Diamond Lake
Total Maximum Daily Load (TMDL)

Implementation Plan
August 25, 2011

Prepared For:

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TMDL Summary Table		
EPA / MPCA Required Elements	Summary	TMDL Page #
Location	Diamond Lake is located in Kandiyohi County , 12 miles northeast of Willmar, Minnesota, within the North Central Hardwoods Ecoregion, Upper Mississippi River Basin	1
303(d) Listing Information	Diamond Lake Assessment Unit Identification Number is 34-0044-00. The MPCA listed Diamond Lake in 1998 because of elevated mercury in fish tissue and concern related to fish consumption. The MPCA identified in 2006 that the lake failed to attain the designated use for aquatic life and recreation, because of excess nutrients and again placed the lake on the 303(d) list. Diamond Lake has remained on the 303(d) list through the current 2010 list. The 2010 303(d) list shows initiation of the TMDL in 2008 and completion by 2012.	3
Applicable Water Quality Standards / Numeric Targets	Diamond Lake is an unlisted water per MR 7050.0430 and is a Class 2B, 3C, 4A, 4B, 5, and 6 water. Classification as 2B means protection as a cool and warm water fisheries. The numeric target is the numeric criteria for a deep lake, Class 2B, located within the North Central Hardwoods Ecoregion. The numeric standards expressed as the June through September average value are: total phosphorus 40 ug/L; chlorophyll-a 14 ug /L; and Secchi disk transparency greater than 1.4 meters.	19
Load Capacity (expressed as daily load)	The loading capacity is the total maximum daily load for Diamond Lake. Based upon “normal” hydrologic conditions. The maximum load capacity is 3.785 kg per day (8.344 lbs/day) expressed as total phosphorus.	55
Wasteload Allocation	The portion of the load capacity attributed to point sources including National Pollutant Discharge Elimination System (NPDES) permitted sources within the contribution drainage is zero. There are no NPDES permitted facilities in the watershed.	55

TMDL Summary Table (CONTINUED)			
EPA / MPCA Required Elements	Summary		TMDL Page #
Load Allocation	The portion of the loading capacity allocated to existing and future nonpoint sources (2008).		55
	Sources	**Load kg/day (lb./day)**	**Load kg/year (lb./day)**
	Atmospheric Deposition	0.321 (0.708)	117 (257.9)
	Subsurface Treatment Systems	0	0
	Watershed Sources	1.926 (4.246)	703 (1,549.9)
	Upstream Lakes	0.426 (0.939)	155.5 (342.8)
	Internal Sources	0.282 (0.622)	103 (227.1)
	TOTAL	**2.955 (6.515)**	**1078.5 (2,377.7)**
Seasonal Variation	Seasonal variation is accounted for by developing targets for the summer critical period where the frequency and severity of nuisance algal growth is greatest. Although the critical period is the summer, the response variables (chlorophyll-a and water clarity) are driven by the variability in annual loads of total phosphorus.		58
Reasonable Assurance	Reasonable assurance is provided by the cooperative efforts of the Middle Fork Crow River Watershed District (MFCRWD), a local unit of government with statutory authority to protect and improve the water quality of water resources including Diamond Lake.		58
Implementation	The TMDL sets forth an implementation framework and general load reduction strategies.		59
Public Participation	A number of stakeholder involvement meetings were completed as a part of the TMDL study		76
Monitoring	The MFCRWD has implemented and operates a water quality monitoring program. Monitoring will continue for a maximum period of 3-years following approval of the TMDL.		79

SECTION 1.0
INTRODUCTION AND APPLICANT DATA

Diamond Lake is a 1,607 acre lake, located in east-central Kandiyohi County in west-central Minnesota. The outlet from Diamond Lake is controlled by a fixed crest dam, constructed in 1952, which is owned by Kandiyohi County. Water leaving Diamond Lake flows into a public drainage system into the Middle Fork of the Crow River, the Crow River, and eventually the Mississippi River. Diamond Lake is about 6 miles northwest of Atwater and 12 miles northeast of Willmar, Minnesota. Diamond Lake is the focus of a Total Maximum Daily Load (TMDL) study lead by the Middle Fork Crow River Watershed District (MFCRWD). The MFCRWD retained Houston Engineering, Inc. (HEI) to assist with technical activities necessary to complete the TMDL study.

The key component of the TMDL report in terms of future activities designed to bring the lake into compliance with water quality standards is the Implementation Plan. This document serves as a request for Minnesota Pollution Control Agency (MPCA) approval of the Diamond Lake TMDL Implementation Plan. The full TMDL report has been submitted to the MPCA; as of the date of this request, EPA approval is pending. The full report is also available upon request.

The MFCRWD is the applicant for this TMDL report. Contact information for the applicant is as follows:

Name of Organization:	Middle Fork Crow River Watershed District
Type of Organization:	Special purpose unit of government – Watershed District
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SECTION 2.0
PROJECT BACKGROUND INFORMATION

The title of this project is the Diamond Lake TMDL Study. **Table 2-1** provides specific information related to this project.

Table 2-1 Project Information for the Diamond Lake TMDL.

