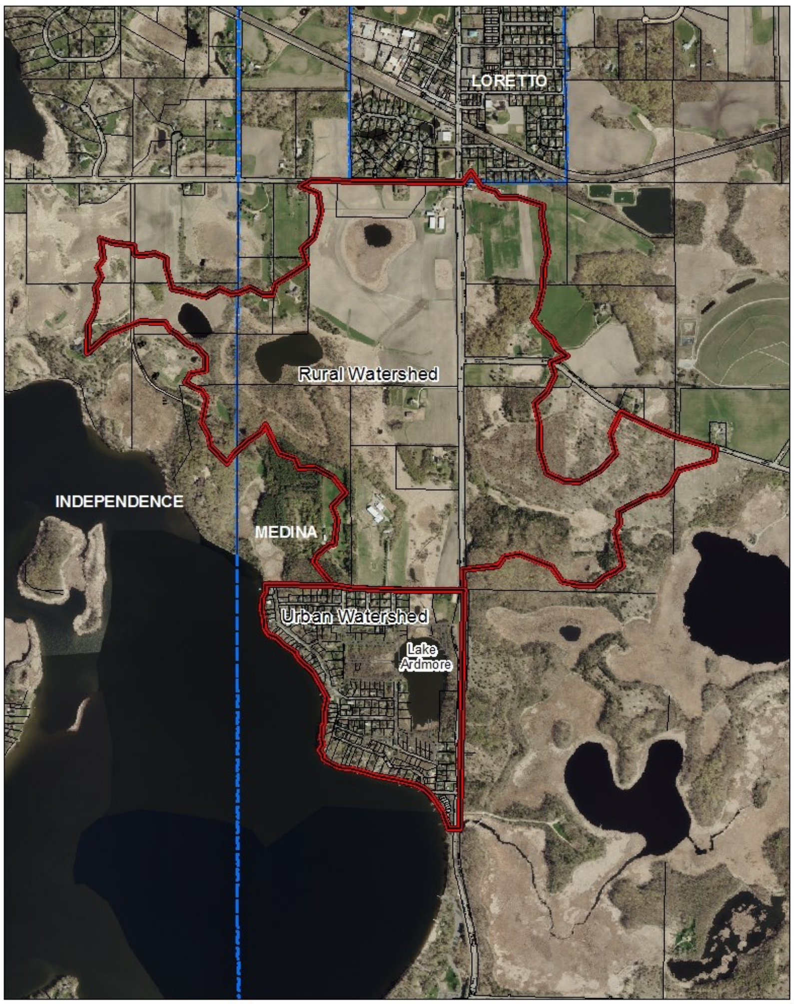
Ardmore Area Subwatershed Stormwater Retrofit Assessment



Hennepin County
Public Works
Environment and Energy

Hakanson Anderson

Prepared by Hakanson Anderson and Hennepin County Department of Environment and Energy with assistance from the Metro Conservation Districts

March 2016

Table of Contents

Executive Summary

This report details urban and rural stormwater assessment studies and Best Management Practices (BMPs) recommendations within the City of Medina to reduce phosphorus loads flowing into Lake Independence and Lake Ardmore. Since different types of BMPs must be utilized in order to be effective for the urban and rural portions of the watershed, the report is organized in two explicit sections. The first section analyzes the residential urban area that it situated between Lake Independence and Lake Ardmore and drains to both basins. The second section analyzes the rural subwatershed that drains to Lake Ardmore and ultimately to Lake Independence.

The rural portion of this assessment (Figure 1A) is approximately 472 acres in size. Four hundred and twenty three acres of that watershed are in Medina and 49 acres are in the City of Independence. The developed community studied for this assessment is 113 acres and located in Medina between Lake Independence and Lake Ardmore (Figure 2A).

The purpose of this report is to assist the City of Medina in its decisions and processes to provide cost effective methods to help reduce phosphorus loads into Lake Ardmore and Lake Independence from these two subwatersheds.

In 2002, Lake Independence was listed as impaired under Section 303(d) of the Clean Water Act due to excessive nutrients affecting aquatic recreation. The Pioneer-Sarah Creek Watershed Commission and Three Rivers Park District prepared a phosphorus Total Maximum Daily Load (TMDL) study to determine the phosphorus reductions needed for Lake Independence to achieve the 40 µg/L water quality standard for Class 2 recreational waters. Each municipality contributing to the Lake Independence (Medina, Independence, and Loretto) watershed has been designated a load reduction proportionate to their existing phosphorous export. The City of Medina must achieve a phosphorus reduction of 284 lbs. per year.

Lake Ardmore is proposed by the Minnesota Pollution Control Agency to be listed as an impaired lake in 2016 for aquatic recreation. Three Rivers Park District, in cooperation with the Pioneer-Sarah Creek Watershed Management Commission, is undertaking a TMDL study to determine the extent of the impairment, provide nutrient budgets and possible solutions to achieve a non-impaired status for the lake. Preliminary numbers from their model indicates that a phosphorus load of 269 pounds per year enters the lake from its contributing watershed.

This study models various stormwater treatment BMPs within the two subwatersheds. These BMPs are analyzed to determine their effectiveness in reducing nutrient loads into Lake Ardmore and Lake Independence. These practices will be rated from the most cost effective project per pound of phosphorus reduction to the least cost effective. To provide a better understanding of each BMP and the approach for implementation, conceptual drawings and/or photos are incorporated within this report. Prior to implementation, more detailed, site-specific designs will need to be prepared for each BMP selected. Most will require additional study and/or engineered plans. For all the recommended projects, partnerships with committed and willing landowners are essential.

The process used to select recommended BMPs was based primarily on a combination of the target pollutant (phosphorus), the project type and their cost/benefit analysis and the location of the project in the watershed. Additional factors should be considered before prioritizing recommended BMPs (e.g., project costs, available funding, economies of scale, landowner willingness, short and long-term impacts on property values and the public infrastructure). As presented in Table 2U on page 12, a total of 10 projects areas were identified for the urbanized Ardmore subwatershed with a combined phosphorus removal of 15.9 pounds per year. The rural Ardmore subwatershed identified 26 projects with a combined phosphorus removal of 99.3 pounds per year as shown in Table 1R on page 37.

Figure 1A: Lake Ardmore Watershed Outline

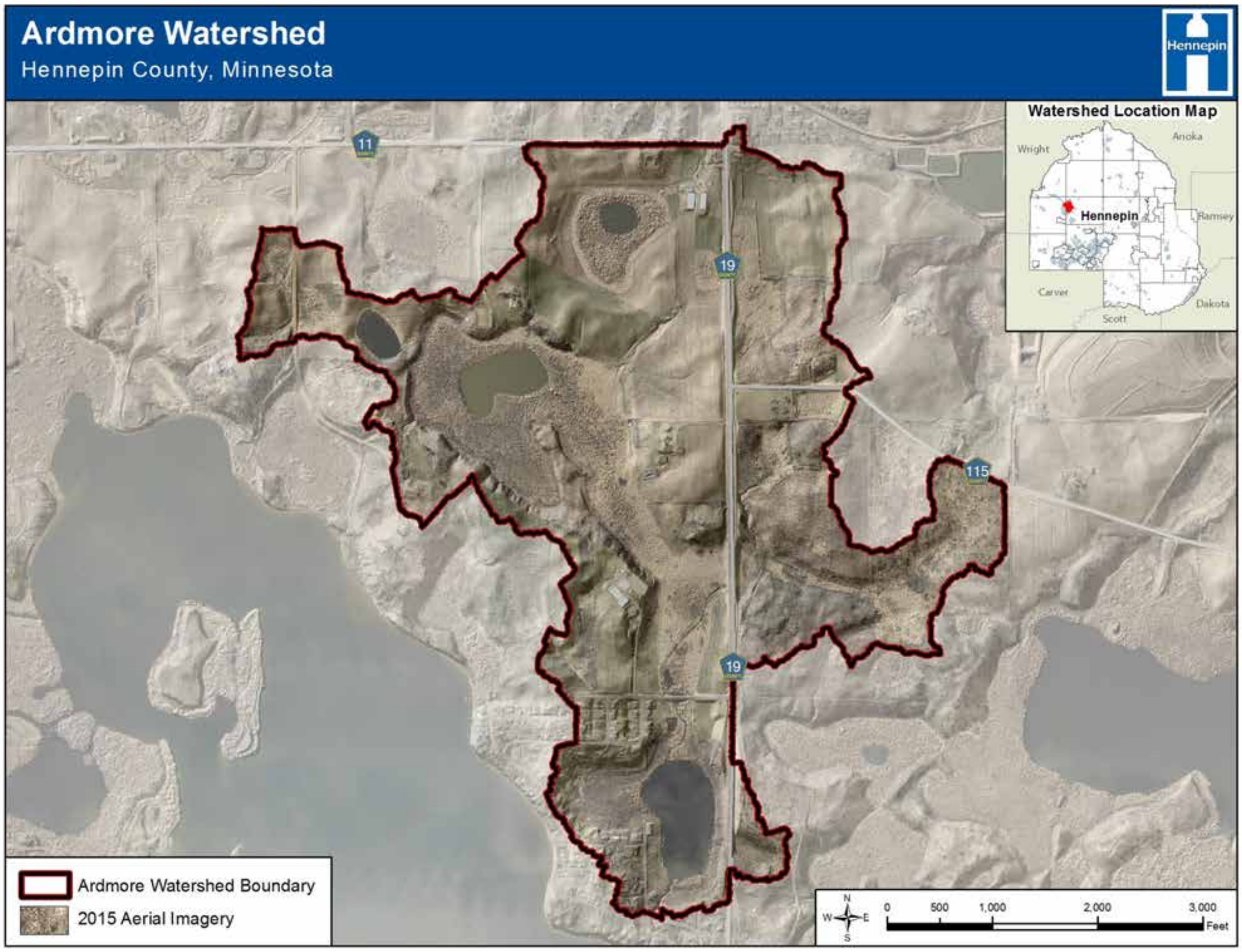


Figure 2A: Urban area of Ardmore Subwatershed Assessment

Document Organization

This document is organized into two separate sections: rural and urban. Both present a brief overview of the processes involved to yield the project rankings and selections. The technical aspect of the subwatershed assessment process and supporting model results are presented throughout the report and in the appendices. The majority of the report focuses on the projects themselves: their rankings in cost per pound of nutrient reduction and the profile of the project.

Selection of the Subwatershed

The TMDL for Lake Independence completed in 2007 determined that the Lake Ardmore Subwatershed contributed 6% of the external phosphorus loads to Lake Independence per year. It further identified direct surface flows (including the developed areas in the SE corner of the lake) as contributing 8% of the phosphorus loads to the lake. Based on these contributions and in anticipation of the Lake Ardmore study, these subwatersheds were chosen for additional analysis through cooperative efforts of the City of Medina, the Hennepin County Environment and Energy Department (HCEED), Hakanson Anderson and the Metropolitan Association of Conservation Districts (MCD).

Analytical Process and Elements

The purpose of subwatershed assessments through stormwater retrofit analysis is to improve water quality, increase groundwater recharge and reduce stormwater runoff volumes by identifying opportunities and developing conceptual designs for BMPs that are contributing the largest pollutant loads to the receiving water body. The following are the steps taken in this assessment process:

Subwatershed Assessment Steps

1. **Identify and prioritize subwatersheds** that contribute the greatest to water quality degradation of high priority water resources.
2. **Map BMP retrofit potential** within neighborhoods of the highest priority subwatersheds utilizing the "Urban Stormwater Retrofit Practices" manual (August 2007).
3. **Design retrofits** primarily involving ponds, wetland restoration, vegetated buffers, water flow controls, vegetative swales and management techniques for rural residential runoff, livestock and tillable land.
4. **Calculate pollutant removal** utilizing Soil and Water Assessment Tool (SWAT), Source Loading and Management Model for Windows (WinSLAMM), Board of Water and Soil Resources Pollution Reduction Model, Revised Universal Soil Loss Equation Version 2(RUSLE2), P8 Urban Catchment Model (Program for Predicting Polluting Particle Passage thru Pits, Puddles, & Ponds), Elm Creek Watershed Management Commission land use phosphorus export loading and Minnesota Feedlot Assessment Runoff model (MinnFARM). See appendix for detailed modeling parameters.
5. **Manage installation** based on landowner's willingness and funding availability.The subwatershed retrofit analysis process is a tool to help identify and prioritize BMPs by performance and cost/benefit analysis.

The process for the Lake Ardmore Subwatershed Analysis was as follows;

- Scoping
- Desktop analysis
- Field Investigation
- Modeling
- Cost estimating
- Project Ranking and Selection

Target Elements

The main element considered for this analysis was the target pollutant of phosphorus for Lakes Ardmore and Independence. Volume and total suspended solid controls were also considered, but it was determined that these two components were so interrelated to the main target of phosphorus that ultimately, the reduction in phosphorus related directly or indirectly to their controls. Therefore, this report focuses primarily on Lake Independence and Lake Ardmore impairments and phosphorus load reductions to ultimately achieve the goal of 40 µg/L water quality standard for Class 2 recreational waters.

Urbanized Ardmore Subwatershed

This section focuses on Total Phosphorus (TP) reduction within the developed community located in Medina between Lake Independence and the smaller Lake Ardmore (**Figure 2A**). Developed areas have increased impervious surfaces, such as rooftops, roads, and sidewalks. Impervious surfaces contribute to greater runoff volume by preventing water infiltration into the soil, and they also cause increased rates of stormwater runoff due to lack of obstruction from the minimal vegetation. Increased rates of stormwater runoff are concerning as it increases the ability to pick up and transport sediment and other pollutants to Lake Independence.

Phosphorus commonly binds with minerals in sediment, so events that transport sediment, in effect, also transport phosphorus. The higher flows from the impervious surfaces are able to transport sediment, and the phosphorus that is bound to it, to other water bodies. Thus, managing stormwater runoff to Lake Independence is critical to reducing the phosphorous loading and complying with the TMDL.

Since much of the phosphorus is in the particulate form, load reduction projects in this area will emphasize limiting the amount of Total Suspended Solids (TSS) within the runoff. TSS is mainly sediment but can also include other non-dissolved floatables such as leaves, sticks, and trash. The projects include shoreline restoration, gully and stream stabilization, pond excavations, and rain gardens, as well as alternative higher efficiency options such as a manufactured filtering device and an iron enhanced sand filter. These projects are discussed in further detail in later sections.

Analysis

This urban area of the Ardmore watershed was delineated to determine the sub-watershed boundaries. Drainage patterns were determined using available LIDAR two-foot contours, aerial photos, and visual observations. The sub-watershed drainage areas are depicted in **Figure 1U**.

The proposed ponds were sized according to Natural Urban Runoff Program (NURP) standards, which requires ponds to retain the runoff generated from 2.5 inches of precipitation within the drainage area. The delineated drainage areas mentioned above were input into HydroCAD Stormwater Modeling software to determine the stormwater runoff volume generated from a 2.5 inch precipitation event. The ponds were then sized to retain the entire runoff volume from the 2.5 inch event below the normal water level. Depth was maximized in order to provide the same amount of volume in a smaller surface area. Depths were limited to eight-feet as deeper ponds may cause hypoxic conditions. Hypoxia, or low oxygen levels, is a concern for phosphorus reduction as it can have the counter effect of releasing the phosphorus within the sediment. The sizes of the rain gardens were more restricted by their proximity to housing and the surrounding landscape.

A P8 Urban Catchment Model and the Minimal Impact Design Standards (MIDS) calculator from the Minnesota Stormwater Manual were utilized to approximate phosphorus loading and possible reductions. The P8 Urban Catchment Model is a useful tool in determining phosphorous reductions associated with pond excavation projects. Since the P8 model does not have a structure that accurately represents rain gardens with an underdrain, the MIDS calculator was used. As the MIDS calculator can also model ponds, it was used to compare the P8 model outputs. The MIDS estimates were more conservative than the P8 model, so this report used the MIDS results.

The phosphorus loads from the gully and stream stabilization and shoreline restoration are based on the amount of erosion occurring. The dimensions of the erosion was measured in the field and entered into the Board of Water and Soil Resources (BWSR) Pollution Reduction Estimator worksheets.

For the two alternative higher efficiency options, neither the P8 model nor MIDS calculator were used directly. The iron enhanced sand filter used calculations found in the Minnesota Stormwater Manual to estimate phosphorus reductions. The enhanced filtering device has a seventy-percent reduction of the phosphorus input load as stated by the manufacture.

Cost Estimates

Determining probable costs of any given BMP is necessary in order to rank projects and determine overall effectiveness. For nearly all projects, there is a capital cost of initially installing or constructing the BMP as well as the maintenance cost for maintaining the device over its life span. Cost estimates for design and easement acquisition were also estimated, if applicable. Most projects are proposed to be within City or County owned property, as seen in **Figure 2U**. For this analysis, the lifespan of a given BMP was assumed to be 20 to 50 years. Therefore, the cost of the installation and maintenance can be divided by the BMP lifespan and phosphorous reduction in order to achieve a cost per pound. The cost per pound is specific to the project and is therefore included in each of the BMP Summary Tables for each project. The following costs were assumed for this report:

Table 1U: Best Management Practices Summary

BMP Type	Promo / Admin (hrs)	Design ($)	Easement Acquisition	Construction Cost ($)	Annual Mainte-nance
Residential Rain Garden	35	$4,500		$15/sq ft	$100
Shoreline Restoration	35	$1,500		$100 /lin ft	$1.50
Stream Stabilization	20	$4,000		$75 /sq ft	$0.50 / sq ft
Gulley Stabilization	10	$4,000		$20/sq ft	$0.25 / sq ft
Pond Excavation	35	$12,500	$20,000/ac	$6/sq ft	$250
Enhanced Filtering Device	10	$20,000		$200,000/Ea	$1,500
Iron Enhanced Sand Filter	35	$15,000		$20/sq ft	$500

Figure 1U: Proposed BMP exhibit within drainage areas

Figure 2U: Proposed BMP exhibit within parcels

Project Ranking

The information within this report will be provided to City and Watershed officials in order to determine the feasibility of certain projects within the urban portion of the Ardmore watershed. One important factor in prioritizing projects is the cost of the project divided by the total pounds of phosphorous removed.

