Golden Lake TMDL Implementation Plan

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Primary Authors and Contributors:

Emmons and Olivier Resources, Inc.
Tom Miller
Andrea Plevan

Rice Creek Watershed District
Matt Kocian

Minnesota Pollution Control Agency
Brooke Asleson

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1. BACKGROUND

Golden Lake is on the 303(d) list of impaired water bodies as being impaired for aquatic recreation, due to excessive nutrients (Table 1). The Total Maximum Daily Load (TMDL) report for this impairment was approved by the Federal Environmental Protection Agency (EPA) in September 2009; the report can be found at http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/upper-mississippi-river-basin-tmdl/project-golden-lake-phosphorus.html

Golden Lake is 57.2 acres in size and has a maximum depth of 24 feet and a mean depth of 8 feet. The littoral area of Golden Lake constitutes approximately 90% of the lake's total surface area (Table 2). The lakeshore area is well developed. The lake is used recreationally for fishing and non-motorized boating, and there is a public access site located along the west side of the lake.

Table 1. Impaired Waters Listings

Lake name:	Golden Lake
DNR ID#:	02-0045
Hydrologic Unit Code:	7010206
Pollutant or stressor:	Nutrient/Eutrophication Biological Indicators
Impairment:	Aquatic recreation
Year first listed:	2002
Target start/completion (reflects the priority ranking):	2004/2008
CALM category:	4A: Impaired, but a TMDL study has been approved by EPA
EPA TMDL Approval Date:	September 30, 2009

Table 2. Lake and Watershed Characteristics

Lake total surface area	57.2 ac
Lake littoral surface area	51.3 ac
Lake volume	458 ac-ft
Mean depth	8.0 ft
Maximum depth	24 ft
Drainage area	6,566 ac

Due to Golden Lake's naturally high tannin concentrations, the lake has a brownish tint that limits light penetration. This was noted in the 1982 study, "Management alternatives report on the diagnostic – feasibility study for Golden Lake, Anoka County, MN." In a 1987 study (Circle Pines 1987), light was measured with a photometer and was used to calculate the light extinction coefficient in Golden Lake. It was concluded that photoinhibition of macrophytes from humics is occurring.

The Golden Lake Watershed is located in the west-central portion of the Rice Creek Watershed District (RCWD) in southern Anoka County and is a sub-watershed of the Upper Mississippi Watershed. This area lies entirely within the North Central Hardwood Forest Ecoregion (NCHF). Golden Lake itself is located in the City of Circle Pines, and the watershed includes the cities of Blaine, Circle Pines, Lexington, and Lino Lakes (Table 3). The main tributary to Golden Lake is Anoka County Ditch 53-62 (ACD 53-62), which enters the lake from the north. Approximately 6,426 acres drain to the lake through the ditch, and approximately 139 acres drain to the lake directly. Golden Lake flows into Rice Creek just below the Rice Creek Chain of Lakes.

Table 3. Municipalities within Golden Lake Watershed

Golden Lake Watershed	
City	**Area [acres]**
Blaine	5,912
Circle Pines	473
Lexington	138
Lino Lakes	43
Total	6,566

Reports regarding phosphorus loads to Golden Lake exist dating to 1977 when the first water quality report was completed by Hickok and Associates. Since this report there have been many other lake assessments, generally containing some monitoring and analysis followed by recommendations for implementation activities. In 2003 there was a water quality management plan for Golden Lake (WSB 2003) created for the City of Circle Pines that contains a thorough list of in-lake and watershed management strategies. The latest of these reports is the 2009 Golden Lake TMDL, which includes a list of implementation strategies. Implementation activities that were outlined in the TMDL are repeated in this section.