Project Title	Diamond Lake TMDL Study
Listed Reach Name	Diamond Lake
Assessment Unit Identification No.	34-0044-00
Year Listed	2006
Impaired Beneficial Use	Aquatic Life and Recreation
Pollutant	Excess Nutrients
303(d) List Scheduled	Start Date: 2008 Target Completion Year: 2012
Contract Amount	$176,215
Project Dates	February 2008 – June 2011

Diamond Lake's lake identification number, as assigned by the Minnesota Department of Natural Resources (MnDNR), (which is the same as the Assessment Unit Identification Number) is 34-0044-00. Minnesota Rule (MR) 7050.0140 *Use Classifications for Waters of the State* identifies the various uses of the state's waters, considered in the best interest of the public (i.e., beneficial uses). These beneficial uses are:

- Drinking water – Class 1
- Aquatic life and recreation – Class 2
- Industrial use and cooling – Class 3
- Agricultural use, irrigation – Class 4A
- Agricultural use, livestock and wildlife watering – Class 4B
- Aesthetics and navigation – Class 5
- Other uses – Class 6
- Limited Resource Value Waters – Class 7

Most water bodies have multiple beneficial uses, rather than a single use. Diamond Lake is an unlisted water, per MR 7050.0430, having multiple (potential) beneficial uses, including aquatic life and recreation (Class 2B), Industrial use and cooling (Class 3C), Agricultural use for irrigation and livestock (Classes 4A and 4B), aesthetics and navigation (Class 5), and other uses (Class 6). Classification as 2B means the lake must be protected as a cool and warm water fishery. Classification as 3C means that the quality of the water shall be such as to permit use for industrial cooling and materials transport without a high degree of treatment being necessary to avoid severe fouling, corrosion, scaling, or other unsatisfactory conditions. Generally, one of these uses requires "better" water quality than the remaining uses. Normally, this use is aquatic life and recreation.

The MPCA listed Diamond Lake in 1998 because of elevated mercury in fish tissue and concern related to fish consumption. The MPCA identified in 2006 that the lake failed to attain the designated use for aquatic life and recreation, because of excess nutrients and again placed the lake on the 303(d) list. Diamond Lake has remained on the 303(d) list through the current 2010 list. The 2010 303(d) list shows initiation of the TMDL in 2008 and completion by 2012. In November 2007, the MFCRWD submitted a workplan in accordance with the TMDL Workplan Guidance (Minnesota Pollution Control Agency, October 2007) and upon approval by MPCA staff in early 2008, the MFCRWD initiated the field work needed to complete the TMDL. Monitoring began in 2008 and because of dry conditions was extended through 2009.

Diamond Lake was the focus of a previous study, which evaluated water quality. The data collected during that study in part became the basis for placing the lake on the 303(d) list. A Diagnostic and Feasibility Study completed for Diamond Lake by Blue Water Science (1996) was funded by a U.S. EPA Clean Lakes Phase I Grant. The study incorporated stream and lake monitoring for approximately two years and limited paleolimnological sediment cores. The models Agricultural Nonpoint Source Model (AGNPS) and Wisconsin Lake Modeling Suite (WiLMS) were used to assess watershed yields and potential lake response. Phosphorus yields were estimated from the contributing watershed drainage areas. An in-lake nutrient goal was identified in the study and phosphorus reductions were recommended for each source area to reduce the measured mean annual total phosphorus concentration of 72 ug/L. Measured annual mean chlorophyll-a concentrations and secchi disk depths were 29.8 ug/L and 5.6 feet (1.7 meters) respectively (in 1993 and 1994). The report recommended a total phosphorus water quality goal of less than 50 micrograms per liter (ug/L) and a 40 percent load reduction from the estimated 3,697 kg annually to achieve that goal. Specific load reductions were assigned to various subwatersheds.

Diamond Lake was also included as one of the lakes used to establish nutrient criteria for the State of Minnesota (see http://www.pca.state.mn.us/publications/reports/lakes-wqdiatoms.pdf). Sedimentation rates were evaluated and used to estimate the pre-European phosphorus levels within Diamond Lake. The analysis completed by the MPCA infers pre-European phosphorus concentrations between 20 and 30 ug/L.

The Diamond Lake watershed was given a priority ranking for TMDL development due to the impairment impacts on aquatic life, the public value of the impaired water resource, the likelihood of completing the TMDL in an expedient manner, the inclusion of a strong base of existing data and the restorability of the water body, the technical capability and the willingness of local partners to assist with the TMDL and the appropriate sequencing of TMDLs within a watershed or basin. Diamond Lake is a popular location for aquatic recreation including, boating, swimming, fishing and hunting. Water quality degradation has led to efforts to improve the water quality within the Diamond Lake watershed since the late 1990’s and to the development of this TMDL.

SECTION 3.0
IMPLEMENTATION PLAN SUMMARY

3.1 GENERAL DESCRIPTION OF POSSIBLE IMPLEMENTATION ACTIVITIES

The TMDL implementation plan focuses on reducing both external watershed and internal in-lake sources of total phosphorus. An estimated 561.3 kilogram annual total phosphorus load reduction (1.5 kg/day) is needed to attain the loading capacity of 1,387 kg/year (3.8 kg/day) to achieve the 40 ug/L annual average total phosphorus water quality standard (see TMDL report). Portions of the loading capacity have been allocated to external watershed and internal in-lake sources (both are part of the non-point source load allocation). The external watershed sources include Subsurface Sewage Treatment Systems (SSTS). The amount of load allocated to each nonpoint source is based in part on the technical feasibility of the probable implementation measures necessary (discussion follows) to achieve the reduction as follows. Implementation priorities are qualitatively ranked as high, moderate and low, reflecting the probable implementation order (i.e., implement high priority activities preferentially).

Implementation activities can occur concurrently or in a sequential manner depending on the availability of funding and the willingness of potential participants. A minimum of 10 years is expected to implement the activities required to achieve the maximum allocated loads and the loading capacity. This section generally describes the range of implementation measures considered to achieve the allocated load by type of source and specifically identifies the proposed implementation activities.