Table 2U. Project Ranking

BMP ID	TP Decrease (lbs/yr)	Project Life (Years)	Project Cost	Cost-Benefit ($/ lbs TP)
GS1	3.4	20	$18,850	$277
SR1	2.0	20	$22,000	$550
PD2*	1.8	30	$47,650	$882
ISF1*	3.1	30	$87,500	$941
RG1	1.1	20	$21,400	$973
PD4	1.2	30	$47,350	$1,315
PD1	1.8	30	$76,350	$1,414
PD5†	1.0	30	$43,750	$1,458
RG2	0.6	20	$18,400	$1,533
PD3	1.1	30	$51,550	$1,562
SS1	0.2	20	$13,200	$3,300
EFD1†	1.4	50	$318,000	$4,542
Totals‡	14.2 / 15.9		$360,500 / $674,600	

*PD2 and ISF1 are in the same location. †PD5 and EFD1 are in the same location. ‡Numbers to the left include PD2 and PD5 and not ISF1 and EFD1, and numbers to the right include ISF1 and EFD1 and not PD2 and PD5.

Projects

The majority of TP in urban runoff is in the particulate form present in sediment (Maestre and Pitt, 2005). Stormwater runoff carries sediment, a main component of TSS, and deposits it into Lake Independence. Treating stormwater to reduce its TSS, and therefore phosphorus, load is essential in order to meet Medina's phosphorus reduction goals. Several projects are proposed to help in reducing TP in this area and are outlined in **Table 3U** below.

Table 3U: Proposed Projects

	Project Type	Label	Drainage Area (ac)	P Reduction (lbs/yr)
1	Rain Garden	RG1	3.3	1.1
2	Rain Garden	RG2	2.0	0.6
3	Stream Stabilization	SS1	N/A	0.2
4	Gully Stabilization	GS1	N/A	3.4
5	Shoreline Restoration	SR1	N/A	2.0
6	Pond Excavation	PD1	2.9	1.8
7	Pond Excavation / Iron Enhanced Sand Filter	PD2	4.1	1.8
		ISF1	4.1	3.1
8	Pond Excavation	PD3	8.0	1.1
9	Pond Excavation	PD4	2.7	1.2
10	Pond Excavation / Enhanced Filtering Device	PD5	1.6	1.0
		EFD1	1.6	1.4
			Total	**14.2 / 15.9**

Rain Gardens

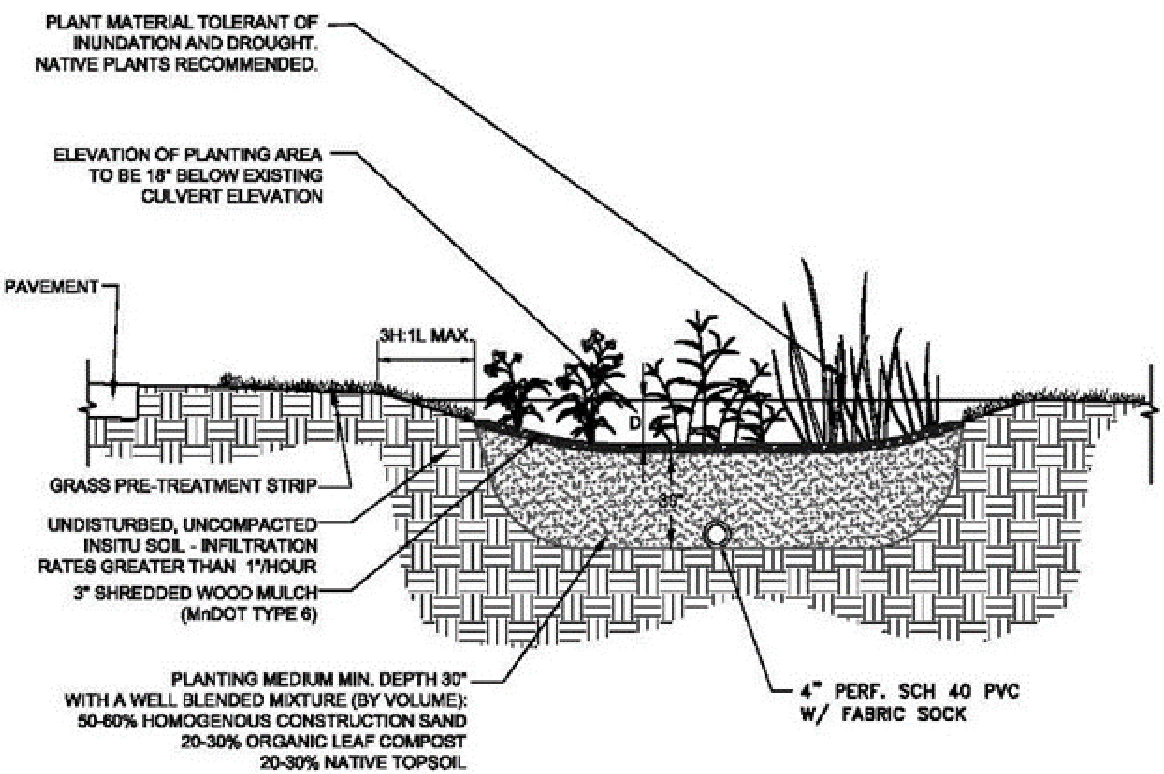
Rain gardens are a practical treatment device for treating runoff and improving water quality for relatively small drainage areas. Rain gardens are small depressions with flood-tolerant vegetation positioned in areas that intercept stormwater runoff from impervious surfaces. During a storm event, stormwater pools in the rain garden, which allows the TSS to settle out of the pooled runoff. This decreases the phosphorus load within the water since the majority of the phosphorus is attached to the sediment.

There are two types of rain gardens that have varying levels of phosphorous removal efficiency. Rain gardens that are situated in areas that have favorable infiltration rates, predominately sandy soils, infiltrate the entire design volume and do not require an underdrain. Since the entire volume stored within the rain garden is infiltrated into the ground, essentially all pollutants are captured within the basin and are not transported downstream for the design rain event. Typically rain gardens are designed to capture 1" of runoff from the impervious surfaces, which represents approximately 90% of the storm events. Therefore, the first type of rain garden has a very high removal rate for approximately 90% of storm events. Rain events larger than 1" result in downstream discharge with little or no treatment. However, sizing a rain garden to treat all storm events as opposed to the 1" event would require an extremely large footprint and would not be practical in most cases.

The second type of rain garden requires an underdrain and is suitable for clay soils or soils that have a relatively low infiltration rates. This type, referred to as biofiltration, is rather efficient at removing the particulate portion of the phosphorous load, but is not as efficient in removing the dissolved portion. During a storm event, the water quality volume is pooled in the rain garden allowing the TSS and the particulate form of phosphorous that is attached to it to settle out. The stormwater is then filtered through the engineered media and discharged downstream via the perforated underdrain. Although the rain water is filtered through the media, it does not remove the dissolved portion of the phosphorous. A relatively small volume that is captured below the underdrain may be infiltrated into the soil, which slightly decreases runoff volume but is more or less negligible. Therefore, given the design rain event, a biofiltration rain garden is efficient at removing the particulate phosphorous, which represents approximately 55% of the phosphorous load, and essentially passes all of the dissolved portion downstream, which represents approximately 45% of the load (MPCA, 2016). Similar to the first type of rain garden, rain events that are larger than the design event (typically 1") receive considerably less treatment and are discharged downstream.

Rain gardens are a practical and relatively low cost BMP that may be implemented in priority subwatersheds that offer treatment benefits prior to discharge into a surface water. In many instances, rain gardens can be implemented in areas where stormwater would otherwise enter the surface water untreated.

Figure 3U: Rain Garden Schematic



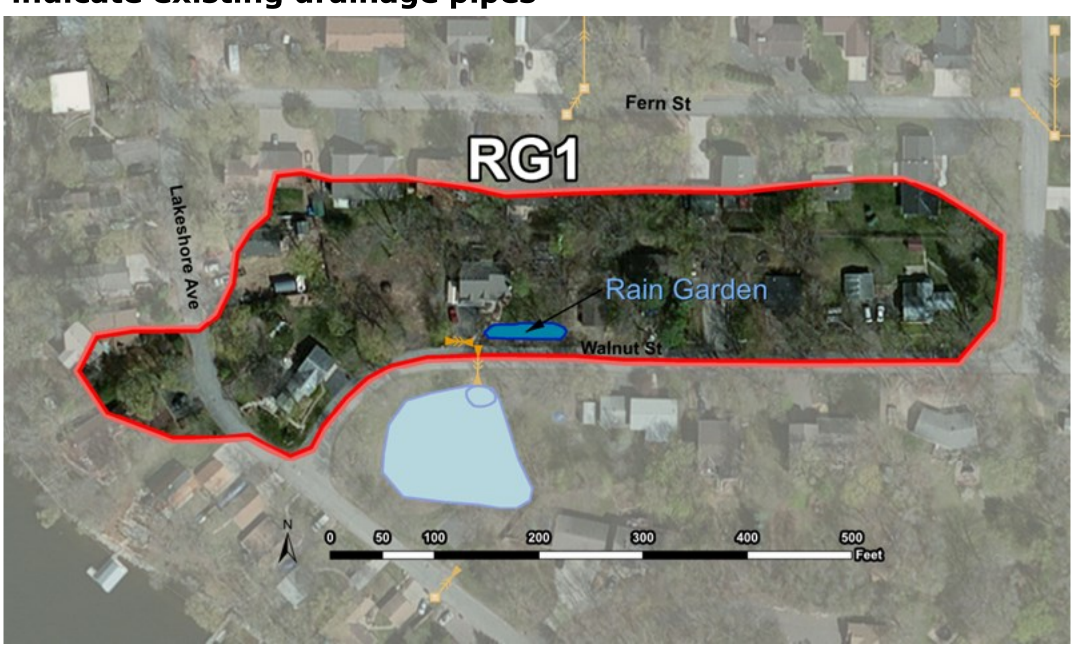
RG1

Two rain garden projects were chosen for this analysis. The first rain garden (RG1) is located on Walnut Street across from Walnut Park. It appears that a rain garden may have been previously attempted for this site; however, it does not appear to be functioning well and enhancements are proposed. There is an existing curb cut leading directly to the rain garden site, which can be seen in **Figure 4U**. In order to be effective, the rain garden must be over-excavated, filled with engineered media, and an underdrain installed. The final surface of the rain garden should be approximately 1.5' below the adjacent culvert to provide ponding during rain events. The phosphorus removal rate was estimated using the MIDS calculator. The projected phosphorus removal for RG1 is 1.1 lbs per year.

Table 4U: Site Summary – RG1	
Model Used	MIDS
Drainage Area	3.3 ac
Rain Garden Size	1,000 sq ft
Estimated TP removal	1.1 lbs/yr
Installation Cost	$15,000
Design/Admin	$4,500
Maintenance / yr	$100
Total 20 Year Cost	$21,400
$/lb-TP removal/yr	$973

Figure 4U: Site photographs at proposed RG1

Figure 5U: Drainage area and locational map. Orange lines indicate existing drainage pipes



RG2

The second proposed rain garden (RG2) is on Lakeshore Avenue across from Brooke Street. There is already a rain garden on the east side of Lakeshore Avenue, but on the west side, the water is directed towards a curb cut that leads straight to Lake Independence (**Figure 6U**). A rain garden at this location could filter the runoff and decrease the phosphorus load before it enters the lake. The existing storm sewer pipe would be modified, with the rain garden intercepting and filtering the stormwater runoff. Suspended solids and particulate phosphorous would be trapped in the rain garden basin.

Table 5U: Site Summary – RG2	
Model Used	MIDS
Drainage Area	1.6 ac
Rain Garden Size	800 sq ft
Estimated TP removal	0.6 lbs/yr
Installation Cost	$12,000
Design/Admin	$4,500
Maintenance Cost/yr	$100
Total 20 Year Cost	$18,400
$/lb-TP removal/yr	$1,533

Figure 6U: Looking west to Lake Independence. The blue circle shows proposed location for RG2.

Figure 7U: Drainage area and location map

Stream Stabilization

Erosion from streams releases sediment and transports it directly into the lake. Since particulate phosphorous is adhered to the soil particles, this results in direct phosphorus loading as well as a reduction of water clarity. The stream on the south side of Lake Ardmore that flows into Lake Independence is experiencing moderate erosion in the area between Ardmore Avenue and Lakeshore Avenue. The moderate erosion is occurring at a sharp natural meander point in the stream. Sharp curves encourage erosion because water on the outside of the curve has to move faster than the water on the inside of the curve to cover more distance in the same amount of time. The force of the accelerated stormwater along the stream bank is greater than the cohesive force of the soil. It is recommended that moderate stream bank erosion is corrected sooner rather than later; as left unrepaired, it will continue to erode the bank and deposit phosphorous rich sediment into the lake.

We measured the volume of the moderate erosion to be approximately 40 cubic feet. The BWSR Pollution Reduction Estimator estimated 0.2 lbs/yr of phosphorus export from this area. Repairing the stream bank erosion would cease its TP loading. Repair and stabilization of this area may be accomplished by placement of toe boulders, brush bundles, or geo-synthetic mats. Native vegetation with deep root systems also helps stabilize these areas but may be difficult to establish in this location due to the extensive tree cover.

Although the remaining portions of the channel are un-vegetated and may be susceptible to erosion, BMPs are not proposed at this time. Active erosion was not observed during field reconnaissance, and similar to the area above, stabilization by establishing a vegetated stream bottom would be extremely difficult due to the extensive tree cover. If observations at a later date determine stream bed erosion to be a concern, this segment should be re-evaluated.

SS1

Table 6U. Site Summary – SS1	
Model Used	BWSR Calculator
Erosion Length	70 ft
Erosion Area	110 sq ft
Estimated TP Removal	0.2 lbs/yr
Installation Cost	$8,250
Design/Admin	$4,000
Maintenance Cost / yr	$50
Total 20 Year Cost	$13,200
$/lb-TP removal /yr	$3,300

Figure 8U: Erosion seen looking southeast

Figure 9U: Drainage area and location map

Gully Stabilization

Gullies are created by concentrated stormwater cutting into the landscape and eroding away the soil. This occurs when the erosive force of the water flow is greater than the cohesive force of the soil. Over time the gulley cuts deeper into the soil, creating unstable side slopes. The near vertical side slopes of the gully then slough in and are transported downstream into the receiving water. Since particulate phosphorous is attached to the sediment, this directly contributes to the phosphorous loading into the receiving water. If not repaired, gullies continue to cut and become larger and contribute to the phosphorous load.

Gullies can be stabilized by using rip rap, boulders, natural vegetation, and manufactured synthetic products. Stabilization of a gully is a similar process to stabilizing a stream. Riprap can often be positioned at strategic locations to dissipate the flow and reduce scouring. Vegetation and synthetic products can also be used to create greater cohesion and resistance to scouring, as well as slowing down the velocity of water flow.

Figure 10U: Stabilization using manufactured synthetic products; Source: Contech Engineered Solutions

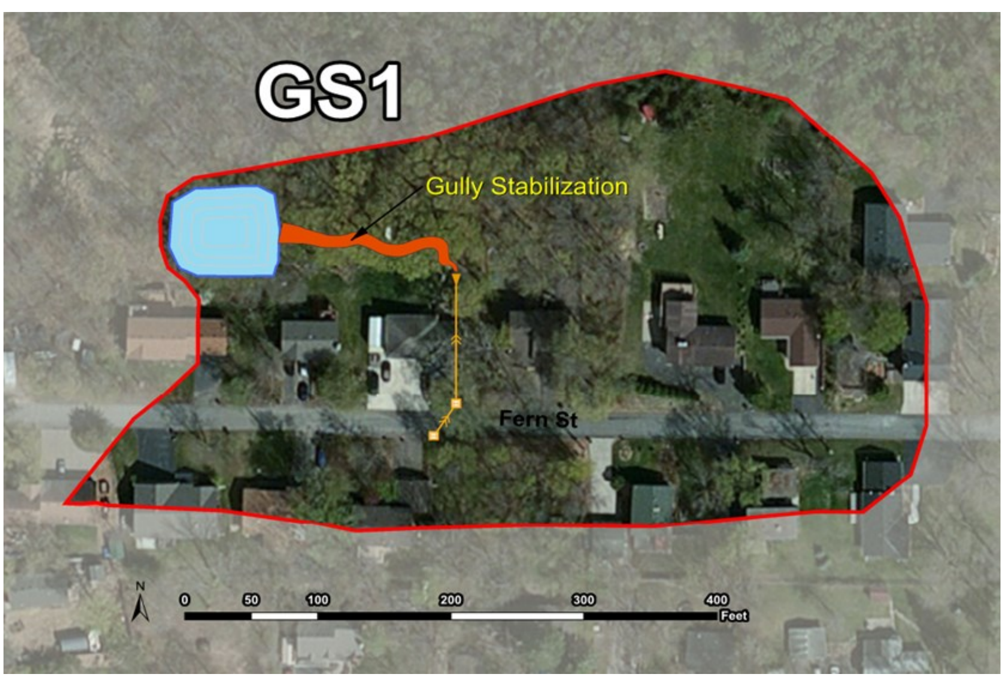
GS1

The gully north of Fern Street receives concentrated flow via a storm sewer pipe. Field measurements showed that the gully is approximately 120 feet long. The largest width measurement was recorded as five-feet, and the largest depth measurement was recorded as four-feet. In total, it is estimated that 1,390 cubic feet or 50 tons of sediment has been eroded to date. The BWSR Pollution Reduction Estimator worksheet was utilized to estimate the phosphorous load that the gully is producing. Stabilizing the gully could reduce the TP load by 100%.