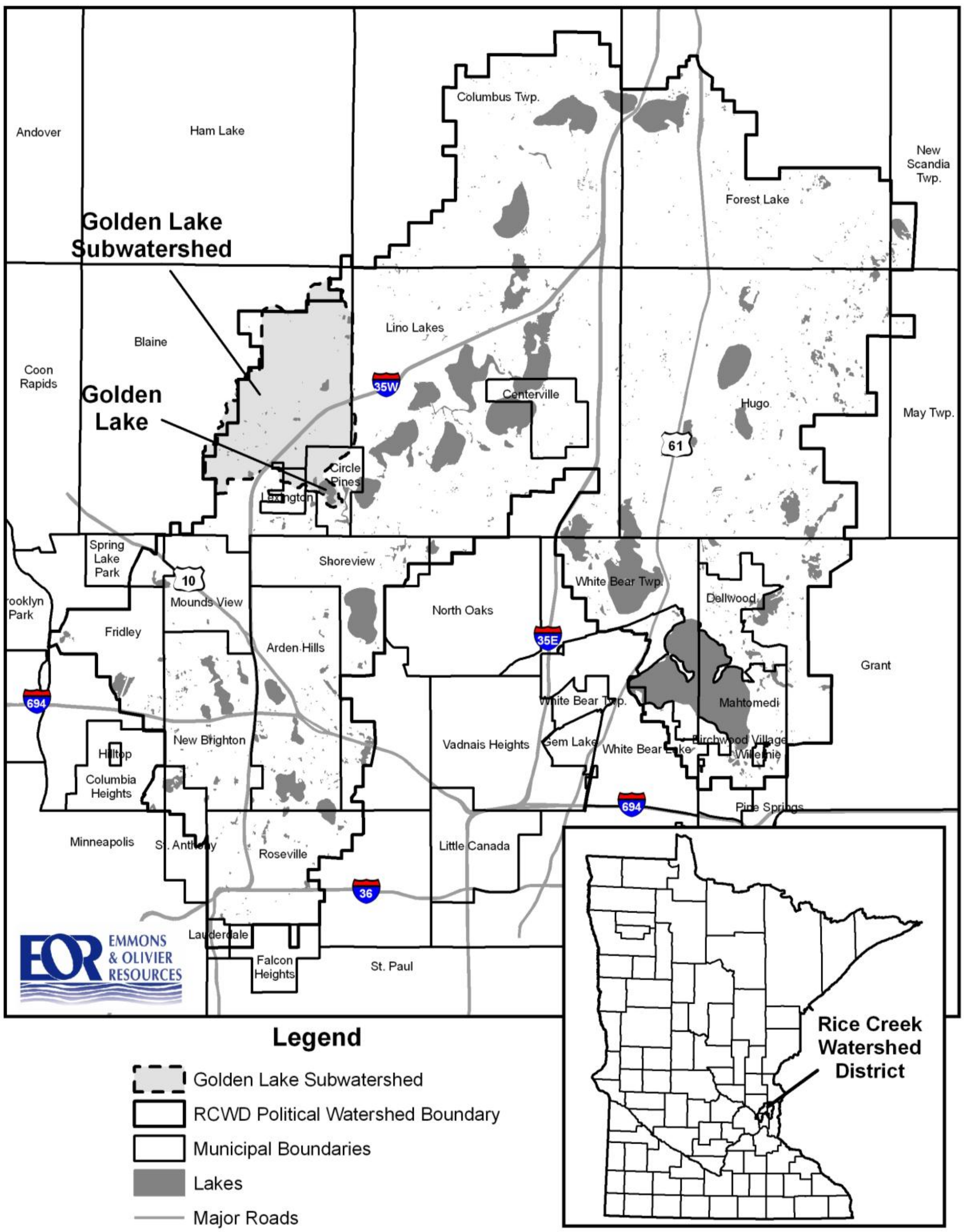

Figure 1. Location of the Golden Lake Watershed

2. WATER QUALITY GOALS

Total phosphorus is often the limiting factor controlling primary production in freshwater lakes. It is therefore the nutrient of focus for this TMDL, and is sometimes referred to as the causal factor. As phosphorus concentrations increase, primary production also increases, as measured by higher chlorophyll-*a* concentrations. Higher concentrations of chlorophyll-*a* lead to lower water transparency. Both chlorophyll-*a* and Secchi transparency are referred to as response factors, since they indicate the ecological response of a lake to excessive phosphorus input.

Minnesota eutrophication standards were used as the in-lake water quality goals for this TMDL (Table 4).

Table 4. Average Annual Water Quality Goals

Parameter	Existing Conditions (1994-2004 growing season mean)	MN Eutrophication Standards for Shallow Lakes
TP (µg/L)	89	60
Chlorophyll-*a* (µg/L)	48	20
Secchi depth (m)	0.8	1.0

3. TMDL ALLOCATIONS AND TARGET LOADS

This section is a summary of the TMDL allocations described in the TMDL report. The methods and assumptions used to calculate the wasteload and load allocations are described here briefly. For additional information, please refer to the TMDL report.

A. TMDL ALLOCATIONS

Phosphorus loads to Golden Lake include the watershed load, one wastewater discharger, internal loading, and atmospheric deposition. A combination of monitoring data and modeling was used to estimate the existing phosphorus loads to Golden Lake.

The wasteload allocations (WLAs) cover all phosphorus sources that are regulated under NPDES permits, including permitted MS4 (municipal separate storm sewer system) stormwater, construction stormwater, industrial stormwater, and the wastewater discharger. The stormwater sources were split into one categorical and two individual WLAs. The categorical WLA includes the storm-sewered portions of the Cities of Blaine, Circle Pines, Lexington, and Lino Lakes; the Rice Creek Watershed District (for ditch maintenance); and construction and industrial stormwater. The individual WLAs are for Anoka County and Minnesota Department of Transportation (Mn/DOT) highways (Table 5).

The one wastewater discharger in the watershed, Aveda Corporation, was given an individual WLA. The WLA was calculated by considering the outfall maximum design flow, and the anticipated concentration. Individual outfall loads were added together and increased by 13% to account for facility variability. In total, Aveda Corporation has a 6 lbs/yr WLA.

Failing septic systems are given a zero WLA as they are out of compliance with Minnesota rule. However, it is recommended in this Implementation Plan that government entities responsible for septic systems will check compliance. A properly operating septic system in this watershed would not be expected to contribute to phosphorus loading of Golden Lake.

The load allocations (LAs) include stormwater that is not regulated by an NPDES MS4 permit, internal loading, and atmospheric deposition. The load from atmospheric deposition is assumed to be constant and its allocation is equal to the estimated existing load.

Table 5. TMDL Allocation Summary

Source	Permit #	Allocation (lbs/yr)	Allocation (lbs/day)
WLA		**150.5**	**0.41**
Blaine	MS400075	138	0.38
Circle Pines	MS400009		
Lexington	MS400027		
Lino Lakes	MS400100		
RCWD	MS400193		
Industrial stormwater	General		
Construction stormwater	General		
Anoka County (highways)	MS400066	3.8	0.010
Mn/DOT	MS400170	2.5	0.007
Aveda	MN0066524	6.0	0.016
LA		**75.5**	**0.21**
Blaine non-regulated area		22	0.060
Lexington non-regulated area		2.5	0.007
Internal Load		36	0.099
Atmospheric Deposition		15	0.041
MOS		**38**	**0.10**
TMDL		***264***	***0.72***

B. TARGET LOADS

An area approach was used to calculate target loads, as described in MPCA's guidance document, "*Guidance for Developing Total Maximum Daily Load Implementation Plans for Permitted MS4 Stormwater*" (http://www.pca.state.mn.us/publications/wq-strm7-31.pdf). The relative proportion of area in each MS4 was used to split up the total wasteload allocation among MS4s. Table 6 summarizes these results. The most significant load reductions are needed from internal loading sources. No load reduction is required of Aveda, the only traditional point source.

Table 6. Target Loads

Source	Area (ac)	Existing Load (lbs/year)	Target Load (lbs/yr)	Reduction Needed (lbs)	Reduction Needed (%)
WLA	**5,501**	**157**	**150.5**	**6.8**	**4%**
Blaine	4,665	105	100	4.6	4%
Circle Pines	455	34	30	4.0	12%
Lexington	94	6.7	6.2	0.5	8%
Lino Lakes	41	2.6	2.3	0.3	11%
RCWD	*	*	*	*	*
Construction stormwater	*	*	*	*	*
Industrial stormwater	*	*	*	*	*
Anoka County (highways)	147	4.0	3.8	0.2	6%
Mn/DOT	98	2.7	2.5	0.2	6%
Aveda	--	3.0	6.0	-3.0	NA
LA	**1,065**	**301**	**75.5**	**225.2**	**75%**
Blaine non-regulated area	1,027	23	22	1.0	4%
Lexington non-regulated area	38	2.7	2.5	0.2	8%
Internal Load	--	260	36	224.0	86%
Atmospheric Deposition	--	15	15	0.0	0%
MOS	--	--	**38**	--	--
TMDL	**6,566**	**458**	***264***	**194.0**	**42%**