3.1.1 Watershed (External) Sources

Three primary watershed sources of total phosphorus to Diamond Lake have been identified that can be controlled to attain the loading capacity and achieve the water quality numeric standards for total phosphorus, cholorophyll-a, and secchi disk visibility. The following section generally discusses the implementation activities for watershed sources followed by specific implementation recommendations.

3.1.1.1 Subsurface Sewage Treatment Systems (SSTS)

SSTS's can directly or indirectly affect the quality of Diamond Lake via subsurface flows, if the systems are aged and failing (meaning it is leaking), have inadequate separation between the treatment systems and the underlying groundwater and are located within soils such that the leachate can move horizontally toward and reach Diamond Lake. The seasonal and year-round residences surrounding Diamond Lake are currently served by Subsurface Sewage Treatment Systems (SSTS) (a.k.a. septic systems). The area surrounding Diamond Lake is developed with 365 permanent and seasonal residences and nearly the entire shoreline is in residential land use. At least 70% of the permanent and seasonal residences were built prior to 1996 and therefore, may have inadequate separation of the SSTS with the seasonal high water table. The lack of separation is one indication of inadequate design and treatment.

Information about SSTSs came from a 2008 study completed by Wenck Associates (Wenck, 2008). The information used from this study included the number of structures located on the lake and the percentage believed to comply with Minnesota standards for design. Those failing to achieve the design standards are considered as potentially failing and contributing total phosphorus to Diamond Lake. Based upon a review of the SSURGO soils, one-half of the residences on Diamond Lake served by an SSTS and not meeting the current design standards, were considered failing and contributing nutrients to Diamond Lake, when constructing the total phosphorus mass balance. (Note: approximately one-half of the soils around Diamond Lake are of a nature that the movement of SSTS leachate has a low probability of reaching Diamond Lake, consisting predominately of clays.) An estimated 128 kg of total phosphorus annually reaches Diamond Lake because of failing septic systems. This equates to 11% and 14% of the total phosphorus entering Diamond Lake in 2008 and 2009, respectively.

Three alternatives for addressing SSTSs were evaluated in the report by Wenck (2008):

1. Managed SSTS program;
2. Cluster systems for each service area; and
3. Connect to the Green Lake Sanitary Sewer District (GLSSD) for the entire Study Area and a subset of Study Area.

Table 3-1 provides the probable cost for various alternatives to address SSTSs serving residences around Diamond Lake.

Table 3-1 Opinion of probable construction cost for addressing Diamond Lake SSTSs.

	Option 1 Managed SSTS Program	**Option 2 Cluster Treatment Systems**	**Option 3 Connect to GLSSD[1]**
Total Assessed System Costs	$ 3,536,000	$ 5,592,000	$ 6,941,000
Average Cost/Unit	$ 10,000	$ 16,000	$ 18,700

[1]Does not include trunk costs carried by the County

Residents elected to proceed with Option 3. Initial estimates were that 170 of the 365 residences would have connected to the GLSSD; at the time the full TMDL report was written, this number grew to 286, and upon project completion, 310 residences will be connected. The estimated load reduction associated with connecting these residences to the regional system (again assuming a 70% failure rate and that one-half of those that fail have soil conditions which allow an actual contribution to the lake) is 59.5 kilograms.

3.1.1.2 Upstream Lake Management

Schultz, Wheeler, and Hubbard lakes, are upstream shallow lakes / wetlands that following current conventional scientific thinking should reduce the amount of total phosphorus load to Diamond Lake when in the clear state, thereby serving as a phosphorus sink. **Table 5-2** in the full TMDL report shows the loads and yields of TP contributed by monitored tributaries to Diamond Lake. The data contained within **Table 5-2** suggest an increase in the total phosphorus load moving downstream through Wheeler Lake and Hubbard Lake into Diamond Lake. Only the 2009 monitoring data are adequate to estimate the change in load through the upstream lakes. The long term data suggest an increase in the annual total phosphorus load through the upstream lakes of 500 kg.

An estimated 48% (433 kg) and 71% (555 kg) of the total phosphorus entering Diamond Lake from ***all*** sources in 2008 and 2009 came through the primary inflow to Diamond Lake (i.e., the DL-1 monitoring location). An estimated 74% (433 kg) and 83% (555 kg) of the total phosphorus entering Diamond Lake from surface runoff in 2008 and 2009, respectively, came through the DL-1 monitoring location from the upstream lakes. The SWAT model estimated 500 kg annually through DL-1.

Monitoring data show that the upstream shallow lakes (wetlands) have elevated turbidity (**Appendix A in the full TMDL report**). Observations during monitoring confirm that the elevated turbidity is most likely the result of a large carp population. Carp have the ability to stir up sediments and disturb vegetation, mobilizing phosphorus that otherwise could be retained in the bottom sediments of the shallow lakes. Essentially no information about the density of the carp population is available. It is known that carp winter killed (i.e. suffered a die off) within Wheeler Lake during the winter of 2009. It is also known that controlling rough fish like carp has the ability to alter the state of a shallow lake from turbid to clear.

These upstream lakes are in a turbid state and conversion to the clear state has considerable potential for improving not only the water quality of the upstream lakes, but the water quality of Diamond Lake. Available water quality data from Lake Christina in central Minnesota shows that total phosphorus and chlorophyll-a concentrations can be reduced dramatically, by maintaining a shallow lake in the clear state compared to the turbid state. Average annual total phosphorus concentrations within Lake Christina are near 100 ug/l when in the turbid state, compared to near 40 ug/l when in clear state (a reduction of 2.5 times). Average annual total chlorophyll-a concentrations are near 50 ug/l when in the turbid state, compared to near 10 ug/l when in the clear state (a reduction of 5 times). For planning purposes the conversion of Hubbard and Wheeler lakes to the clear state from the current state is assumed to reduce average annual total phosphorus and cholorphyll-a concentrations by 2 and 4 times respectively.