Table 7U. Site Summary – GS1	
Model Used	BWSR worksheet
Erosion Length	120 ft
Erosion Area	600 sq ft
Estimated TP Removal	3.4 lbs/yr
Installation Cost	$12,000
Design/Admin	$4,000
Maintenance Cost	$150
Total 20 Year Cost	$18,850
$/lb-TP remov-al /yr	$277

Figure 11U: Left— Erosion to the eastern side of the gully. Right - West side of the gully, eventually flowing into wetland connected to Lake Independence.

Figure 12U: Drainage area and location map



Shoreline Restoration

Shoreline erosion is also a source of phosphorus. All of the sediment created by shoreline erosion is directly deposited into the lake with no chance for treatment. Visual observations revealed that shoreline erosion is occurring near Lakeshore Park on either side of the boat ramp. The erosion is approximately 160 ft. long and is estimated to contribute 2 lbs/yr of phosphorus to Lake Independence. This phosphorus load could be greatly reduced by stopping the erosion and restoring the shoreline.

Shoreline restoration is not much different than gully and stream stabilization. Shoreline restoration may include the use of rip rap boulders near the water surface to armor the shore against the wave action. Vegetation can be re-established above the hard armor, which will penetrate deep into the underlying soil to prevent erosion and reduce the velocity of the stormwater that flows down the bank.

Figure 13U: Photo of shoreline stabilization; Source: MN DNR

SR1

Table 8U. Site Summary - SR1	
Model Used	BWSR worksheet
Eroding Shoreline	160 ft
Estimated TP Removal	2.0 lbs/yr
Installation Cost	$16,000
Design/Admin	$1,500
Maintenance Cost / yr	$240
Total 20 Year Cost	$22,000
$/lb-TP removal /yr	$550

Figure 14U: Close up of the shoreline erosion

Figure 15U: The erosion exists on both sides of the boat launch. It extends approximately 120 ft. to the right of the launch and 40 ft. to the left.

Figure 16U: Drainage area and location map

Pond Excavation

Traditional stormwater ponds can reduce phosphorus loads in urban runoff by allowing for sedimentation to occur. Once the water reaches the pond the velocity is greatly reduced, and thus allowing the suspended solids to settle out. This traps the phosphorous rich sediment in the bottom of the pond and prevents it from entering downstream surface waters. Ponds are a good way to treat large areas, and the larger the pond, the greater the efficiency.

Five pond excavation projects are proposed. Two of the projects already have existing ponds and are proposed to be expanded to NURP standards. The other three pond excavation projects are new ponds in locations that could benefit from the water quality treatment.

The first proposed pond to be excavated (PD1) is an already existing pond in Walnut Park. The current pond is estimated to have a surface area of 620 square feet and has a drainage area of 2.9 acres. This pond is severely undersized and is providing little treatment in the existing condition. To meet NURP standards, the pond must be enlarged considerably. It is noted that a rain garden is also proposed within this sub-watershed, which would remove a fraction of the suspended solids before entering the pond. Routing stormwater through multiple BMPs is often referred to as a treatment train and can have increased water quality benefits. The phosphorous reduction reported in **Table 9U** takes into account the minimal treatment that is occurring in the existing condition in the undersized pond.

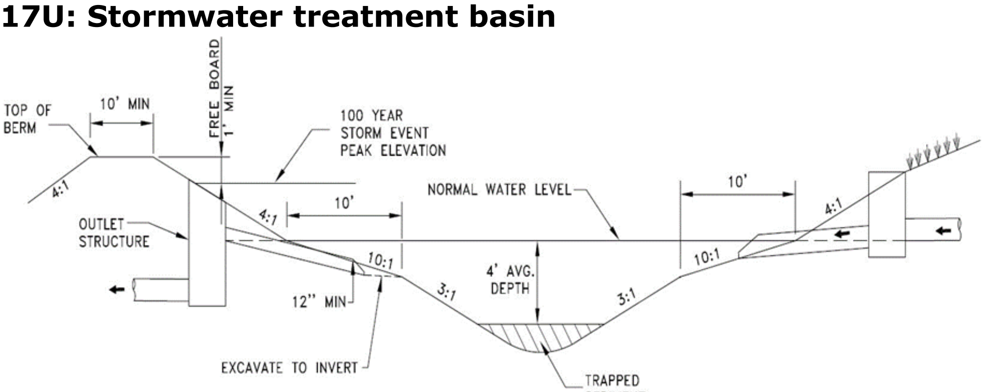
The second proposed pond (PD2) would be located at the receiving end of the eroding gully, north of Fern Street. This is a new proposed pond that would be approximately 2,900 square feet in surface area. This pond would have water quality benefits as it would intercept particulate phosphorous prior to discharging into the large downstream wetland, which is directly connected to Lake Independence. It should be noted that a gulley stabilization project is proposed upstream of PD2, and it would be critical that the gulley stabilization project be completed prior to implementing PD2.

The third pond (PD3) would be an expansion of an existing pond east of Aspen Avenue and south of Maple Street. Visual observations have determined that this pond requires maintenance to remove sediment. Removal of sediment and expansion of the pond is proposed to increase pollutant removal efficiency. The pond is proposed to be expanded westward as to not impact surrounding wetlands.

The fourth pond (PD4) would be a new pond west of the stream erosion. In the current condition, the storm sewer from Lakeshore Avenue directs stormwater into the vicinity of the proposed PD4, and it enters the stream untreated. A stormwater pond in this location would treat the stormwater and remove pollutants before discharging it into the stream and ultimately Lake Independence.

The fifth pond (PD5) would be excavated north of Pine Street near Lakeshore Avenue. The new 4,000 square-foot pond would treat street runoff that would otherwise flow into the lakes.

Figure 17U: Stormwater treatment basin



PD1

Table 9U. Site Summary – PD1	
Model Used	MIDS
Drainage Area	6.2 ac
Existing Pond Area	620 sq ft
Proposed Pond Area	9,445 sq ft
Estimated TP removal	1.8 lbs/yr
Installation Cost	$56,600
Design/Admin	$12,500
Maintenance Cost	$250
Total 30 Year Cost	$76,350
$/lb-TP removal /yr	$1,414

Figure 18U: Top– The existing pond. Bottom– The purple line shows location of proposed pond.

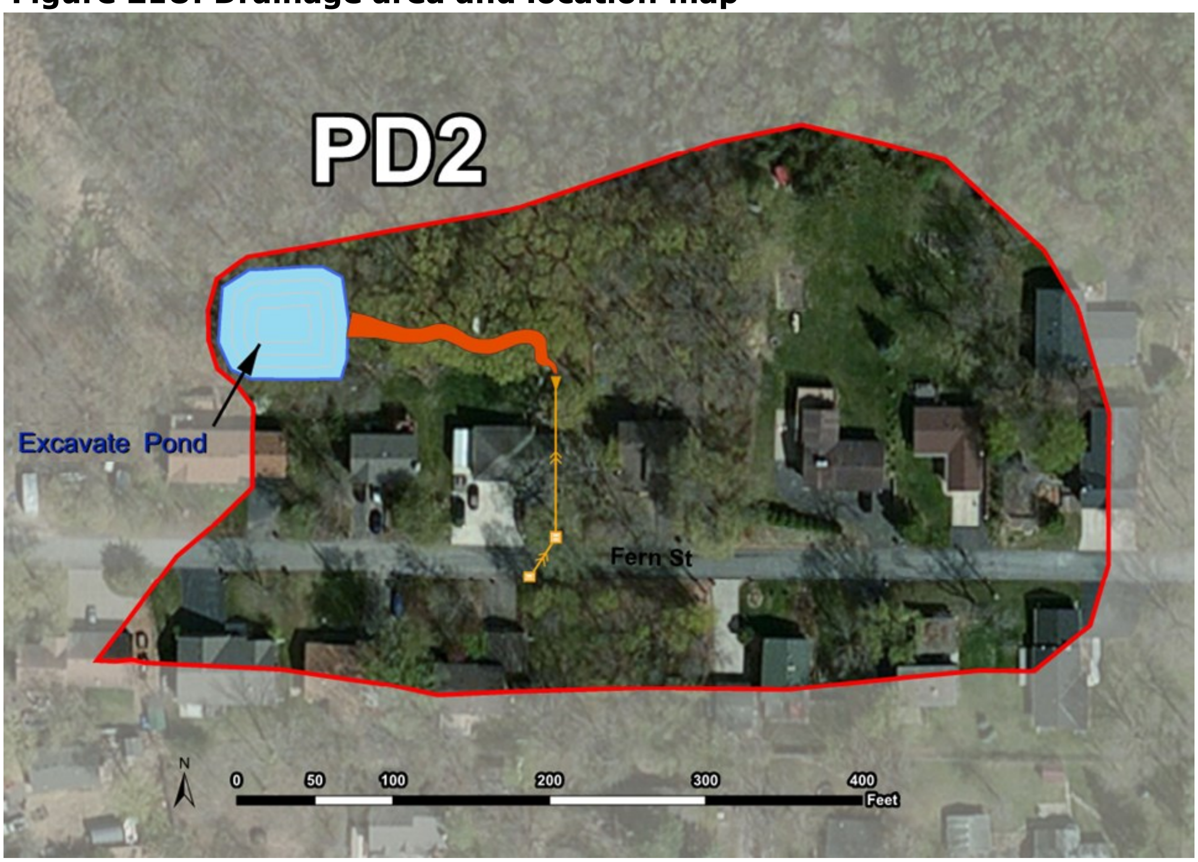
Figure 19U: Drainage area and location map

PD2

Table 10U. Site Summary – PD2	
Model Used	MIDS
Drainage Area	4.1 ac
Proposed Pond Area	5,400 sq ft
Estimated TP removal	1.8 lbs/yr
Installation Cost	$32,400
Design/Admin	$8,000
Maintenance Cost / yr	$250
Total 30 Year Cost	$47,650
$/lb-TP removal /yr	$882

Figure 20U: Purple outline below shows proposed location of PD2.

Figure 21U: Drainage area and location map

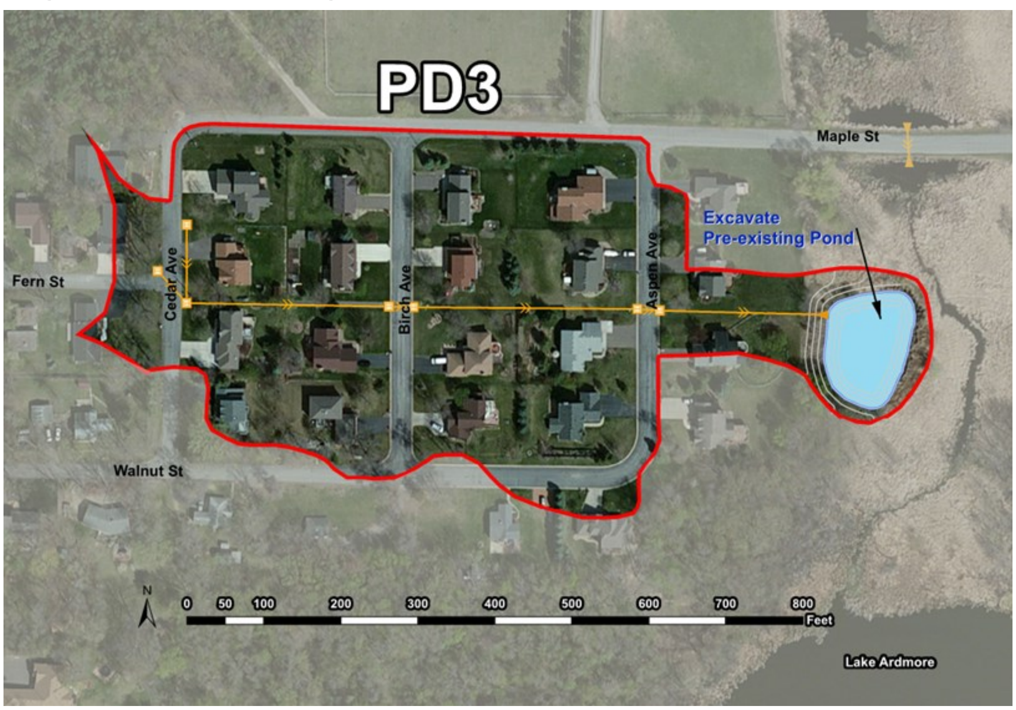


PD3

Table 11U. Site Summary – PD3	
Model Used	MIDS
Drainage Area	8.0 ac
Existing Pond Area	8,700 sq ft
Proposed Pond Area	14,000 sq ft
Estimated TP removal	1.1 lbs/yr
Installation Cost	$31,800
Design/Admin	$12,500
Maintenance Cost/yr	$250
Total 30 Year Cost	$51,550
$/lb-TP removal /yr	$1,562

Figure 22U: Purple outline shows proposed enlarged pond for PD3. Above– view looking south. Below– view looking west.

Figure 23U: Drainage area and location map

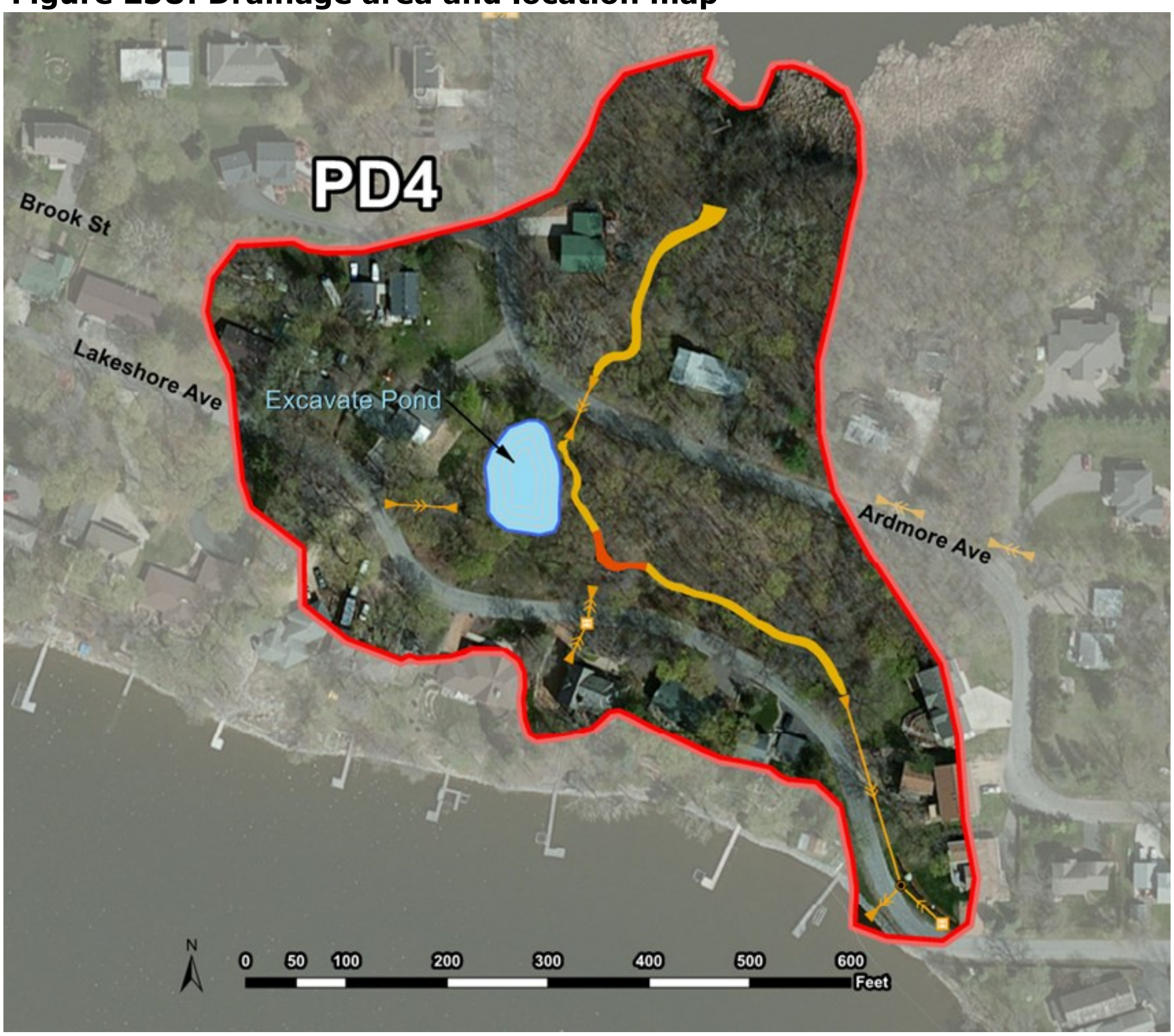


PD4

Table 12U. Site Summary – PD4	
Model Used	MIDS
Drainage Area	2.7 ac
Proposed Pond Area	4,600 sq ft
Estimated TP removal	1.2 lbs/yr
Installation Cost	$27,600
Design/Admin	$12,500
Maintenance Cost/yr	$250
Total 30 Year Cost	$47,350
$/lb-TP removal /yr	$1,315

Figure 24U: Orange outline shows the proposed location of PD4. View is looking southwest.

