically not met their water quality goals in the Plan. Gervais and Phalen (Figures 3 and 5), however, have typically met their Plan goals.

For deep lakes, such as Gervais and Phalen, in this ecoregion (North Central Hardwood Forests), the MPCA's total phosphorus guideline is 40 µg/L. This is the threshold above which a lake does not provide full support of primary contact recreation and aesthetics ("swimmable use") as defined by the MPCA. A deep lake having an average Total Phosphorus (TP) concentration more than 40 µg/L (calculated over a certain number of observations) can by definition be listed as "swimming impaired" in the MPCA's Impaired Waters List and be required to meet the guideline through an implementation plan outlined in a Total Maximum Daily Load (TMDL) Study.

For shallow lakes, such as Kohlman and Keller, in this ecoregion, the MPCA's TP guideline is expected to be increased to 60 µg/L (based on current drafts of proposed changes to Minnesota Rules Chapter 7050). More information about the MPCA's Impaired Waters Program can be found on the internet at www.pca.state.mn.us/water/tmdl.html.

Figure 6 shows the historical water quality of all four lakes along with the MPCA's TP guidelines for deep and shallow lakes on one graph to show the wide range of water quality along the Phalen Chain of Lakes.

Looking at Figure 6 one can see why Kohlman and Keller are on the MPCA's Impaired Waters List and why Gervais and Phalen Lakes are not. Kohlman Lake's summer total phosphorus averages are significantly higher than 60 µg/L almost every year for the past 20 years. Kohlman Lake's summer average TP concentration has also frequently exceeded 60 µg/L over the last 20 years, although less so in the last 10 years. Phalen and Gervais Lakes, however, rarely if ever exceed their 40 µg/L guideline. Kohlman and Keller lakes can be taken off the Impaired Waters List if projects are implemented to reduce their average total phosphorus concentration to 60 µg/L or lower. It is possible for Kohlman and Keller Lakes to reach this goal, but only with significant total phosphorus removals within both their watersheds and/or in each lake's internal loads. Whether a case can be made that it is unreasonable for these lakes to ever meet the total phosphorus guideline is unclear.

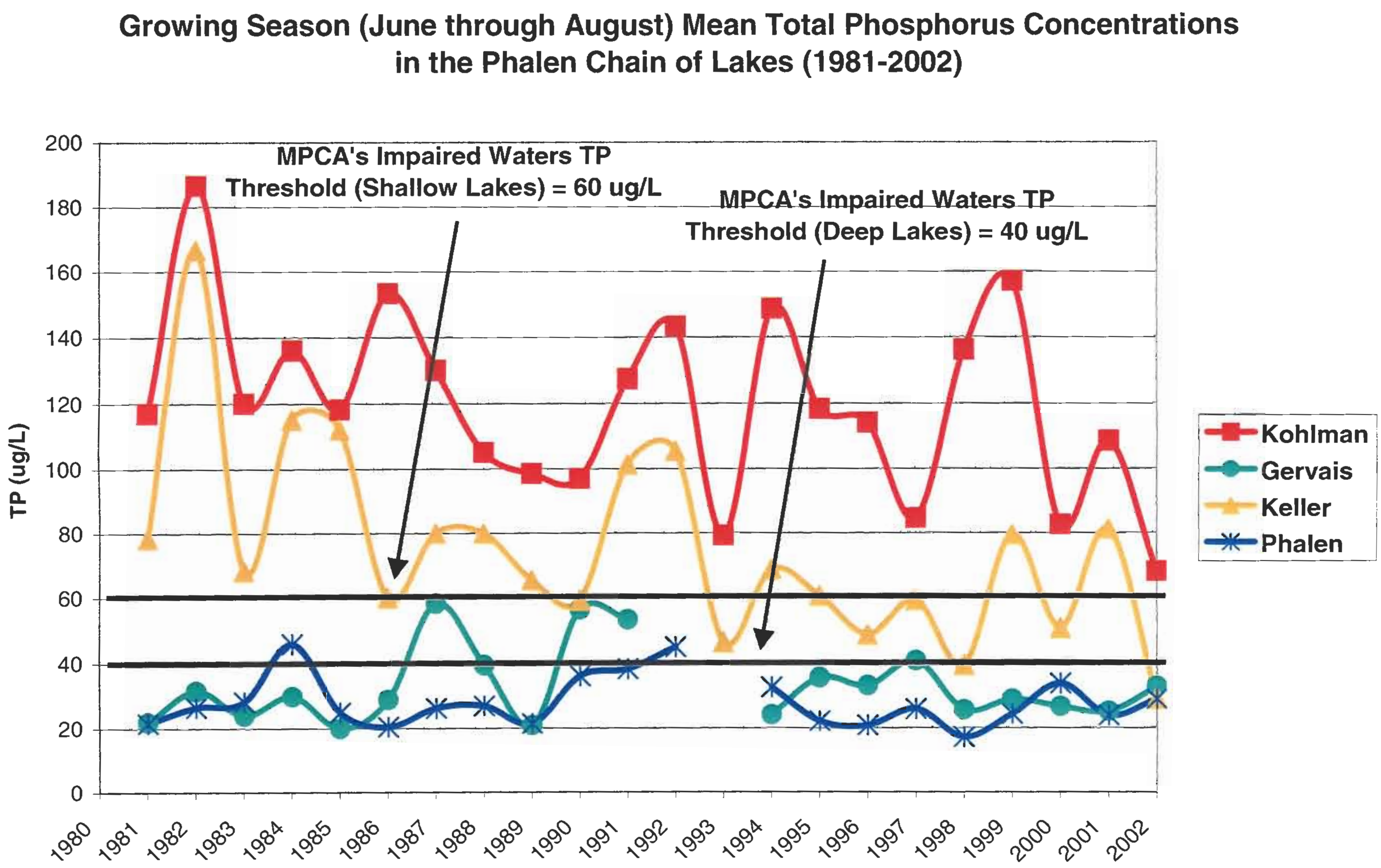

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Figure 6

Gervais and Phalen lakes are not currently on the MPCA's Impaired Waters List because their water quality has historically met the "swimmable use" criteria (their summer average TP concentrations are usually less than 40 µg/L). The fact that these lakes are not considered "impaired," however, does not mean that these lakes could not benefit from some degree of water quality improvement. Certainly, at the very least, protecting these lakes' current level of water quality is wise.

1.4 SLMP Coverage

This report is organized so that the reader is immediately directed to the improvement options for each lake and its subwatershed. It is important to realize, however, that the lake improvement options and ultimate recommendations shown in the body of this SLMP are based on intensive modeling of each lake and its tributary subwatershed. Although this effort is not highlighted in the main body of this report, a large volume of supporting information, including project methodology and detailed results of the project's water quality modeling efforts are included in the appendices of this SLMP for those readers who wish to have more background information.

The following information is provided in Sections 2.0 and 3.0:

Section 2.0: **Improvement Options**—Best Management Practices (BMPs) that will help meet the water quality goals for each lake are identified. The estimated effectiveness and cost for these improvements are also discussed.

Section 3.0: **Conclusions and Recommendations**—The recommended improvement options are summarized in this section.

The appendices in this SLMP are extensive, because they contain all of the supporting information that helped to make the ultimate management recommendations for the lakes and their subwatersheds. Also, a few appendices are included here to familiarize the reader with some general concepts in lake water quality, a general public survey, and the modeling methodology used in the SLMP process.

Specifically, the following information is presented in the appendices of this SLMP:

Appendix A: **Criteria for Lake Water Quality Evaluation—**This appendix describes the types of information gathered for each lake for the SLMP process.

Appendix B: **Example of Public Survey to Determine Desired Lake Uses.**

Appendix C: **General Concepts in Lake Water Quality.**

Appendix D: **Owasso Basin Performance Improvements—**Results of Monitoring P8, modeling and Assessment of Potential Water Quality Treatment Improvements and Feasibility.

Appendix E.1: Lake and Subwatershed Existing Conditions- Kohlman Lake—The appendix includes an overview of Kohlman Lake and its tributary subwatershed. The in-lake water quality data and watershed land use information that were collected in 2002 and used to develop and calibrate models of each lake and its subwatershed are presented here, as well as information on the lake's historical water quality trends.

Appendix E.2: Lake and Subwatershed Existing and Historical Conditions- Gervais Lake.

Appendix E.3: Lake and Subwatershed Existing and Historical Conditions- Keller Lake.

Appendix E.4: Lake and Subwatershed Existing and Historical Conditions- Lake Phalen.

Appendix E.5: Lake and Subwatershed Existing Conditions -Other Lakes in the Phalen Chain of Lakes Subwatershed—A general description of the other lakes in the Phalen Chain of Lakes subwatershed (Round-Little Canada, Wakefield, Twin Lakes, Willow Lake and Round Lake-Maplewood) is included here. While these lakes were not evaluated in detail, they are included in the Phalen Chain of Lakes P8 models.

Appendix F: In-Lake Water Quality Data for the Phalen Chain of Lakes.

Appendix G: Pond Survey Information Compared to Nationwide Urban Runoff Program (NURP) Criteria.

Appendix H: Results of Macrophyte Surveys Conducted in the Phalen Chain of Lakes in 2003.

Appendix I: Recent MDNR Fisheries Surveys of the Phalen Chain of Lakes—This appendix contains tabulated results from pond surveys conducted throughout the Phalen Chain of Lakes subwatershed and compares each pond or wetland's dead storage volume to the volume recommended by the Nationwide Urban Runoff Program (NURP). The purpose of this comparison was to determine whether improvements to existing retention ponds and "utilizable" wetlands were justified in terms of their water quality improvement potential.

Appendix J: P8 Modeling of the Phalen Chain of Lakes Subwatersheds—In this appendix, the P8 modeling methodology is described. The P8 model was used to generate daily water and TP loads to each of the lakes under a range of climatic conditions. Also, detailed P8 modeling results that were not included in the body of the SLMP report are included here. They provide more detailed information about the nature of the TP load coming off of each lake's subwatershed.

Appendix K: In-Lake Modeling of the Phalen Chain of Lakes—In-lake modeling involved taking lake bathymetry data, climatic data and the water and TP loads from the P8 models and combining them in a spreadsheet to predict each lake's TP concentration over the summer months (June through August). The methods used to create the in-lake spreadsheet models and to determine whether or not the lakes experienced an internal load of phosphorus are described in this appendix.

2.0 Improvement Options

2.1 Using the Water Quality Models to Evaluate Existing and Potential Future CIP Performance

The P8 and in-lake models created for this SLMP were used to evaluate not only existing water quality conditions in each lake and its subwatershed, but also the water quality conditions before certain CIPs were implemented and after potential future CIPs are implemented.

Each time a CIP scenario was evaluated with the water quality models, three different climatological conditions were used (in terms of wet, dry, and average years of precipitation). The water quality impact of past and potential future projects on the lakes was evaluated this way because the lakes' water quality conditions are not only affected by the projects themselves, but also by the weather. Also, depending on lake characteristics, average treatment performance in CIPs may not coincide with average precipitation conditions. By looking at a range of precipitation conditions, a more realistic range of potential CIP effectiveness could be considered.

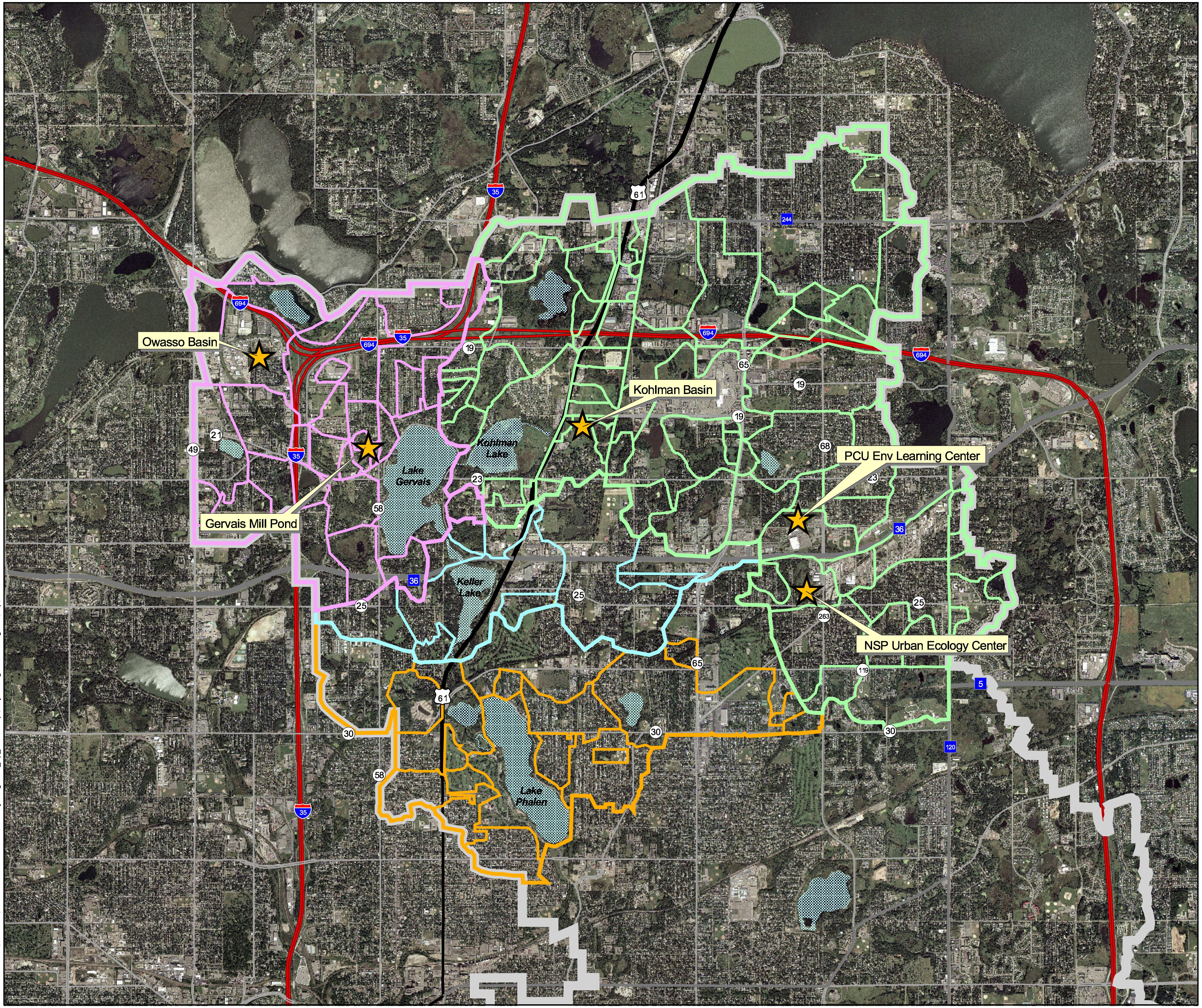
2.2 Success of Past Improvement Projects on Water Quality in the Phalen Chain of Lakes

Several capital improvement projects (CIPs) have already been implemented in the Phalen Chain of Lakes tributary subwatershed. As a part of the SLMP process, the success of each of these projects was evaluated, both in terms of percent reduction of TP, as well as reduction in the lakes' summer average TP concentrations.

The following projects were evaluated:

- Kohlman Basin (Kohlman Lake subwatershed)
- NSP Urban Ecology Center (Kohlman Lake subwatershed)
- PCU Environmental Learning Center (Kohlman Lake subwatershed)
- Owasso Basin (Gervais Lake subwatershed)
- Gervais Mill Pond (Gervais Lake subwatershed)

The locations of these CIPs are shown in Figure 7.



LEGEND

- Existing Capital Improvement Projects
- Gervais Lake Subwatershed
- Kohlman Lake Subwatershed
- Keller Lake Subwatershed
- Lake Phalen Subwatershed
- Lakes
- RWMWD Hydrologic Boundary

2000 0 2000 4000 6000 8000

Scale in Feet

Figure 7

EXISTING CAPITAL IMPROVEMENT PROJECTS ANALYZED FOR PERFORMANCE

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures2_lkp_feb2004.apr, Layout: Fig 07 - Existing CIP , lkp, Tue Jul 19 16:14:20 2005

Figure 8 shows the impact of each of these CIPs individually on the removal of TP, based on modeling results. These figures compare the cumulative percent reduction in TP at the location of the CIP, before and after its construction. A “cumulative percent reduction” means that the treatment effect of upstream ponds and wetlands are taken into account in the calculation. If upstream removals were not taken into account, one wouldn’t know if a CIP were performing poorly, or simply responding to the fact that most particulate matter had already been removed upstream. For this reason, previous conditions in Kohlman Basin, PCU Environmental Learning Center, Owasso Basin and Gervais Mill Pond already had some removal of TP by the time stormwater reached the CIP site. However, in all cases (to varying degrees), the construction of the CIP has helped to increase the percent of TP removed. By showing both previous and existing cumulative removals side-by-side, one can see the impact that each CIP has by noting the difference in cumulative percent removal.

Figure 9 shows the impact of the CIPs, collectively, on the in-lake TP concentration of each lake. It is important to note that because the Phalen Lakes are all connected, decreasing the TP load to upstream lakes can affect the TP concentrations of all of the lakes downstream.

Owasso Basin

The chart shown for Owasso Basin has not two, but three scenarios: “Previous,” “Existing” and “Optimized.” A recent study of Owasso Basin’s performance indicated that a large fraction of the flows entering Owasso Basin from its immediate subwatershed are short-circuited through the basin bypassing the basin’s deeper water that provides treatment. Because the basin’s secondary inlets are so close to the basin’s outlet, inflows from the northern and western drainage areas essentially exit the basin before they have been treated. In Figures 8 and 9, Owasso Basin’s cumulative percentage TP removal and its effect on Gervais Lake’s TP concentration under “existing” conditions reflects this compromised treatment condition. Nonetheless, the construction of Owasso Basin has resulted in improved treatment of the flows leaving the area (58 percent cumulative TP removal versus 16 percent under previous conditions).

Figure 8: Impact of Existing CIPs on TP Removal

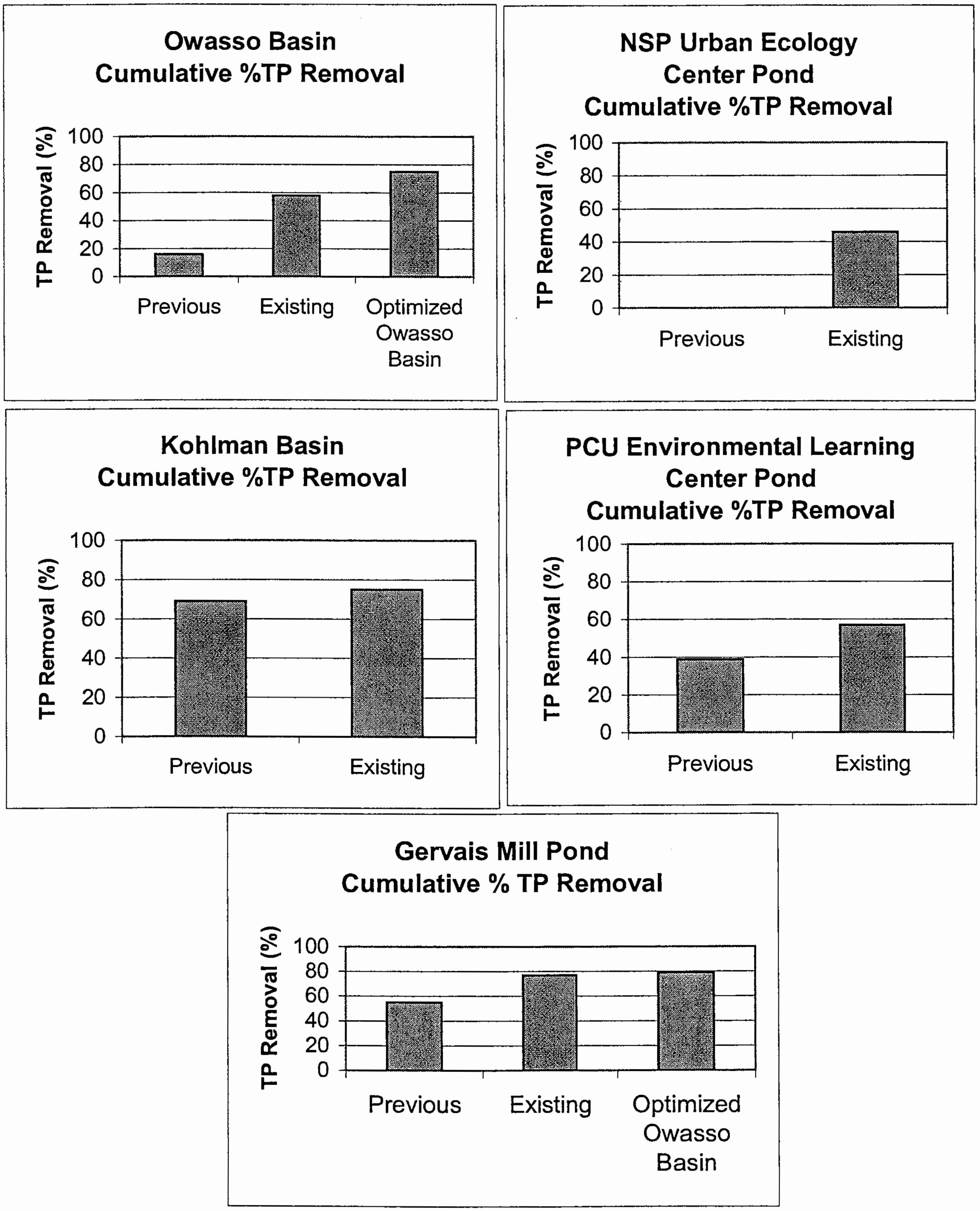
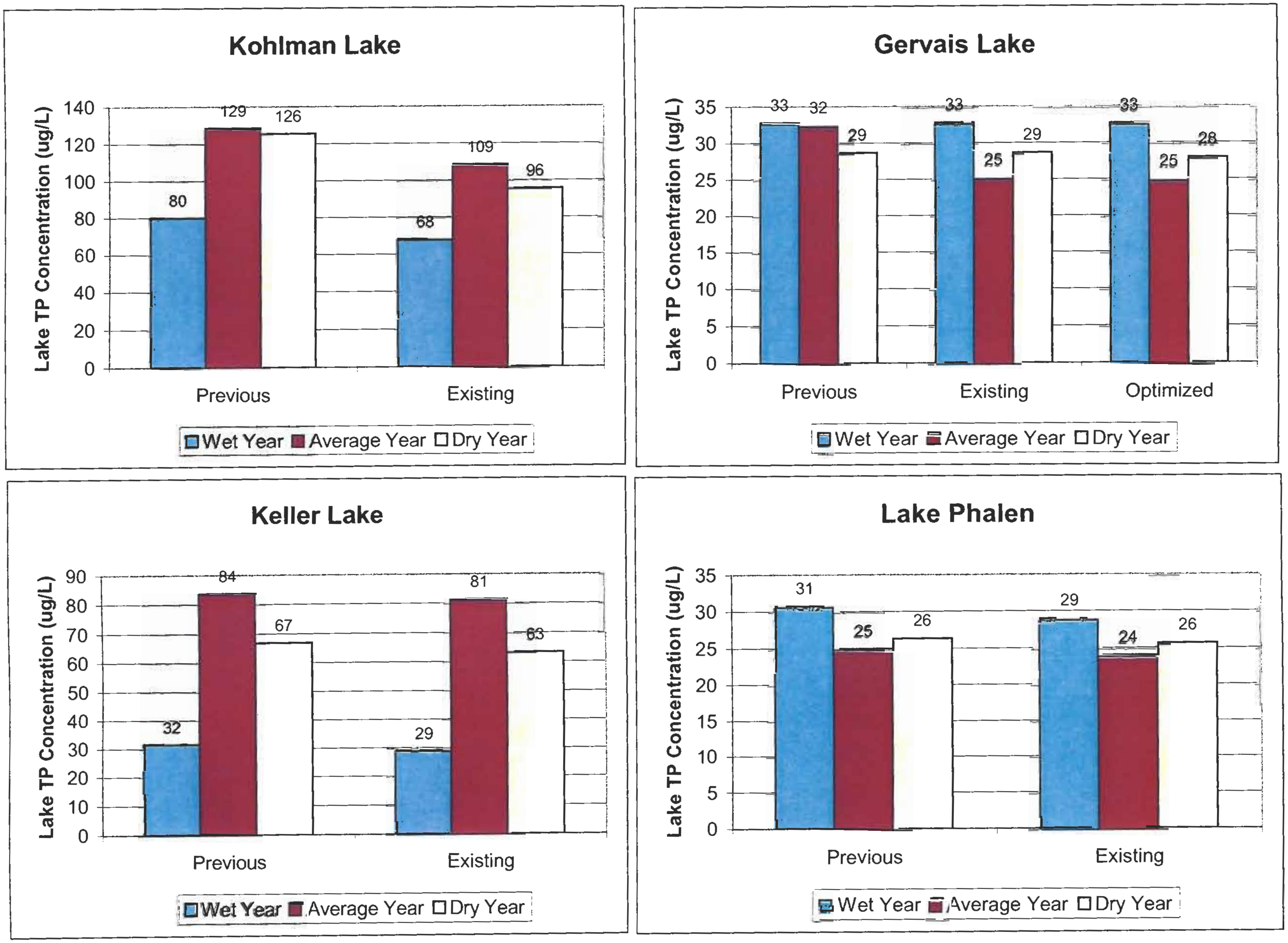


Figure 9: Impact of Existing CIPs on Lakes' TP Concentration



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If Owasso Basin were optimized to better detain runoff from its immediate subwatershed, a higher percentage TP reduction from the site could be expected, on the order of 75 percent. Optimization of the basin would be accomplished by diverting flows from the northwestern and western drainage areas into the deeper water portions of the basin. Optimizing Owasso Basin's performance would not, by itself, significantly improve Gervais Lake's water quality. Currently, any particulate TP not settled out in Owasso Basin is later removed in Gervais Mill Pond. However, because Owasso Basin's tributary subwatershed is an industrial area, there may be other kinds of pollutants that are best removed upstream in Owasso Basin rather than allowed to travel downstream to the Gervais Mill Pond project.

Another option for Owasso Basin involves diverting flows from the Minnesota Department of Transportation's (Mn/DOT's) future treatment pond east of Owasso Basin around Owasso Basin, bypassing it and flowing southward. While this option is not expected to significantly alter the outflowing water quality of Owasso Basin or the water quality of the water entering Gervais Lake, it could safeguard the performance of Owasso Basin. This option is discussed in further detail in Section 2.4 of this SLMP.

A more detailed account of a recent study done on the performance of Owasso Basin and its recommended future improvements can be found in Appendix D of this SLMP.

Kohlman Basin

Before Kohlman Basin was constructed, the long chain of ponds and wetlands that are tributary to the Basin were together removing 69 percent of the TP that had runoff from the upstream subwatershed. The particle fraction of the remaining TP was comprised of soluble and very small particles that require a long detention time to settle out of suspension. Therefore, it's not surprising that after construction, the cumulative percent TP removal at Kohlman Basin rose only to 75 percent. Nonetheless, the Kohlman Basin drainage district as a whole does an incredible job of removing what would otherwise be a huge TP load to Kohlman Lake through settling in ponds and wetlands. Because Kohlman Basin is located at the terminus of this network, it acts as a polishing pond, catching any remaining particles that were missed upstream and offsetting the effects of development in upstream subwatersheds.

If Kohlman Basin were more highly vegetated, it would likely provide even greater TP removal through plant uptake and trapping. This option is discussed in greater detail in Section 2.4 of this SLMP.

2.3 Discussion of Future Improvement Options Considered for the Phalen Chain of Lakes

Future CIPs in the Phalen Chain of Lakes should be implemented if:

- A defined water quality goal is not met
- In the absence of a water quality goal, a water quality improvement is desired
- A desired use of the lake is limited
- A lake needs to be protected from future degradation

The first case is straightforward. If a water quality goal is not met, CIPs are "tested" through modeling until the goal is met. If the successful CIPs are deemed feasible, they can be implemented. The remaining cases are less straightforward, however.

In the second case, managers must decide how much improvement they are interested in pursuing. A manager may be interested in improving a lake's water quality as much as possible, but ultimately, the issue of "cost/benefit" arises. The degree to which CIPs are pursued depends on how much one is willing to spend to attain the resultant water quality improvement. These decisions are especially difficult when the benefit of a water quality improvement is not easily quantified. For example, the following statement is difficult, if not impossible, to come by: A decrease in lake TP by X% will result in an increase of Y lbs. of the lake's fish per year.

The third case may involve improvement of lake water quality or other related issues such as fisheries, macrophyte management or shoreline conditions. The extent of the CIPs for these improvements depends on the nature of the desired uses.

The fourth case depends on the future of the subwatershed and the types of regulations that will be imposed upon future developments.

This section discusses various improvement options and general best management practices (BMPs) to remove phosphorus and/or reduce sediment and litter entering a lake. The BMPs discussed here do not represent an exhaustive list of all available options—only the options that were considered to have potential value for the lakes in the Phalen Chain of Lakes. If a particular BMP was considered and then ruled out based on findings in the SLMP process, the reason that the BMP was discarded is described here. BMPs that were not ruled out are described in further detail in Section 2.4 of this report.

Three types of BMPs were considered during the preparation of this report: structural, nonstructural, and in-lake.

- Structural BMPs remove a fraction of the pollutants and sediment loads contained in stormwater runoff prior to discharge into receiving waters.
- Nonstructural BMPs (source control) eliminate pollutants at the source and prevent pollutants from entering stormwater flows.
- In-lake BMPs reduce phosphorus already present in a lake, and/or prevent the release of phosphorus from anoxic lake sediments.

2.3.1 Watershed Structural BMPs

Structural BMPs temporarily store and treat urban stormwater runoff to reduce flooding, remove pollutants, and/or provide other amenities (Schueler, 1987). Water quality BMPs are specifically designed for pollutant removal. It's important to note that pollutant removal effectiveness is highly dependent on maintenance and proper design of BMPs for their tributary watershed. Structural BMPs control total suspended solids and total phosphorus loadings by slowing stormwater and allowing particles to settle in areas before they reach the stream. Settling areas can be ponds, storm sewer sediment traps, or vegetative buffer strips. Settling can be enhanced by treatment with a flocculent prior to entering the settling basin. Particles, as well as soluble forms of pollutants, can also be removed by infiltrating stormwater through infiltration basins or rainwater gardens.

When choosing a structural BMP, the ultimate objective must be well understood. The BMP should accomplish the following:

- Remove at least a moderate amount of most urban pollutants
- Require reasonable maintenance
- Have a neutral or a positive impact on the natural and human environments
- Be reasonably cost-effective compared with other BMPs

Examples of structural BMPs commonly installed to improve water quality or lake aesthetics include:

- Retention Ponds
- Enhanced Wetlands
- Filtration Systems
- Oil and Grit Separators
- Chemical Treatment of Inflows

- Infiltration Systems
- Rainwater Gardens
- Vegetated Buffer Strips
- Shoreline Restoration

Each of the BMPs is described below and their general effectiveness in removing total phosphorus (if available) is summarized in Table 2. The values shown here should be used as a rough guideline, as a BMP's actual effectiveness depends on many site-specific factors. These values assume that each BMP is designed for, and situated in, a subwatershed that is appropriate for the BMP.

Table 2 Estimated TP Reduction in Structural BMPs Designed for Water Quality Treatment

BMP	Estimated TP Reduction
Retention Ponds	40 to 60 Percent
Enhanced Wetlands	30 to 60 Percent
Filtration Systems	40 to 60 Percent
Oil and Grit Separators	0 to 20 Percent
Chemical Treatment of Inflows	60 to 90 Percent
Infiltration Systems	40 to 60 Percent
Rainwater Gardens	40 to 60 Percent
Vegetated Buffer Strips	20 to 60 Percent
Shoreland Restoration	N/A

Sources: Schueler, 1987
Erickson, et al. 2004
Barr Engineering Company, 2003
N/A: Information not available

2.3.1.1 Retention Ponds

Retention ponds detain runoff and retain pollutants transported in stormwater runoff. Retention ponds (sometimes called wet detention ponds or "NURP" ponds after the Nationwide Urban Runoff Program) are impoundments that have a permanent pool of water and also have the capacity to hold runoff and release it at slower rates than incoming flows. Retention ponds are one of the most effective methods available for treatment of stormwater runoff. Retention ponds are used to interrupt the transport phase of sediment and pollutants associated with it, such as trace metals, hydrocarbons, nutrients, and pesticides. When designed properly, retention ponds can also provide some removal of dissolved nutrients. Retention ponds have also been credited with reducing the amount of bacteria and oxygen-demanding substances as runoff flows through the pond.

During a storm, polluted runoff enters the retention basin and displaces "clean" water until the plume of polluted runoff reaches the basin's outlet structure. When the polluted runoff does reach the outlet, it has been diluted by the water previously held in the basin. This dilution further reduces the pollutant concentration of the outflow. In addition, much of the total suspended solids and total phosphorus being transported by the polluted runoff and the pollutants associated with these sediments are trapped in the retention basin. A well designed retention pond could remove approximately 80 to 95 percent of total suspended solids and 40 to 60 percent of total phosphorus entering the pond (MPCA, 1989).

As storm flows subside, finer sediments suspended in the pond's pool will have a relatively longer period of time to settle out of suspension during the intervals between storm events. These finer sediments eventually trapped in the pond's permanent pool will continue to settle until the next storm flow occurs. In addition to efficient settling, this long detention time allows some removal of dissolved nutrients through biological activity (Walker, 1987). Dissolved nutrients are mainly removed by algae and aquatic plants. After the algae die, the dead algae can settle to the bottom of the pond, carrying with them the dissolved nutrients that were consumed, to become part of the bottom sediments.

The effectiveness of new or improved retention ponds in removing more phosphorus in the Phalen Chain of Lakes tributary subwatershed was estimated in this study using the P8 computer model and the in-lake water quality models. Unfortunately, good locations for retention ponds were difficult to find, due to the fact that the subwatershed is already highly developed. Also, with few exceptions, by the time stormwater reaches the lakes, it has already traveled through a large network of ponds and wetlands, losing a large fraction of its particulate phosphorus. When stormwater reaches the lake, a significant portion of its phosphorus is already in soluble form. For these reasons, retention ponds represent a small number of the BMPs that are suggested for the Phalen Chain of Lakes subwatershed in Section 2.4 of this report.

2.3.1.2 Enhanced Wetlands

Some of the wetlands surrounding the Phalen Chain of Lakes could be improved to better treat some of the stormwater runoff that they receive. Ensuring the highest possible residence time in the wetland and establishing high levels of vegetative cover can ensure that particulate forms of pollutants are settled out, and that (if possible) soluble forms can be removed through plant uptake as well. Some maintenance may be required to optimize TP removal, and more study of these areas may be necessary to understand the best routes of improvement.

Studies of the sorptive capacity of wetland soils can be done to gain understanding of the potential for wetlands to remove soluble TP. However, relying on wetlands to consistently remove soluble TP is risky, as certain climatic conditions can cause wetlands to actually release their stores of soluble TP downstream. At present, it is unclear how to best solve this problem. Rather, it is best to consider enhanced wetlands as potential “polishing ponds” under most conditions.

2.3.1.3 Filtration Systems

Sand filters can be above or below ground and generally consist of a pretreatment basin, a water storage reservoir, a flow spreader, and underdrain piping. These systems are intended to address the spatial constraints found in intensely developed, highly impervious urban areas. Sand filters work by receiving the first flush of runoff and settling out heavier sediment in the pretreatment basin. Water flows to and is spread over the sand filter, where pollutants are either trapped or strained out.

Because they are prone to clogging, sand filters should be used only at stabilized sites (not at construction sites, for example), and are best when they are situated “off-line” receiving only the first inch of runoff from a site. Maintenance plans are especially important for sand filters because of their tendency to clog.

Although these systems are typically known for removing only particulate forms of pollutants (phosphorus, for example), current research at the University of Minnesota is attempting to define what types of filter media could remove soluble fractions as well (Erickson et al, 2004). Filtration systems are best used to treat small areas (less than 5 acres).

Because of their relatively small space requirements, sand filters could be useful in some of the small, currently untreated subwatersheds near each of the lakes in the Phalen Chain of Lakes.

2.3.1.4 Oil and Grit Separators

Oil and grit separators are concrete chambers designed to remove oil, sediments, and floatable debris from runoff, and are typically used in areas with heavy traffic or high potential for petroleum spills such as parking lots, gas stations, roads, and holding areas. A three-chamber design is common; the first chamber traps sediment, the second chamber separates oil, and a third chamber holds the overflow pipe. The three-chambered unit is enclosed in reinforced concrete. They are good at removing coarse particulates, but soluble pollutants probably pass through. In order to operate properly, they must be cleaned out regularly (at least twice a year). The major benefit of a water oil-grit separator is as a pre-treatment for an infiltration basin or pond. They can also be incorporated into an existing stormwater system or included in an underground vault detention system when no available land exists for a surface detention basin. Only moderate removals of total suspended solids can be expected; however, oil and floatable debris are effectively removed from properly designed oil and grit separators.

Because the stormwater runoff that reaches the lakes is already largely soluble, oil and grit separators will not play a significant role in future Phalen Chain of Lakes BMPs except, perhaps, as a pre-treatment device for an infiltration system.

2.3.1.5 Chemical Treatment of Inflows

In addition to the commonly installed structural BMPs discussed above, chemical treatment plants are becoming an option for efficiently removing phosphorus from tributaries, rather than directly treating the lake with chemicals to remove phosphorus. Alum (aluminum sulfate) is commonly used as a flocculent in water treatment plants and as an in-lake treatment for phosphorus removal. However, other chemicals, such as ferric chloride or other coagulants are also used. To treat inflows in streams or storm sewers, part of the flow is diverted from the main flow and treated with the chemical. After the chemical is injected in the diverted flow, it passes to a retention pond to allow the flocculent to settle out before the water enters the lake. Alum treatment at the Tanner's Lake Treatment Plant has been shown to remove up to 80 percent (Barr Engineering Company, 2003) of the soluble and particulate phosphorus from the inflows.

This treatment option may be of particular benefit to Kohlman Lake and its subwatershed if a significant decrease in lake TP is desired.

2.3.1.6 Infiltration Systems

Infiltration basins and infiltration trenches are designed to capture the first flush of runoff (typically up to the first inch) and infiltrate it into the ground over a period of days. These systems have no permanent pool of water and are (in the case of infiltration basins) vegetated in order to prevent scour and to provide infiltration channels where roots penetrate the soil.

While infiltration basins are shallow, vegetated depressions that receive surface runoff, infiltration trenches are largely underground, unvegetated, trenches lined with filter fabric and filled with stone.

Like filtration systems, infiltration basins and trenches require pretreatment as they have a tendency to clog under high sediment loads. These systems are best used for small, stabilized sites (less than 2 acres) and must be situated above the soil that can drain runoff in an appropriate amount of time, and at least 3 feet above the groundwater table to ensure sorption of soluble pollutants.

Because of their capacity to remove soluble pollutants (such as soluble phosphorus), these systems were considered for some of the smaller, currently untreated subwatersheds near each of the lakes in the Phalen Chain of Lakes.

2.3.1.7 Rainwater Gardens and First Flush Gardens

Rainwater gardens are small, vegetated depressions used to promote infiltration of stormwater runoff (Barr, 2001). Unlike infiltration basins or trenches, runoff reaches rainwater gardens via sheet flow from individual lots. Like infiltration basins, the vegetation in rainwater gardens is carefully selected to facilitate pollutant trapping and infiltration of runoff, as well as to withstand periods of inundation.

First flush gardens are more regional rainwater gardens that accept runoff from several lots. First flush gardens are not as large as infiltration basins, but are designed in a similar manner. These designs can be a good option in areas where individual homeowners are not willing to participate, but where community or other open land is available.

Because of their potential for removing both particulate and soluble forms of phosphorus, each of the lakes' untreated tributary areas was evaluated to see whether rainwater or first flush gardens would be an appropriate addition (in terms of the degree of re-grading that would be needed, whether sidewalks would have to be removed, soil type, etc.). Several locations were deemed suitable for retro-fit rainwater or first flush gardens, and were considered as treatment options for several areas along the Phalen Chain of Lakes.

2.3.1.8 Vegetated Buffer Strips

Vegetated buffer strips are low sloping areas that are designed to accommodate stormwater runoff traveling by overland sheet flow. Vegetated buffer strips perform several pollutant attenuation functions, mitigating the impact of development. Urban watershed development often involves disturbing natural vegetated buffers for the construction of homes, parking lots, and lawns. When natural vegetation is removed, pollutants are given a direct path to the lake—sediments cannot settle out; nutrients and other pollutants cannot be removed. Additional problems resulting from removal of natural vegetation include streambank erosion and loss of valuable wildlife habitat (Rhode Island Department of Environmental Management, 1990).

The effectiveness of buffer strips is dependent on the width of the buffer, the slope of the site, and the type of vegetation present. Buffer strips should be 20 feet wide at a minimum, however 50 to 75 feet is recommended (Barr Engineering Company, 2001). Many attractive native plant species can be planted in buffer strips to create aesthetically pleasing landscapes, as well as havens for wildlife and birds. When properly designed, buffer strips can remove up to 20 percent of total phosphorus from lawn runoff. In addition, well designed buffer strips will discourage waterfowl from nesting and feeding on shoreland lawns. Such waterfowl can be a significant source of phosphorus to the pond, by grazing turfed areas adjacent to the water and defecating in or near the water's edge where washoff into the pond is probable.

These systems may be of particular interest in the subwatersheds directly tributary to each lake. All four lakes in the chain receive runoff that is largely untreated from the areas directly adjacent to the lakes. The success of buffer strip implementation throughout the Phalen Chain of Lakes would depend on the cooperation of several parties including the District, Ramsey County, and private citizens.

2.3.1.9 Shoreline Restoration

The Lake Phalen Shoreland Restoration Project is a prime example of how urban shorelines can be improved to serve many purposes at once: erosion control, fish and wildlife habitat, public safety, native plant species growth, and improvement of aesthetics for public enjoyment. Also, to some extent, this project will serve to improve the water quality in Lake Phalen as shoreline erosion is decreased. A recent survey of the primary phosphorus sources to the five main river basins in Minnesota revealed that streambank erosion can be a significant source of phosphorus to our waterways (Barr Engineering Company, 2004).

Kohlman, Gervais and Keller Lakes have no such restoration plan in place, nor have shoreline surveys been performed in recent years. Because the Phalen restoration project is already showing signs of success in reaching its goals, similar surveys and plans could be of great benefit to the other lakes in the chain, as well. The stream channel between Keller and Round/Phalen Lakes is of particular restoration interest as it is a high-profile area that is heavily used throughout the year.

Much of the shoreline around Kohlman and Gervais Lakes belongs to private homeowners. In these areas, it is important to enlist homeowners' support of shoreline restoration efforts on their property to ensure a significant ring of protection for the lake.

2.3.2 Watershed Nonstructural BMPs

Nonstructural ("good housekeeping") BMPs reduce pollutants at their sources or serve other functions for lakes and their subwatersheds.

Nonstructural BMPs discussed below include:

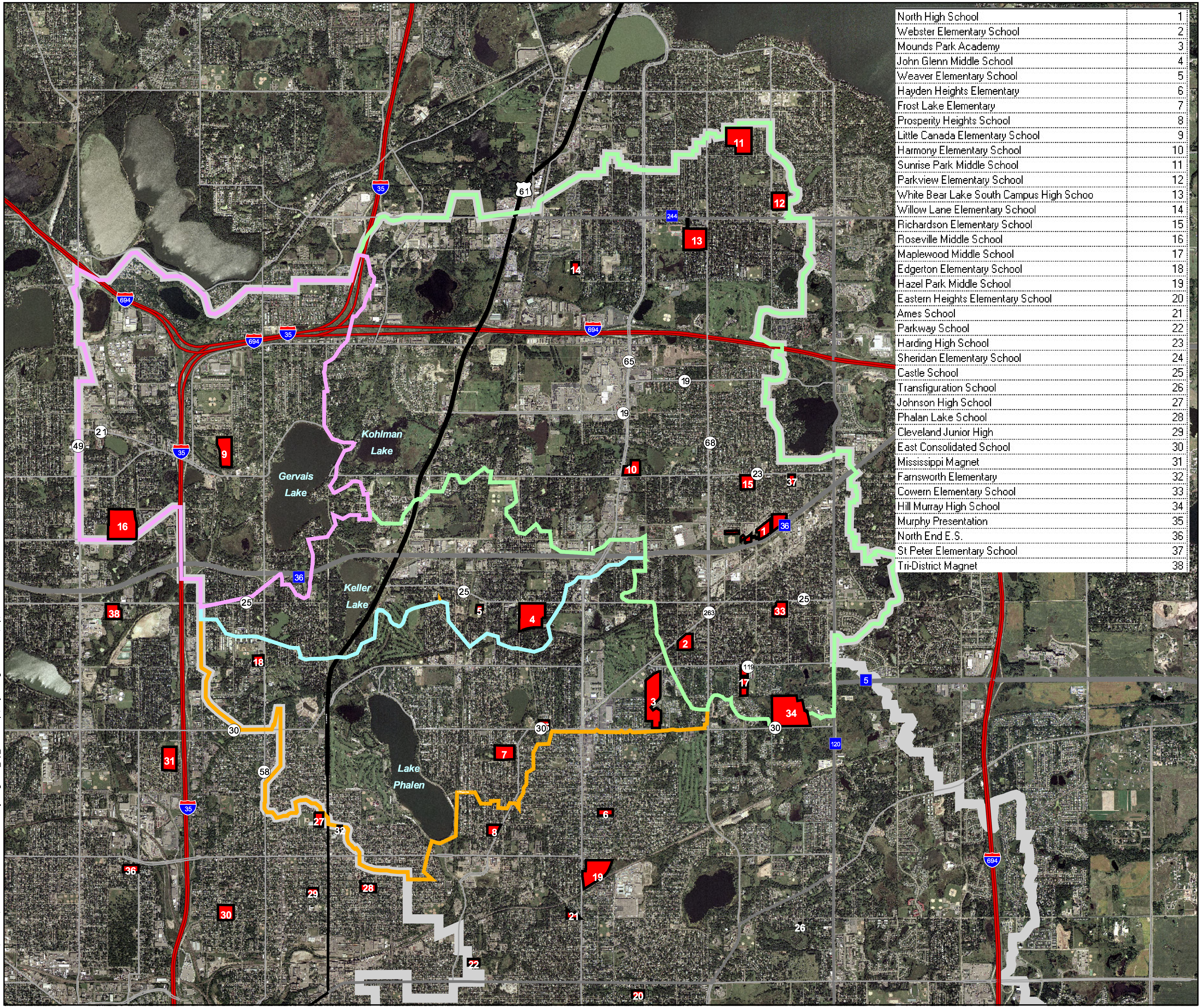
- Public Involvement and Education
- City Ordinances
- Pavement Management—Street Sweeping, Snow and Ice Control, and Catch Basin Maintenance—With Public Support
- Deterrence of Canada Geese
- Maintenance of Existing Structural BMPs

Some of these practices, such as public involvement and education and pavement management, are already a part of the District's philosophy.

2.3.2.1 Public Involvement and Education

Watershed-wide, as well as District-wide, the District has an ongoing public awareness-raising program through collaborative public education activities with member cities, Ramsey and Washington Counties, Metro WaterShed Partners, and the Metro Media Campaign.

The District also has an ongoing multi-faceted education program that includes approximately 20 schools per year, with up to 70 teachers now teaching some aspect of watershed stewardship. The school location map for Phalen Watershed, Figure 10, shows the distribution of schools in the watershed. These schools are or could be engaged in watershed stewardship learning, service and outreach to parents and school neighbors. The adoption by schools of watershed stewardship curricula, practices, and community services that enhance their drainage areas is a major element of the District Public Involvement and Education Program. Professional educators who live and/or work in the District can effectively influence many students, parents and others to value watershed stewardship.



North High School	1
Webster Elementary School	2
Mounds Park Academy	3
John Glenn Middle School	4
Weaver Elementary School	5
Hayden Heights Elementary	6
Frost Lake Elementary	7
Prosperity Heights School	8
Little Canada Elementary School	9
Harmony Elementary School	10
Sunrise Park Middle School	11
Parkview Elementary School	12
White Bear Lake South Campus High Schoo	13
Willow Lane Elementary School	14
Richardson Elementary School	15
Roseville Middle School	16
Maplewood Middle School	17
Edgerton Elementary School	18
Hazel Park Middle School	19
Eastern Heights Elementary School	20
Ames School	21
Parkway School	22
Harding High School	23
Sheridan Elementary School	24
Castle School	25
Transfiguration School	26
Johnson High School	27
Phalan Lake School	28
Cleveland Junior High	29
East Consolidated School	30
Mississippi Magnet	31
Farnsworth Elementary	32
Cowern Elementary School	33
Hill Murray High School	34
Murphy Presentation	35
North End E.S.	36
St Peter Elementary School	37
Tri-District Magnet	38

LEGEND

- Phalen Schools
- Gervais Subwatershed
- Kohlman Subwatershed
- Keller Subwatershed
- Phalen Subwatershed
- RWMWD Hydrologic Boundary

2000 0 2000 4000 6000 8000

Scale in Feet

Figure 10

SCHOOLS IN RELATION TO SUBWATERSHEDS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures2_lkp_feb2004.apr, Layout: Fig 10 - Schools, lkp, Tue Jul 19 16:22:25 2005

Workshops are developed and made available for city, county and development industry staff. Local environmental educators, nature center staff, and other relevant professionals residing in the District area also sought for involvement in various events, projects, discussions and planning. WaterFest is a major annual event that is held at the Lake Phalen Pavilion, co-sponsored by the City of St. Paul Division of Parks and Recreation, and supported with exhibits, volunteers and cash from a wide variety of local and metro entities and individuals; event visitation has grown to 1,500 in May 2003.

Intensive, focused public education and involvement will be planned and implemented on a pilot-project basis within high priority drainage areas of the Phalen Watershed. Successful pilot projects will lend to improving the District's overall education program as it is applied across the Phalen Chain of Lakes subwatershed and the entire District, as appropriate.

Public involvement and education should be comprehensive in the drainage areas that do not receive any pollutant removal treatment. Residents of these target drainage areas will be notified by direct mail about their watershed address, the watershed condition, and goals for stormwater quality improvement. The District will seek collaboration with the cities in which these drainage areas lie. Collaborative efforts will include crafting appropriate educational messages, information distribution, scheduling and planning public involvement processes and Public Works Forum assistance in planning appropriate public partnership in tandem with street management and storm system management BMPs used by each city and the District. The Metro Media Campaign will be sought for assistance in crafting educational messages and media.

The outcome of intensive public education and involvement in the target drainage areas will be:

1. Improved communication to the public about city pollution prevention efforts and pertinent city services.
2. Improved response by the public when their cooperation is needed by the city and District.
3. Creative ways to improve stormwater quality as determined by discussions among the drainage area residents, municipal leadership and staff, and District staff.
4. Emergence of drainage area leaders, mentors, youth, students, teachers and volunteers willing to support and promote pilot projects (products of government-resident dialogues) within their drainage area.
5. Improved public support for NPDES water quality protection activities and expenditures.

Pilot projects in target drainage areas could include but are not limited to:

- Rainwater gardens (also discussed in Section 2.3.1.7 and Section 2.4 of this SLMP).
- Seasonal street sweeping for water quality.
- Increased communication and dialogue process development for resident-government communication.
- Storm drain marking.
- Citizen task forces or stewardship teams who influence compliance with street parking or other NPDES-related ordinances, communicate resident complaints to government staff, and seek sensible solutions to balancing environmental costs and public service costs for a better long-term, cost-efficient approach to both stormwater quality improvement and public service.
- Development of pilot project demonstration sites for public education and promotion of successful pilot projects.

2.3.2.2 City Ordinances

Ordinances pertaining to littering, pet feces, and buffer strips adjacent to lakes and other water bodies could be strengthened or created. Also, existing, unenforced ordinances that protect lake water quality (such as a ban on raking leaves into the street, feeding waterfowl, or using phosphorus fertilizers on established lawns) should be strengthened, if possible. Other new ordinances could require reductions in the runoff volumes leaving new developments or reductions in the directly connected impervious surfaces (and/or total impervious area) of developments.

It is possible that some existing city ordinances may be in conflict with some of the watershed management recommendations in this SLMP. For example, existing city ordinances that pertain to vegetation heights should be examined if rainwater gardens or buffer strips are pursued.

2.3.2.3 Pavement Management - Street Sweeping, Snow and Ice Control and Catch Basin Maintenance- With Public Support

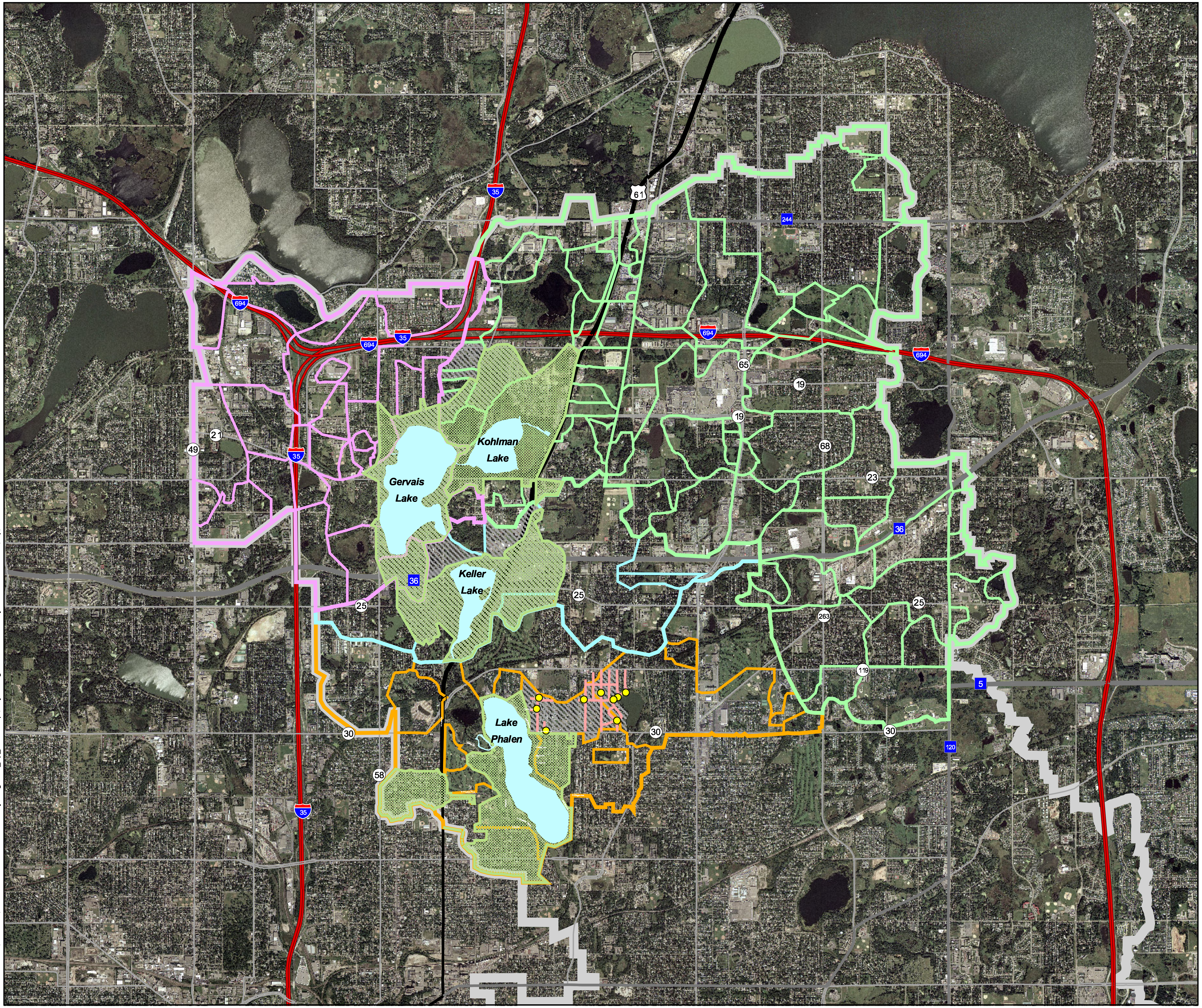
The District is examining the feasibility of increased street sweeping in certain areas of high concern. During the winter, snow and ice control measures create a significant amount of sand and salt and possibly other deicing chemicals. City staff are refining application methods so as to reduce the volume of materials applied. Public support for less materials application will be sought. City staff began a rigorous schedule of catch basin cleaning in 2003. Refinement of pertinent BMPs are being considered in the Ramsey-Washington Public Works Forum, and public support for storm drain protection will be sought, especially in the high concern drainage areas.

The definition for “high concern” is also being examined. Citizen input from prospective areas of concern will assist in this process.

Street sweeping BMPs will be examined alone as well as in tandem with other pollutant removal BMPs including: property-owner BMPs, stormceptor-type products, and municipal season-specific BMPs to reach a mix of seasonal BMPs that will result in significant annual pollutant reduction levels. Municipal service providers are being consulted regarding costs and feasibility of various service levels. The current street sweeping program implementation plan is being developed by the District with maximum input from municipal street management staff, and a prototype street sweeping contract will be developed and studied through the Ramsey-Washington Public Works Forum. Criteria for drainage areas of concern, where street source reduction is critical, will include:

- Dominated by street-side mature trees.
- A ratio of watershed area to connected surfaces of more than 30 percent.
- Inadequate space for infiltration basins.
- A lake or other water resources of aesthetic, recreational, educational or wildlife value.
- Stormwater treatment ponds requiring frequent maintenance.

Figure 11 shows the Phalen Chain of Lakes subwatershed, existing rainwater gardens, and first flush basins as well as the drainage areas that currently provide no stormwater treatment before runoff reaches the lakes. In these areas, the drainage areas that were deemed appropriate for rainwater gardens are indicated by color. The extent of annually stenciled storm drains and stormwater treatment ponds requiring frequent maintenance should also be located to help identify high priority drainage areas.



LEGEND

- First Flush Gardens
- Rainwater Garden Locations
- Untreated Drainage Areas
- Proposed Rainwater Gardens
- Gervais Subwatershed
- Kohlman Subwatershed
- Keller Subwatershed
- Phalen Subwatershed
- RWMWD Hydrologic Boundary

2000 0 2000 4000 6000 8000

Scale in Feet

Figure 11

EXISTING INFILTRATION PROJECTS, PROPOSED RAINWATER GARDENS AND UNTREATED DRAINAGE AREAS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Barr: Arcview 3.3, OPT2609, I:\Client\Rwmwd\LakePhalen\Project\figures2_lkp_feb2004.apr, Layout: Fig 11 - Infiltration Projects/Untreated Areas, lkp, Tue Jul 19 16:28:34 2005

2.3.2.4 Deterrence of Waterfowl

The role of waterfowl in the transport of phosphorus to lakes is often not considered. However, when the waterfowl population of a lake is large relative to the lake size, a substantial portion of the total phosphorus load to the lake may be caused by the waterfowl. Waterfowl tend to feed primarily on plant material in or near a lake; the digestive processes alter the form of phosphorus in the food from particulate to dissolved. Waterfowl feces deposited in or near a lake may result in an elevated load of dissolved phosphorus to the lake. One recent study estimated that one Canada goose may produce 82 grams of feces per day (dry weight) while a mallard may produce 27 grams of feces per day (dry weight) (Scherer et al., 1995). Other researchers have cited even higher fecal production rates for Canada geese, as high as 3 to 4 pounds per day (wet weight) (Dr. James Cooper, 2004). Waterfowl prefer to feed and rest on areas of short grass adjacent to a lake or pond. Therefore, shoreline lawns which extend to the water's edge will attract waterfowl. The practice of feeding bread and scraps to waterfowl at the lakeshore not only adds nutrients to the lake, but attracts more waterfowl to the lake and encourages migratory waterfowl to remain at the lake longer in the fall.

Fortunately, as of fall 2002, the City of St. Paul has an ordinance prohibiting the feeding of waterfowl. Two practices often recommended to deter waterfowl are construction of vegetated buffer strips (discussed in Section 2.3.1.8), and prohibiting the feeding of waterfowl on public shoreline property. As stated above, vegetated strips along a shoreline will discourage geese and ducks from feeding and nesting on lawns adjacent to the lake, and may decrease the waterfowl population.

2.3.2.5 Maintenance of Existing Structural BMPs

All of the BMPs proposed in this SLMP, as well as the existing BMPs throughout the Phalen Chain of Lakes subwatershed, will need maintenance from time to time. If this maintenance is neglected, BMPs will not perform as they were intended, and will not be worth the time and money spent to create them. Examples of the types of maintenance that may be needed throughout the Phalen Chain subwatershed include:

- Sediment removal in ponds, wetlands, grit chambers, sand filters, infiltration basin and trenches, and rainwater gardens.
- Removal of floatables from pond outlet structures.
- Vegetative maintenance in constructed wetland systems, vegetative buffers, infiltration basins, and rainwater gardens.

2.3.3 In-Lake BMPs

Some in-lake BMPs reduce phosphorus already present in a lake or prevent the release of phosphorus from the lake sediments. Other in-lake BMPs improve the recreational-use, aesthetics and habitat suitability for the lake. Four in-lake BMPs are discussed below: removal of benthivorous (bottom-feeding) fish, chemical inactivation of sediment phosphorus release, macrophyte management, and the removal of sediments through hydraulic dredging.

2.3.3.1 Removal of Benthivorous (Bottom-Feeding) Fish

Benthivorous fish, such as carp and bullhead, can have a direct influence on the phosphorus concentration in a lake (LaMarra, 1975). These fish typically feed on decaying plant and animal matter and other organic particulates found at the sediment surface. The fish digest the organic matter, and excrete soluble nutrients, thereby transforming sediment phosphorus into soluble phosphorus available for uptake by algae at the lake surface. Depending on the number of benthivorous fish present, this process can occur at rates similar to watershed phosphorus loads. Benthivorous fish can also cause resuspension of sediments in shallow ponds and lakes, causing reduced water clarity and poor aquatic plant growth, as well as high phosphorus concentrations (Cooke et al., 1993). In some cases, the water quality impairment caused by benthivorous fish can negate the positive effects of BMPs and lake restoration. Depending on the numbers of fish present, the removal of benthivorous fish may cause an immediate improvement in lake water quality. The predicted water quality improvement following removal of the bottom-feeding fish is difficult to estimate, and will require permitting and guidance from the Minnesota Department of Natural Resources (MDNR). In addition, using fish barriers to prevent benthivorous fish from spawning may adversely affect the spawning of game fish, such as northern pike.

The MDNR fisheries reports do not indicate that carp are a significant part of the lakes' fisheries. They indicate that the carp and bullhead populations in the Phalen Chain of Lakes are an older population, dominated by smaller numbers of large carp. Conversely, anecdotal evidence suggests that there is a large carp population in Kohlman and Keller Lakes. It is possible that the surveying techniques employed by the MDNR in these lakes do not adequately sample the carp populations—gill nets, for example, are known to select against these species. Therefore, the true extent of the carp population in the Phalen Chain of Lakes is currently unknown.

2.3.3.2 Chemical Inactivation of Sediment Phosphorus Release

There is, at times, a significant internal load of phosphorus from the bottom sediments in Kohlman and Keller Lakes. In shallow lakes such as these, sediment release of phosphorus to the lake basins can occur during the summer months, when the oxygen in the water overlying the sediments is depleted of oxygen. This internal load of phosphorus is transported to the entire lake intermittently during the summer, when wind or other disturbances cause the lake to mix. Phosphorus released from the sediments is typically in a dissolved form, which can be quickly utilized by algae, leading to intense algae blooms.

Both extensive water quality modeling, as well as the modeling conducted for this study, indicate that Kohlman and Keller Lakes' internal loads can dramatically influence their TP concentrations throughout the year. On average, Kohlman Lake's internal load contributes 5 to 40 percent of its summer average TP concentration. Keller Lake's internal load contributes 40 to 80 percent of its summer average TP concentration. However, both lakes' internal loads can contribute up to 80 percent of their TP concentration at any given time throughout the summer, creating large spikes in TP concentration. The magnitude of the internal load in the lakes depends on the environmental conditions on and around each lake.

Areal application of chemicals such as alum, have been proven to be a highly effective and long-lasting control of phosphorus release from the sediments, especially where an adequate dose has been delivered to the sediments and where watershed sediment and phosphorus loads have been minimized (Moore and Thorton, 1988). Alum, for example, will remove phosphorus from the water column as it settles and then forms a layer on the lake bottom that covers the sediments and prevents phosphorus from entering the lake as internal load. Appropriate alum treatments are likely to be effective for approximately 10 years, depending on the control of watershed nutrient loads. At present, however, Minnesota agencies such as the MDNR and the MPCA are often reluctant to issue permits for alum treatments.

Other types of treatments have either proven effective in controlling sediment phosphorous release in the past, or show promise for the future. The applicability of other coagulants and chemicals such as lime slurry are currently being researched. The District is following these activities in order to gain knowledge that can be applied to its own projects.

Several lake factors determine the success and longevity of in-lake treatments to control sediment phosphorus release.

- Macrophyte Coverage
- Benthivorous Fish Population
- Invertebrates—Quantity and Distribution

- Lake Sediment Characteristics
- Boat Traffic
- Watershed TP Runoff

These six factors should be investigated in Kohlman and Keller Lakes before a treatment is planned.

Macrophytes are known to limit the effective cover of in-lake treatments as the treatment substance (alum, coagulants, etc.) can get caught on leaves and stems rather than sinking to the bottom to form a cohesive layer. Because Kohlman and Keller Lakes have some degree of Eurasian watermilfoil, macrophyte management may be an important precursor to an in-lake chemical treatment. In addition, a macrophyte management program may be an important part of these lakes after an in-lake treatment. If the lakes' aquatic plants take advantage of the increased light availability in the water column, they could turn the lake from an algae-dominated to a macrophyte-dominated ecosystem.

Benthivorous fish, such as carp and bullheads, feed off of the bottoms of lakes, rooting through the sediment. They are notorious for stirring up sediments and increasing lake turbidity. Because the effectiveness of in-lake treatments depend on the cohesive coverage of floc or coagulants (a cohesive treatment layer), these fish can play a detrimental role by moving the treatment layer around and creating patches of uncovered sediments.

Likewise, the lake's invertebrates can stir up the lake bottom (i.e., bioturbation) if they are present in large enough numbers. Tubifex worms, for example, can burrow into the treatment layer, transporting untreated sediment to the top of the layer where it can continue to release TP (McComas, 2004 and Cooke et al, 1993).

Certain lake sediments are more appropriate for in-lake treatments than others. The water content of the sediments, for example, can dictate whether the treatment layer stays atop the sediments in a uniform, cohesive layer (in denser sediments) or whether it sinks unevenly into the sediment (in looser, more watery sediments). Also, knowing the sediment release rate of TP from the sediments is useful, as it dictates the dose needed for inactivation of the TP release.

It should be noted that if an in-lake treatment is pursued for Kohlman and Keller lakes, there is some question as to whether motorboating, speedboating and skiing would still be appropriate lake uses. Some studies have shown that boat props can stir up sediments in shallow lakes (in areas less than 10 feet deep), making the treatment layer less intact and less able to control the internal flux of TP from the lake's sediments (Anthony and Downing, 2003; Beachler and Hill, 2003 and WDNR, 1996).