3.1.1.3 Surface Inflow

Agricultural Conservation Practices

Surface inflow or surface water runoff from the surrounding watershed from agricultural lands is a source of total phosphorus. The estimated loads from gaged and ungaged surface inflow to Diamond Lake are 586 kg per year (48%) and 669 kg per year (71%), for 2008 and 2009 respectively.

A broad range of Agricultural Conservation Practices (ACPs) can potentially be used to reduce the amount of phosphorus entering Diamond Lake. The costs for the ACPs vary and some have limited applicability. ACPs can often be used in combination to gain the greatest benefit. A recent report by the Natural Resource Conservation Service (NRCS) (USDA-NRCS, 2010), http://www.nrcs.usda.gov/technical/nri/ceap/umrb/index.html suggests that combinations of ACPs often provide the most effective means of reducing soil loss and nutrients to downstream areas. One of the most challenging aspects of installing ACPs is getting support and commitment of local landowners and other stakeholders. Education and financial support often are needed to initiate and maintain a long-term commitment to ACP implementation and function. Local organizations including the MFCRWD and the Kandiyohi County Soil & Water Conservation District are important in providing the education and support needed to establish ACPs wherever possible and effective.

Table 3-2 identifies a range of potential ACPs suggested by the Minnesota office of the NRCS for agricultural lands. The table also provides estimates of the 2009 probable installation costs by the type of ACP. The costs for the same practice can vary considerably depending upon the cost of land and site, specific design and implementation considerations. Operation, maintenance, and forgone income previously provided by harvested crops, are not included in the probable installation cost.

Considering the current physical characteristics of the landscape contributing runoff to Diamond Lake (see **Section 3.0**, Description of the Watershed in the full TMDL report), certain ACPs seem more logical for implementation based on wind and water erosion rates, the slope of the land surface, and the locations of potential storage areas. These ACPs are:

- Filter strips adjacent to waterways;
- Wetland restorations;
- Temporary storage of water adjacent to drainage systems and waterways; and
- Residue and tillage management.

The maps contained within **Section 3.0** of the full TMDL report, provide information about soil erosivity from wind and water, the location of drained wetlands, and the locations of watercourses and public drainage systems, can be used to prioritize the locations of these ACPs for implementation. Information derived from the watershed source assessment can also be used to prioritize potential implementation areas (see **Section 3.0** of the full TMDL report).

Table 3-3 summarizes the estimated range of removal efficiencies for sediment and total phosphorus for these ACPs. This range has been used to identify the probable reduction associated with the various implementation strategies in Section 3.2 Implementation Plan.

Urban Best Management Practices

Because of the largely rural nature of the Diamond Lake watershed, there is little opportunity for the use of Best Management Practices, typically used within urbanized areas. These BMPs can include rain gardens, infiltration trenches, porous pavers, biofiltration swales, wet and dry detention ponds, and similar BMPs. There is an opportunity however, for residents on the lake to improve water quality. The BMPs applicable to lake residents include the use of no-phosphorus fertilizers and establishing native planting / buffer strips adjacent to the lakeshore to filter runoff. The effectiveness of buffer strips in reducing total phosphorus is similar to filter strips used for agricultural purposes. Residents that decide not to connect to the regional wastewater treatment system that have a failing SSTS, should be expected to upgrade their system to be in compliance with design standards.

Table 3-2 NRCS Suggested Agricultural Conservation Practices and Associated Costs - 2009.

Practice/Activity Name	Practice/Activity Type	Unit Type	Total Cost
Conservation Crop Rotation	Annual Crops to 2 Years with Cover	Acre	$11.61
Conservation Crop Rotation	Annual Crops to 2 Years with Cover - Organic	Acre	$15.48
Conservation Crop Rotation	Low Residue Crops to High Residue Crop Rotation	Acre	$15.48
Filter Strip	Single Species Introduced or Native Grass	Acre	$127.09
Filter Strip	Introduced Grasses and Legumes	Acre	$99.35
Filter Strip	Mixed Native Grasses with or without Forbs	Acre	$168.46
Filter Strip	Single Species Introduced or Native Grass with Shaping	Acre	$216.92
Filter Strip	Introduced Grasses and Legumes with Shaping	Acre	$179.49
Filter Strip	Mixed Native Grasses with or without Forbs with Shaping	Acre	$248.60
Pasture and Hayland Planting	Lime	ton	$29.21
Pasture and Hayland Planting	Introduced Grasses for Pasture into Cropland	acre	$123.73
Pasture and Hayland Planting	Introduced Grasses for Hayland into Cropland	acre	$118.69
Pasture and Hayland Planting	Seed Native Grasses into Existing Cropland	acre	$153.23
Pasture and Hayland Planting	Introduced Grasses for Pasture into Sod or CRP	acre	$150.07
Pasture and Hayland Planting	Introduced Grasses for Hayland into Sod or CRP	acre	$140.53
Pasture and Hayland Planting	Seed Native Grasses into Sod or CRP	acre	$179.57
Pasture and Hayland Planting	Broadcast Legumes into Existing Pasture	acre	$36.50

Table 3-2 (continued) NRCS Suggested Agricultural Conservation Practices and Associated Costs - 2009.