*Loads are included within MS4 target loads

Modeling Baseline

The models used to estimate watwershed loading (EPA Simple Method) and lake response (BATHTUB) were calibrated with water quality, flow, and precipitation data through 2004. **Therefore, the baseline for tracking possible changes in watershed loading is 2004.**

4. IMPLEMENTATION ACTIVITIES

The implementation strategy presented below contains recommendations that will reduce the watershed phosphorus load into Golden Lake, reduce the internal load, or improve in-lake water clarity through shifting ecological interactions within the lake. A range of costs for each recommendation are presented to account for economic, scale and design uncertainties related to each recommendation. The recommendations are prioritized to efficiently and cost-effectively achieve the load reductions (as described below). However, any combination of implementation activities could be used, as long as the wasteload allocations, load allocations, and water quality goals are achieved. Phosphorus reduction activities were ranked as having either a high, medium, or limited potential for phosphorus load reduction, or unknown for experimental activities. These ranking were used in lieu of numeric reductions due to the uncertainty and variability involved with estimating phosphorus reductions associated with each recommendation. Project partners for each implementation activity are also included.

The menu of options (Table 7) is a comprehensive list of management practices that could be used to restore Golden Lake. Since the most significant load reductions are needed from internal loading sources, in-lake phosphorus reduction activities will be the primary load reduction method to restore Golden Lake. Some of the internal load reduction practices directly remove phosphorus from the water column, while others aim to shift ecological interactions within the lake, resulting in phosphorus reduction/immobilization and a reduction in algae blooms.

RCWD Rule M and the Anoka County Ditch 53-62 Resource Management Plan (RMP) will be major components of reducing TP loads from the upper watershed, so the majority of the recommended watershed implementation activities are aimed at the Cities of Circle Pines, Lexington, Lino Lakes, and Blaine (south of 35W), which are already predominately developed. These rules are discussed in more detail under the Existing Activities section.

This chapter is divided into three sections:

A. Existing Activities
B. High Priority Implementation Activities
C. Secondary Implementation Activities

Existing activities are best management practices that already exist in the watershed and are described here for reference. Some existing activities are also included as future implementation activities if there is an opportunity to expand the existing activity.

High priority implementation activities are identified first in the menu of options (Table 7). This list was created by reviewing existing reports (EOR 2005, EOR 2009, WSB 2003), estimating costs, phosphorus removal potential, and feasibility of implementation. This list of nine activities should be used to direct implementation activities in the first ten years of implementation (2011-2021). During this time it is expected that the WLA will be achieved by MS4s by implementing some or all of the high priority WLA BMPs. Because of the high non-regulated load (mostly internal), it is expected the non-regulated sources will be controlled within 15 years by 2026. Five-year time spans will be used to help prioritize activities and set a timeline for completion and interim measurable milestones. These timelines will coincide with the three MS4 permit cycles it is expected to take for implementation to be achieved (2011-2016, 2016-2021, and

2021-2026) for regulated and non-regulated sources. The secondary implementation activities in Table 7 are meant to be a more exhaustive list to provide maximum flexibility in securing funding and selecting the options that are best for the stakeholders as needs and priorities change.

A detailed cost-benefit analysis has not been completed for each recommendation but it is estimated that lake restoration will cost approximately $1.8 to 5.5 million.

Table 7. Implementation Plan Summary

Priority Level	Category	Implementation Activity	In-lake practice (Non-regulated sources)	Referenced in Other Plans		Phosphorus Removal	Frequency	Cost Low ($)	Cost High ($)	*Timeline (Permit Cycle)	**Project Partner
				WSB 2003****	TMDL						
High	Engineering	In-lake alum treatment	x		x	High	5-10 years	$ 8,000	$ 47,000	1, 2, 3	Circle Pines and RCWD
		Upstream alum treatment		x	x	High	Annually, Summer	$ 200,000	$ 400,000	1	Circle Pines and RCWD
		Scraping littoral sediments during a lake drawdown	x	x	x	High	25 years	$ 300,000	$ 900,000	2	Circle Pines and RCWD
		Diversion/retention of flows		x		Medium	Once	$ 250,000	$ 350,000	2	Cities and RCWD
		Hypolimnetic withdrawal	x	x		Medium	Annually	$ 75,000	$ 150,000	1	Circle Pines and RCWD
		Expand/enhance current aeration system	x	x		High	Once	$ 100,000	$ 200,000	1	Circle Pines and RCWD
	Stormwater Management	Rule M and Rule RMP-1 implementation			x	High	Continually	$ -	$ -	1, 2, 3	RCWD
		Stormwater retrofits		x	x	High	Once	$ 25,000	$ 500,000	1, 2	Cities and RCWD
	Vegetation	Shoreline buffers			x	Medium	Once	$ 50,000	$ 100,000	1, 2	Lakeshore Owners, Circle Pines and RCWD
Secondary	Engineering	Street sweeping			x	Limited	Monthly	$ 100,000	$ 200,000	1, 2, 3	Cities
		Upstream ferric chloride treatment		x		High	Annually, Summer	$ 200,000	$ 400,000	3	Circle Pines and RCWD
		Lake level drawdown in winter	x	x	x	Limited	25 years	$ 50,000	$ 100,000	2	Circle Pines and RCWD
		Sediment delta removal	x	x	x	Medium	25 years	$ 100,000	$ 300,000	2	The City of Circle Pines
		Water level fluctuation	x			Variable	2-10 years	$ 50,000	$ 100,000	2	Circle Pines and RCWD
		Septic system compliance verification				Unknown	Continually	$ -	$ -	1, 2, 3	Responsible LGU
	Fisheries Manipulation	Fish stocking	x	x		Variable	1-5 years	$ 50,000	$ 200,000	1, 2, 3	MNDNR and RCWD
		Rotenone	x			Variable	Once			2	MNDNR and RCWD
		Reverse aeration	x			Variable	Once			2	MNDNR and RCWD
		Rough fish exclusion	x			Variable	Variable			2	MNDNR, Circle Pines and RCWD
	Stormwater Management	P-free fertilizer		x	x	High	Continually	$ -	$ -	1, 2, 3	MN Legislature
		Support enforcement of existing regulations			x	Unknown	Continually	$ -	$ -	1, 2, 3	RCWD, and MPCA
		Upstream wetland enhancement		x		Limited	Once	$ 200,000	$ 400,000	3	Cities and RCWD
	Vegetation	Protect and enhance fringe wetland vegetation	x		x	Medium	Once	$ 5,000	$ 100,000	2, 3	Circle Pines and RCWD
		Herbicide treatment of curlyleaf pondweed	x	x		Limited/Unkn.	Annually	$ 2,000	$ 5,000	1, 2, 3	Circle Pines and RCWD
	Experimental	Artificial floating islands	x			Unknown	Once	$ 10,000	$ 50,000	3	None
		Solarbee	x			Unknown	Once	$ 10,000	$ 100,000	3	None
		Barley straw	x			Unknown	Annually	$ 5,000	$ 15,000	3	None
		Other***	**			Unknown	Unknown	$ -	$ -	1, 2, 3	Cities and RCWD