Even if the lake's sediments are well sealed under a treatment layer, the lake will still be affected by the TP coming in from the atmosphere, its tributary subwatershed and from any upstream lakes (called external sources). In-lake treatments can do nothing to control these other sources of TP and, in fact, these other sources can bury the treatment layer, creating a new layer of TP-rich sediment. Fortunately, the impact of these external sources on each of the lakes in the Phalen Chain of Lakes has already been evaluated through the modeling effort for this SLMP, and the estimated post-treatment TP concentration in the lakes (shown in Section 2.4) reflects the fact that the external sources are left intact after the treatment (unless they are treated by their own set of BMPs).

2.3.3.3 Macrophyte Management

Eurasian watermilfoil is present in the Phalen Chain of Lakes. In 2003, it was the second most abundant species in Lake Phalen and Keller Lake and the third most abundant species in Gervais Lake. In Kohlman Lake, however, it was only the eighth most abundant species.

Past macrophyte management in the Phalen Chain of Lakes has involved mechanical harvestings, on an as-needed basis. Harvesting has been conducted only to improve lake access and aesthetics. The District considers this a temporary fix that is not intended to affect lake TP concentrations.

The District has not used herbicide applications to control macrophytes in the lakes, although several homeowners around Gervais Lake have used private contractors for small-scale applications to improve their lake access. The MDNR currently limits lake herbicide treatments to 15 percent of the littoral zone. In the future, the District plans to rely on mechanical harvesting as their management tool, so no other macrophyte management options are proposed in Section 2.4 of this SLMP.

Curlyleaf pondweed does not appear to be an issue in the Phalen Chain of Lakes. Typically, lakes that experience an internal load from Curlyleaf dieoff show a spike in TP concentration in late-June or early-July. This type of spike was not seen for any of the lakes in the calibration, average, wet or dry years that were studied in detail. Therefore, it is anticipated that any degree of macrophyte management would be in terms of Eurasian watermilfoil or other pervasive species.

2.3.3.4 Hydraulic Dredging

Because sediments can be such a significant source of phosphorus to lakes such as Kohlman and Keller, sediment removal might be expected to reduce their internal rates of nutrient recycling, thus improving their water quality conditions (Cooke et al, 1993).

Hydraulic dredging consists of removing lake sediments through suction and carrying the sediments out of the lake to a dewatering site. This lake management technique has had success in the past in deepening lakes, and some success in reducing lakes' internal phosphorus loads.

However, there are several concerns surrounding this lake management technique that must be considered:

- During the dredging process, sediment and phosphorus can be resuspended into the water column, causing algal blooms and sending sediment and its attached phosphorus to downstream water bodies.
- The depth of nutrient-rich sediment that would need to be removed from an internally loaded lake is often extensive (on the order of several feet) to make an impact in the internal load.
- The disposal of the watery sediments removed from the lake bottom can pose a logistical (and financial) problem, not only in terms of the sheer volume that would need to be transported, but also in terms of content (whether there were urban contaminants in the sediments that would limit disposal options), dewatering issues, and the distance that the dewatered sediments would need to be transported.

For these reasons (unless sediment core experiments show otherwise) this technique is not expected to be a viable option for Kohlman or Keller Lakes as there are other onsite options available.

2.4 Site-Specific Management Options for the Phalen Chain of Lakes

After a list of potentially viable BMPs was developed for the Phalen Chain of Lakes in Section 2.3 of this SLMP, actual site-specific BMPs were explored in greater detail. Only the in-lake improvement options and site-specific structural BMPs that were considered the most viable for the Phalen Chain of Lakes are presented in this section.

Section 2.4.1 discusses site-specific structural BMPs for each of the lakes' subwatersheds. Section 2.4.2 discusses in-lake improvement options. Section 2.4.3 discusses combinations of structural and in-lake options and their estimated combined impact on both TP load reduction and lake TP concentrations in all four lakes.

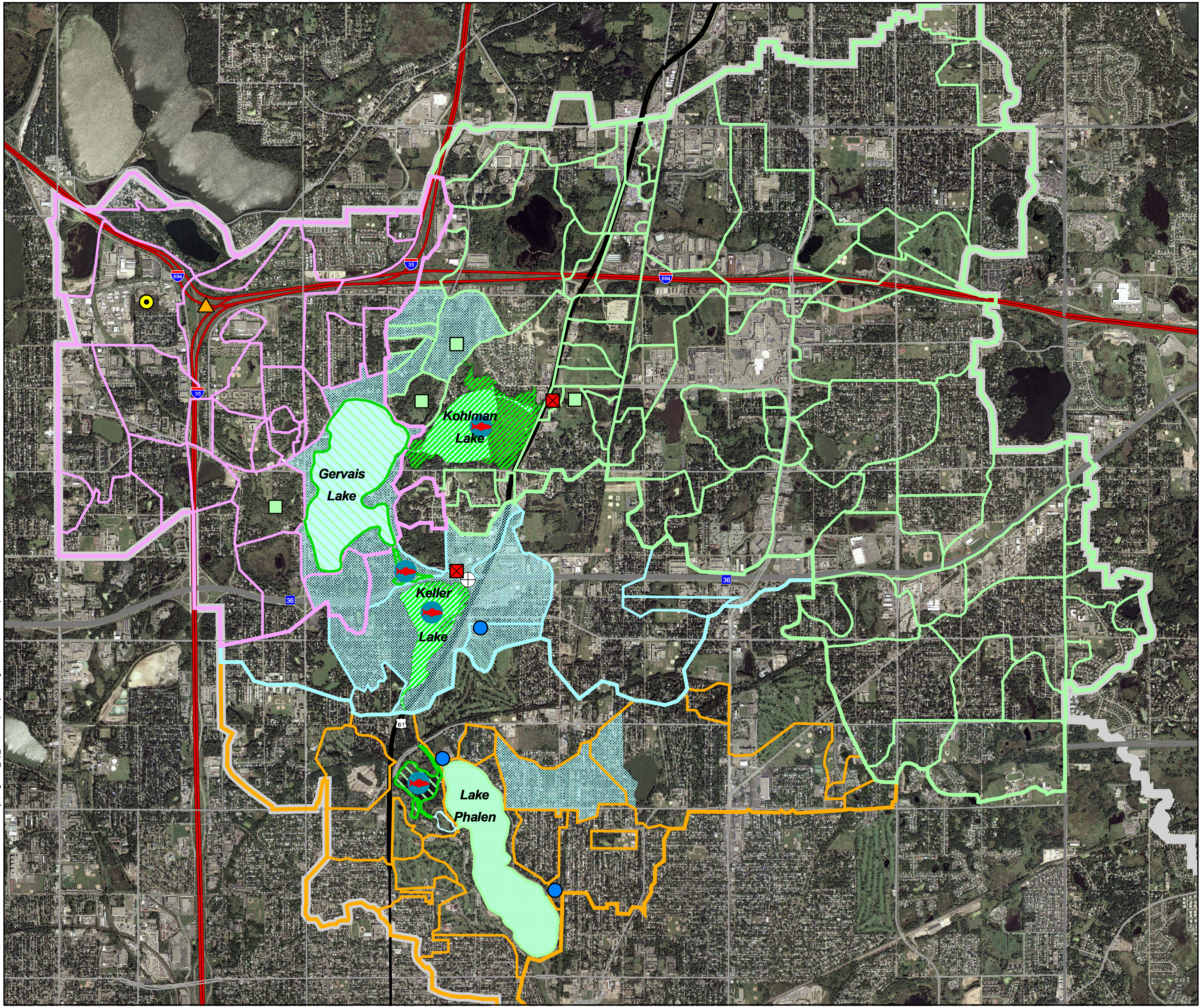
Lastly, Section 2.4.4 discusses the importance of nonstructural, prescriptive practices in the future management of the Phalen Chain of Lakes.

2.4.1 Site-Specific Structural BMPs

Several site-specific structural BMPs were examined that would reduce the subwatershed TP loads to the lakes. The site-specific BMPs were targeted at drainage areas that either:

- Currently receive no treatment.
- Have an existing BMP that provides less than a cumulative 60 percent removal of total phosphorus.
- Are at the terminus of a drainage district that contributes a large percentage of the lake's total phosphorus load.

P8 modeling of the Phalen Chain of Lakes tributary subwatershed generated useful data that indicated where BMPs should be located, based on the criteria listed above. A detailed discussion of P8 modeling results and the figures that show them can be found in Appendix F of this report. Figure 12 shows the location of these potential sites.



LEGEND

Proposed CIP's
- Benthivorous Fish Management
- Benthivorous Fish Management and Improved Fishing Access
- Chemical Treatment of Outflow
- Improved Canoe Passage
- Optimize Owasso Basin/Bypass MNDOT Pond Flows
- Require 60% TP Removal
- Retention Pond
- Treatment System
- Wetland Enhancement

Proposed In-lake CIP's
- Macrophyte Management
- Macrophyte Management and Shoreland Restoration Plan
- Macrophyte Management, Shoreland Restoration Plan and Chemical Inactivation of Sediment TP Release

- Proposed Rainwater Gardens
- Gervais Subwatershed
- Kohlman Subwatershed
- Keller Subwatershed
- Phalen Subwatershed
- RWMWD Hydrologic Boundary

1500 0 1500 3000 4500 6000

Scale in Feet

Figure 12

POTENTIAL STRUCTURAL AND IN LAKE CAPITAL IMPROVEMENT PROJECTS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures2_lkp_feb2004.apr, Layout: Fig 12 - Potential CIPs, lkp, Wed Jul 20 11:24:51 2005

Descriptions of BMPs for each lake's subwatershed follow. As mentioned earlier, only the most viable of the BMP options presented in Section 2.2 are included here.

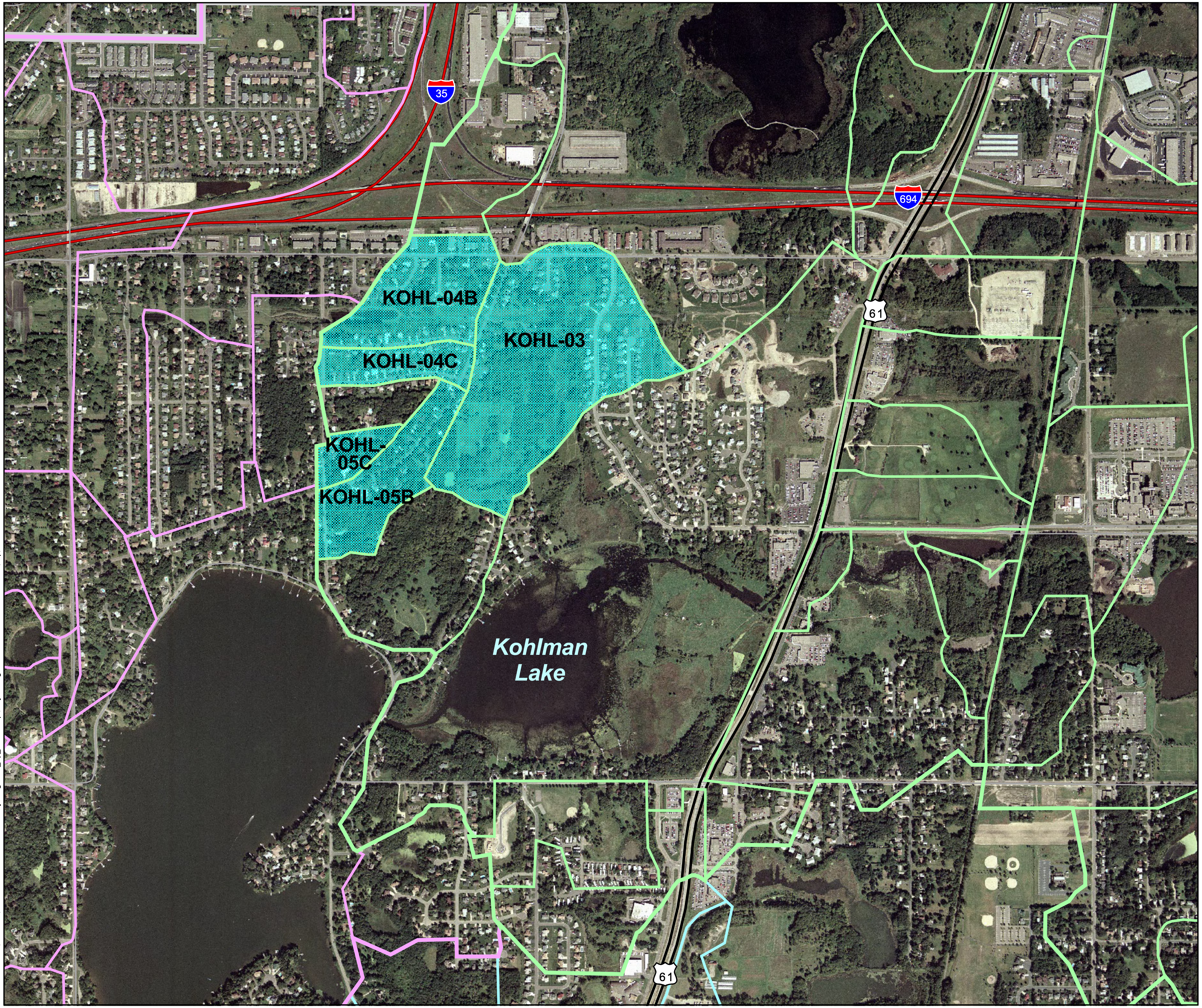
2.4.1.1 Kohlman Lake

- **Option KO-1:** Shoreline Condition Survey and Shoreline Management Plan for Kohlman Lake (including vegetated buffer)
- **Option KO-2:** Wetland Enhancement of Kohlman Basin
- **Option KO-3**: KOHL-05A Wetland Enhancement
- **Option KO-4**: KOHL-03 Wetland Enhancement
- **Option KO-5:** Chemical Treatment of Outflow from Kohlman Basin
- **Option KO-6:** Rainwater Gardens in KOHL-3, KOHL-04B, KOHL-04C, KOHL-05B, KOHL-05C

  A field visit to drainage areas that currently receive no treatment of stormwater runoff indicated that these drainage areas show good potential for infiltration, due to their soils (mostly hydrologic group A) and their topography. Table 3 shows the inches of runoff from impervious areas that could be captured in rainwater gardens throughout these drainage areas. Figure 13 shows these drainage areas in more detail.

Table 3 Proposed Rainwater Garden Infiltration in the Kohlman Lake Subwatershed

Drainage Area	KOHL-04B	KOHL-04C	KOHL-05B	KOHL-05C	KOHL-03
Inches of Runoff Captured from Impervious Surfaces	1 inch	1 inch	0.5 inch	1 inch	2 inches



LEGEND

- Rainwater Gardens
- Gervais Subwatershed
- Kohlman Subwatershed
- Keller Subwatershed
- Phalen Subwatershed
- RWMWD Hydrologic Boundary

500 0 500 1000 1500 2000

Scale in Feet

Figure 13

KOHLMAN LAKE SUBWATERSHED
PROPOSED RAINWATER GARDEN LOCATIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures2_lkp_feb2004.apr, Layout: Fig 13 - Kohlman Rainwater Gardens, lkp, Wed Jul 20 11:42:55 2005

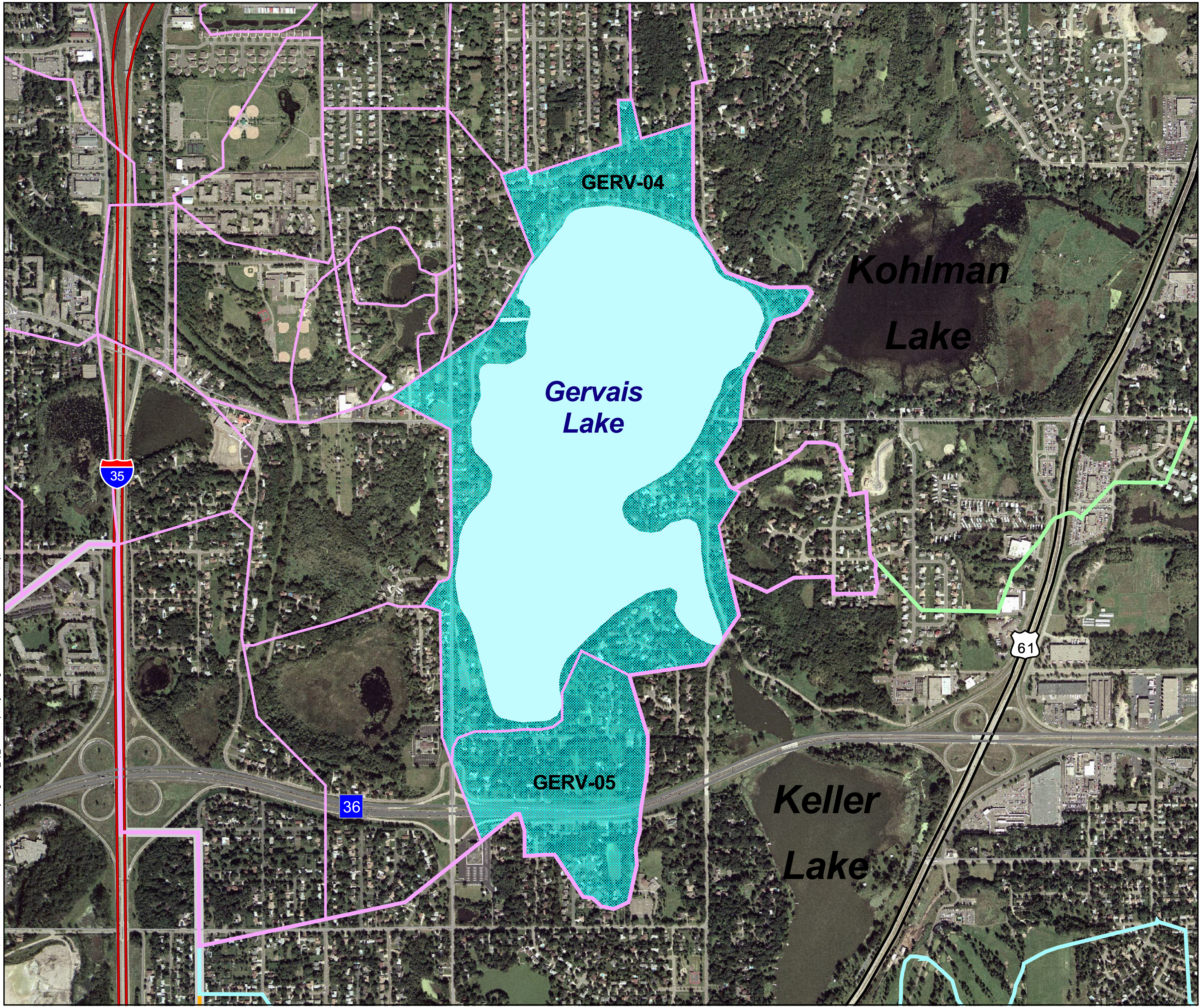
2.4.1.2 Gervais Lake

- **Option GE-1**: Shoreline condition survey and Shoreline Management Plan for Gervais Lake (including vegetated buffer)
- **Option GE-2**: Owasso Basin Optimization
- **Option GE-3:** Require 60 percent TP Removal from Mn/DOT's "Unweave the Weave" Project and Bypass its Flows Around Owasso Basin
- **Option GE-4**: GERV-03 Wetland Enhancement
- **Option GE-5**: Rainwater gardens in GERV-04 and GERV-05

A field visit to drainage areas that currently receive no treatment of stormwater runoff indicated that these drainage areas show good potential for infiltration, due to their soils (mostly hydrologic group A) and their topography. Table 4 shows the inches of runoff from impervious areas that could be captured in rainwater gardens throughout these drainage areas. Figure 14 shows these drainage areas in more detail.

Table 4 Proposed Rainwater Garden Infiltration in the Gervais Lake Subwatershed

Drainage Area	GERV-04	GERV-05
Inches of Runoff Captured from Impervious Surfaces	1 inch	0.5 inch



LEGEND

- Rainwater Gardens
- Gervais Subwatershed
- Kohlman Subwatershed
- Keller Subwatershed
- Phalen Subwatershed
- RWMWD Hydrologic Boundary

500 0 500 1000 1500 2000

Scale in Feet

Figure 14

GERVAIS LAKE SUBWATERSHED
PROPOSED RAINWATER GARDEN LOCATIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

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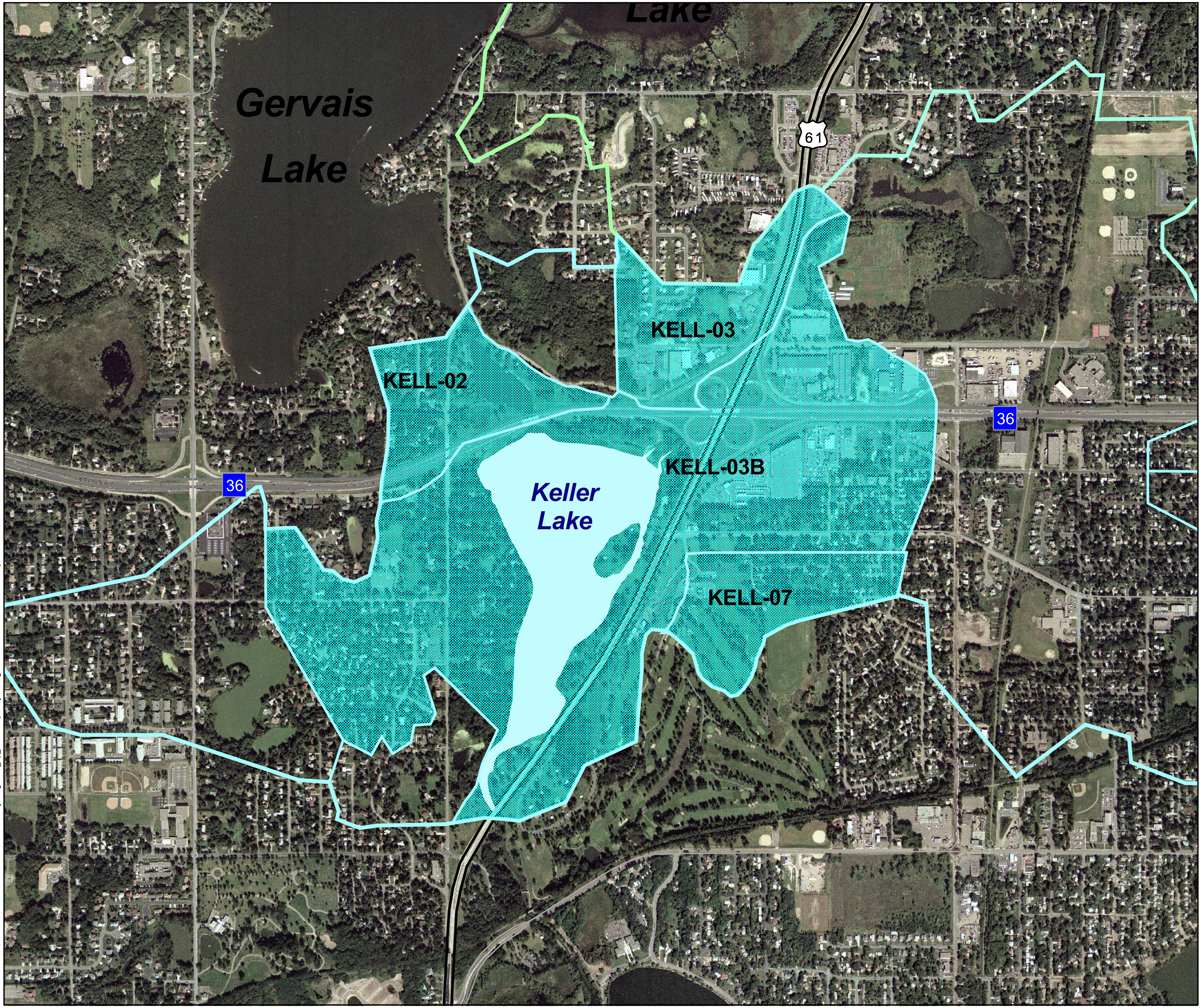
2.4.1.3 Keller Lake

- **Option KE-1:** Shoreline condition survey and Shoreline Management Plan for Keller Lake (including vegetated buffer)
- **Option KE-2**: Wetland Treatment System in KELL-03B (northeast side of the lake)
- **Option KE-3**: Chemical Treatment of Outflows from KELL-03
- **Option KE-4**: Retention Pond in KELL-07
- **Option KE-5**: Rainwater gardens in KELL-02, KELL-03, KELL-03B and KELL-07

A field visit to drainage areas that currently receive no treatment of stormwater runoff indicated that these drainage areas show good potential for infiltration, due to their soils (mostly hydrologic group A) and their topography. Table 5 shows the inches of runoff from impervious areas that could be captured in rainwater gardens throughout these drainage areas. Figure 15 shows these drainage areas in more detail.

Table 5 Proposed Rainwater Garden Infiltration in the Keller Lake Subwatershed

Drainage Area	KELL-02	KELL-03	KELL-03B	KELL-07
Inches of Runoff Captured from Impervious Surfaces	0.5 inch	0.75 inch	0.75 inch	1 inch



LEGEND

- Rainwater Gardens
- Gervais Subwatershed
- Kohlman Subwatershed
- Keller Subwatershed
- Phalen Subwatershed
- RWMWD Hydrologic Boundary

N
500 0 500 1000 1500 2000

Scale in Feet

Figure 15

KELLER LAKE SUBWATERSHED
PROPOSED RAINWATER GARDEN LOCATIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

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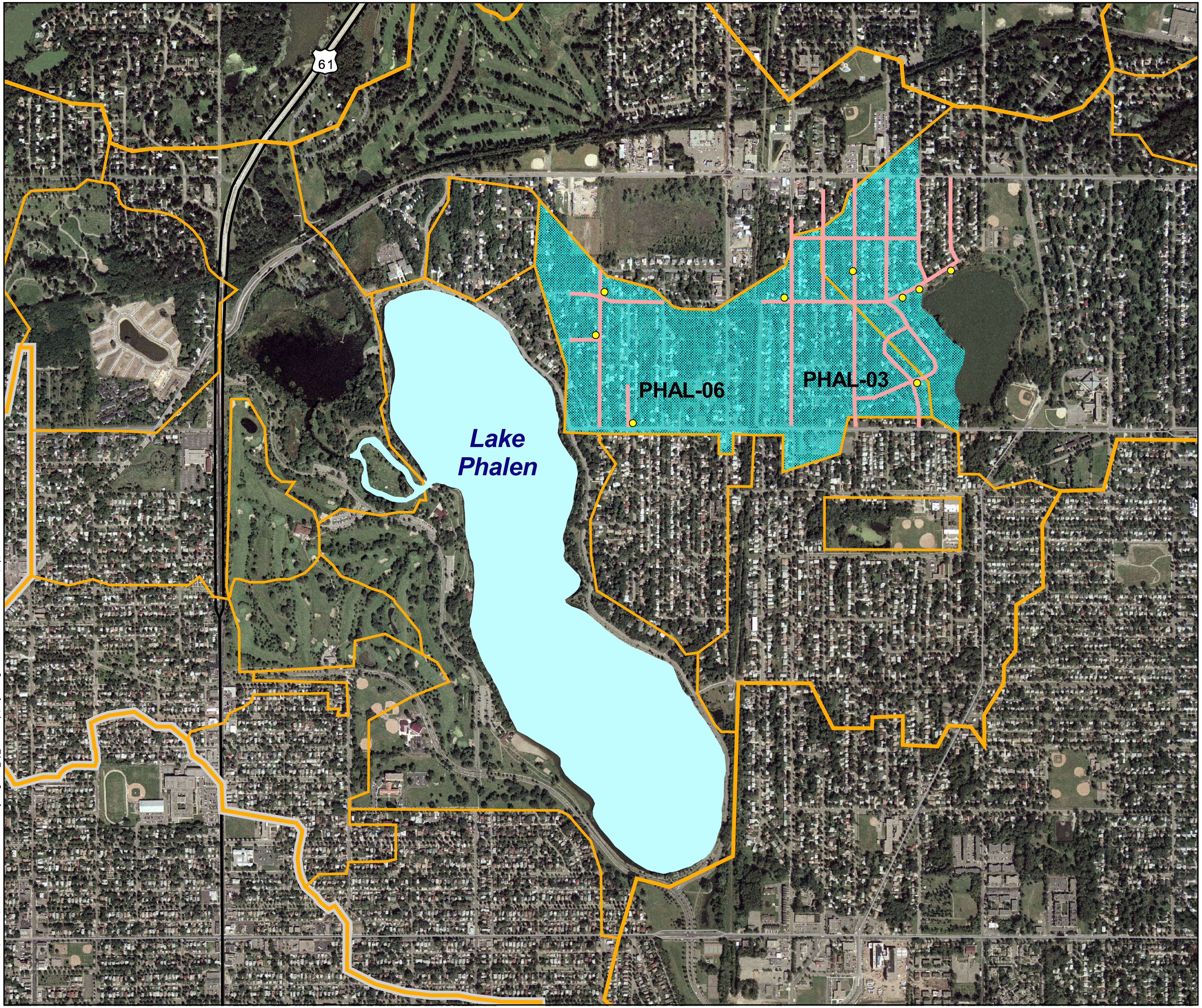
2.4.1.4 Lake Phalen

- **Option PH-1:** Improvement of Retention Pond in PHAL-16
- **Option PH-2:** Improvement of Retention Pond in PHAL-08
- **Option PH-3**: Rainwater Gardens in PHAL-06 and PHAL-03, west of Wakefield Lake

  This could include a demonstration infiltration site at Our Redeemer Church parking lot on Larpenteur and Birmingham streets (east side of PHAL-06). Figure 16 shows this subwatershed in more detail.

  Although some rainwater gardens and infiltration basins already exist in these areas, a field visit revealed that there are still some opportunities for capturing even more runoff in these drainage areas. The inches of impervious surface runoff captured in the existing rainwater garden/first flush basin systems have not yet been estimated. Therefore no such table is presented here.



LEGEND

- Proposed Rainwater Gardens
- Existing Rainwater Gardens
- Existing Flush Gardens
- Gervais Subwatershed
- Kohlman Subwatershed
- Keller Subwatershed
- Phalen Subwatershed
- RWMWD Hydrologic Boundary

500 0 500 1000 1500 2000

Scale in Feet

Figure 16

LAKE PHALEN SUBWATERSHED
PROPOSED AND EXISTING
RAINWATER GARDEN LOCATIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

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2.4.1.5 Estimated Costs and Phosphorus Removal for Structural BMPs

Table 6 summarizes the estimated costs and phosphorus removal for each structural BMP. Estimated costs reflect 2004 dollars and do not include cost to acquire land or easements, obtain permits, or to mitigate wetland loss. Table 6 also includes annual operation and maintenance costs, as well as an annualized cost to allow for direct comparisons between the various BMP options.

2.4.2 In-Lake Improvement Options

Two in-lake BMPs involving macrophyte management were identified as potential improvement options for Kohlman, Gervais and Keller Lakes. Figure 12 shows the type of in-lake CIPs that are described for each lake. Another two options involving in-lake chemical inactivation of sediments for Kohlman and Keller Lakes are included for consideration. These options are discussed below. As mentioned earlier, only the most viable of the in-lake BMP options presented in Section 2.3, are included here. Table 7 shows the estimated impact that these treatments would have on the lakes' water quality (if available) and the estimated cost of their implementation.

- **Option IL-1**: Removal of benthivorous fish from Kohlman, Keller, and Round Lakes.
- **Option IL-2:** Mechanical removal of Nuisance Eurasian watermilfoil growths in Kohlman, Gervais, Keller, and Phalen Lakes
- **Option IL-3:** Chemical inactivation of sediment phosphorus release in Kohlman Lake.
- **Option IL-4** Chemical inactivation of sediment phosphorus release in Keller Lake.
- **Option IL-5** Direct Keller Lake outflows through Round Lake.

  Currently the flows leaving Keller Lake appear to enter Lake Phalen directly, without first traveling through Round Lake. If Keller Lake outflows were instead routed through Round Lake, they would receive more treatment before reaching Lake Phalen.

Table 6:
Preliminary Cost Estimates and Estimated Phosphorus Removal of Proposed Structural BMPs

Watershed Structural BMP	Description	Capital Costs ($)	Assumed Life Span (years)	Annual Costs ($)	Total Annualized Costs Assume yearly interest rate is: 6%	TP Reduction (lbs)	Annualized Cost per lb TP Reduced ($/lb)	See footnote #:	Year(s) of Completion
KO-1	Shoreline Management Plan for Kohlman Lake	To be completed by District staff	20	To be completed by District staff		NA	NA	1	2006
KO-2	Wetland Enhancement of Kohlman Basin	$20,000	20	$2,500	$4,200	NA	NA	2	2005
KO-3	Kohl-05A Wetland Enhancement	$32,000	20	$3,300	$6,100	NA	NA	3	2007
KO-4	Kohl-03 Wetland Enhancement	$32,000	20	$2,860	$5,600	NA	NA	3	2007
KO-5	Chemical Treatment of Outflow from Kohlman Basin	$2,100,000	20	$224,000	$407,100	1445	$280	4	2010
KO-6	Retrofit Infiltration Practices in Currently Untreated Kohlman Subwatersheds	$1,000,000	20	$500	$87,700	192	$460	5	2005-2009
GE-1	Shoreline Management Plan for Gervais Lake	To be completed by District staff	20	To be completed by District staff		NA	NA	1	2006
GE-2	Owasso Basin Optimization	$400,000	20	$500	$35,400	34	$1,040	6	2004
GE-3	Require 60% TP Removal from MNDOT's "Unweave the Weave" Project and Bypass its Flows Around Owasso Basin	$0	20	$0	$0	10	$0	7	2004
GE-4	Gerv-03 Wetland Enhancement	$32,000	20	$4,400	$7,200	NA	NA	3	2007
GE-5	Retrofit Infiltration Practices in Currently Untreated Gervais Subwatersheds	$2,400,000	20	$500	$209,700	85	$1,090	5	2005-2009
KE-1	Shoreline Management Plan for Keller Lake	To be completed by District staff	20	To be completed by District staff		NA	NA	1	2006
KE-2	Filtration Treatment System in Kell-03B	$150,000	20	$5,000	$18,100	171	$110	8	2008
KE-3	Chemical Treatment of Outflows from Kell-03	$270,000	20	$28,000	$51,500	214	$240	4	NA
KE-4	Retention Pond in Kell-07	$100,000	20	$1,100	$9,800	11	$890	9	2008
KE-5	Retrofit Infiltration Practices in Currently Untreated Keller Subwatersheds	$3,700,000	20	$500	$323,100	400	$810	5	2005-2009
PH-1	Improvement of Retention Pond in Phal-16	$380,000	20	$6,600	$39,700	108	$370	10	2006
PH-2	Improvement of Retention Pond in Phal-08	$110,000	20	$1,300	$10,900	134	$80	11,3	2006
PH-3	Retrofit Infiltration Practices in Currently Untreated Phalen Subwatersheds	$2,000,000	20	$500	$174,900	393	$440	5	2005-2009

General Notes:
All costs are in 2004 dollars and include a 40% engineering cost and a 40% contingency cost.
Estimates of TP reduction are shown for an average year of precipitation.
All structural BMPs listed here are conceptual- each specific BMP should be studied in more detail to determine feasibility. The estimated cost of each feasibility study is shown in Table 8.
If "NA" is shown for the estimated TP reduction, there is currently insufficient data to make an estimate, or there is currently not an established cause-effect relationship between the action and the reduction of TP. In the former case, an estimate will be made as a part of a feasibility study.
"NA" is shown for KE-3's completion year because it is not required to meet the TMDL phosphorus guideline if other recommended options are pursued.

Notes on Cost Estimates:
[1] Similar in scope to Phalen survey and restoration plan
[2] Involves planting new vegetation, controlling the basin's water level, weir maintenance, weeding, weir alterations as necessary to enhance vegetation.
[3] Involves installation of a multi-staged outlet ($15,000) and vegetation restoration ($2,500). Annual maintenance is assumed to be $2,200/acre/year.
[4] Annual cost includes chemicals and sludge cleanout.
[5] Assumes retrofit rainwater garden construction in suitable areas (see Figures 13 through 16).
[6] Annual costs is for inspection of new construction. Pond maintenance is covered under previous Owasso Basin Plan
[7] Cost is incurred by MNDOT
[8] Possibilitites include cationic exchange units, peat filters, amended sand filters, etc.
[9] Capital cost assumes $10 per cubic yd for excavation, mobilization and erosion control, a new multi-stage outlet ($15,000), topsoil at $20/cy (6 inch depth), site restoration at $3000 per acre, clearing/grubbing at $2000 per acre. Annual maintenance is assumed to be $2,200/acre/year.
[10] Increase surface area from ~1.5 acres to ~2.5 acres, deepen pond to 4 feet. Capital cost assumes $10 per cubic yd for excavation, mobilization and erosion control, a new multi-stage outlet ($15,000), topsoil at $20/cy (6 inch depth), site restoration at $3000 per acre, clearing/grubbing at $2000 per acre. Annual maintenance is assumed to be $2,200/acre/year.
[11] Increase surface area from ~0.3 acres to ~0.6 acres, deepen pond to 4 feet, wetland enhancement. Capital cost assumes $10 per cubic yd for excavation, mobilization and erosion control, a new multi-stage outlet ($15,000), topsoil at $20/cy (6 inch depth), site restoration at $3000 per acre, clearing/grubbing at $2000 per acre. Annual maintenance is assumed to be $2,200/acre/year.

Table 7:
Preliminary Cost Estimates and Estimated Phosphorus Removal of Proposed In-Lake BMPs

In-Lake BMP	Description	Capital Costs ($)	Assumed Life Span (years)	Annual Costs ($)	Total Annualized Costs Assume yearly interest rate is: 3%	TP Reduction (lbs)	Annual Cost per lb TP Reduced ($/lb)	See footnote #:	Year of Completion
IL-1	Removal of Benthivorous Fish from the Phalen Chain of Lakes	$25,000	5	$4,400	$10,300	NA	NA	1	2005
IL-2	Nuisance Macrophyte Removal in the Phalen Chain of Lakes	$160,000	3	$0	$59,900	NA	NA	2	2005
IL-3	Chemical Inactivation of Sediment Phosphorus Release in Kohlman Lake	$94,000	10	$0	$12,800	1890	$10	3	2006
IL-4	Chemical Inactivation of Sediment Phosphorus Release in Keller Lake	$94,000	10	$0	$12,800	1890	$10	3	2006
IL-5	Direct Keller Lake outflows through Round Lake	$90,000	20	$500	$8,300	NA	NA	4	2008

General Notes:
All costs are in 2004 dollars and include a 40% engineering cost and a 40% contingency cost.
Estimates of TP reduction are shown for an average year of precipitation.
All structural BMPs listed here are conceptual- each specific BMP should be studied in more detail to determine feasibility. The estimated cost of each feasibility study is shown in Table 8.
If "NA" is shown for the estimated TP reduction, there is currently insufficient data to make an estimate, or there is currently not an established cause-effect relationship between the action and the reduction of TP.
In the former case, an estimate will be made as a part of a feasibility study.

Notes on Cost Estimates:
[1]Assume 75,000 lbs of carp caught the first year and 25,000 lbs of carp caught in subsequent visits. Includes a "Carp Festival" every 5 years, similar in cost to Water Fest.
[2]Assumes mechanical harvesting (twice yearly) of: 50% of Kohlman and Keller's littoral zones, 25% of Gervais Lake's littoral zone and 15% of Lake Phalen's littoral zone.
[3]Based on Beaver Lake's sediment TP release rate and recommended alum dose.
[4]Based on the cost of Target Pond's sheet pile. The sheet pile baffle would block flows from Lake Phalen (until after Keller Channel flows traveled through Round Lake)

2.4.3 Combinations of Options—Effect of Structural and In-Lake BMPs on Lake Water Quality

In this section, the estimated costs and water quality benefits of different structural and in-lake BMPs are shown together for each lake in the Phalen Chain of Lakes. Also, the effect of BMPs in upstream lakes and their subwatersheds on downstream lakes are presented here.

Although nonstructural BMPs are important in reducing phosphorus and other pollutants from entering the lake, their quantitative effect on water quality could not be estimated. This is because the actual reduction in pollutant loading is largely unknown and difficult to quantify. The water quality effect of nonstructural BMPs requires detailed monitoring and sampling which are beyond the scope of this study. However, a detailed discussion of the reasons for pursuing nonstructural BMPs is included in the next section, entitled "The Importance of Prescriptive Practices in Managing the Phalen Chain of Lakes."

Figures 17 through 20 show the same suite of BMPs and BMP combinations in terms of their effect on the TP concentration in each lake. The in-lake modeling effort for the SLMP provided useful information that helped predict changes in lake water quality as a result of the structural and in-lake BMPs. Detailed information on the in-lake modeling methodology and its results can be found in Appendix G of this SLMP.

Some BMPs and BMP combinations have larger impacts on lake water quality than others. In-lake treatments of internal loads, for example, dramatically effect the lake TP concentrations of Kohlman and Keller Lakes. The effect of rainwater gardens on lake water quality, however, is much smaller. When comparing between BMP options, however, it is important to remember that there are other, less measurable, benefits to BMPs such as rainwater gardens. These types of benefits are discussed in further detail in the next section of this SLMP.

Definition of CIP Scenarios

A: Pre-CIP Conditions

B: Existing Conditions

C: Rainwater Gardens in Appropriate Subwatersheds

D: Kohlman Basin Outflow TP Reduced By 50%

E: Kohlman Basin Outflow TP Reduced By 75%

F: Kohlman Lake's Internal Load Reduced By 90%

G: Kohlman Basin Outflow TP Reduced By 50%, Kohlman Lake's Internal Load Reduced By 90%

H: Kohlman Basin Outflow TP Reduced By 75%, Kohlman Lake's Internal Load Reduced By 90%

I: Estimated Pre-Settlement Conditions

Kohlman Lake
Effect of CIP Scenarios on Lake TP Concentration
Average, Wet and Dry Climatic Years

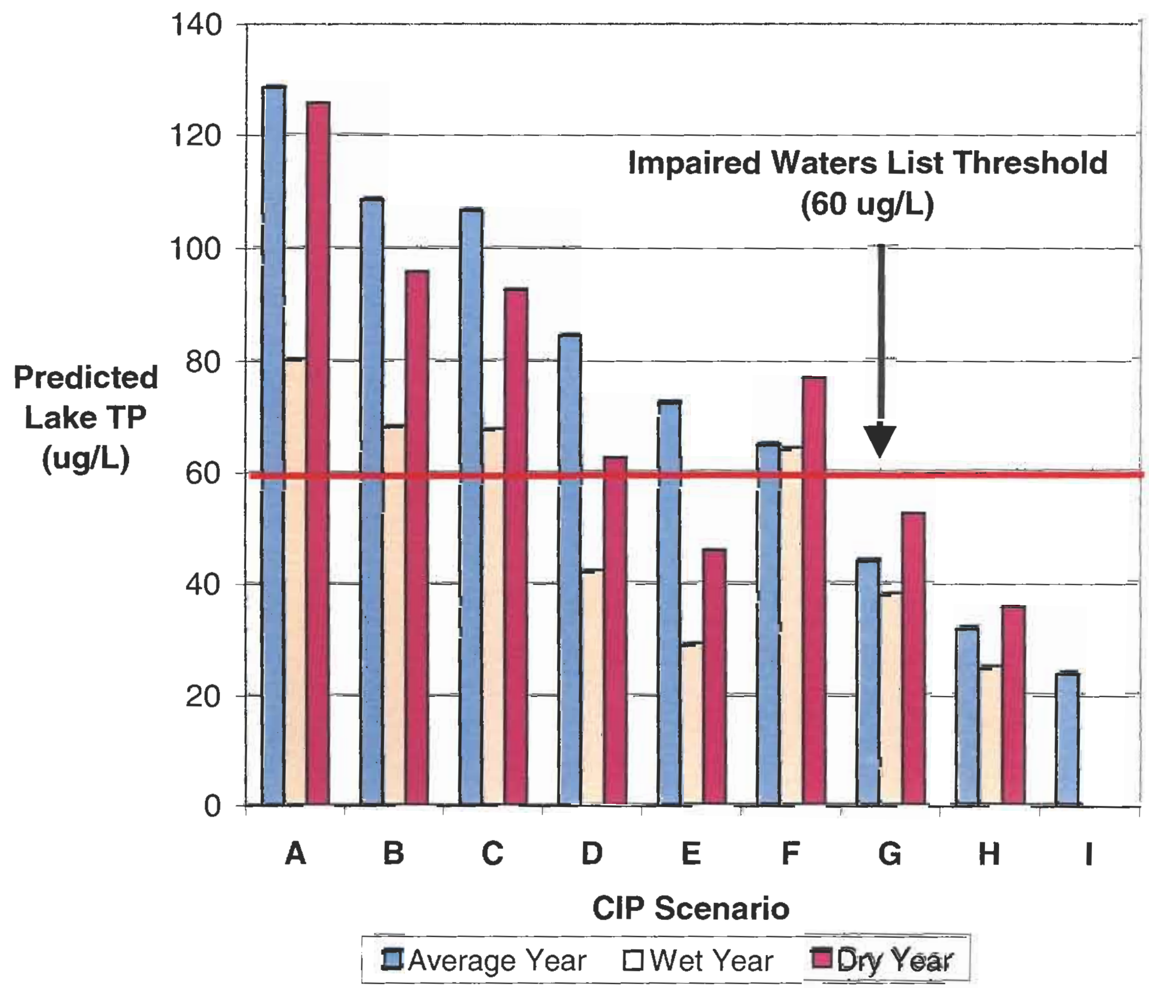

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Figure 17

Definition of CIP Scenarios

A: Pre-CIP Conditions

B: Existing Conditions

C: Owasso Basin Optimized

D: 60% TP Removal Through MNDOT Pond That Bypasses Existing Owasso Basin

E: 60% TP Removal Through MNDOT Pond That Flows Through Optimized Owasso Basin

F: 60% TP Removal Through MNDOT Pond That Bypasses Optimized Owasso Basin

G: CIP Scenario F and Rainwater Gardens in Appropriate Kohlman and Gervais Subwatersheds

H: CIP Scenario F and Kohlman Basin Outflow TP Reduced By 50%, Kohlman Lake's Internal Load Reduced By 90%

I: Estimated Pre-Settlement Conditions

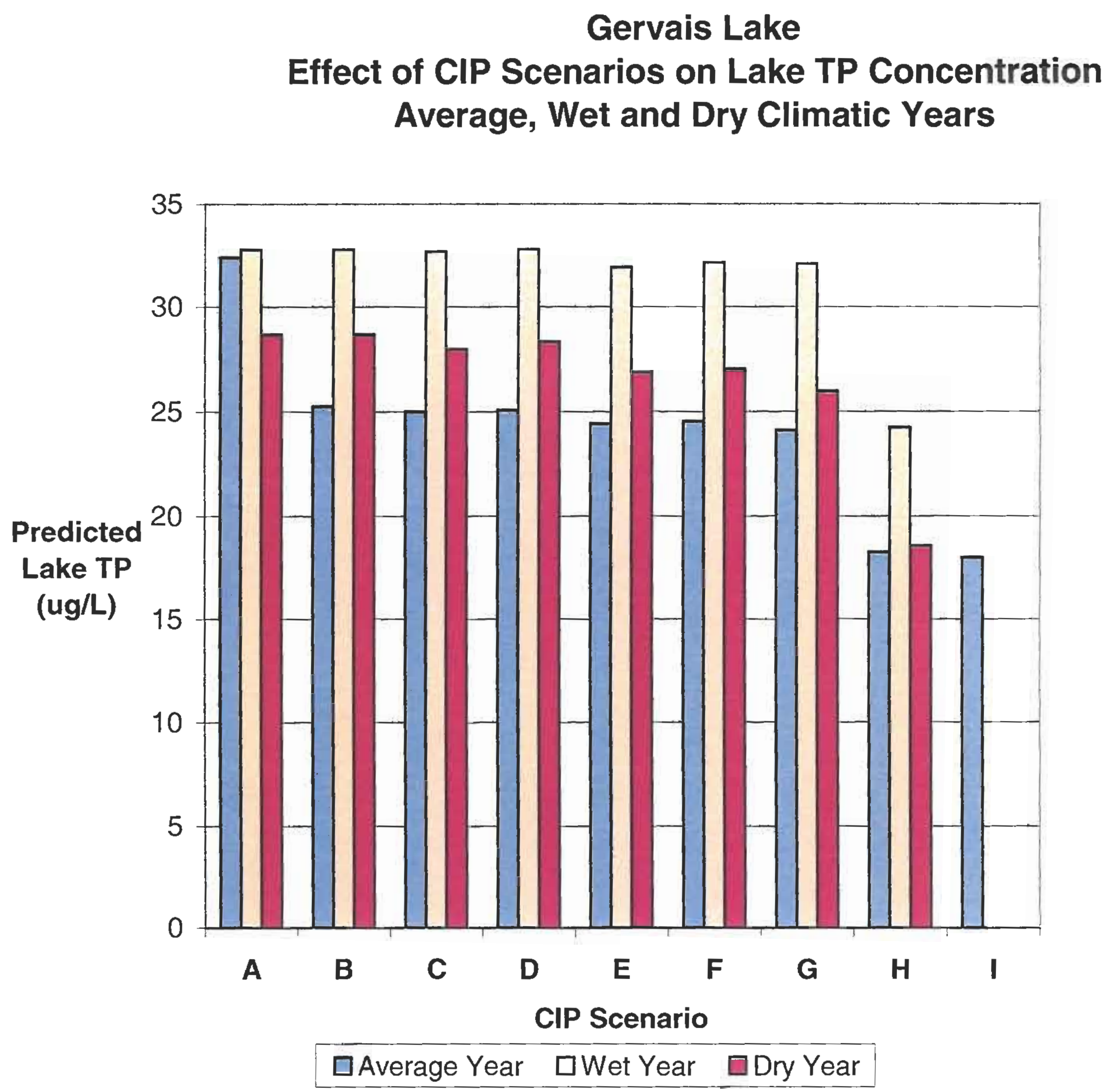

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Figure 18

55

Definition of CIP Scenarios

A: Pre-CIP Conditions
B: Existing Conditions

C: 60% TP Removal Through MNDOT Pond That Bypasses Optimized Owasso Basin, Rainwater Gardens in Appropriate Kohlman, Gervais and Keller Subwatersheds

D: 60% TP Removal Through MNDOT Pond That Bypasses Optimized Owasso Basin, Kell-03 Outflow TP Reduced By 75%

E: 60% TP Removal Through MNDOT Pond That Bypasses Optimized Owasso Basin, Kohlman Basin Outflow TP Reduced By 50%, Kohlman Lake's Internal Load Reduced By 90%

F: Scenario F and Kell-03 Outflow TP Reduced By 75%

G: Keller Lake's Internal Load Decreased By 70%

H: Keller Lake's Internal TP Load Decreased By 90%

I: Estimated Pre-Settlement Conditions

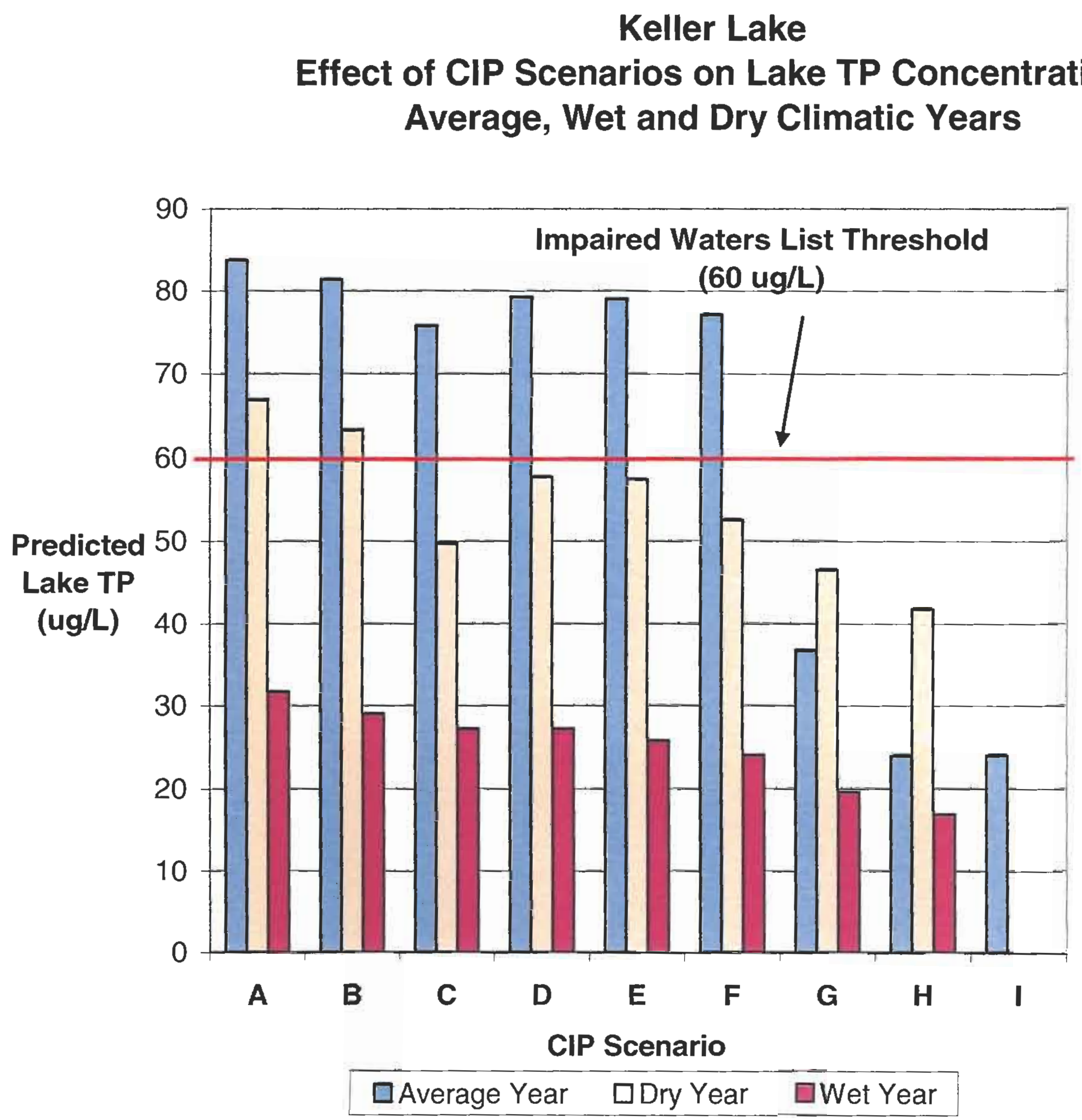

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Figure 19

Definition of CIP Scenarios

A: Pre-CIP Conditions
B: Existing Conditions

C: 60% TP Removal Through MNDOT Pond That Bypasses Optimized Owasso Basin, Rainwater Gardens in Appropriate Kohlman, Gervais, Keller and Phalen Subwatersheds

D: 60% TP Removal Through MNDOT Pond That Bypasses Optimized Owasso Basin, Retention Pond Improvements in Phal-16 and Phal-08

E: 60% TP Removal Through MNDOT Pond That Bypasses Optimized Owasso Basin, Kohlman Basin Outflow TP Reduced By 50%, Kohlman Lake's Internal Load Reduced By 90%

F: Keller Lake's Internal Load Decreased By 70%

G: Keller Lake's Internal Load Decreased By 70%, Retention Pond Improvements in Phal-16 and Phal-08

H: Estimated Pre-Settlement Conditions

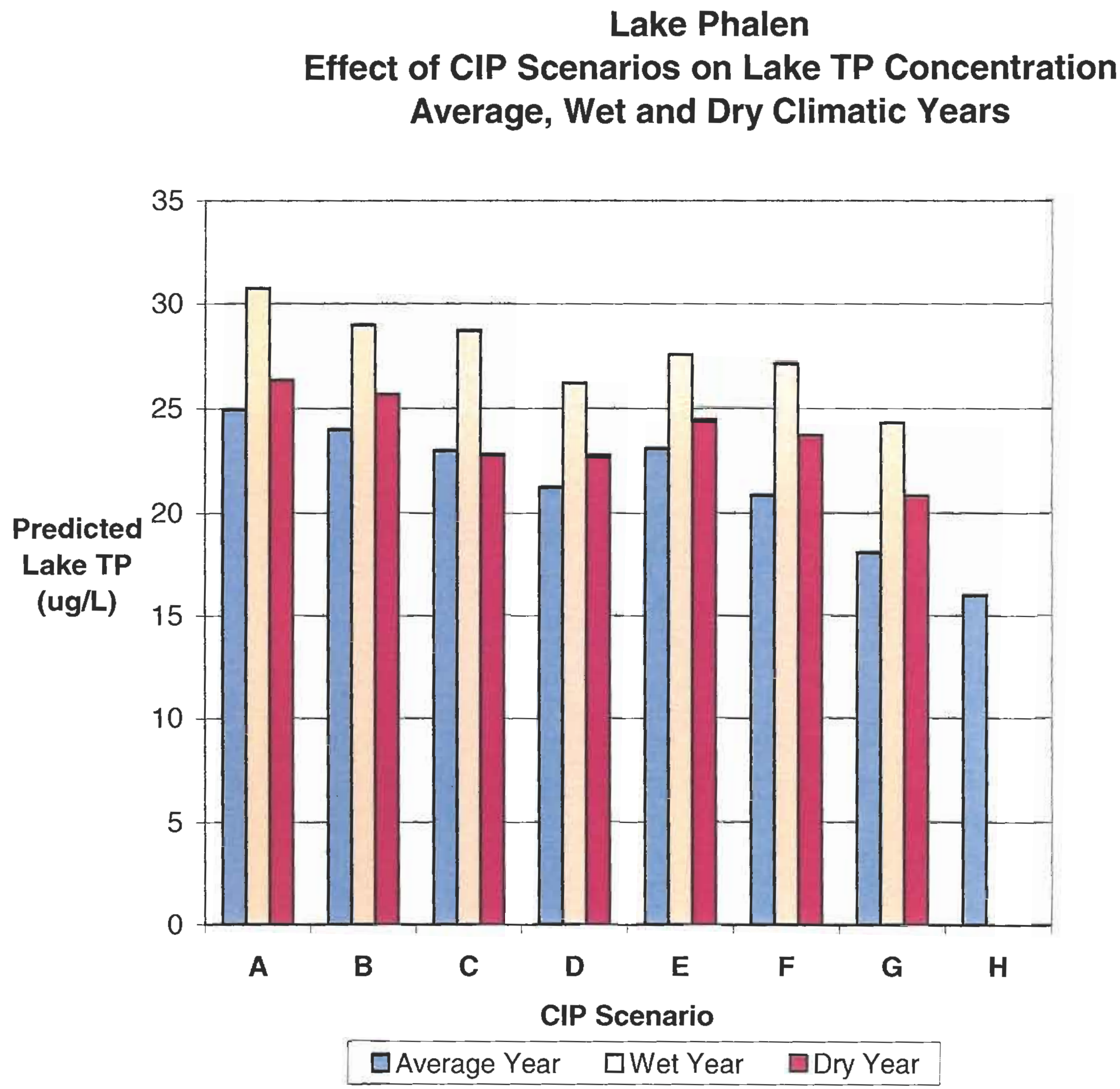

Figure 20

2.4.4 The Importance of Prescriptive Practices in Managing Phalen Chain of Lakes

Not everything that we do to protect lakes' water quality can be justified by model results (at least not yet). Although we have come a long way in our knowledge of the physical processes at work in our environments, we are still better at predicting the effects of large-scale actions (such as chemical removal of pollutants from a large tributary) than we are at showing the effects of smaller, more localized actions throughout our watersheds. While this is mostly true of nonstructural BMPs, some structural BMPs are equally hard to model predicatively.

This is frustrating for decision-makers who need to decide what money should be spent and where. Cost/benefit analyses are useful in decision-making because they provide concrete information against which to weigh decisions. When such information is not available, what is a decision-maker to do? Some classic lake management stumbling blocks include predicting the water quality effects of:

- Rainwater Gardens
- Shoreline Restoration Activities (Erosion Control)
- Habitat Restoration
- Public Education
- Street Sweeping
- Wetland Enhancement
- Phosphorus Bans on Fertilizer

In some cases, the problem is that we don't yet know enough about how our actions will affect water quality. In other cases, the problem is that the effect of an individual, small-scale project (such as a rainwater garden) does not show up amidst other larger forces that are dictating water quality.

And yet, these types of projects are still implemented by lake managers on a regular basis. Why? Because there are different reasons, above and beyond predictive modeling, to justify these types of projects.

That said, there is a large community of people currently conducting research that will help gain further understanding of the magnitude of the water quality impacts that these actions have (Yetka, 2004).

The City of Burnsville, for example, is currently conducting a 2-year study of the performance of retro-fit rainwater gardens constructed in 2003. The study compares the water quality of runoff leaving the rainwater garden subwatershed versus that of the runoff leaving a nearby, similar subwatershed with no rainwater gardens (Yetka, 2004). The District itself is concluding a study of the Carver Lake subwatershed, investigating the feasibility of infiltration projects in developed areas draining to the lake.

In the meantime, as we wait for the insight that these studies and books will provide, we can turn to other ways of looking at the benefits of these types of projects. It is perhaps useful to think of an analogy, in terms of the types of prescriptions that we are given by our doctors.

When we are ailing, we visit our doctors for advice. At times, that advice might include a written prescription for medicine to combat an infection, for example. In less straightforward cases, though, our prescription may be the advice to "exercise and eat a balanced diet." Although both prescriptions are equally important, the effects of medicine are often more measurable and dramatic than the effects of exercise and a balanced diet.

However, by exercising and eating a balanced diet, you are still doing everything that you can to hedge your bet on maintaining good health. While you may not currently be able to prove that this lifestyle will ensure you a long, healthy life, you know that you are doing what you can to minimize the chance of something going wrong.

Likewise, in a lake management framework, pursuing some or all of the projects described in this section can be justified in a similar manner. We know that to some degree, we are bettering our environments by pursuing these projects. We are hedging our bets on maintaining the good health of our lakes. The extent to which they are pursued, of course, becomes a financial matter that can only be decided upon through discussion of all of the options and though reflection on the water quality goals that we hold for the lakes, their subwatersheds and the District as a whole.

To help guide decision makers to this end, Table 8 provides a list of the benefits (other than simply water quality benefits) that these projects can provide.

Table 8 Potential Benefits of Prescriptive Practices in the Phalen Chain of Lakes

Project	Benefits				
	Improves Aesthetics	Public Relations Opportunity	Public Participation	Wildlife Habitat	Decreases TP Load to the Lakes*
Rainwater Gardens	X	X	X	X	X
Shoreline Restoration	X	X	Potentially	X	X
Habitat Restoration	Potentially	X	Potentially	X	Potentially
Public Education		X	X		X
Street Sweeping	X	X			X
Phosphorus Bans in Fertilizer		X	X		X
Wetland Enhancement	Potentially	X		X	X

*Though we don't always know to what extent TP is decreased through these actions, most sources agree that some level of TP reduction can be expected if these actions are pursued.

3.0 Conclusions and Recommendations

This section provides conclusions and recommendations for improving and managing the Phalen Chain of Lakes to meet water quality goals.

3.1 Conclusions

Water quality varies widely throughout the Phalen Chain of Lakes. Gervais and Phalen Lakes typically have good water quality that meets the goals set for them. Kohlman and Keller Lakes, however, typically meet neither the preliminary water quality goals set forth in the District's Plan nor the MPCA's TMDL guideline, landing them on the MPCA's Impaired Waters List. However, it is not clear that either set of goals is appropriate for Kohlman or Keller Lakes in terms of the District's approach to lake management. Kohlman Lake is a fishing lake with no public access. Keller Lake appears to be thriving as a fishing lake, both evidenced by DNR reports and the heavy, year-round traffic it receives from the fishing public. However, all of the lakes in the Phalen Chain would surely benefit from some degree of water quality improvement, as well as improvements in shoreline condition, macrophyte growth and fisheries composition (in terms of a decreased carp population).

The lakes are in no imminent threat of water quality degradation. Statistical trend analyses of historical water quality show no significant trends toward either improvement or degradation. The lake's subwatersheds are largely developed already, and as long as future subwatershed development is controlled and existing treatment facilities are effectively maintained, these lakes are expected to remain at approximately the same level of water quality that they experience today.

The evaluation of potential future CIPs and their impact on the lakes' water quality reveals that in order to affect significant change in the water quality of any of the lakes in the Phalen Chain, it would be necessary to turn to chemical TP treatment that targets significant inflow points (such as Kell-03 or Kohlman Basin) or the internal loads in Kohlman and Keller Lakes. For the greatest water quality impact, the inflow point at Kohlman Basin and the internal load of both lakes would both be treated. If all these treatments were pursued, Kohlman and Keller Lakes would reach a water quality that meets the MPCA's TMDL guideline for phosphorus, and the lakes would be delisted from the Impaired Waters List. However, because the MPCA's water quality goals for Kohlman and Keller Lakes are not shared by the District, there appears to be little reason to pursue this aggressive approach to managing the Phalen Chain of Lakes in the near future.

It is important to remember, however, that Kohlman Lake is the most upstream lake in the chain and it has the worst water quality. Therefore, it may be justified to focus BMP efforts on Kohlman Lake and its subwatershed. For example, an in-lake treatment of Kohlman Lake would also improve the water quality of Gervais Lake, and to a smaller degree, that of Keller Lake. To significantly improve Keller Lake's water quality, however, an in-lake treatment of its own sediments would be needed since its water quality is so often controlled by its internal TP load. However, before these in-lake treatment options are considered any further, many factors deserve more attention as there is some question as to whether in-lake treatments would be successful or appropriate in these lakes.

A clear focus for future BMP efforts should be the currently untreated areas that drain to each of the lakes. Although these areas do not represent a large fraction of each lake's total subwatershed area, their untreated TP loads account for a significant fraction of the total TP that each lake receives. These areas deserve further attention—both now, and in the future as redevelopment occurs.

Other efforts should be focused at improving the aesthetics, stability and recreational value of the Phalen Chain of Lakes. Specifically, future efforts should be focused on improving the condition of the shorelines of Kohlman, Gervais and Keller Lakes and the channels that connect them and on controlling the nuisance carp population in the lakes. Improving these aspects of the lake also improves the lakes' water quality as shoreline erosion and carp are known detriments to lake water quality.

The last sections of this SLMP list the specific BMPs that are recommended for the Phalen Chain of Lakes, in terms of site-specific structural BMPs, in-lake BMPs and prescriptive practices. Nearly all of these recommendations come with a caveat—that their feasibility be studied in further detail in the form of a Phase II feasibility study. Examples of the details that would be evaluated in such a study are described in the final section of this SLMP ("Recommendations for Additional Study"). Based on the results of the proposed feasibility study, these recommended options may or may not be considered viable as their success depends on many factors yet to be determined.