Figure 25U: Drainage area and location map



PD5

Table 13U. Site Summary – PD5	
Model Used	MIDS
Drainage Area	1.6 ac
Proposed Pond Area	4,000 sq ft
Estimated TP removal	1.0 lbs/yr
Installation Cost	$24,000
Design/Admin	$12,500
Maintenance Cost/yr	$250
Total 30 Year Cost	$43,750
$/lb-TP removal /yr	$1,458

Figure 26U: Purple outline shows location of proposed PD5

Figure 27U: Drainage area and location map

Alternative Higher Efficiency BMPs

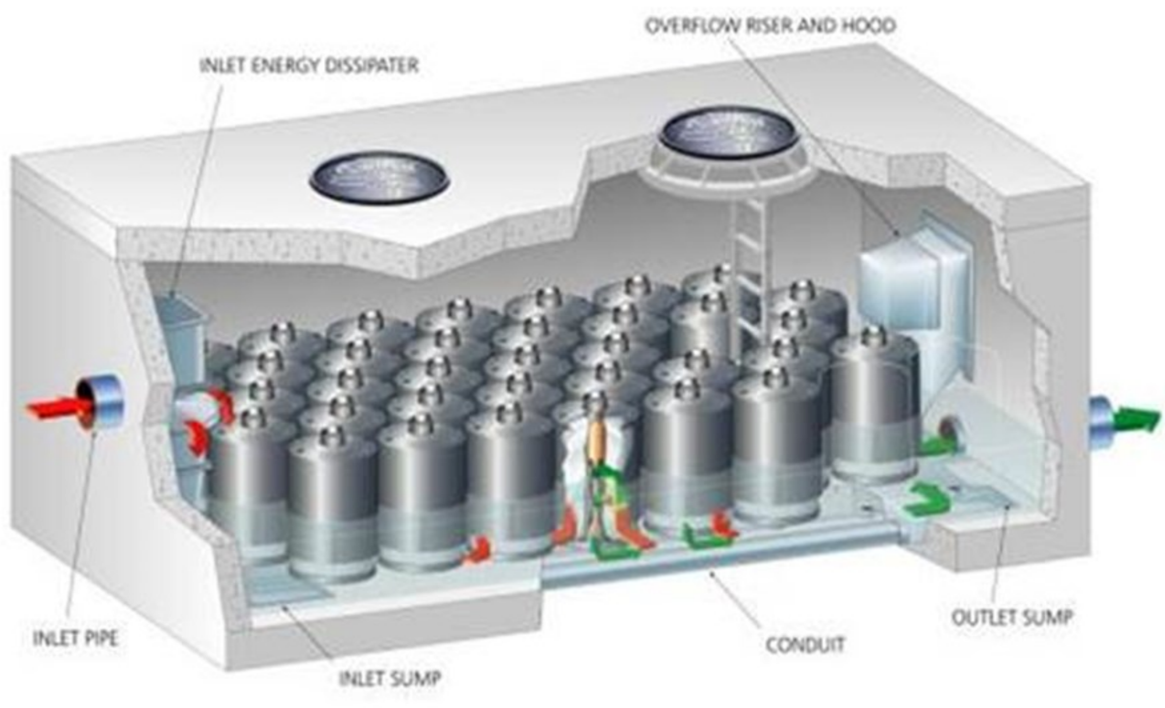
Enhanced Filtering Device

Although the rain gardens and ponds as previously discussed are rather effective in removing the particulate phosphorous contained in stormwater, they are not very effective in removing the dissolved portion of the phosphorous. Since it is estimated the dissolved portion is 45% of the total phosphorous, utilizing treatment methods that do not target dissolved phosphorous can result in lost opportunity.

The dissolved phosphorous is the most difficult portion of the phosphorous load to capture. Traditional settling and even filtering methods have not proven to be effective in removing dissolved phosphorous. However, certain methods such as introducing aluminum or iron in a filter media cause the dissolved portion of the phosphorous to bind to the media, and thereby removing it from the stormwater.

The schematic shown in **Figure 28U** below is a proprietary device developed by Contech Engineered Solutions. The device filters the stormwater through an aluminum enhanced media contained within the internal cartridges. The dissolved phosphorous binds to the internal media, allowing the filters to pass clean stormwater. The clean stormwater exits the internal cartridges through the bottom into a trench within the false floor, which leads to the outlet. Pre-treatment of stormwater is recommended prior to entering the device; however, remaining suspended solids will also settle out in the bottom of the structure.

Figure 28U: Enhanced filtering device; Source: Contech Engineered Solutions



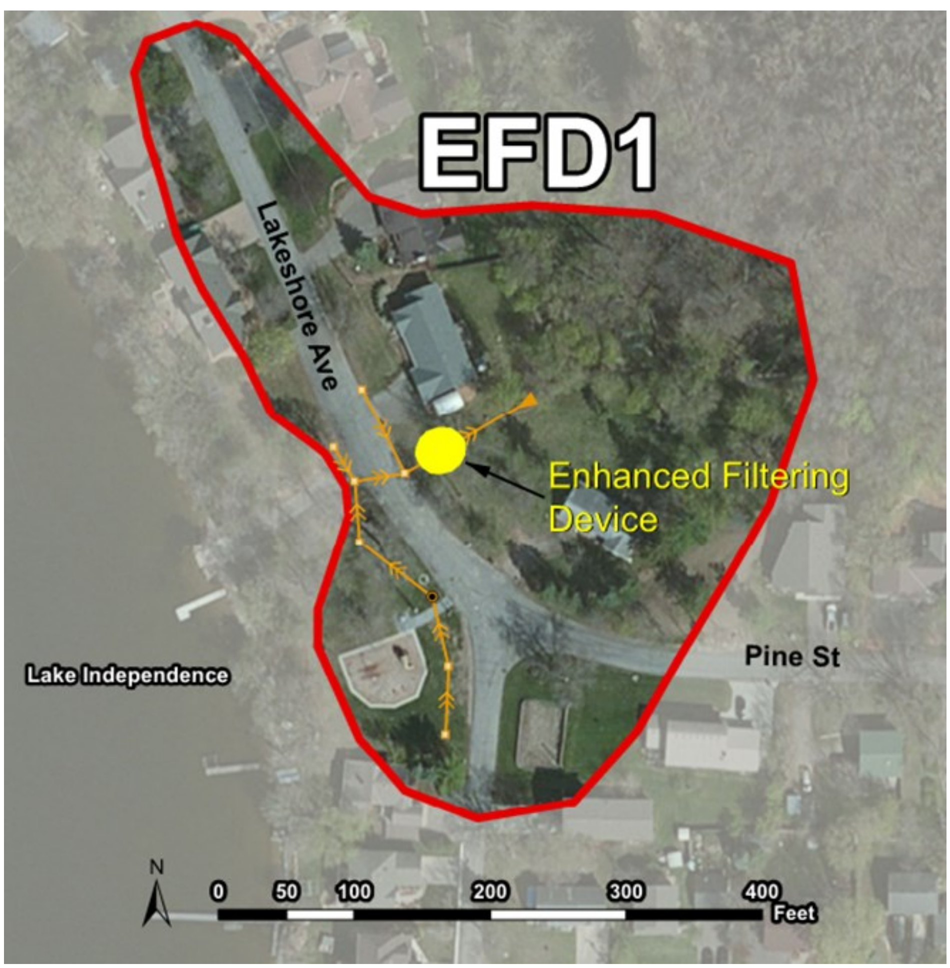
Large filtering devices require periodic maintenance and must be easily accessible by a vacuum truck. Therefore, they must be located within or in close proximity to a driving surface. The site previously mentioned for PD5 would be ideal for an enhanced filtering device (EFD1). EFD1 is an alternative BMP to PD5, so if the enhanced filtering device were to be installed in this location, the pond would not be excavated.

EFD1

Table 14U. Site Summary – EFD 1	
Model Used	N/A
Drainage Area	1.6 ac
Estimated TP removal	1.4 lbs/yr
Installation Cost	$200,000
Design/Admin	$20,000
Maintenance Cost	$2,000
Total 50 Year Cost	$318,000
$/lb-TP removal /yr	$4,543

Figure 29U: Possible location of underground enhanced filtering device

Figure 30U: Drainage area and location map

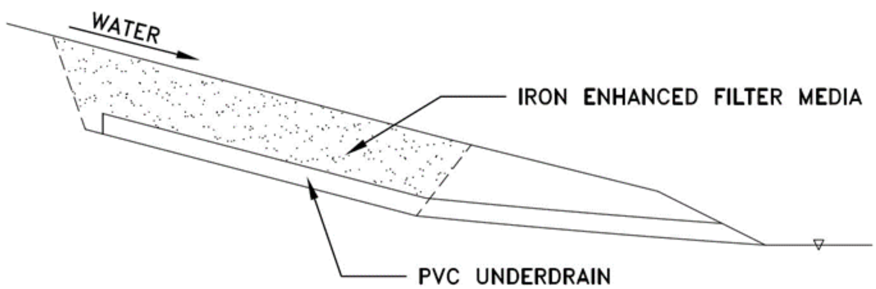


Iron Enhanced Sand Filters (MN Filter)

Similar to enhanced filter devices, iron enhanced sand filters are efficient in reducing the dissolved portion of the phosphorous. Iron enhanced filters utilize iron filings within the filter media. As the stormwater passes through the media, the dissolved phosphorous attaches to the iron filings within the media, effectively treating the stormwater. A pre-treatment settling basin is utilized upstream of the iron enhanced filter to settle out the sediment. Any sediment that passes through the pre-treatment will still have an opportunity to settle out in the iron enhanced filter; however, over time, sediment may plug the iron enhanced filter and reduce overall effectiveness.

In order for iron enhanced sand filters to be effective, they must be designed to drain after a storm event in order to prevent hypoxic conditions.

Figure 31U: Schematic of iron enhanced sand filter



There is one iron enhanced sand filter (ISF1) proposed in this watershed, which is in the same location as PD2. Only one BMP should be considered at this site; therefore, if an iron enhanced sand filter is utilized, pond PD2 would not be constructed.

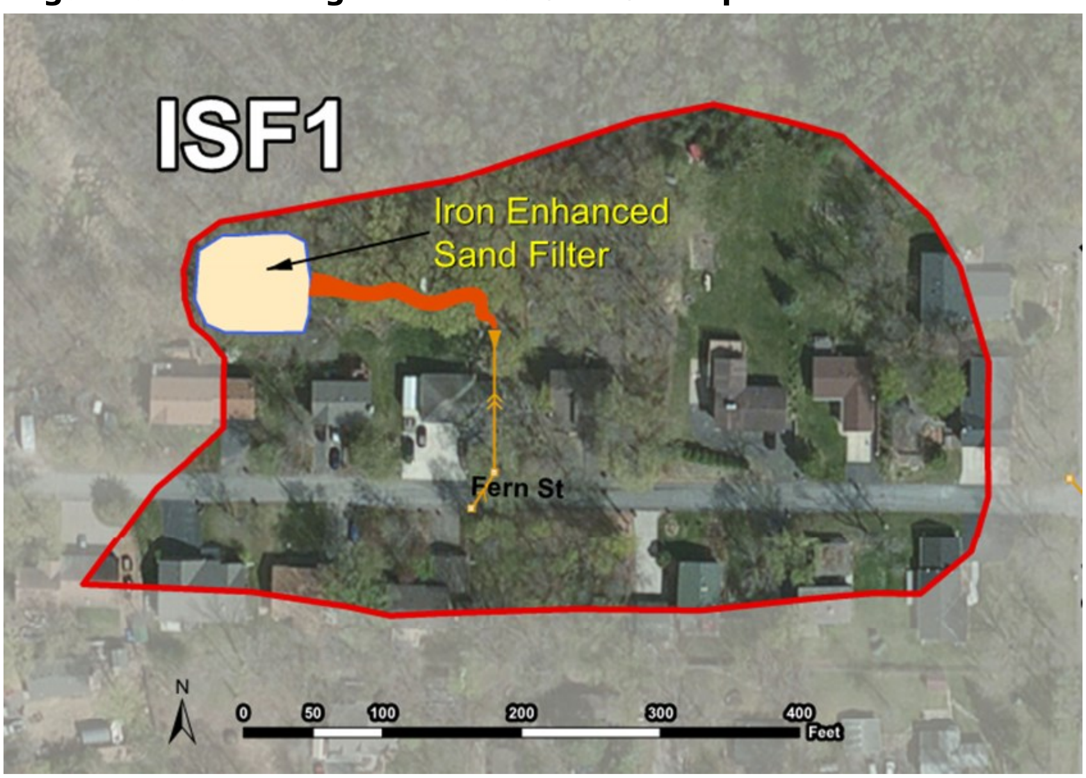
Figure 32U: Iron enhanced sand filter; Source: BWSR

ISF1

Table 15U. Site Summary –ISF1	
Model Used	N/A
Drainage Area	4.1 ac
Proposed Pond Area	5,400 sq ft
Estimated TP removal	3.1 lbs/yr
Installation Cost	$58,000
Design/Admin	$15,000
Maintenance Cost / yr	$500
Total 30 Year Cost	$87,500
$/lb-TP removal /yr	$941

Figure 33U: Location of the proposed ISF1

Figure 34U: Drainage area and location map



Urbanized Ardmore Subwatershed Summary

Twelve projects in ten areas have been identified that will reduce the phosphorus load up to a combined 15.9 pounds per year to Lake Independence from the urban area of the Ardmore subwatershed. The data included within this report should be utilized for determining feasibility and prioritizing projects. Before any project is advanced, preliminary design should be completed to confirm the results included herein. Prior to construction of any of the proposed projects, detailed plans and specifications should be prepared by a professional engineer.

Hennepin County
Rural Subwatershed Assessment

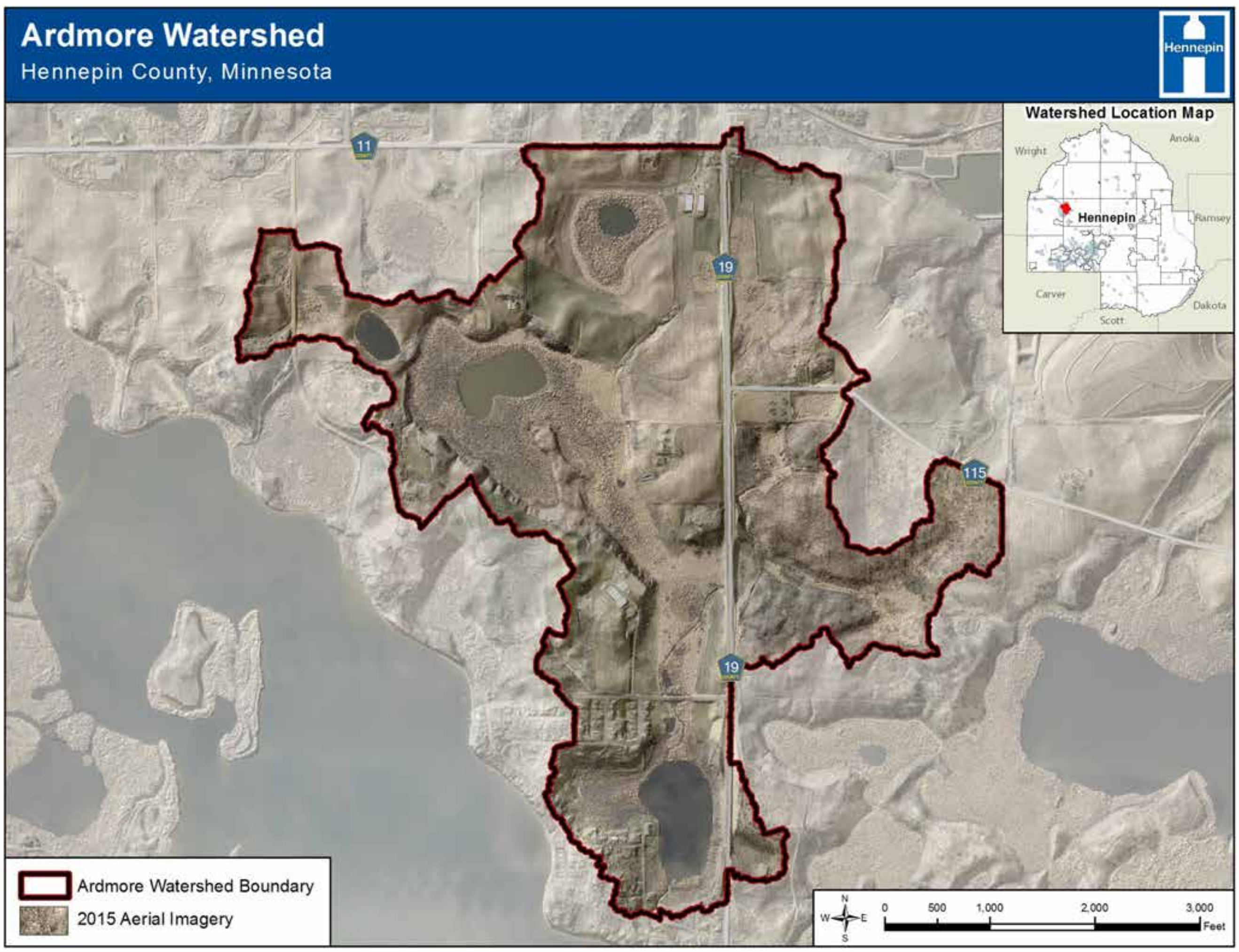


Figure 1R: Lake Ardmore Rural Watershed Outline

Introduction

This report details a stormwater assessment with BMP recommendations within the Lake Ardmore rural watershed. Its purpose is to assist the City of Medina in its decisions and processes to provide cost effective methods to help reduce phosphorus loads into Lake Ardmore and ultimately into Lake Independence.