* Timeline is listed by the MPCA permit cycle that the recommendation is expected to be completed in. Permit cycles are 2011-2016 (1), 2016-2021 (2), and 2021-2026(3).
**"Cities" refers to the City of Blaine, the City of Circle Pines, the City of Lexington, and the City of Lino Lakes. A city or cities listed as the Project Partner are not responsible for the load reduction associated with LA.
***Other practices will be considered as they are proposed and may include in-lake or watershed restoration activities.
****Included in this report as Appendix A.

A. Summary of Existing Activities

A number of best management practices already exist in the Golden Lake watershed.

1. Street Sweeping
   The cities of Circle Pines, Lexington, Lino Lakes, and Blaine perform street sweeping once each spring, summer, and fall.
2. Golden Lake Pond
   A water quality pond is located in Circle Pines just north of the Golden Lake inlet. This pond treats runoff from watersheds 111-131 (TMDL report Figure 2).
3. Aerator
   A hypolimnetic aerator was installed in Golden Lake in the late 1980s and was modified in 1992. The purpose of this aerator was to prevent winter fish kills and limit internal loading due to anoxic conditions in the hypolimnion.

1) RCWD Rule M and Rule RMP-1

In 2004, the Rice Creek Watershed District adopted a Comprehensive Wetland Management Plan (Village Meadows CWMP) for a 1,132-acre portion of the Golden Lake watershed within the City of Blaine. This area is facing intense development pressure due to its close proximity to the urbanizing fringe of the Twin Cities Metropolitan Area and the major road corridor, I-35W. This area included the location for a future stadium for the Minnesota Vikings and other extensive commercial development plans.

The CWMP creates a balance between wetland enhancement and preservation and land development. The CWMP provides for full replacement of disturbed wetland, in addition to wetland functions and values, on an area rather than a parcel basis. The CWMP aggregates existing and replacement wetlands to create a larger, contiguous wetland complex providing ecological functions and values exceeding what would result from a parcel-based application of the Wetland Conservation Act (WCA). At the same time, it allows developable upland, referred to as the development envelope, to be aggregated in proximity to existing and planned development infrastructure in a manner that enhances the value of the property for development and facilitates municipal implementation of a comprehensive plan for development and open space protection.

Incorporated into the CWMP is a large effort to address regional water conveyance and water quality. By implementing the CWMP, ACD 53-62 will be converted from a ditch conveyance system into a wet meadow waterway that contains multiple flow-through wetlands. Portions of this redesigned waterway have already been constructed. The creation of the waterway and the wetland restorations do not substitute for water quality treatment required for runoff from the development envelope. Areas within the development envelope will need to use water resource best management practices (BMPs) to improve water quality and control runoff volume. Examples include infiltration areas, ponding, swales, shared parking, and other low-impact development techniques. These stormwater requirements are enforced under the District's Rule M, which was created solely to implement the CWMP. This rule regulates activities on both developable upland and protected wetlands within the CWMP area in order to fully enhance and protect the water resources of the CWMP area and Golden Lake without unduly limiting the benefits created for property owners and municipal development.

RCWD has also adopted a Resource Management Plan (RMP) over the entire City of Blaine located within the Golden Lake watershed. This expanded plan is referred to as the 53-62 RMP (resource management plan). It emphasizes the benefits afforded to all natural resources within the area and not just the wetlands. Watershed District Rule RMP-1, adopted to implement the RMP, was used in this Golden Lake TMDL to set watershed phosphorus loading goals (*Section 1.C: Pollutant of Concern – Point Sources – Methods*) and to form the basis of the implementation strategy (*Section 8: Implementation Strategy*). Appendix J of the RMP includes specific wetland restoration strategies throughout the drainage area (Appendix C of this TMDL report). Additionally, Rule RMP-1 emphasizes wetland protection and stormwater infiltration. For more information on the Resource Management Plan, contact the Rice Creek Watershed District or visit the District website.

2) Educational efforts

The City of Blaine includes a stormwater article in each monthly newsletter, sent to all residents. RCWD employs a full-time environmental education coordinator.

B. High Priority Implementation Activities

Engineering

1) Alum treatment for Golden Lake

Aluminum sulfate (alum) is a chemical addition that binds with phosphorus to form a non-toxic precipitate (floc). Alum impairs plant uptake of phosphorus by two processes. The first process is the flocculation and removal of phosphorus from the water column. The second process forms a barrier between lake sediments and the water column to restrict phosphorus release from the sediments. This alternative is relatively inexpensive and can provide immediate results. However, due to the fact that Golden Lake is a shallow lake, it is unclear how long the floc would remain effective before being resuspended through wind mixing or disturbance by bottom feeding fish. Curlyleaf pondweed can also decrease longevity, by acting as a phosphorus pump across the alum-sediment barrier. Treating only the deeper portions of the lake (> 15ft) might be considered, as wind mixing and biological effects would be less in deeper areas.

2) Upstream alum treatment

In the spring of 2009, a temporary upstream alum treatment system was installed in Golden Lake pond located on ACD 53-62 just upstream of Golden Lake. This system pumps water from the pond/ditch, mixes it with aluminum sulfate to precipitate the phosphorus, and then returns the low-phosphorus water to the ditch/pond. The effectiveness of this measure will be assessed to determine if this practice should be continued, expanded, or stopped.

3) Lake drawdown and scraping of littoral sediments

This option consists of drawing the water levels within the lake down by four to six feet in the winter, and allowing the sediments in the shallower areas to freeze, consolidate, and decompose under significantly different conditions than those present in the lake when they are under water. Water levels would be allowed to rebound to previous levels in the spring following this treatment. This process has been shown to reduce the growth of curly-leaf pondweed, enhance the consolidation of lake bottom sediments, and expand the oxidation of organic bottom sediments in these shallow areas.

In addition to the drawdown activity, dredging, scraping, and removal of sediments that are present in these areas could be undertaken. This activity would reduce the presence of aquatic seed beds, remove organic sediments, and deepen the lake in the littoral areas.