3.2 Recommendations for Site-Specific Structural BMPs

Several of the proposed structural watershed BMPs that were discussed in Section 2.4.1 of this SLMP are recommended for further consideration in terms of a feasibility study. In fact, all of the options presented in Section 2.4 are recommended here, with the exception of the chemical treatment of outflows from subwatershed KELL-03 (Option KE-3). Although both options KO-5 and KE-3 would improve the water quality of the lakes, such high flow treatment plants are costly and require a significant effort to operate and maintain. The overall cost/benefit of such plants in these locations make their feasibility questionable at this time, and therefore they are not recommended in the near future. However, as technology in this area progresses and costs decline, the District may wish to reconsider this or similar technologies for these locations in the future. For this reason, KO-5 is recommended, but only for future consideration as it is hoped that feasibility studies and technological advances will shed light on how to make this option more feasible.

The other projects recommended here are considered more reasonable at present and are within the District's current philosophy of lake management. All of the projects recommended below are discussed in further detail in earlier sections of this SLMP.

The following projects are recommended for the Kohlman Lake subwatershed:

- **KO-1:** KO-1: Shoreline Condition Survey and Shoreline Management Plan for Kohlman Lake (including vegetated buffer)
- **KO-2:** Wetland Enhancement of Kohlman Basin
- **KO-3:** KOHL-05A Wetland Enhancement
- **KO-4:** KOHL-03 Wetland Enhancement
- **KO-5:** Chemical treatment of outflow from Kohlman Basin
- **KO-6:** Rainwater gardens in KOHL-03, KOHL-04B, KOHL-04C, KOHL-05B and KOHL-05C

The following projects are recommended for the Gervais Lake subwatershed.

- **GE-1:** Shoreline Condition Survey and Shoreline Management Plan for Gervais Lake (Including Vegetated Buffer)
- **GE-2:** Owasso Basin Optimization (Eliminate Short-circuiting of Flows from The Basin's Immediate Subwatershed)
- **GE-3:** Require 60% TP removal from Mn/DOT's "Unweave the Weave" Project and Bypass its Flows around Owasso Basin
- **GE-4:** GERV-03 Wetland Enhancement
- **GE-5:** Rainwater Gardens in GERV-04 and GERV-05

The following projects are recommended for the Keller Lake subwatershed:

- **KE-1:** Shoreline Condition Survey and Shoreline Management Plan for Keller Lake (Including Vegetated Buffer)
- **KE-2:** Wetland Treatment System in KELL-03B (northeast side of the lake)
- **KE-4:** Retention Pond in KELL-07
- **KE-5:** Rainwater gardens in KELL-02, KELL-03, KELL-03B and KELL-07

The following projects are recommended for the Lake Phalen subwatershed:

PH-1: Improvement of retention pond in PHAL-16

PH-2: Improvement of retention pond in PHAL-08

PH-3: Rainwater gardens in PHAL-06 and PHAL-03 (west of Wakefield Lake)

3.3 Recommendations for In-Lake BMPs

All of the proposed in-lake BMPs that were discussed in Section 2.4.2 of this SLMP are recommended for further consideration. All of the projects recommended below are discussed in further detail in earlier sections of this SLMP. It should be noted that project IL-2 is intended to consist of the District's current macrophyte management actions in the Phalen Chain, and is not intended to change or replace the District's current policy.

IL-1: Removal of Benthivorous Fish from Kohlman, Keller and Round Lakes

IL-2: Mechanical Removal of Nuisance Eurasian Water Milfoil Growths in Kohlman, Gervais, Keller and Phalen Lakes

IL-3: Chemical Inactivation of Sediment Phosphorus Release in Kohlman Lake

IL-4: Chemical Inactivation of Sediment Phosphorus Release in Keller Lake

IL-5: Direct Keller Lake Outflows Through Round Lake

3.4 Recommendations for Prescriptive Practices

It is not possible to effectively model the effects of nonstructural BMPs, but studies have shown that they are effective at reducing phosphorus loads. The results of this study have shown that existing wetlands and ponds will be effective at removing large-diameter particles and the associated phosphorus from stormwater runoff after completion of proposed developments. However, soluble phosphorus and phosphorus associated with extremely small particles may not be effectively removed. Therefore, source control (reduction of particles and phosphorus deposited onsite) will be extremely important in all watersheds to reduce the mass of phosphorus in the runoff, and to prevent degradation of the lakes. Examples of effective nonstructural BMPs that would be appropriate for these watersheds include:

1. Require wet detention and/or infiltration (whichever is most appropriate) so that both peak runoff rate and total volume of stormwater are the same before and after construction for all

new or redeveloped properties, where applicable. Skimming devices to trap floating material should also be included at the outlet of all wet detention ponds.

2. Enforce the metro-wide (or city-wide) ban on the use of phosphorus fertilizers. Continue to educate watershed residents about soil testing and the importance of using phosphorus-free fertilizers. Exceptions to the ban are granted in cases where a resident was able to demonstrate, by means of soil analyses, that phosphorus was required.

3. Implement a program to educate watershed residents and lake users on proper handling of wastes, pet wastes, soaps and detergents, and other practices that would reduce pollutants entering the lake.

4. Encourage industrial/commercial areas to institute good housekeeping practices, including appropriate disposal of yard wastes, appropriate disposal of trash and debris, and appropriate storage and handling of soil and gravel stockpiles.

5. Enact new ordinances, or revise and enforce existing ordinances, regarding litter and animal waste. This enforcement should concentrate in areas where the depositing of debris would likely enter the stormwater system and enter the lake (i.e., direct drainage district and other areas where stormwater does not drain to wet detention before entering the lakes).

6. Implement a street sweeping program that gives priority to the watershed areas within the direct drainage districts of each lake.

7. Require vegetated buffers between yards and the shore of each lake. Vegetated buffer strips are effective at trapping suspended solids and nutrients from runoff. Requiring/encouraging vegetated buffer strips between yards and the lake will reduce the amount of phosphorus from yard runoff, and will prevent shoreline erosion. Vegetated buffer strips also discourage waterfowl from nesting and feeding on yards adjacent to the lake. Lakescaping for Wildlife and Water Quality (Henderson et al., 1999) describes beneficial natural plants for shoreline landscaping; copies of this book could be kept on hand at the city offices for use by lakeshore homeowners. Vegetated buffer strips need not be overgrown and weedy; this book has many examples of attractively landscaped shoreline buffers.

8. Continue to discourage the feeding of waterfowl at shoreline areas around District Lakes. Waterfowl feces can add a significant amount of dissolved phosphorus to a lake or pond. Shoreline areas provide essential nesting and feeding habitat for some waterfowl, however, the habit of leaving bread scraps and other food for waterfowl encourages a large number to congregate and nest. This happens most often at shoreline parks, where large numbers of people and large expanses of short grass attract unusually large numbers of waterfowl. Continuing to prohibit the feeding of waterfowl on public shorelands may reduce the number of waterfowl congregating on the lake.

3.5 Recommendations for Additional Study

Before any lake improvement options are ultimately pursued for the Phalen Chain of Lakes, there are several topics that deserve more attention in the form of a Phase II study, namely:

- *The nature of the carp population in the Phalen Chain of Lakes.*

  The number, size, type and general location of the carp in the Phalen Chain of Lakes should be evaluated to decide whether carp management practices should be pursued, and to determine whether in-lake treatments of Kohlman and Keller Lakes' internal loads would be hindered by the carp's presence.

  Also, carp management options should be researched. Options that involve the public are of particular interest. Some initial brainstorming ideas include: educating the fishing public about how they can help control the carp population through fishing, sponsoring a "Carp Fest," and finding other ways to remove, dispose, and make use of carp remains.

- *The drainage patterns of stormwater in the untreated areas surrounding each lake.*

  The untreated subwatersheds should be further subdivided and studied to determine exactly where localized treatment systems, such as self-contained treatment manholes or catch basins, sand filters and infiltration systems, could be used to provide treatment. Maps of the storm sewers in these areas would need to be obtained from the City of St. Paul and the City of Maplewood and a field visit would be needed to complete this task.

- *A survey of lake users to determine the desired uses of each lake.*

  If there is any doubt as to the nature of the public's desired uses of the Phalen Chain of Lakes, a public survey, either in person at the lakes themselves or via mail, could be conducted.

- *The performance of the wetlands in KOHL-05A, KOHL-03, and GERV-03 and their enhancement opportunities.*

  The extent and type of vegetation, the residence time of water and the flow path through these wetlands should be evaluated to determine whether improvements can be made that would improve the water quality leaving the wetlands.

- *The creation of a "hotspot handout" that would alert developers when their proposed project falls within a subwatershed that currently provides no stormwater treatment.*

  This handout, which could be developed as part of the plan update, would encourage the construction of stormwater treatment technologies as new sites are being constructed, as roads are re-done, etc. These projects would come out of cost-sharing and cooperative planning between the District and the developer.

- *The possibility of using rainwater or first flush gardens to treat runoff in the areas indicated in Figures 13 through 16.*

  If rainwater or first flush gardens are seen as a potential alternative, their implementation could be evaluated further to estimate effectiveness, gage the interest of the public, and develop initial layout drawings.

- *The potential for cooperative arrangements that would increase the use of prescriptive practices.*

  Establishing cooperative relationships with commercial organizations and others would not only boost the use of prescriptive practices, but also create cost-sharing opportunities for the District. Also, these relationships could increase the potential for area-wide treatment projects.

- *The feasibility of treating flows from KELL-03, KELL-03B, KELL-07, Phal-08, and Phal-16, either through improved retention ponds or other treatment technologies.*

- *The feasibility of routing Keller Channel flows through Round Lake before they reach Lake Phalen.*

If chemical-in-lake treatments of Kohlman and Keller Lakes' sediments are of interest.

- *Following the ongoing research concerning the treatment of sediment phosphorus release. As new research is conducted in this field, new technologies may become available that would be of interest to the management of the Phalen Chain of Lakes as well as other lakes within the District's boundary.*

- *Sediment core release rate experiments for Kohlman and Keller Lakes.*

  If chemical in-lake treatments of Kohlman and Keller Lakes' sediments are of interest, sediment core experiments that determine the release rate of TP from the sediments should be conducted. These experiments provide useful information that is used to come up with the appropriate dose of chemicals for each individual lake. Also, these experiments help determine the water content of the sediment layer—a factor that can affect the longevity of an alum treatment.

- *The nature of the invertebrate population in Kohlman and Keller Lakes>*
  The number, size, type and general locations of the invertebrates in the Phalen Chain of Lakes should be evaluated to determine whether the invertebrate population poses a threat to the longevity of an alum treatment in the lakes.

Table 9 lists these areas of additional study, the estimated costs of performing each study, and the proposed year(s) of each study's completion.

Table 9:
Preliminary Cost Estimates for Areas of Additional Study

Recommended studies that would provide further, valuable information about the Phalen Chain of Lakes to help guide future decisions:		Estimated Cost (2004 Dollars)	Year of Completion	Notes
ST-1	Shoreline Condition Survey of Kohlman Lake	To be completed by District staff	2005 (first survey)	To be conducted every 5 years
ST-2	Shoreline Condition Survey of Gervais Lake	To be completed by District staff	2005 (first survey)	To be conducted every 5 years
ST-3	Shoreline Condition Survey of Keller Lake	To be completed by District staff	2005 (first survey)	To be conducted every 5 years
ST-4	Lake Users' Survey of Current and Desired Lake Uses and Water Quality	$20,000	2004	
ST-5	Study of the Benthivorous Fish Population in the Phalen Chain of Lakes	$10,000	2005	
ST-6	Study of the Drainage Patterns of Stormwater in the Untreated Subwatersheds Around Each Lake in the Chain	$28,000	2005	
ST-7	Study of the Current Performance of the Wetlands in Kohl-05A, Kohl-03 and Gerv-03 and Their Enhancement Opportunities	$20,000	2006	
ST-8	Invertebrate Survey of Keller and Kohlman Lakes to Determine the Potential for Bioturbation of Sediments	$10,000	2005	
ST-9	Sediment Core Survey and Sediment TP Release Rate Experiments for Kohlman and Keller Lakes	$32,000	2005	
ST-10	Research Current Options in Prefabricated filtration units that would be appropriate for Kell-03B	$13,000	2006	

Feasibility Studies of Recommended BMPs:		Estimated Cost (2004 Dollars)	Year of Completion	Notes
ST-11	Feasibility Study of Retrofit Rainwater Gardens in Suitable Untreated Subwatersheds	$30,000	2005	
ST-12	Feasibility Study of Creating/Improving Retention Ponds in Kell-07, Phal-16, Phal-08	$15,000	2006	
ST-13	Feasiblity Study of Routing Keller Channel Flows Through Round Lake	$16,000	2007	

Other Recommended Actions:		Estimated Cost (2004 Dollars)	Year of Completion	Notes
ST-14	Create a "Hot-Spot" Handout that Delineates Currently Untreated Subwatersheds for Developers and Cities and Suggests Options for Cost-Sharing Projects with the District	$10,000	2005	
ST-15	Follow New Research for Treatment of Sediment TP Release, Treatment of TP in Lake Inflows	$10,000	2005-2007	
ST-16	Look for Co-Operative Arrangments that Would Increase Prescriptive Practices Throughout the Phalen Chain	$10,000	2005-2009	

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Appendix A

Criteria for Lake Water Quality Evaluation

Appendix A: Criteria for Lake Water Quality Evaluation

A.1 Trophic State and Percentile Rankings

Several different organizations have monitored the water quality of the water bodies in this study area since 1961. These organizations include Ramsey County, the Minnesota Department of Natural Resources, the Ramsey Washington Metro Watershed District (RWMWD) and others, including CAMP and lake association volunteers. Some of these organizations have chosen different sampling stations throughout each lake, but for the most part, readings were taken either in the deepest location of a bay or in the main basin of each water body. Twenty-two years of historical data (1981-2002) was examined to determine if any degradation or improvement in the lakes' water quality has occurred. Limnological data such as temperature, dissolved oxygen, Secchi disc transparency (water clarity), total phosphorus concentration (limiting nutrient), and chlorophyll a concentration were reviewed.

> ***Phosphorus—****is the plant nutrient that most often limits the growth of algae. Phosphorus-rich lake water indicates a lake has the potential for abundant algal growth, which can lead to lower water transparency and a decline in hypolimnetic oxygen levels in a lake.*
>
> ***Chlorophyll a****—is a measure of algal abundance within a lake. High chlorophyll a concentrations indicate excessive algal abundance (i.e., algal blooms), which can lead to recreational use impairment.*
>
> ***Secchi disc transparency—****is a measure of water clarity. Perceptions and expectations of people using a lake are generally correlated with water clarity. Results of a survey completed by the Metropolitan Council (Osgood, 1989) revealed the following relationship between a lake's recreational use impairment and Secchi disc transparencies:*
>
> - *Moderate to severe use-impairment occurs at Secchi disc transparencies less than 1 meter (3.3 feet).*
> - *Moderate impairment occurs at Secchi disc transparencies of 1 to 2 meters.*
> - *Minimal impairment occurs at Secchi disc transparencies of 2 to 4 meters.*
> - *No impairment occurs at Secchi disc transparencies greater than 4 meters*

The data was analyzed using the Carlson Trophic State Index, (Carlson, 1977), which assigns a trophic state index ("TSI") to a lake based on the total phosphorus concentration, chlorophyll *a* concentration, and Secchi disc transparency. The lake classification index is summarized below.

Lake Classification	TSI Values	Total Phosphorus Conc. (µg/L)	Chlorophyll *a* Conc. (µg/L)	Secchi Transparency (feet)
Oligotrophic	<38	<10.5	<2.0	>15
Mesotrophic	38–50	10.5–24.5	2.0–7.5	15–6.6
Eutrophic	50–62	24.5–57.0	7.5–26.0	6.6–2.8
Hypereutrophic	>62	>57.0	>26.0	<2.8
RWMWD Level I Goal		30	10	5.25
RWMWD Level II Goal		40	15	3.9
RWMWD Level III Goal		60	32	2.4

A.2 Lake Water Quality Goal Attainability

The Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) is intended to be used as a screening tool for estimating lake conditions and for identifying "problem" lakes. MINLEAP is particularly useful for identifying lakes requiring "protection" versus those requiring "restoration" (Heiskary and Wilson, 1990). In addition, MINLEAP modeling by has been done in the past to identify Minnesota lakes which may be in better or worse condition than they "should be" based on their location, watershed area and lake basin morphometry (Heiskary and Wilson, 1990).

Vighi and Chiaudani (1985) developed another method to determine the phosphorus concentration in lakes that are not affected by anthropogenic (human) inputs. As a result the phosphorus concentration in a lake resulting from natural, background phosphorus loadings can be calculated from information about the lake's mean depth and alkalinity or conductivity. Alkalinity is considered more useful for this analysis because it is less influenced by the modifying effect of anthropogenic inputs.

A.3 Trend Analyses

As part of this study, trend analyses of lake water quality data was completed to determine if the lake had experienced significant degradation or improvement during all of the years for which water quality data are available. Lake water quality data from the growing season (June-August) from 1981-2002 were used for each analysis. Long-term trends were determined using standard statistical methods (i.e., linear regression and analysis of variance).

Two criteria must be met to conclude the lake's water quality has significantly improved or declined. First, the trend in a variable was considered significant if the slope of the regression was statistically significant at the 95 percent confidence level. Second, a conclusion of improved water quality requires concurrent decreases in total phosphorus and chlorophyll a concentrations, and increases in Secchi disc transparencies; a conclusion of degradation requires the inverse relationship.

A.4 Biological Data

Two types of biological data were compiled and evaluated (in addition to with the physical and chemical parameters) for each water body during this study. Macrophyte (aquatic weeds) and fisheries data provide insight into the health of the aquatic ecosystem associated with each water body. Aquatic communities interact with each other and influence both short- and long-term variations in observed water quality.

> ***Aquatic plants****—(i.e., macrophytes and phytoplankton) are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. They are the primary producers in the aquatic food chain, providing food for other aquatic life. Macrophytes describe the aquatic plants growing in the shallow (littoral) area of the lake.*
>
> ***Fisheries*** *—form the top level of the food chain within the lake environment. Smaller fish feed upon the zooplankton and are food themselves for many larger fish species. The populations and species of fish can have an effect on lake water quality. Depending on the size and population, certain species of fish can adversely affect the zooplankton community, which will in turn, increase the number of algae and diminish water transparency within a lake.*

Appendix B

Example of Public Survey to Determine Desired Lake Uses

Long Lake Questionnaire

1. Please indicate the term that best defines what you consider the water clarity of the lake to be during the summer months currently and what you think it should be.

Current Clarity

a. Crystal Clear
b. Clear
c. Cloudy
d. Murky

Desired Clarity

a. Crystal Clear
b. Clear
c. Cloudy
d. Murky

2. Please indicate the recreational activities currently supported by Long Lake and the recreational activities you feel the lake should support.

Current Activities

a. Fishing
b. Observing Wildlife
c. Swimming
d. Scuba Diving
e. Snorkeling
f. Appreciate Peace and Tranquility
g. Enjoying the View
h. Water Skiing
i. Jet Skiing
j. Motorized Boating
k. Non-Motorized Canoeing, Rowing
l. Sailing, Wind Surfing
m. Other (Please State)

____

Desired Activities

a. Fishing
b. Observing Wildlife
c. Swimming
d. Scuba Diving
e. Snorkeling
f. Appreciate Peace and Tranquility
g. Enjoying the View
h. Water Skiing
i. Jet Skiing
j. Motorized Boating
k. Non-Motorized Canoeing, Rowing
l. Sailing, Wind Surfing
m. Other (Please State)

____

3. Please circle the following Lake Management Goals that are important to you.

a. Protect existing water quality of the lakes
b. Improve the lakes' water quality
c. Protect existing fisheries
d. Improve fisheries
e. Protect existing weed growth
f. Increase weed growth
g. Decrease weed growth
h. Protect aesthetics (i.e., how the lake looks)
i. Improve aesthetics (i.e., how the lake looks)

Appendix C

General Concepts in Lake Water Quality

Appendix C: General Concepts in Lake Water Quality

Before discussing each lake, it is useful to consider some general concepts involved in assessing lake water quality. This section provides a brief discussion of the following topics:

- Eutrophication
- Trophic states
- Limiting nutrients
- Stratification
- Nutrient recycling and internal loading

C.1 Eutrophication

The water quality problems caused by sediment and nutrients from a lake's watershed are described by the word "eutrophication." Eutrophication, or lake degradation, is the process whereby lakes accumulate sediments and nutrients from their watersheds. Over time, a lake naturally becomes more fertile. Nutrients serve as a catalyst for algae and weed growth in a lake. Biological production, aided by sediment inflow from the lake's watershed, eventually fills the lake's basin. Over a period of many years, the lake successively becomes a pond, a marsh and, ultimately, a terrestrial site. The process of eutrophication is natural and results from the normal environmental forces that influence a lake.

Cultural eutrophication, however, is an acceleration of the natural process caused by human activities. This acceleration may result from point-source nutrient loadings, such as effluent from wastewater treatment plants and septic tanks. It may also be caused by diffuse (i.e., nonpoint) sources of sediments and nutrients, such as stormwater runoff. Sediments and nutrients may be added to the lake via runoff from an agricultural watershed. In addition, nutrients may be released by the lake's bottom sediments. The accelerated rate of water quality degradation caused by these pollutants results in unpleasant consequences. These include profuse and unsightly growths of algae (algal blooms) and/or the proliferation of rooted aquatic weeds (macrophytes).

C.2 Trophic States

Not all lakes are at the same stage of eutrophication; therefore, criteria have been established to evaluate the nutrient "status" of lakes. Trophic state indices (TSIs) are calculated for lakes on the basis of total phosphorus, chlorophyll a concentrations, and Secchi disc transparencies. A TSI value is obtained from any one of these three parameters. TSI values range upward from 0, describing the condition of the lake in terms of its trophic status (i.e., its degree of fertility). Four trophic status designations for lakes are listed below with corresponding TSI value ranges:

1. **Oligotrophic—[TSI < 37]** Clear, low productivity lakes with total phosphorus concentrations less than or equal to 10 µg/L.
2. **Mesotrophic—[38 < TSI < 50]** Intermediate productivity lakes with total phosphorus concentrations greater than 10 µg/L, but less than 25 µg/L.
3. **Eutrophic—[51 < TSI < 63]** High productivity lakes generally having 25 to 60 µg/L total phosphorus.
4. **Hypereutrophic—[64 < TSI]** Extremely productive lakes which are highly eutrophic, disturbed and unstable (i.e., fluctuating in their water quality on a daily and seasonal scale, producing gases, off-flavor, and toxic substances, experiencing periodic anoxia and fish kills, etc.) with total phosphorus concentrations above 60 \ µg/L.

Determining the trophic status of a lake is an important step in diagnosing water quality problems. Trophic status indicates the severity of a lake's algal growth problems and the degree of change needed to meet its recreational goals. Additional information, however, is needed to determine the cause of algal growth and a means of reducing it.

C.3 Limiting Nutrients

The quantity or biomass of algae in a lake or pond is usually limited by the water's concentration of an essential element or nutrient—the "limiting nutrient." In contrast, rooted aquatic plants derive most of their nutrients from lake or pond sediments. The limiting nutrient concept is a widely applied principle in the study of eutrophication. It is based on the idea that, in considering all of the substances needed for biological growth, only one will be present in limited quantity. The availability of this limiting nutrient will, therefore, control the rate of algal growth. It follows then, that the identification of a lake's limiting nutrient will point the way toward a solution for its algal problems.

Nitrogen (N) and phosphorus (P) are generally the two growth-limiting nutrients for algae in most natural waters. Analysis of the nutrient content of lake water and algae provides ratios of N:P that can indicate whether one or the other of these elements is growth-limiting. By comparing the tissue concentrations of important nutrients in algae to the concentrations of the same nutrients in the ambient waters, one can estimate whether a particular nutrient may be limiting.

Algal growth is generally phosphorus-limited in waters with N:P ratios greater than 15. It has been amply demonstrated, in experiments ranging from laboratory bioassays to fertilization of in-situ enclosures to whole-lake experiments, that phosphorus is generally the nutrient that limits algal growth in this region. Algal abundance is nearly always phosphorus-dependent. A reduction in the phosphorus concentration in a lake is, therefore, necessary in order to reduce algal abundance and improve water transparency. Failure to reduce phosphorus concentrations will allow the process of eutrophication to continue at an accelerated rate.

C.4 Stratification

The first step in solving the eutrophication problem is realizing that the solution must focus on phosphorus reduction. Phosphorus enters lakes, wetlands and ponds from internal and/or external sources. An understanding of the depth-temperature patterns, or "structure" of a lake helps determine whether the solution should focus on internal and/or external sources.

In any water body, certain physical phenomena occur that can profoundly influence its chemistry and biology. Probably the most important of these phenomena is "thermal stratification." Because the density of water decreases as it warms, warmer water tends to rise to the surface. As a result, lakes and ponds in temperate regions tend to form temperature layers, or "stratify", when they are exposed to the heat of the sun.

When ice melts in the spring, the water temperature in a lake is usually around 4˚C (~39˚F) from top to bottom. At this temperature, water is most dense (heaviest). During the spring and summer months, the sun warms the surface layer of the lake causing it to become warmer and less dense (lighter). The warm surface layer of the lake is called the epilimnion. In shallow portions of a lake, the sun's rays are often able to reach the lake's bottom in most places. During the summer, the water temperature in these portions (which are usually near the shore, or in the "littoral zone") may be warm throughout.

The deeper portions of lakes typically have a thermal/density structure that differs from the shallow regions. Because sunlight does not reach the bottom of the deeper portions of the lake, these waters remain cool and more dense. Therefore, the warmer, lighter water lies near the surface and the cooler, heavier water stays at the bottom of the lake.

The cooler, deeper water layer of the lake is called the hypolimnion, and the warm surface zone is known as the epilimnion. Between the warm epilimnion and the cool hypolimnion is a transitional layer of water known as the metalimnion. This layer of the lake is characterized by a rapidly-declining temperature.

C.5 Nutrient Recycling and Internal Loading

The significance of thermal stratification in lakes is that the density change in the metalimnion provides a physical barrier to mixing between the epilimnion and the hypolimnion. While water above the metalimnion may circulate as a result of wind action, hypolimnetic waters at the bottom generally remain isolated. Consequently, very little transfer of oxygen occurs from the atmosphere to the hypolimnion during the summer.

Shallow water bodies may circulate many times during the summer as a result of wind mixing. Lakes possessing these wind mixing characteristics are referred to as polymictic lakes. In contrast, deeper lakes generally become well-mixed only twice each year. This usually occurs in the spring and fall. Lakes possessing these mixing characteristics are referred to as dimictic lakes. During these periods, the lack of strong temperature/density differences allow wind-driven circulation to mix the water column throughout. During these mixing events, oxygen may be transported to the deeper portions of the lake, while dissolved phosphorus is brought up to the surface.

If the lake or pond sediments are rich in organic matter, microbial decomposition and respiration can deplete the hypolimnion of dissolved oxygen. Phosphorus contained in the sediment may then be released into the water column as a result of changes in the oxidation-reduction (REDOX) potential of the system caused by oxygen depletion. Later, this phosphorus will contribute to the growth of algae in surface waters when the thermal stratification of the lake breaks down and the lake or pond mixes. This resuspension or dissolution of nutrients from the sediments to the lake water is known as "internal loading." The relative amounts of phosphorus coming from internal and external loading vary with each lake. The amount of phosphorus released from internal loading can be estimated from depth profiles (measurements from surface to bottom) of dissolved oxygen and phosphorus concentrations

Appendix D

Owasso Basin Performance Improvements

Memorandum

To: Brad Lindaman, Barr Engineering Company
Ramsey-Washington Metro Watershed District (RWMWD)

From: Greg Wilson

Subject: Owasso Basin Performance Improvements—Results of Monitoring, P8 Modeling and Assessment of Potential Water Quality Treatment Improvements and Feasibility

Date: April 4, 2003

Project: 23/62-831 BJL 020

This memorandum has been prepared to discuss potential improvements to the water quality treatment performance of Owasso Basin. This discussion is based on a review of past monitoring data and the results of water quality modeling done for the Owasso Basin watershed as part of this study. This memorandum is intended to:

- Summarize conclusions from the previous study of Owasso Basin
- Describe the methodology used to complete the water quality modeling and assessments for this study
- Discuss the results of this assessment of potential water quality treatment improvements
- Discuss benefits, limitations and feasibility of potential water quality treatment improvements

Results of Previous Study

This section discusses the previous monitoring study, completed by Barr Engineering and RWMWD in 1995. Figure 1 shows a map of the Owasso Basin watershed. The Black Tern Pond subwatershed was not tributary to Owasso Basin during 1995, but drains to the northwest corner of the basin under current conditions. Figure 2 provides a detailed view of Owasso Basin and shows the locations of the primary inlet (inlet), outlet and the eight (numbered) inflow sites where grab samples were collected in the past. The monitoring report, Addressing the Water Quality Benefits of Smaller Wet Detention Ponds (*Barr Engineering Company; February 1996; Prepared for Ramsey-Washington Metro Watershed District and the Metropolitan Council*), concluded that:

- The total suspended solids (TSS) and (TP) concentrations at the basin outlet were as high or higher the than the concentrations observed at the primary inlet to the east end of the basin, indicating poor pollutant removal by Owasso Basin
- Grab sample results taken during three storm events from eight other minor inlets, located on the westerly or downstream side of the basin, indicated that TSS and TP concentrations were generally higher than the concentrations observed at the primary inlet and that runoff is likely being short-circuited through the basin

- Three of the grab sample locations are within 90 to 280 feet of the outlet, while all of the other grab sample sites discharge into the western arm of the basin
- The monitoring data from six significant (and discrete) storm events suggest that:
    - The eight minor inflow sites contribute between 24 and 55 percent of the total flow to the basin
    - Using average grab sample constituent concentrations, the apparent TP removal efficiencies ranged from –7 to 61 percent, with an average removal of 27 percent
    - The apparent TSS removal efficiencies ranged from –55 to 67 percent, with an average removal of 2 percent
- The following structural improvements should be considered for implementation to increase the treatment efficiency of Owasso Basin:
    - Install a baffle or series of baffles near the outlet to encourage flow of the industrial stormwater runoff towards the deeper portion of the basin
    - Dredge sufficient material (approximately four to six additional feet) from the base of the entire western portion of the basin to eliminate sediment resuspension and reduce short-circuiting
    - Construct new outlet in extreme southeast corner of the basin so that flow from the industrial stormwater runoff will travel across the length of the deeper portion of the basin

Methodology for Water Quality Modeling and Assessment of Improvements

This evaluation involved a more detailed assessment of the 1995 monitoring data and development of a P8 Urban Catchment Model of the watershed that could be calibrated, or optimized to match the observed monitoring data. Our approach for the first portion of this study began with a detailed review of the available monitoring data and determining the relationships between the observed treatment efficiencies and the available climatic data. In each case, the TP, TSS and soluble reactive phosphorus (SRP) removal percentages were plotted against the storm event rainfall amounts, antecedent dry periods, average daily and maximum wind speeds. Then, statistical regressions were developed for each combination of constituent removal percentages and climatic data type to determine the significance of the relationship.

For the second portion of this study, Barr updated an existing P8 Model of the watershed, optimized the model to the 1995 monitoring data, and subsequently used P8 to estimate the benefits of potential water quality improvements under 2002 land use conditions. The following four P8 water quality modeling scenarios were completed for this study, along with the specific assumptions attributed to each:

1. Calibrated to monitoring data from six significant (and discrete) storm events during 1995, based on 1995 land use conditions
    a. Assumed Owasso Basin pollutant removal efficiency was negligible

   b. 1.5 times more of the largest particle fraction than the NURP 50th percentile particle size distribution
   c. 3500 mg/kg TP for each particle size fraction (compared to 3850 mg/kg) from the NURP 50th percentile particle size distribution
   d. Doubled scale factor for particulate loads from subwatersheds (1, 3, 4, 5, 6, and 7) with bare soil or gravel lots
   e. Highway pavement was not directly-connected to stormwater conveyances and drained condition for Hydrologic Soil Group was assumed for determination of pervious curve number
2. Updated Scenario #1 model imperviousness and pervious curve number based on 2002 land use and drainage conditions
3. Inserted new MnDOT wet detention pond (designed according to RWMWD requirements) immediately upstream of Owasso Basin in Scenario #2 model
   a. Assumed that flow diversion structure or baffle would be constructed to divert flow of the industrial stormwater runoff towards the deeper portion of the basin so that pollutant removal efficiency would be consistent with NURP Pond design
   b. No treatment of runoff from Subwatershed 8 would occur
4. Same as Scenario #3 model, except new MnDOT wet detention pond bypasses Owasso Basin
   a. Existing Owasso Basin outlet would be closed off and new 18” outlet pipe would be constructed in the extreme southeast corner of the basin

For each scenario, all of the modeling results were reported for the period between April 28 and October 31, 1995, since site-specific hourly precipitation was available and this time period also corresponded with the monitoring record.

Assessment of Potential Water Quality Treatment Improvements

As previously mentioned, the TP, TSS and SRP removal percentages were plotted against the storm event rainfall amounts, antecedent dry periods, average daily and maximum wind speeds. The statistical regressions developed for each combination of constituent removal percentage and climatic data type revealed that there was no statistically significant relationship between the TP, SRP and TSS removal percentages and the rainfall amounts for each runoff event, the antecedent dry periods, and the average and maximum daily wind speeds. This indicates that the poor treatment efficiency of Owasso Basin is not due (primarily) to:

- Sediment resuspension from wind mixing
- Short detention times or scour during higher flows
- Anoxic sediment phosphorus release

As previously mentioned, four P8 modeling scenarios were set up and run as part this study, with the first scenario intended to calibrate the P8 Model to the 1995 monitoring data. The second modeling scenario involved updating the calibrated model with imperviousness and pervious curve numbers based on 2002 land use and drainage conditions. The P8 Model results from this scenario provide estimates of the water and pollutant loadings that would be expected under current conditions, when the observed rainfall for 1995 (April 28 through October 31) is simulated. Figure 2 presents the P8 Model predictions for runoff volume, TSS and TP loads, and TSS and TP concentrations at each of the 1995 monitoring locations, for the second modeling scenario. The results show that:

- 63% of the total flow into Owasso Basin comes from the primary inlet, while only 42% of the TSS load and 49% of the TP load to the basin come from the inlet
- A disproportionately higher percentage of the TSS and TP loadings to Owasso Basin are coming from Subwatersheds 1, 3, 4, 5, 6, and 7, relative to their respective flow volumes
- Subwatersheds 1, 3, 4, 5, 6, and 7 account for 33% of the combined TSS load and 27% of the combined TP load to Owasso Basin, but combine for just 12% of the total flow to the basin
- Subwatersheds 1 through 8 all discharge into the shallow, western arm of Owasso Basin, greatly increasing the likelihood for short-circuiting (or preventing flow from reaching the deeper, middle portion of the basin) and for scour of particles from the bottom of this shallow portion of the basin

As previously mentioned, two scenarios involving potential improvements were modeled in P8. The following table provides a comparison of the P8 modeling results for what would be expected under current conditions (Scenario #2) and the two potential improvement options (Scenarios #3 and #4) with simulation of the 1995 climatic conditions (April 28 – October 31, 1995).

Modeling Scenario #	Scenario Description	Discharge from Study Area (lbs.)	
		TSS Load	TP Load
2	Current Land Use and Drainage Conditions	69,723	213
3	Same as Scenario #2, except with a new MnDOT wet detention pond immediately upstream of Owasso Basin	6,660	107
4	Same as Scenario #3, except new MnDOT wet detention pond would bypass Owasso Basin under normal flow	6,628	107

The results show that either of the improvement option scenarios should significantly reduce the pollutant loadings (90% reduction for TSS, 50% for TP) that currently discharge from the existing Owasso Basin watershed. Since the same assumption, that Owasso Basin treatment efficiency would be consistent with that of an optimal NURP Basin pond design, was made for both Scenarios #3 and #4, the results do not show a significant difference between the water quality benefits of either design scenario. The reason for this is that, since the proposed MnDOT detention pond drains into Owasso Basin in the third modeling scenario, the higher flow rate results in less detention time in the basin and offsets the benefit of treating more of the total flow in the system, in comparison with the fourth modeling scenario. In addition, the third modeling scenario does not allow for adequate treatment of the runoff from Subwatershed 8.

Feasibility and Benefits/Limitations of Potential Water Quality Treatment Improvements

The results of this analysis showed that either of the improvement options should significantly reduce the pollutant loadings from the existing Owasso Basin watershed, primarily due to the assumption that the Owasso Basin treatment efficiency would be consistent with that of an optimal NURP Basin for each design. Either improvement option should be feasible, although construction of a flow diversion structure or baffle to divert flow from the industrial stormwater runoff towards the deeper portion of the basin may have some uncertainty with regard to cost and assurance of water quality treatment effectiveness. The uncertainty about the assurance of the water quality treatment effectiveness with the diversion structure or baffle has to do with the potential for particle resuspension or scour associated with further concentrating the flow through the western arm of the basin. The predicted water quality treatment effectiveness of this improvement option could be tested by installing a flotation silt curtain in the proposed location of the baffle, and then subsequently collect samples from the inflow and outflow locations to verify the water quality treatment. Therefore, if the water quality improvement is not as good as expected, RWMWD could avoid spending funds to construct the permanent diversion structure or baffle without the assurance of how well it might work.

It is my opinion that there is less uncertainty and more assurance that the water quality treatment effectiveness predicted for the fourth modeling scenario can be attained after construction. Therefore, as long as the estimated construction cost for the improvements proposed in the third and fourth modeling scenarios are comparable, I recommend construction of the improvements proposed under the fourth modeling scenario. Another potential benefit of the proposed improvements associated with reversing the flow through Owasso Basin (Scenario #4) is that we may also be able to divert untreated stormwater runoff from the southwest corner of the trailer court and the area southwest of Subwatershed 7 (see Figure 1) into the basin under normal flow conditions. The feasibility of these diversions and the relative flood control benefit of this improvement option should be further evaluated before preliminary construction design, if this is chosen as the preferred option.

If there is reason to believe that the MnDOT pond may not be constructed, or is not constructed to the RWMWD or NURP pond design guidelines, there would likely be more water quality benefit from directing the MnDOT flow into Owasso Basin. If this should occur, another improvement option exists that may function better than the improvements in the third modeling scenario. This new improvement option would involve closing off the existing Owasso Basin outlet, constructing a new outlet in the extreme southeast corner of the basin and a baffle between the primary inlet and new outlet, to prevent short-circuiting. This potential improvement option would likely be more expensive to construct than either of the aforementioned improvement options and would not need to be considered if the MnDOT flow normally bypasses the basin.

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Figure 1

WATERSHED MAP
Owasso Basin Feasibility Study
Ramsey-Washington Metro
Watershed District

Owasso Basin Subwatershed ID
Flow in acre-feet
TSS and TP Load in lbs.
TSS and TP Conc. in mg/L

Owasso Basin Subwatershed Divides

N
W E
S

150 0 150 Feet

Figure 2

P8 MODELING RESULTS,
CURRENT CONDITIONS,
1995 CLIMATE DATA
Owasso Basin Feasibility Study
Ramsey-Washington Metro
Watershed District

Appendix E

Lake and Subwatershed Existing and Historical Conditions

E-1: Kohlman Lake

E-2: Gervais Lake

E-3: Keller Lake

E-4: Lake Phalen

E-5: Other Lakes in the Phalen Chain of Lakes Subwatershed

Appendix E: Lake and Subwatershed Existing and Historical Conditions

This section provides a summary of the physical features and water quality of each water body and its subwatershed. Existing in-lake water quality data, watershed land use and historical water quality studies are used to evaluate the existing nutrient and water balances for each lake. This evaluation establishes a baseline condition for determining the effectiveness of various options for improving lake water quality.

E.1 Kohlman Lake

E.1.1 Overview of Kohlman Lake and Subwatershed

E.1.1.1 Description of Kohlman Lake

Kohlman Lake is a DNR-protected water (#62-0006) located in the city of Maplewood (Figure E-1). The lake has a surface area of 74 acres and a maximum depth of approximately 9 feet and a mean depth of 4 feet. Most of the lake is less than 6 feet deep, with the littoral area comprising 74 acres or 100% of the lake (DNR Lake Data). The watershed area in comparison to the lake area is relatively large (101:1).

Kohlman Lake is a fishing lake used lake primarily for motorboating, canoeing, fishing, picnicking, and viewing. Other recreational uses include limited wildlife habitat. According to the Plan, the designated Use Level is 3.

Kohlman Lake is polymictic; it mixes several times throughout the year. At times, this mixing can entrain TP that is released from the lake's sediments into the water column, making more Total Phosphorus (TP) available to algae.

E.1.1.2 Land Use

The existing land use in the Kohlman Lake watershed can be seen in Figure E-2. Development in the tributary subwatershed is essentially complete.

E.1.1.3 Drainage Systems Flowing into Lake

The Kohlman Lake watershed comprises a total of 7,484 acres (excluding the lake surface area) and drains portions of the cities of Gem Lake, White Bear Lake, Vadnais Heights, Maplewood, North St. Paul, Little Canada, and Oakdale. There are no landlocked areas in the Kohlman Lake subwatershed. Runoff enters the lake from storm sewer outfalls and culverts at various points along the lakeshore and from sheet flow running off the lake's immediate drainage area.

The Kohlman Lake subwatershed can be described in terms of four different "drainage districts." A drainage district is described as a network of drainage areas that all drain to the same point before entering the lake.

Each Kohlman Lake drainage district is described below:

- **Kohlman Lake Main Drainage District—**This 6831-acre drainage district east of the lake represents more the majority of the Kohlman Lake subwatershed. Runoff from this drainage district flows through a series of ponds, wetlands and/or storm sewers and, ultimately, Kohlman Basin before reaching Kohlman Lake.
- **Kohlman Lake North Drainage District—**This 107-acre drainage district north of the lake represents a very small portion of the Kohlman Lake subwatershed. Runoff from this drainage district flows to a flow splitter, where the flow is routed either to Kohlman or Gervais Lake, depending on the level of water in the flow splitter.
- **Kohlman Lake South Drainage District—**This 83-acre drainage district south of the lake also represents a very small portion of the Kohlman Lake subwatershed. Runoff from this drainage district is routed to two ponds, neither of which have outlets—therefore, only overflow from the ponds reaches the lake.
- **Kohlman Lake Direct Drainage District—**This 463-acre drainage district consists of the area that drains directly to Kohlman Lake without passing through a retention pond. The runoff from this area receives no treatment before it reaches the lake.

These drainage districts are shown in Appendix J of this SLMP.

E.1.1.4 Kohlman Lake Outlet

The outlet from Kohlman Lake is a channel that is connected to Gervais Lake. The channel typically holds water at an elevation of 858 MSL (the elevation of the weir crest downstream of Keller Lake).

E.1.2 Historical Water Quality

Figures E-3 through E-5 show the growing season means (June through August) of Kohlman Lake's Total Phosphorus (TP), Chlorophyll *a* (Chla) and Secchi Disc (SD) measurements, respectively. Each column in each graph shows the number of readings (N) that resulted in the summer average.

The mean surface water concentrations of TP in Kohlman Lake have ranged from 68 μg/L (in 2002) to 187 μg/L (in 1982) over the past 22 years, giving the lake a hypereutrophic classification. The average lake TP concentration from 1981 to 2002 is 120 µg/L- twice the District's preliminary TP goal for Kohlman Lake (the goal is not met).

The summer average Chla concentrations have ranged from 11.56 µg/L (in 2002) to 74.1 µg/L (in 1999) over the past 22 years, giving the lake a hypereutrophic classification in some years and a eutrophic classification in others. The average Chla concentration from 1981 to 2002 is 40.2 µg/L, which is higher than the District's preliminary Chla goal for Kohlman Lake (the goal is not met).

The summer average SD measurements have ranged from 5.64 feet (in 2002) to 1.21 (in 1982) giving the lake a hypereutrophic classification in some years and a eutrophic classification in others. The average SD concentration from 1981 to 2002 is 2.9 feet, which is higher than the District's preliminary SD goal for Kohlman Lake (the goal is met).

Figure E-6 shows the relationship between SD and TP measurements taken throughout the year (1981-2002) in Kohlman Lake. At lower TP concentrations (less than 60 µg/L), changes in the lake's TP result in significant changes in the lake's transparency. At higher TP concentrations, changes in lake TP result in relatively smaller changes in the lake's transparency. This figure also shows the typical timing of higher and lower lake TP concentrations throughout the year in Kohlman Lake. Lower TP concentrations are typically seen in the late spring and early summer, while higher TP concentrations typically occur later in the summer months.

Figure E-7 shows the historical TP concentrations relative to three different classifications- MNLEAP's range for "Minimally Impacted Lakes", the MPCA's TP threshold above which a lake is placed on the Impaired Waters List and Vighi and Chiaudani's TP Range for Pre-Settlement Watershed Conditions in the Kohlman Lake subwatershed. These classifications are described in further detail in the main body of this SLMP (Impaired Waters List) or in Appendix A (MNLEAP and Vighi and Chiaudani's Pre-Settlement TP concentration).

As shown in this figure, Kohlman Lake's water quality is, on average, at the upper end of the range of water quality in other lakes with a similar size, shape and ecoregion. Also, Kohlman Lake has clearly been degraded since pre-settlement times due to anthropogenic inputs. Finally, the lake's high summer average TP concentrations have easily placed Kohlman Lake on the MPCA's Impaired Waters List.

E.1.3 Trend Analyses of Total Phosphorus, Chlorophyll *a* and Secchi Disc Transparency Data

There was no statistically significant water quality trend that could be distinguished for Kohlman Lake from 1981 to 2002.

E.2 Gervais Lake

E.2.1 Overview of Gervais Lake and Subwatershed

E.2.1.1 Description of Gervais Lake

Gervais Lake is a DNR-protected water (#62-0007) located mostly in the city of Little Canada, with a very small portion located in the city of Maplewood (Figure E-8). The lake has a surface of 234 acres, a maximum depth of approximately 45 feet and mean depth of approximately 22 feet. The littoral area comprises approximately 91 acres or 39% of the lake (DNR Lake Data). The watershed area in comparison to the lake area is relatively small (12:1).

Gervais Lake is a recreational lake used lake primarily for swimming, skiing, and speedboating. Other recreational uses include limited wildlife habitat. The lake has public boating access and a swimming beach. According to the Plan, Gervais Lake's designated Use Level is 1.

Gervais Lake is dimictic; it generally only mixes twice a year- once in the spring and once in the fall. Although TP is at times released from the lake's sediments, this TP is generally not mixed throughout the water column during summer months and is not made available to algae in the surface waters.

E.2.1.2 Land Use

The existing land use in the Gervais Lake watershed can be seen in Figure E-9. Development in the tributary subwatershed is essentially complete.

E.2.1.3 Drainage Systems Flowing into Lake

The Gervais Lake subwatershed has a total area of 2,693 acres, excluding the lake surface area, and drains portions of the cities of Vadnais Heights, Little Canada, and Maplewood. There are no landlocked areas in the Gervais Lake subwatershed. Runoff enters the lake from storm sewer outfalls and culverts at various points along the lakeshore and from sheet flow running off the lake's immediate drainage area.

The Gervais Lake subwatershed can be described in terms of four different "drainage districts." A drainage district is described as a network of drainage areas that all drain to the same point before entering the lake.

Each Gervais Lake drainage district is described below:

- **Gervais Lake Main Drainage District—**This 2063-acre drainage district northwest of the lake represents more than half of the Gervais Lake subwatershed. Runoff from this drainage district flows through a series of ponds, wetlands and/or storm sewer before reaching Gervais Lake.

- **Gervais Lake East Drainage District**—This 42-acre drainage district east of the lake represents a very small portion of the Gervais Lake subwatershed. Runoff from this drainage district flows to single detention pond before reaching Gervais Lake.
- **Gervais Lake Southwest Drainage District**—This 362-acre drainage district south and southwest of the lake represents about 13% of the Gervais Lake subwatershed. Runoff from this drainage district flows through a series of ponds, wetlands and/or storm sewer before reaching Gervais Lake.
- **Gervais Lake Direct Drainage District**—This 226-acre drainage district consists of the area that drains directly to Gervais Lake without passing through a detention pond.

These drainage districts are shown in Appendix J of this SLMP.

E.2.1.4 Gervais Lake Outlet

The outlet from Gervais Lake is a channel that is connected to Spoon Lake (connected to Keller Lake). The channel typically holds water at an elevation of 858 MSL (the elevation of the weir crest downstream of Keller Lake).

E.2.2 Historical Water Quality

Figures E-10 through E-12 show the growing season means (June through August) of Gervais Lake's Total Phosphorus (TP), Chlorophyll *a* (Chla) and Secchi Disc (SD) measurements, respectively. Each column in each graph shows the number of readings (N) that resulted in the summer average.

The mean surface water concentrations of TP in Gervais Lake have ranged from 20 μg/L (in 1985) to 58 μg/L (in 1987) over the past 22 years, giving the lake a mesotrophic classification in some years and a eutrophic classification in others. The average lake TP concentration from 1981 to 2002 is 30 μg/L- equal to the District's preliminary TP goal for Gervais Lake (the goal is met).

The summer average Chla concentrations have ranged from 2.0 μg/L (in 1992) to 26.15 μg/L (in 1991) over the past 22 years, giving the lake a mesotrophic classification in some years and a eutrophic classification in others. The average Chla concentration from 1981 to 2002 is 15 μg/L, which is higher than the District's preliminary Chla goal for Gervais Lake (the goal is not met).

The summer average SD measurements have ranged from 9.8 ft (in 1994) to 2.8 (in 1991 and 1992) giving the lake a mesotrophic classification in some years and a eutrophic classification in others. The average SD concentration from 1981 to 2002 is 6.1 feet, which is higher than the District's preliminary SD goal for Gervais Lake (the goal is met).

Figure E-13 shows the relationship between SD and TP measurements taken throughout the year (1981-2002) in Gervais Lake. Compared to Kohlman Lake's SD-TP relationship (Figure E-6), there is less of an apparent trend in Gervais Lake's SD-TP relationship. However, lower TP concentrations tend to result in higher SD transparencies, as expected. This figure shows the typical timing of higher and lower lake TP concentrations throughout the year in Gervais Lake. Contrary to Kohlman Lake, Gervais Lake's lower TP concentrations are typically seen later in the summer months, while higher TP concentrations typically occur in the spring and the fall, conceivably when the lake turns over. This is a trend typically seen in deep, dimictic lakes that do not experience high internal loads of TP during the summer months.

Figure E-14 shows the historical TP concentrations relative to three different classifications- MNLEAP's range for "Minimally Impacted Lakes", the MPCA's TP threshold above which a lake is placed on the Impaired Waters List and Vighi and Chiaudani's TP Range for Pre-Settlement Watershed Conditions in the Gervais Lake subwatershed. These classifications are described in further detail in the main body of this SLMP (Impaired Waters List) or in Appendix A (MNLEAP and Vighi and Chiaudani's Pre-Settlement TP concentration).

As shown in this figure, Gervais Lake's water quality is, on average, well within the range of water quality in other lakes with a similar size, shape and ecoregion. Gervais Lake has been degraded since pre-settlement times due to anthropogenic inputs. Finally, the lake's summer average TP concentrations are low enough to keep the lake off of the MPCA's Impaired Waters List.

E.2.3 Trend Analyses of Total Phosphorus, Chlorophyll a and Secchi Disc Transparency Data

There was no statistically significant water quality trend that could be distinguished for Gervais Lake from 1981 to 2002.

E.3 Keller Lake

E.3.1 Overview of Keller Lake and Subwatershed

E.3.1.1 Description of Keller Lake

Keller Lake is a DNR-protected water (#62-0010) located in the city of Maplewood (Figure E-15). The lake has a surface area of 72 acres and a maximum depth of approximately 8 feet and a mean depth of 4 feet. Most of the lake is less than 6 feet deep, with the littoral area comprising 72 acres or 100% of the lake (DNR Lake Data). The watershed area in comparison to the lake area is relatively small (8:1).

Keller Lake is a fishing lake used lake primarily for motorboating, canoeing, fishing, picnicking, and viewing. Other recreational uses include limited wildlife habitat. According to the Plan, Keller Lake's designated Use Level is 2.

Keller Lake is polymictic; it mixes several times throughout the year. At times, this mixing can entrain TP that is released from the lake's sediments into the water column, making more Total Phosphorus (TP) available to algae.

E.3.1.2 Land Use

The existing land use in the Keller Lake subwatershed can be seen in Figure E-16. Development in the tributary subwatershed is essentially complete. The lake is surrounded by County parkland.

E.3.1.3 Drainage Systems Flowing into Lake

The Keller Lake tributary subwatershed is 1,407 acres (excluding the lake surface area and landlocked areas) and drains portions of the cities of Little Canada and Maplewood. Runoff enters the lake from storm sewer outfalls and culverts at various points along the lakeshore and from sheet flow running off the lake's immediate subwatershed.

The Keller Lake subwatershed can be described in terms of five different "drainage districts." A drainage district is described as a network of drainage areas that all drain to the same point before entering the lake.

Each Keller Lake drainage district is described below:

- **Keller Lake Main Drainage District—**This 802 -acre drainage district east and northeast of the lake represents almost 60% of the Keller Lake watershed. Runoff from this drainage district flows through a series of ponds, wetlands and/or storm sewer before reaching Keller Lake.

- **Keller Lake Spoon Lake Drainage District—**This 50-acre drainage district north of the lake includes the surface area for Spoon Lake, and represents a small portion of the Keller Lake subwatershed. Runoff from this drainage district flows through Spoon Lake before reaching Keller Lake.
- **Keller Lake West Drainage District**—This 140-acre drainage district west of the lake represents less than 10% of the Keller Lake subwatershed. Runoff from this drainage district flows through a series of detention ponds, and/or storm sewer before reaching Keller Lake.
- **Keller Lake Southwest Drainage District**—This 36-acre drainage district southwest of the lake represents less than 3% of the Keller Lake watershed. Runoff from this drainage district flows to a single pond located less than 50 feet from the lake. This pond does not have an outlet, so runoff from this drainage district reaches the lake when the pond overflows.
- **Keller Lake Direct Drainage District**—This 379-acre drainage district consists of the area that drains directly to Keller Lake without passing through a detention pond.

These drainage districts are shown in Appendix J of this SLMP.

E.3.1.4 Keller Lake Outlet

The outlet from Keller Lake is a channel that is connected to Phalen Lake. The channel typically holds water at an elevation of 858 MSL (the elevation of the weir crest downstream of Keller Lake).

E.3.2 Historical Water Quality

Figures E-17 through E-19 show the growing season means (June through August) of Keller Lake's Total Phosphorus (TP), Chlorophyll *a* (Chla) and Secchi Disk (SD) measurements, respectively. Each column in each graph shows the number of readings (N) that resulted in the summer average.

The mean surface water concentrations of TP in Keller Lake have ranged from 29 μg/L (in 2002) to 167μg/L (in 1982) over the past 22 years, giving the lake a hypereutrophic classification in some years and a eutrophic classification in others. The average lake TP concentration from 1981 to 2002 is 75 μg/L higher than the District's preliminary TP goal for Keller Lake (the goal is not met).

The summer average Chla concentrations have ranged from 12.71 μg/L (in 2002) to 71.58 μg/L (in 1999) over the past 22 years, giving the lake a hypereutrophic classification in some years and a eutrophic classification in others. The average Chla concentration from 1981 to 2002 is 33.5 μg/L, which is twice the District's preliminary Chla goal for Keller Lake (the goal is not met).

The summer average SD measurements have ranged from 5.4 ft (in 1999) to 1.1 (in 1982) giving the lake a hypereutrophic classification in some years and a eutrophic classification in others. The average SD concentration from 1981 to 2002 is 2.7 feet, which is lower than the District's preliminary SD goal for Keller Lake (the goal is not met).

Figure E-20 shows the relationship between SD and TP measurements taken throughout the year (1981-2002) in Keller Lake. Similar to Kohlman Lake, at lower TP concentrations (less than 60 μg/L), changes in the Keller Lake's TP result in significant changes in the lake's transparency. At higher TP concentrations, changes in lake TP result in relatively smaller changes in the lake's transparency. This figure also shows the typical timing of higher and lower lake TP concentrations throughout the year in Keller Lake. Lower TP concentrations are typically seen in the late spring and early summer, while higher TP concentrations typically occur later in the summer months.

Figure E-21 shows the historical TP concentrations relative to three different classifications- MNLEAP's range for "Minimally Impacted Lakes", the MPCA's TP threshold above which a lake is placed on the Impaired Waters List and Vighi and Chiaudani's TP Range for Pre-Settlement Watershed Conditions in the Keller Lake subwatershed. These classifications are described in further detail in the main body of this SLMP (Impaired Waters List) or in Appendix A (MNLEAP and Vighi and Chiaudani's Pre-Settlement TP concentration).

As shown in this figure, Keller Lake's water quality is, on average, well within the range of water quality in other lakes with a similar size, shape and ecoregion. Keller Lake has clearly been degraded since pre-settlement times due to anthropogenic inputs. Finally, the lake's high summer average TP concentrations have easily placed Keller Lake on the MPCA's Impaired Waters List.

E.3.3 Trend Analyses of Total Phosphorus, Chlorophyll a and Secchi Disc Transparency Data

Trend analyses of Keller Lake's historical water quality data indicate a statistically significant, slight trend towards improved water quality. However, this trend results in very small gains over time (-3 μg/L/year TP, 0.12 ft/year SD, 0.8 μg/L/year Chla) and cannot be relied upon to produce noticeable improvements in Keller Lake in the near future.

E.4 Phalen Lake

E.4.1 Overview of Phalen Lake and Subwatershed

E.4.1.1 Description of Phalen Lake

Lake Phalen is a DNR-protected water (#62-0013) located in the cities of Maplewood and St. Paul (Figure E-22). The lake has a surface of 200 acres, a maximum depth of approximately 95 feet and mean depth of approximately 22 feet. The littoral area comprises approximately 80 acres or 40% of the lake (DNR Lake Data). The watershed area in comparison to the lake area is relatively small (12:1).

Lake Phalen is a recreational lake used lake primarily for swimming, fishing, picnicking and viewing. The lake has public boating access and a swimming beach. According to the Plan, Lake Phalen's designated Use Level is 1.

Lake Phalen is dimictic; it generally only mixes twice a year- once in the spring and once in the fall. Although TP is at times released from the lake's sediments, this TP is generally not mixed throughout the water column during summer months and is not made available to algae in the surface waters.

E.4.1.2 Land Use

The existing land use in the Keller Lake watershed can be seen in Figure E-23. Development in the tributary subwatershed is essentially complete. The lake is surrounded by County parkland.

E.4.1.3 Drainage Systems Flowing into Lake

The Lake Phalen subwatershed is 2,418 acres (excluding the lake surface area and landlocked areas) and drains portions of the cities of Maplewood and St. Paul. Runoff enters the lake from storm sewer outfalls and culverts at various points along the lakeshore and from sheet flow running off the lake's immediate subwatershed.

The Lake Phalen subwatershed can be described in terms of six different "drainage districts." A drainage district is described as a network of drainage areas that all drain to the same point before entering the lake.

Each Lake Phalen drainage district is described below:

- **Lake Phalen Main Drainage District—**This 1,058 -acre drainage district northeast of the lake represents just less than half of the Lake Phalen subwatershed. Runoff from this drainage district flows through a series of ponds and wetlands, including Wakefield Lake, and storm sewers before reaching Lake Phalen.

- **Lake Phalen Round Lake Drainage District—**This 242-acre drainage district northwest of the lake includes the surface area for Round Lake, and represents about 10% of the Lake Phalen subwatershed. Runoff from this drainage district flows through Round Lake before reaching the Lake Phalen via two different channels- one on the northeast side of Round Lake, and one south of Round Lake, east of the Phalen pavilion.
- **Lake Phalen North Drainage District—**This 369-acre drainage district north of the lake represents about 15% of the Lake Phalen subwatershed. Runoff from this drainage district flows through a series of ponds and wetlands before reaching Lake Phalen.
- **Lake Phalen East Drainage District—**This 202-acre drainage district east of the lake represents less than 10% of the Lake Phalen subwatershed. Runoff from this drainage district flows through a single, small retention pond before reaching Lake Phalen.
- **Lake Phalen West Drainage District—**This 106-acre drainage district west of the lake represents less than 4 percent of the Lake Phalen subwatershed. Runoff from this drainage district flows through retention ponds in the Lake Phalen Regional Golf Course before reaching Lake Phalen.
- **Lake Phalen Direct Drainage District**—This 441-acre drainage district consists of the area that drains directly to Lake Phalen without passing through a detention pond.

These drainage districts are shown in Appendix J of this SLMP.

E.4.1.4 Phalen Lake Outlet

Lake Phalen has two main outlets (one on the southeast side and one on the southwest side) that are designed to keep the lake at an elevation of 857.5 MSL. The outlets are designed so that if the lake bounces higher during storm events, it is quickly drawn back down to 857.5 MSL.

E.4.2 Historical Water Quality

Figures E-24 through E-26 show the growing season means (June through August) of Lake Phalen's Total Phosphorus (TP), Chlorophyll *a* (Chla) and Secchi Disk (SD) measurements, respectively. Each column in each graph shows the number of readings (N) that resulted in the summer average.

The mean surface water concentrations of TP in Lake Phalen have ranged from 17 μg/L (in 1998) to 46 μg/L (in 1984) over the past 22 years, giving the lake a mesotrophic classification in some years and a eutrophic classification in others. The average lake TP concentration from 1981 to 2002 is 28 μg/L- lower than the District's preliminary TP goal for Lake Phalen (the goal is met).

The summer average Chla concentrations have ranged from 2.4 μg/L (in 1989) to 14.9 μg/L (in 1991) over the past 22 years, giving the lake a mesotrophic classification in some years and a eutrophic classification in others. The average Chla concentration from 1981 to 2002 is 8.3 μg/L, which is lower than the District's preliminary Chla goal for Lake Phalen (the goal is met).

The summer average SD measurements have ranged from 12.93 ft (in 1996) to 3.28 (in 1992) over the past 22 years, giving the lake a mesotrophic classification in some years and a eutrophic classification in others. The average SD concentration from 1981 to 2002 is 8.3 feet, which is higher than the District's preliminary SD goal for Lake Phalen (the goal is met).

Figure E-27 shows the relationship between SD and TP measurements taken throughout the year (1981-2002) in Lake Phalen. Compared to Kohlman Lake's SD-TP relationship (Figure E-6), there is less of an apparent trend in Lake Phalen's SD-TP relationship. However, lower TP concentrations tend to result in higher SD transparencies, as expected. This figure shows the typical timing of higher and lower lake TP concentrations throughout the year in Lake Phalen. Contrary to Kohlman and Keller Lakes, Lake Phalen's lower TP concentrations are typically seen later in the summer months, while higher TP concentrations typically occur in the spring and the fall, conceivably when the lake turns over. This is a trend typically seen in deep, dimictic lakes that do not experience high internal loads of TP during the summer months.

Figure E-28 shows the historical TP concentrations relative to three different classifications- MNLEAP's range for "Minimally Impacted Lakes", the MPCA's TP threshold above which a lake is placed on the Impaired Waters List and Vighi and Chiaudani's TP Range for Pre-Settlement Watershed Conditions in the Lake Phalen subwatershed. These classifications are described in further detail in the main body of this SLMP (Impaired Waters List) or in Appendix A (MNLEAP and Vighi and Chiaudani's Pre-Settlement TP concentration).

As shown in this figure, Lake Phalen's water quality is, on average, well within the range of water quality in other lakes with a similar size, shape and ecoregion. Lake Phalen has been degraded since pre-settlement times due to anthropogenic inputs. Finally, the lake's summer average TP concentrations are low enough to keep the lake off of the MPCA's Impaired Waters List.

E.4.3 Trend Analyses of Total Phosphorus, Chlorophyll a and Secchi Disc Transparency Data

There was no statistically significant water quality trend that could be distinguished for Lake Phalen from 1981 to 2002.

E.5 Other Lakes in the Phalen Chain Tributary Watershed

Five other lakes that exist within the Phalen Chain tributary subwatershed are briefly described below. These five lakes do not represent all of the smaller lakes within the Phalen Chain subwatershed. However, these are the only other lakes that have Strategic Lake Management Plan recommendations shown in the District's Plan.

E.5.1 Round Lake (M)

Round Lake (M) is located in Maplewood, connecting to Lake Phalen on both the northwest and west sides of Lake Phalen. The lake's DNR number is 62-0012. The lake has a total surface area of 30 acres, and a maximum depth of 8 feet.

According to the Minnesota Pollution Control Agency's (MPCA's) lake water quality data summary (available on www.pca.state.mn.us), the lake's mean total phosphorus concentration (averaged over many different years) is 81 μg/L. The lake's mean chlorophyll a concentration is 20 μg/L. The lake's mean Secchi Disk measurement is 1.7 meters. These measurements define Round Lake as eutrophic.

The preliminary water quality goals set forth in the District's Plan for Round Lake are as follows:

- TP = 60 μg/L
- Chlorophyll a = 32 μg/L
- Secchi Disk = 2.6 feet

Round Lake currently does not meet the preliminary TP goal set forth for the lake in the District's Plan.

According to the District's Plan, Round Lake is primarily used for canoeing, picnicking, wildlife habitat and aesthetic viewing.

E.5.2 Twin Lakes

Twin Lake is located in Little Canada, just northeast of Owasso Basin. The lake's DNR number is 62-0039. The lake has a total surface area of 35.5 acres, and a maximum depth of 33 feet.

Although no in-lake water quality monitoring has been conducted on Twin Lake since 1991, more current satellite imagery indicates that the lake's transparency depth is between 3 and 6 feet (according to Minnesota Lake Browser information acquired between 1999 and 2001- available on www.dnr.state.mn.us.)

The preliminary water quality goals set forth in the District's Plan for Twin Lake are as follows:

- TP = 45-75 μg/L
- Chlorophyll a = 20-40 μg/L
- Secchi Disk = 2-3 feet

Twin Lake currently meets the preliminary water quality goals (at least in terms of Secchi Disk transparency) set forth for the lake in the District's Plan.

According to the District's Plan, Twin Lake is primarily used for canoeing, wildlife habitat, viewing, occasional jet skiing and fishing (to a low degree). There is currently no public access to the lake.

E.5.3 Willow Lake

Willow Lake is located in Vadnais Heights, north of Highway 694 and west of Highway 61. The lake's DNR number is 62-0040. The lake has a total surface area of 75 acres, and a maximum depth of 5 feet.

According to the MPCA's lake water quality data summary (available on www.pca.state.mn.us), the lake's mean total phosphorus concentration (averaged over many different years) is 80 μg/L. The lake's mean chlorophyll a concentration is 7 μg/L. The lake's mean Secchi Disk measurement is 1.3 meters. These measurements define Willow Lake as eutrophic.

The preliminary water quality goals set forth in the District's Plan for Willow Lake are as follows:

- TP = 60 μg/L
- Chlorophyll a = 32 μg/L
- Secchi Disk = 2.6 feet

Willow Lake currently does not meet the preliminary TP goal set forth for the lake in the District's Plan.

According to the District's Plan, Willow Lake is primarily used for private corporation uses only, such as: canoeing, fishing, wildlife habitat, aesthetic viewing, and picnicking.

E.5.4 Round Lake (LC)

Round Lake (LC) is located in Little Canada, south of Little Canada Road and east of North Rice Street. The lake's DNR number is 62-0009. The lake has a total surface area of 12 acres.