Because of excessive nutrients, Lake Ardmore is proposed by the Minnesota Pollution Control Agency to be listed as an impaired lake in 2016 for aquatic recreation. Three Rivers Park District, in cooperation with the Pioneer-Sarah Creek Watershed Management Commission, is undertaking a TMDL study to see the extent of the impairment, provide nutrient budgets and possible solutions to achieve a non-impaired status for the lake. Preliminary numbers from their model show 269 pounds per year phosphorous loads from its contributing watershed. This report will focus specifically on the nutrient loads from the rural section of the watershed located north of Maple Street that drains into Lake Ardmore.

The Lake Ardmore watershed is approximately 537 acres in size. The primary land uses that make up this watershed are wetlands (158 acres), woodlands (143 acres), farmsteads/residential/hobby farms (119 acres) cropland (95 acres) grassland (7 acres), and roads and right of ways (14 acres). The focus of this analysis is the rural section of the watershed north of Maple Street which encompasses 472 acres. Four hundred and twenty three acres are in Medina, and 49 acres are in Independence.

Lake Ardmore outlets into a channel that flows approximately 1,000 feet before entering Lake Independence. In 2002 the Minnesota Pollution Control Agency listed Lake Independence as impaired for aquatic recreation under Section 303 (d) of the Clean Water Act. The Lake Ardmore subwatershed is one of the 6 primary subwatersheds that drain to Lake Independence. The Lake Independence TMDL study identified the Ardmore Lake watershed as contributing 6% (96 lbs.) of the external load running into Lake Independence, causing its impairment.

This stormwater assessment will model various stormwater treatment BMPs within the 472 acres of rural watershed that drains into Lake Ardmore. These BMPs are analyzed to determine their effectiveness in reducing nutrient loads into the lake. These practices will be rated from the most cost effective project per pound of phosphorus reduction to the least effective. To provide a better understanding of each BMP and approach for implementation, conceptual drawings and/or photos are incorporated within this report. Prior to implementation, more detailed, site-specific designs will need to be prepared for each BMP selected. Most will require additional study and/or engineered plans. For all the recommended projects, partnerships with committed and willing landowners are essential.

The process used to select recommended BMPs was based primarily on a combination of the target pollutant (phosphorus), the project type and their cost/benefit analysis, and the location of the project in the watershed. Additional factors should be considered prior to the prioritization of recommended BMP (e.g., project costs, available funding, economies of scale, landowner willingness, short- and long-term impacts on property values and the public infrastructure).

Basic conclusions

This study, using site specific observations and measurements; new topographic data (2 foot contour LiDAR data); land use; and modeling processes, supports the findings from previous studies, which show a direct correlation between land use, land management and phosphorus transport to the amount of pollutants in the Lake Ardmore watershed. The implementation of any land practices that helps rainfall stay on the land, keeps it from running off and prevents nutrients (attached to soil and dissolved in the runoff water) from reaching the drainage system and benefits the water quality of Lake Ardmore and ultimately Lake Independence.

The cost/benefit relationship of putting these BMPs into place is highly dependent upon how severe the land disturbance is and how close the practice is to Lake Ardmore.

Table 1R shows the reductions of phosphorus at the source of a BMP and at Lake Ardmore. It breaks down what the total project cost is estimated at and cost per pound of total phosphorus (TP) removed from the lake.

As part of this process, the cost effectiveness and nutrient reductions for some conceptual practices were generalized. For example, livestock facilities were not modeled due to the specific site and management techniques each facility uses. However, the concept of on-site nutrient management systems that would adequately store, manage and apply manure and nutrients to cropland along with adequate pasture management techniques were evaluated, and a delivery ratio of nutrients to Lake Ardmore was determined based on distance to the drainage systems and lake. A generalized load reduction and cost/benefit analysis can be estimated to locate livestock BMPs that warrant additional study. If the landowner is interested in such a study, the exact nutrient reductions must be analyzed on a site by site basis.

Rural watershed assessment: document organization

This rural section of the document is organized to present a brief overview of the processes involved to get to the project rankings and selections. The technical aspect of the Subwatershed assessment process and supporting model results are presented in the appendices. The majority of the report focuses on the projects themselves: their rankings in cost per pound of nutrient reduction and the profile of the project.

Recommended projects

Table 1R: Ardmore Lake retrofit projects and rankings

Project rank	Retrofit type (refer to catchment profile pages for additional detail)	Project identified	Total phosphorus reduction	Phorphorus delivery ratio to Lake Ardmore	Phosphorus reduction to Lake Ardmore	Total project cost	Estimated cost
			(lb/yr)		(lb/yr)	(includes 10-yr maintenance)	(lb-TP/year for 10 years)
1	Nutrient Management System	Lvst D	8.8	0.5	4.4	$4,200	$96
2	Field Buffer	FB-4	10.3	0.9	9.2	$12,760	$139
3	Pasture & Paddock Management	Lvst A	2.5	1.0	2.5	$4,750	$190
4	Field Buffer	FB-5 (lvst A)	6.3	1.0	6.3	$12,098	$192
5	Gully Stabilization	G-1 (lvst C)	22.1	0.4	6.7	$19,165	$218
6	Field Buffer	FB-3 (lvst D)	12.7	0.4	5.1	$12,169	$239
7	Exclusion Fencing	EsFn D-1 (lvst D)	4.6	0.5	2.3	$5,875	$255
8	Field Buffer	FB-2E	13.1	0.4	5.2	$14,450	$278
9	Exclusion Fencing	ExFn A-1 (lvst A)	2.0	1.0	2.0	$5,775	$289
10	Field Buffer	FB-2W	26.0	0.3	7.8	$27,970	$359
11	Field Buffer	FB-1	11.0	0.2	2.2	$7,960	$362
12	Field Buffer	FB-2S	4.0	0.6	2.4	$8,704	$363
13	Gully Stabilization	G-2 (lvst A)	12.8	0.7	8.9	$36,200	$407
14	Exclusion Fencing	ExFn A-2 (lvst A)	1.8	1.0	1.8	$7,875	$438
15	Grass Waterway	GW-A1 (lvst A)	1.8	1.0	1.8	$9,180	$510
16	Manure Storage System	Lvst C	6.0	0.4	2.4	$14,375	$599
17	Manure Storage System	Lvst B	2.0	0.5	1.0	$7,875	$788
18	Wetland Restoration 2E	WR-2E	30.8	0.4	12.3	$204,375 (20 year cost)	$831 (20 year cost)
19	Regional Pond 1	RP-1	30.9	0.4	12.4	$208,125 (20 year cost)	$846 (20 year cost)
20	Wetland Restoration 2W	WR-2W	5.0	0.4	2.0	$226,500 (20 year cost)	$5,663 (20 year cost)
21	Gully Stabilization	G-3	0.4	0.7	0.3	$19,500	$6,500

Table 1R: Ardmore Lake retrofit projects and rankings (continued)

Project rank	Retrofit type (refer to catchment profile pages for additional detail)	Project identified	Total phosphorus reduction	Phorphorus delivery ratio to Lake Ardmore	Phosphorus reduction to Lake Ardmore	Total project cost	Estimated cost
			(lb/yr)		(lb/yr)	(includes 10 -yr maintenance)	(lb-TP/year for 10 years)
22	Wetland Restoration 1	WR-1	3.2	0.1	0.3	$43,750 (20 year cost)	$6,836 (20 year cost)
23	Manure Storage System	Lvst A				$66,200	N/A
24	Clean Water Diversion	Lvst A				$7,325	N/A
25	Clean Water Diversion (roof gutters)	Lvst C				$4,000	N/A
26	Manure Storage System	Lvst D				$35,400	N/A

Figure 2R: Ardmore watershed projects and best management practices map

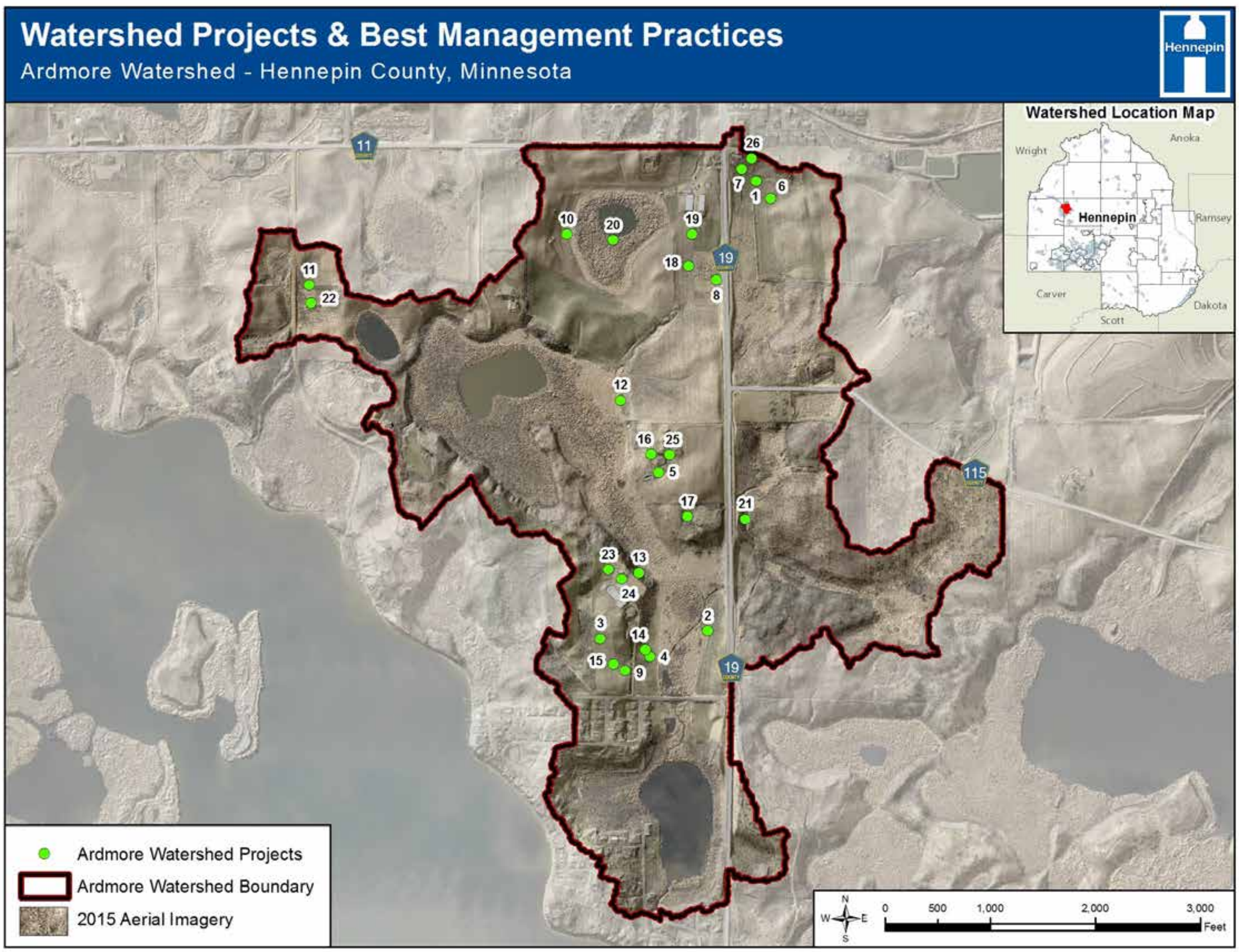


Figure 3R: Ardmore watershed

Table 2R: Priority elements analyzed in Lake Ardmore subwatershed assessment

Priority elements analyzed	Description
Total phosphorous	Phosphorus is an essential nutrient for plants, animals and humans. Under natural conditions, phosphorus (P) is typically scarce in water. However, changes in pre-settlement land use activities have resulted in excessive loading of phosphorus into many freshwater systems. This can cause water pollution by promoting excessive algae growth, particularly in lakes. Total Phosphorus is a combination of particulate phosphorus, which is bound to sediment and organic materials, and dissolved phosphorus, which is phosphorus in solution available for plant growth. Total Suspended Solids (TSS) are particles remaining dispersed in a liquid due to turbulent mixing that can create turbid or cloudy conditions. Reducing TSS will reduce particulate phosphorus loads to Lake Ardmore. Volume of water: Higher runoff volumes and velocities can carry greater amounts of TSS and dissolved phosphorus to Lake Ardmore. Reductions in volume will reduce total phosphorus loads to Lake Ardmore.
Cost	Each retrofit practice has been analyzed for the annual cost per pound of phosphorous load reduction into Lake Ardmore. Cost includes installation, annual maintenance, life expectancy, design and project oversight.
Watershed location	All projects are analyzed by determining their phosphorus load reductions entering Lake Ardmore. Our methods of modeling takes into account the modeled, edge of field phosphorus load reductions multiplied by a pollutant delivery ratio to estimate what actually gets into the lake. The pollutant delivery ratio was arrived at by the report authors and other natural resource professionals utilizing maps showing the project location in the watershed, distance to Lake , aerial photographs, topography, type of phosphorus (soluble vs. particulate) and flow paths. Each project was assigned a number from 0.1 to 1.0 with 0.1 having a lower nutrient reduction benefit that 1.0.

Potential project types

The retrofit analysis considered various stormwater and erosion/sediment control BMPs. Table 3R describes these BMPs and how their benefits were analyzed.

Table 3R: Potential project types for Ardmore Lake subwatershed assessment

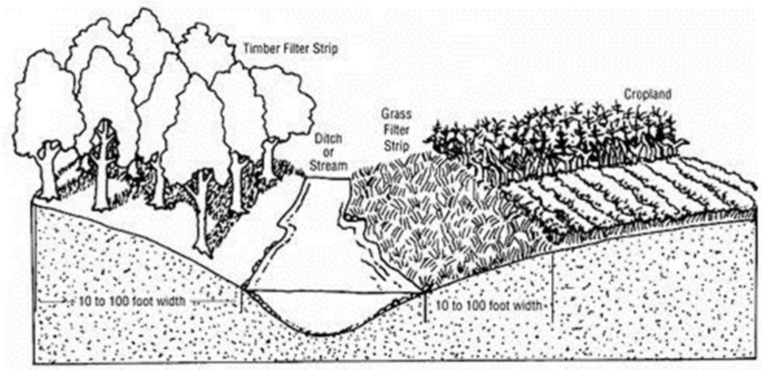
Project type	Description	Modeling methods
Vegetated buffer strip	A strip or area of herbaceous vegetation situated between cropland, grazing land or disturbed land and environmentally sensitive areas.	RUSLE 2/ BWSR Pollution Reduction Estimator
Grassed waterway	A natural or constructed channel that is shaped or graded to required dimensions and established with suitable vegetation for the stable conveyance of runoff.	BWSR Pollution Reduction Estimator
Gully stabilization	Corrective actions on active gully erosion with rock rip rap, check dams or other stabilization measures and vegetation for the stable conveyance of channelized flows.	BWSR Pollution Reduction Estimator
Livestock best management practices	Restricting livestock access to critical or sensitive areas through the use of fencing or other restrictive forms of animal exclusion. Analyzing manure storage needs for livestock facilities. Analyzing the potential use of compost, stacking slabs, storage facilities, and pasture and nutrient management.	MinnFARM/RUSLE2/Elm Creek and U of WI loading estimates
Wetland restoration	Restoring hydrology to cropland areas that have been partially or completely drained.	SWAT
Ponding	Creating new regional or local ponds to capture and treat runoff.	SWAT/NURP

Project profiles

Buffer strips

Buffer strips are land areas of vegetation, situated between a potential, pollutant-source area and a surface-water body that receives runoff (Figure 3R). The term 'buffer strip' is sometimes used interchangeably with filter strip. Runoff may carry sediment and organic matter and plant nutrients and pesticides that are either bound to the sediment or dissolved in the water. A properly designed and operating buffer strip provides water-quality protection by reducing the amount of sediment, organic matter, and some nutrients and pesticides in the runoff at the edge of the field and before the runoff enters the surface-water body. Buffer strips also provide localized erosion protection since the vegetation covers an area of soil that otherwise might have a high erosion potential.

Figure 3R: Examples of vegetative buffer strips



Often constructed along stream, lake, pond or wetland boundaries, buffer strips installed on cropland not only help remove pollutants from runoff, but also serve as habitat for wildlife and provide an area for field turn rows and haymaking. In some instances, a buffer strip could be used as pasture in a controlled-grazing, livestock management system if livestock are kept fenced out of the stream or lake.

Buffer strips are an edge-of-the-field BMP. They often are used in conjunction with other sound agricultural and land management practices, such as contour plowing, pest scouting, conservation tillage, crop rotations, strip cropping, soil testing, and proper nutrient and pest management. Because of their potential environmental benefits, buffer strips are a recommended urban and agricultural BMP.

Most field research supports the use of buffer widths in the range of 10 to 40 feet depending on the receiving water and amount of flows it is designed to intercept. This report uses a 35 foot strip in its analysis for pollutant reductions and cost/benefits.