4) Diversion/retention of flows
Opportunity exists to divert and retain flows from ACD 53-62. The original Golden Lake watershed was heavily modified by ditching, which has significantly increased the drainage area. Diverting some flow to vast wetland complexes north of 35W would decrease runoff through evapotranspiration, and reduce overall phosphorus loads to Golden Lake. Stormsewer systems should be evaluated near drainage divides to determine the feasibility of treating and rerouting these drainage areas.

5) Hypolimnetic withdrawal
This practice would involve removing water from the hypolimnetic zone of the lake, treating it chemically to remove phosphorus, and returning it to the lake. This practice could be part of the aeration system enhancement and would likely involve the use of alum or ferric chloride. The existing system draws water by gravity through a pipe to a sump, which is them pumped up to a “stair-step” type aerator. Water then runs back down a pipe to a diffuser at the same depth as the intake. The system would need to be evaluated to determine the feasibility of meeting hypolimnetic withdrawal needs.

6) Expand/enhance aeration system
The Rice Creek Watershed District will work with the Department of Natural Resources and the City of Circle Pines to develop an aerator operations plan that sustains winter oxygen levels for fish, while taking into consideration the effects of hypolimnetic circulation and sediment phosphorus release. This enhancement may be tied with hypolimnetic withdrawal and treatment, or may be a stand alone improvement.

Stormwater Management
7) RCWD’s Rule M and RMP-1
Rule M and RMP-1 affect the upstream portions of the ACD 53-62 drainage area. These rules will reduce phosphorus loading to the lake over time through wetland restorations and enhanced stormwater management rules. These rules have been adopted, but implementation will be an ongoing process as development occurs, so it is included as an existing and proposed implementation activity. Additional details regarding these rules can be found in the existing activities section of this report.

8) Stormwater Retrofits
Incentives and/or cost-share grants should be offered to property owners (residential, commercial, and institutional) who are willing to create infiltration, water re-use, and volume reduction practices.

Through the creation of matching grants and demonstration projects, the volume of stormwater that infiltrates to the groundwater instead of reaching Golden Lake could be increased. Key components include:

- Create residential infiltration projects.
- Utilize existing cost-share programs, such as RCWD's Water Quality Cost-Share Program, to financially support creation of infiltration and water quality treatment practices on private property.
- Utilize existing cost-share program, such as RCWD's Urban Stormwater Remediation Cost-Share, to financially support creation of infiltration and water quality treatment practices on public lands, especially on stormsewer outlets that are currently untreated.

Even though the majority of the lower watershed is developed, there are still opportunities for stormwater infiltration. Either neighborhood-scale rain gardens or subsurface filtration and infiltration devices could be used.

A neighborhood-scale rain garden would resemble large rain gardens, with native vegetation in depressional areas that would assist in stormwater infiltration. In areas where soil type or structure is not suitable for stormwater infiltration, under-drains could be incorporated into raingardens – i.e. a filtration system. Although such systems will not be as effective at reducing volume, they are effective at removing particulate phosphorus. The raingardens would also provide aesthetic benefits to the neighborhood and would provide an educational benefit. Educational displays would inform the public of the function of the rain garden and would explain the connection between stormwater management and the water quality of the lake. Incorporating iron-enhanced sand into rainagrdens could also serve to remove dissolved phosphorus from stormwater – especially when used with filtration-style raingardens.

If above-ground bioretention areas are not a possibility, subsurface chambers could serve a similar purpose. A subsurface stormwater drainage system is installed below a paved surface. Stormwater is diverted through the system, which stores the water and allows it to infiltrate into the ground. Stormwater could also be captured in underground tanks and reused for irrigation – a possibility for large commercial areas or athletic fields A cost-benefit analysis comparing these two options should be completed to aid in the decision of which approach to take.

In situations where surface infiltration/filtration gardens or underground infiltration systems are not feasible or desirable to landowners, other simple practices to reduce runoff could be encouraged. These practices include, but are not limited to, perennial gardens, trees, and soil de-compaction. In some cases, due to the limited potential for runoff reduction, these practices may not qualify for RCWD cost-share programs.

Vegetation

9) Shoreline buffers

Buffers of native vegetation around the perimeter of Golden Lake would help remove runoff pollutants from the drainage area before they reach the lake, as well as provide stability to the lakeshore, thus reducing wave induced erosion. Native vegetation also discourages geese from grazing the near shore areas. Maintaining and creating shoreline buffers can be accomplished through incentive programs.

C. Secondary Implementation Activities

Engineering

11) Street Sweeping

Street sweeping already exists in the Golden Lake watershed. At minimum, street sweeping should occur at least three times per year – early spring, late June, and fall.
Research suggests that sweeping monthly with a brush sweeper can reduce phosphorus loading by 3% *off of the swept surface*, but improving the practice to weekly sweeping with a vacuum-assist sweeper or regenerative-air sweeper will remove approximately 8% of the TP. The wide range in cost shown in the Table 7 reflects the wide range implementation options. Costs are variable, based on equipment used, and the number of street miles. Similarly, benefits are variable, based on street conditions, type of equipment used organic inputs to streets (based on tree cover, etc.). A more thorough analysis of cost benefit is recommended for each city.

12) Upstream ferric chloride treatment

This system would operate similarly to the upstream alum treatment, but uses ferric chloride instead of alum as the chemical component. The chemical reaction of ferric chloride and water creates iron oxyhydroxide, an insoluble material that bonds and precipitates the phosphorus. Under some conditions, the bond created between iron and phosphorus is slightly weaker than the bond between aluminum and phosphorus; ensuring the correct water chemistry (pH, DO conc.) would be crucial to success.

13) Sediment delta removal

The City of Circle Pines recently received Metropolitan Council funding to dredge the sediment delta that has accumulated at the inlet of Golden Lake. This delta has formed from sediment deposits from the 53-62 watershed and likely has high phosphorus content that can be released during lake mixing. Monitoring and removing this delta as needed in the future would reduce this source of internal phosphorus loading.

14) Water level fluctuation

This practice would reap the same benefits as a lake drawdown but would be conducted on an irregular basis every 2-10 years to simulate pre-outlet control water fluctuations. Water fluctuations encourage the growth of beneficial littoral vegetation through enhanced seed germination, and the aquatic vegetation can then improve habitat for fish and plankton.