The MPCA's Citizen Lake Monitoring Program information (available on www.pca.state.mn.us) shows that Round Lake had a Secchi Disk depth of 1.7 feet in 1995 and of 2.0 feet in 1996. Also, satellite imagery indicates that the lake's transparency depth is less than 1.5 feet (according to Minnesota Lake Browser information acquired between 1999 and 2001 - available on www.dnr.state.mn.us.) These measurements define Round Lake as eutrophic.

The preliminary water quality goals set forth in the District's Plan for Round Lake are as follows:

- TP = 45-75 μg/L
- Chlorophyll a = 20-40 μg/L
- Secchi Disk = 2-3 feet

Round Lake currently does not meet the preliminary water quality goals (at least in terms of Secchi Disk transparency) set forth for the lake in the District's Plan.

According to the District's Plan, Round Lake is primarily used for canoeing, picnicking and aesthetic viewing, although swimming is also desired.

E.5.5 Wakefield Lake

Wakefield Lake is located in Maplewood, just north of East Larpenteur Avenue and west of Prosperity Road. The lake's DNR number is 62-0011. The lake has a total surface area of 23 acres.

According to the MPCA's lake water quality data summary (available on www.pca.state.mn.us), the lake's mean total phosphorus concentration (averaged over many different years) is 112 μg/L. The lake's mean chlorophyll a concentration is 34 μg/L. The lake's mean Secchi Disk measurement is 1.1 meters. These measurements define Round Lake as hypereutrophic.

The preliminary water quality goals set forth in the District's Plan for Wakefield Lake are as follows:

- TP = 60 μg/L
- Chlorophyll a = 32 μg/L
- Secchi Disk = 2.6 feet

Wakefield Lake currently does not meet either the preliminary TP or chlorophyll a goals set forth for the lake in the District's Plan.

According to the District's Plan, Wakefield Lake is primarily used for aesthetic viewing, wildlife habitat and picnicking.

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NOTE: Bathymetry depth in feet.

300 0 300 600 900 1200

Scale in Feet

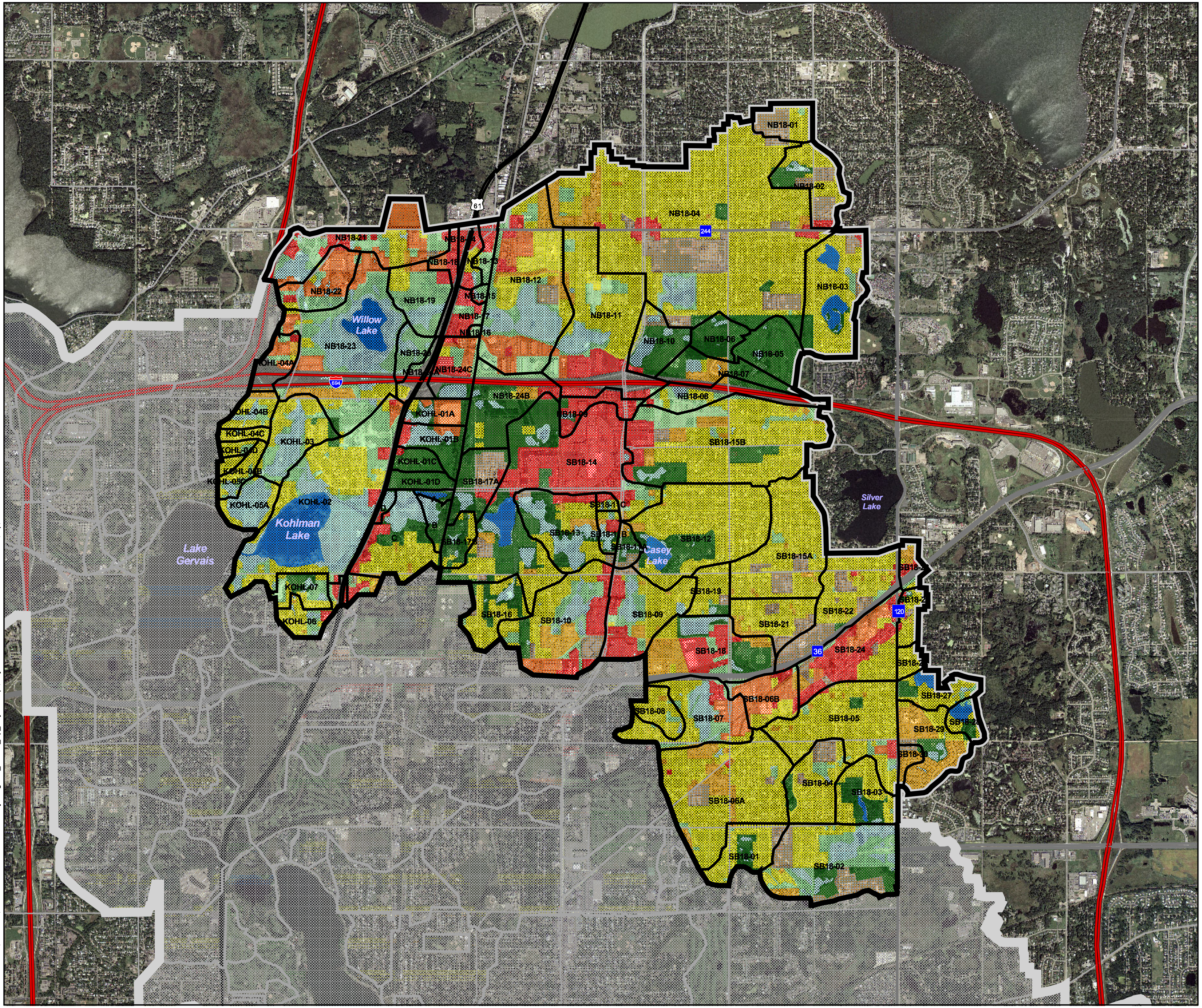
Figure E-1

KOHLMAN LAKE:
BATHYMETRY

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

Landuse
- Natural/Park/Open
- Developed Parkland
- Golf Course
- Agricultural
- Very Low Density Residential
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Institutional
- Institutional - High Imperviousness
- Airport
- Highway
- Commercial
- Industrial/Office
- Other
- Open Water
- Wetland
- No Data

- Kohlman Lake Subwatershed
- Kohlman Lake Drainage Areas
- RWMWD Boundary
- Other Watersheds within RWMWD

1500 0 1500 3000 4500

Scale in Feet

Figure E-2

KOHLMAN LAKE SUBWATERSHED:
EXISTING LAND USE

Phalen Chain of Lales SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

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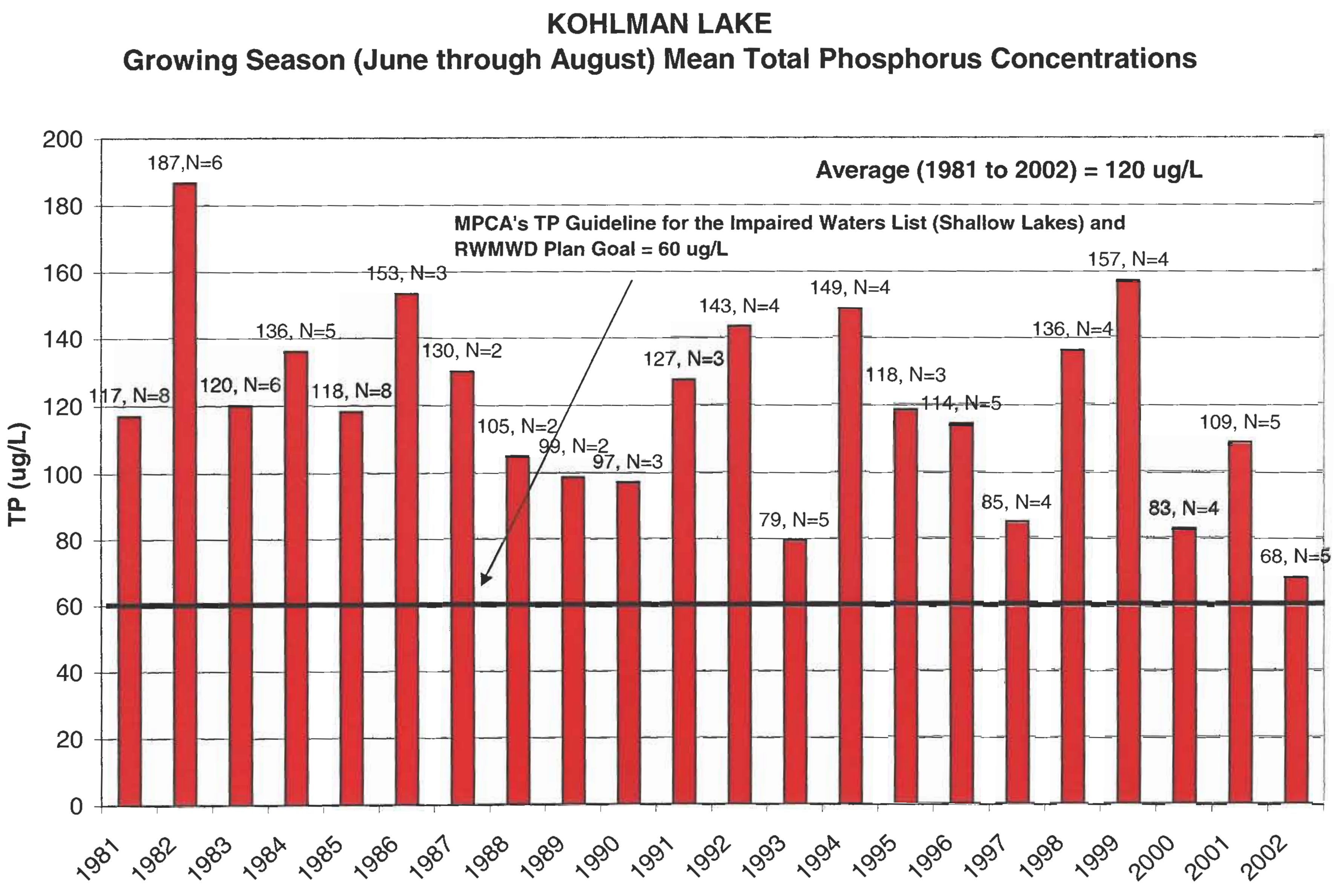

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Figure E-3

KOHLMAN LAKE
Growing Season (June through August) Mean Total Chlorophyll a Concentrations

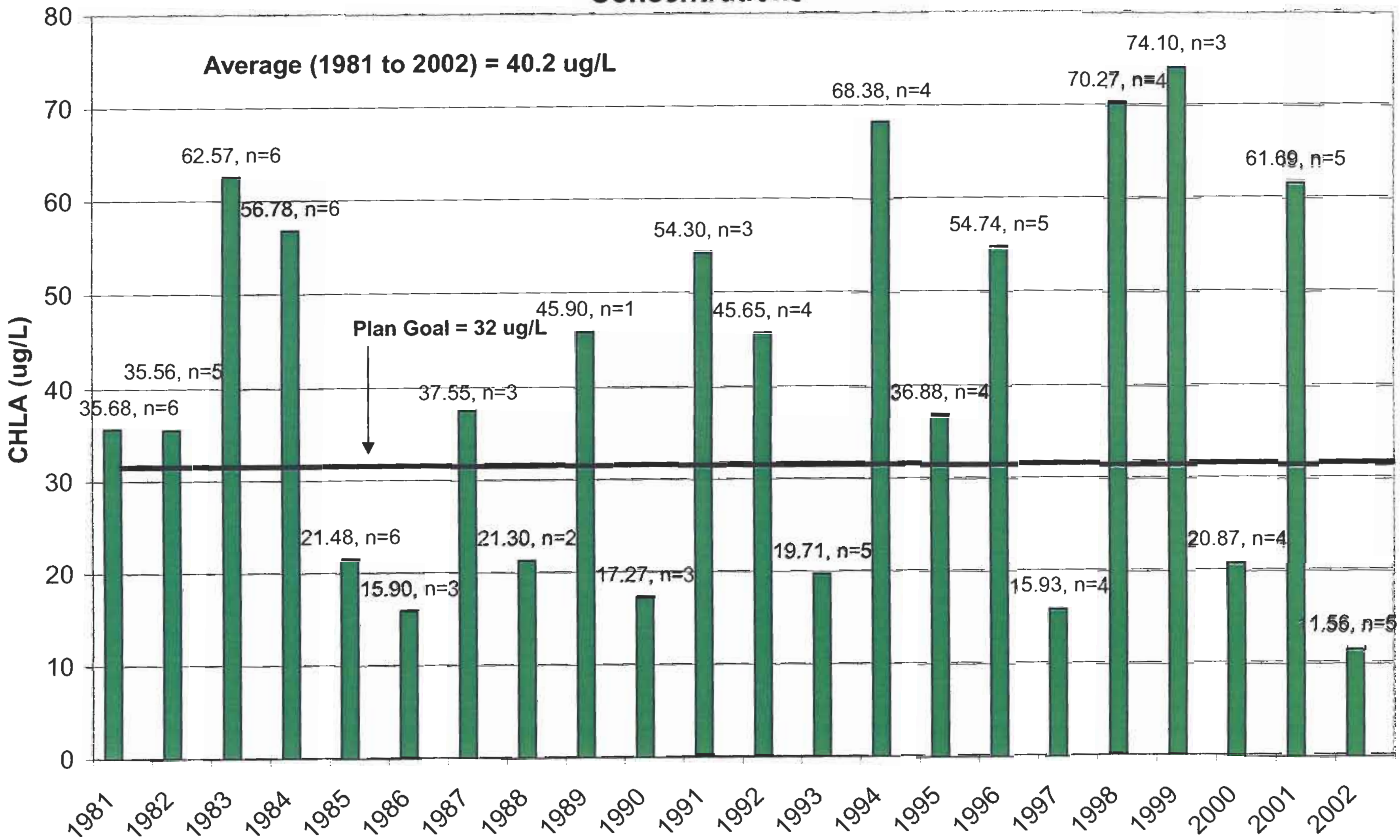

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Figure E-4

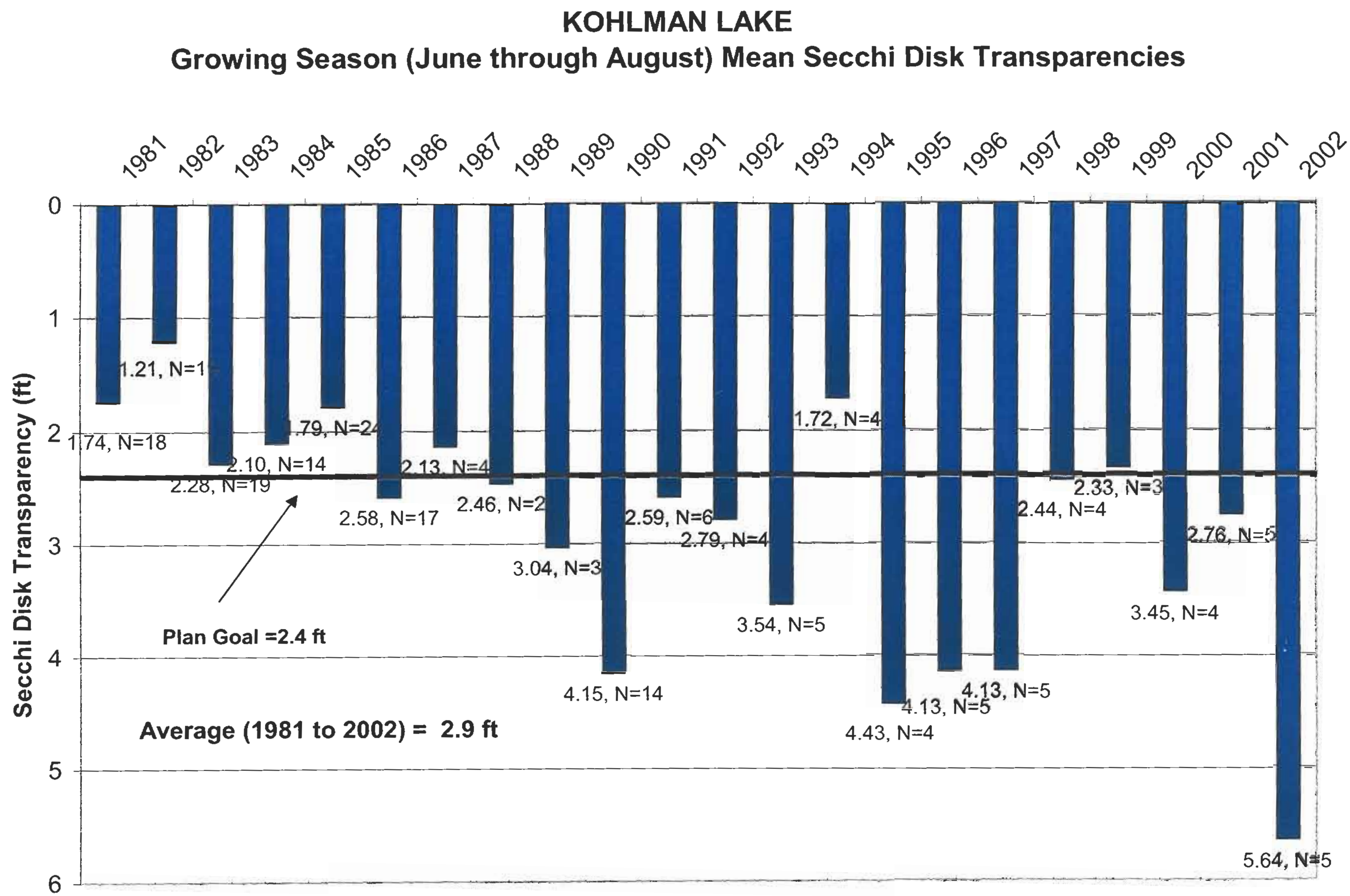

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Figure E-5

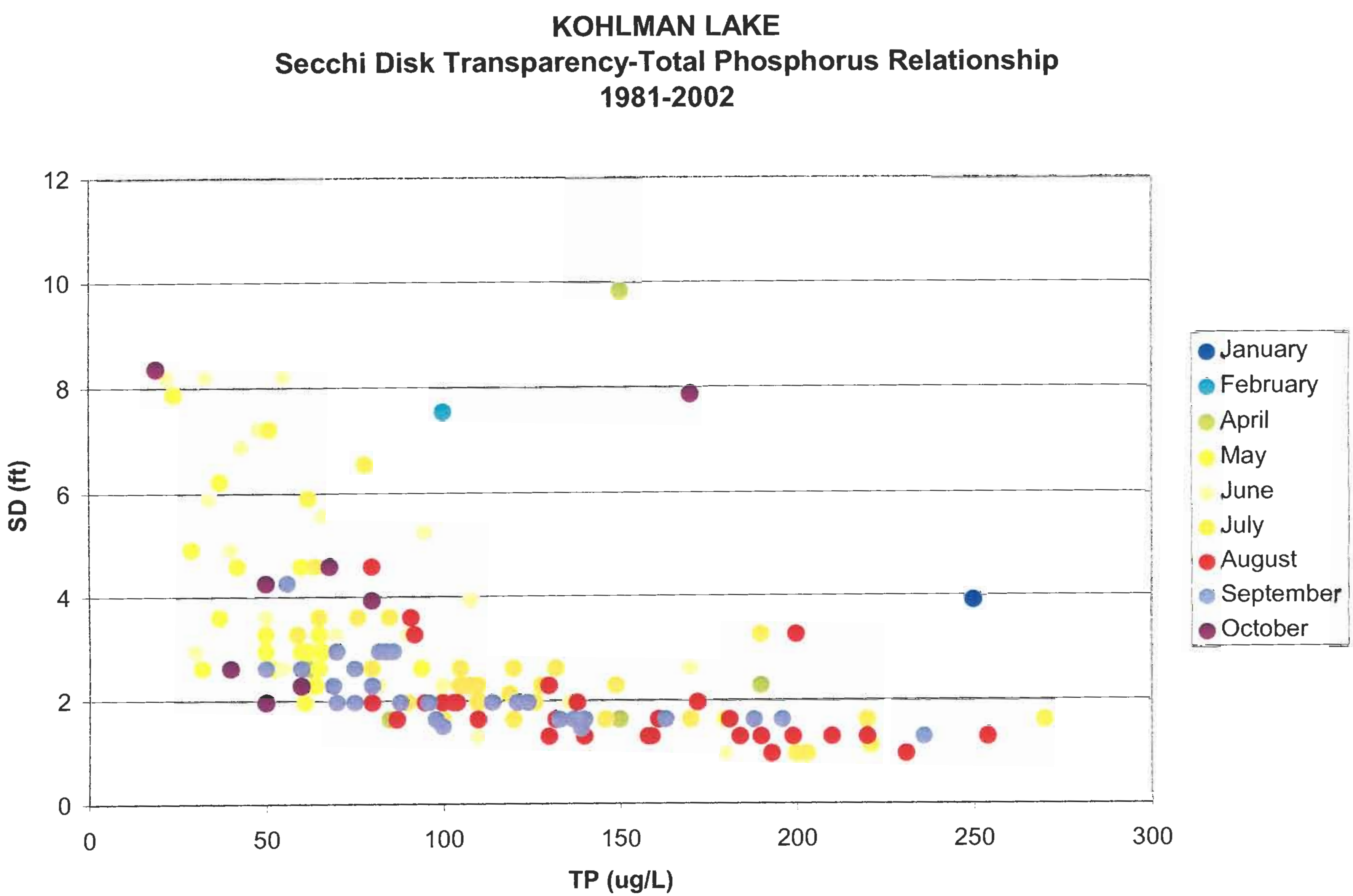

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Figure E-6

KOHLMAN LAKE
Growing Season (June through August) Mean Total Phosphorus Concentrations

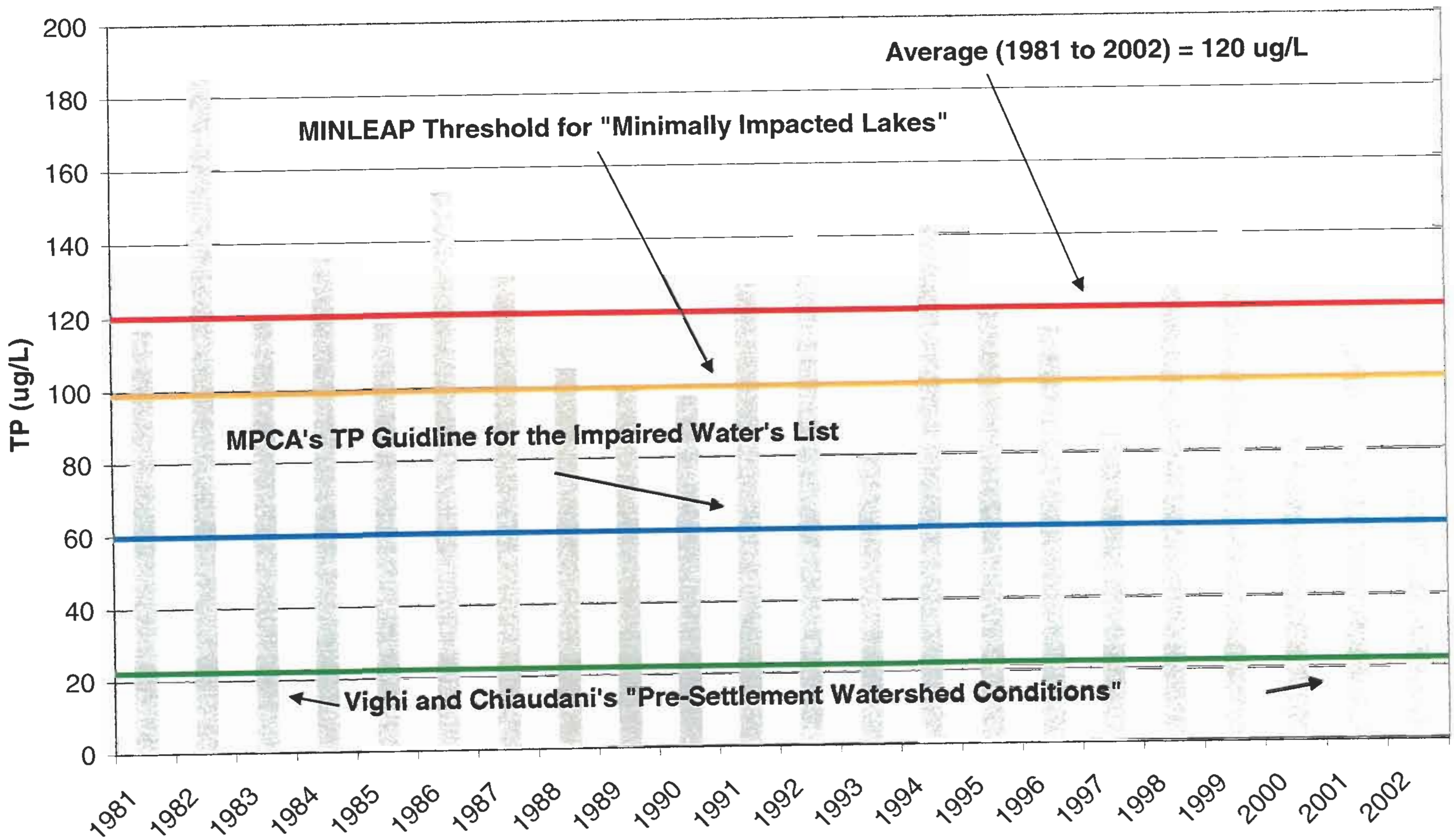

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Figure E-7

NOTE: Bathymetry depth in feet.

300 0 300 600 900 1200

Scale in Feet

Figure E-8

GERVAIS LAKE:
BATHYMETRY

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

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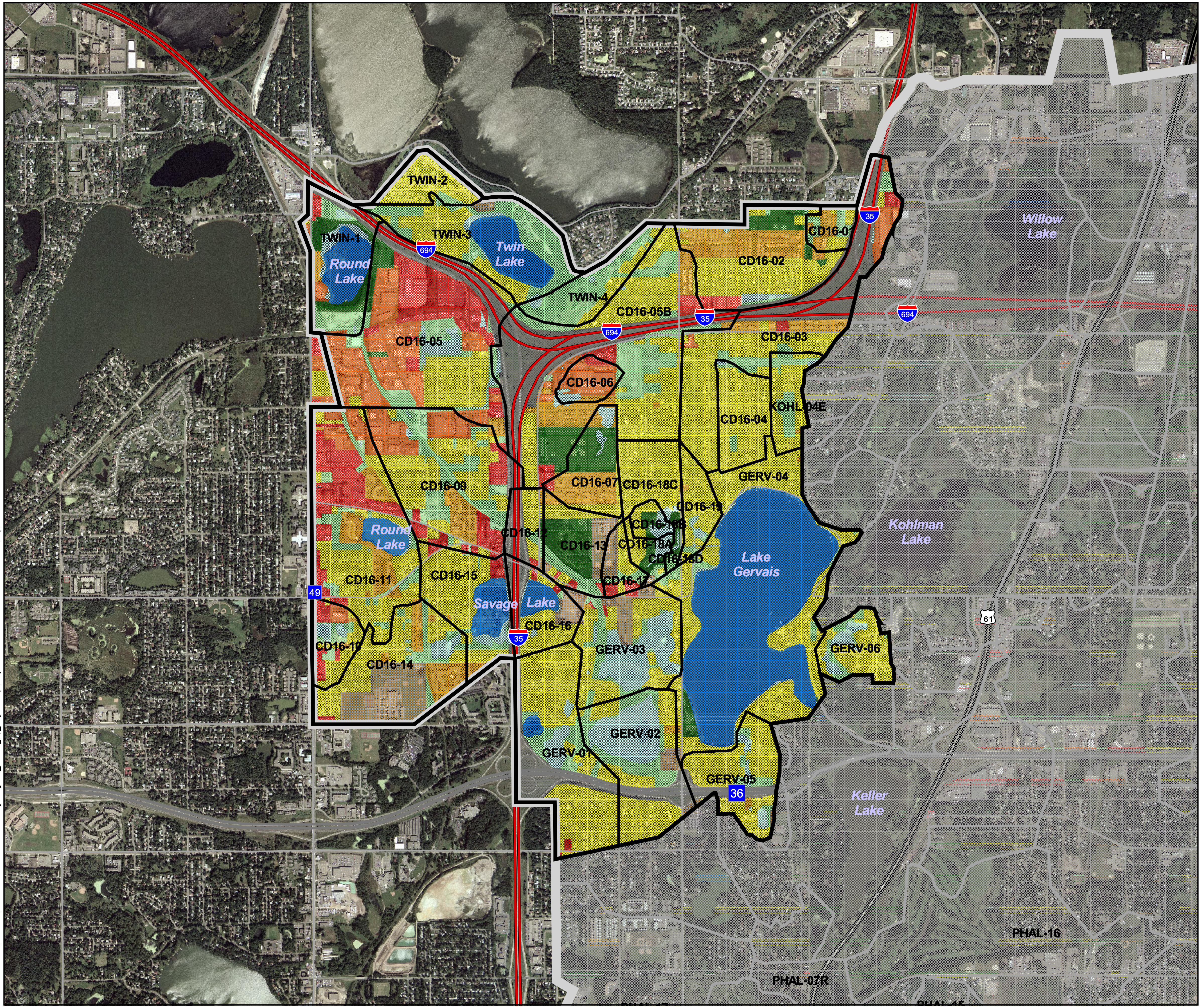

Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_eseries_lkp_may2004.apr, Layout: E-09 - Gervais Lake Exist Land Use , lkp, Wed Jul 20 13:48:50 2005

LEGEND

Landuse
- Natural/Park/Open
- Developed Parkland
- Golf Course
- Agricultural
- Very Low Density Residential
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Institutional
- Institutional - High Imperviousness
- Airport
- Highway
- Commercial
- Industrial/Office
- Other
- Open Water
- Wetland
- No Data

- Gervais Lake Subwatershed
- Gervais Lake Drainage Areas
- RWMWD Boundary
- Other Watersheds within RWMWD

1000 0 1000 2000 3000

Scale in Feet

Figure E-9

GERVAIS LAKE SUBWATERSHED:
EXISTING LAND USE

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

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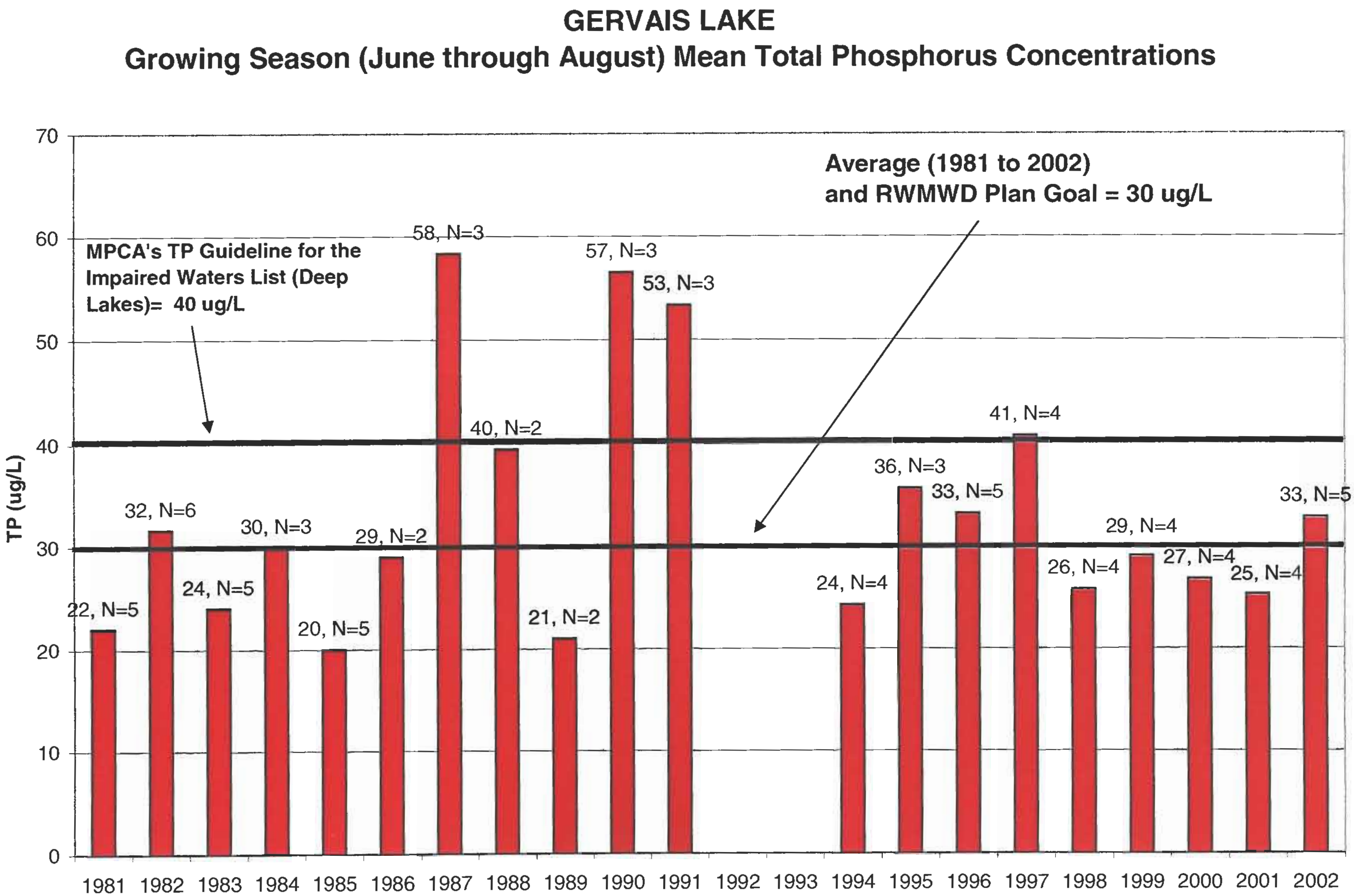

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Figure E-10

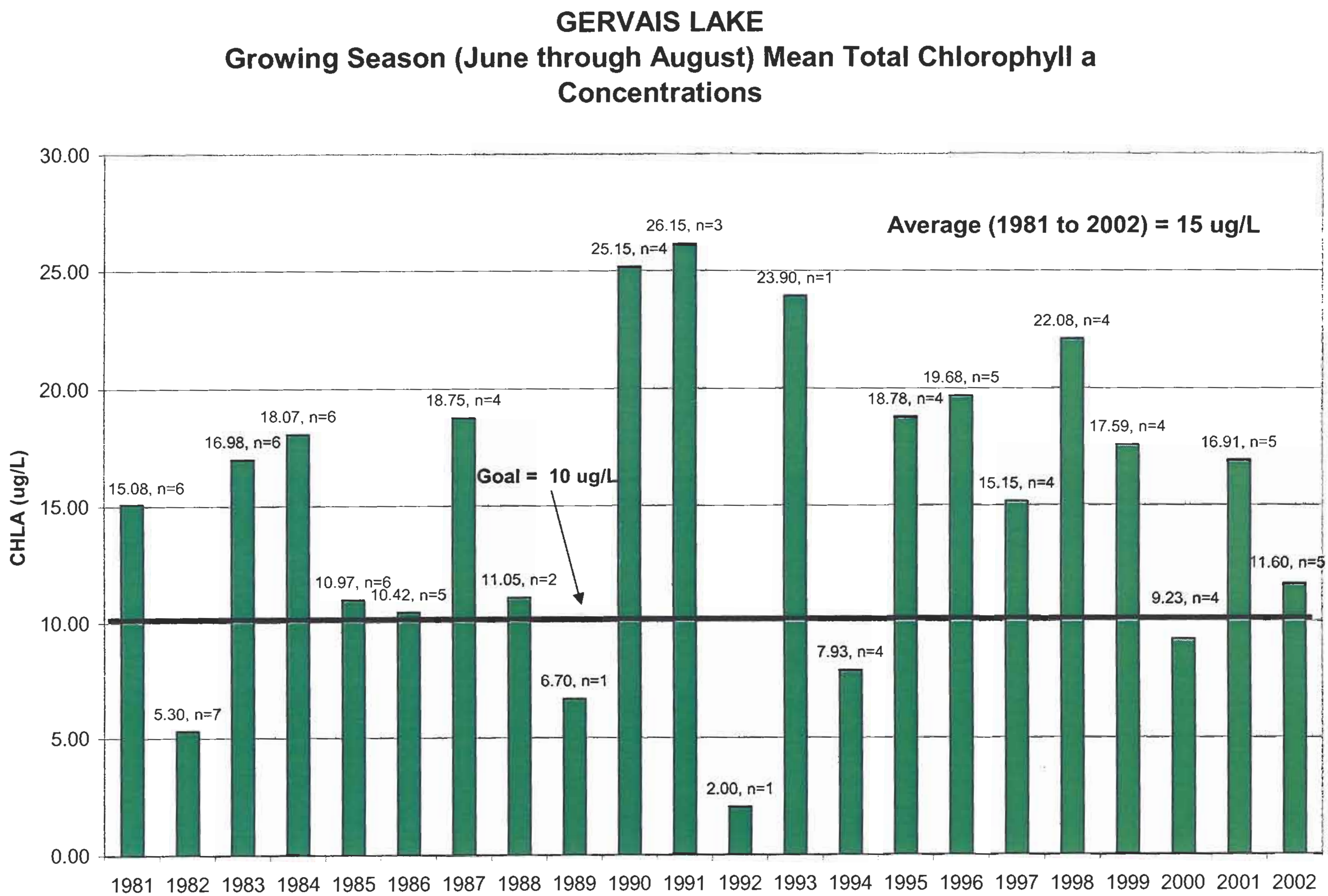

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Figure E-11

GERVAIS LAKE
Growing Season (June through August) Mean Secchi Disk Transparencies

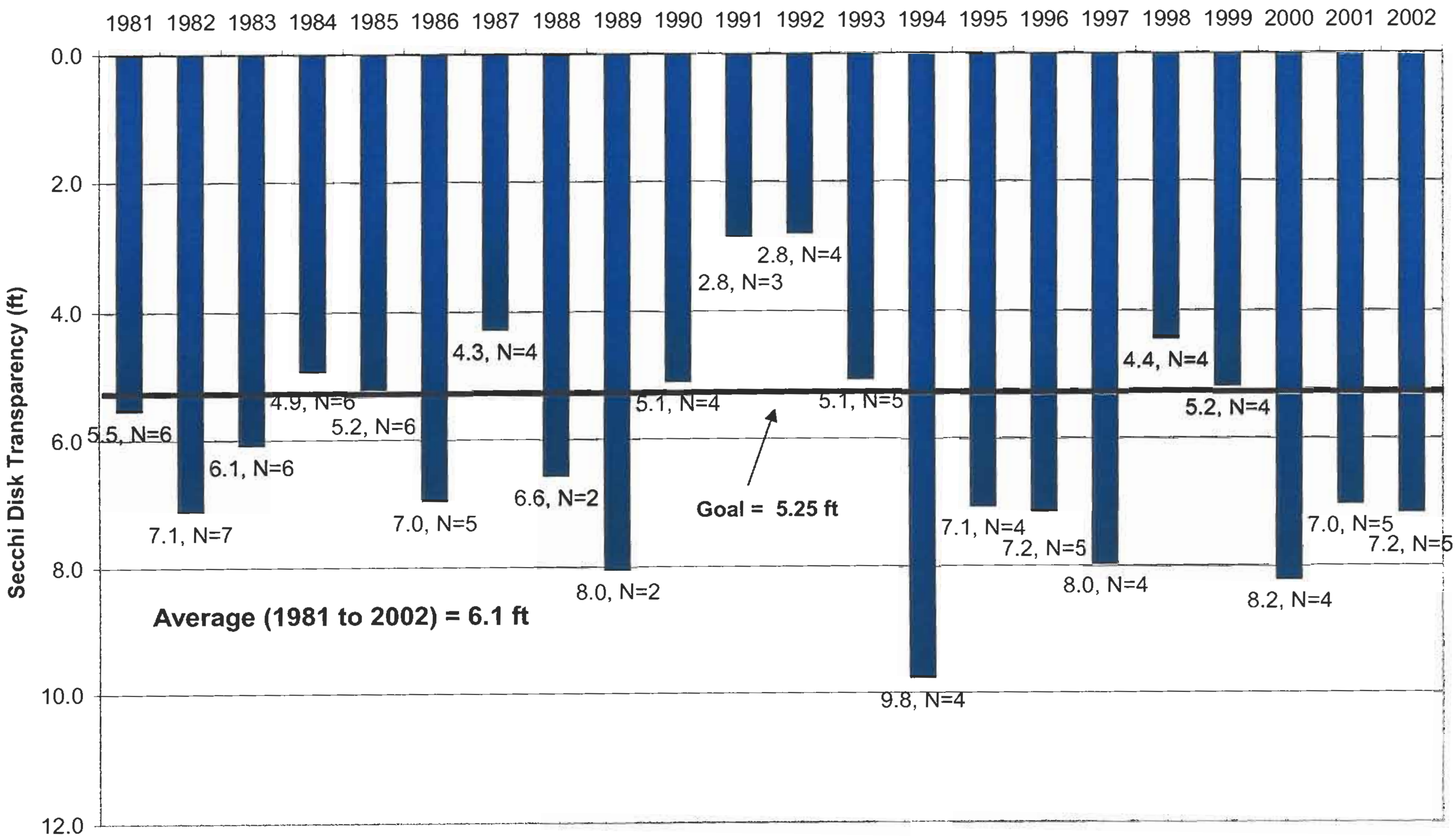

Figure E-12

GERVAIS LAKE
Secchi Disk Transparency-Total Phosphorus Relationship

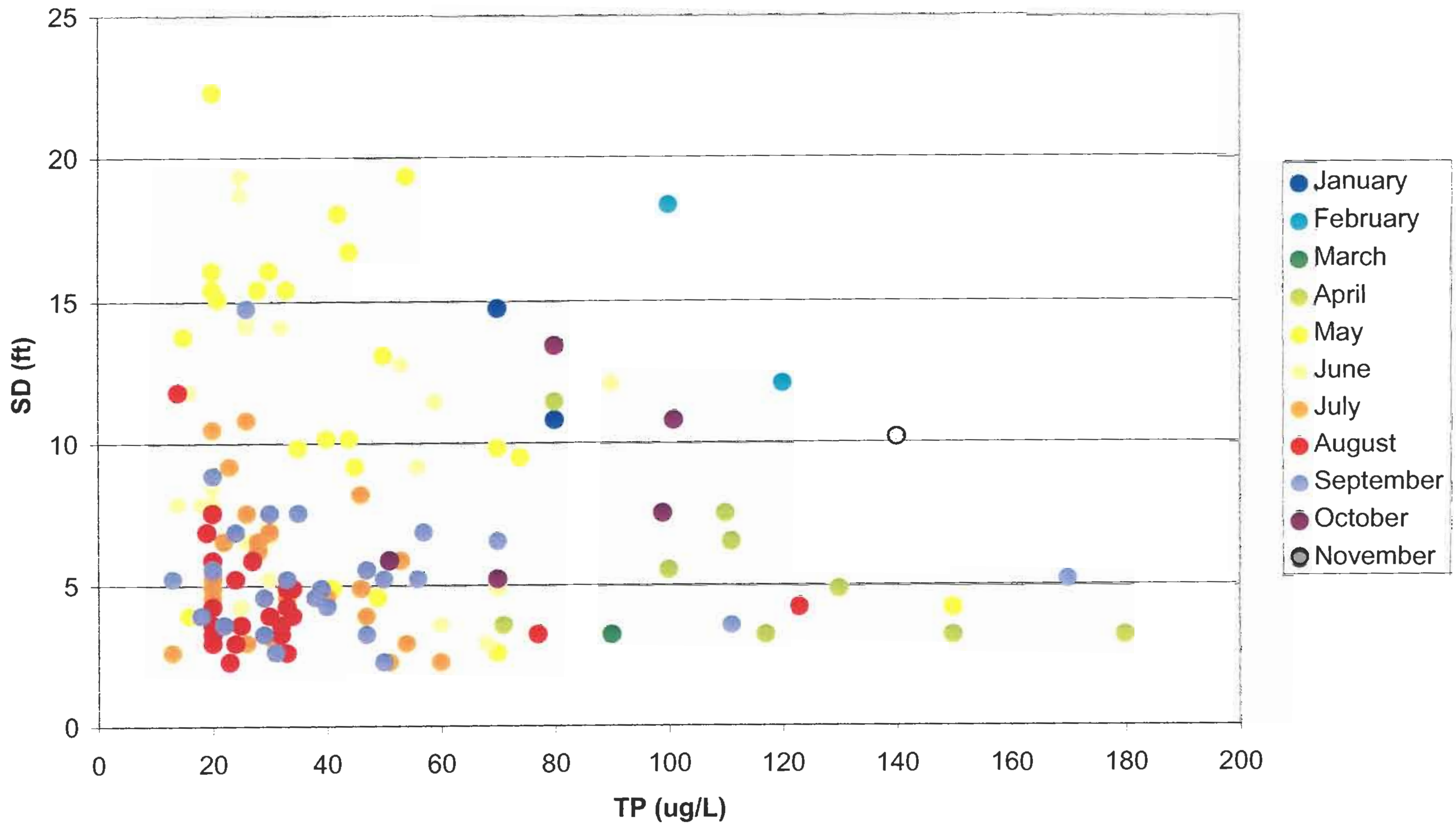

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Figure E-13

GERVAIS LAKE
Growing Season (June through August) Mean Total Phosphorus Concentrations

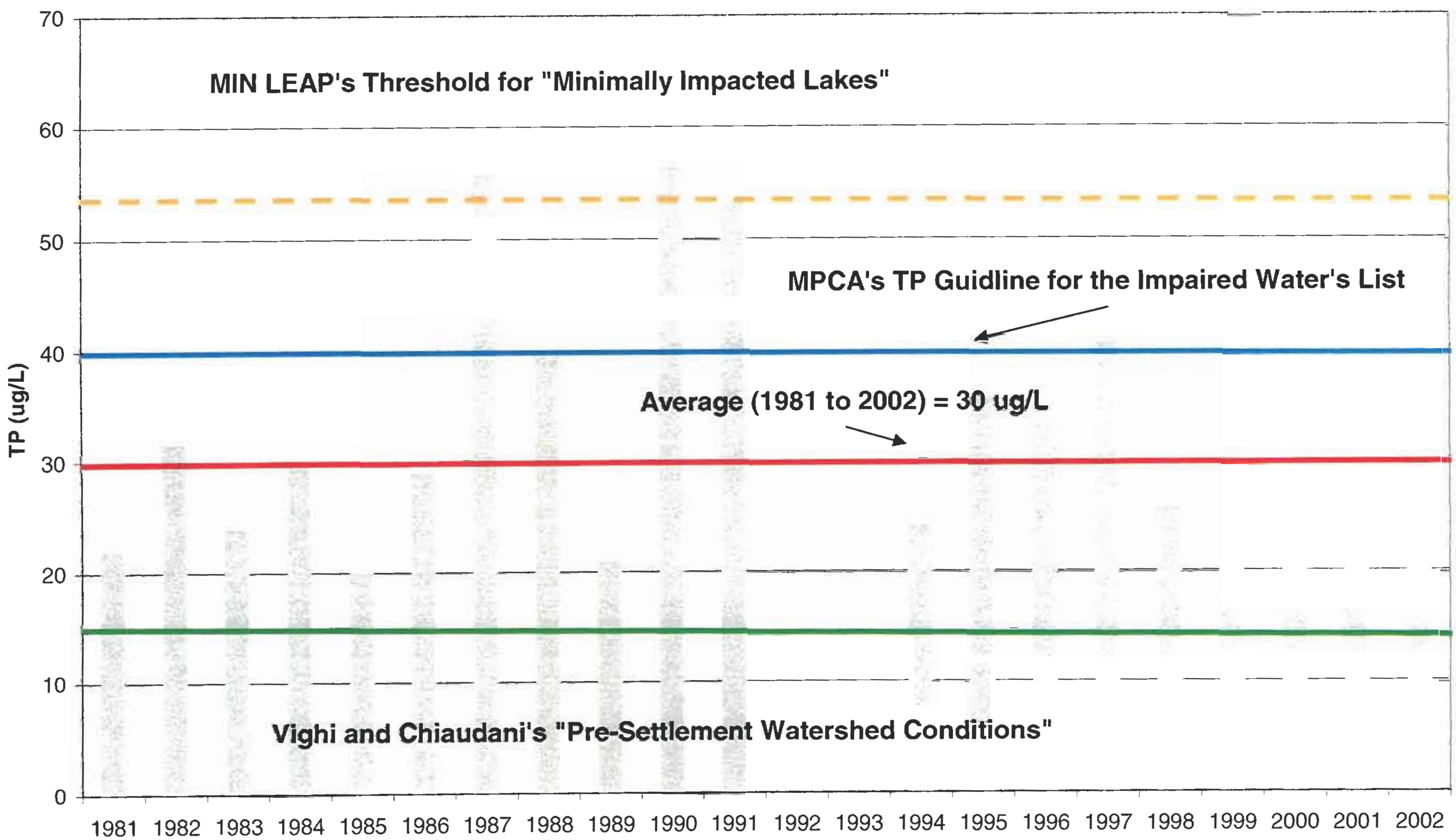


Figure E-14

NOTE: Bathymetry depth in feet.

300 0 300 600 900 1200

Scale in Feet

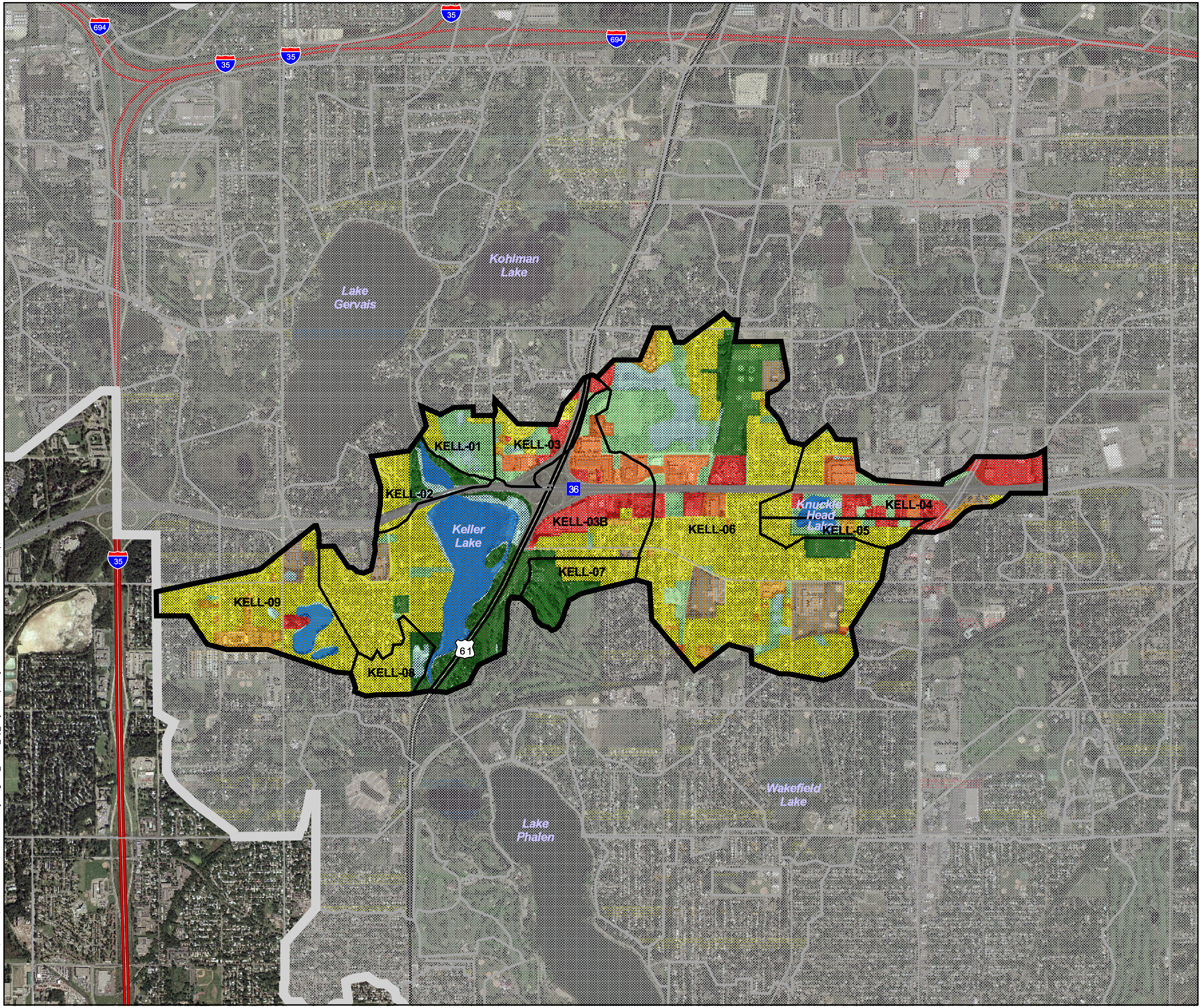
Figure E-15

KELLER LAKE:
BATHYMETRY

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

Landuse
- Natural/Park/Open
- Developed Parkland
- Golf Course
- Agricultural
- Very Low Density Residential
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Institutional
- Institutional - High Imperviousness
- Airport
- Highway
- Commercial
- Industrial/Office
- Other
- Open Water
- Wetland
- No Data

- Keller Lake Subwatershed
- Keller Lake Drainage Areas
- RWMWD Boundary
- Other Watersheds within RWMWD

1000 0 1000 2000 3000

Scale in Feet

Figure E-16

KELLER LAKE SUBWATERSHED:
EXISTING LAND USE

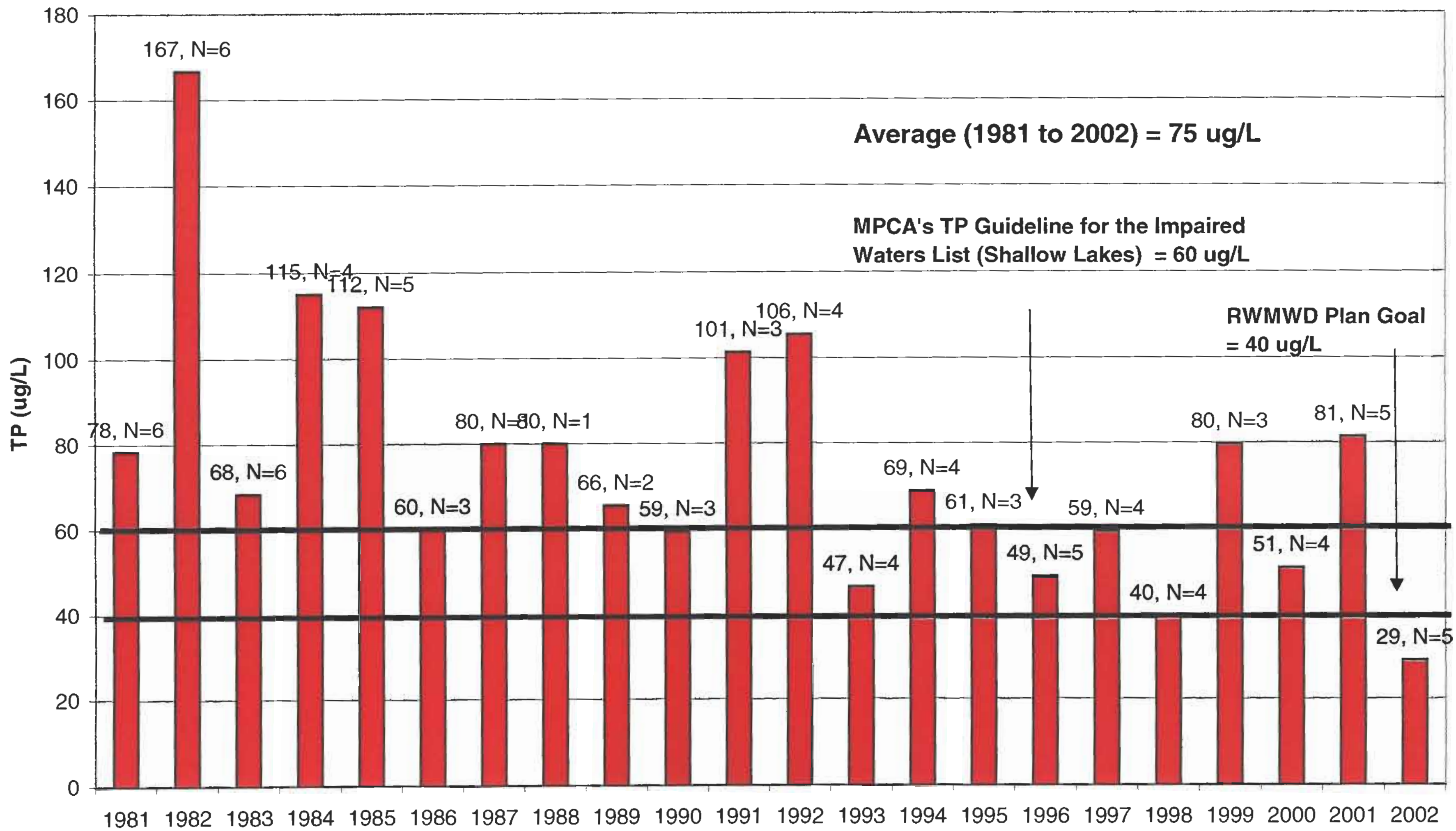
Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

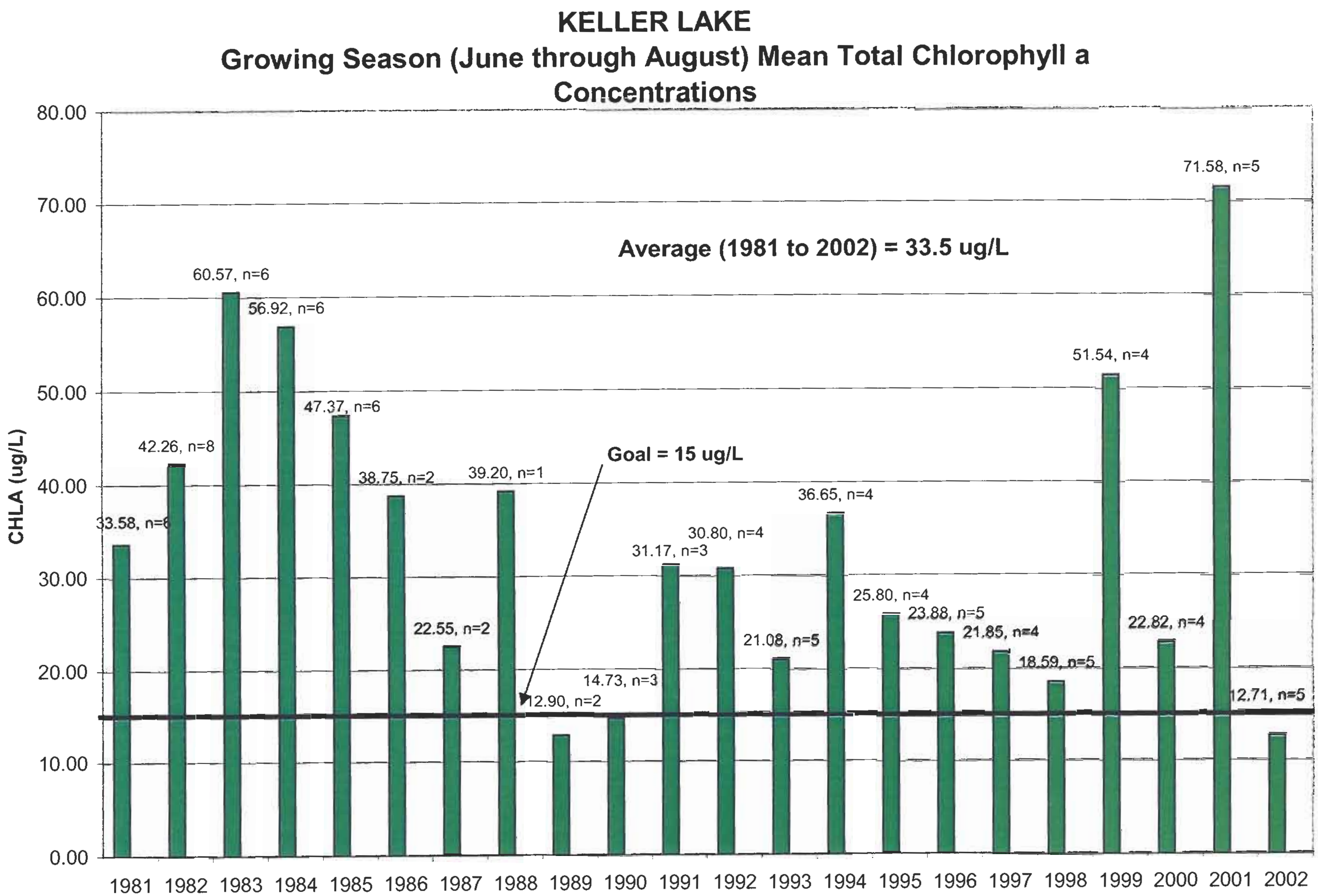
Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_eseries_lkp_may2004.apr, Layout: E-16 - Keller Lk Exist Land Use, lkp, Thu Jul 21 14:45:21 2005

KELLER LAKE
Growing Season (June through August) Mean Total Phosphorus Concentrations



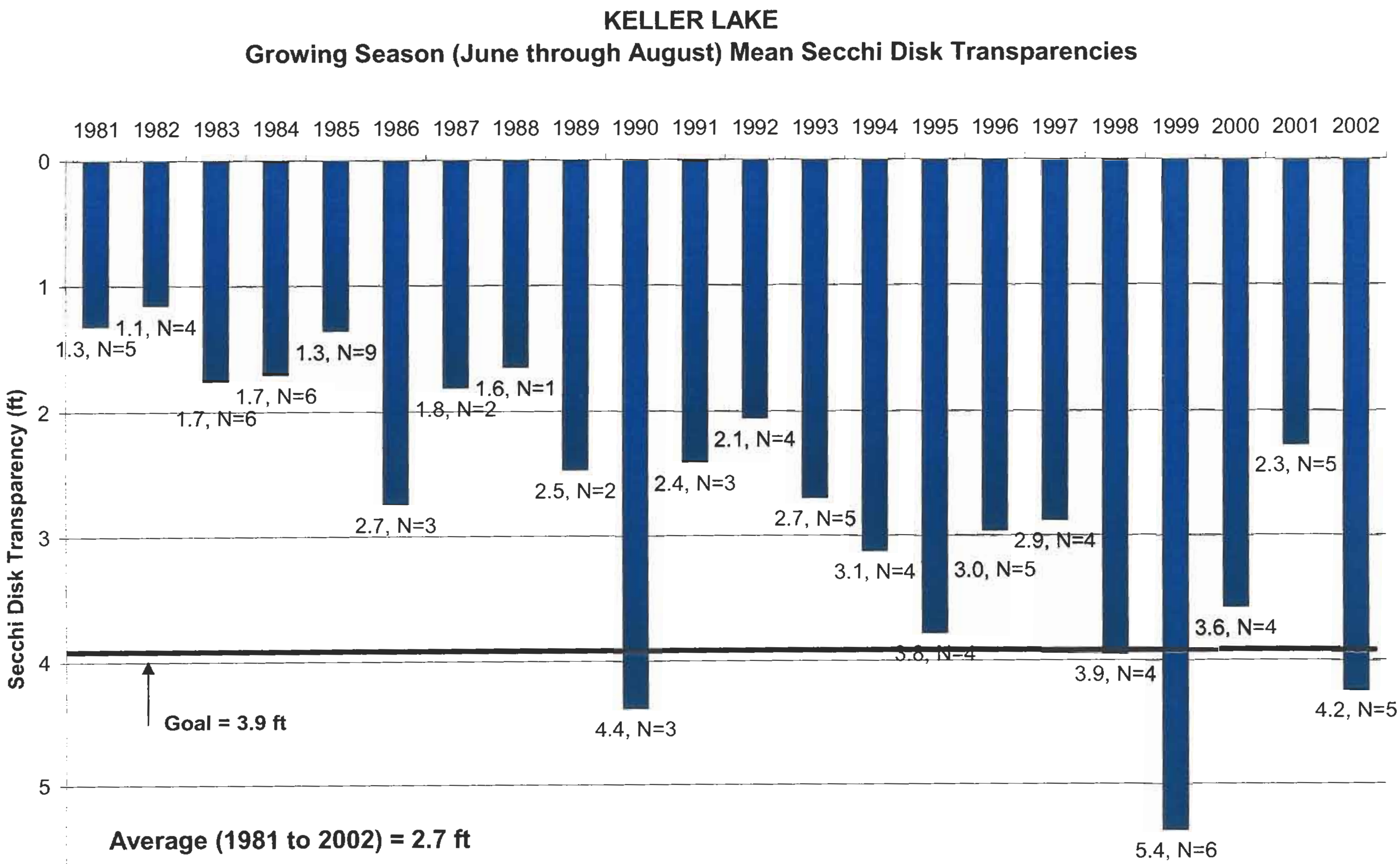
P:\Rwmwd_Projects\2362797\Historical Water Quality Data\Lake_Summaries\Keller_alldata.xls

Figure E-17



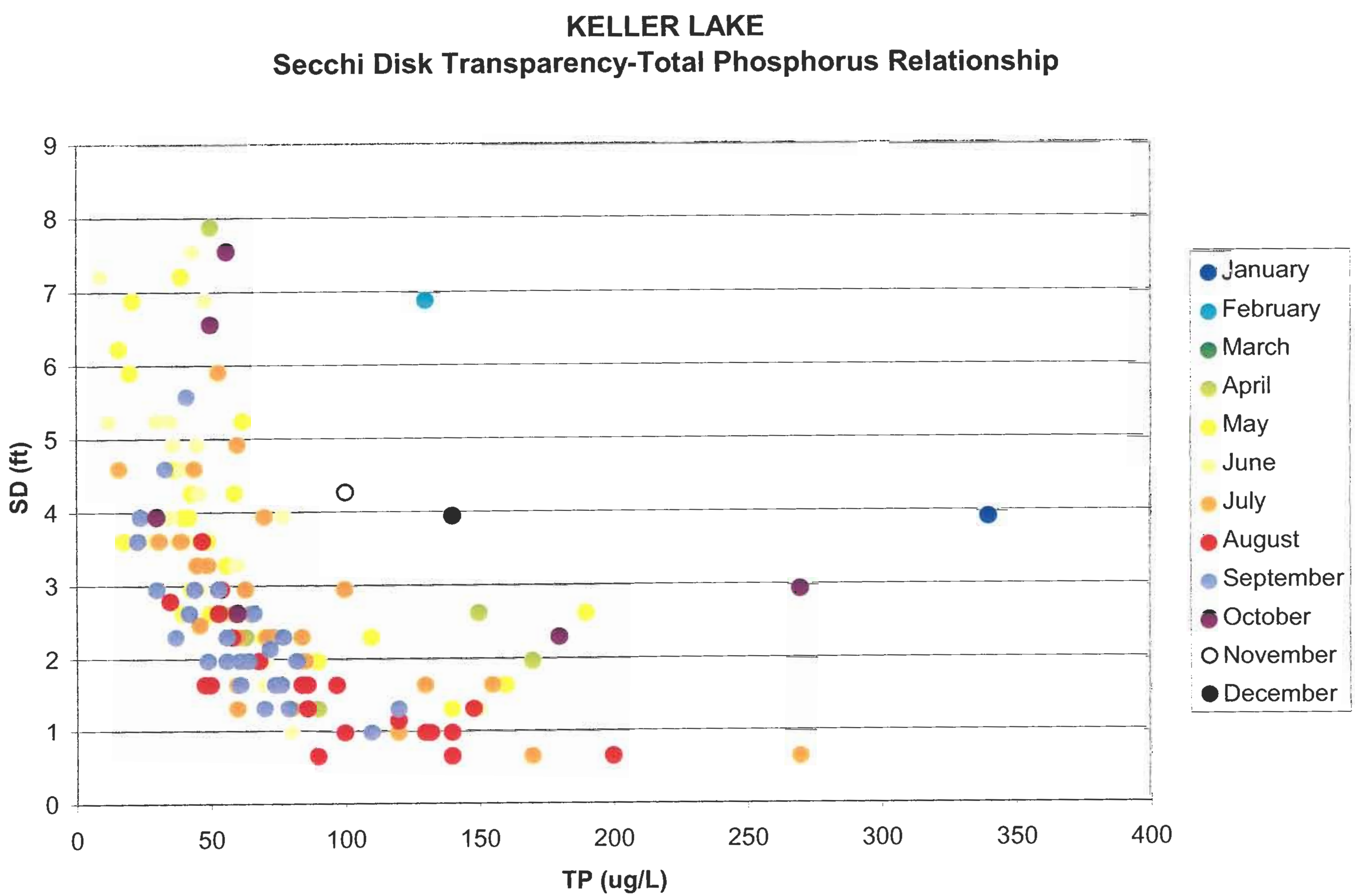
P:\Rwmwd_Projects\2362797\Historical Water Quality Data\Lake_Summaries\Keller_alldata.xls

Figure E-18



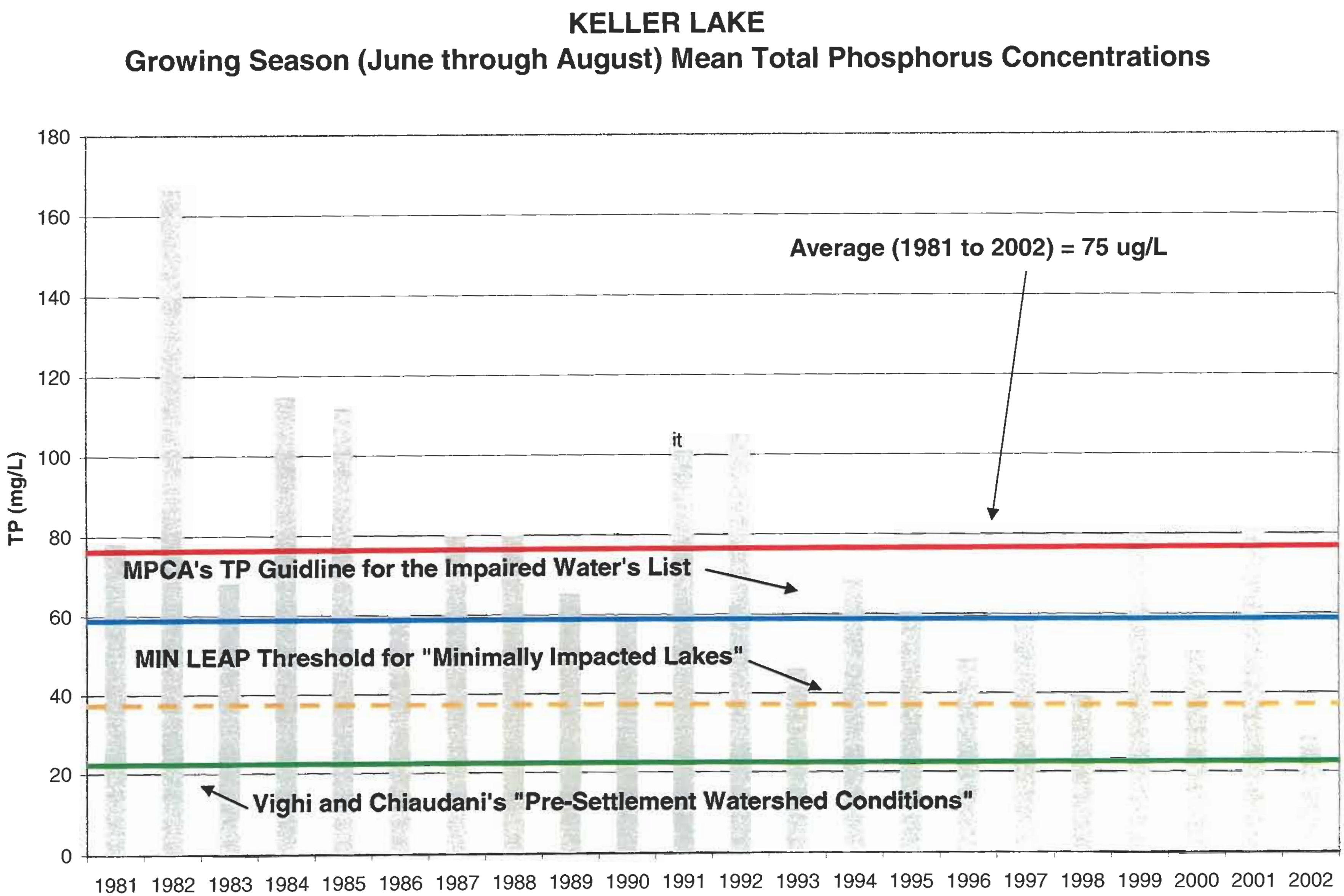
P:\Rwmwd_Projects\2362797\Historical Water Quality Data\Lake_Summaries\Keller_alldata.xls

Figure E-19



C:\Erin's Projects\Phalen Chain of Lakes\Keller_alldata.xls

Figure E-20



P:\Rwmwd_Projects\2362797\Historical Water Quality Data\Lake_Summaries\Keller_alldata.xls

Figure E-21

NOTE: Bathymetry depth in feet.