Buffer strips are proposed in areas where active agricultural activities are occurring near a water course or wetland. The benefits of the buffer strip will vary greatly depending on many variables, including: whether the water flowing over it is in a channelized or sheet type of flow, the slope of the land, type of vegetation in the strip, width of the strip, distance to the stream or wetland and distance to Lake Ardmore to name a few.

The cost/benefits of buffer strips are estimated based on the pollutant reductions, which is determined by the width of the filter strip, pollutant reduction, life span, crop loss, design and promotion costs and maintenance costs.

The expected life span of a buffer strip is 10 years. It is highly determined by the amount of soil/sediment that the grass in the filter strip traps. Eventually the cropland at the edge of the grass will build up with sediment causing the water to back up at the edge of the filter creating wetness issues in the cropland. This edge between the filter strip and cropland will need to be re-established to allow for the water to flow into and through it as intended. If upland erosion is not controlled, the lifespan of the filter strip is greatly reduced.

To help remove nutrients during the lifespan of the buffer strip, we encourage harvesting the hay at least once a year (after August for nesting bird protection).

Lake Ardmore vegetated buffer analysis parameters

Buffer width

The standard vegetated buffer width used in this report is 35 feet wide, which provides the necessary benefits with good representative costs.

Buffer length and area

Buffer lengths are established based on the sensitivity of the water resources being protected. Buffer area is determined by multiplying the buffer length by 35 feet (the standard buffer width) and converted to acres.

Phosphorus reductions

The phosphorus reduction that will be provided by a buffer strip is estimated by using the Board of Water and Soil Resources (BWSR) Pollution Reductions Calculator for Filter Strips (*www.bwsr.state.mn.us/outreach/eLINK/ index.html)*, and is calculated in pounds and imeasured at the edge of the field using the following input parameters:

- Soil type: Silt was used for all sites
- Area: Measured in acres draining into and through the buffer
- Average soil loss: Measured in tons per acre of the contributing area
- Average field soil loss: Determined for each site using the USDA, NRCS Revised Universal Soil Loss Equation (RUSLE2). RUSLE2 uses the following input parameters:
  - Specific slope length: Measured from top of slope to where the water channelizes (LS factor)
  - Specific slope steepness: Measured from 2-foot topographic maps of Hennepin County LiDAR information (LS factor)
  - Site-specific soil: From the Hennepin County Soil Survey (k factor)
  - Crop rotation and tillage history: Based on review of aerial photos from 2006, 2008, 2011 and 2012 (c factor)
  - Existing conservation practice: Based on aerial photographic reviews (p factor)
  - Regional climate conditions for Hennepin County

Phosphorus delivery ratio

Depending on the distance between the buffer strip and the protected target resource, some of the phosphorus reduction benefit may be diminished. All the vegetated buffers were further analyzed to determine the reduction of phosphorus that would reach Lake Ardmore. This reduction is the Phosphorus Delivery Ratio (PDR) of the vegetated buffer strip. Therefore, the phosphorus load that actually reaches Lake Ardmore was estimated by multiplying phosphorus reduction at the field edge and PDR. The PDR was estimated for each site by considering the location and distance of the buffer strip with respect to Lake Ardmore, flow restrictions, aerial photographs, topography and the type of nutrient available for transport (soluble versus particulate). Each buffer site was assigned a PDR from 0.1 to 1.0, with 0.1 having a lowest delivery ratio (10% from the field edge), and 1.0 having the highest delivery ratio (100% from the field edge) to Lake Ardmore.

Cost basis for vegetated buffers

Construction costs are estimated at $350 per acre of buffer area and include seedbed preparation, fertilizer and planting.

Maintenance costs are estimated at $100 per acre of buffer area and are figured for the complete lifespans of the practice (10 years). Maintenance costs cover weed suppression and reseeding where needed.

Crop production losses are estimated at $800 per acre of buffer area. The largest cost associated with vegetated buffers is the losses incurred from taking cropland out of production. Although this will vary based on type of crop, land productivity and crop pricing, this report uses a standard of $800 in crop production losses per acre per year, totaling $8,000 per acre over 10 years.

Design, easement and oversight costs are estimated as a lump sum of $6,000 per buffer and is largely for easement development and recording.

Lake Ardmore specific buffer assumptions

- Buffer width = 35 feet
- Buffer length = varies
- Project lifespan = 10 years
- Cost (estimated by the Metropolitan Association of Conservation Districts' BMP Cost Estimator):
  - Construction cost = $350/acre
  - 10-year maintenance cost = $100/acre
  - 1-year production cost lost = $800/acre
  - Design, easement and oversight costs = $6,000 lump sum
- Nutrient and sediment reductions: Estimated by BWSR Pollution Reductions Calculator for Filter Strips
- Soil: Assumed as silt with average bulk density of 85 lbs./cu.ft.

Table 4R shows the estimated phosphorus reduction entering Lake Ardmore from the fields analyzed and the associated cost for the life span of the project due to the implementation of buffer strips.

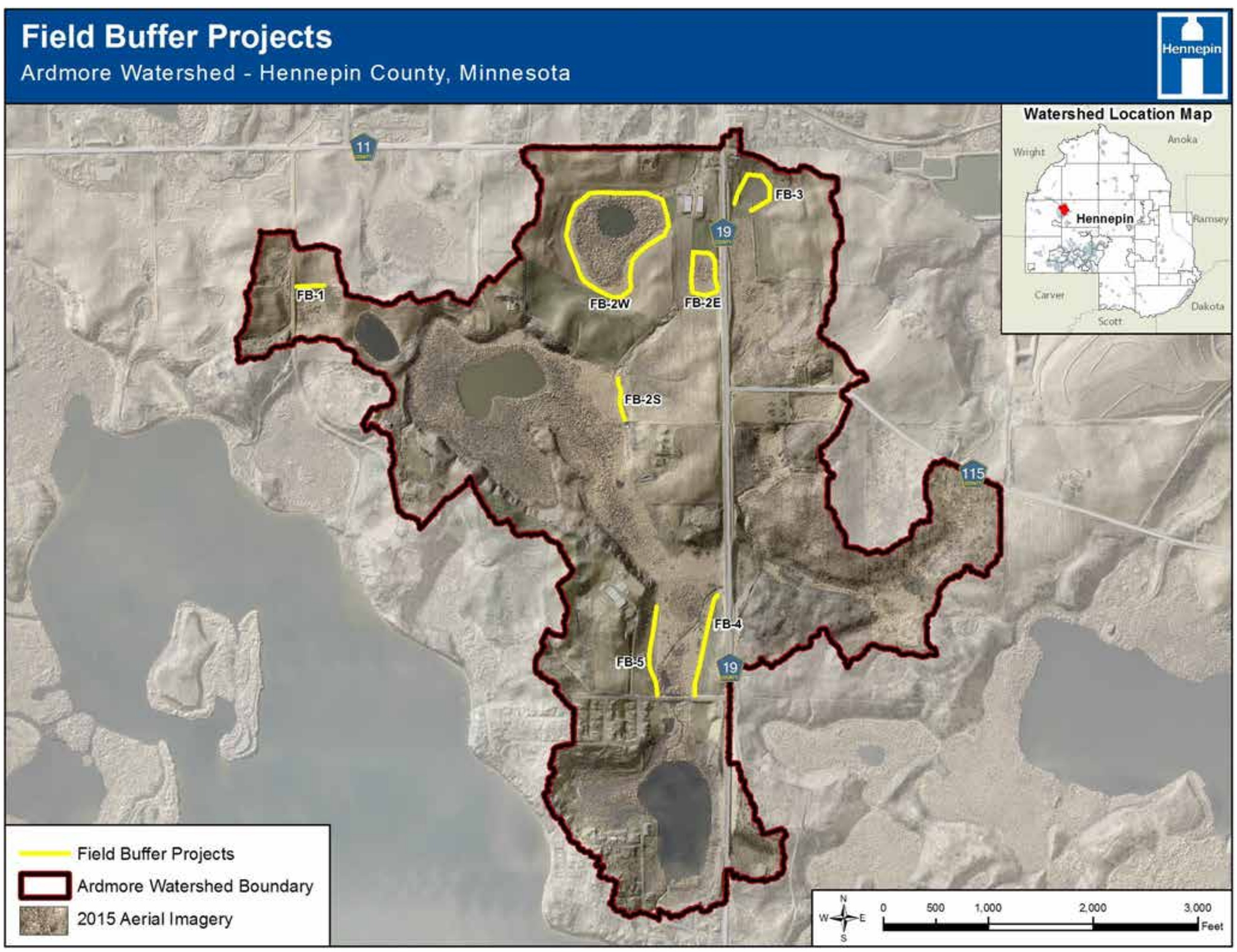
Buffer 1 is in the far west portion of the Lake Ardmore watershed. It is the south field boundary above an existing, drained wetland basin.
Buffer 2W would be around the large wetland basin in field 2
Buffer 2E would be around the small wetland basin near CSAH 19 in field 2
Buffer 2S would be along the southwest field boundary in field 2
Buffer 3 is located between the wetland and pasture in livestock area D
Buffer 4 is located along the west field boundary in field 4.
Buffer 5 is located along the horse pasture on livestock site A

Table 4R: Phosphorous reduction to Lake Ardmore and associated costs of proposed buffer strips

Field buffer ID	Buffer		Area up-stream of buffer	Total 10-year cost	Average soil loss from contributing field	P reduction	PDR	Phosphorus reduced to Lake Ardmore	Cost of P reduction to Lake Ardmore for lifespan of practice
	Length	Area							
	(ft)	(acres)	(acres)	($)	(tons/acre)	(lbs/year)		(lbs/year)	($/lbs)
FB-4	1000	0.8	4.2	12,760	6.4	10.3	09	9.2	$139
FB-5	900	0.72	5.6	12,098	2.3	6.3	1.0	6.3	$192
FB-3	910	0.73	8.4	12,169	3.6	12.7	0.4	5.1	$239
FB-2E	1165	1.0	9.0	14,450	3.4	13.1	0.4	5.2	$278
FB-2W	3200	2.6	21.7	27,970	6.5	26.0*	0.3	7.8	$359
FB-1	275	0.22	3.1	7,960	11.1	11.0	0.2	2.2	$362
FB-2S	400	0.3	1.4	8,704	7.8	4.0	0.6	2.4	$363

*P reductions is 50% of modeled reduction due to variables associated with a large contributing watershed

Figure 4R: Location of proposed buffer strips



Grassed waterways

Grassed waterways are constructed graded channels that are seeded to grass or other suitable vegetation. The vegetation slows the water, and the grassed waterway conveys the water to a stable outlet at a non-erosive velocity. Grass or permanent vegetation established in waterways protects the soil from concentrated flows. Grassed waterways significantly reduce gully erosion.

A natural drainage way is graded and shaped to form a smooth, bowl-shaped channel. This area is seeded to sod-forming grasses. Runoff water that flows down the drainage way flows across the grass rather than tearing away soil and forming a larger gully. An outlet is often installed at the base of the drainage way to stabilize the waterway and prevent a new gully from forming.

Figure 5R: Photo of well-functioning grassed waterway

Grass cover protects the drainage way from gully erosion. Vegetation may act as a filter, absorbing some of the chemicals and nutrients in runoff water. Vegetation provides cover for small birds and animals.

The expected life span of a waterway is 10 years. It is highly determined by the amount of sediment that the grass in the waterway traps. Eventually the cropland at the edge of the grass and the waterway itself will need to be re-excavated to allow for the water to flow into and down the waterway. If upland erosion is not controlled, the lifespan of the waterway is greatly reduced.

Lake Ardmore grassed waterway analysis parameters

Grassed waterway siting
The Lake Ardmore rural watershed was analyzed for sites that would benefit from waterway construction. The sites were determined by in-field site observations, topographic information (LiDAR) and aerial photographic desktop analysis.

Visual evidence was gathered by observations of the sites during various times throughout 2015

Topographic evidence was based on LiDAR indicators, including incised topographic settings and well-defined drainage areas leading to water collection flowage areas.

Aerial photographs were also used to site waterway projects. In areas we could not observe during our field reconnaissance, photographic evidence of erosion coupled with the LiDAR indicators mentioned above were utilized.

Phosphorus reductions
At this time, only one site where a waterway could be beneficial was determined within this watershed. The site is in a pasture area located in Livestock Site A. Utilizing an erosion equation such as the BWSR pollution reduction calculator for gullies and waterways was not feasible on this site because soil erosion itself is not a significant contributor to phosphorus transport in this area. Although erosion isn't a significant factor in this pasture area, the concentrated flows in this channel create the opportunity to transport a high volume of any waste material located within the flow path of the water during runoff events. The amount will vary on how concentrated the animals are in the vicinity of the waterway. The phosphorus reductions were estimated based on an average mean phosphorus load as cited in various University of Wisconsin Discovery Farm, Iowa State University and other studies in pasture situations. These studies have determined loads from a pasture can vary from 0.20 lbs. per acre to 12.0 lbs. per acre. Because of the channelized nature of the water running through a pasture area, this study chose the middle of the loads/reductions, or the 6 lbs./acre of load from the area of the waterway.

Phosphorus delivery ratio

The phosphorus delivery ratio for the one waterway analyzed was considered at 100% because of its proximity to Lake Ardmore.

Cost basis for grassed waterways

Construction costs were estimated at $10.00 per foot for the waterway and drain tile associated with it on this site. This includes 600 feet of 4" drain tile, excavation and distribution of the material on site, seeding and mulching. Drain tile was a component of this waterway because the slope of the waterway appear to be at ±1% near the upper reaches of it. Drain tile will assist in removing excess water in the vicinity of the waterway to minimize damage to the grass areas from the horses when they are near the waterway.

Maintenance costs were estimated at $0.25 per year per foot for the water and tile system over a 10 year period.

Design and oversight costs were estimated as a lump sum of $1,680 per project site. This includes surveying, design, staking and construction inspection.

Table 5R: Phosphorous reduction to Lake Ardmore and associated costs of proposed grassed waterways

Field ID	Total length of waterways	Total 10-year cost	P reduction	Distance to surface water (ditch system)	Phosphorus reduced to Lake Ardmore	Cost of P reduction to Lake Ardmore for the life span of the practice
	(ft)	($)	(lbs/year)	(ft)	(lbs/year)	($/lbs)
GW-A1	600	9,180	1.8	0	1.8	$510

Figure 6R: Location of proposed grassed waterway projects

Gully stabilization


Figure 7R: Photo of unstable streambank in Baker Park Reserve

Gullies are a specific form of severe erosion typically caused by concentrated water flow on erosive soils. Concentrated water flow may begin as minor sheet flow that produces rills and eventually results in major gully formation. Gullies can have major impacts on an area by taking land out of production, lowering the groundwater table and acting as a major source of sediment. Once formed, gullies typically get deeper and wider until they reach a resistant material. Gullies often form at the outlet of culverts due to the concentrated flows and relatively fast water velocities.

Stabilization of gullies typically requires reducing the volume and the velocity of water flowing through the gully. This can be achieved by refilling the gully and building dikes or small check dams at specific intervals along the gully. Reshaping and stabilizing long and steep banks may also be needed. Typical gully stabilization structures are constructed of rock, gabions or vegetative barriers. Biotechnical methods offer a combination of physical structures along with vegetative.

Lake Ardmore gully analysis parameters

Gully locations

Gully erosion sites in the Lake Ardmore watershed were located through in-field identification, aerial photograph and LiDAR desk top analysis. Areas that would benefit from a gully project were determined by in-field site observations, topographic information (LiDAR) and aerial photographic desktop analysis.

Visual evidence was gathered by observations of the sites at various times in 2015 and previous site visits.

Topographic evidence was based on LiDAR indicators, including incised topographic settings and well-defined drainage areas leading to water collection flowage areas.

Aerial photographs were also used to site gullies. In areas we could not observe during our field reconnaissance, photographic evidence of erosion scars, sediment fans and the LiDAR indicators mentioned above were utilized.

Phosphorus reductions

The phosphorus reduction that would be achieved through gully stabilization projects is estimated using the BWSR Pollution Reductions Calculator for Gully Stabilization (*www.bwsr.state.mn.us/outreach/eLINK/index.html*), and is calculated in pounds and measured at the bottom of the gully using the following input parameters:

- Soil type: Silt with an average bulk density of 85 lbs./cubic foot was used for all sites
- Soil volume voided per year (cubic feet): Based on the severity of erosion occurring within the specific gully. These were based on the Rapid Assessment Point Method (Inventory and Evaluation of Erosion and Sediment for Illinois by R.D. Windhorn, December, 2000.)

The two gully areas (G1 and G2) observed within the watershed are described as a moderate yearly recession rate. This is generally a gully with predominantly bare banks with some rills and vegetative overhang and some exposed tree roots. A moderate recession rate used for the Ardmore analysis was 4 inches per year along the length and width of the gully. One gully (G3) was described as a slight recession rate because of stabilization efforts done in the past. This gully was generally stable with approximately 6 areas where some additional bank and in-stream stabilization could benefit areas of slope instability. *(continued)*

Phosphorus reductions (continued)

- For the BWSR pollution reduction calculator, gully conditions were assumed to be channelized with no filter/buffer strips upstream. Gullies 1 and 3 were measured from aerial photographs at 525 feet and 750 feet long respectively. Gully 2 is actually a compilation of a series of gullies that have formed over time along the north and easterly slopes adjacent to the farmstead area where they are located. For the purpose of this analysis we summarized Gully 2 assuming two gullies, both 90 feet long by 5 foot wide. The actual area of Gully Site 2 will need to have a more thorough, on site survey conducted for the costs and benefits derived from this practice
- For Gully Sites 1 and 3, the wetted perimeter of the gully was assumed to be 3 feet. For Gully Site 2 it was assumed as 5 feet wide.