Practice/Activity Name	Practice/Activity Type	Unit Type	Total Cost
Residue and Tillage Management - No Till, Strip Till	Residue and Tillage Management - No-till, Strip Till	acre	$30.50
Residue and Tillage Management - Ridge Till	Residue and Tillage Management - Ridge-Till	acre	$30.70
Sediment Basin	Feedlot Slotted Wall	Feet	$55.35
Sediment Basin	Concrete Bottom	sq ft	$4.19
Sediment Basin	*Silt Fence*	*Feet*	*$2.30*
Water and Sediment Control Basin	*3 ft of fill height or less*	*each*	*$1,000.00*
Water and Sediment Control Basin	Fill height of greater than 6 and a drainage area of less than 10 acres	each	$4,500.00
Water and Sediment Control Basin	Fill height of 3.1 to 6 feet	each	$3,000.00
Water and Sediment Control Basin	Greater than 6 feet fill height and a drainage area 10 to 20 acres	each	$6,000.00
Water and Sediment Control Basin	6.1 feet to 10 feet fill height and a drainage area 20 to 40 acres	each	$9,000.00
Water and Sediment Control Basin	Greater than 10 feet fill height and a drainage area 20 to 40 acres	each	$12,000.00
Wetland Restoration	Ditch Plugs	Each	$500.00
Wetland Restoration	Embankments	Cu Yd	$6.00
Wetland Restoration	Scrapes	acre	$6,000.00
Wetland Restoration	Tile Breaks	each	$500.00
Wetland Restoration	Water Control Structure	each	$2,500.00

NOTE: Total Cost includes Material, Equipment/Installation, Labor and Mobilization. It does not include operation and maintenance or foregone income. These rates were developed for FY2009.

Table 3-3 Estimate range of annual removal rates for various Agricultural Conservation Practices.

Practice / Activity Name	Estimate Range of Annual Removal Rates	
	Total Phosphorus	Sediment
Filter Strips [1]	0.09-0.67 lbs/acre treated/year	0.0001-0.19 tons/acre treated/year
Pasture and Hayland Planting (conversion to permanent cover) [1]	0.13-0.65 lbs/acre treated/year	-0.0005-0.19 tons/acre treated/year
Temporary Storage (i.e., wetland restoration or side inlet controls) [1]	0.07-4.11 lbs/AF additional storage/year	-0.03-0.56 tons/AF additional storage/year

[1.] BMP effectiveness estimated from simulation in the Diamond Lake SWAT model. Load reductions represent net reductions – i.e., those achieved at the outlet of a subbasin and not at the field level.

3.1.2 Internal (In-Lake) Sources

Internal sources of TP may also be addressed to reduce total phosphorus loading. In many deep lakes, phosphorus accumulated in bottom sediments through time can be released back into the water column under anoxic conditions. The amount released from the sediments depends in part upon whether there is a lack of oxygen (actually reduced conditions) at the sediment – water interface. Higher release rates occur during anoxic conditions.

Because Diamond Lake typically does not thermally stratify and develop an anoxic hypolimnion for a long period of time, this source of phosphorus can be small relative to the amount from surface runoff. The estimated range for the internal load of total phosphorus released from sediment is 386 (31% of the budget) kg per and 20 kg per year (2.8% of the budget) for 2008 and 2009 respectively (an average 206 kg per year which was used in the modeling) based upon the monitoring data.

There are several potential methods to reduce internal loading. These methods include aeration of the hypolimnetic water and the use of aluminum sulfate to “sequester” phosphorus within the sediment. The use of aeration is considered marginal because Diamond Lake only weakly thermally stratifies. The use of aluminum sulfate is a viable implementation activity although the longevity of the treatment is a concern because the lake has a large littoral zone. Experience with the use of aluminum sulfate in lakes shows reduced longevity (on the order of 3 to 7 years) for lakes which fail to or only weakly thermally stratify compared to deep lakes that strongly thermally stratify (on the order of 10 or more years). Longevity is also reduced in lakes, where the external load has not been effectively reduced.

An aluminum sulfate treatment can be effective in reducing the internal loading. The reduction in lake concentration is typically 80%. Aluminum sulfate treatment costs range from $280 to $700 per acre (average $450 per acre).

Another source of phosphorus to the lake is the annual growth and summer die-off of curly leaf pondweed, which can result in the release of phosphorus, which may lead to algal blooms. In two lakes in east-central Minnesota, the concentration of TP increased by 21 ug/L and 52 ug/L following the senescence of curly leaf pondweed (http://www.elmcreekwatershed.org/2004ARapp3.pdf accessed July 9, 2010). This exotic infestation is confined to a relatively small part of Diamond Lake and may be relatively easy for professional applicators to control.

3.1.3 Public Information and Education

Some load reduction may be achieved by changing the behavior of residents within the drainage area contributing runoff to Diamond Lake. Examples of behaviors that can be changed through providing information to and education of the public, include the use of no-phosphorus fertilizers, the proper disposal of yard waste, the implementation of buffer strips adjacent to the lake, and disconnecting impervious surfaces.

3.2 RECOMMENDED IMPLEMENTATION PLAN

This section describes the recommended Implementation Plan. Each implementation strategy is described in tabular format and includes an estimated implementation cost.

3.2.1 Watershed (External) Sources

The goal for these sources is a reduction of 550 kilograms of phosphorus annually, which includes a 155.5 kg reduction internally within the upstream lakes. The MFCRWD will work with other organizations and agencies to educate landowners, homeowners, and farmers about the benefits of reducing nutrient loads. The MFCRWD will identify and promote cost share and reimbursement programs that will encourage participation and minimize financial burdens. Agricultural conservation practices likely eligible for these programs will include filter strips, conservation tillage, and the planting of cover crops. Wetland restorations will also be considered. Around lake homes, rain gardens, shoreline filter strips and fertilizer management, can reduce negative impacts on Diamond Lake.