300 0 300 600 900 1200

Scale in Feet

Figure E-22

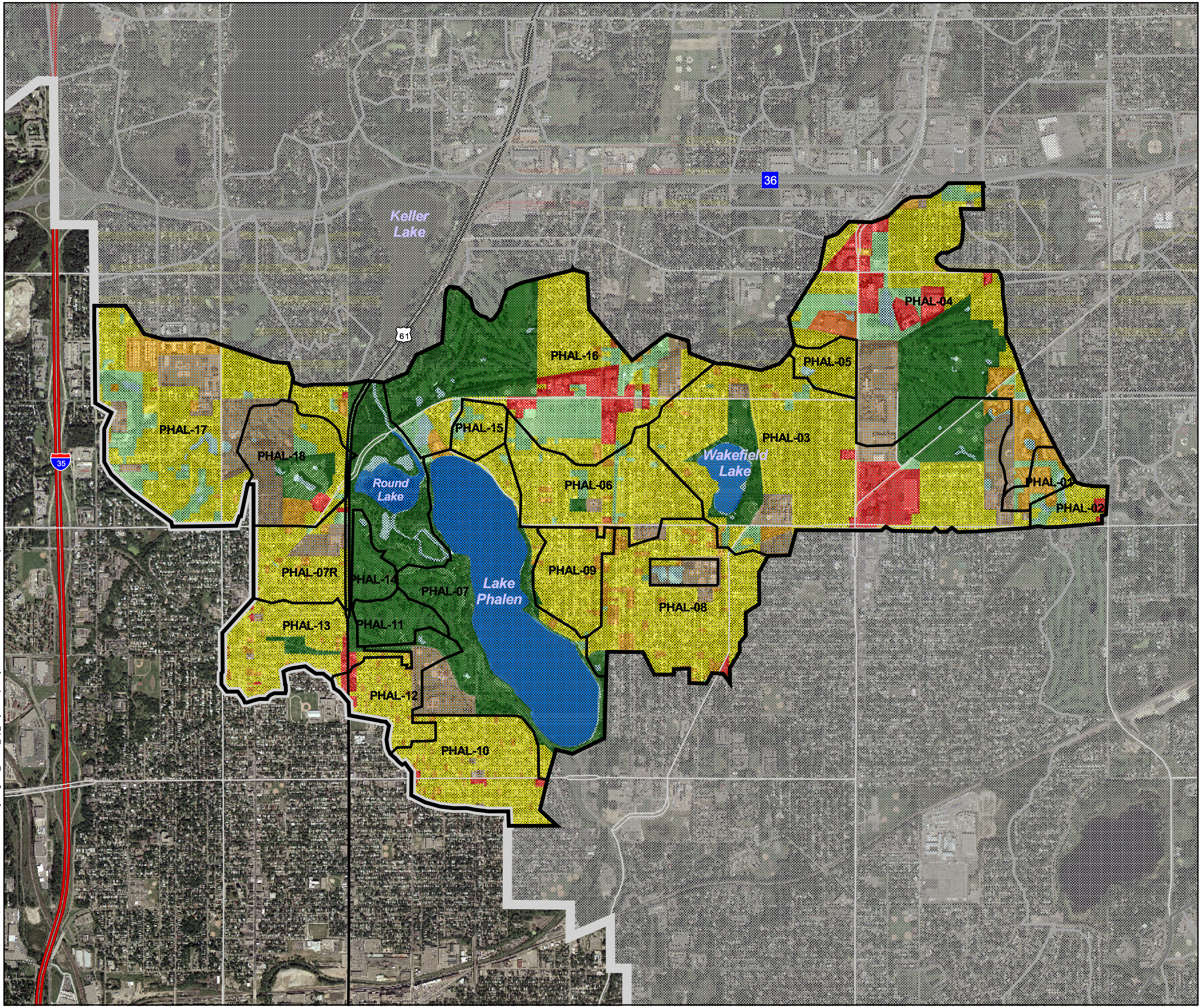
LAKE PHALEN:
BATHYMETRY

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_eseries_lkp_may2004.apr, Layout: E-22 - Phalen Bathymetry, lkp, Wed Jul 20 16:11:35 2005



Barr: Arcview 3.3, OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_eseries_lkp_may2004.apr, Layout: E-23 - Phalen Exist Land Use , lkp, Wed Jul 20 16:16:19 2005

LEGEND

Landuse
- Natural/Park/Open
- Developed Parkland
- Golf Course
- Agricultural
- Very Low Density Residential
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Institutional
- Institutional - High Imperviousness
- Airport
- Highway
- Commercial
- Industrial/Office
- Other
- Open Water
- Wetland
- No Data

- Lake Phalen Subwatershed
- Lake Phalen Drainage Areas
- RWMWD Boundary
- Other Watersheds within RWMWD

1000 0 1000 2000 3000

Scale in Feet

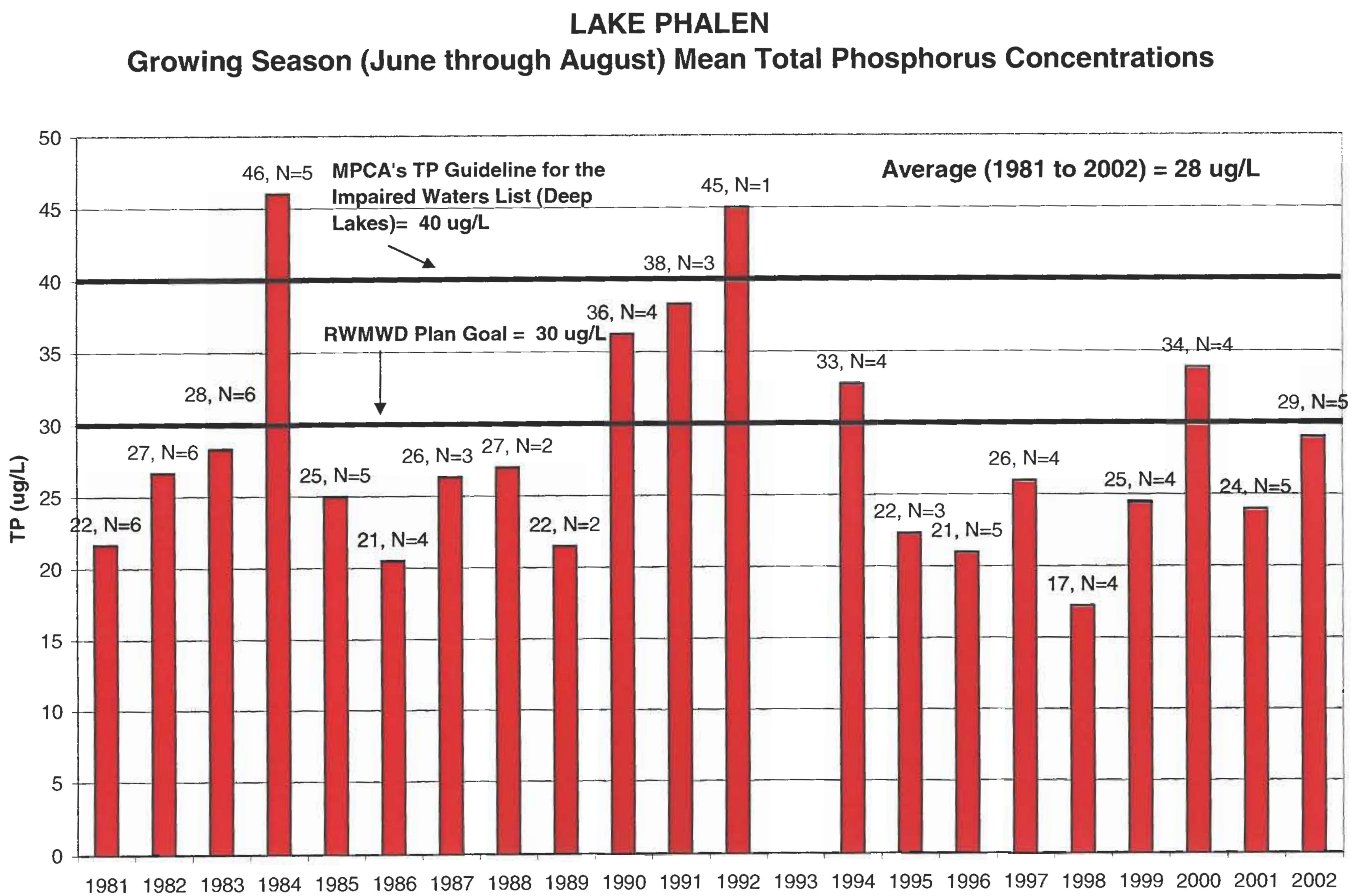
Figure E-23

LAKE PHALEN SUBWATERSHED:
EXISTING LAND USE

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

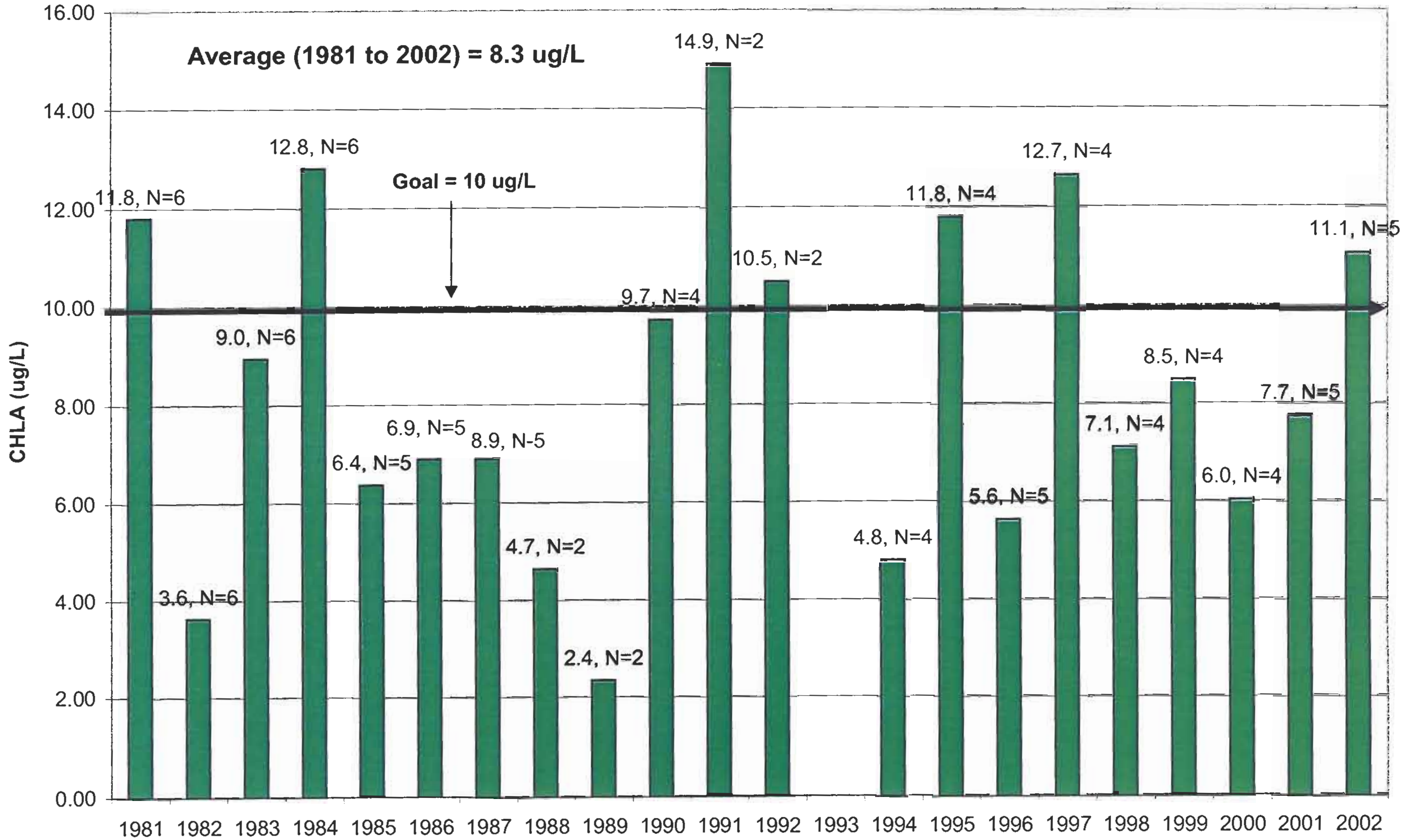
BARR



P:\Rwmwd_Projects\2362797\Historical Water Quality Data\Lake_Summaries\Phalen_alldata.xls

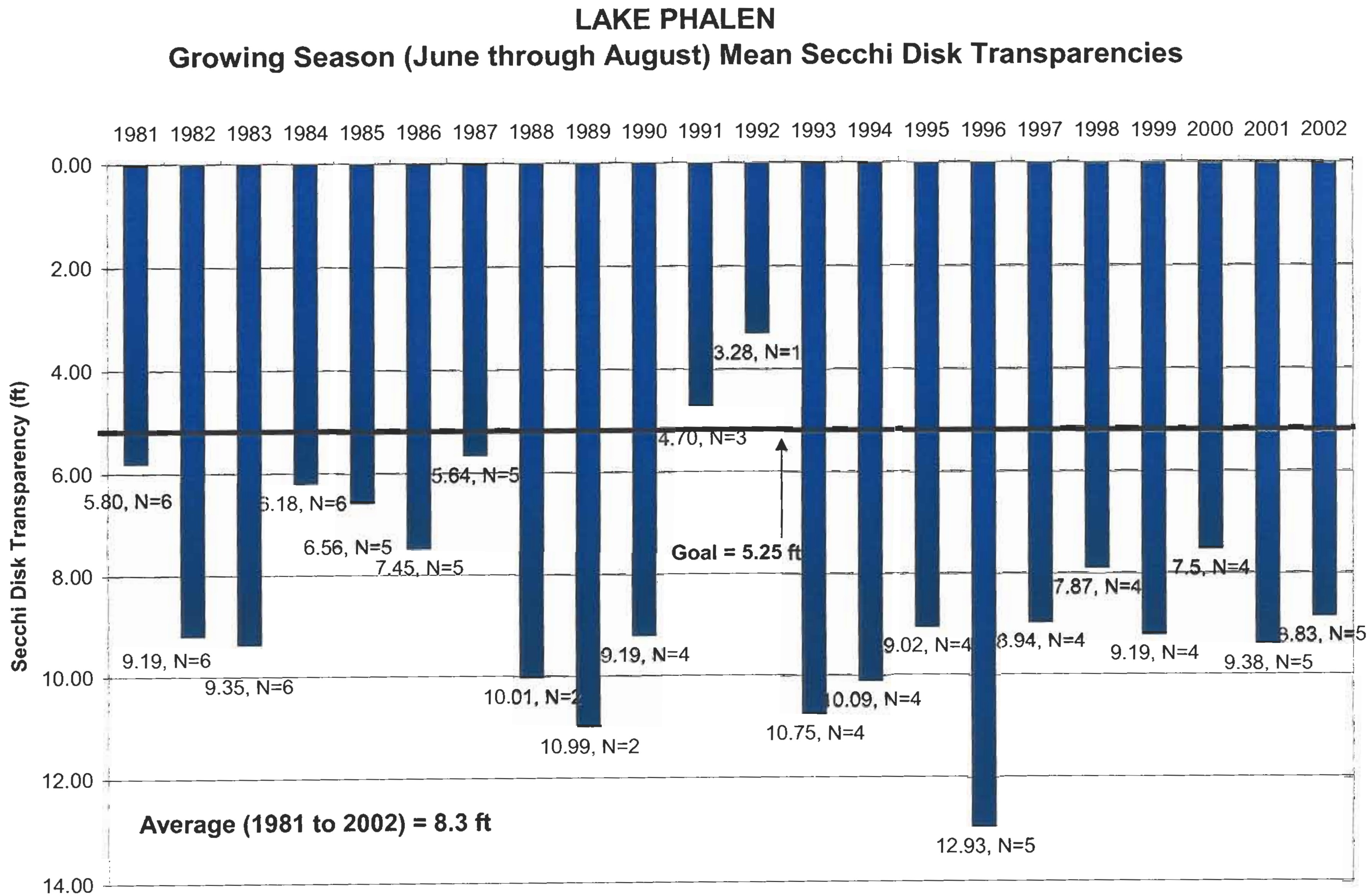
Figure E-24

LAKE PHALEN
Growing Season (June through August) Mean Total Chlorophyll a Concentrations



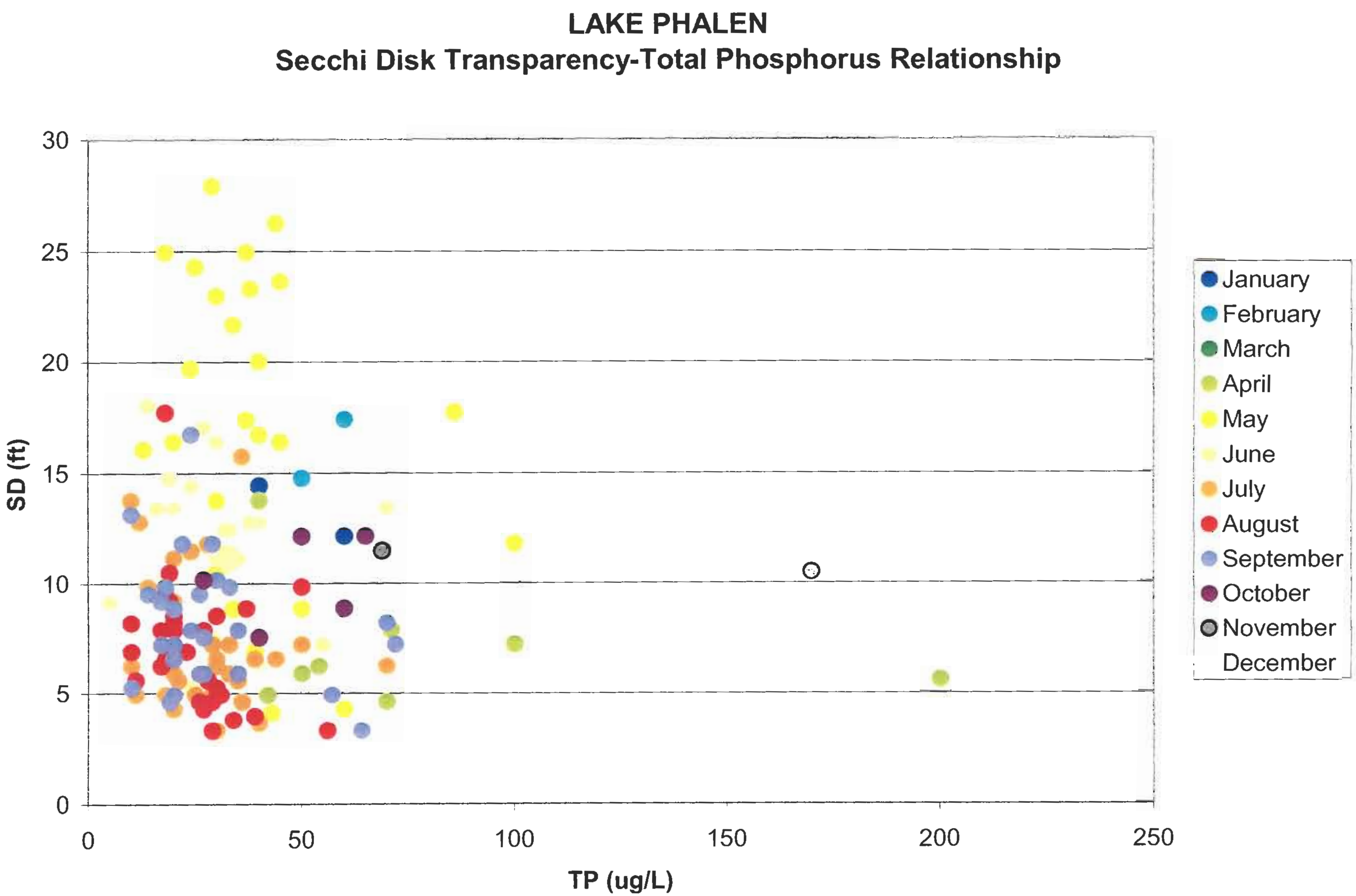
P:\Rwmwd_Projects\2362797\Historical Water Quality Data\Lake_Summaries\Phalen_alldata.xls

Figure E-25



P:\Rwmwd_Projects\2362797\Historical Water Quality Data\Lake_Summaries\Phalen_alldata.xls

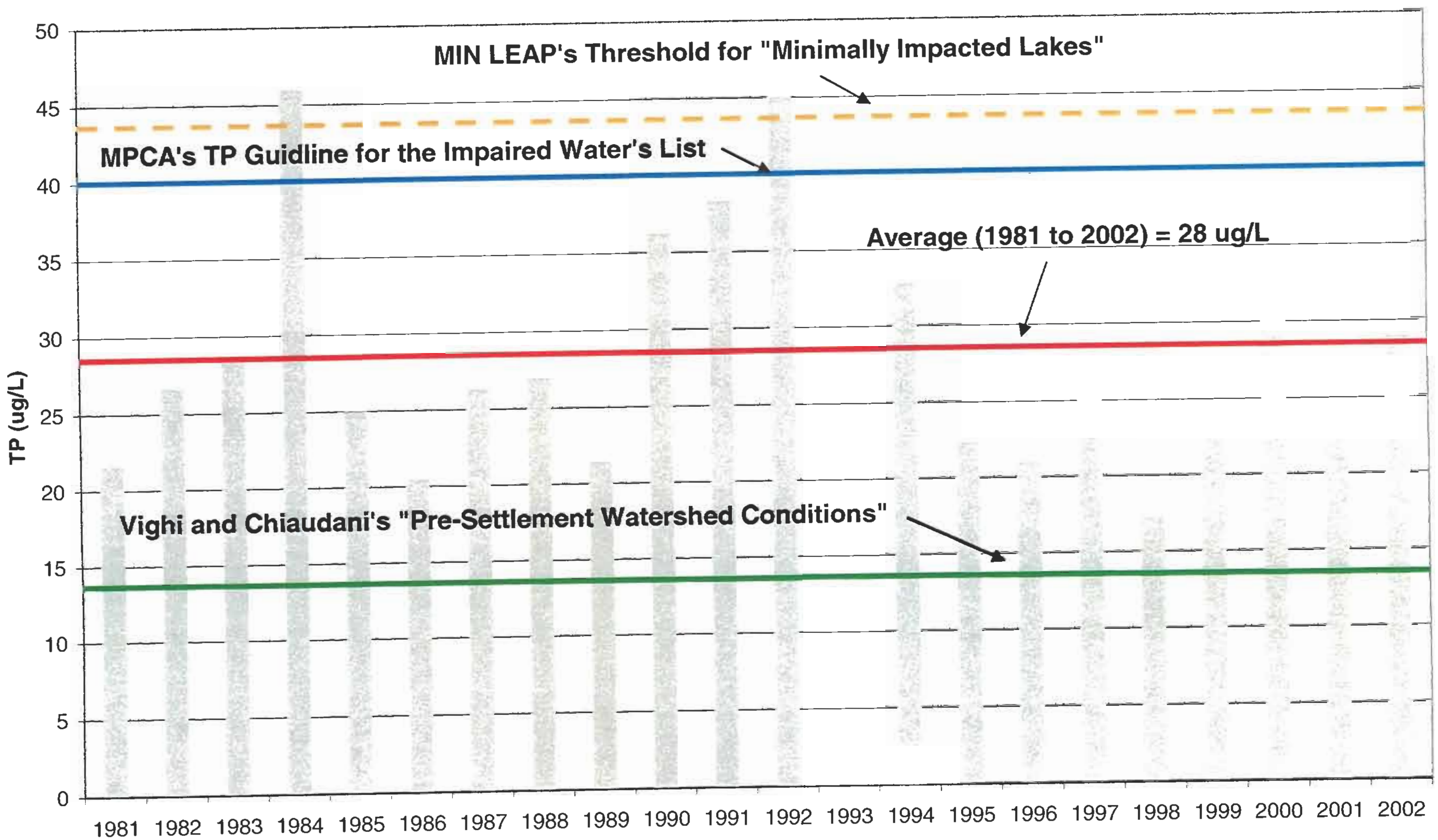
Figure E-26



LAKE PHALEN
Secchi Disk Transparency-Total Phosphorus Relationship
SD (ft)
30
25
20
15
10
5
0
0
50
100
150
200
250
TP (ug/L)
January
February
March
April
May
June
July
August
September
October
November
December

Figure E-27

LAKE PHALEN
Growing Season (June through August) Mean Total Phosphorus Concentrations



P:\Rwmwd_Projects\2362797\Historical Water Quality Data\Lake_Summaries\Phalen_alldata.xls

Figure E-28

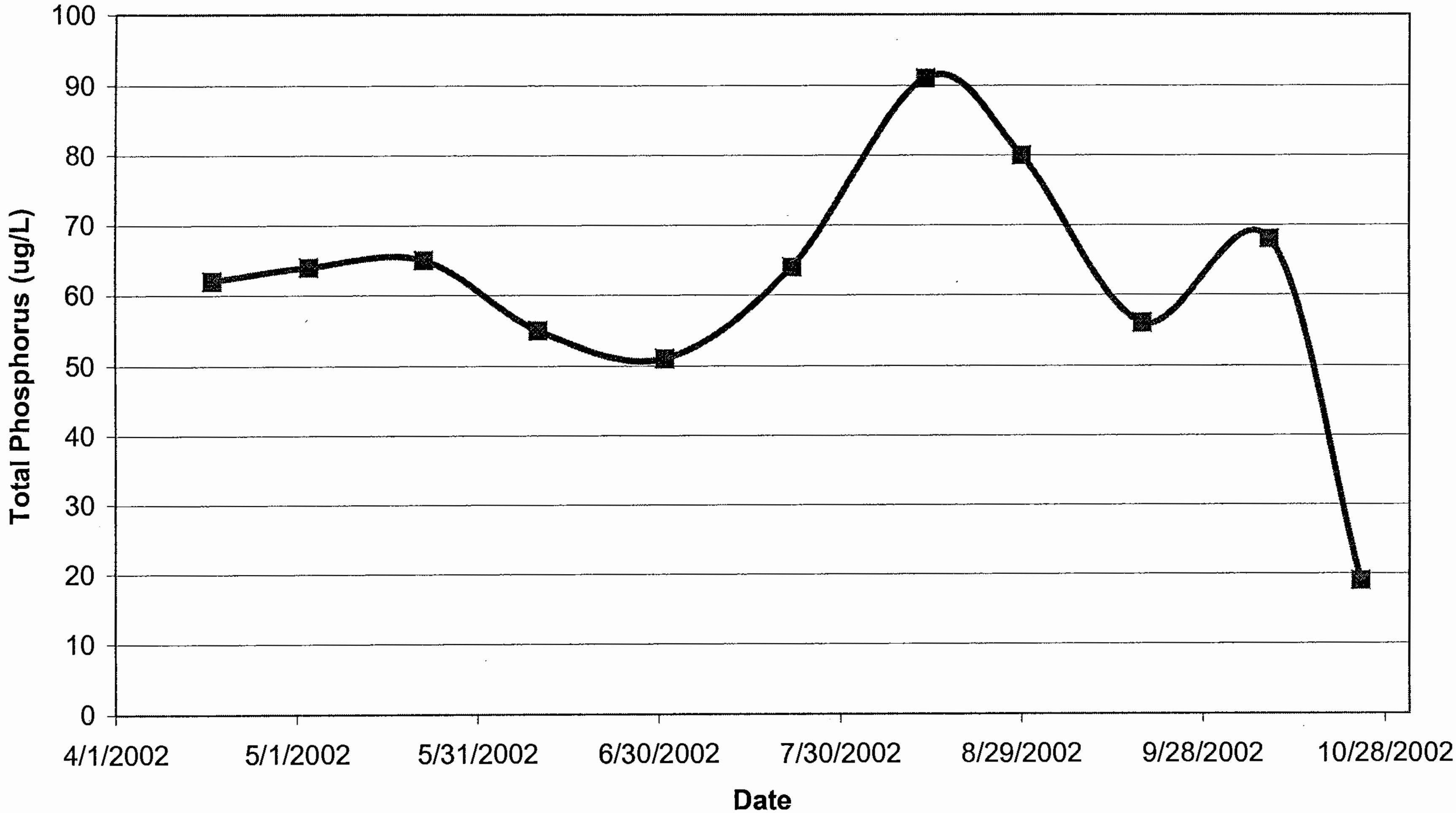
Appendix F

2002 In-Lake Water Quality Data for the Phalen Chain of Lakes

Appendix F: 2002 In-Lake Water Quality Data for the Phalen Chain of Lakes

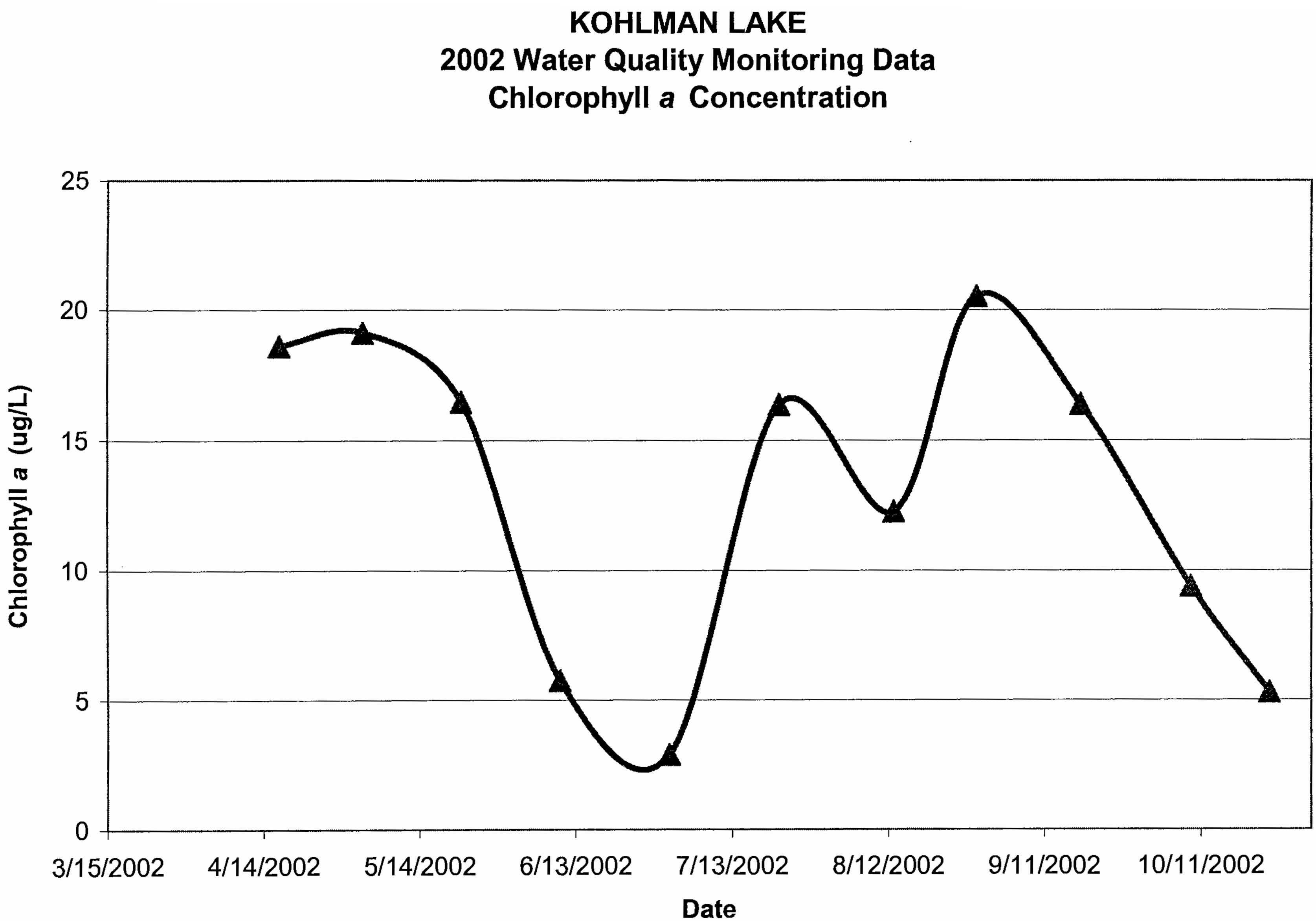
This appendix contains the 2002 in-lake water quality data that was collected for each of the lakes in the Phalen Chain of Lakes. This data was used to both characterize the lakes' current water quality as well as to provide calibration data for the in-lake modeling effort.

KOHLMAN LAKE
2002 Water Quality Monitoring Data
Total Phosphorus Concentration



C:\Erin's Projects\Phalen Chain of Lakes\Kohlman_alldata.xls

Figure F-1



C:\Erin's Projects\Phalen Chain of Lakes\Kohlman_alldata.xls

Figure F-2

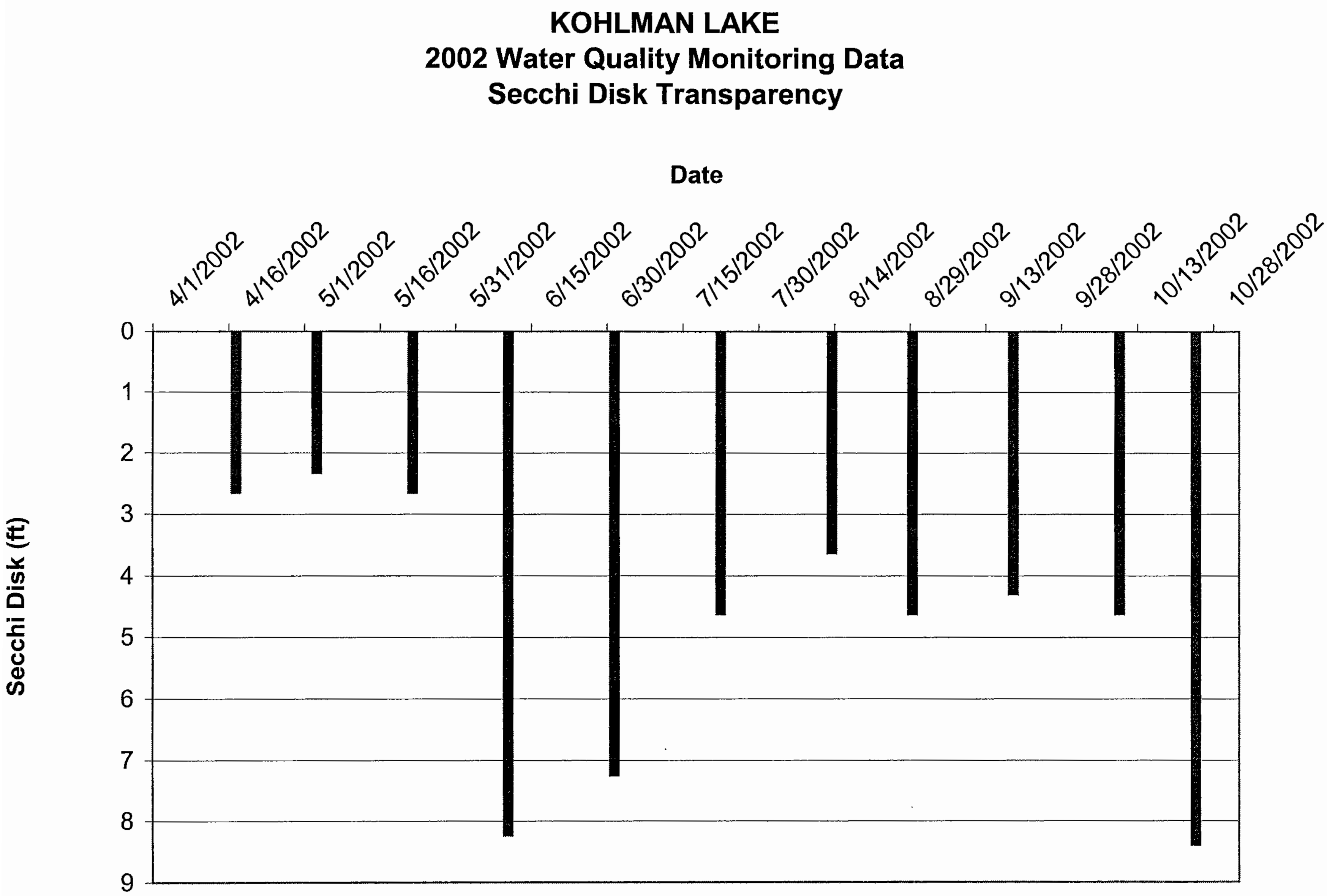
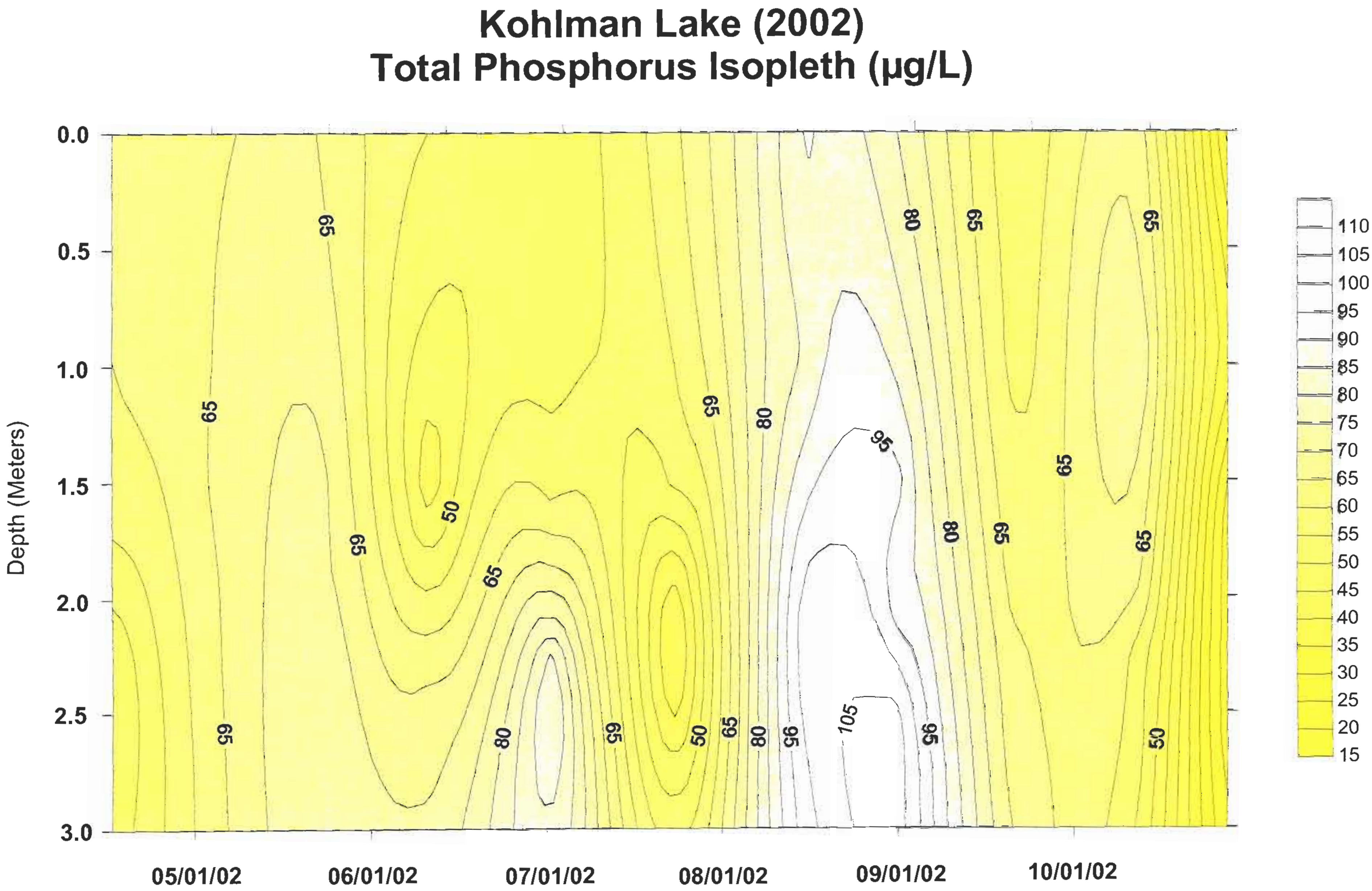
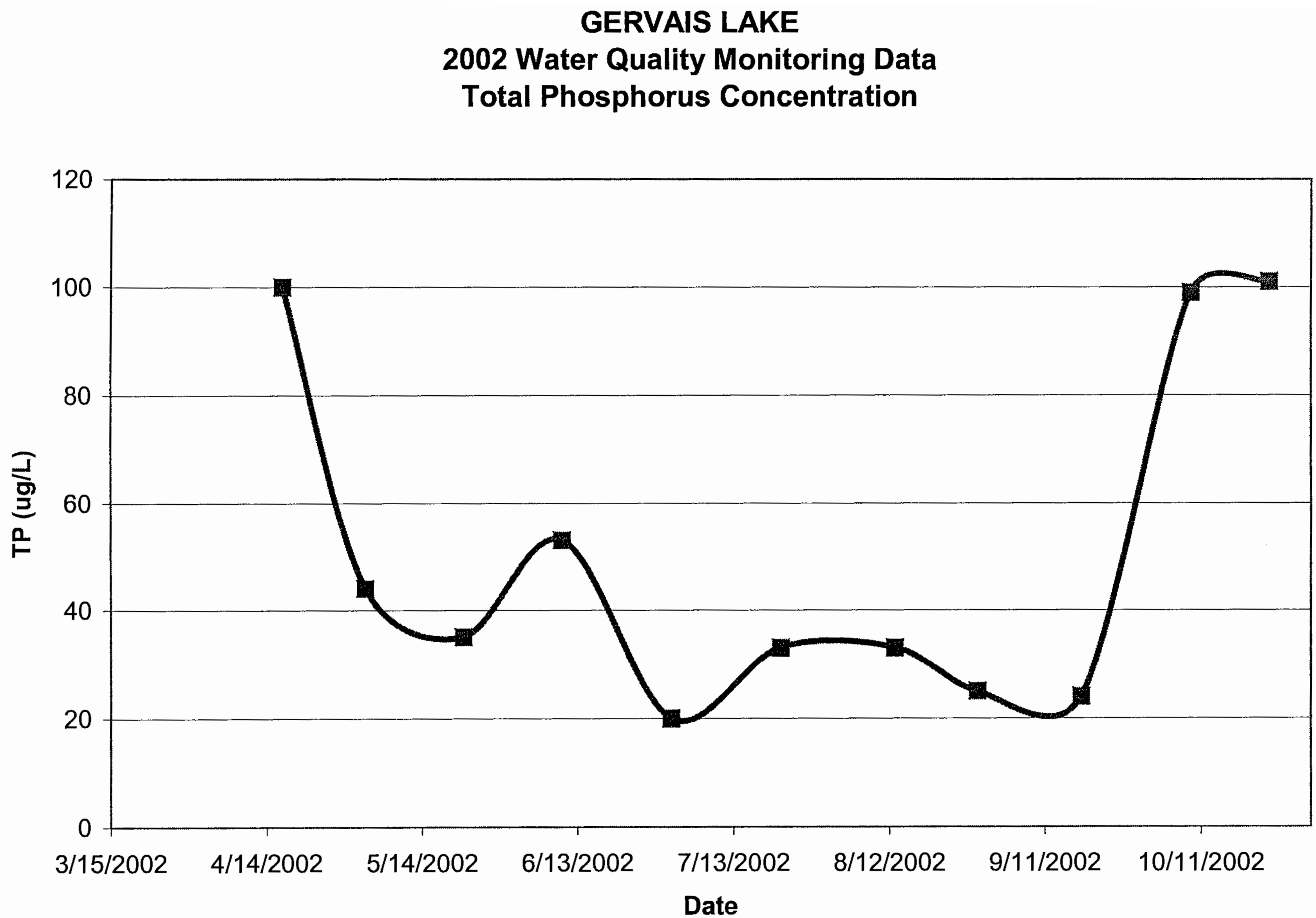

KOHLMAN LAKE
2002 Water Quality Monitoring Data
Secchi Disk Transparency
Date
4/1/2002
4/16/2002
5/1/2002
5/16/2002
5/31/2002
6/15/2002
6/30/2002
7/15/2002
7/30/2002
8/14/2002
8/29/2002
9/13/2002
9/28/2002
10/13/2002
10/28/2002
Secchi Disk (ft)
0
1
2
3
4
5
6
7
8
9

Figure F-3

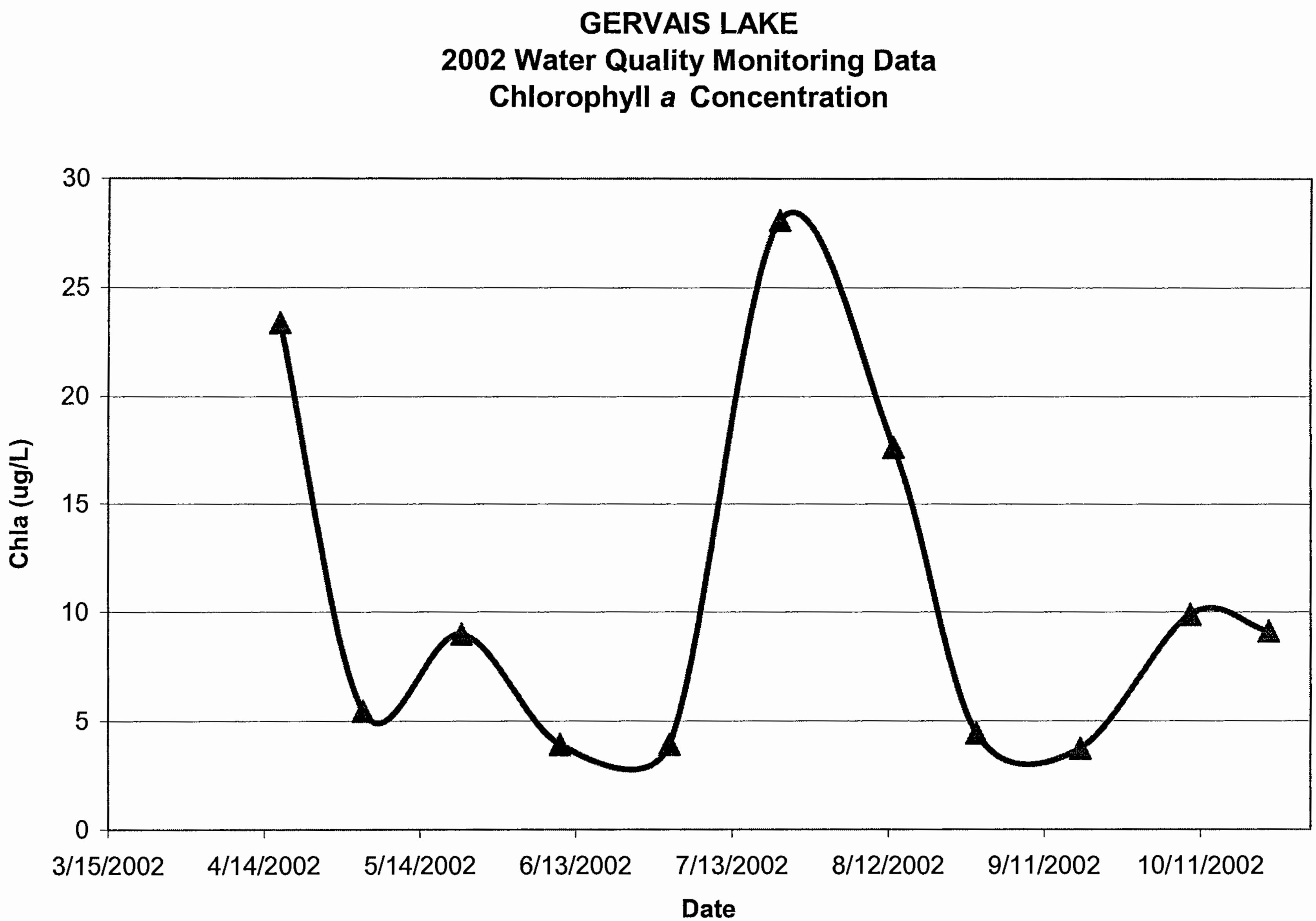


Kohlman Lake (2002)
Total Phosphorus Isopleth (µg/L)
Depth (Meters)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
05/01/02
06/01/02
07/01/02
08/01/02
09/01/02
10/01/02
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15



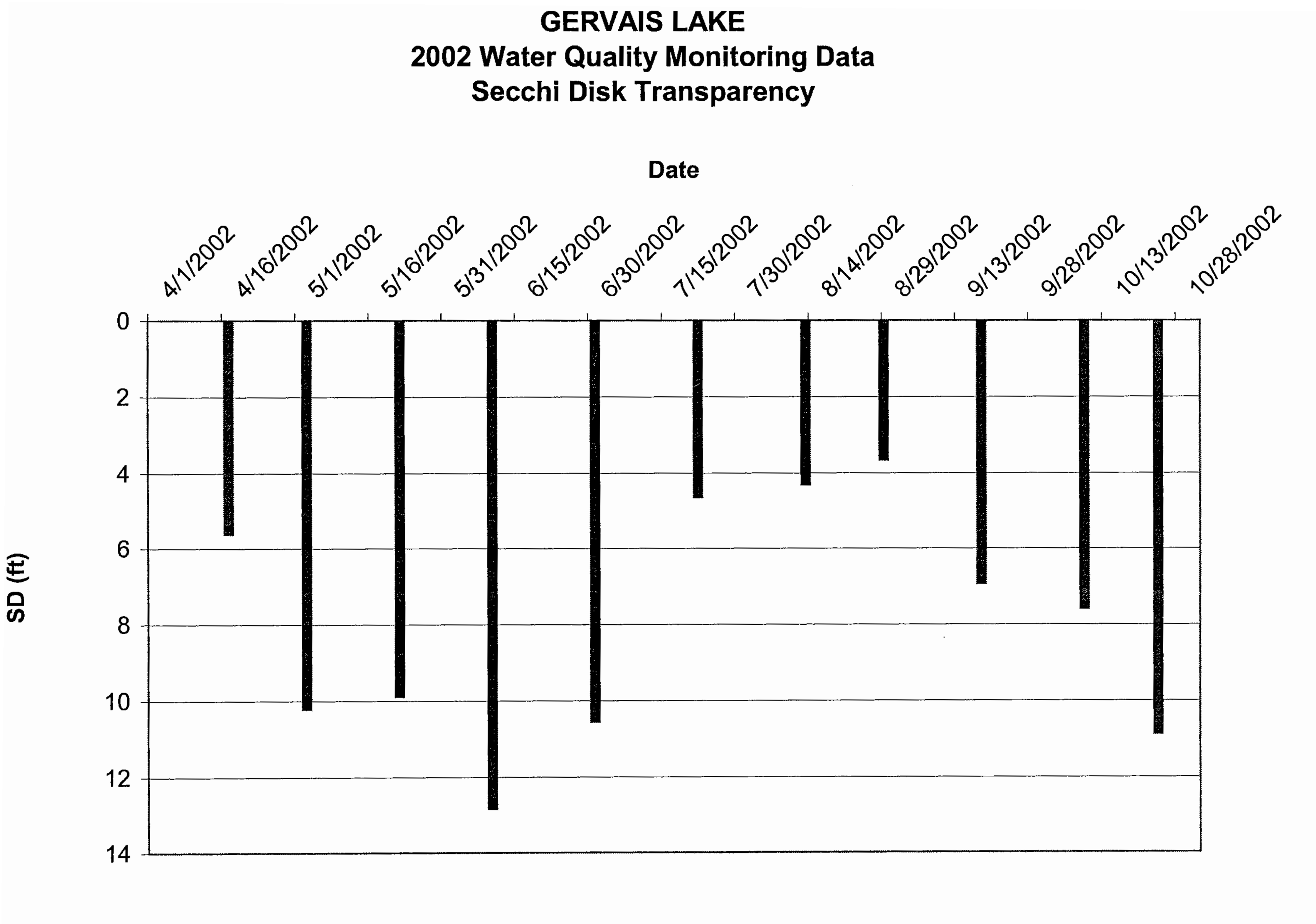
P:\Rwmwd_Projects\2362797\Historical Water Quality Data\Lake_Summaries\Gervais_alldata_ela.xls

Figure F-5



C:\Erin's Projects\Phalen Chain of Lakes\Gervais_alldata_ela.xls

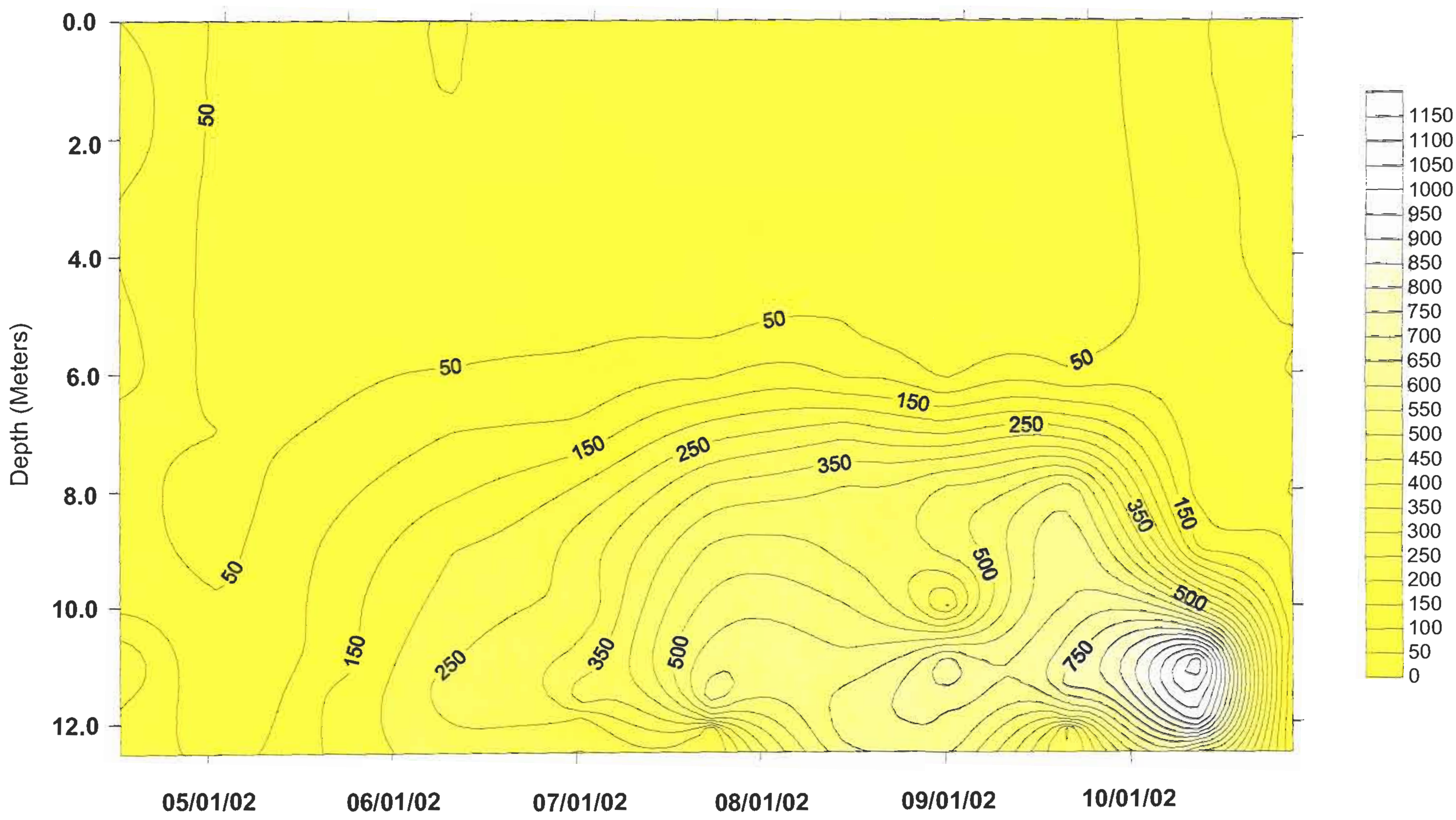
Figure F-6



GERVAIS LAKE
2002 Water Quality Monitoring Data
Secchi Disk Transparency
Date
4/1/2002
4/16/2002
5/1/2002
5/16/2002
5/31/2002
6/15/2002
6/30/2002
7/15/2002
7/30/2002
8/14/2002
8/29/2002
9/13/2002
9/28/2002
10/13/2002
10/28/2002
SD (ft)
0
2
4
6
8
10
12
14

Figure F-7

Gervais Lake (2002)
Total Phosphorus Isopleth (µg/L)



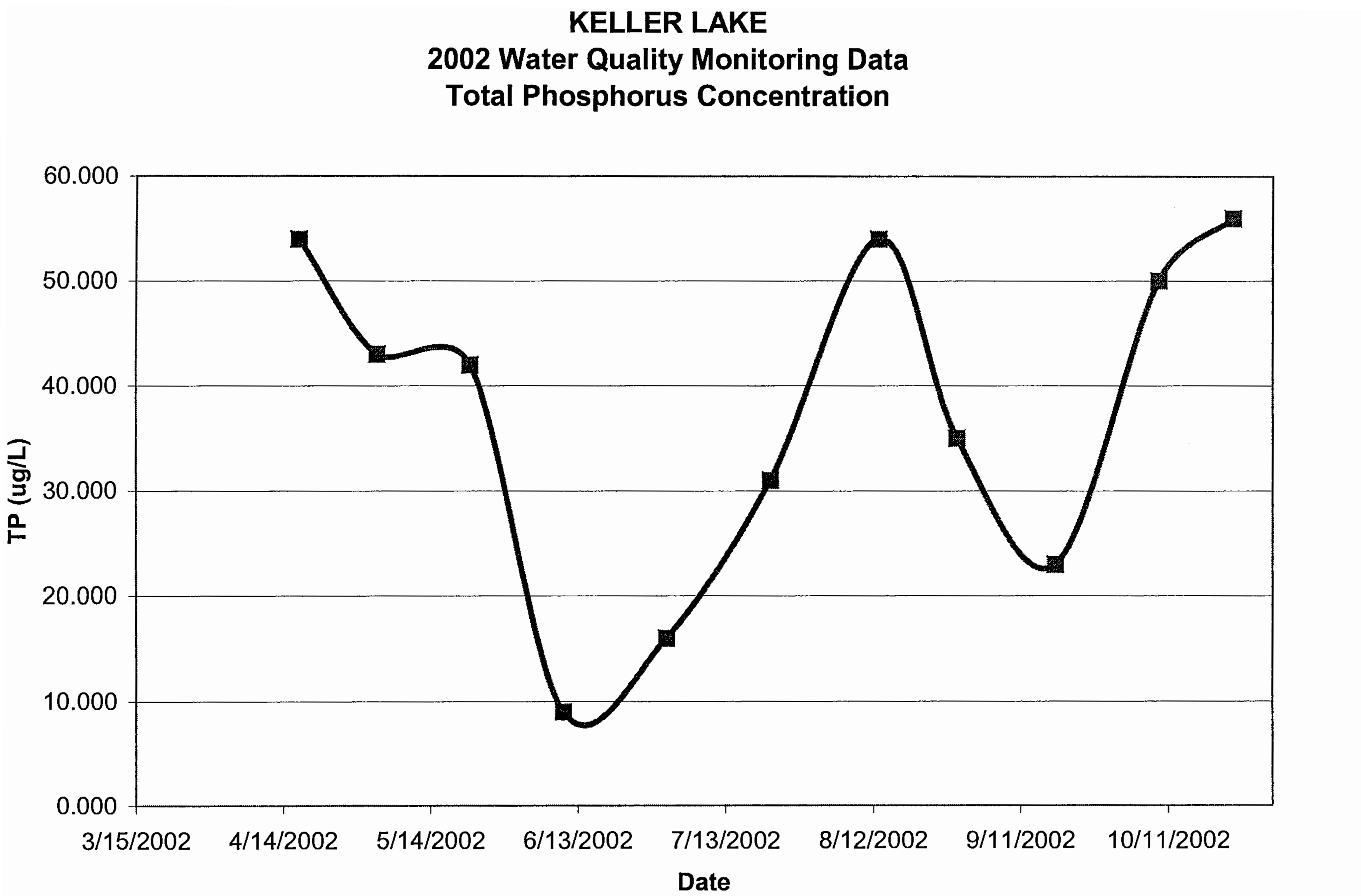

KELLER LAKE
2002 Water Quality Monitoring Data
Total Phosphorus Concentration
60.000
50.000
40.000
30.000
20.000
10.000
0.000
TP (ug/L)
3/15/2002
4/14/2002
5/14/2002
6/13/2002
7/13/2002
8/12/2002
9/11/2002
10/11/2002
Date