Phosphorus delivery ratio (PDR)

Depending on the distance between the gully and Lake Ardmore, some of the phosphorus reduction benefits will be diminished. All the gullies were analyzed to determine the reduction of phosphorus that would reach to Lake Ardmore. Therefore, the phosphorus load that actually reaches Lake Ardmore was estimated by multiplying phosphorus reduction at the bottom of the gully and the phosphorus delivery ratio (PDR). The PDR was estimated for each site by considering the location and distance of the gully with respect to Lake Ardmore, flow restrictions, flow route, topography and the type of nutrient available for transport (particulate in the case of sediment from gully erosion). Each gully was assigned a PDR between 0.1 to 1.0, with 0.1 having a lowest delivery ratio and 1.0 having the highest delivery ratio to Lake Ardmore.

Cost basis for gully stabilization

Construction costs were estimated at $90 per linear foot for Gully 2 based on access and material disposal limitations. Costs for Gully 1 were estimated at $45 per linear foot because of ease of access and material disposal. Gully 3 would be estimated at $120 per linear foot of repair due to intermittent repair needs and difficulty of access. Moderate recession rate projects would generally consist of clearing and grubbing, shaping, rip rap lined channels, check dams and restoration work. Projects with slight recession rate gullies usually involve check dams, minimal rip rap work with more vegetation restoration.

Figure 8R: Photo of rip-rap lined gully stabilization BMP

Design and oversight costs were estimated at a $5,000 lump sum per gully site and include scoping work, survey, staking, design and construction inspection.

Maintenance costs were assumed to be a $250 lump sum per year per gully site and include repair work, restoration work and other erosion and vegetation control.

Table 6R: Phosphorous reduction to Lake Sarah and associated costs of proposed gully stabilization projects

Gully site ID	Total length of gully	Recession rate	P reduction	Total 10-year cost	PDR	P reduced to Lake Ardmore	Cost of P reduction to Lake Ardmore for the practice lifespan
	(ft.)	(ft^3/year)	(lbs./yr.)	($)		(lbs./yr.)	($/lbs.)
G-1	525	moderate	22.1	19,167	0.4	6.7	$218
G-2*	180	moderate	12.75	36,200	0.7	8.9	$407
G-3	750	Slight	0.4	19,500	0.7	0.3	$6,500

*Gully 2 design and maintenance costs were doubled due to multiple gullies anticipated on site.

Figure 9R: Location of proposed gully stabilization projects

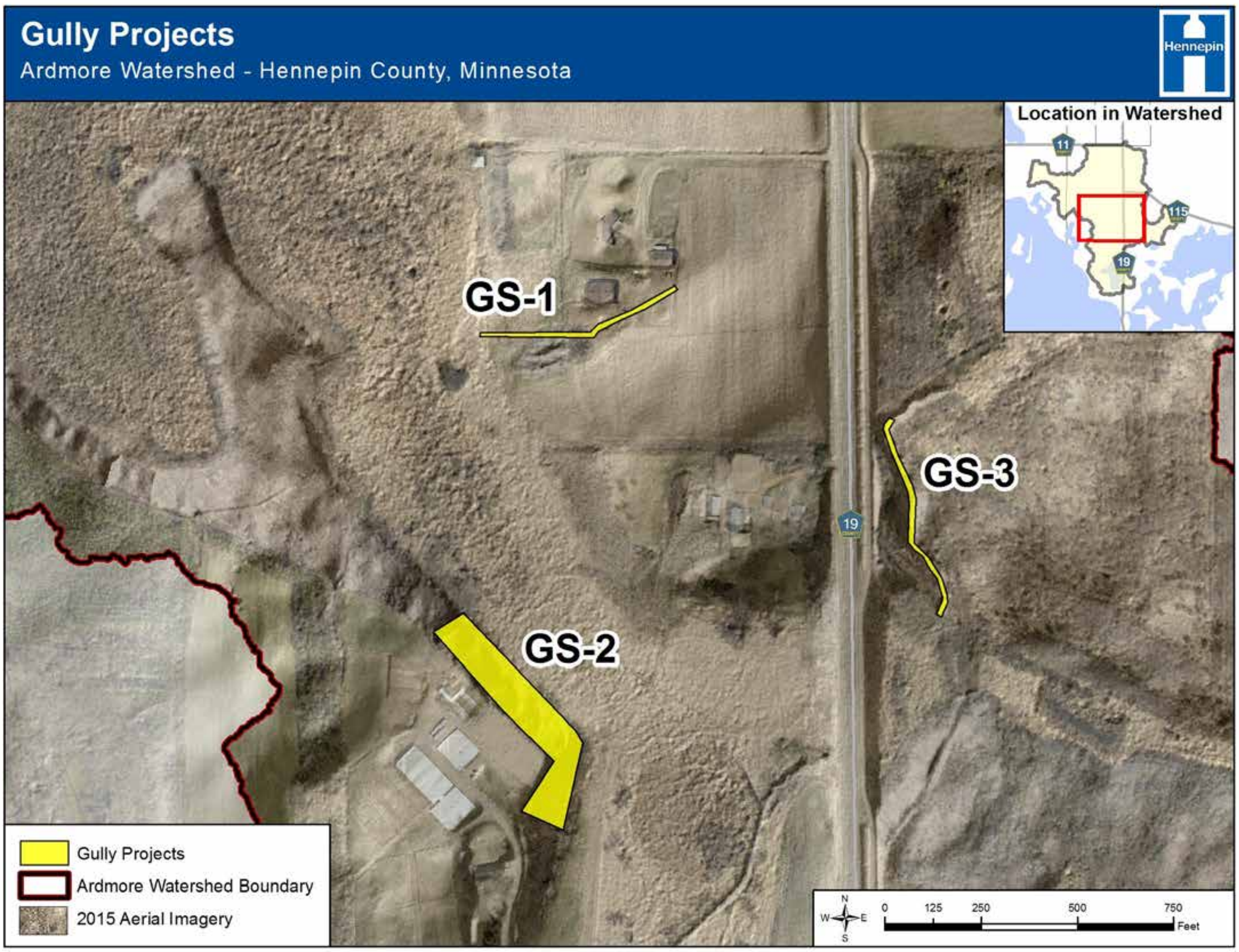
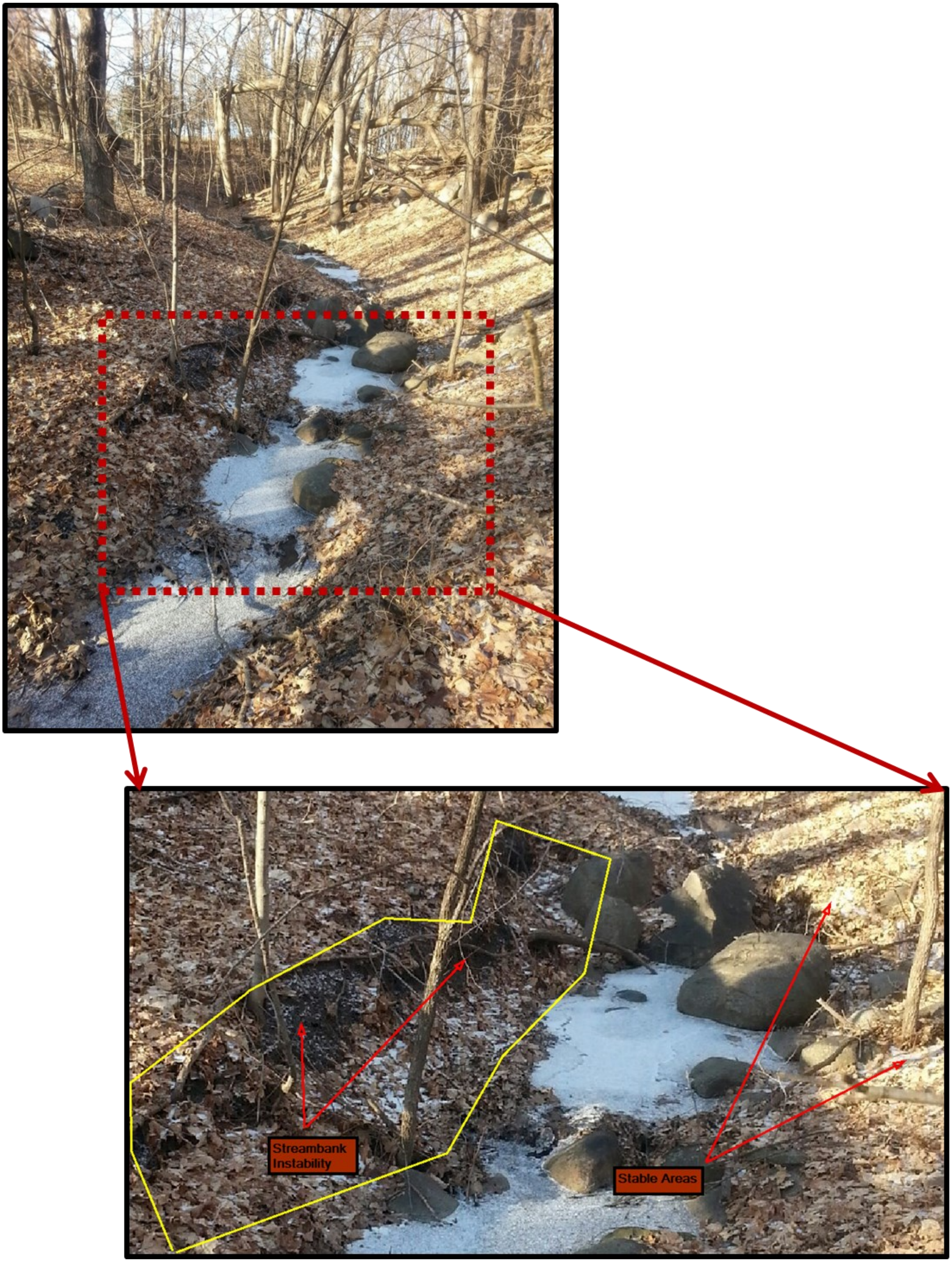


Figure 10R: Photo of Baker Park Reserve Gully East of CSAH 19



Livestock best management practices

The subwatershed to Lake Ardmore has four (4) known livestock facilities. Three are horse facilities, and one is beef. The total estimated animal units in the subwatershed is 40.5 at the time of this analysis.

This report is primarily concerned about the protections necessary to prevent nutrients from entering the stream system leading into Lake Ardmore. Because each livestock facility is unique and analysis of the requirements, needs and desires of each producer or landowner cannot begin to be examined without a complete and detailed facility study with the owner, this study generalizes many aspects of the individual sites identified as livestock production sites in the report. On site investigations are necessary before specific projects can move forward. Individual management and structural practices observed by site observations and aerial photo reviews are used in the report analysis and assumptions. Final analysis must be done in cooperation with the producer. Various models are used in our study to determine the Watershed and Lake Ardmore nutrient loads. Elm Creek Watershed Management Commission phosphorus loads based on land use, RUSLE2, and BWSR water pollution calculator are used in this report for livestock facilities, depending on the site, individual observations, topography and aerial photo analysis.

This report assumes non-production livestock facilities (i.e. horses) do not have a managed manure storage or disposal system, which may not be the case in some instances. Storage is primarily stacking onsite on the ground with no protections. Disposal is on an opportunity, not organized/planned type of basis. This report further assumes the one beef production facility has a managed, short term (1 or 2 month) storage and disposal system. It further assumes manure, crop and land nutrient needs are analyzed infrequently (every 4 or more years). Again, these assumptions may not be accurate in this instance.

Phosphorus reductions practices used to evaluate and rank cost/benefits for livestock and horse facilities within the Ardmore Watershed are as follows:

- Exclusion Fencings
- Manure Storage Facilities
- Pasture Management
- Channel and Gully Erosion Controls (see waterway and gully sections)
- Nutrient Management Plans

Phosphorus Delivery Ratio

Depending on the distance between the buffer strip and the protected target resource, some of the phosphorus reduction benefit may be diminished. All the vegetated buffers were further analyzed to determine the reduction of phosphorus that would reach Lake Ardmore. This reduction is the Phosphorus Delivery Ratio (PDR) of the vegetated buffer strip. Therefore, the phosphorus load that actually reaches Lake Ardmore was estimated by multiplying phosphorus reduction at the field edge and PDR. The PDR was estimated for each site by considering the location and distance of the buffer strip with respect to Lake Ardmore, flow restrictions, aerial photographs, topography and the type of nutrient available for transport (soluble versus particulate). Each buffer site was assigned a PDR from 0.1 to 1.0, with 0.1 having a lowest delivery ratio (10% from the field edge) and 1.0 having the highest delivery ratio (100% from the field edge) to Lake Ardmore.

A brief description of the livestock practices used in this report are as follows;

Livestock Exclusion (or access control): The temporary or permanent exclusion of livestock from a designated area— often to protect streambanks, wetlands, woods, cropland, wildlife habitat or conservation buffers. *(continued)*

In this analysis, livestock exclusion is closely associated with wetland and stream corridor protection from the water quality impacts related to the waste produced by the animal. Eliminating that waste source by exclusion fencing will eliminate the transport of that source into the Lake Ardmore system.

Livestock exclusion can be a component of many conservation practices, especially wetland and streambank protection, stream habitat improvement, rotational grazing, and riparian buffers including grass filter strips and forested riparian buffers.

Figure 11R: Photo of livestock exclusion

Phosphorus reductions

This report assumes a standard phosphorus coefficient load of 2 lbs. per acre per year from pasture areas. This is based on standard export models for phosphorus loads from uncontrolled pasture areas.

Costs of exclusion fencing

Instillation costs for fencing was assumed at $3.00 per linear foot (adjusted from 2012 MN Dept. of Ag BMP Handbook). Maintenance costs were assumed at $0.30 per foot per year. Design and oversight was assumed at $75 per hour.

Manure storage facilities

Manure storage is any properly designed and installed pit, lagoon or above-ground structure that safely holds manure from livestock production. Manure storage is a key component of manure management, nutrient management and feedlot runoff management. For barns housing 15 or more animal units (1000 lbs. livestock weight = 1 animal unit) manure volume increases substantially. Facility design and construction costs can be significant, but can save labor and costs in the long term. The principles are similar to smaller facilities, but access to larger equipment, sturdier designs and impervious footings are critical.

For the two larger facilities in the watershed, the storage facilities used in this analysis were above ground concrete containment systems. They take into account:

- 6 months (or more) of storage
- Easy equipment access
- Ease of collection
- Prevent surface water, spring melt and storm water from running into the pile
- Durable floor material
- Convenient location from the barn

For the two smaller facilities this report used composting as the primary practice to store and dispose of the horse waste and bedding. Livestock site B was designed as a smaller compost storage facility (2 bins 8’x8’x3’ for 2 horses). Livestock site C was designed with a larger compost facility (4 bins 8’x8’x3’ for 6 horses).

Figure 12R: Photo of aboveground concrete storage system for horse waste

Phosphorus reductions from manure storage facilities

As a component of a properly designed nutrient and storage management plan and system where the manure was utilized on cropland this report used an average savings of 0.25 lbs./yr./ac of phosphorus reduction. These rates were based on average mean phosphorus reduction results cited from the University of Wisconsin Discover Farm Program in cooperation with the Department of Interior USGS. These reductions can vary from 0.20 lbs. per acre to 6.0 lbs. per acre. Where compost bins were analyzed, a savings of 1 lbs. of phosphorus per horse was assumed based on the same studies.

Costs used for manure storage facilities

Construction of an above ground concrete facility was assumed at $7.50 per cubic foot of storage. Maintenance for the facility was assumed at $0.01 per year per cubic foot of storage. Design and oversight was assumed at a set cost of $5,000 per facility. Cost assumptions for compost storage facility:

Compost bin material and construction costs	$5,000
Yearly compost bin maintenance cost ($250)	$2,500
Design and oversight = 5 hours at $75/hour	$ 375
Total	$7,875

Pasture management

Pasture management, also called rotational grazing, prescribed or managed grazing, is a management-intensive system of raising livestock on subdivided pastures called paddocks. Livestock are regularly rotated to fresh paddocks at the right time to prevent overgrazing and optimize grass growth. A rotational grazing system is an alternative to continuous grazing in which a one-pasture system is used that allows livestock unrestricted access to the entire pasture throughout the grazing season.

Figure 13R: Photo of mixed pasture seeding of red clover and grass

Animal rotations can vary from a simple rotational grazing system in which animals move or rotate to a fresh paddock every 3 to 6 days, to an intensive rotational grazing system in which animals are moved to a fresh paddock as frequently as every 12 hours. Grazing is started when forage is about 8 inches tall and stopped once it is grazed down to about 4 inches tall (depending on vegetation type). This means less need to feed hay, silage or grain. The primary benefit of rotational grazing to the producer is a more efficient and productive pasture allowing for increased carrying capacity, longer stays on pasture, resulting in less need to feed hay, silage or grain.

Phosphorus reductions from pasture management.