Implementation Activity WS-1: Connect Diamond Lake SSTSs to the Green Lake Regional Wastewater Treatment System

Description	Based upon currently available estimates up to 310 of the 365 residences surrounding Diamond Lake will be connected to the regional wastewater treatment system.
Implementation Priority	High
Estimated Total Phosphorus Load Reduction	The estimated load reduction associated with connecting residences to the regional system is 59.5 kilograms from 127.5 kilograms annually.
Assumptions Implicit in the Estimated Load Reduction	Assumes a 70% failure rate and one-half of those that fail have soil conditions which allow an actual contribution to the lake. No other failing SSTSs will be upgraded to reduce loads. Load reduction based upon earlier estimate of 170 residences becoming connected.
Responsible Parties	MFCRWD, DLARA, Green Lake Sanitary Sewer District
Timeline	Completed 2014
Planning Level Estimated Cost	$6,941,000

Implementation Activity WS-2: Upstream Lake Management To Achieve Clear Water States within Hubbard and Wheeler Lakes

Description	Develop and implement a management plan for Hubbard and Wheeler Lakes, with the purposes of maintaining the lakes in the clear phase. Expectations are that the plan would focus on the management of "rough fish" and primarily carp populations. The plan is expected to consist of installing fish barriers between Diamond Lake and Hubbard Lake and between Wheeler Lake and Schultz lake, to isolate the carp population to Hubbard and Wheeler Lakes. A gravity flow water level management system from Wheeler Lake to the outlet bypassing Diamond Lake appears to be technically feasible. Therefore, lowering the water surface elevation of these lakes to induce a winterkill as a means of controlling the carp population appears feasible. The use of rotenone is another probable approach for reducing the density of carp within Hubbard and Wheeler Lakes, to a level considered sufficient to initially change the lake from the turbid to clear states. Expectations are that periodic rough fish removal may be necessary (~ once every ten years) to maintain these lakes in the clear phase. This may be accomplished either by commercial fishing, future rotenone applications, or by inducing winterkill by some other means. The winter conditions in 2009 did lead to an observed die-off of carp within Wheeler Lake.
Implementation Priority	Moderate
Estimated Total Phosphorus Load Reduction	The annual average total phosphorus concentration for 2008 and 2009 is 117 ug/l. For the purposes of estimating the load reduction, based on experience with similar shallow lakes, the annual average total phosphorus concentration could be reduced by a factor of 2 to 58.8 ug/l. Assuming an annual average inflow to Diamond Lake from Hubbard Lake of 2.64 cubic hectometers per year (2144 af per year) and a reduction in the annual average total phosphorus concentration of 58.8 ug/l, the estimated load reduction is 155.5 kg/year (total watershed sources by 1,490 kg/yr).
Assumptions Implicit in the Estimated Load	The volume of water delivered from Hubbard to Diamond Lake will be equal to the average annual amount and the annual mean total

Reduction	phosphorus concentration as described by the 2008 and 2009 monitoring data for Hubbard Lake reduced by a factor of two.
Responsible Parties	MnDNR, MFCRWD
Timeline	Complete Carp Management 2014 Fish Barrier Installation 2016 First Carp Control Treatment 2017
Planning Level Estimated Cost	Carp Management Plan: $15,000 Administration and Engineering $35,000 Fish Barriers ($160,000): Physical barrier between Wheeler and Schultz $15,000 Physical barrier between Hubbard and Diamond $150,000 Initial Rotenone Treatment (powder application) ($46,500 rounded) Chemical Unit Cost $20 to $30 per acre-foot treated (use $30) Application Cost $10 to $25 per surface acre treated (use $25) Hubbard Lake 32.1 acres @ 5 ft ave. depth = $5,617.50 Wheeler Lake (@ 5-ft ave. depth) South-west lobe 83 acres = $14,525 North-east lobe 173 = $25,950 Carp Reduction Maintenance @ 10 years assuming same as initial rotenone treatment $46,500 Gravity System for Water Level Management $500,000 *Note: rotenone chemical cost for liquid nearly doubles. Based on cost ranges provided by MnDNR Shallow Lakes program.*

Implementation Activity WS-3: Implement Agricultural Conservation Practice Program

<table>
<tr><td>Description</td><td>Implementation of agricultural conservation practices within priority subwatersheds as identified by the watershed loading (SWAT) model. The following assumes that a load reduction of 344.5 kg is achieved entirely through a single practice.