Figure F-9

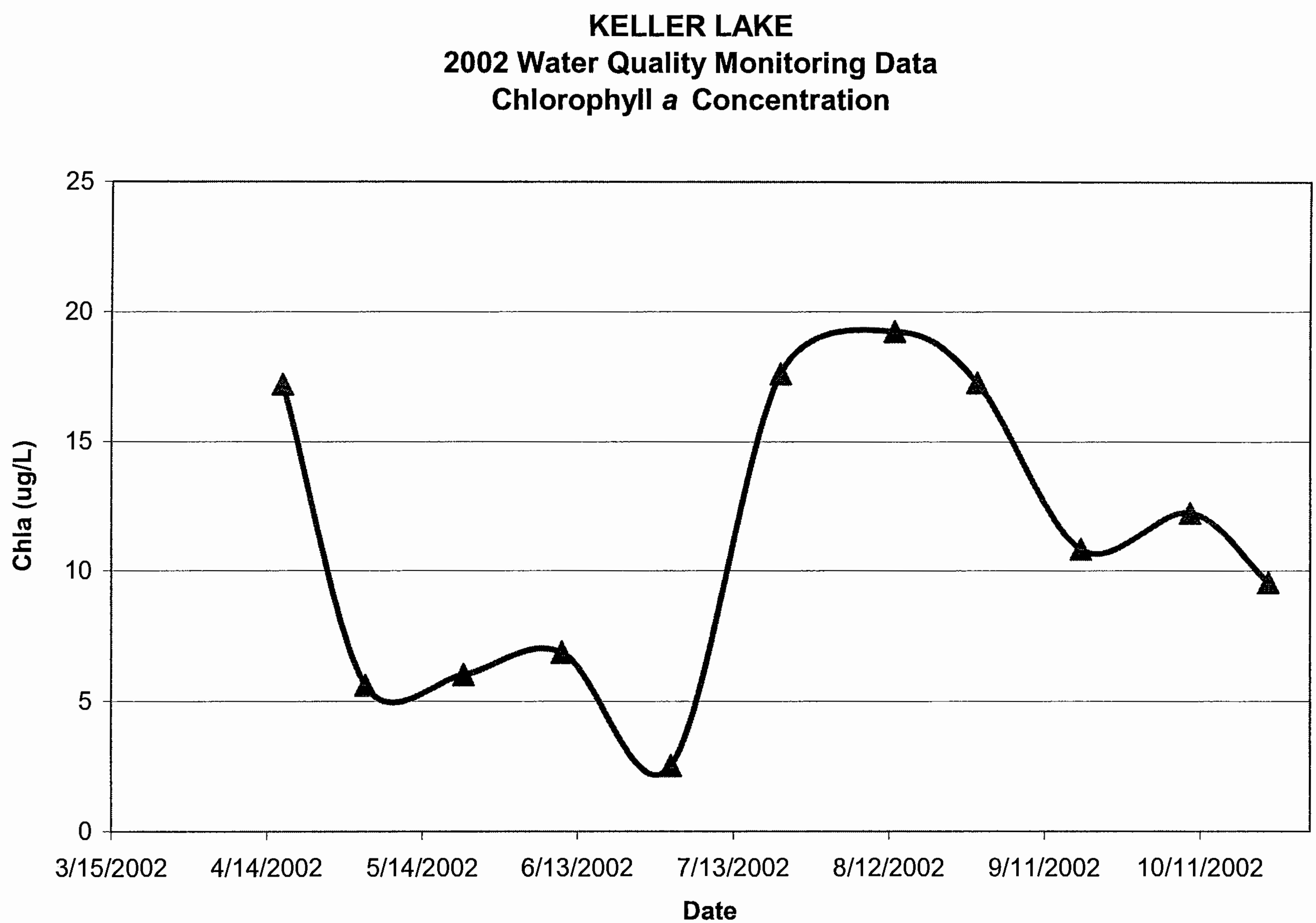

KELLER LAKE
2002 Water Quality Monitoring Data
Chlorophyll *a* Concentration
Chla (ug/L)
25
20
15
10
5
0
3/15/2002
4/14/2002
5/14/2002
6/13/2002
7/13/2002
8/12/2002
9/11/2002
10/11/2002
Date

Figure F-10

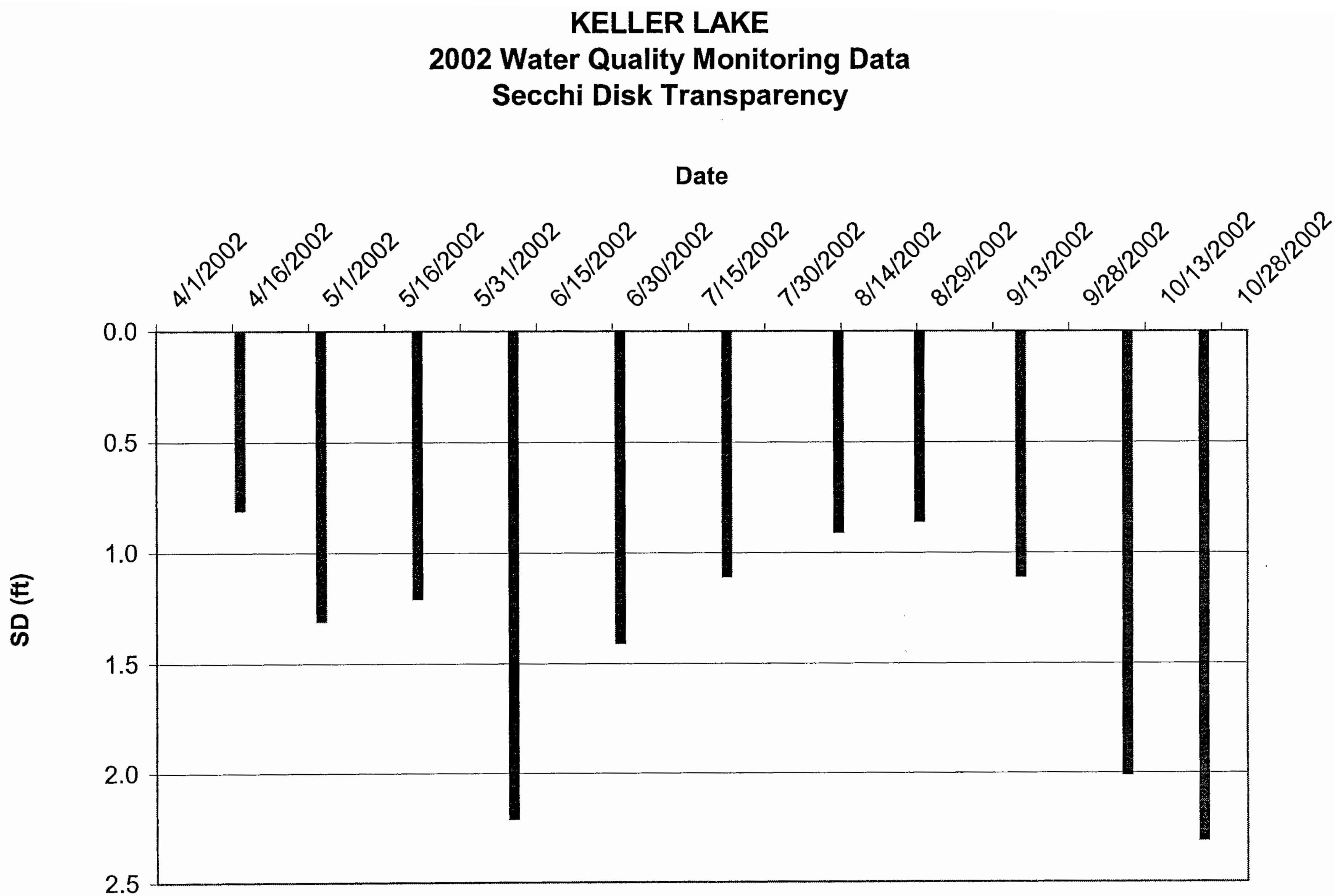
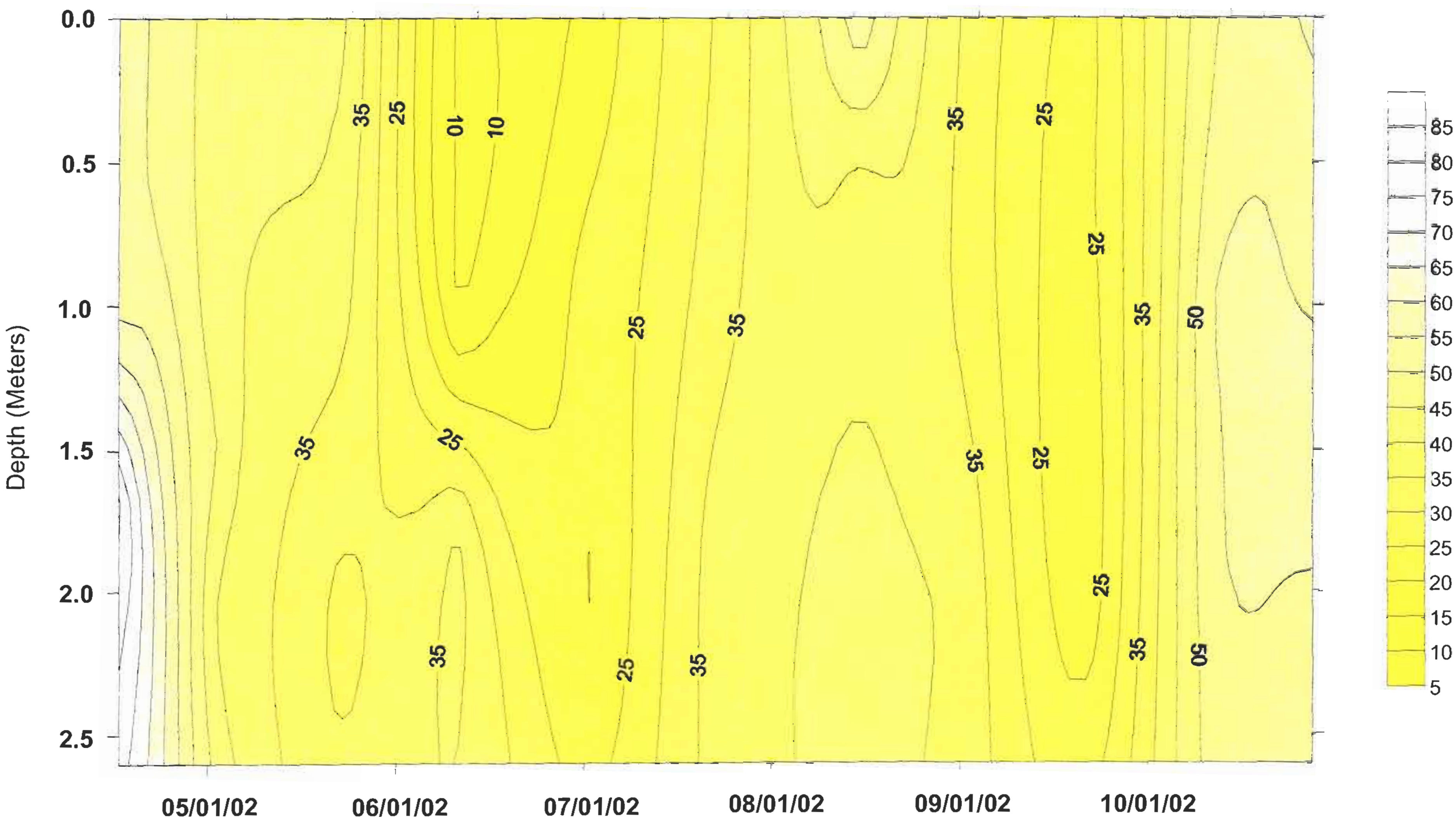
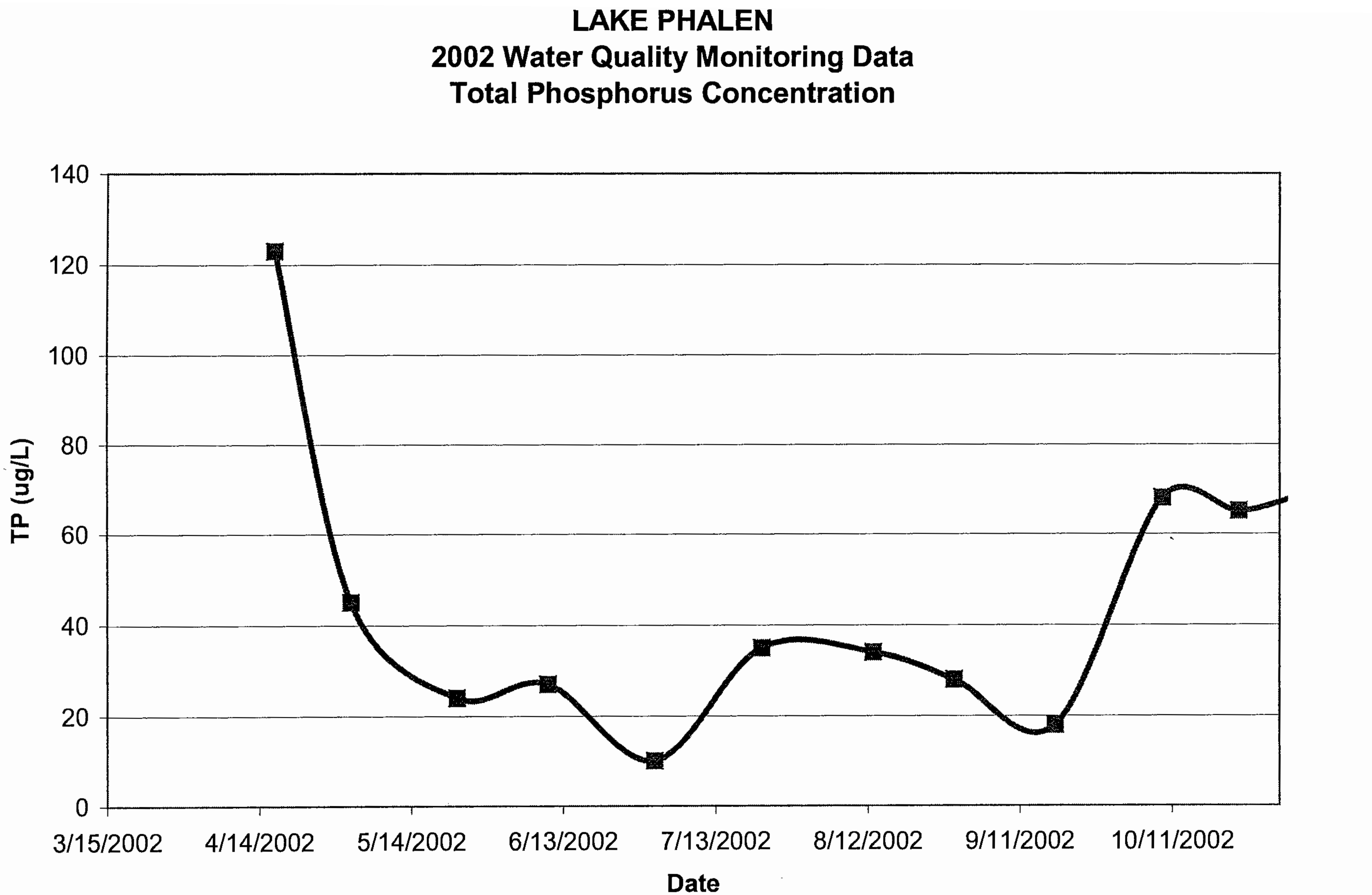

KELLER LAKE
2002 Water Quality Monitoring Data
Secchi Disk Transparency
Date
4/1/2002
4/16/2002
5/1/2002
5/16/2002
5/31/2002
6/15/2002
6/30/2002
7/15/2002
7/30/2002
8/14/2002
8/29/2002
9/13/2002
9/28/2002
10/13/2002
10/28/2002
SD (ft)
0.0
0.5
1.0
1.5
2.0
2.5

Figure F-11

Keller Lake (2002)
Total Phosphorus Isopleth (µg/L)





LAKE PHALEN
2002 Water Quality Monitoring Data
Total Phosphorus Concentration
140
120
100
80
60
40
20
0
TP (ug/L)
3/15/2002
4/14/2002
5/14/2002
6/13/2002
7/13/2002
8/12/2002
9/11/2002
10/11/2002
Date

Figure F-13

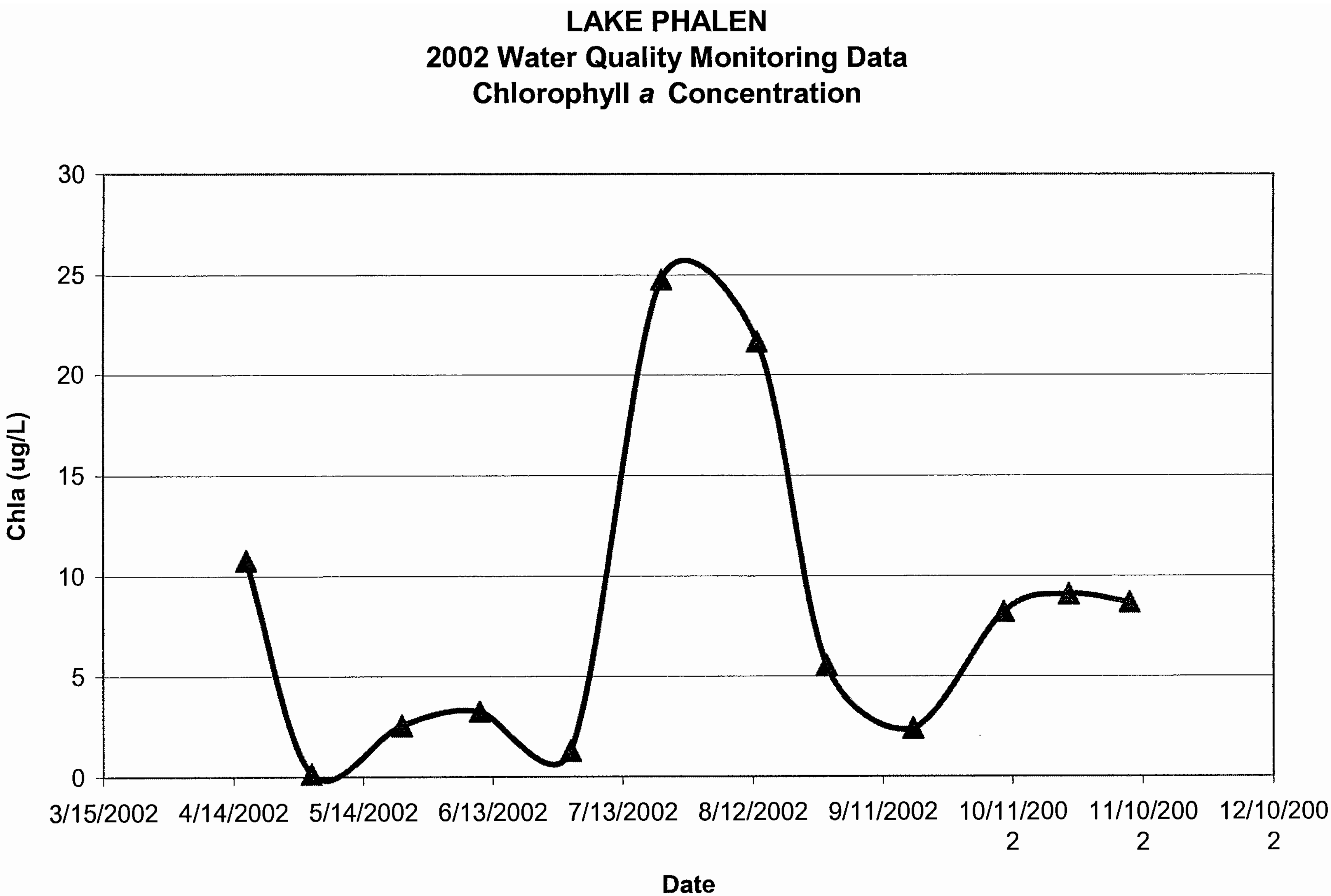

LAKE PHALEN
2002 Water Quality Monitoring Data
Chlorophyll *a* Concentration
Chla (ug/L)
30
25
20
15
10
5
0
3/15/2002
4/14/2002
5/14/2002
6/13/2002
7/13/2002
8/12/2002
9/11/2002
10/11/2002
11/10/2002
12/10/2002
Date

Figure F-14

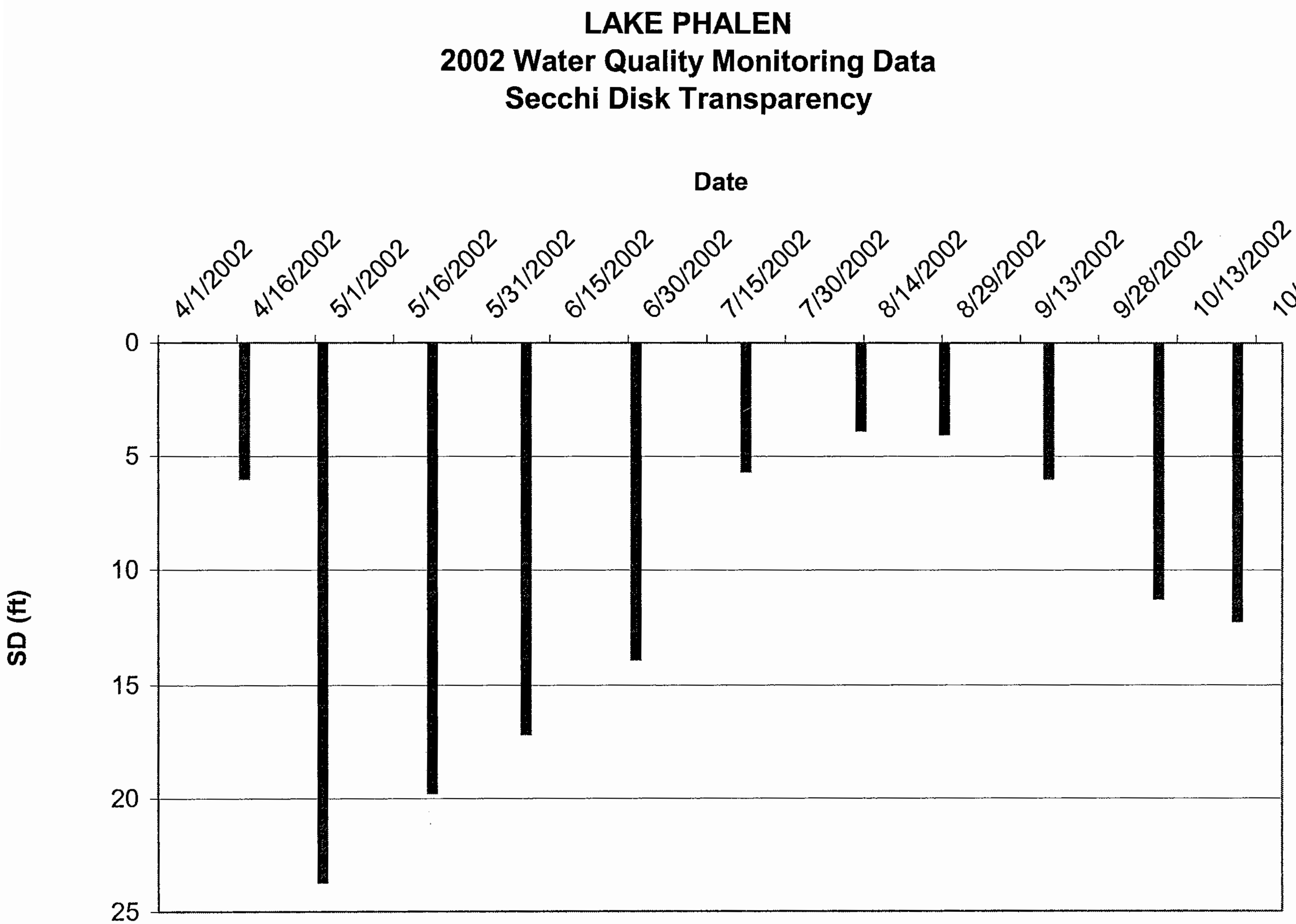
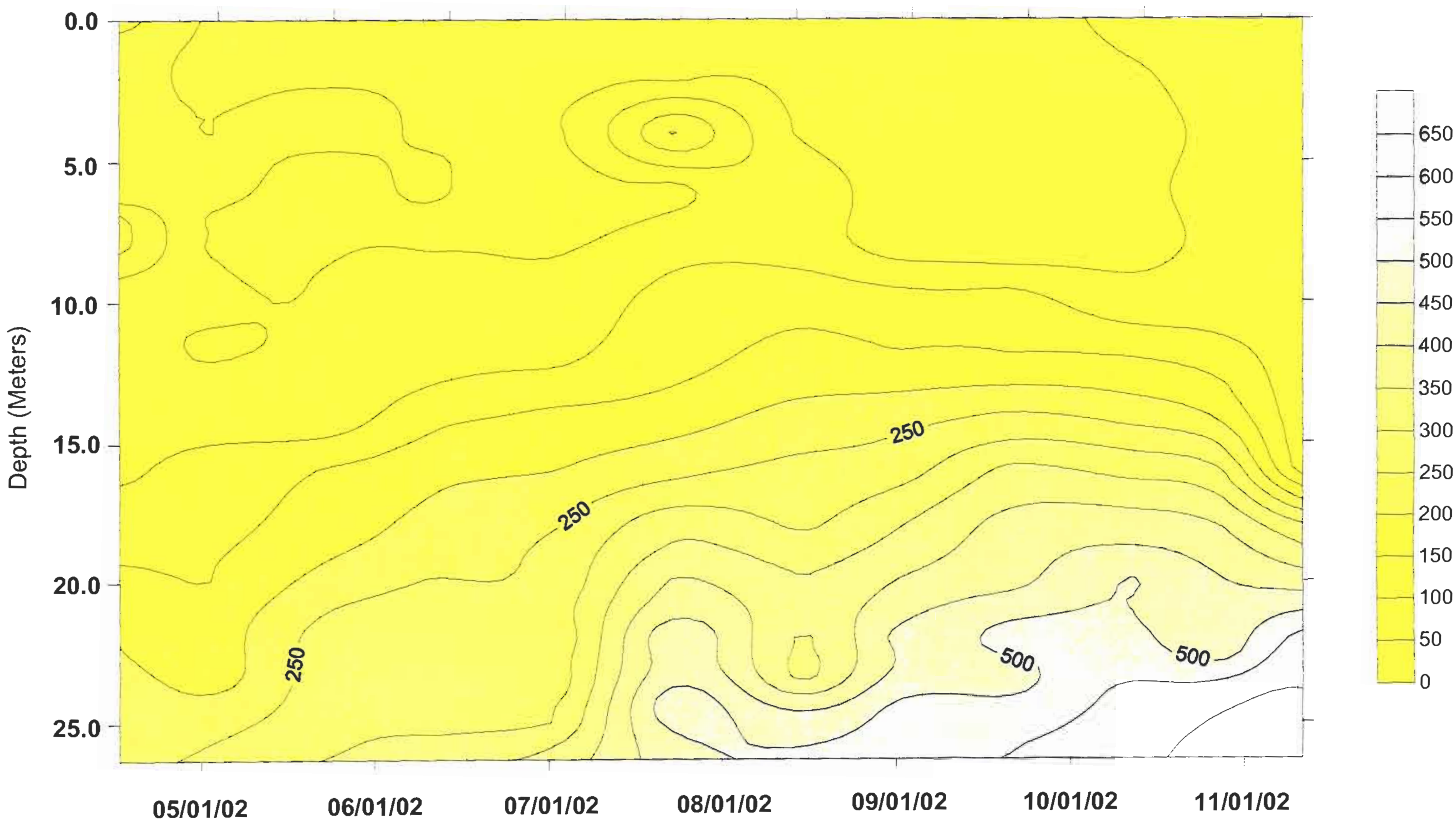

LAKE PHALEN
2002 Water Quality Monitoring Data
Secchi Disk Transparency
Date
4/1/2002
4/16/2002
5/1/2002
5/16/2002
5/31/2002
6/15/2002
6/30/2002
7/15/2002
7/30/2002
8/14/2002
8/29/2002
9/13/2002
9/28/2002
10/13/2002
10/28/2002
SD (ft)
0
5
10
15
20
25

Figure F-15

Lake Phalen (2002)
Total Phosphorus Isopleth (µg/L)



Appendix G

Pond Survey Information Compared to Nationwide Urban Runoff Program (NURP) Criteria

Appendix G: Pond Survey Information Compared to Nationwide Urban Runoff Program (NURP) Criteria

As a part of the SLMP process, most of the ponds and wetlands throughout the Phalen Chain subwatershed were surveyed. The dead storage volumes of every surveyed pond or wetland, together with the land use characteristics in each pond or wetland's tributary drainage area were compared to Nationwide Urban Runoff Program (NURP) criteria. This comparison was done to check whether the ponds and wetlands currently had the amount of dead storage that the NURP guidelines would recommend. In addition, the drainage areas that currently have no ponds or wetlands were identified. In this case, hypothetical ponds were evaluated for the untreated areas based on NURP criteria. Spreadsheets containing this information are contained in this appendix.

Where ponds and wetlands were found to be deficient or currently nonexistent, they were evaluated further to determine whether improvements to meet NURP guidelines (to optimize TP removal performance) were justified.

Retention pond improvements were deemed justifiable if:

- The pond or wetland is classified as "Utilize" in the District's Plan
- The pond or wetland was located in a network of subwatersheds that is not already cumulatively removing at least 60% of its overall TP load

In drainage areas where retention pond improvements seemed justifiable, a few other factors were investigated, namely, the availability of land in the area of the proposed pond as well as the concentration of the stormwater runoff through the area (whether the runoff arrived through a stormsewer to a single location, or via sheet flow to the lake). If land was generally undeveloped around the pond, and runoff flow was not sheet flow, the retention pond improvement or creation was evaluated further and is discussed in Section 2.3 of this SLMP.

Kohlman Lake MPCA/NURP Wet Detention Volumes (Required per MPCA/NURP)

(Full Development Watershed Land Use Conditions)

Watershed	Impervious Fraction	Pervious Fraction	Perv. CN*	Watershed Composite CN*	Potential Abstraction	Watershed Runoff** 2.5" Storm (One-year event)	Watershed Area (acres)	Required NURP Dead Storage Volume (acre-ft)	Enter Proposed Avg. Depth (ft)	Dead Storage Surface Area (acres)	Existing Dead Storage Volume (ac-ft)	Deficient?	Volume of Deficient Dead Stroage (ac-ft)	Wetland Type(s)	Land Uses
A	0.00	1.00	69	69	4.4	0.4	4.87	0.17	4.00	0.04	7.39	NO	-7.21		
B	0.01	0.99	82	82	2.3	1.0	24.01	1.97	4.00	0.49	0.22	YES	1.75	Manage 1	Open
C	0.20	0.80	78	82	2.2	1.3	109.29	11.75	4.00	2.94	0.88	YES	10.87	Manage 1	Open
D	0.24	0.76	88	90	1.1	1.8	9.22	1.37	4.00	0.34	0.14	YES	1.24	Manage 1	Open
KOHL-01A	0.37	0.63	76	84	1.9	1.6	37.93	5.14	4.00	1.29	0.00	YES	5.14	Protect	Open and Industrial
KOHL-01B	0.17	0.83	76	80	2.5	1.2	49.32	4.80	4.00	1.20	1.11	YES	3.69	Protect	Open and Industrial
KOHL-01C	0.08	0.92	58	61	6.4	0.4	24.49	0.75	4.00	0.19	0.00	YES	0.75	No Wetland	Open
KOHL-01D	0.02	0.98	57	58	7.3	0.2	26.07	0.40	4.00	0.10	0.00	YES	0.40	No Wetland	Open
KOHL-02	0.13	0.87	83	85	1.8	1.3	290.84	32.31	4.00	8.08	0.00	YES	32.31		
KOHL-03	0.08	0.92	80	82	2.2	1.1	89.54	8.20	4.00	2.05	0.00	YES	8.20	Protect	Open and Single Family
KOHL-04A	0.48	0.52	60	78	2.8	1.6	39.65	5.26	4.00	1.32	0.00	YES	5.26	Manage 1 and Manage 2	Hwy and Industrial
KOHL-04B	0.18	0.82	67	72	3.8	0.9	33.01	2.45	4.00	0.61	1.14	YES	1.31	Protect and Manage 1	Single Family
KOHL-04C	0.16	0.84	68	73	3.8	0.9	14.30	1.02	4.00	0.25	0.00	YES	1.02	No Wetland	Single Family
KOHL-04D	0.13	0.87	69	73	3.7	0.8	11.26	0.77	4.00	0.19	0.00	YES	0.77	No Wetland	Single Family
KOHL-05A	0.05	0.95	89	90	1.2	1.5	48.94	6.32	4.00	1.58	0.00	YES	6.32	Protect	Single Family and Open
KOHL-05B	0.12	0.88	68	71	4.0	0.7	26.14	1.59	4.00	0.40	0.00	YES	1.59	Protect	Single Family
KOHL-05C	0.17	0.83	57	64	5.6	0.6	7.65	0.41	4.00	0.10	0.00	YES	0.41	No Wetland	Single Family
KOHL-06	0.25	0.75	74	80	2.5	1.3	42.55	4.61	2.00	2.30	0.41	YES	4.20	Manage 1, Manage 2 and Utilize	Mixed
KOHL-07	0.06	0.94	73	75	3.4	0.8	39.01	2.45	4.00	0.61	6.58	NO	-4.13		
NB18-01	0.25	0.75	70	77	2.9	1.2	44.75	4.43	4.00	1.11	0.00	YES	4.43	No Wetland	School and Single Family
NB18-02	0.22	0.79	70	76	3.2	1.1	83.62	7.50	4.00	1.88	1.37	YES	6.13	Manage 2	Open and Single Family
NB18-03	0.17	0.83	71	75	3.3	1.0	137.13	11.13	4.00	2.78	67.56	NO	-56.42		
NB18-04	0.21	0.79	71	77	3.0	1.1	807.63	74.62	4.00	18.66	9.45	YES	65.17	Protect	Single Family
NB18-05	0.00	1.00	63	63	5.9	0.2	66.09	1.31	4.00	0.33	5.32	NO	-4.00		
NB18-06	0.01	0.99	64	64	5.5	0.3	40.44	1.04	4.00	0.26	0.00	YES	1.04	Protect	Open
NB18-07	0.19	0.81	69	74	3.5	1.0	62.15	4.99	4.00	1.25	4.36	YES	0.63	Utilize	Open
NB18-08	0.23	0.77	73	79	2.7	1.2	66.45	6.76	4.00	1.69	44.34	NO	-37.58		
NB18-09	0.69	0.31	78	92	0.9	2.2	36.64	6.80	4.00	1.70	1.74	YES	5.06	Utilize	Industrial
NB18-10	0.07	0.93	71	73	3.7	0.7	63.25	3.75	4.00	0.94	25.27	NO	-21.52		
NB18-11	0.29	0.71	73	80	2.4	1.4	256.43	29.26	4.00	7.31	24.06	YES	5.20	Protect	Single Family and Industrial
NB18-12	0.28	0.72	78	84	1.9	1.5	276.47	34.47	4.00	8.62	23.63	YES	10.84	Protect	Commercial
NB18-13	0.40	0.60	74	83	2.0	1.6	21.16	2.90	4.00	0.73	0.00	YES	2.90	No Wetland	Open and Industrial
NB18-14	0.52	0.48	75	87	1.5	1.9	30.16	4.81	4.00	1.20	4.07	YES	0.75	Manage 2	Hwy, Commercial and Open
NB18-15	0.18	0.82	80	83	2.1	1.3	5.97	0.65	4.00	0.16	0.44	YES	0.21	Manage 2	Open
NB18-16	0.14	0.86	79	81	2.3	1.2	2.99	0.29	4.00	0.07	0.00	YES	0.29	No Wetland	Parking Lot
NB18-17	0.57	0.43	73	87	1.5	2.0	30.63	5.06	4.00	1.27	0.00	YES	5.06	No Wetland	Industrial and Open
NB18-18	0.62	0.38	74	89	1.3	2.1	24.10	4.19	4.00	1.05	0.00	YES	4.19	No Wetland	Industrial and Open
NB18-19	0.11	0.89	81	83	2.1	1.2	74.60	7.50	5.00	1.50	9.39	NO	-1.89		
NB18-20	0.03	0.97	85	86	1.7	1.3	28.92	3.02	6.00	0.50	0.13	YES	2.89	Protect and Manage 1	Industrial and Open
NB18-21	0.37	0.63	78	85	1.7	1.7	153.72	21.49	7.00	3.07	6.86	YES	14.63	Protect, Utilize and Manage 1	Mixed
NB18-22	0.43	0.57	74	85	1.8	1.7	69.69	10.02	8.00	1.25	0.71	YES	9.31	Protect and Manage 1	Industrial and Open
NB18-23	0.18	0.82	80	83	2.0	1.3	264.65	29.42	9.00	3.27	178.05	NO	-148.63		
NB18-24A	0.38	0.62	73	83	2.1	1.6	29.53	3.89	10.00	0.39	0.00	YES	3.89	No Wetland	Hwy and Open
NB18-24B	0.15	0.86	75	78	2.8	1.0	107.22	9.20	11.00	0.84	1.50	YES	7.70	Manage 1, Manage 2 and Protect	Open and Multi Family
NB18-24C	0.42	0.58	79	87	1.5	1.8	56.01	8.35	12.00	0.70	0.00	YES	8.35	Protect	Industrial and Open
SB18-01	0.15	0.85	70	74	3.5	0.9	65.61	4.87	13.00	0.37	0.08	YES	4.80	Protect	Single Family and Open
SB18-02	0.12	0.88	77	79	2.6	1.1	204.82	18.12	14.00	1.29	3.14	YES	14.97	Protect and Manage 1	Single Family and Open
SB18-03	0.10	0.90	69	72	3.8	0.7	69.22	4.22	15.00	0.28	4.15	YES	0.07	Manage 1	Single Family and Open
SB18-04	0.17	0.84	70	75	3.3	1.0	86.54	6.86	16.00	0.43	0.33	YES	6.53	Protect	Single Family and Open
SB18-05	0.19	0.81	71	76	3.1	1.1	185.78	16.29	17.00	0.96	0.00	YES	16.29	Utilize	Single Family
SB18-06A	0.24	0.76	72	78	2.8	1.2	256.15	25.43	18.00	1.41	0.00	YES	25.43	Utilize	Single Family
SB18-06B	0.53	0.47	75	87	1.5	1.9	63.94	10.33	19.00	0.54	0.00	YES	10.33	Utilize	Industrial
SB18-07	0.26	0.74	80	85	1.8	1.5	122.67	15.29	20.00	0.76	1.89	YES	13.40	Manage 1	Single Family and Industrial
SB18-08	0.16	0.84	72	76	3.1	1.0	36.44	3.03	21.00	0.14	2.30	YES	0.73	Utilize	Single Family
SB18-09	0.33	0.67	76	84	2.0	1.6	120.66	15.60	22.00	0.71	7.23	YES	8.38	Protect	Single Family and Commercial
SB18-10	0.34	0.66	75	83	2.1	1.5	188.10	23.92	23.00	1.04	6.69	YES	17.23	Protect and Manage 1	Mixed
SB18-11A	0.20	0.80	77	81	2.3	1.3	19.22	2.01	24.00	0.08	6.46	NO	-4.45		
SB18-11B	0.26	0.74	85	88	1.4	1.7	19.07	2.65	25.00	0.11	14.08	NO	-11.43		
SB18-11C	0.37	0.63	77	85	1.8	1.7	8.07	1.12	26.00	0.04	0.00	YES	1.12	Protect and Utilize	Open and Commercial
SB18-12	0.14	0.86	71	74	3.4	0.9	229.78	17.00	27.00	0.63	23.63	NO	-6.63		
SB18-13	0.16	0.84	82	85	1.8	1.4	116.08	13.17	28.00	0.47	0.00	YES	13.17	Protect	Single Family and Open
SB18-14	0.41	0.59	75	85	1.8	1.7	363.74	51.54	29.00	1.78	53.74	NO	-2.20		
SB18-15A	0.19	0.81	74	78	2.8	1.1	181.11	16.84	30.00	0.56	0.00	YES	16.84	No Wetland	Single Family
SB18-15B	0.21	0.79	69	75	3.3	1.0	331.02	28.76	31.00	0.93	21.80	YES	6.97	Manage 1	Single Family and Open
SB18-16	0.11	0.89	75	78	2.9	1.0	67.60	5.41	32.00	0.17	1.80	YES	3.61	Manage 2	Single Family and Open
SB18-17A	0.20	0.80	77	81	2.4	1.2	65.14	6.74	33.00	0.20	0.00	YES	6.74	Protect	Industrial and Open
SB18-17B	0.05	0.95	78	79	2.7	0.9	32.45	2.44	34.00	0.07	0.00	YES	2.44	Protect and Manage 1	Single Family and Open
SB18-18	0.40	0.60	76	85	1.8	1.7	152.40	21.46	35.00	0.61	24.94	NO	-3.48		
SB18-19	0.15	0.85	71	75	3.4	0.9	41.45	3.15	36.00	0.09	0.00	YES	3.15	Protect	Single Family and Open
SB18-21	0.25	0.75	75	81	2.4	1.3	73.89	8.09	37.00	0.22	0.00	YES	8.09	No Wetland	Single Family
SB18-22	0.27	0.73	73	80	2.5	1.3	144.55	15.80	38.00	0.42	0.00	YES	15.80	No Wetland	Single Family and School
SB18-23	0.46	0.54	79	88	1.4	1.9	22.23	3.47	39.00	0.09	0.00	YES	3.47	Protect	Hwy and Multi Family
SB18-24	0.56	0.44	73	87	1.5	2.0	132.00	21.64	40.00	0.54	1.72	YES	19.93	No Wetland	Commercial and Single Family

Watershed	Impervious Fraction	Pervious Fraction	Perv. CN*	Watershed Composite CN*	Potential Abstraction	Watershed Runoff** 2.5" Storm (One-year event)	Watershed Area (acres)	Required NURP Dead Storage Volume (acre-ft)	Enter Proposed Avg. Depth (ft)	Dead Storage Surface Area (acres)	Existing Dead Storage Volume (ac-ft)	Deficient?	Volume of Deficient Dead Stroage (ac-ft)	Wetland Type(s)	Land Uses
SB18-25	0.23	0.77	74	80	2.5	1.2	29.73	3.09	41.00	0.08	0.00	YES	3.09	Manage 2	Single Family
SB18-26	0.16	0.84	71	76	3.2	1.0	18.08	1.45	42.00	0.03	0.00	YES	1.45	No Wetland	Single Family
SB18-27	0.11	0.89	73	76	3.1	0.9	44.07	3.33	43.00	0.08	15.41	NO	-12.09		
SB18-28	0.08	0.92	73	75	3.3	0.8	18.54	1.24	44.00	0.03	0.00	YES	1.24	No Wetland	Open and Single Family
SB18-29	0.45	0.55	75	85	1.7	1.8	94.27	13.97	45.00	0.31	16.32	NO	-2.35		
SB18-30	0.54	0.46	75	88	1.4	2.0	14.52	2.38	46.00	0.05	0.00	YES	2.38	No Wetland	Single Family

*CN_{perv} includes indirectly connected impervious surfaces (e.g., rooftops)

** SRO (inches) = Imp Frac * (P - (Imp Depression)) + ((P - 0.2S)^2/(P+0.8S))*Perv Frac

P = 2.50 Inches

Imp Depression = 0.02 Inches

S = $1000/CN_{perv}$-10

Watersheds where a NURP pond could be added or improved if land space and wetland type are appropriate.

Gervais Lake MPCA/NURP Wet Detention Volumes (Required per MPCA/NURP)

(Full Development Watershed Land Use Conditions)

Watershed	Impervious Fraction	Pervious Fraction	Perv. CN*	Watershed Composite CN*	Potential Abstraction	Watershed Runoff** 2.5" Storm (One-year event)	Watershed Area (acres)	Required NURP Dead Storage Volume (acre-ft)	Enter Proposed Avg. Depth (ft)	Required Dead Storage Surface Area (acres)	Existing Dead Storage Volume (ac-ft)	Deficient?	Volume of Deficient Dead Stroage (ac-ft)	Wetland Type(s)	Land Uses
CD16-01	0.31	0.69	65	75	5.4	1.0	19.29	1.56	4.00	0.39	0.00	YES	1.56	No Wetland	Multi Family
CD16-02	0.33	0.67	82	87	1.5	1.7	119.25	16.81	4.00	4.20	0.03	YES	16.78	Utilize	Single and Multi Family
CD16-03	0.33	0.67	69	79	2.7	1.4	165.81	19.02	4.00	4.76	0.00	YES	19.02	No Wetland	Hwy and Single Family
CD16-04	0.15	0.85	76	79	2.6	1.1	48.99	4.49	4.00	1.12	0.71	YES	3.78	Utilize	Single Family and Open
CD16-05	0.38	0.62	76	84	1.9	1.7	515.87	71.02	4.00	17.76	22.99	YES	48.03	Utilize	Industrial and Multi Family
CD16-06	0.61	0.40	84	92	0.8	2.2	21.83	3.96	4.00	0.99	0.92	YES	3.05	Protect	Commercial
CD16-07	0.31	0.69	74	82	2.3	1.4	50.90	6.12	4.00	1.53	4.63	YES	1.49	Protect and Manage 1	Open and Multi Family
CD16-09	0.35	0.65	61	74	3.5	1.3	159.39	16.69	4.00	4.17	0.00	YES	16.69	Utilize	Single Family, Commercial and Open
CD16-10	0.34	0.66	76	84	1.9	1.6	33.98	4.45	4.00	1.11	2.54	YES	1.92	Manage 1	Commercial and Single Family
CD16-11	0.45	0.55	68	81	2.3	1.6	167.66	22.86	4.00	5.72	43.47	NO	-20.61		
CD16-12	0.31	0.69	61	73	3.8	1.1	27.07	2.59	4.00	0.65	0.00	YES	2.59	No Wetland	Hwy , Open and Single Family
CD16-13	0.15	0.85	57	63	5.8	0.6	52.48	2.53	4.00	0.63	0.00	YES	2.53	No Wetland	School and Open
CD16-14	0.29	0.71	72	80	2.5	1.4	122.36	13.77	4.00	3.44	1.48	YES	12.29	Protect	School and Single Family
CD16-15	0.22	0.78	64	71	4.0	0.9	63.45	4.92	4.00	1.23	48.23	NO	-43.31		
CD16-16	0.29	0.71	70	78	2.8	1.3	39.82	4.28	4.00	1.07	28.88	NO	-24.60		
CD16-17	0.12	0.88	71	74	3.5	0.8	77.25	5.36	4.00	1.34	0.00	YES	5.36	No Wetland	Open and Single Family
CD16-18	0.12	0.88	71	74	3.5	0.8	77.25	5.36	4.00	1.34	22.95	NO	-17.59		
CD16-19	0.15	0.85	67	71	4.0	0.8	29.09	1.94	4.00	0.48	0.00	YES	1.94	Manage 2	Single Family
GERV-01	0.21	0.80	74	79	2.6	1.2	141.72	14.00	4.00	3.50	22.34	NO	-8.34		
GERV-02	0.13	0.87	81	83	2.0	1.3	111.66	11.70	4.00	2.93	52.86	NO	-41.16		
GERV-03	0.12	0.88	81	83	2.1	1.2	105.02	10.67	4.00	2.67	1.35	YES	9.32	Protected	Open and Single Family
GERV-04	0.16	0.86	69	74	3.6	0.9	129.61	9.40	4.00	2.35	0.00	YES	9.40		
GERV-05	0.18	0.82	77	80	2.4	1.2	70.09	6.96	4.00	1.74	0.00	YES	6.96	Manage 1, Manage 2 and Utilize	Single Family
GERV-06	0.11	0.89	76	78	2.8	1.0	41.90	3.41	4.00	0.85	0.76	YES	2.65	Manage 1	Single Family and Open
KOHL-04	0.11	0.89	69	73	3.8	0.8	34.45	2.20	4.00	0.55	0.00	YES	2.20	No Wetland	Open and Single Family
TWIN-1	0.21	0.79	72	77	2.9	1.1	57.67	5.36	4.00	1.34	126.46	NO	-121.10		
TWIN-2	0.15	0.85	67	72	4.0	0.8	33.91	2.26	4.00	0.57	0.00	YES	2.26	No Wetland	Multi Family and Open
TWIN-3	0.08	0.92	71	73	3.6	0.7	86.41	5.32	4.00	1.33	1058.16	NO	-1052.84		
TWIN-4	0.04	0.96	76	77	3.0	0.8	48.31	3.20	4.00	0.80	0.00	YES	3.20	Protect and Manage 1	Open and Single Family

*CN_{perv} includes indirectly connected impervious surfaces (e.g., rooftops)

** SRO (inches) = Imp Frac * (P - (Imp Depression)) + ((P - 0.2S)^2/(P+0.8S))*Perv Frac

P = 2.50 Inches

Imp Depression = 0.02 Inches

$S = 1000/CN_{perv}-10$

Watersheds where a NURP pond could be added or improved if land space and wetland type are appropriate.

Keller Lake MPCA/NURP Wet Detention Volumes (Required per MPCA/NURP)

(Full Development Watershed Land Use Conditions)

Watershed	Impervious Fraction	Pervious Fraction	Perv. CN*	Watershed Composite CN*	Potential Abstraction	Watershed Runoff** 2.5" Storm (One-year event)	Watershed Area (acres)	Required NURP Dead Storage Volume (acre-ft)	Enter Proposed Avg. Depth (ft)	Dead Storage Surface Area (acres)	Existing Dead Storage Volume (ac-ft)	Deficient?	Volume of Deficient Dead Stroage (ac-ft)	Wetland Type(s)	Land Uses
KELL-02	0.13	0.87	73	77	3.6	0.8	43.32	3.00	4.00	0.75	0.00	YES	3.00	Manage 2	Single Family
KELL-03	0.37	0.63	73	83	2.1	1.6	53.22	6.93	4.00	1.73	0.00	YES	6.93	Utilize	Commercial, Single Family, Hwy, and Open
KELL-03B	0.26	0.74	71	78	2.8	1.2	332.63	33.76	4.00	8.44	Lake	NO	#VALUE!		
KELL-04	0.48	0.52	73	85	1.7	1.8	130.09	19.66	4.00	4.91	23.03	NO	-3.37		
KELL-05	0.21	0.79	72	77	2.9	1.1	30.99	2.91	4.00	0.73	11.48	NO	-8.57		
KELL-06	0.19	0.81	74	79	2.7	1.1	578.47	54.87	4.00	13.72	35.07	YES	19.80	Protect	Single Family, Commercial, and Open
KELL-07	0.07	0.93	65	67	4.9	0.5	45.92	1.96	4.00	0.49	0.00	YES	1.96	No Wetland	Golf Course and Single Family
KELL-08	0.12	0.88	72	75	3.3	0.9	35.69	2.57	4.00	0.64	0.00	YES	2.57	Manage 1 and Protect	Single Family and Open
KELL-09	0.26	0.74	66	75	3.4	1.1	126.91	11.70	4.00	2.93	39.30	NO	-27.60		

*CN_{perv} includes indirectly connected impervious surfaces (e.g., rooftops)

** SRO (inches) = Imp Frac * (P - (Imp Depression)) + ((P - 0.2S)^2/(P+0.8S))*Perv Frac

P = 2.50 Inches

Imp Depression = 0.02 Inches

$S = 1000/CN_{perv} - 10$

Watersheds where a NURP pond could be added or improved if land space and wetland type are appropriate.

Phalen Lake MPCA/NURP Wet Detention Volumes (Required per MPCA/NURP)

(Full Development Watershed Land Use Conditions)

Watershed	Impervious Fraction	Pervious Fraction	Perv. CN*	Watershed Composite CN*	Potential Abstraction	Watershed Runoff** 2.5" Storm (One-year event)	Watershed Area (acres)	Required NURP Dead Storage Volume (acre-ft)	Enter Proposed Avg. Depth (ft)	Dead Storage Surface Area (acres)	Existing Dead Storage Volume (ac-ft)	Deficient?	Volume of Deficient Dead Stroage (ac-ft)	Wetland Type(s)	Land Uses
PHAL-01	0.39	0.61	75	84	3.3	1.4	22.69	2.61	4.00	0.65	0.90	YES	1.71	Utilize	Multi Family and Open
PHAL-02	0.20	0.80	75	80	2.6	1.2	26.73	2.65	4.00	0.66	0.88	YES	1.76	Utilize	Single Family and Open
PHAL-03	0.22	0.78	69	76	3.2	1.1	440.23	39.76	4.00	9.94	66.64	NO	-26.88		
PHAL-04	0.24	0.76	70	77	3.0	1.2	382.33	36.83	4.00	9.21	11.16	YES	25.67	Manage 2 and Utilize	Golf Course, Single Family and Commercial
PHAL-05	0.15	0.85	72	76	3.2	1.0	28.37	2.27	4.00	0.57	0.99	YES	1.29	Utilize	Single Family and Open
PHAL-06	0.17	0.83	71	76	3.2	1.0	136.39	11.21	4.00	2.80	0.00	YES	11.21	No Wetland	Single Family
PHAL-07	0.09	0.91	60	63	5.8	0.5	149.26	5.60	4.00	1.40	0.00	YES	5.60		
PHAL-07R	0.11	0.89	67	70	4.2	0.7	191.32	10.98	4.00	2.74	66.87	NO	-55.89		
PHAL-08	0.23	0.77	71	77	3.0	1.1	184.87	17.64	4.00	4.41	0.53	YES	17.10	No Wetland	Single Family
PHAL-08L	0.26	0.74	77	83	2.1	1.4	17.39	2.04	4.00	0.51	14.04	NO	-12.00		
PHAL-09	0.19	0.81	71	76	3.2	1.0	64.54	5.50	4.00	1.38	0.00	YES	5.50	No Wetland	Single Family
PHAL-10	0.21	0.79	71	76	3.1	1.1	120.48	10.82	4.00	2.71	0.00	YES	10.82	No Wetland	Single Family
PHAL-11	0.00	1.00	53	53	8.8	0.1	34.31	0.16	4.00	0.04	0.00	YES	0.16	No Wetland	Golf Course
PHAL-12	0.23	0.77	69	75	3.3	1.1	71.57	6.47	4.00	1.62	0.00	YES	6.47	Utilize	Single Family, Golf Course, and Park
PHAL-13	0.21	0.80	70	75	3.3	1.0	107.14	9.27	4.00	2.32	0.00	YES	9.27	No Wetland	Single Family
PHAL-14	0.00	1.00	53	53	8.7	0.1	26.88	0.13	4.00	0.03	0.00	YES	0.13	Utilize	Golf Course
PHAL-15	0.13	0.87	72	76	3.2	0.9	25.87	1.96	4.00	0.49	0.00	YES	1.96	Manage 1	Single Family and Open
PHAL-16	0.16	0.84	69	74	3.5	0.9	343.26	25.96	4.00	6.49	0.54	YES	25.42	Utilize	Golf Course, Single Family, and Open

*CN_{perv} includes indirectly connected impervious surfaces (e.g., rooftops)

** SRO (inches) = Imp Frac * (P - (Imp Depression)) + ((P - 0.2S)^2/(P+0.8S))*Perv Frac

P =	2.50	Inches
Imp Depression =	0.02	Inches

$S = 1000/CN_{perv} - 10$

Watersheds where a NURP pond could be added or improved if land space and wetland type are appropriate.

Appendix H

Results of Macrophyte Surveys Conducted in the Phalen Chain of Lakes in 2003

Appendix I

Recent MDNR Fisheries Surveys of the Phalen Chain of Lakes

Shortcuts: go!

Site Map | Contact the DNR | What's New? | Newsroom | Events | Search

MN DNR Home > Lake Finder >

Lake information report

PRINTABLE VERSION

Name: KOHLMAN

Nearest Town: MAPLEWOOD
Primary County: Ramsey

Survey Date: 08/14/2000
Inventory Number: 62-0006-00

Public Access Information

Ownership	Type	Description
Unknown	Unknown	No designated public accessroad & channel from Lk Gervais.

Lake Characteristics

Lake Area (acres): 74.00
Littoral Area (acres): 74.00
Maximum Depth (ft): 9.00
Water Clarity (ft): 1.50

Dominant Bottom Substrate: N/A
Abundance of Aquatic Plants: N/A
Maximum Depth of Plant Growth (ft): N/A

Did you know? Minnesota has 11,482 lakes 10 acres or larger, of which 5,483 are fishing lakes. Excluding Lake Superior, the state has 3.8 million acres of fishing water. Minnesota's portion of Lake Superior is 1.4 million acres.

Fish Sampled up to the 2000 Survey Year

Species	Gear Used	Number of fish per net: Caught	Number of fish per net: Normal Range	Average Fish Weight (lbs)	Normal Range (lbs)
Black Crappie	Trap net	2.1	1.3 - 27.7	0.25	0.1 - 0.4
Bluegill	Trap net	86.7	2.8 - 43.3	0.14	0.1 - 0.3
Common Carp	Trap net	0.4	0.4 - 2.9	4.38	1.4 - 4.5
Golden Shiner	Trap net	0.1	0.4 - 3.9	0.12	0.1 - 0.1
Pumpkinseed Sunfish	Trap net	0.6	0.8 - 9.3	0.08	0.1 - 0.2
Snapping Turtle	Trap net	0.6	N/A - N/A	ND	N/A - N/A

Softshell Turtle	Trap net	1.3	N/A - N/A	ND	N/A - N/A
Walleye	Trap net	0.3	0.3 - 1.3	2.93	0.7 - 2.2
Yellow Bullhead	Trap net	0.3	0.3 - 4.2	0.76	0.5 - 0.8

Normal Ranges represent typical catches for lakes with similar physical and chemical characteristics.

Length of Selected Species Sampled for All Gear for the 2000 Survey Year

	Number of fish caught in each category (inches)								
Species	***0-5***	***6-8***	***9-11***	***12-14***	***15-19***	***20-24***	***25-29***	***>29***	***Total***
Black Crappie	3	11	1	0	0	0	0	0	15
Bluegill	122	135	0	0	0	0	0	0	257
Pumpkinseed Sunfish	4	0	0	0	0	0	0	0	4
Walleye	0	0	1	0	0	1	0	0	2
Yellow Bullhead	0	0	1	1	0	0	0	0	2

For the record, the largest ***Longnose Gar*** *taken in Minnesota weighed 16 lbs., 12 oz. and was caught by:*

Who: Doug Fullerton, Maplewood, MN
Where: St. Croix River, Prescott
When: 5/4/82.
Statistics: 53" length, 16.5" girth

Fish Consumption Advisory

No fish consumption information is available for this lake. For more information, see the "Fish Consumption Advice" pages at the Minnesota Department of Health.

Status of the Fishery (as of 08/14/2000)

Kohlman Lake is the headwater lake in a chain of five lakes, including Gervais, Keller, Round, and Phalen. Access for the public is available via the channel to Gervais Lake.

Over 95% of the fish captured were bluegill. Half of the fish were between 6 and 7 inches, with a few over 7 inches. Growth was above average for this type of lake.

A few black crappie were captured, with nearly 50% over 8 inches long. Pumpkinseed sunfish, carp, walleye, yellow bullhead, and golden shiner were all captured in low numbers (maximum of 4 fish/species).

For Additional Information

Area Fisheries Supervisor:

1200 WARNER ROAD
ST. PAUL, MN 55106
(651) 772-7950

Lake maps can be obtained from:

Minnesota Bookstore
660 Olive Street
St. Paul, MN 55155
(651) 297-3000 or (800) 657-3757
To order, use C1224 for the map-id.

General DNR Information:

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(651) 296-6157 or (888) MINNDNR
TDD: (651) 296-5484 or (800) 657-3929
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Turn in Poachers (TIP):

Toll-free: (800) 652-9093

Main Categories: Outdoor Activities | Regulations, Licenses, Permits | Natural Resources | Education & Safety | About the DNR | Maps | Publications | Employment | Volunteering | Technical & Financial Assistance | Public Input

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Lake information report

PRINTABLE VERSION

Name: GERVAIS

Nearest Town: LITTLE CANADA
Primary County: Ramsey

Survey Date: 08/07/2000
Inventory Number: 62-0007-00

Public Access Information

Ownership	Type	Description
County	Concrete	COUNTY OWNED ACCESS ON ADJACENT SPOON LAKE PROVIDES NAVIGABLE ACCESS TO GERVAIS.
County	Unknown	Swimming beach, southwest shore of the lake.

Lake Characteristics

Lake Area (acres): 234.00
Littoral Area (acres): 91.00
Maximum Depth (ft): 41.00
Water Clarity (ft): 6.50

Dominant Bottom Substrate: N/A
Abundance of Aquatic Plants: N/A
Maximum Depth of Plant Growth (ft): N/A

Did you know? Much of Minnesota's fisheries program is reimbursed by the Federal Aid in Sport Fish Restoration Program (federal excise tax), administered by the U.S. Fish and Wildlife Service.

Fish Sampled up to the 2000 Survey Year

		Number of fish per net			
Species	Gear Used	Caught	Normal Range	Average Fish Weight (lbs)	Normal Range (lbs)
Black Crappie	Gill net	1.7	2.5 - 16.5	0.24	0.1 - 0.3
	Trap net	2.9	1.8 - 21.2	0.24	0.2 - 0.3
Bluegill	Gill net	13.5	N/A - N/A	0.15	N/A - N/A
	Trap net	86.9	7.5 - 62.5	0.14	0.1 - 0.3
Common Carp	Trap net	1.1	0.4 - 2.0	6.72	2.6 - 6.0

Golden Shiner	Gill net	0.3	0.3 - 1.5	0.18	0.1 - 0.1
Hybrid Sunfish	Gill net	0.2	N/A - N/A	0.11	N/A - N/A
	Trap net	0.4	N/A - N/A	0.09	N/A - N/A
Largemouth Bass	Gill net	0.5	0.3 - 0.8	1.01	0.4 - 1.0
Northern Pike	Gill net	0.2	1.5 - 7.3	3.69	2.0 - 3.5
	Trap net	0.1	N/A - N/A	9.48	N/A - N/A
Pumpkinseed Sunfish	Gill net	0.3	N/A - N/A	0.10	N/A - N/A
	Trap net	0.1	0.7 - 4.2	0.20	0.1 - 0.2
Snapping Turtle	Trap net	0.3	N/A - N/A	ND	N/A - N/A
Softshell Turtle	Trap net	0.4	N/A - N/A	ND	N/A - N/A
Tiger Muskellunge	Gill net	0.2	N/A - N/A	8.16	N/A - N/A
Walleye	Gill net	3.5	1.2 - 6.3	1.49	1.2 - 2.7
	Trap net	0.4	0.3 - 1.2	1.06	0.8 - 2.8
White Sucker	Gill net	3.3	0.4 - 2.2	ND	1.5 - 2.4
Yellow Bullhead	Trap net	0.3	0.9 - 5.7	0.10	0.5 - 0.8
Yellow Perch	Gill net	8.0	2.0 - 27.9	0.13	0.1 - 0.2
	Trap net	0.9	0.3 - 1.7	0.11	0.1 - 0.2

Normal Ranges represent typical catches for lakes with similar physical and chemical characteristics.

Length of Selected Species Sampled for All Gear for the 2000 Survey Year

	Number of fish caught in each category (inches)								
Species	***0-5***	***6-8***	***9-11***	***12-14***	***15-19***	***20-24***	***25-29***	***>29***	***Total***
Black Crappie	3	30	0	0	0	0	0	0	33
Bluegill	128	147	0	0	0	0	0	0	275
Hybrid Sunfish	4	0	0	0	0	0	0	0	4
Largemouth Bass	0	0	2	0	1	0	0	0	3
Northern Pike	0	0	0	0	0	0	1	1	2
Pumpkinseed Sunfish	2	1	0	0	0	0	0	0	3
Tiger Muskellunge	0	0	0	0	0	0	0	1	1
Walleye	0	0	10	3	5	6	0	0	24
Yellow Bullhead	1	1	0	0	0	0	0	0	2
Yellow Perch	3	42	0	0	0	0	0	0	45

*For the record, the largest **Lake Whitefish** taken in Minnesota weighed 12 lbs., 4.5 oz. and was caught by:*

Who: Darryl L. Peterson, St. Paul, MN
Where: Leech Lake near Walker
When: 3/21/99.
Statistics: 28.5" length, 20" girth

Fish Stocked by Species for the Last Five Years

Year	Species	Age	Number
1997	*Tiger Muskellunge*	Fingerling	260
1998	*Walleye*	Fingerling	3,800
2000	*Tiger Muskellunge*	Fingerling	103
	Walleye	Fingerling	4,040
2001	*Tiger Muskellunge*	Fingerling	125
2002	*Walleye*	Fingerling	2,944

Fish Consumption Advisory

Meal Advice for Pregnant Women, Women who may become pregnant and Children under age 15

Species	less than 15"	15" to 20"	20" to 25"	25" to 30"	greater than 30"
Bluegill Sunfish	◔				
Carp			◔	◔	
Northern Pike			◔	◑	
Walleye		◑	◑		

Meal Advice for the General Population

Species	less than 15"	15" to 20"	20" to 25"	25" to 30"	greater than 30"
Bluegill Sunfish	○				
Carp			○	◧	
Northern Pike			◔	◔	
Walleye		◔	◔		

Symbol Key	unlimited	1 meal per week	1 meal per month	1 meal every 2 months	do not eat
Mercury	○	◔	◑		●
PCBs	□	◧	◩	⬒	■

Status of the Fishery (as of 08/07/2000)

Gervais Lake is the largest of a chain of five lakes located in the cities of Little Canada and St. Paul. The chain of lakes includes, from upstream to down, Kohlman (74 acres), Gervais (234 acres), Keller (82 acres), Round (20 acres) and Phalen (198 acres). Boat access to Kohlman, Gervais, and Keller is from a Ramsey County Park on a subbasin of Keller Lake (Spoon Lake). The access has parking for 10 vehicle/trailer combinations.

Bluegill were the most abundant fish captured in this assessment, making up 42% of the gillnet catch and 93% of the trapnet catch. Over half of the fish were between 6 and 7 inches long, with few over 7 inches. All fish captured were 4 years old or less and exhibited good growth.

Black crappie captured were small, with few over 8 inches long. Numbers were below average for this type of lake and near historic lows for netting done on this lake.

Walleye were caught in numbers of 3.50/gillnet, the second highest ever for this lake and the highest since stocking started in 1994. All fish were age 2 or 4, matching stockings in 1998 and 1996. Over one-third of the fish were at least 20 inches long.

Largemouth bass were captured in moderate numbers during daytime electrofishing. Most were small, however some 15 and 16 inch fish were measured.

Northern pike were low in number, with only two fish captured (25.55 and 34.92 inches).

One tiger muskellunge was captured, measuring 32.68 inches and age III, matching the 1997 stocking.

White sucker were captured in good numbers for this type of lake and near the median of historic catches in Gervais Lake. Yellow perch numbers, after reaching historic highs in 1995, dropped to near the historic median for the lake. Golden shiner were present in low numbers.

Yellow bullhead were present in low numbers, with only two fish captured. No black bullhead were captured, the first time this species was not found in the lake.

For Additional Information

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E-Mail: info@dnr.state.mn.us

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Lake information report

PRINTABLE VERSION

Name: KELLER

Nearest Town: MAPLEWOOD
Primary County: Ramsey

Survey Date: 07/09/2001
Inventory Number: 62-0010-00

Public Access Information

Ownership	Type	Description
County	Concrete	County owned access is located on the west shore of the lake. County park surrounds all of Spoon Lake.