Fisheries Manipulation

15) Food web manipulation

A balance of the biological components (predatory fish, planktivorous fish, zooplankton, aquatic plants, and algae) within a lake can affect the lake's water quality through trophic interactions that ultimately encourage a clear-water state with low algae concentrations. A 2007 DNR fisheries survey shows high densities of small bluegill and black crappie planktivores (Tables 8 and 9). This survey shows bluegill and black crappie numbers that are 38% and 77% above the normal range for similar lakes. At these high densities, the planktivores are likely overgrazing the zooplankton and decreasing the zooplankton's capacity to control algae concentrations. Additionally, when palatable zooplankton become limited, some planktivorous fish forage in the benthic sediments, which has the effect of releasing phosphorus from the sediments into the water column. Although some piscivores do exist in Golden Lake, the numbers are likely not enough to control the high numbers of planktivores.

Table 8. 2007 DNR Fisheries Survey Data, Fish Sampled for the 2007 Survey Year

Species	Gear Used	Number of fish per net		Average Fish Weight (lbs)	Normal Range (lbs)
		Caught	Normal Range		
Black Bullhead	Trap net	1.50	1.5 - 58.0	0.65	0.2 - 0.5
	Gill net	3.33	7.7 - 104.7	0.53	0.2 - 0.5
Black Crappie	Trap net	14.62	2.1 - 24.1	0.16	0.2 - 0.4
	Gill net	31.00	1.7 - 17.5	0.14	0.1 - 0.3
Bluegill	Trap net	79.25	3.5 - 57.1	0.14	0.1 - 0.3
	Gill net	23.33	N/A	0.16	N/A
Channel Catfish	Gill net	2.00	N/A	5.83	N/A
Hybrid Sunfish	Trap net	0.38	N/A	0.16	N/A
Largemouth Bass	Trap net	0.38	0.2 - 0.8	0.23	0.3 - 1.5
Northern Pike	Trap net	0.25	N/A	4.39	N/A
	Gill net	6.00	2.0 - 10.8	3.68	1.7 - 3.1
Pumpkinseed	Trap net	0.50	0.7 - 6.5	0.19	0.1 - 0.2
Walleye	Trap net	0.12	0.3 - 0.8	3.20	0.9 - 3.5
	Gill net	0.33	0.8 - 3.8	2.87	1.4 - 3.0

Table 9. 2007 DNR Fisheries Survey Data, Length of Selected Species (Trapnet, Gillnet) Sampled

Species	Number of fish caught in each category								
	0-5 in	6-8 in	9-11 in	12-14 in	15-19 in	20-24 in	25-29 in	30+ in	Total
Black bullhead	2	1	19	0	0	0	0	0	22
Black crappie	6	203	1	0	0	0	0	0	210
Bluegill	344	354	0	0	0	0	0	0	704
Channel catfish	0	0	0	0	0	4	2	0	6
Hybrid sunfish	2	1	0	0	0	0	0	0	3
Largemouth bass	1	1	1	0	0	0	0	0	3
Northern pike	0	0	0	0	3	6	11	0	20
Pumpkinseed	1	3	0	0	0	0	0	0	4
Walleye	0	0	0	0	0	2	0	0	2

Zooplankton data are presented in Figure 2. The zooplankton community in Golden Lake is typical of a turbid shallow lake with a low abundance of aquatic plants. There is a pulse of large *Daphnia* early in the growing season. Increased predation by planktivorous fish and a lack of refuge for the zooplankton (in submerged macrophytes) leads to a crash in the *Daphnia*, followed by species that are more resistant to fish predation, in this case *Diaphanasoma* and *Bosmina*.

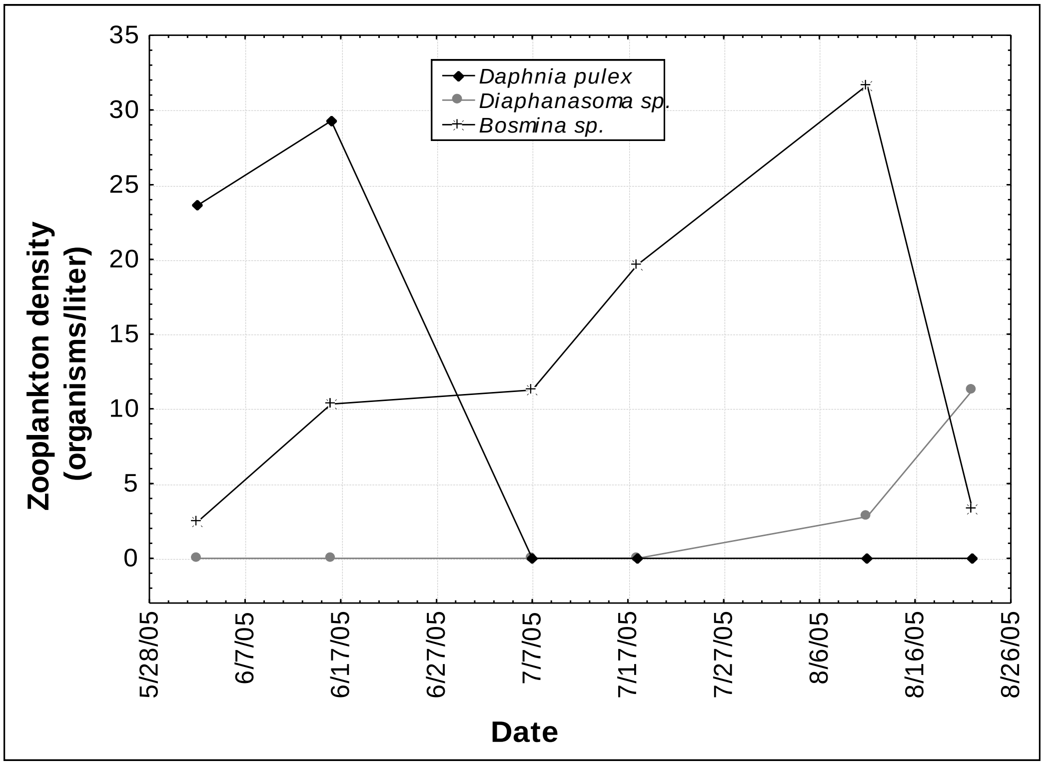

Figure 2. Zooplankton densities at Golden Lake site z001, 2005
*These three zooplankton groups were selected to illustrate the changing zooplankton community composition.