<table>
<tr><th>Practice</th><th>No.</th><th>Cost Units</th><th>Cost per Unit</th><th>Estimated Cost</th></tr>
<tr><td>Filter / Buffer Strips</td><td>36.6 acres or 15.1 miles @ 20-feet width</td><td>Acre</td><td>$3,170 including land</td><td>$116,000</td></tr>
<tr><td>Pasture and Hayland Planting (conversion to permanent cover)</td><td>1,946 acres converted from agricultural product to permanent cover</td><td>Acres</td><td>$3,160</td><td>$6,149,360</td></tr>
<tr><td>Temporary Storage (i.e., wetland restoration or side inlet controls)</td><td>165 acre-feet of new storage</td><td>Acre-feet</td><td>$1000</td><td>$165,000</td></tr>
</table>
Assumes permanent easement needed for BMPs with land value of $3,000 per acre. Only first costs are included (no maintenance or recurring cost). No estimate is provide for loss of revenue for land set-aside. Total estimate agricultural land acreage in contributing drainage area is 11,385 acres. Generally assumes native grass plantings.</td></tr>
<tr><td>Implementation Priority</td><td>High</td></tr>
<tr><td>Estimated Total Phosphorus Load Reduction</td><td>An estimated 476 kg/year is needed. This assumes that the upstream lakes will be successfully managed to convert them to the clear state with a corresponding 155.5 kg load reduction. The current watershed load including the upstream lakes load is 1,490 kg/yr.</td></tr>
<tr><td>Assumptions Implicit in the Estimated Load Reduction</td><td>SWAT modeled unit load reductions represent actual field performance. Values used were 0.11 lbs/acre/year (0.0.05 kg/acre/year), 2.09 lb/acre/year (0.95 kg/acre/year) and 0.39 lbs/acre/year (0.177 kg/acre/year) for filter strips, temporary storage, and conversion of agricultural land to permanent cover.</td></tr>
<tr><td>Responsible Parties</td><td>Responsible Parties MFCRWD, Kandiyohi county SWCD</td></tr>
<tr><td>Timeline</td><td>2011 and ongoing.</td></tr>
<tr><td>Planning Level Estimated Cost</td><td>No maintenance cost assumed.</td></tr>
</table>

Implementation Activity WS-4: Lakeshore and Urban Best Management Practices

Description	Implement Best Management Practices (BMPs) to reduce pollutant loads directly from lakeshore development and other areas within increased amounts of impervious surface. These BMPs may include rain gardens, infiltration trenches, biofiltration swales and similar related BMPs.
Implementation Priority	High
Estimated Total Phosphorus Load Reduction	An estimated 476 kg/year is needed for all external source reduction strategies. A portion of this load reduction can be achieved through this implementation activity in addition to the agricultural conservation practices.
Assumptions Implicit in the Estimated Load Reduction	None
Responsible Parties	Responsible Parties MFCRWD
Timeline	2011 and ongoing.
Planning Level Estimated Cost	Depends upon the type of BMP

3.2.2 Internal (In-Lake) Sources

The goal for reduction of internal loading is 103 kilograms of phosphorus over the growing season. To achieve that goal, the internal sources of phosphorus require management of the invasive, nuisance curly leaf pondweed. The reduction of curly leaf pondweed is expected to reduce internal phosphorus loading caused by this macrophyte as can the use of aluminum sulfate.

Implementation Activity IS-1: Macrophyte Management to Control Curly Leaf Pondweed

Description	Treat the affected parts of Diamond Lake with herbicide or mechanical means to limit the growth of curly leaf pondweed and reduce the internal phosphorus loading from curly leaf pondweed.
Implementation Priority	High
Estimated Total Phosphorus Load Reduction	No estimate made.
Assumptions Implicit in the Estimated Load Reduction	Not applicable.
Responsible Parties	MFCRWD, MnDNR
Timeline	2011-2012 (seasonal treatment)
Planning Level Estimated Cost	$ 25,000 per treatment

Implementation Activity IS-2: Inactivation of Sediment Released Phosphorus

Description	Aluminum Sulfate Treatment
Implementation Priority	Low
Estimated Total Phosphorus Load Reduction	Because the lake is shallow and only weakly stratifies, the estimated reduction in the annual mean in-lake concentration is 50% (103 kilograms).
Assumptions Implicit in the Estimated Load Reduction	Surface area treatment applied only to the open water portion of the lake. Assumes area less than 6-feet in depth (20% of the lake) is littoral area and not treated.
Responsible Parties	MFCRWD
Timeline	2020
Planning Level Estimated Cost	Engineering Plan for Application and Initial Feasibility Analysis $30,000 Alum Treatment of 1,285 acres at $450 per acre = $578,250.

3.2.3 Public Information and Education

Implementation Activity PIE-1: Educate Lakeshore Property Owners to Reduce Phosphorus Runoff

Description	An annual newsletter or similar advertisement, with a copy on the MFCRWD web site could be provided to local landowners pointing out ways they can protect their lake. This also should point out the other activities that will further protect the lake: agricultural BMPs, SSTS enhancements, etc.
Implementation Priority	High
Estimated Total Phosphorus Load Reduction	No estimate made.
Assumptions Implicit in the Estimated Load Reduction	Not applicable.
Responsible Parties	MFCRWD
Timeline	2011 and seasonally thereafter.
Planning Level Estimated Cost	Approximate Cost: Design in house, print 500 for $300, address and mail 400 for $300; total $600 per year. Items to promote include: rain gardens, porous pavement, nutrient management for fertilizers and household detergents, lawn overwatering, and pet wastes.

3.3 Implementation Plan Cost Range

The total estimated planning level cost range for implementing the recommendations in this TMDL including tasks that address both external and internal source phosphorus reductions is provided in **Table 3-4**.

Table 3-4 Planning Level Estimated Cost Range for TMDL Implementation.

Implementation Activity	Estimated TP Load Reduction (kg)	Probable Initial Cost Range (excludes operation and maintenance)	
		Low	High
WS-1: Connect Diamond Lake SSTSs to the Green Lake Regional Wastewater Treatment System	59.5	$6,941,000	
WS-2: Upstream Lake Management To Achieve Clear Water States within Hubbard and Wheeler Lakes	155.5	$500,000	
WS-3: Implement Agricultural Conservation Practice Program	344.5*	~ $116,000	
WS-4: Lakeshore and Urban Best Management Practices	None estimated	Use current District Programs	
IS-1: Macrophyte Management to Control Curly Leaf Pondweed	None estimated	$25,000 per treatment	
IS-2: Inactivation of Sediment Released Phosphorus	Reduction of in lake total P concentration for 5-7 years by 50%	$578,250	
PIE-1: Educate Lakeshore Property Owners to Reduce Phosphorus Runoff.	None estimated	$600 per year	

*Additional reduction of 389 needed to achieve Margin of Safety

3.4 Long Term Planning

After the first 10 years, a comprehensive analysis of the program will be conducted, to determine if the activities planned and implemented are achieving the required reductions in phosphorus concentrations within Diamond Lake. If the water quality standards are not achieved within this 10-year time frame, the MFCRWD will meet with MPCA staff and local citizen organizations and other stakeholders to determine future direction and if additional participation by these groups is needed, as well as more aggressive measures for achieving the water quality standards. Consideration of the need for an alum treatment would occur at this time.