Lake Characteristics

Lake Area (acres): 72.00
Littoral Area (acres): 72.00
Maximum Depth (ft): 8.00
Water Clarity (ft): 2.00

Dominant Bottom Substrate: N/A
Abundance of Aquatic Plants: N/A
Maximum Depth of Plant Growth (ft): N/A

Did you know? Much of Minnesota's fisheries program is reimbursed by the Federal Aid in Sport Fish Restoration Program (federal excise tax), administered by the U.S. Fish and Wildlife Service.

Fish Sampled up to the 2001 Survey Year

		Number of fish per net			
Species	**Gear Used**	**Caught**	**Normal Range**	**Average Fish Weight (lbs)**	**Normal Range (lbs)**
Black Bullhead	Trap net	0.8	2.5 - 70.2	0.73	0.1 - 0.5
Black Crappie	Trap net	9.0	1.3 - 27.7	0.14	0.1 - 0.4
Bluegill	Trap net	164.0	2.8 - 43.3	0.16	0.1 - 0.3
Common Carp	Trap net	0.5	0.4 - 2.9	6.91	1.4 - 4.5
Golden Shiner	Trap net	0.5	0.4 - 3.9	0.19	0.1 - 0.1
Hybrid Sunfish	Trap net	0.3	N/A - N/A	0.15	N/A - N/A

Largemouth Bass	Trap net	0.5	0.2 - 1.1	1.08	0.3 - 1.0
Pumpkinseed Sunfish	Trap net	1.3	0.8 - 9.3	0.07	0.1 - 0.2
Walleye	Trap net	0.8	0.3 - 1.3	2.64	0.7 - 2.2
White Sucker	Trap net	1.5	0.2 - 2.2	2.13	1.0 - 2.0
Yellow Bullhead	Trap net	0.7	0.3 - 4.2	1.08	0.5 - 0.8
Yellow Perch	Trap net	1.0	0.4 - 3.5	0.12	0.1 - 0.2

Normal Ranges represent typical catches for lakes with similar physical and chemical characteristics.

Length of Selected Species Sampled for All Gear for the 2001 Survey Year

	Number of fish caught in each category (inches)								
Species	***0-5***	***6-8***	***9-11***	***12-14***	***15-19***	***20-24***	***25-29***	***>29***	***Total***
Black Bullhead	0	0	4	1	0	0	0	0	5
Black Crappie	35	19	0	0	0	0	0	0	54
Bluegill	106	111	0	0	0	0	0	0	217
Hybrid Sunfish	1	1	0	0	0	0	0	0	2
Largemouth Bass	1	0	1	0	1	0	0	0	3
Pumpkinseed Sunfish	8	0	0	0	0	0	0	0	8
Walleye	0	1	0	0	2	1	1	0	5
Yellow Bullhead	0	0	1	3	0	0	0	0	4
Yellow Perch	1	5	0	0	0	0	0	0	6

For the record, the largest ***Rainbow Trout*** *taken in Minnesota weighed 17 lbs., 6 oz. and was caught by:*

Who: Ottway Stuberud, Knife River, MN
Where: Knife River, Lake County
When: 1/19/74.
Statistics: 36.9" length

Fish Stocked by Species for the Last Five Years

Year	**Species**	**Age**	**Number**
2001	*Channel Catfish*	Yearling	600

Fish Consumption Advisory

No fish consumption information is available for this lake. For more information, see the "Fish Consumption Advice" pages at the Minnesota Department of Health.

Status of the Fishery (as of 07/09/2001)

Keller Lake's fish population is dominated by bluegills. They made up over 90% of the trap net catch. The average length sampled was 5.9 inches. Over 50% of the bluegills sampled were 6 inches and larger, but only 4% were larger than 7 inches. Black crappies were more numerous in this survey compared to previous years, but are still small. Their average length sampled was only 6.2 inches. Yellow perch are of average abundance but they are also small. Both black and yellow bullheads are present in low numbers in Keller Lake, but their size makes up for a lack of abundance. A few walleyes were sampled during this survey. They are not stocked in this lake, but can make their way downstream from Gervais Lake, or up stream from Lake Phalen. Largemouth bass numbers dropped since the last survey, but the average size has increased.

For Additional Information

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ST. PAUL, MN 55106
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(651) 296-6157 or (888) MINNDNR
TDD: (651) 296-5484 or (800) 657-3929
E-Mail: info@dnr.state.mn.us

Turn in Poachers (TIP):

Toll-free: (800) 652-9093

Lake information report

PRINTABLE VERSION

Name: PHALEN

Nearest Town: ST. PAUL
Primary County: Ramsey

Survey Date: 06/14/1999
Inventory Number: 62-0013-00

Public Access Information

Ownership	Type	Description
City	Concrete	South of inlet from Round Lake on NW shore
City	Unknown	Park land surrounds the lake.

Lake Characteristics

Lake Area (acres): 198.00
Littoral Area (acres): 80.00
Maximum Depth (ft): 91.00
Water Clarity (ft): 9.60

Dominant Bottom Substrate: N/A
Abundance of Aquatic Plants: N/A
Maximum Depth of Plant Growth (ft): N/A

Did you know? Minnesota has 11,482 lakes 10 acres or larger, of which 5,483 are fishing lakes. Excluding Lake Superior, the state has 3.8 million acres of fishing water. Minnesota's portion of Lake Superior is 1.4 million acres.

Fish Sampled up to the 1999 Survey Year

		Number of fish per net			
Species	**Gear Used**	**Caught**	**Normal Range**	**Average Fish Weight (lbs)**	**Normal Range (lbs)**
Black Bullhead	Trap net	0.1	0.7 - 25.7	0.45	0.3 - 0.6
Black Crappie	Gill net	1.8	2.5 - 16.5	0.11	0.1 - 0.3
	Trap net	4.6	1.8 - 21.2	0.15	0.2 - 0.3
Bluegill	Gill net	23.2	N/A - N/A	0.14	N/A - N/A
	Trap net	38.9	7.5 - 62.5	0.14	0.1 - 0.3

Golden Shiner	Trap net	1.0	0.2 - 0.8	0.13	0.1 - 0.1
Green Sunfish	Trap net	0.6	0.2 - 1.3	0.03	0.1 - 0.2
Hybrid Sunfish	Trap net	2.0	N/A - N/A	0.07	N/A - N/A
Largemouth Bass	Gill net	0.8	0.3 - 0.8	1.39	0.4 - 1.0
Northern Pike	Gill net	4.5	1.5 - 7.3	3.00	2.0 - 3.5
	Trap net	0.1	N/A - N/A	0.43	N/A - N/A
Pumpkinseed Sunfish	Gill net	0.3	N/A - N/A	0.07	N/A - N/A
	Trap net	2.6	0.7 - 4.2	0.06	0.1 - 0.2
Sauger	Gill net	0.5	N/A - N/A	1.61	N/A - N/A
Snapping Turtle	Trap net	0.2	N/A - N/A	ND	N/A - N/A
Tadpole Madtom	Trap net	0.1	N/A - N/A	0.02	N/A - N/A
Walleye	Gill net	6.7	1.2 - 6.3	1.29	1.2 - 2.7
	Trap net	0.4	0.3 - 1.2	0.45	0.8 - 2.8
White Bass	Gill net	0.2	0.3 - 3.8	0.64	N/A - N/A
White Sucker	Gill net	2.0	0.4 - 2.2	2.52	1.5 - 2.4
	Trap net	0.3	0.2 - 1.0	2.56	1.6 - 2.8
Yellow Bullhead	Gill net	0.2	0.5 - 7.5	0.54	0.5 - 0.8
	Trap net	0.6	0.9 - 5.7	0.43	0.5 - 0.8
Yellow Perch	Gill net	27.3	2.0 - 27.9	0.10	0.1 - 0.2

Normal Ranges represent typical catches for lakes with similar physical and chemical characteristics.

Length of Selected Species Sampled for All Gear for the 1999 Survey Year

	Number of fish caught in each category (inches)								
Species	***0-5***	***6-8***	***9-11***	***12-14***	***15-19***	***20-24***	***25-29***	***>29***	***Total***
Black Bullhead	0	0	1	0	0	0	0	0	1
Black Crappie	10	42	0	0	0	0	0	0	52
Bluegill	312	177	0	0	0	0	0	0	489
Green Sunfish	5	0	0	0	0	0	0	0	5
Hybrid Sunfish	18	0	0	0	0	0	0	0	18
Largemouth Bass	0	3	0	1	1	0	0	0	5
Northern Pike	0	0	0	1	2	19	5	1	28
Pumpkinseed Sunfish	25	0	0	0	0	0	0	0	25
Sauger	0	0	0	0	3	0	0	0	3
Walleye	0	1	18	9	11	5	0	0	44
White Bass	0	0	1	0	0	0	0	0	1
Yellow Bullhead	0	3	3	0	0	0	0	0	6
Yellow Perch	63	101	0	0	0	0	0	0	164

For the record, the largest ***Smallmouth Bass*** *taken in Minnesota weighed 8 lbs. and was caught by:*

Who: John Creighton, Minneapolis, MN
Where: W. Battle Lake, Otter Tail County
When: 1948.

Fish Stocked by Species for the Last Five Years

Year	Species	Age	Number
1998	*Walleye*	Fingerling	54
	Walleye	Fingerling	644
	Walleye	Fingerling	1,242
	Tiger Muskellunge	Fingerling	281
2000	*Channel Catfish*	Yearling	13,725
	Channel Catfish	Yearling	4,787
	Walleye	Fingerling	3,028
2001	*Tiger Muskellunge*	Fingerling	307
2002	*Channel Catfish*	Yearling	2,356
	Walleye	Fingerling	2,336

Fish Consumption Advisory

Meal Advice for Pregnant Women, Women who may become pregnant and Children under age 15

Species	less than 15"	15" to 20"	20" to 25"	25" to 30"	greater than 30"
Walleye	◔				

Meal Advice for the General Population

Species	less than 15"	15" to 20"	20" to 25"	25" to 30"	greater than 30"
Walleye	◔				

Symbol Key	unlimited	1 meal per week	1 meal per month	1 meal every 2 months	do not eat
Mercury	○	◔	◑		●
PCBs	□	◩	◪	◘	■

Status of the Fishery (as of 06/14/1999)

Phalen Lake is surrounded by a City of St. Paul Regional Park. Only electric motors are allowed on the lake. Over 3/4 of the fishing pressure is from the piers and shore. Walleye numbers reached a historic high in 1999, with almost 7 per gillnet. Sizes ranged from 8-24 inches. Yellow perch were moderately abundant with no large individuals sampled. Largemouth bass were common, with fish near 20 inches long captured. Northern pike were average in number with some over 30 inches long. Bluegill were abundant with a few over 7 inches long. Other sunfish species were low in number and small in size. Black crappie were few in number with none measuring 9 inches. White sucker, yellow bullhead, sauger, white bass and black bullhead were present in low numbers.

For Additional Information

Area Fisheries Supervisor:

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Appendix J

P8 Modeling of the Phalen Chain of Lakes Subwatersheds

Appendix J: P8 Modeling of the Phalen Chain of Lake Subwatersheds

This appendix provides an overview of the methodology used in the water quality modeling of the Phalen Chain of Lake's tributary subwatershed. Many figures showing the results of this modeling effort are also presented in this appendix.

J.1 P8 Urban Catchment Model Calibration

The P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds; IEP, Inc., 1990) Urban Catchment (computer) Model (Version 2.4) was used to estimate watershed flow and total phosphorus loads. The model was calibrated to monitoring data and the model results were used to estimate the water and phosphorus loads reaching each lake over a range of climatic conditions.

P8 is a useful "diagnostic" tool for evaluating and designing watershed improvements and Best Management Practices (BMPs) because it can estimate the treatment effect of several different kinds of potential BMPs. As stormwater runoff carries phosphorus across watersheds to lakes and streams, the effect of retention ponds, infiltration basins, flow splitters, etc., are incorporated, changing phosphorus loads accordingly.

P8 also uses long-term climatic data so that watersheds and BMPs can be evaluated for varying hydrologic conditions. In this study, P8 was used to generate a range of water and phosphorus loadings from each lake's subwatershed during three different water years (October 1 through September 30) with varying climatic conditions: a wet year (2001-2002: 49.7 inches of precipitation), a dry year (1988 89: 28.8 inches of precipitation), and a year with near average precipitation and temperatures (2000-2001: 39.2 inches of precipitation).

When evaluating modeling results, it is important to consider that the results are more accurate in terms of relative differences than in absolute results. The model will predict the percent difference in phosphorus reduction between various BMP options in the watershed fairly accurately. It also provides a realistic estimate of the relative differences in phosphorus and water loadings from the various subwatersheds and major inflow points to the lake. However, since runoff quality is highly variable with time and location, the values for phosphorus loadings given from the model for a specific watershed may not necessarily reflect the actual loadings. Calibration does help to improve the accuracy of absolute results, however. Various site-specific factors, such as lawn care practices, illicit point discharges and erosion due to construction or streambank failure are not accounted for in the model. The model provides values that are considered to be "typical" of the region for the watershed's respective land uses.

P8 runoff volumes and phosphorus loads were calibrated using observed flow data collected by RWMWD staff during 2002. Figure J-1 shows the locations of the monitoring stations used for each lake's subwatershed. Detailed information on the calibration parameters used for each subwatersheds P8 model can be found in the last pages of this appendix.

J.2 P8 Watershed Modeling Results

P8 modeling of the Phalen Chain tributary subwatershed generated useful data that: characterized the existing subwatershed loadings, estimated the performance of existing BMPs and indicated where future BMPs should be located. Many different types of figures were created for each lake's subwatershed to highlight different information. All of the figures presented here represent conditions during an average year of precipitation.

For example, Figure J-2 shows the different drainage districts in the Kohlman Lake subwatershed and the percent of annual TP that each drainage district contributes to the lake during an average year of precipitation. It should be noted that each drainage district's TP contribution is after any TP treatment that occurs within the drainage district.

Figure J-3 shows the cumulative percent TP removal at the terminus of every drainage area in the Kohlman Lake subwatershed under existing conditions. The term "cumulative removal" implies that the TP removed in all of the ponds and wetlands upstream of any given subwatershed is taken into account in that subwatershed's TP removal percentage.

Figure J-4 shows the cumulative percent TP removal in the Kohlman subwatershed before any of the major existing CIPs were constructed (Kohlman Basin, the PCU Environmental Learning Center and the NSP Urban Ecology Center).

Figures J-5 and J-6 show the percent of the TP load coming off of each drainage area that is soluble, under existing and pre-CIP conditions (respectively) in the Kohlman Lake subwatershed.

Figure J-7 shows the areal TP loading (lbs/acre) generated by each of Kohlman Lake's drainage areas. These values reflect the loadings in each drainage area before any treatment occurs. Subwatersheds with higher TP loadings are areas that have more impervious area.

Figures J-8 through J-13 show the same suite of figures for the Gervais Lake subwatershed. Any pre-CIP figures reflect the absence of Gervais Mill Pond and Owasso Basin.

Figures J-14 through J-17 show nearly the same suite of figures for the Keller Lake subwatershed. However, there are no pre-CIP figures because the performance of any existing CIPs in the Keller Lake subwatershed was not evaluated in this SLMP.

Figures J-18 through J-21 show the same suite of figures for the Lake Phalen subwatershed. There are no pre-CIP figures because the performance of any existing CIPs in the Lake Phalen subwatershed was not evaluated in this SLMP.

P8 Model Parameter Selection- Kohlman Lake Subwatershed

From the data that were collected for the Kohlman Lake Subwatershed, model calibration afforded the opportunity to select P8 parameters that resulted in a good fit between modeled and observed data. The parameters selected for the Kohlman Lake P8 model are discussed in the following paragraphs. P8 parameters not discussed in the following paragraphs were left at the default setting. P8 version 2.4 was used for the modeling.

Time Step, Snowmelt, & Runoff Parameters (Case-Edit-Other)

- Growing Season Range (months)—6 to 10.

- Growing Season AMC—II = 1.4 and AMC—III = 100. Selection of this factor was based upon the observation that the model accurately predicted runoff water volumes from monitored watersheds when the Antecedent Moisture Condition II was selected (i.e., curve numbers selected by the model are based upon antecedent moisture conditions). Modeled water volumes were less than observed volumes when Antecedent Moisture Condition I was selected, and modeled water volumes exceeded observed volumes when Antecedent Moisture Condition III was selected. The selected parameters tell the model to only use Antecedent Moisture Condition I when less than 1.4 inches of rainfall occur during the five days prior to a rainfall event and to only use Antecedent Moisture Condition III if more than 100 inches of rainfall occur within five days prior to a rainfall event.

Particle Composition (Case-Edit-Components)

- Particle Composition—TP Particle fraction 1 was changed to 52,800 mg/kg, and TP Particle fractions 2 through 4 were changed to 12,000 mg/kg (KOHLMAN.PAR).

Precipitation File Selection (Case—Edit—First—Precip. Data File)

- Precipitation Data File—ADJUSTED.PCP.

- Precipitation Data File description: Tanner's Lake Alum Plant Rain Gage April 11, 2002 to October 2002, MSP Airport October 2001 to April 11, 2002 (sum of hourly values, for each day, are correct; hourly values computed as a fraction of hourly values from Eden Prairie gage); 4/30/02 through 9/30/02 adjusted to match HB Fuller gage near Kohlman lake.

Air Temperature File Selection (Case—Edit—First—Air Temp. File)

- MSP4902.tmp. The temperature file was comprised of temperature data from the Minneapolis–St. Paul International Airport during the period from 1949 through 2002.

Devices Parameter Selection (Case—Edit—Devices—Data—Select Device)

- Detention Pond— Permanent Pool— Area and Volume— The surface area and dead storage volume of each detention pond was determined and entered here.

- Detention Pond— Flood Pool— Area and Volume— The surface area and storage volume under flood conditions (i.e., the storage volume between the normal level and flood elevation) was determined and entered here.

- Detention Pond— Orifice Diameter and Weir Length— The orifice diameter or weir length was determined from field surveys or development plans of the area for each detention pond and entered here.

- Detention Pond or Generalized Device— Particle Removal Scale Factor— Particle Removal Scale Factor— 0.3 for ponds less than two feet deep and 1.0 for all ponds three feet deep or greater. For ponds with normal water depths between two and three feet, a particle removal factor of 0.6 was selected. The factors were selected based on similar work in the *Round Lake Use Attainability Analysis,* Barr Engineering, March 1999.

- Detention Pond or Generalized Device— Outflow Device Nos.— The number of the downstream device receiving water from the detention pond outflow was entered.

Watersheds Parameter Selection (Case—Edit—Watersheds—Data—Select Watershed)

- Pervious Curve Number— A weighted SCS Curve number was used, as outlined in the following procedure. The Washington and Ramsey County Soil Surveys were consulted to determine the soil types within each subwatershed and a pervious curve number was selected for each subwatershed based upon soil types, land use, and hydrologic conditions (e.g., if watershed soils are type B and pervious areas are comprised of grassed areas with >75% cover, then a Curve Number of 79 would be selected). The pervious curve number was then weighted with indirect (i.e., disconnected) impervious areas in each subwatershed as follows:

$$WCN = \frac{[(Indirect\ Impervious\ Area] * (98)] + [(Pervious\ Area) * (Pervious\ Curve\ Number)]}{Total\ Area}$$

The assumptions for direct, indirect, and total impervious were based upon measurements from the Kohlman Lake Watershed and areas with similar land use.

The following assumptions shown in Table B-1, for percent impervious and percent directly connected, were used to determine the weighted curve numbers.

Table B-1 Percent Impervious and Percent Directly Connected Based on Land Use

Land Use	Percent Impervious	Percent Directly Connected
Natural/Park/Open	2	0
Developed Parks	10	0
Golf Course	5	2
Agricultural	5	0
Very Low Density Residential (< 1 unit/ac)	20	8
Low Density Residential (1-4 units/ac)	38	16
Medium Density Residential (4-8 units/ac)	65	30
High Density Residential (>8 units/ac)	75	65
Institutional	50	35
Institutional- High Impervious	70	50
Airport	85	80
Highway	65	45
Commercial	90	80
Industrial/Office	80	70
Open Water	100*	0
Wetland	90	0

* Using 100% impervious may skew model results. Therefore open water was not accounted for while determining the pervious curve number.

- Swept/Not Swept—An "Unswept" assumption was made for the entire impervious watershed area. A Sweeping Frequency of 0 was selected. Selected parameters were placed in the "Unswept" column since a sweeping frequency of 0 was selected.

- Impervious Fraction—The direct or connected impervious fraction for each subwatershed was determined and entered here. The direct or connected impervious fraction includes driveways and parking areas that are directly connected to the storm sewer system. The previous table indicates what was used to determine the direct impervious fraction for each land use type. Then, the average direct impervious fraction was determined by weighting the acres of each land use with the direct impervious fraction to obtain a weighted average.

- Scale Factor for Pervious Area Load— 2.5.

- Scale Factor for Particle Load— 1.5.

- Depression Storage— 0.03.

- Impervious Runoff Coefficient— 0.99.

Passes Through the Storm File (Case—Edit—First—Passes Through Storm File)

- Passes Through Storm File—15. The number of passes through the storm file was determined after the model had been set up and a preliminary run completed. The selection of the number of passes through the storm file was based upon the number required to achieve model stability. Multiple passes through the storm file were required because the model assumes that dead storage waters contain no phosphorus. Consequently, the first pass through the storm file results in lower phosphorus loading than occurs with subsequent passes. Stability occurs when subsequent passes do not result in a change in phosphorus concentration in the pond waters. To determine the number of passes to select, the model was run with five passes, ten passes, fifteen passes, and twenty passes. A comparison of phosphorus predictions for all devices was evaluated to determine whether changes occurred between the four scenarios. If there is no difference between ten and fifteen passes, ten passes are sufficient to achieve model stability. If differences are noted between ten and fifteen passes and no differences are noted between fifteen and twenty passes, then fifteen passes are sufficient to achieve model stability. No differences were noted between fifteen and twenty passes. Therefore, it was determined that fifteen passes through the storm file resulted in model stability for the Kohlman Lake project.

P8 Model Parameter Selection-
Gervais Lake Subwatershed

From the data that were collected for the Gervais Lake Subwatershed, model calibration afforded the opportunity to select P8 parameters that resulted in a good fit between modeled and observed data. The parameters selected for the Gervais Lake P8 model are discussed in the following paragraphs. P8 parameters not discussed in the following paragraphs were left at the default setting. P8 version 2.4 was used for the modeling.

Time Step, Snowmelt, & Runoff Parameters (Case-Edit-Other)

- Growing Season Range (months)—6 to 10.

- Growing Season AMC—II = 1.4 and AMC—III = 100. Selection of this factor was based upon the observation that the model accurately predicted runoff water volumes from monitored watersheds when the Antecedent Moisture Condition II was selected (i.e., curve numbers selected by the model are based upon antecedent moisture conditions). Modeled water volumes were less than observed volumes when Antecedent Moisture Condition I was selected, and modeled water volumes exceeded observed volumes when Antecedent Moisture Condition III was selected. The selected parameters tell the model to only use Antecedent Moisture Condition I when less than 1.4 inches of rainfall occur during the five days prior to a rainfall event and to only use Antecedent Moisture Condition III if more than 100 inches of rainfall occur within five days prior to a rainfall event.

Particle Composition (Case-Edit-Components)

- Particle Composition—TP Particle fraction 1 was decreased to 26,000 mg/kg, and TP Particle fractions 2 through 4 were decreased to 7,000 mg/kg (GERVAIS.PAR).

Precipitation File Selection (Case—Edit—First—Precip. Data File)

- Precipitation Data File—ADJUSTED.PCP.

- Precipitation Data File description: Tanner's Lake Alum Plant Rain Gage April 11, 2002 to October 2002, MSP Airport October 2001 to April 11, 2002 (sum of hourly values, for each day, are correct; hourly values computed as a fraction of hourly values from Eden Prairie gage); 4/30/02 through 9/30/02 adjusted to match HB Fuller gage near Kohlman lake.

Air Temperature File Selection (Case—Edit—First—Air Temp. File)

- MSP4902.tmp. The temperature file was comprised of temperature data from the Minneapolis–St. Paul International Airport during the period from 1949 through 2002.

Devices Parameter Selection (Case—Edit—Devices—Data—Select Device)

- Detention Pond— Permanent Pool— Area and Volume— The surface area and dead storage volume of each detention pond was determined and entered here.

- Detention Pond— Flood Pool— Area and Volume— The surface area and storage volume under flood conditions (i.e., the storage volume between the normal level and flood elevation) was determined and entered here.

- Detention Pond— Orifice Diameter and Weir Length— The orifice diameter or weir length was determined from field surveys or development plans of the area for each detention pond and entered here.

- Detention Pond or Generalized Device— Particle Removal Scale Factor— Particle Removal Scale Factor— 0.3 for ponds less than two feet deep and 1.0 for all ponds three feet deep or greater. For ponds with normal water depths between two and three feet, a particle removal factor of 0.6 was selected. The factors were selected based on similar work in the *Round Lake Use Attainability Analysis,* Barr Engineering, March 1999.

- Detention Pond or Generalized Device— Outflow Device Nos.— The number of the downstream device receiving water from the detention pond outflow was entered.

Watersheds Parameter Selection (Case—Edit—Watersheds—Data—Select Watershed)

- Pervious Curve Number— A weighted SCS Curve number was used, as outlined in the following procedure. The Washington and Ramsey County Soil Surveys were consulted to determine the soil types within each subwatershed and a pervious curve number was selected for each subwatershed based upon soil types, land use, and hydrologic conditions (e.g., if watershed soils are type B and pervious areas are comprised of grassed areas with >75% cover, then a Curve Number of 79 would be selected). The pervious curve number was then weighted with indirect (i.e., disconnected) impervious areas in each subwatershed as follows:

$$WCN = \frac{[(Indirect\ Impervious\ Area]*(98)] + [(Pervious\ Area)*(Pervious\ Curve\ Number)]}{Total\ Area}$$

The assumptions for direct, indirect, and total impervious were based upon measurements from the Gervais Lake Watershed and areas with similar land use.

The following assumptions shown in Table B-1, for percent impervious and percent directly connected, were used to determine the weighted curve numbers.

Table B-1 Percent Impervious and Percent Directly Connected Based on Land Use

Land Use	Percent Impervious	Percent Directly Connected
Natural/Park/Open	2	0
Developed Parks	10	0
Golf Course	5	2
Agricultural	5	0
Very Low Density Residential (< 1 unit/ac)	20	8
Low Density Residential (1-4 units/ac)	38	16
Medium Density Residential (4-8 units/ac)	65	30
High Density Residential (>8 units/ac)	75	65
Institutional	50	35
Institutional- High Impervious	70	50
Airport	85	80
Highway	65	45
Commercial	90	80
Industrial/Office	80	70
Open Water	100*	0
Wetland	90	0

* Using 100% impervious may skew model results. Therefore open water was not accounted for while determining the pervious curve number.

- Swept/Not Swept—An "Unswept" assumption was made for the entire impervious watershed area. A Sweeping Frequency of 0 was selected. Selected parameters were placed in the "Unswept" column since a sweeping frequency of 0 was selected.

- Impervious Fraction—The direct or connected impervious fraction for each subwatershed was determined and entered here. The direct or connected impervious fraction includes driveways and parking areas that are directly connected to the storm sewer system. The previous table indicates what was used to determine the direct impervious fraction for each land use type. Then, the average direct impervious fraction was determined by weighting the acres of each land use with the direct impervious fraction to obtain a weighted average.

- Scale Factor for Pervious Area Load— 1.
- Scale Factor for Particle Load— 1.
- Depression Storage— 0.03.
- Impervious Runoff Coefficient— 0.94.

Passes Through the Storm File (Case—Edit—First—Passes Through Storm File)

- Passes Through Storm File—15. The number of passes through the storm file was determined after the model had been set up and a preliminary run completed. The selection of the number of passes through the storm file was based upon the number required to achieve model stability. Multiple passes through the storm file were required because the model assumes that dead storage waters contain no phosphorus. Consequently, the first pass through the storm file results in lower phosphorus loading than occurs with subsequent passes. Stability occurs when subsequent passes do not result in a change in phosphorus concentration in the pond waters. To determine the number of passes to select, the model was run with five passes, ten passes, fifteen passes, and twenty passes. A comparison of phosphorus predictions for all devices was evaluated to determine whether changes occurred between the four scenarios. If there is no difference between ten and fifteen passes, ten passes are sufficient to achieve model stability. If differences are noted between ten and fifteen passes and no differences are noted between fifteen and twenty passes, then fifteen passes are sufficient to achieve model stability. No differences were noted between fifteen and twenty passes. Therefore, it was determined that fifteen passes through the storm file resulted in model stability for the Gervais Lake project.

P8 Model Parameter Selection-
Keller Lake Subwatershed

From the data that were collected for the Keller Lake Subwatershed, model calibration afforded the opportunity to select P8 parameters that resulted in a good fit between modeled and observed data. The parameters selected for the Keller Lake P8 model are discussed in the following paragraphs. P8 parameters not discussed in the following paragraphs were left at the default setting. P8 version 2.4 was used for the modeling.

Time Step, Snowmelt, & Runoff Parameters (Case-Edit-Other)

- Growing Season Range (months)—6 to 10.

- Growing Season AMC—II = 1.4 and AMC—III = 100. Selection of this factor was based upon the observation that the model accurately predicted runoff water volumes from monitored watersheds when the Antecedent Moisture Condition II was selected (i.e., curve numbers selected by the model are based upon antecedent moisture conditions). Modeled water volumes were less than observed volumes when Antecedent Moisture Condition I was selected, and modeled water volumes exceeded observed volumes when Antecedent Moisture Condition III was selected. The selected parameters tell the model to only use Antecedent Moisture Condition I when less than 1.4 inches of rainfall occur during the five days prior to a rainfall event and to only use Antecedent Moisture Condition III if more than 100 inches of rainfall occur within five days prior to a rainfall event.

Particle Composition (Case-Edit-Components)

- Particle Composition—TP Particle fraction 1 was changed to 71,900 mg/kg, and TP Particle fractions 2 through 4 were changed to 7,000 mg/kg (KELLER.PAR).

Precipitation File Selection (Case—Edit—First—Precip. Data File)

- Precipitation Data File—ADJUSTED.PCP.

- Precipitation Data File description: Tanner's Lake Alum Plant Rain Gage April 11, 2002 to October 2002, MSP Airport October 2001 to April 11, 2002 (sum of hourly values, for each day, are correct; hourly values computed as a fraction of hourly values from Eden Prairie gage); 4/30/02 through 9/30/02 adjusted to match HB Fuller gage near Kohlman lake.

Air Temperature File Selection (Case—Edit—First—Air Temp. File)

- MSP4902.tmp. The temperature file was comprised of temperature data from the Minneapolis–St. Paul International Airport during the period from 1949 through 2002.

Devices Parameter Selection (Case—Edit—Devices—Data—Select Device)

- Detention Pond— Permanent Pool— Area and Volume— The surface area and dead storage volume of each detention pond was determined and entered here.

- Detention Pond— Flood Pool— Area and Volume— The surface area and storage volume under flood conditions (i.e., the storage volume between the normal level and flood elevation) was determined and entered here.

- Detention Pond— Orifice Diameter and Weir Length— The orifice diameter or weir length was determined from field surveys or development plans of the area for each detention pond and entered here.

- Detention Pond or Generalized Device— Particle Removal Scale Factor— Particle Removal Scale Factor— 0.3 for ponds less than two feet deep and 1.0 for all ponds three feet deep or greater. For ponds with normal water depths between two and three feet, a particle removal factor of 0.6 was selected. The factors were selected based on similar work in the *Round Lake Use Attainability Analysis*, Barr Engineering, March 1999.

- Detention Pond or Generalized Device— Outflow Device Nos.— The number of the downstream device receiving water from the detention pond outflow was entered.

Watersheds Parameter Selection (Case—Edit—Watersheds—Data—Select Watershed)

- Pervious Curve Number— A weighted SCS Curve number was used, as outlined in the following procedure. The Washington and Ramsey County Soil Surveys were consulted to determine the soil types within each subwatershed and a pervious curve number was selected for each subwatershed based upon soil types, land use, and hydrologic conditions (e.g., if watershed soils are type B and pervious areas are comprised of grassed areas with >75% cover, then a Curve Number of 79 would be selected). The pervious curve number was then weighted with indirect (i.e., disconnected) impervious areas in each subwatershed as follows:

$$WCN = \frac{[(Indirect\ Impervious\ Area]*(98)] + [(Pervious\ Area)*(Pervious\ Curve\ Number)]}{Total\ Area}$$

The assumptions for direct, indirect, and total impervious were based upon measurements from the Keller Lake Watershed and areas with similar land use.

The following assumptions shown in Table B-1, for percent impervious and percent directly connected, were used to determine the weighted curve numbers.

Table B-1 Percent Impervious and Percent Directly Connected Based on Land Use

Land Use	Percent Impervious	Percent Directly Connected
Natural/Park/Open	2	0
Developed Parks	10	0
Golf Course	5	2
Agricultural	5	0
Very Low Density Residential (< 1 unit/ac)	20	8
Low Density Residential (1-4 units/ac)	38	16
Medium Density Residential (4-8 units/ac)	65	30
High Density Residential (>8 units/ac)	75	65
Institutional	50	35
Institutional- High Impervious	70	50
Airport	85	80
Highway	65	45
Commercial	90	80
Industrial/Office	80	70
Open Water	100*	0
Wetland	90	0

* Using 100% impervious may skew model results. Therefore open water was not accounted for while determining the pervious curve number.

- Swept/Not Swept—An “Unswept” assumption was made for the entire impervious watershed area. A Sweeping Frequency of 0 was selected. Selected parameters were placed in the “Unswept” column since a sweeping frequency of 0 was selected.

- Impervious Fraction—The direct or connected impervious fraction for each subwatershed was determined and entered here. The direct or connected impervious fraction includes driveways and parking areas that are directly connected to the storm sewer system. The previous table indicates what was used to determine the direct impervious fraction for each land use type. Then, the average direct impervious fraction was determined by weighting the acres of each land use with the direct impervious fraction to obtain a weighted average.

- Scale Factor for Pervious Area Load— 1.
- Scale Factor for Particle Load— 1.
- Depression Storage— 0.03.
- Impervious Runoff Coefficient— 0.90.

Passes Through the Storm File (Case—Edit—First—Passes Through Storm File)

- Passes Through Storm File—5. The number of passes through the storm file was determined after the model had been set up and a preliminary run completed. The selection of the number of passes through the storm file was based upon the number required to achieve model stability. Multiple passes through the storm file were required because the model assumes that dead storage waters contain no phosphorus. Consequently, the first pass through the storm file results in lower phosphorus loading than occurs with subsequent passes. Stability occurs when subsequent passes do not result in a change in phosphorus concentration in the pond waters. To determine the number of passes to select, the model was run with five passes, ten passes, and fifteen passes. A comparison of phosphorus predictions for all devices was evaluated to determine whether changes occurred between the three scenarios. If there is no difference between five and ten passes, five passes are sufficient to achieve model stability. If differences are noted between five and ten passes and no differences are noted between ten and fifteen passes, then ten passes are sufficient to achieve model stability. No differences were noted between five and ten passes. Therefore, it was determined that five passes through the storm file resulted in model stability for the Keller Lake project.

P8 Model Parameter Selection-
Lake Phalen Subwatershed

From the data that were collected for the Lake Phalen Subwatershed, model calibration afforded the opportunity to select P8 parameters that resulted in a good fit between modeled and observed data. The parameters selected for the Lake Phalen P8 model are discussed in the following paragraphs. P8 parameters not discussed in the following paragraphs were left at the default setting. P8 version 2.4 was used for the modeling.

Time Step, Snowmelt, & Runoff Parameters (Case-Edit-Other)

- Growing Season Range (months)—6 to 10.

- Growing Season AMC—II = 1.4 and AMC—III = 2.1. Selection of this factor was based upon the observation that the model accurately predicted runoff water volumes from monitored watersheds when the Antecedent Moisture Condition II was selected (i.e., curve numbers selected by the model are based upon antecedent moisture conditions). Modeled water volumes were less than observed volumes when Antecedent Moisture Condition I was selected, and modeled water volumes exceeded observed volumes when Antecedent Moisture Condition III was selected. The selected parameters tell the model to only use Antecedent Moisture Condition I when less than 1.4 inches of rainfall occur during the five days prior to a rainfall event and to only use Antecedent Moisture Condition III if more than 100 inches of rainfall occur within five days prior to a rainfall event.

Particle Composition (Case-Edit-Components)

- Particle Composition—TP Particle fraction 1 was changed to 51,400 mg/kg, and TP Particle fractions 2 through 4 were changed to 15,000 mg/kg (PHALEN.PAR).

Precipitation File Selection (Case—Edit—First—Precip. Data File)

- Precipitation Data File—ADJUSTED.PCP.

- Precipitation Data File description: Tanner's Lake Alum Plant Rain Gage April 11, 2002 to October 2002, MSP Airport October 2001 to April 11, 2002 (sum of hourly values, for each day, are correct; hourly values computed as a fraction of hourly values from Eden Prairie gage); 4/30/02 through 9/30/02 adjusted to match HB Fuller gage near Kohlman lake.

Air Temperature File Selection (Case—Edit—First—Air Temp. File)

- MSP4902.tmp. The temperature file was comprised of temperature data from the Minneapolis–St. Paul International Airport during the period from 1949 through 2002.

Devices Parameter Selection (Case—Edit—Devices—Data—Select Device)

- Detention Pond— Permanent Pool— Area and Volume— The surface area and dead storage volume of each detention pond was determined and entered here.

- Detention Pond— Flood Pool— Area and Volume— The surface area and storage volume under flood conditions (i.e., the storage volume between the normal level and flood elevation) was determined and entered here.

- Detention Pond— Orifice Diameter and Weir Length— The orifice diameter or weir length was determined from field surveys or development plans of the area for each detention pond and entered here.

- Detention Pond or Generalized Device— Particle Removal Scale Factor— Particle Removal Scale Factor— 0.3 for ponds less than two feet deep and 1.0 for all ponds three feet deep or greater. For ponds with normal water depths between two and three feet, a particle removal factor of 0.6 was selected. The factors were selected based on similar work in the *Round Lake Use Attainability Analysis,* Barr Engineering, March 1999.

- Detention Pond or Generalized Device— Outflow Device Nos.— The number of the downstream device receiving water from the detention pond outflow was entered.

Watersheds Parameter Selection (Case—Edit—Watersheds—Data—Select Watershed)

- Pervious Curve Number— A weighted SCS Curve number was used, as outlined in the following procedure. The Washington and Ramsey County Soil Surveys were consulted to determine the soil types within each subwatershed and a pervious curve number was selected for each subwatershed based upon soil types, land use, and hydrologic conditions (e.g., if watershed soils are type B and pervious areas are comprised of grassed areas with >75% cover, then a Curve Number of 79 would be selected). The pervious curve number was then weighted with indirect (i.e., disconnected) impervious areas in each subwatershed as follows:

$$WCN = \frac{[(Indirect\ Impervious\ Area] * (98)] + [(Pervious\ Area) * (Pervious\ Curve\ Number)]}{Total\ Area}$$

The assumptions for direct, indirect, and total impervious were based upon measurements from the Keller Lake Watershed and areas with similar land use.

The following assumptions shown in Table B-1, for percent impervious and percent directly connected, were used to determine the weighted curve numbers.

Table B-1 Percent Impervious and Percent Directly Connected Based on Land Use

Land Use	Percent Impervious	Percent Directly Connected
Natural/Park/Open	2	0
Developed Parks	10	0
Golf Course	5	2
Agricultural	5	0
Very Low Density Residential (< 1 unit/ac)	20	8
Low Density Residential (1-4 units/ac)	38	16
Medium Density Residential (4-8 units/ac)	65	30
High Density Residential (>8 units/ac)	75	65
Institutional	50	35
Institutional- High Impervious	70	50
Airport	85	80
Highway	65	45
Commercial	90	80
Industrial/Office	80	70
Open Water	100*	0
Wetland	90	0

* Using 100% impervious may skew model results. Therefore open water was not accounted for while determining the pervious curve number.

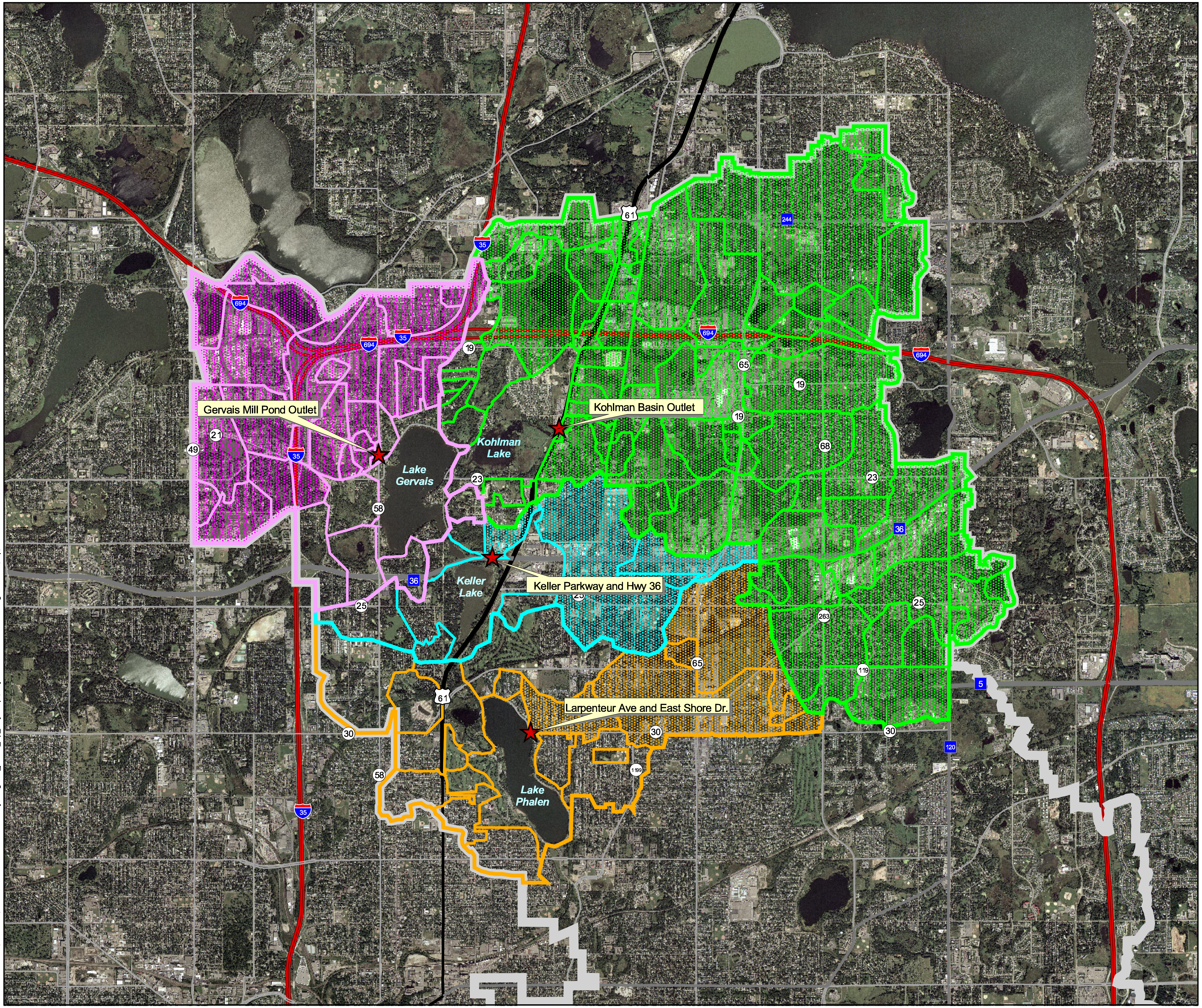
- Swept/Not Swept—An "Unswept" assumption was made for the entire impervious watershed area. A Sweeping Frequency of 0 was selected. Selected parameters were placed in the "Unswept" column since a sweeping frequency of 0 was selected.

- Impervious Fraction—The direct or connected impervious fraction for each subwatershed was determined and entered here. The direct or connected impervious fraction includes driveways and parking areas that are directly connected to the storm sewer system. The previous table indicates what was used to determine the direct impervious fraction for each land use type. Then, the average direct impervious fraction was determined by weighting the acres of each land use with the direct impervious fraction to obtain a weighted average.

- Scale Factor for Pervious Area Load— 1.
- Scale Factor for Particle Load— 1.
- Depression Storage— 0.03.
- Impervious Runoff Coefficient— 0.94.

Passes Through the Storm File (Case—Edit—First—Passes Through Storm File)

- Passes Through Storm File—10. The number of passes through the storm file was determined after the model had been set up and a preliminary run completed. The selection of the number of passes through the storm file was based upon the number required to achieve model stability. Multiple passes through the storm file were required because the model assumes that dead storage waters contain no phosphorus. Consequently, the first pass through the storm file results in lower phosphorus loading than occurs with subsequent passes. Stability occurs when subsequent passes do not result in a change in phosphorus concentration in the pond waters. To determine the number of passes to select, the model was run with five passes, ten passes, and fifteen passes. A comparison of phosphorus predictions for all devices was evaluated to determine whether changes occurred between the three scenarios. If there is no difference between five and ten passes, five passes are sufficient to achieve model stability. If differences are noted between five and ten passes and no differences are noted between ten and fifteen passes, then ten passes are sufficient to achieve model stability. No differences were noted between ten and fifteen passes. Therefore, it was determined that ten passes through the storm file resulted in model stability for the Lake Phalen project.



LEGEND

Flow Monitoring Locations

Drainage to Monitoring Locations

Lake Gervais Watershed

Kohlman Lake Watershed

Keller Lake Watershed

Lake Phalen Watershed

RWMWD Boundary

2000 0 2000 4000 6000

Scale in Feet

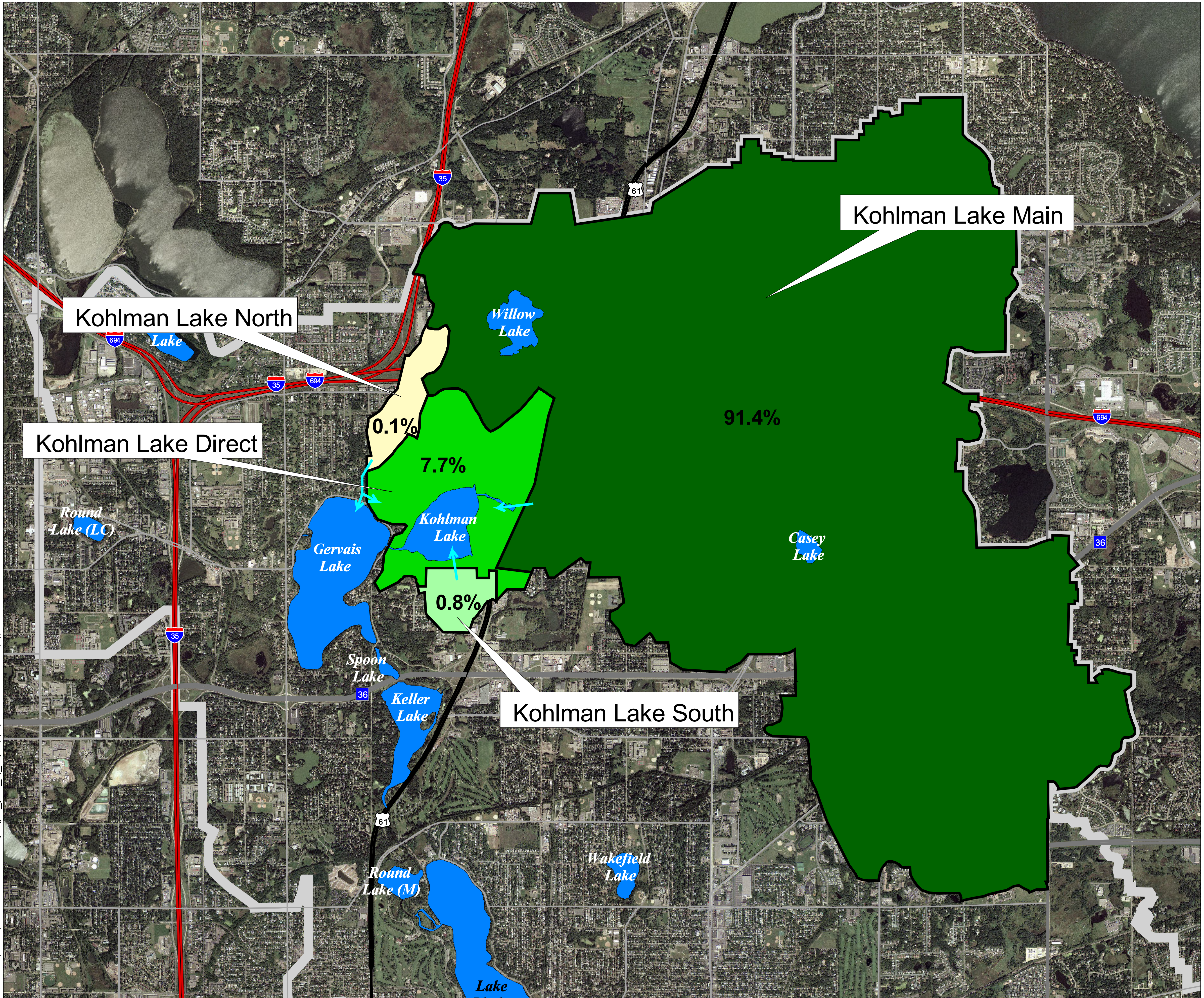
Figure J-1

FLOW MONITORING LOCATIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

Flow Direction
Lakes
Percent of TP Load
0.1 %
0.7 %
19 %
80 %
RWMWD Boundary

1500 0 1500 3000 4500
Scale in Feet

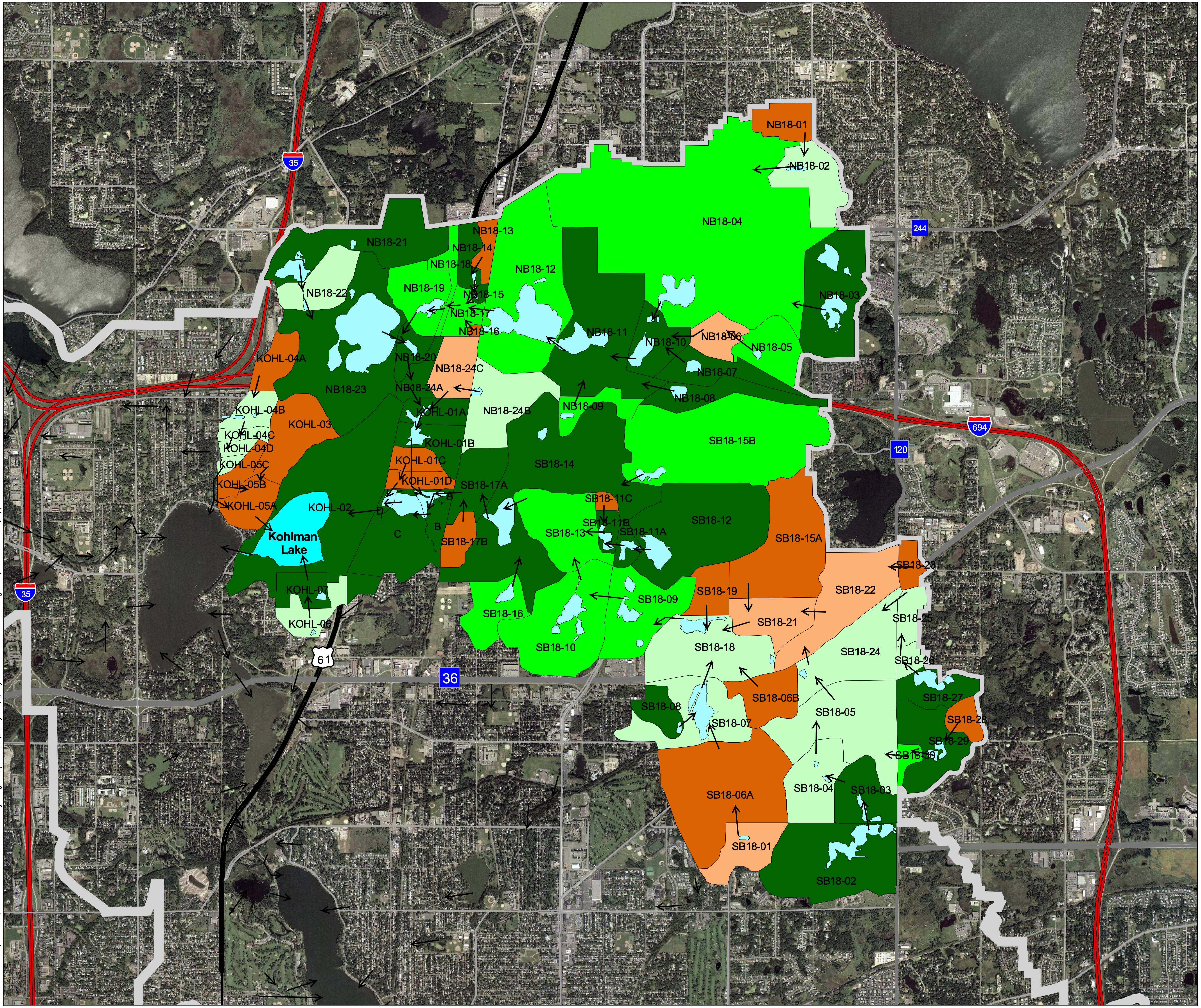
Figure J-2

KOHLMAN LAKE:
DRAINAGE DISTRICTS AND THEIR
TP CONTRIBUTIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

Flow Direction

Kohlman Lake

Ponds

Percent of Upstream Total Phosphorus Removed

0 - 20%

20 - 40%

40 - 60%

60 - 70%

> 70%

1500 0 1500 3000

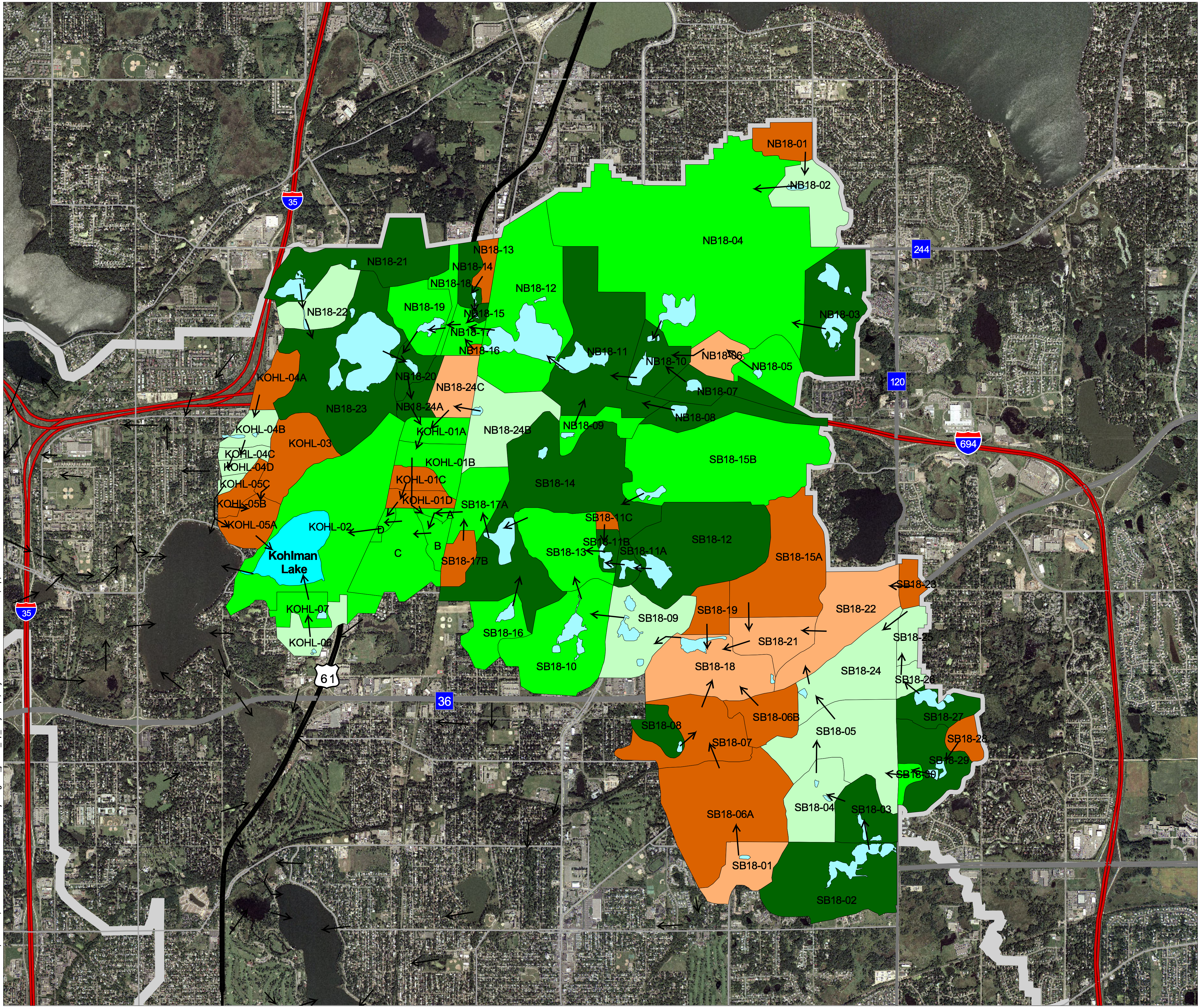
Scale in Feet

Figure J-3

KOHLMAN LAKE:
EXISTING CUMULATIVE
TOTAL PHOSPHORUS REMOVAL

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Barr: Arcview 3.3, OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_jsories_lkp_may04.apr, Layout: J-03 - Kohlman Existing Phosphorus Removal_lkp, Wed Jul 20 16:45:14 2005



Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_jsnies_lkp_may04.apr, Layout: J-04 - Kohlman Pre CIP, lkp, Wed Jul 20 16:50:37 2005

LEGEND

Flow Direction

Kohlman Lake

Ponds

Percent of Upstream Total Phosphorus Removed

0 - 20%

20 - 40%

40 - 60%

60 -70%

> 70%

1500 0 1500 3000 4500

Scale in Feet

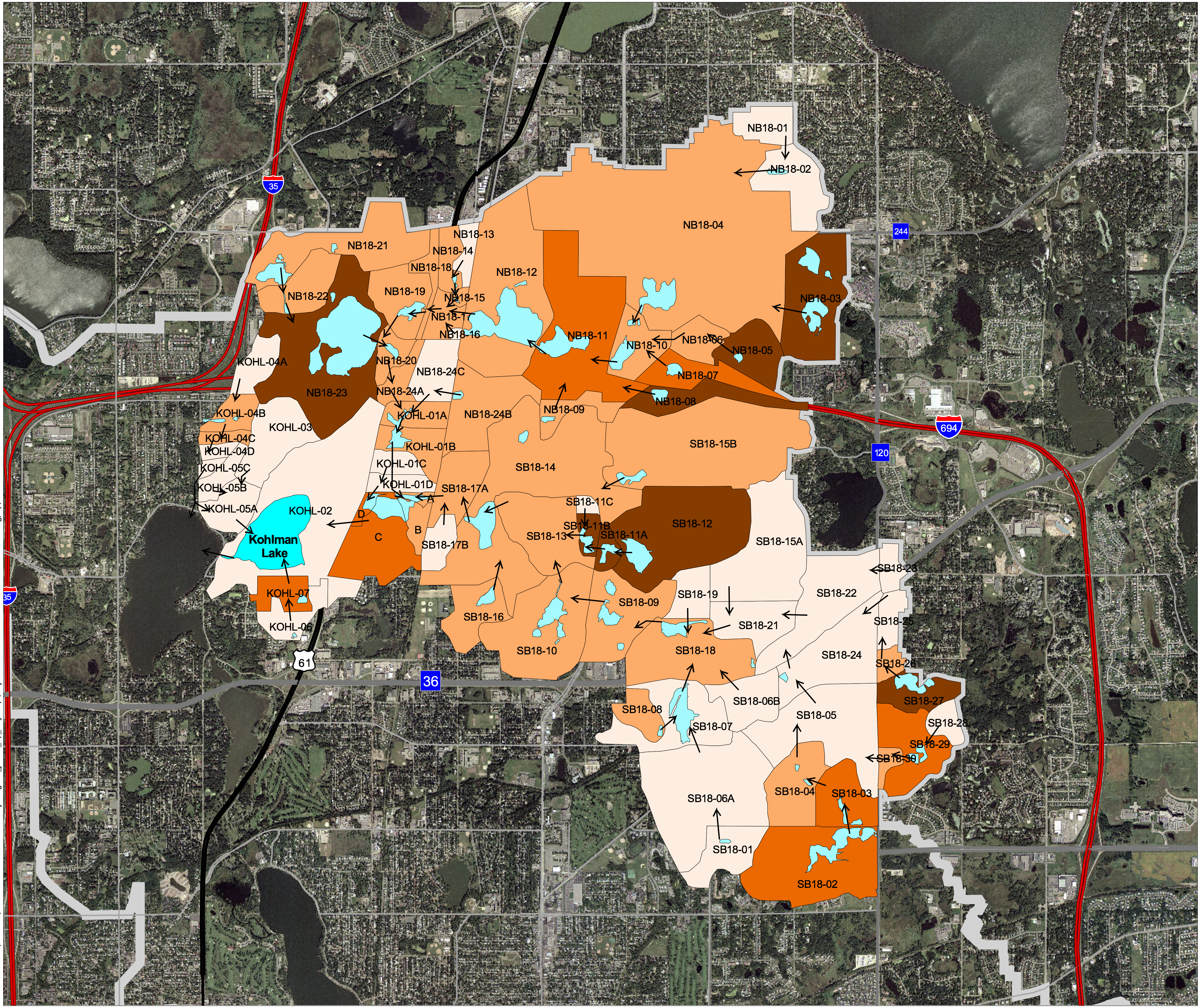
Figure J-4

KOHLMAN LAKE:
PRE-CAPITAL IMPROVEMENT PROJECT
CUMULATIVE TOTAL PHOSPHORUS REMOVAL

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

→ Flow Direction

Kohlman Lake

Ponds

Percent of Soluble Phosphorus in Outflow

- 0 - 20%
- 20 - 40%
- 40 - 60%
- > 60%

N
W E
S

1500 0 1500 3000 4500

Scale in Feet

Figure J-5

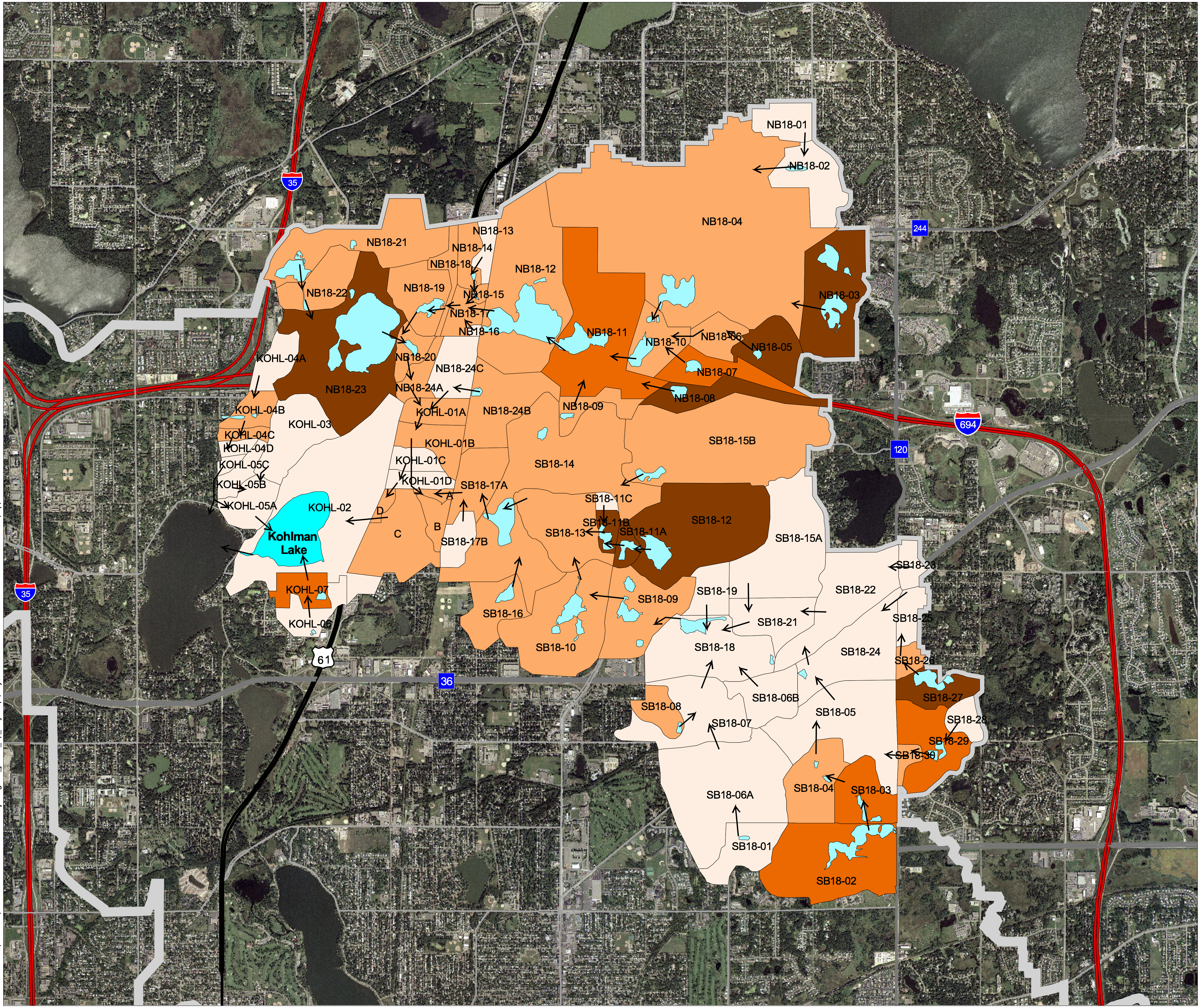
KOHLMAN LAKE:
PERCENT OF SOLUBLE
PHOSPHORUS IN OUTFLOW
EXISTING CONDITIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr: Arcview 3.3, OPT2629, I:\Client\Rwmwd\Lakes\Phalen\Project\figures_jseries_lkp_may04.apr, Layout: J-05 - Kohlman Soluble TP in Outflow - Existing, lkp, Wed Jul 20 17:03:27 2005