The fish and zooplankton data together suggest that managing the densities of planktivores might allow more *Daphnia* to persist throughout the summer, which would have a beneficial impact on the algae concentrations. Options to consider include the addition of more piscivorous fish, limiting the harvest of piscivorous fish, or increasing the harvest of planktivores. The lack of vegetation in the lake, which is at least partially due to the high tannin concentrations in the lake and not just suspended algae, would have to be considered, as vegetation normally serves as a refuge for zooplankton. The DNR and other stakeholders would need to meet and consider all aspects of a fisheries management strategy.

Stormwater Management
16) P-free fertilizer
Minnesota Statute (Chapter 18C) was updated to include the Phosphorus Lawn Fertilizer Law (SF 1555), which went into effect in 2004 and restricts the use of fertilizer containing phosphorus in non-cropped land. Since this is a relatively recent law, its full effect has not yet been observed. It has the potential to decrease phosphorus concentrations in residential runoff by approximately 10%.

17) Support enforcement of existing regulations
Existing regulations are often sufficient to improve water quality in these watersheds, but a lack of enforcement capabilities of the regulations can result in them being less effective. Enforcement of existing regulations by entities with management authority should be supported.

18) Upstream wetland enhancement
Wetlands along ACD 53-62 downstream of 35W could be modified to increase phosphorus removal outside of the area regulated by RCWD Rule RMP-1. This could include modifications to the Golden Lake pond, wetlands adjacent to the ditch, or promoting riparian vegetation and establishing buffers.

Vegetation
19) Protect and enhance fringe wetland vegetation
Fringe wetland vegetation is an integral part of a shallow lake's ecosystem and benefits water quality by filtering out incoming nutrients and stabilizing the shoreline and bottom sediments. This habitat should be enhanced in order to improve its function.

20) Curly-leaf Pondweed Management
Curly-leaf pondweed has been identified in Golden Lake. This invasive species acts as a winter annual, dying in early-summer and releasing phosphorus into the water column. This release of phosphorus can cause algae blooms and is not a natural part of the lake's phosphorus cycle. Spot treatment using herbicides to control curly-leaf pondweed would result in less phosphorus available for algal uptake. Herbicides are generally applied in April as the water temperatures reach 50-55˚. Treatments would likely need to be continued annually as infestations are monitored. Another management options could be to harvest curlyleaf pondweed. Unlike using herbicides, this option could result in the removal of phosphorus from the system. However, this option does NOT provide any long-term benefit for curlyleaf pondweed reduction. Any management strategy aimed at curlyleaf pondweed would need to be developed with cooperation from the DNR, as they are the permitting agency for such activities. As with all potential activity, but especially with this, costs would need to be compared to potential reductions in phosphorus loading. Lastly, there is some evidence to suggest that curlyleaf pondweed may be providing a winter oxygen refuge for fish in Golden Lake. Potential management strategies must take this into consideration.

Education
RCWD's education program works to reduce stormwater runoff across the watershed and meet water quality goals, with the Blue Thumb (bluethumb.org) program focusing on individual lots. As projects are constructed, RCWD will take the lead on educating the public about the goals of the project. Existing city newsletters can be utilized to present residential BMP opportunities to residents. Cities also have educational components in their surface Water Management Plans and MS4 permits.

Experimental
Experimental techniques are included in this implementation plan to provide an extensive menu of options for stakeholders. These practices would generally require partnerships and be considered pilot-projects. The following list is not exhaustive but represents the practices that were discussed during development of this plan; other developing technologies will be considered as they are developed.

21) Artificial floating islands
Artificial floating islands consist of a plastic-matrix planting medium (similar to a Brillo pad) that is vegetated with wetland plants. This practice creates additional wetland vegetation for nutrient uptake.

22) Solarbee
Solarbee is a solar-powered artificial circulation device that reduces anoxia in the hypolimnion, and disrupts blue-green algae growing conditions (stagnant water). Solarbees may provide a competitive advantage to green algae; since green algae are generally more palatable for zooplankton, this option might be done in conjunction with fisheries manipulation.

23) Barley straw
Barley straw is an emerging approach that is generally used on projects with small drainage areas. The barley straw is applied to the pond/lake annually and is thought to improve water quality by encouraging harmless bacteria growth and consequently reducing algal growth. This technique seems to be having a positive impact on Powderhorn Lake in Minneapolis.

24) Other
Other practices will be considered as they are proposed and may include in-lake or watershed restoration activities.

5. MONITORING AND VERIFICATION OF TMDL ACHIEVEMENT

The RCWD will act as the coordinator for implementation activities. In that role, they will facilitate meetings among project partners as activities or projects are proposed, designed, and implemented. When a proposed project or program targets reductions from the WLA (e.g. infiltration or stormwater retrofit), the RCWD will work with the appropriate MS4 permitee(s). When a proposed project or program targets reductions from the LA (i.e. alum or fisheries management), they will work with the appropriate agency and stakeholders. The RCWD will also lead or facilitate grant applications and management, and provide educational materials to residents by using various media (website, targeted emails, "e-blasts", and mailings). As BMPs are implemented by the MS4s, phosphorus reductions will be estimated and tracked. To track WLA achievement, the MS4s will be responsible for tracking and evaluating the implementation of BMPs and submitting this to MPCA via permit requirements. When implementation activities necessary to meet the target reductions have been implemented, the WLA will be considered achieved. As outlined in Section 3B, the baseline year for BMP implementation is 2004.

The RCWD has been monitoring Golden Lake fairly consistently since 1999. Efforts should be made to monitor the lake for phosphorus, chlorophyll-*a*, and Secchi transparency, at a minimum, on a bi-weekly basis for five growing seasons. The data will be evaluated by RCWD to assess the water quality trends occurring in the lake. Summer and winter dissolved oxygen profiles will be measured by the RCWD to better characterize oxygen and sediment phosphorus release dynamics. Adaptive management may require additional monitoring when different BMPs are implemented. Details of the RCWD monitoring protocol can be found in the RCWD's Water Quality Monitoring Reports.

Monitoring of ACD 53-62 should be completed for additional years in order to confirm the low TP yields calculated from the existing monitoring data. If further monitoring data suggest that loading rates are substantially higher than what was estimated for the TMDL, the TMDL may have to be re-opened to redistribute the WLAs and LA. This monitoring will also serve as an interim milestone for reduction of upstream loads due to Rule M and upstream wetland restorations.

Follow-up biological monitoring of Golden Lake should be conducted to track the progress of the response of the biological community to implementation activities. Monitoring should include fisheries surveys, zooplankton monitoring, algae monitoring if possible, and macrophyte surveys (DNR and RCWD).