3.5 Public Participation

3.5.1 Introduction

The MFCRWD has an excellent track record with inclusive participation of its citizens, as evidenced through the establishment of the District itself in 2005 (led by an active citizen base), the development and completion of the MFCRWD Watershed Management Plan in 2007, and its very active citizen volunteer monitoring program. The MFCRWD has utilized stakeholder meetings, surveys, open houses, and a citizens' advisory committee, to share information with the public and to gather input to help guide implementation activities (**Appendix E of the TMDL report**). The extensive public participation has helped guide the development of the implementation plan herein, and will help direct future projects to improve the water quality of Diamond Lake.

3.5.2 Technical Advisory Committee

The Diamond Lake TMDL Technical Advisory Committee (TAC), was established as an ad hoc committee, to guide the process of the Diamond Lake TMDL. The TAC consisted of the following advisors:

- 1 Board Conservationist from the Minnesota Board of Water and Soil Resources
- 1 Program Coordinator from the County Soil and Water Conservation District
- 1 Area Hydrologist from the Minnesota Department of Natural Resources
- 1 County Director of Environmental Services
- 1 County Ditch Inspector

The TAC met as a group one time with MCFRWD and MPCA staff on October 9, 2008, following the first season of monitoring. The purpose of the meeting was to discuss the overall role of the Committee, provide an overview of the project, a status report on the major project tasks and next steps. TAC discussion centered on the need to conduct sampling for a second water year, the importance of sampling, and ultimately addressing water quality issues in the Schultz/Wheeler/Hubbard Chain of Lakes, and ideas that could eventually be used in the implementation plan.

3.5.3 Public Meetings/Information

A webpage dedicated to the Diamond Lake TMDL was created on the Minnesota Pollution Control Agency's website, to provide the public with a background on the TMDL study, a map indicating project location within the state, a link to a fact sheet, an announcement of upcoming public meetings, relevant links, and contact information for the MPCA Project Manager and MFCRWD Administrator.

A fact sheet was prepared for the TMDL, and provided background information on the study, progress to date, and opportunities on ways that residents can learn more on the TMDL process and reduce nutrient loading into the lake. One fact sheet was prepared and posted on the MPCA website in November 2008, and an updated fact sheet was prepared and posted on the website in July 2010.

Stakeholders were given the opportunity to participate in the TMDL process on several levels throughout the study, including public meetings, small group discussions, a survey, MFCRWD open houses, and Citizens Advisory Committee (CAC) meetings, and at monthly MFCRWD Board meetings. Public meetings were announced, via notices on the MPCA website, news releases in newspapers, newsletter articles, and individual invitations to all residents of the Diamond Lake watershed, in addition to county commissioners, local legislators, townships, implementation partners, and others. The first public meeting, held on December 10, 2008, was attended by 68 individuals, and was designed to share information, solicit input from the public, encourage their participation in the process, and offer an opportunity for questions and answers. A second public meeting took place on June 19, 2010, at the invitation of the Diamond Lake Area Recreation Association. Similar to the first public meeting, it entailed a presentation that provided a background of the TMDL process, and an update on the current status of the study. Preliminary water quality conclusions and data were shared with the audience, which numbered approximately 30 people. Questions were asked and answered, and the next planned public meeting was announced. Following the second public meeting, a third public meeting was publicized in a similar way as the first, and was held on July 29, 2010 with 39 attendees. The third public meeting followed a similar format as the first, with some additional opportunity to include public input. Following a presentation and question/answer session, attendants were given the opportunity to split up and join small group discussions on monitoring results, phosphorus dynamics, and implementation ideas. This strategy was employed in consideration of the fact that many people are reticent to ask questions and voice opinions in large groups. Attendees were also asked to complete a survey that was designed to allow those uncomfortable to offer ideas in the small group setting with the opportunity to have their voices heard. A summary of some of the comments received:

- Solar Bee technology to increase oxygen levels through all water columns to prevent phosphorus from releasing into the lake
- Holding ponds in Ag ditches to slow up the runoff
- Have all lake property owners contribute to problem solving fund
- Need a carp kill
- Buffer strips
- Deepen existing wetlands near the lake

- Chain of lakes management
- Better manage lake water levels by making the dam
- Utilize drained wetland inventory to restore strategic wetlands (most bang for the buck).
- Incentives to promote establishment of permanent vegetation along streams/ditches (intensive rotational grazing, biomass generation from grasses, brush, etc.).

3.5.4 PUBLIC PARTICIPATION CONCLUSION

Extending the opportunity for the public to participate in the TMDL process was emphasized from the outset, as indicated by the high attendance levels in public meetings and resultant feedback. A variety of methods for sharing information with the public were employed, including large group meetings, small group meetings, anonymous surveys, website announcements, fact sheets, newsletter articles, and others. Much of the feedback that was provided by the public has been included in the implementation plan, and will continue to be solicited and utilized as the implementation plan is carried out.