LEGEND

Flow Direction

Kohlman Lake

Ponds

Percent of Soluble Phosphorus in Outflow

- 0 - 20%
- 20 - 40%
- 40 - 60%
- > 60%

1500 0 1500 3000 4500

Scale in Feet

Figure J-6

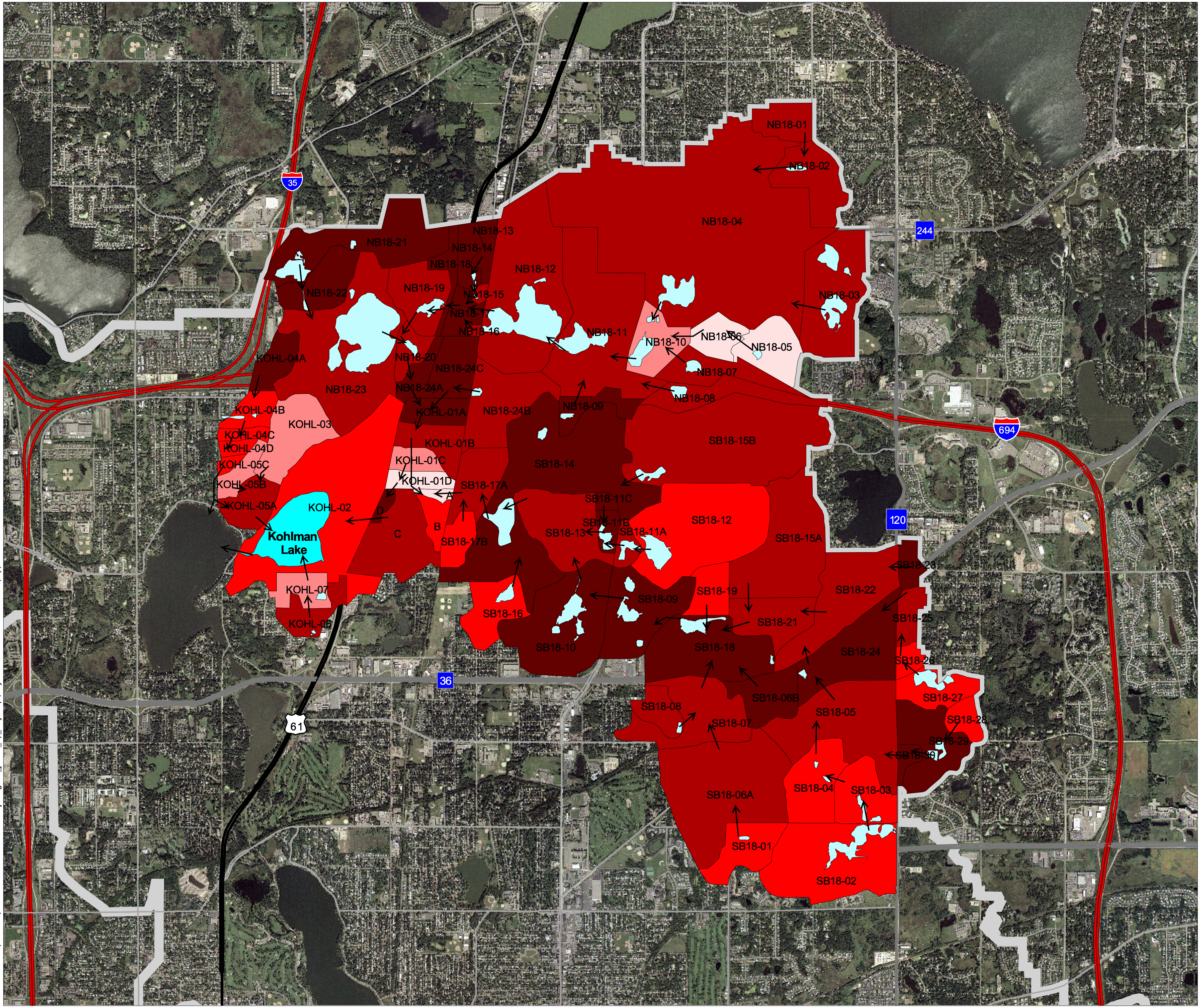
KOHLMAN LAKE:
FRACTION OF SOLUBLE
PHOSPHORUS IN OUTFLOW
PRE-CAPITAL IMPROVEMENT
PROJECT CONDITIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr: Arcview 3.3, OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_jseries_lkp_may04.apr, Layout: J-06 - Kohlman Soluble TP in Outflow - Pre-CIP, lkp, Wed Jul 20 17:09:35 2005



LEGEND

Flow Direction

Kohlman Lake

Ponds

Subwatershed Areal Total Phosphorus Loading (lbs\ac\yr)

- 0.1 - 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- 1.2 - 2
- 2 - 4

RWMWD Boundary

1500 0 1500 3000 4500

Scale in Feet

Figure J-7

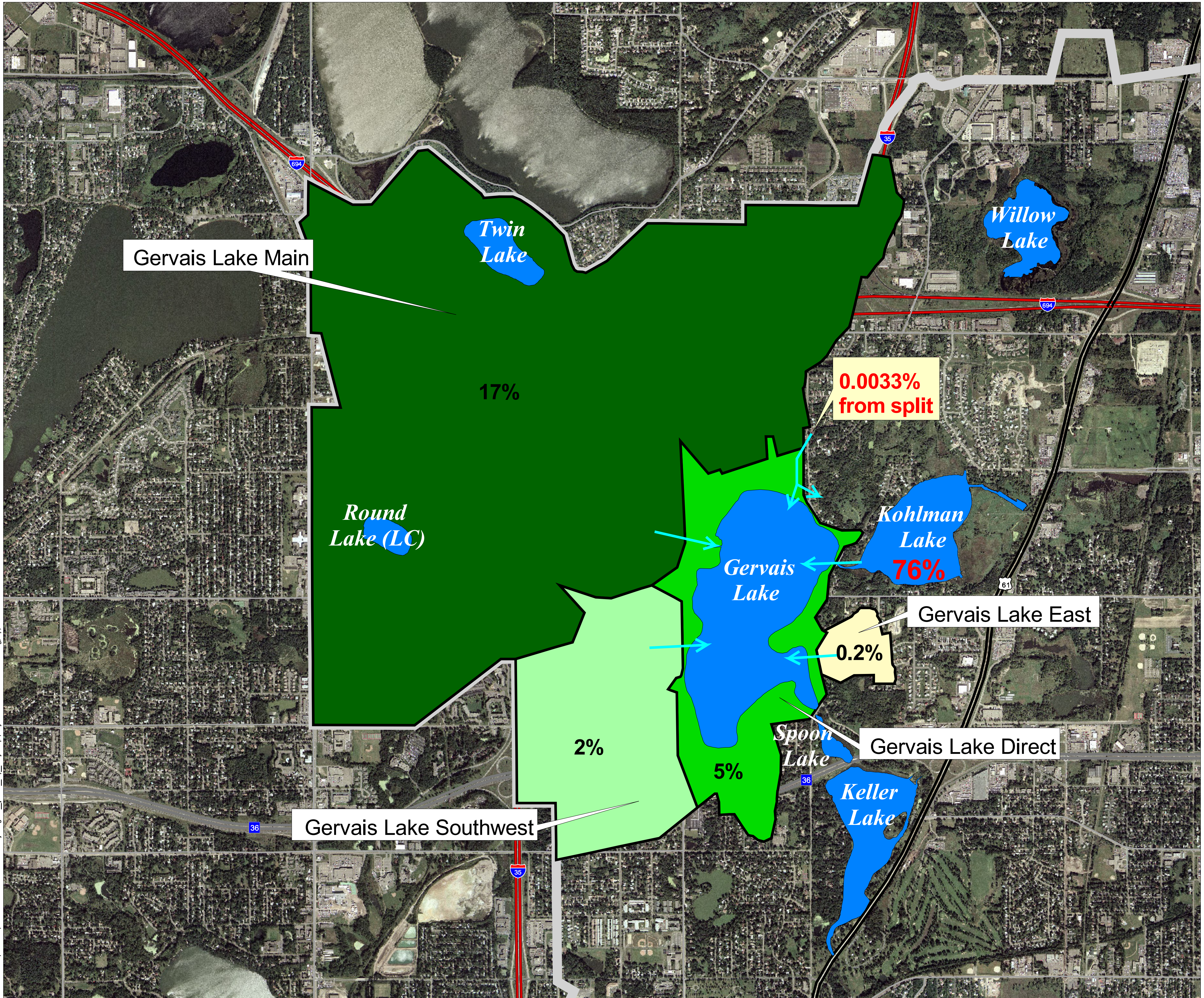
KOHLMAN LAKE:
EXISTING SUBWATERSHED
AREAL TOTAL PHOSPHORUS LOADING

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr Arcview 3.3, OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_jseries_lkp_may04.apr, Layout: J-07 - Kohlman Aerial Load, lkp, Wed Jul 20 17:23:44 2005



LEGEND

Flow Direction
Lakes
Percent of TP Load
0.2%
2 %
5 %
17 %
RWMWD Boundary

1000 0 1000 2000 3000

Scale in Feet

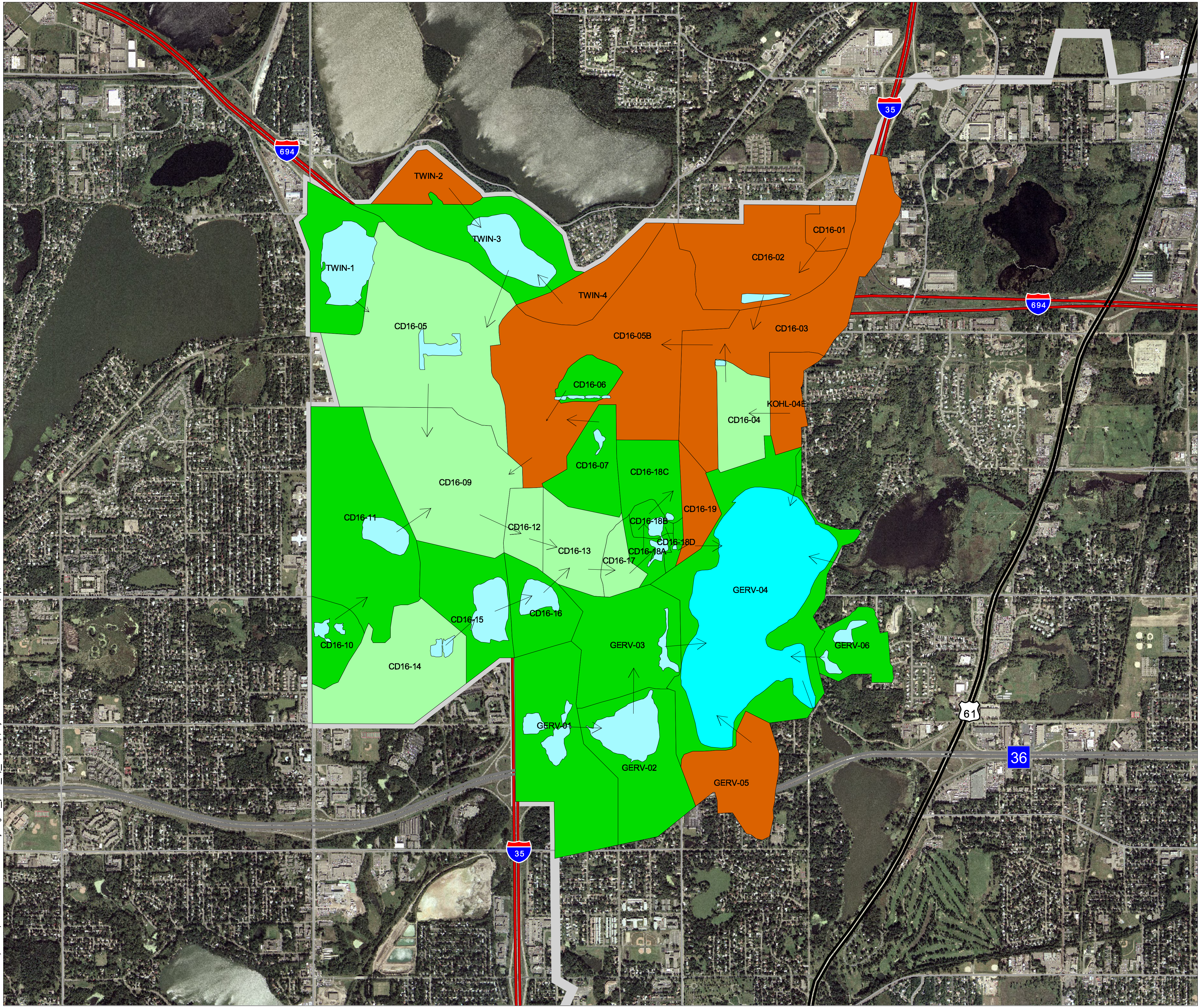
Figure J-8

GERVAIS LAKE:
DRAINAGE DISTRICTS AND THEIR
TP CONTRIBUTIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

Flow Direction

Gervais Lake

Ponds

Percent of Upstream Total Phosphorus Removed

0 - 20%

20 - 40%

40 - 60%

> 60%

RWMWD Boundary

1000 0 1000 2000 3000

Scale in Feet

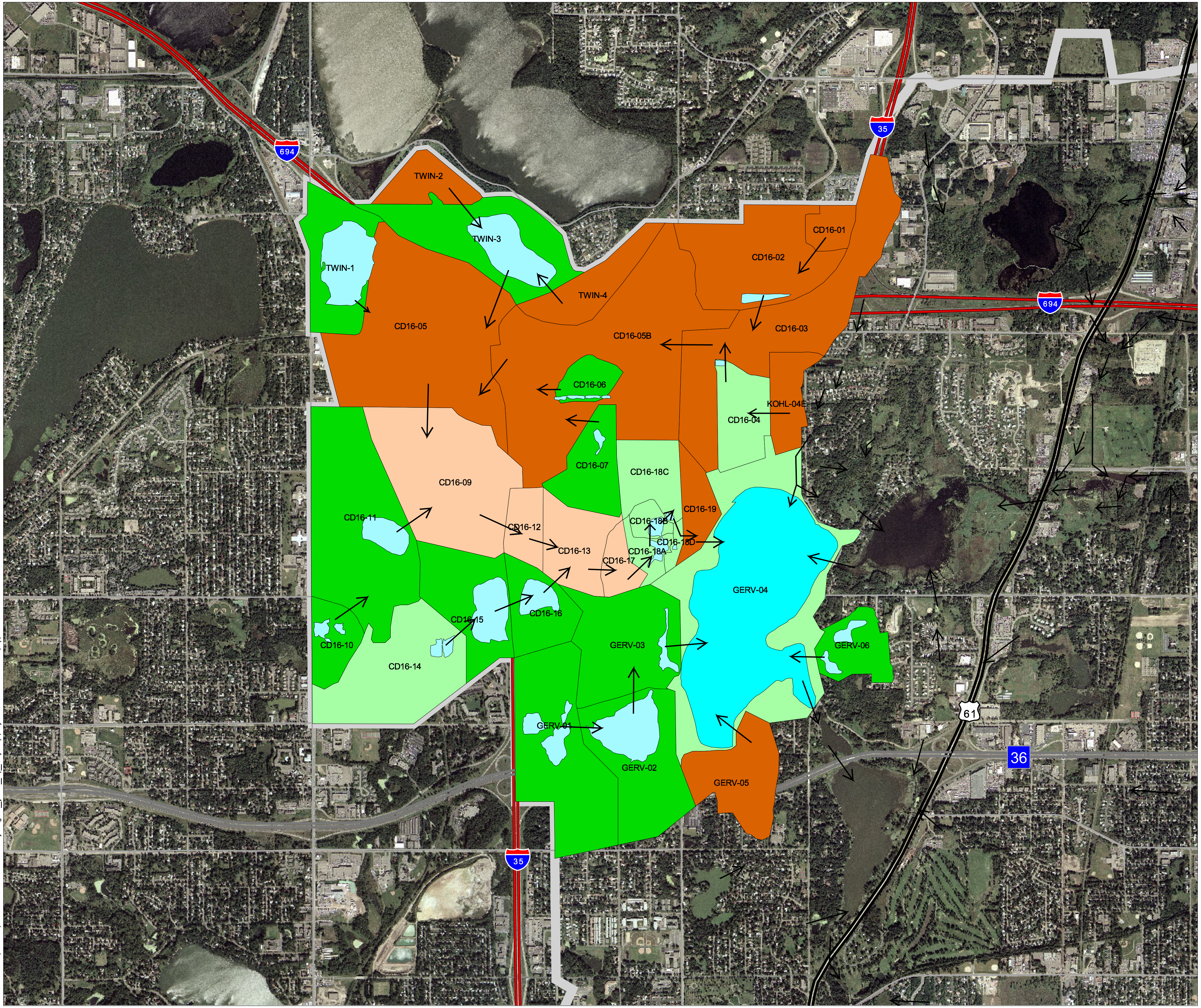
Figure J-9

GERVAIS LAKE:
EXISTING CUMULATIVE
TOTAL PHOSPHORUS REMOVAL

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

Flow Direction

Gervais Lake

Ponds

Percent of Upstream Total Phosphorus Removed

0 - 20%

20 - 40%

40 - 60%

> 60%

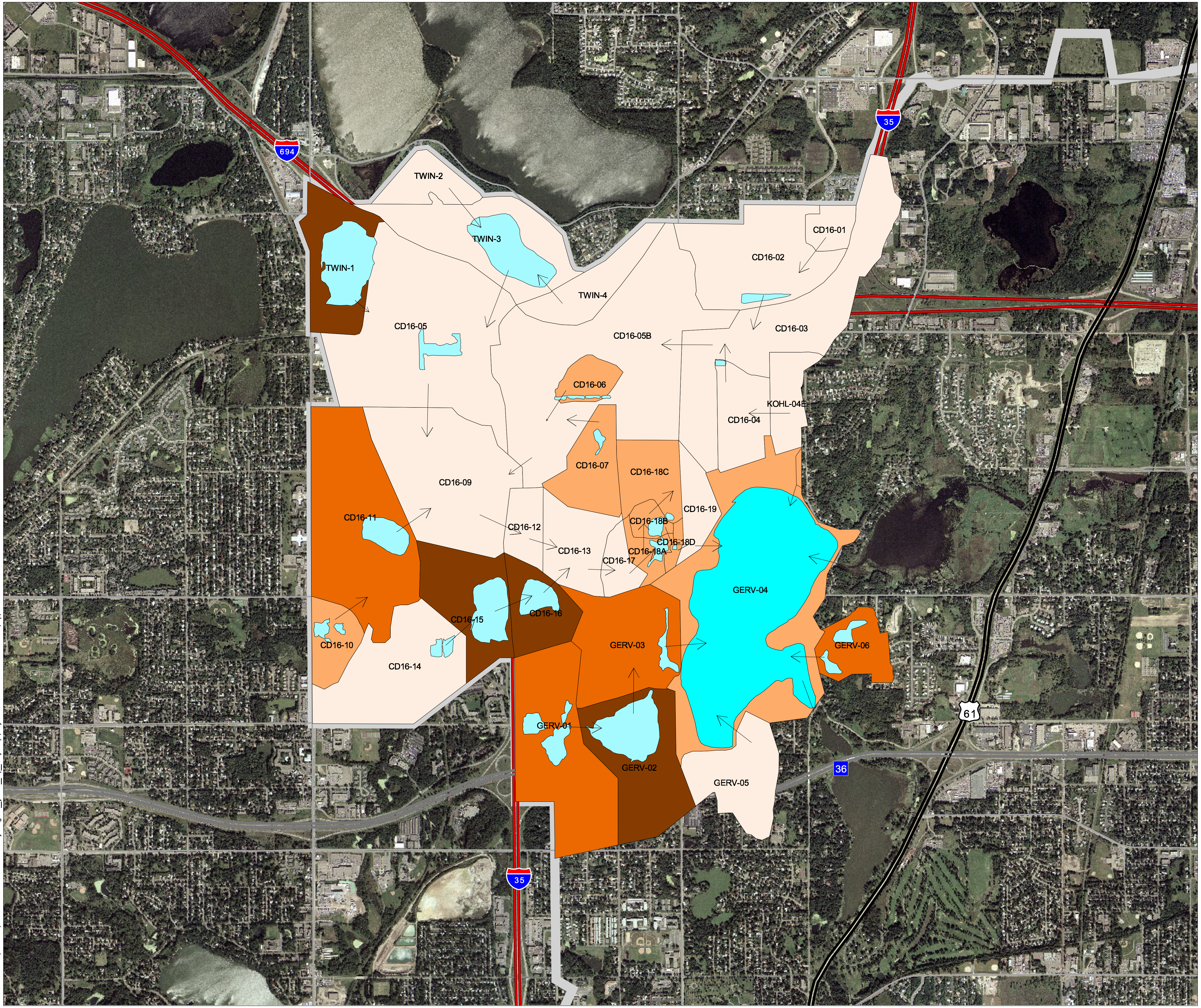
1000 0 1000 2000 3000

Scale in Feet

Figure J-10

GERVAIS LAKE:
PRE-CAPITAL IMPROVEMENT PROJECT
CUMULATIVE TOTAL PHOSPHORUS REMOVAL

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District



LEGEND

Flow Direction
Gervais Lake
Ponds
Percent of Soluble Phosphorus in Outflow
0 - 20%
20 - 40%
40 - 60%
> 60%
RWMWD Boundary

1000 0 1000 2000 3000
Scale in Feet

Figure J-11

GERVAIS LAKE:
PERCENT OF SOLUBLE
PHOSPHORUS IN OUTFLOW
EXISTING CONDITIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_jseries_lkp_may04.apr, Layout: J-11 - Gervais Soluble TP Exist, lkp, Thu Jul 21 15:08:33 2005

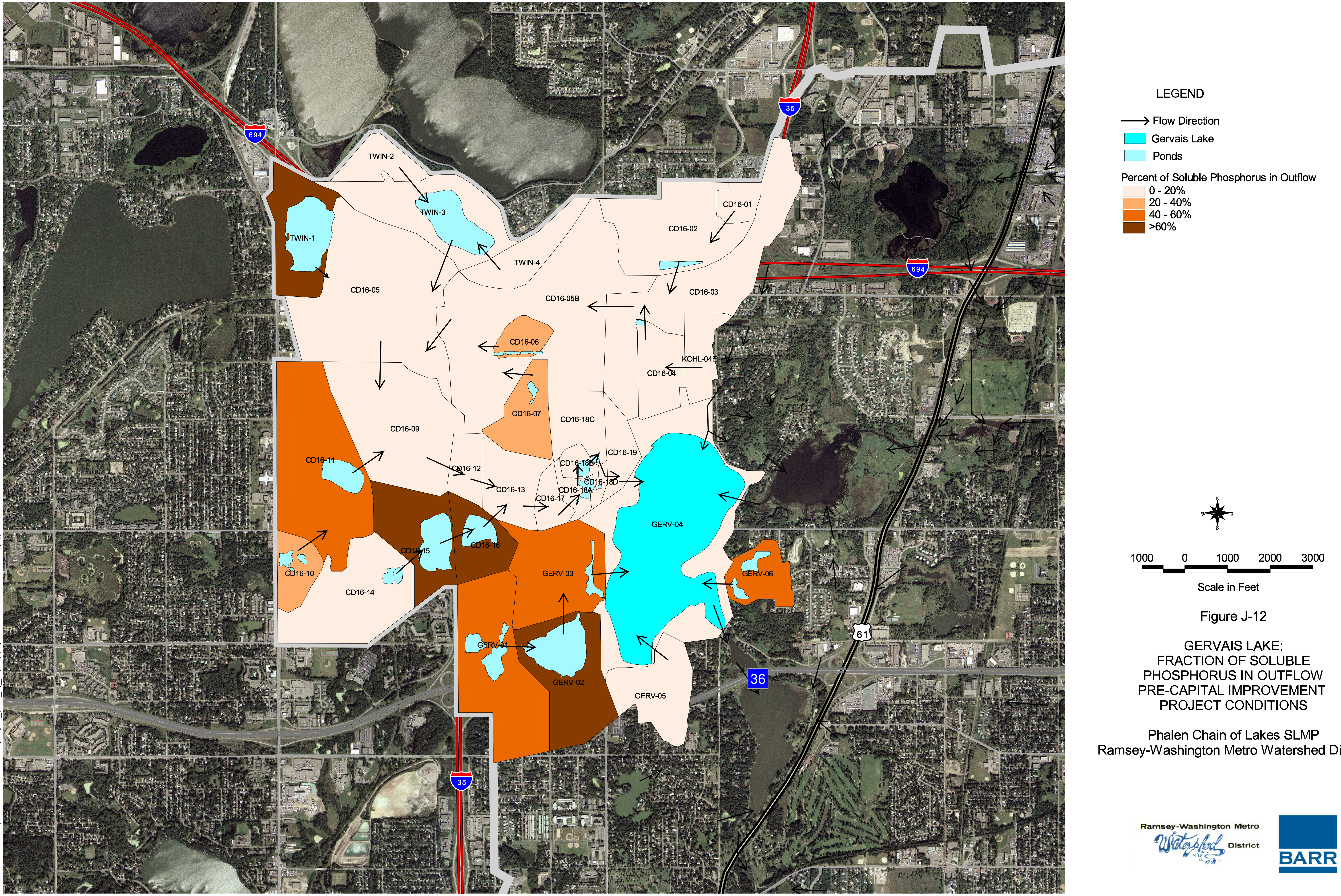


Figure J-12

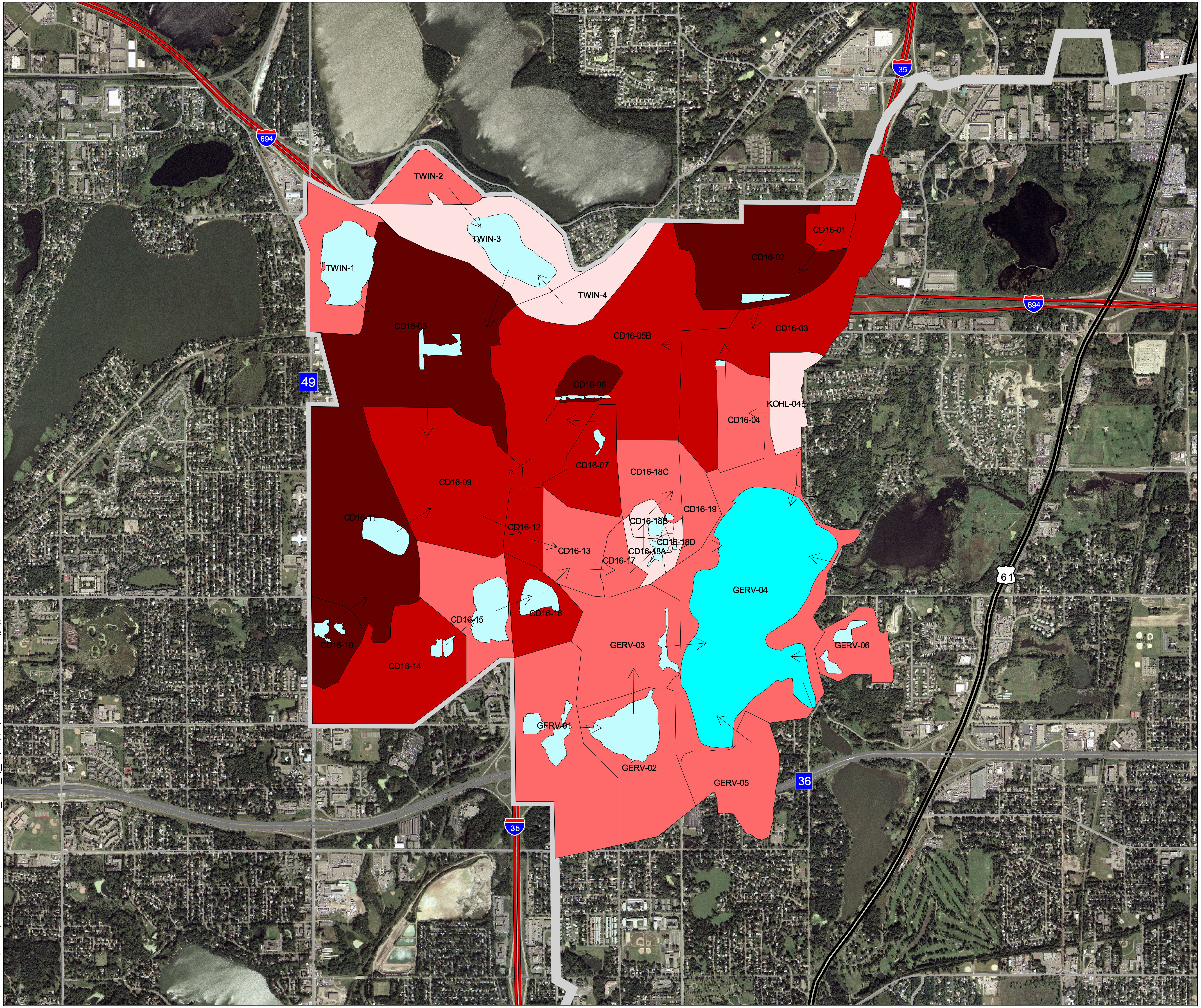
GERVAIS LAKE:
FRACTION OF SOLUBLE
PHOSPHORUS IN OUTFLOW
PRE-CAPITAL IMPROVEMENT
PROJECT CONDITIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_jseries_lkp_may04.apr, Layout: J-12 - Gervais Soluble TP - Pre-CIP, lkp, Thu Jul 21 10:10:59 2005



LEGEND

Flow Direction

Gervais Lake

Ponds

Subwatershed Areal Total Phosphorus Loading (lbs\ac\yr)

0.1 - 0.4

0.4 - 0.8

0.8 - 1

1 - 1.8

RWMWD Boundary

1000 0 1000 2000 3000

Scale in Feet

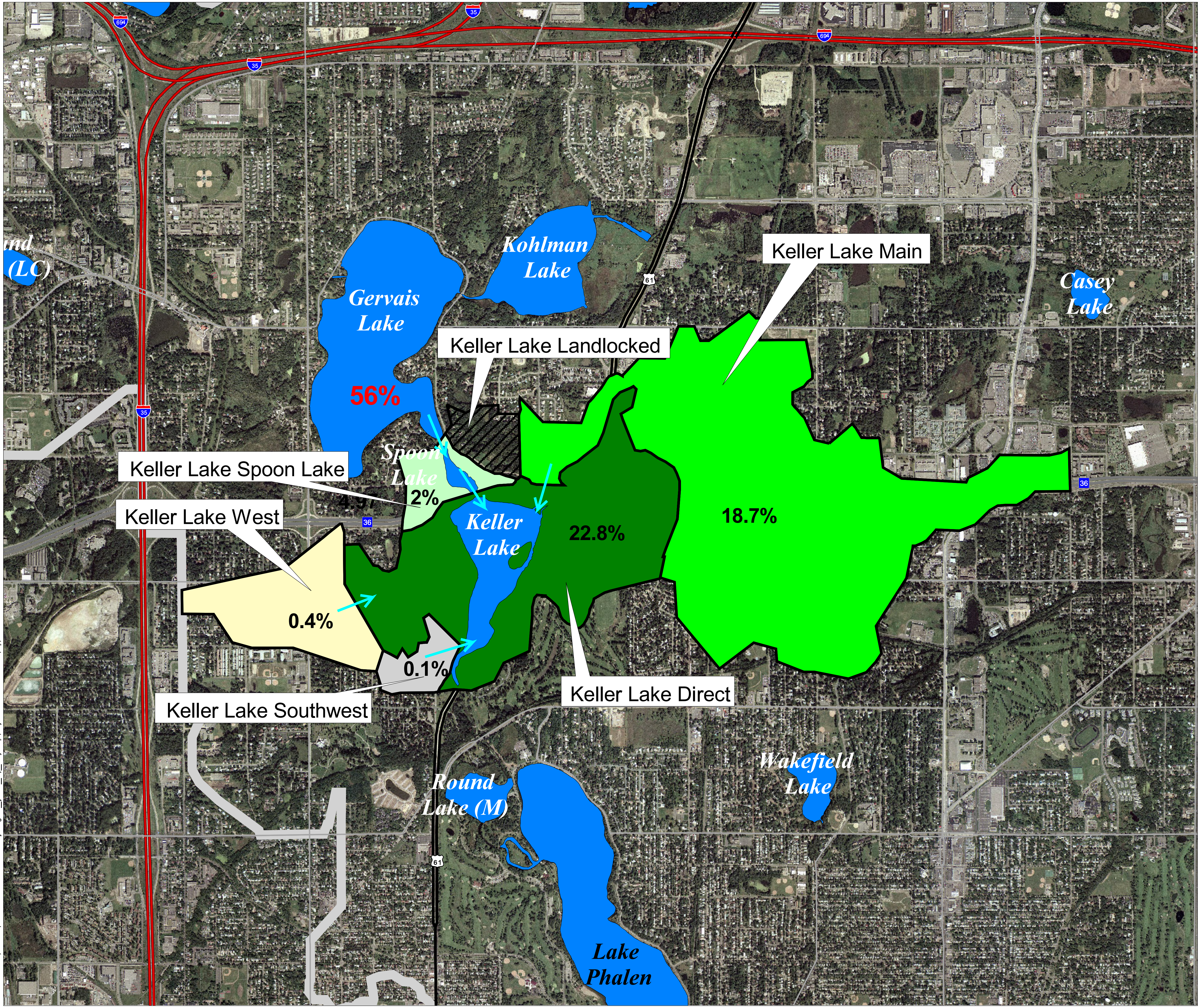
Figure J-13

GERVAIS LAKE:
EXISTING SUBWATERSHED
AREAL TOTAL PHOSPHORUS LOADING

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

- Flow Direction
- Lakes

Percent of TP Load

- 0.1 %
- 0.4 %
- 2 %
- 19 %
- 23 %

RWMWD Boundary

1000 0 1000 2000 3000

Scale in Feet

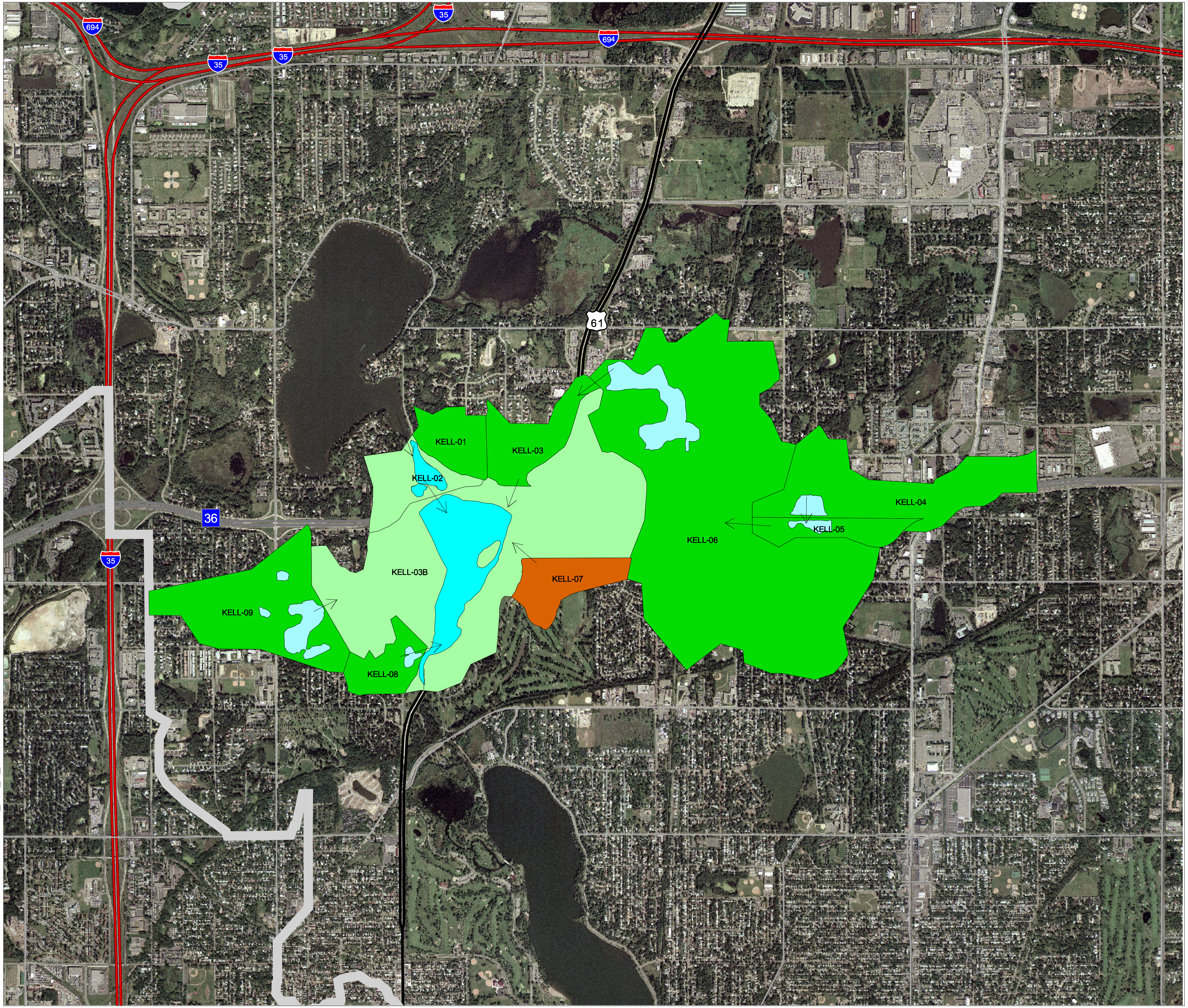
Figure J-14

KELLER LAKE:
DRAINAGE DISTRICTS AND THEIR
TP CONTRIBUTIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

Flow Direction
Keller Lake
Ponds

Percent of Upstream Total Phosphorus Removed
0 - 20%
20 - 40%
40 - 60%
> 60%

1000 0 1000 2000 3000

Scale in Feet

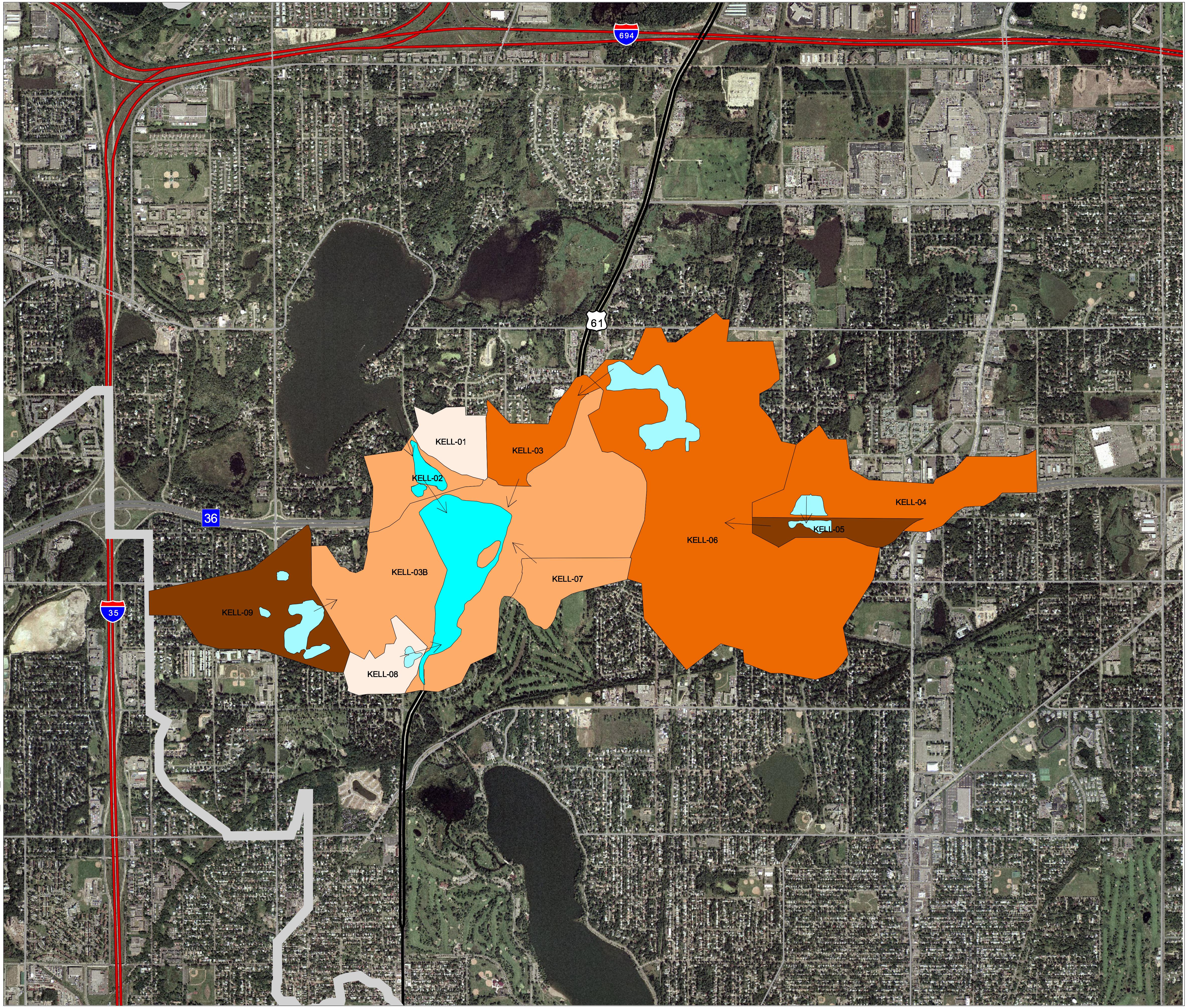
Figure J-15

KELLER LAKE:
EXISTING CUMULATIVE
TOTAL PHOSPHORUS REMOVAL

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

Flow Direction
Keller Lake
Fraction of TP Removal by Device
Percent of Soluble Phosphorus in Outflow
0 - 20%
20 - 40%
40 - 60%
> 60%

1000 0 1000 2000 3000
Scale in Feet

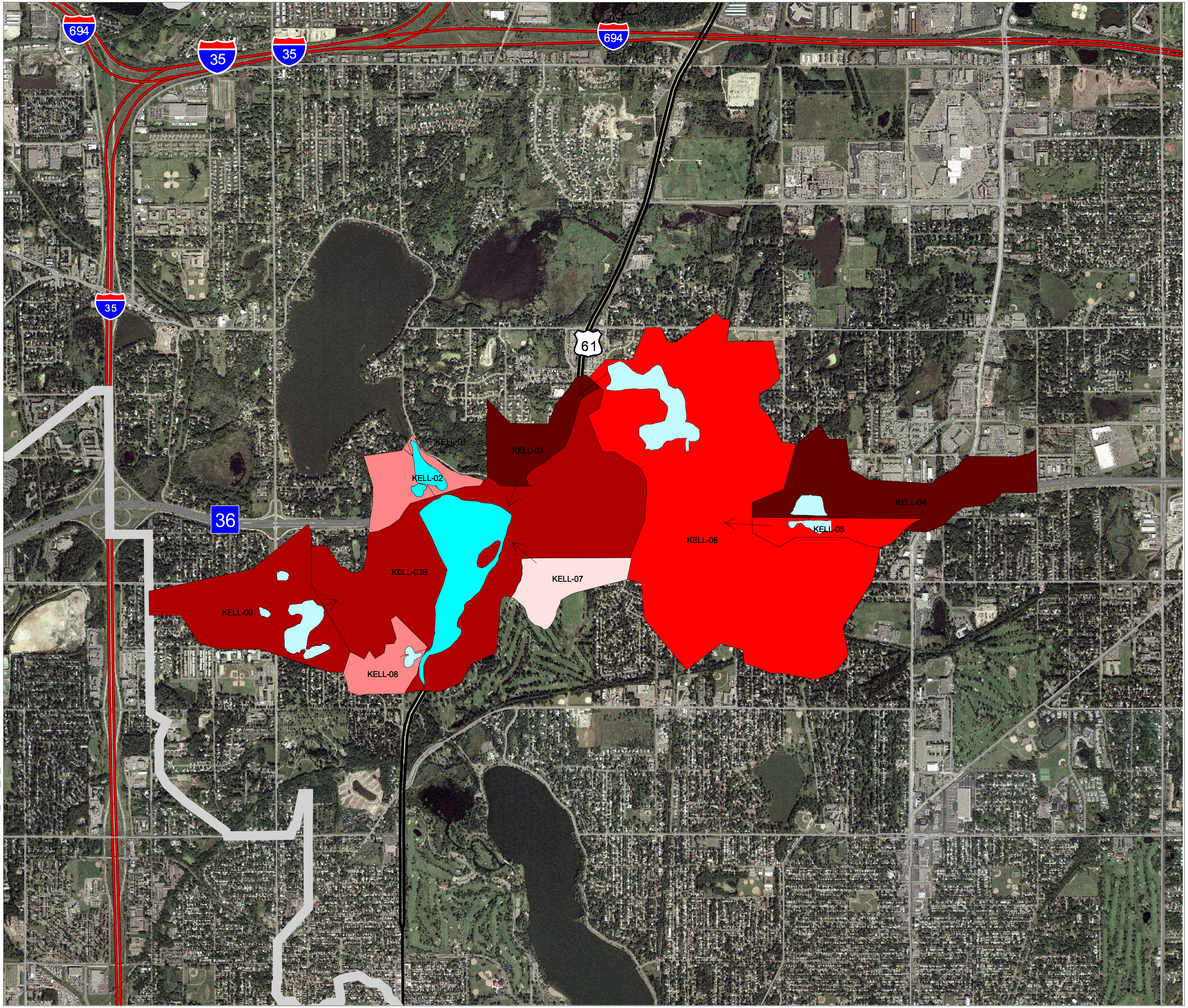
Figure J-16

KELLER LAKE:
PERCENT OF SOLUBLE
PHOSPHORUS IN OUTFLOW
EXISTING CONDITIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

Flow Direction
Keller Lake
Ponds

Subwatershed Areal Total Phosphorus Loading (lbs/ac/yr)

0.2 - 0.4
0.4 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 1.4

RWMWD Boundary

1000 0 1000 2000 3000

Scale in Feet

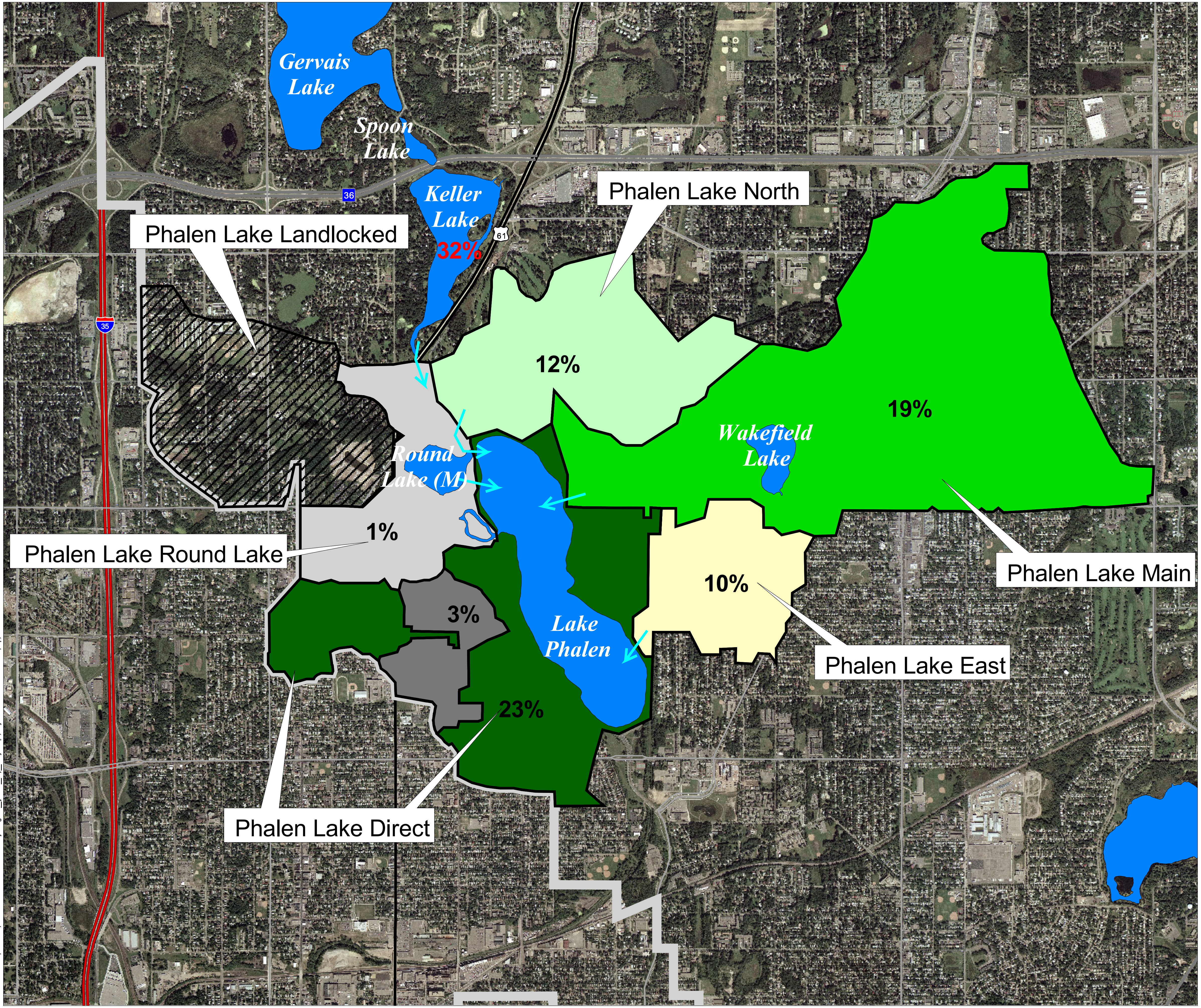
Figure J-17

KELLER LAKE:
EXISTING SUBWATERSHED
AREAL TOTAL PHOSPHORUS LOADING

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

Flow Direction
Lakes
Percent of TP Load
1 %
10 %
12 %
3 %
19 %
23 %
RWMWD Boundary

1000 0 1000 2000 3000
Scale in Feet

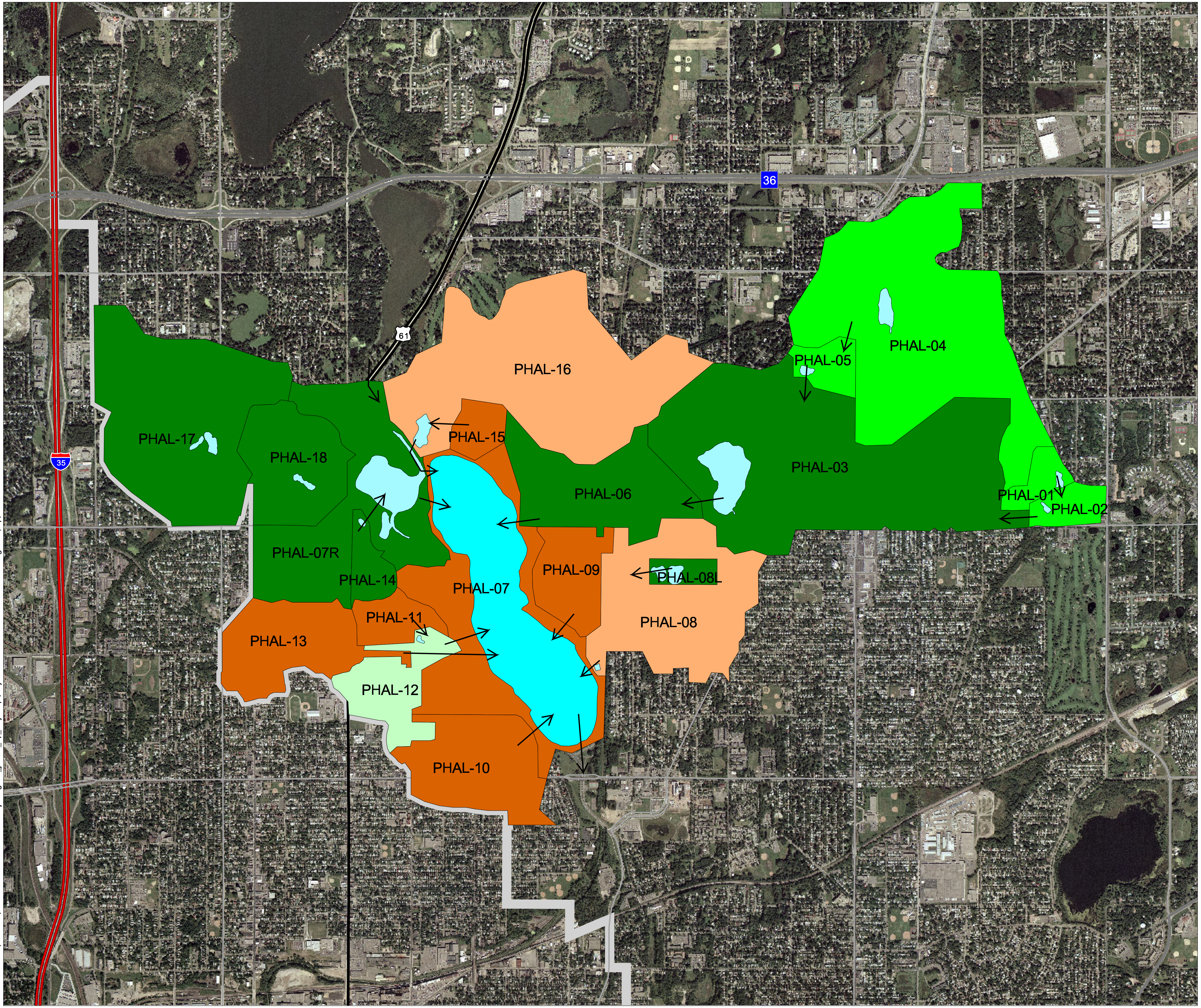
Figure J-18

LAKE PHALEN:
DRAINAGE DISTRICTS AND THEIR
TP CONTRIBUTIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR



LEGEND

Flow Direction
Phalen Lake
Ponds
Percent of Upstream Total Phosphorus Removed
0 - 20%
20 - 40%
40 - 60%
60 - 70%
> 70%
RWMWD Boundary

1000 0 1000 2000 3000

Scale in Feet

Figure J-19

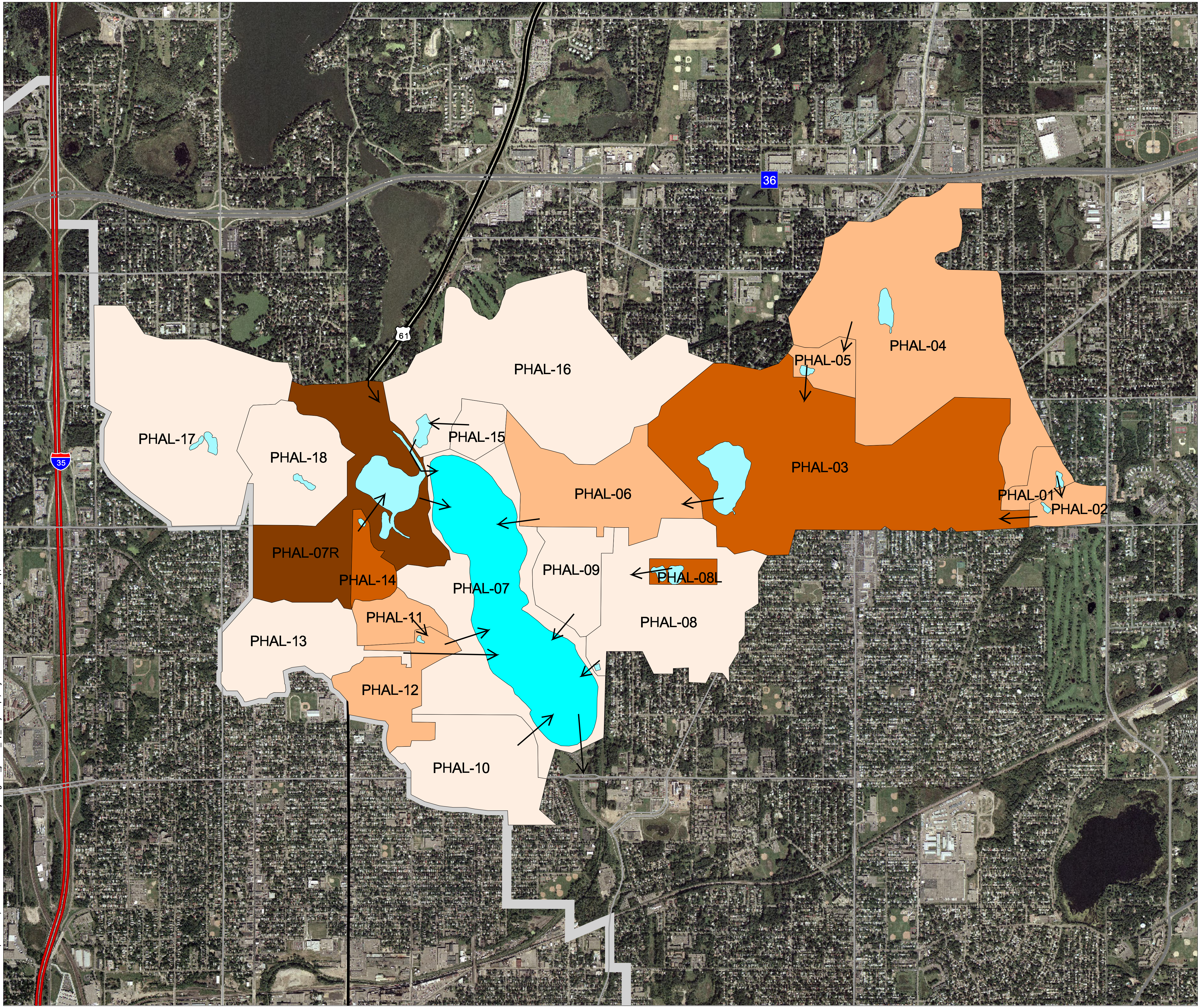
LAKE PHALEN:
EXISTING CUMULATIVE
TOTAL PHOSPHORUS REMOVAL

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_jseries_lkp_may04.apr, Layout: J-19 - Phalen Phos Removal Existing Cond, lkp, Fri Jul 22 10:28:18 2005



LEGEND

Flow Direction
Phalen Lake
Ponds
Percent of Soluble Phosphorus in Outflow
0 - 15%
15 - 40%
40 - 60%
> 60%
RWMWD Boundary

1000 0 1000 2000 3000

Scale in Feet

Figure J-20

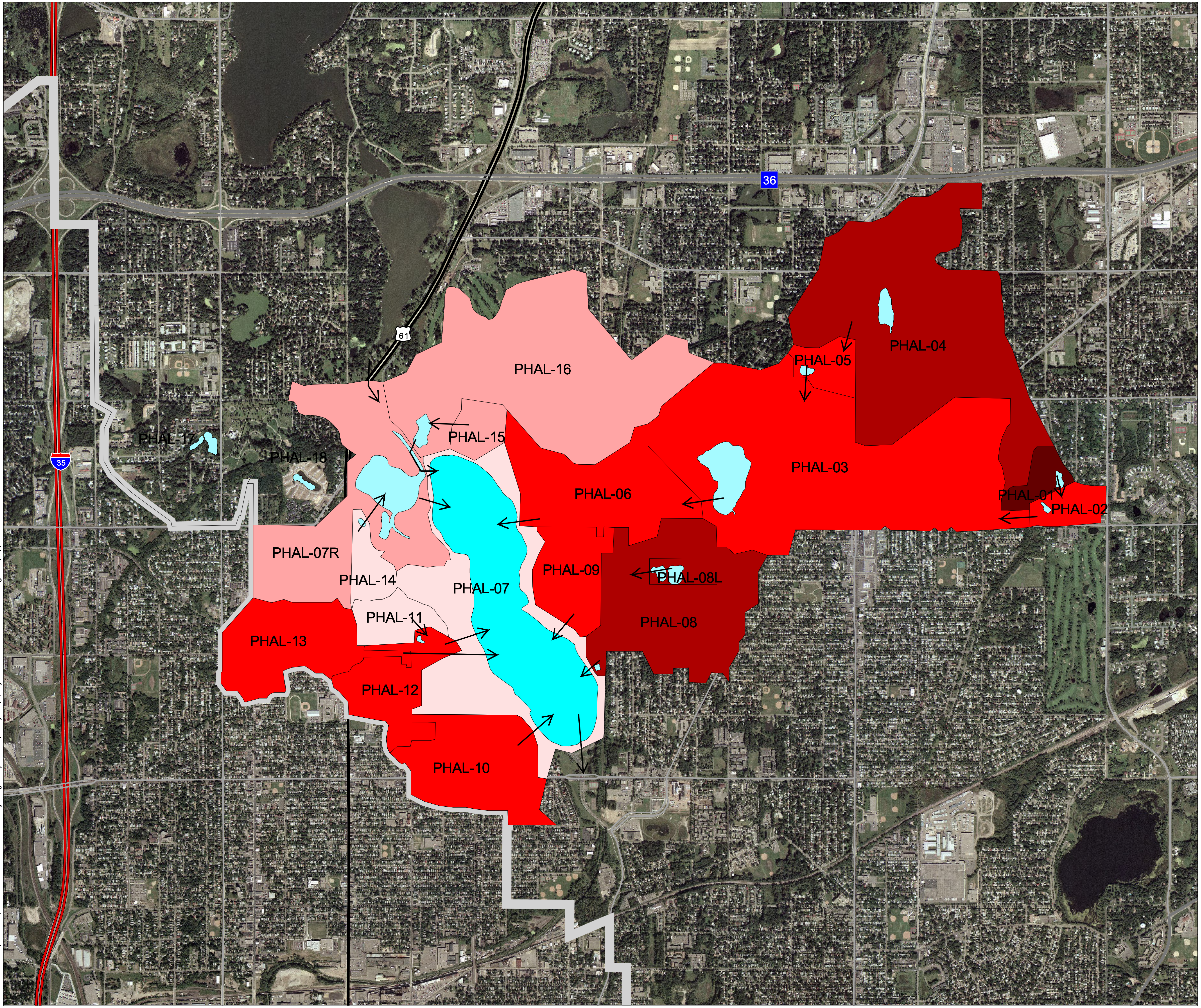
LAKE PHALEN:
PERCENT OF SOLUBLE
PHOSPHORUS IN OUTFLOW
EXISTING CONDITIONS

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr: Arcview 3.3, OPT2629, I:\Client\Rwmwd\Lake\Phalen\Project\figures_jseries_lkp_may04.apr, Layout: J-20 - Phalen TP Sol Exist, lkp, Thu Jul 21 12:08:39 2005



LEGEND

Flow Direction
Phalen Lake
Ponds
Subwatershed Areal Total Phosphorus Loading (lbs/ac/yr)
0 - 0.8
0.8 - 1.4
1.4 - 1.8
1.8 - 2.3
2.3 - 2.7
No Data
RWMWD Boundary

1000 0 1000 2000 3000
Scale in Feet

Figure J-21

LAKE PHALEN:
EXISTING SUBWATERSHED
AREAL TOTAL PHOSPHORUS LOADING

Phalen Chain of Lakes SLMP
Ramsey-Washington Metro Watershed District

Ramsey-Washington Metro Watershed District

BARR

Barr: Arcview 3.3,OPT2629, I:\Client\Rwmwd\LakePhalen\Project\figures_jseries_lkp_may04.apr, Layout: J-21 - Phalen Aerial Loading Exist, lkp, Thu Jul 21 12:15:29 2005

Appendix K

In-Lake Modeling of the Phalen Chain of Lakes

Appendix K: In Lake Modeling of the Phalen Chain of Lakes

In-lake modeling for each of the lakes in the Phalen Chain was accomplished through the creation of a daily timestep mass balance model that tracked the flow of water and total phosphorus (TP) through each of the lakes over a range of climatic conditions. Essentially, a modified version of Vollenweider's (1969) mass balance equation was used:

$$TP = \frac{L}{\bar{z}(\rho + \sigma)} + \frac{L\text{int}}{V}$$

Where $\bar{z}$ *= average lake depth in meters*

ρ *= flushing rate in* yr^{-1}

σ *= sedimentation rate in* yr^{-1}

L = aerial loading rate in $mg/(m^2*yr)$

Lint = internal aerial loading rate in $mg/(m^2*yr)$

V = lake volume in m^3

The aerial loading rate of total phosphorus (from the watershed only) was obtained from P8 model output for wet (2001-2002), dry (1988-1989), and average (2000-2001) water years. Daily values for average lake depth, lake volume, and the flushing rate were calculated using a daily water balance that incorporated P8 output for watershed inflows, observed daily precipitation data, observed lake level measurements, and daily evaporation rates that were estimated by using the Meyer Model for the wet, dry, and average years.

The term $\bar{z}*\sigma$ is a sedimentation rate in m/yr that can be assumed to fall within the range cited by O'Meara (1974). This sedimentation rate was calibrated for the wet, dry, and average summers in each lake during periods when the lakes were assumed to have only negligible internal TP loads.

Isopleth diagrams and monitoring data of Gervais and Phalen Lakes indicated that these lakes rarely, if ever, destratify during the summer months. Therefore, internal loads were assumed to be negligible during the summer. For these lakes, the entire summer's in-lake TP monitoring data could be used to calibrate the sedimentation coefficient.

Isopleth diagrams and monitoring data of Keller and Kohlman Lakes, however, indicated that these lakes do, at times, receive internal loads of TP from the their sediments. The sedimentation rates for Kohlman and Keller lakes was calibrated using in-lake TP monitoring data from stratified (non internally loaded) periods. Then, the internal load could be estimated for destratified (internally loaded) periods by calculating the difference between the predicted lake TP (using the sedimentation rate that assumes no internal load) and the observed lake TP. In this manner, a predictive model could be created and used to evaluate the effects of current and potential future CIPs.

Table K-1 below shows the sedimentation coefficients that were calibrated for each lake in the Phalen Chain.

Lake	O'Meara's Sedimentation Rate (in m/day)		
	Wet Year (2001-2002)	**Dry Year (1988-1989)**	**Average Year (2000-2001)**
Kohlman Lake	0.100	0.050	0.075
Gervais Lake	0.210	0.080	0.170
Keller Lake	0.102	0.005	0.070
Lake Phalen	0.200	0.175	0.225

Linear regressions evaluating the relationship between each lake's summer overflow rate (q_s in m/day) during the wet, dry, and average years and their corresponding calibrated sedimentation rates were performed. In general, higher overflow rates resulted in higher calibrated sedimentation rates for each lake. The only exception to this rule was seen in Lake Phalen, where the calibration rate remained relatively constant over the range of summer overflow rates. The results of this exercise are shown in Table K-2.

Table K-2: Results of linear regressions between summer overflow rates and calibrated sedimentation rates for each lake in the Phalen Chain

	Regression Equation Relating Summer q_s and Calibrated Sedimentation Rate	R^2 of equation
Kohlman Lake	y = 0.0648Ln(x) + 0.2298	1
Gervais Lake	y = 0.1156Ln(x) + 0.6478	0.8276
Keller Lake	y = 0.0901Ln(x) + 0.3475	0.8678
Lake Phalen	y = 0.0175Ln(x) + 0.2667	0.1066

Sources:

O'Melia, C.R. 1974. "Phosphorus Cycling in Lakes." North Carolina Water Resources Research Institute. Prepared for the Office of Water Research and Technology. Distributed by the National Technical Information Service, U.S. Department of Commerce.

Vollenweider, R.A. 1969. "Possibilities and Limits of Elementary Models Concerning the Budget of Substances in Lakes." Archiv fur Hydrobiologie., 66, 1-36