6. COMPLIANCE SCHEDULE

The WLA will be met as soon as the implementation activities, or equivalent phosphorus reduction projects, are completed. It is expected that the WLA will be met by the end of the third permit cycle (i.e. by 2031). LA targets should be met by the end of the 3rd permit cycle.

7. ADAPTIVE MANAGEMENT APPROACH

Source, structural, and non-structural BMPs will be identified and implemented to the extent practical during the first five years (permit cycle #1). Stormwater retrofits will be tied to re-development plans and will focus on opportunities to get the greatest reduction in pollutant loading per unit cost of implementing the BMPs. Selection of BMPs and the BMP strategy may be modified as BMP research and monitoring results become available.

The RCWD will formally evaluate water quality data biennially. This evaluation will categorize the lake as improving or declining as compared to lake water quality during the time period used in the TMDL. If the lake is improving, the course or action will be to continue the prescribed implementation plan as defined in this document. The implementation plan will be reevaluated and amended to better meet the needs of the lake if improvement is not being shown.

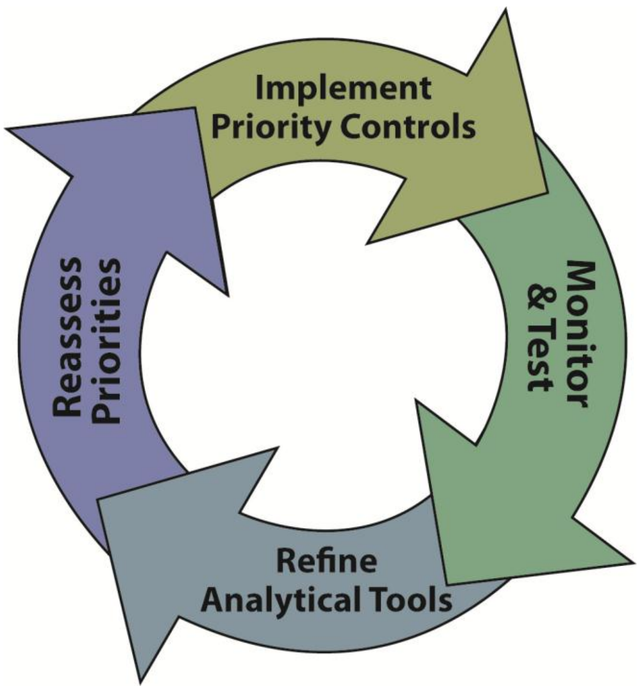

Figure 3. Adaptive Management Process

(Source: *Adaptive Implementation of Water Quality Improvement Plans: Opportunities and Challenges*, Nicholas School of the Environment and Earth Sciences, Nicholas Institute, Duke University, September, 2007)

8. FUNDING

Funding for implementation activities will come primarily from the MS4 capital improvement plans and state, watershed and federal grants as they become available. Funding sources were also described in Appendix A. Entities implementing the BMPs in this plan will be responsible for securing funding.

Clean Water Act Section 319 Programs – Financial assistance is provided to address non-point source water pollution, including the study of water bodies with pollution problems, development of action plans, and implementation of the action plans.

Minnesota Clean Water Legacy Program – Passage of the Clean Water, Land and Legacy Amendment in 2008 made funding available for TMDL implementation activities. Four state agencies are involved in distributing the funds: the Board of Water and Soil Resources, the Minnesota Pollution Control Agency, the Minnesota Department of Agriculture, and the Minnesota Department of Natural Resources.

State Cost-Share – State Cost-Share is a program of the Minnesota Board of Water and Soil Resources. It is administered through local SWCDs and is designed to provide base grants of up to 75% of a project cost in order to help local landowners/occupiers with projects that protect and improve water quality, such as controlling soil erosion and reducing sedimentation. By reducing soil loss there should be commensurate reduction in phosphorus (that is attached to the soil) delivered to surface water.

Environmental Quality Incentives Program (EQIP) – EQIP is a program of the Natural Resources Conservation Service whose funds are provided through the Federal Farm Bill. It is designed to help private landowners with technical assistance and a cost-share of up to 50% in order to protect local soil and water resources. They fund such things as nutrient management plans, designs for animal waste structures, wetland restoration, rotational grazing management plans and conservation tillage

Agriculture Best Management Practices Loan Program (AgBMP Loan Program) – AgBMP Loan Program is a program of the Minnesota Department of Agriculture. It is administered through local SWCDs, and offers low interest loans (currently 3%) for implementation of best management practices to improve water quality problems that are caused by agricultural activities or failing septic systems.

Conservation Reserve Program – USDA program that shares the cost of establishing riparian buffers with the landowner, and provides landowner land rental payments for a minimum of 10 year. Landowner must enter in to a contractual agreement with the USDA, and is required to meet minimum federal standards. Contact the USDA-NRCS office for details.

Partners for Wildlife Program – US Fish and Wildlife Service (USFWS) financial assistance program to establish wildlife habitat projects such as wetland rehabilitations and riparian rehabilitations. Contact USFWS for more details.

State Conservation Easement Programs – BWSR program locally administered by SWCDs, which purchases conservation easements and provides funding for establishment of BMPs. Easements between the State of MN and the landowner are perpetual. Contact the local conservation district office for more details.

RCWD Water Quality Cost-Share - The RCWD has created a dedicated cost-share grant program to assist landowners with the implementation of Best Management Practices (BMPs) aimed at improving the quality of surface waters within the District. In many cases, the RCWD can cost share up to 50% of total project costs.

RCWD Urban Stormwater Remediation Cost-Share - Cost-Share funding is available to assist counties, cities, villages, townships, school districts, libraries, colleges and universities and other public and private entities located within the RCWD to incorporate water quality improvement practices into redevelopment, roadway and storm sewer improvement projects in 2009

In-Kind Contributions – Many of the actions will be implemented by Rice Creek Watershed District, counties, municipalities, and others using in-kind funding and Capital Improvement Plans.

REFERENCES

Emmons and Olivier Resources, Incorporated. Resource Management Plan: Alternative for the Repair of Anoka County Ditch 53-62. Prepared for the Rice Creek Watershed District. 2005.

Emmons and Olivier Resources, Incorporated. Golden Lake TMDL. Prepared for the Minnesota Pollution Control Agency. August 2009.

WSB & Associates, Incorporated. Water Quality Management Plan for Golden Lake. Prepared for the City of Circle Pines. January 2003.

APPENDIX A