Pasture management doubles as a system of perennial grassland management, providing exceptional erosion and runoff control on uplands as well as stream corridors. It offers a productive alternative for marginal, erosion-prone or flood-prone cropland and other environmentally sensitive land, including overgrazed pastures. Rotational grazing also provides built-in manure management. Manure on healthy, well-managed grassland decomposes into the soil rather than running off. Rotating livestock from paddock to paddock allows time for manure to be incorporated into the soil. The manure helps maintain soil fertility for new grass growth, eliminating the need to store, process, haul or spread manure as a nutrient. As with other pasture and nutrient management practices, phosphorus reduction for proper pasture and paddock management is assumed to be 0.25 lbs/year/acre. This is based on average mean phosphorus reduction results cited from the University of Wisconsin Discover Farm Program in cooperation with the Department of Interior USGS. These reductions can vary from 0.20 lbs. per acre to 6.0 lbs. per acre.

Costs of pasture management

Rotational grazing costs are low in comparison to other agricultural production practices. Pasture management costs do not typically entail taking land out of production. Costs for fencing and water systems can be higher than with continuous grazing and tend to increase with increased intensity of the grazing system. For this report we used a cost of $200 per acre to design and establish the system. This assumed minimal fence and equipment needs.

Nutrient management
Nutrient management is the management of the amount, method, and timing of applications of fertilizers, manure, and other soil amendments. The nutrients that have the greatest impact on water quality are nitrogen (N) and phosphorus (P). Among all BMPs, nutrient management BMPs are one of the most effective ways to improve water quality because of the extent of nutrient related water quality issue. Nutrient management can be divided into three management areas: amount, method and timing.

Phosphorus reductions from nutrient management
As part of a nutrient management system, proper manure application annually or less frequently is known to reduce soil erosion and amount of runoff from the field. At several locations in Minnesota, Iowa, and Wisconsin where manure was applied annually on agricultural fields, runoff was reduced 2% to 62%, and soil erosion was decreased 15% to 65 % compared to the sites without manure application. Again, this report assumed proper nutrient management reduces phosphorus loads 0.25 lbs./year/acre. This is based on average mean phosphorus reduction results cited from the University of Wisconsin Discover Farm Program in cooperation with the Department of Interior USGS. These reductions can vary from 0.20 lbs. per acre to 6.0 lbs. per acre.

Cost for nutrient management
The cost of nutrient management consists of soil sampling and testing for nutrient availability, as well as calculation of fertilizer and/or manure need based on information such as soil productivity, crop nutrient budgeting, and recent proven yields. This report assumed the cost of a crop consultant would be $20/acre per year for the first two years to get the plan established, and $10/ac per year thereafter to operate and maintain the plan. The total cost per acre for a 10 year period would be $120.

Individual Lake Ardmore Watershed Livestock Site analysis and nutrient export assumptions

Horse Facility A
This livestock facility is unique, and analysis of the requirements, needs and desires of this site cannot begin to be examined without a complete and detailed facility study with the owner. The following analysis generalizes many aspects of this site. A final analysis must be done in cooperation with the producer to better understand the existing conditions and needs of this facility.

Site A existing conditions
This site appears to have approximately 25 horses (25 animal units) with 16 moderately vegetated pasture/paddock areas on 10 acres. Various sparsely vegetated small paddocks and the outdoor arena on this facility cover about 1.5 acres of the site. Manure appears to be stored northwest of the outdoor arena near a barn in a fenced in, open air location approximately 35’x 25’x 3.5’ high open on the north end. Based on aerial photos, the bedding/manure storage area appears somewhat contained. It is unknown how the material is disposed from this storage area.

The barn, arena and paddock areas do not appear to have adequate runoff control measures to prevent water from running uncontrolled over the steeper slope north and east of the buildings. The lack of water controls, channelization of the water and the steepness of the slope are the primary reasons for the gullying issues on this slope area. The pasture and paddock areas appear to be somewhat overgrazed, creating the opportunity for excess runoff on these areas. One channelized area runs uncontrolled through portions of four paddocks. Approximately 1.0 acre of the three easterly most paddocks are located in the wetland basin that flows into Lake Ardmore.

Site A proposed conditions

- Roof gutters to control and redirect clean water away from contamination sources (un-vegetated surfaces and areas where horses or manure are located).
- A waterway with exclusion fencing is proposed through the southerly area of the paddock to channelize the water in a controlled manner creating the opportunity for it to be filtered in the grass waterway
- Stabilizing the steep gully and washing areas on the slopes below the farmstead area was addressed in the gully section for site G2
- Exclusion fencing to prevent the horses from entering the wetland and buffer area along the easterly paddocks.
- A 35 foot buffer area above the wetland on the easterly paddocks
- Pasture and paddock management plans to maximize the pasture potential for grazing and minimizing runoff potential
- Manure storage and disposal

Site A exclusion fencing

Two primary areas of livestock exclusion fencing are proposed on this site.

- Wetland/Buffer exclusion along the easterly paddock area (900 feet of fence)
- Waterway exclusion for the channel that runs from west to east through the southerly paddocks (1250 feet of fence)

Construction costs for fencing		
ExFn A-1 $3.00/ft. wetland/buffer fence (900 feet)		$2,700
ExFn A-2 $3.00/ft. waterway fence (1250 feet)		$3,750
Maintenance costs		
ExFn A-1= $0.30/ft./yr. (900 ft.) over 10 years.		$2,700
ExFn A-2=$0.30/ft./yr. (1250 ft.) over 10 years		$3,750
Design and oversight		
ExFn A-1= 5 hours at $75/hr.		$375
ExFn A-2= 5 hours at $75/hr.		$375
Total cost		
ExFn A-1	=	$5,775
ExFn A-2	=	$7,875

Phosphorus reductions for exclusion fencing

Assume a standard phosphorus coefficient load of 2 lbs. per acre per year export in the wetland area, 6 lbs. per acre in the waterway area, and a 100% delivery ratio for this site.

- Site ExFn A-1= 1.0 acre of wetland is proposed for exclusion. = 2.0 lbs. of phosphorus.
- Site ExFn A-2=0.3 acres of waterway exclusion = 1.8 lbs./year

With a 100% delivery ratio the amount of phosphorus reduction to Lake Ardmore would be:

- 2.0 lbs./yr. for site ExFn A-1
- 1.8 lbs./yr. for site ExFn A-2

Cost per lb. of reduction for exclusion fencing is:

- Site ExFn A-1 = $5,775/20 = $289/lb.
- Site ExFn A-2 = $7,875/18 = $438/lb.

Site A wetland buffer

Specifics for the costs and phosphorus reductions from the wetland buffer for this site (see buffer #5 on page 14) are described in the buffer section. It is proposed to be 0.72 acres in size and filter out approximately 6.3 lbs./year phosphorus from the contributing watershed area (5.6 acres) for a cost of $192/lb. over a 10 year period.

Site A pasture and paddock management

600 feet of waterway with drain tile to control and filter the channelized water through the site (this was evaluated as project GW A-1 and ExFn A-1)

10 acres of pasture and paddock management plan.

Construction costs for pasture and paddock management

$200/ac for pasture/paddock management plan	$2,000
$20/ac per year for maintenance	$2,000
Design and oversight, pasture mgmt.10 hr.@ $75/hr.	$750
Total Cost	= $4,750

Phosphorus reduction for proper pasture and paddock management is assumed to be 0.25 lbs./year/acre. This is based on average mean phosphorus reduction results cited from the University of Wisconsin Discover Farm Program in cooperation with the Department of Interior USGS. These reductions can vary from 0.20 lbs. per acre to 6.0 lbs. per acre. With this site assumed to be 100% delivery to Lake Ardmore, the total phosphorus reduction would be 2.5 lbs./year.

The costs/benefits for phosphorus reductions from the waterway/tile system were determined in the exclusion fencing section of this site analysis. Cost per pound for pasture management with a constructed waterway and drain tile would be $4,750/25= $190/lb. of phosphorus reduction.

Site A grassed waterway

Specifics for the costs from the grassed waterway for this site (see waterway GW-A1 on page 45) are described in the waterway section. The waterway is proposed to be 600 feet long by approximately 25 feet wide. A specific cost per pound of phosphorus reduced was not analyzed for the waterway. This was based on the fact if exclusion fencing as described for Ex Fn A-2 was established, and this fencing contained the waterway flows, the phosphorus reduction could be achieved without a waterway constructed. A waterway was provided as a BMP for this site because a constructed waterway would better contain the flows, and the instillation of drain tile would assist in drying the saturated surfaces adjacent to the waterway establishing a better pasture/paddock environment for the horses and general maintenance in the vicinity.

Site A manure storage and disposal

A designed manure and disposal system for a 6 month period will be analyzed for this site. Twenty five horses with bedding material stored for 6 months will be approximately 6,000 cubic feet of storage. Construction costs for storage system are as follows:

6000 cubic foot concrete storage facility	$45,000
10 year maintenance at $0.01 c.f.	$600
Design and oversight	$5,000
Total Cost	$50,600

Phosphorus reductions for proper manure storage and disposal was not calculated for this facility. Too many variables are associated with this site to make a determination. If the current facility currently hauls the manure off site, the phosphorus advantage would be negligible. If not, it could be significant.

Site A clean water diversion

Based on past site visits from other resource experts, various areas of the farmstead were reported to have flows from roof and high traffic areas creating erosive and uncontrolled flows into the steeper slopes along the east and north sides of the farmstead. This in turn has helped exasperate the gully conditions addressed on page 47 (Gully G2). Additional costs associated with diverting and controlling this water should be mentioned as part of the overall costs on this facility to adhere to good housekeeping BMPs and water controls over the long run. Phosphorus reductions will not be a component of this BMP. It is addressed in a compilation of all the other BMPs on this site.

Costs for a clean water diversion were estimated taking into account roof gutters for the buildings near the slope, manure storage area and a berm/diversion to direct water from the farmstead area to the gully. The roof gutters would total approximately 270 feet. The berm/diversion would also be approximately 270 feet.

Costs for clean water diversions:

Roof Gutters (270 feet)		
	$10/ft. for gutter and downspouts	$2,700
	Oversight/maintenance (lump sum)=	$500
Berm/diversion (270 feet)		
	$10/ft construction	$2,700
	Oversight and design (10 hrs. @ $75/hr.)	$ 750
	Maintenance $0.25/ft./yr.	$675
	Total Clean Water Diversion Costs =	$7,325

Horse Facility B

This site appears to have 2 horses with two pasture areas approximately 2 acres in size and a small outdoor horse arena approximately 0.2 acres in size. Paddock and pasture areas appear well vegetated, outside of wetland areas with no excessive erosion or uncontrolled runoff issues. Based on previous site visits, this site is well maintained. Wetland areas appear to be fenced off adequately. Some minor benefits from manure storage and disposal could occur. This analysis made a general assumption of 2.0 lbs/year reduction of phosphorus to Lake Ardmore if proper storage and disposal of manure and good housekeeping practices were followed. To achieve that assumption, a manure compost facility was analyzed for the cost/benefit. The phosphorus delivery ratio to Lake Ardmore was estimated at 50% from this site

Please remember, this livestock facility is unique, and analysis of the requirements, needs and desires of this site cannot begin to be examined without a complete and detailed facility study with the owner. The following analysis generalizes many aspects of this site. A final analysis must be done in cooperation with the producer to better understand the existing conditions and needs of this facility.

Site B manure storage and disposal

A manure compost facility was analyzed for this site because there is less than 3 horses located here.

Construction Costs

Compost bin material and construction costs =	$5,000
Yearly compost bin maintenance cost ($250)	$2,500
Design and oversight costs (5 hours @ $75/hr.)	$375
Total =	$7,875

Phosphorus reductions from this storage facility were assumed at 2.0 lbs./year based on proper storage and disposal of the manure/compost. The site was estimated to have a phosphorus delivery ratio to Lake Ardmore of 0.5.

Horse Facility C

This site appears to have 6 horses with two pasture areas approximately 9 acres is size. The pasture appears to be well vegetated. Wetland areas appear to be fenced off adequately. Runoff has created an erosion problem through the main paddock/feedlot section of the facility. This was addressed in the gully section of the report. Additional storage and disposal alternatives were explored on this site and analyzed in this section. Some clean water diversion of roof water was analyzed for this site. Removing this water from the feedlot area will eliminate runoff from the high use area and decrease mud issues.

Again remember, this livestock facility is unique, and analysis of the requirements, needs and desires of this site cannot begin to be examined without a complete and detailed facility study with the owner. The following analysis generalizes many aspects of this site. A final analysis must be done in cooperation with the producer to better understand the existing conditions and needs of this facility

Site C manure storage and disposal

A larger manure compost facility was analyzed for this facility because there is 6 horses on this site.

Construction costs

Compost bin material and construction		$10,000
Yearly compost bin maintenance ($400)		$4,000
Design and oversight (5 hours @ $75/hr.)		$375
Total	=	$14,375

Phosphorus reductions were based on standard models for uncontrolled vs controlled storage and disposal techniques for livestock systems. For 6 horses, assume 6 lbs. less phosphorus entering the Lake Ardmore drainage system. This site has an estimated phosphorus delivery ratio of 0.4.

Site C grassed diversion/waterway/clean water diversion livestock

These items are all a component of controlling water from running through the high use area on this site. Barn roof gutters and a grassed diversion/waterway to route clean water away from and around the feedlot area will reduce sediment and phosphorus loads from entering the Lake Ardmore drainage system. The grassed diversion and waterway was analyzed under the gully section of this report (see Gully Stabilization G-1).

The diversion/waterway was measured at 525 feet and would cost approximately $19,167. With a phosphorus delivery ratio of 0.4 this conservation system would reduce nutrient load to Lake Ardmore by 6.7 lbs./year. Costs for roof gutters for the buildings near the high use feedlot area where also analyzed as part of the overall best management practices recommended for the site. These gutters would direct clean water away from the high use areas, keeping the roof water relatively clean and uncontaminated with the soil and manure in the feedlot. The roof gutters would total approximately 350 feet.

Costs for 350 ft. of roof gutters (clean water diversion)

$10/ft. for gutter and downspouts		$3,500
Oversight and maintenance (lump sum)		$ 500
Total	=	$4,000

Livestock Facility D

This livestock facility is unique, and analysis of the requirements, needs and desires of this site cannot begin to be examined without a complete and detailed facility study with the owner. The following analysis generalizes many aspects of this site. A final analysis must be done in cooperation with the producer to better understand the existing conditions and needs of this facility.

Site D existing conditions

This facility has approximately 15 beef cattle. The feedlot (denuded of vegetation) area is 0.25 acre in size. An area of 'high use' pasture with poor vegetation establishment is 1.5 acres. There is approximately 3 acres of lower use, moderately vegetated pasture on site. This moderately used pasture has about 1.5 acres of wetland in it.

Site D proposed conditions

- Long term storage is necessary for manure collection and distribution from the site. This would assist in the planning and timing needed for a nutrient management plan for this facility.
- Exclusion fencing to prevent the cattle from entering the wetland and buffer areas.
- Nutrient Management Plan

Site D storage and nutrient management

For this beef production facility we assumed an average of 0.25 lbs. of phosphorus reduction per acre of cropland/ paddock/feedlot area, if proper long term handling and managed disposal of livestock waste is accomplished based on a cropland and manure nutrient management. This is based on average mean phosphorus reduction results cited from the University of Wisconsin Discover Farm Program in cooperation with the Department of Interior USGS. These reductions can vary from 0.20 lbs. per acre to 6.0 lbs. per acre. Storage and nutrient management costs are as follows:

10-15 animal units (15 beef cattle @ 750 lbs./beef)

Construction costs for storage system (6 months)		
4,000 cubic foot concrete storage facility		$30,000
10 year maintenance at $0.01 c.f.		$400
Design and oversight		<u>$5,000</u>
Total	=	$35,400

Assume for 35 acres of crop land on this parcel, soil GPS and grid samples/applications and manure sampling and applications for nutrient management plan costs

Crop consultant charge	($20/ac)	$700/year for years 1-2	$1,400
	($10/ac)	$350/year for year 3-10	<u>$2,800</u>
Total			= $4,200

Site D phosphorus reductions from manure and nutrient management

- Average soil loss in fields where manure is spread is 2.4 to 3.2 ton/year
- Delivery ratio will vary, but use 0.5 as an average
- Soil loss will not generally decrease, but phosphorus export will, based on the assumption soil p is > 21 ppm Bray P1 or 16 ppm Olson. Assume reductions comparable to 0.25 lb./ac on 35 acres=8.75 lbs./year. This is assumed to be soluble. With a delivery ratio of 0.5, actual reduction will be 4.4 lbs./year.
- Nutrient management reduction will be 4.4 lbs./year for a cost of $4,200/44=$95.50 per pound of phosphorus reduction.
- Storage system phosphorus benefits were not analyzed as part of this report. To prevent winter spreading of manure and adequately prevent spring runoff in the cropland, a storage system is essential.

Site D Exclusion Fencing (ExFn-D1)

Livestock Exclusion costs= 1100 feet of fencing

Construction costs =1,100 ft. at $2.50/ft.	$2,750
Maintenance costs= 1100 ft. at $0.25/ft./yr.	$2,750
Design and oversight= 5 hours at $75/hr.	$375
Total cost	= $5,875

- Assume a standard phosphorus coefficient load of 2 lbs. per acre per year export and a 50% delivery ratio (1 lb./ac/yr.)
- 2.3 acres of pasture/wetland excluded would be 2.3 lbs. of phosphorus reduction to Lake Ardmore
- Cost per lb. of reduction is $5,875/23 = $256/lb.

Site D wetland buffer

Specifics for the costs and phosphorus reductions from the wetland buffer for this site (see buffer #3 on page 43) are described in the buffer section. It is proposed to be 0.73 acres in size and filter out approximately 5.1 lbs./year phosphorus from the contributing watershed area (8.4 acres) for a cost of $239/lb. over a 10 year period.

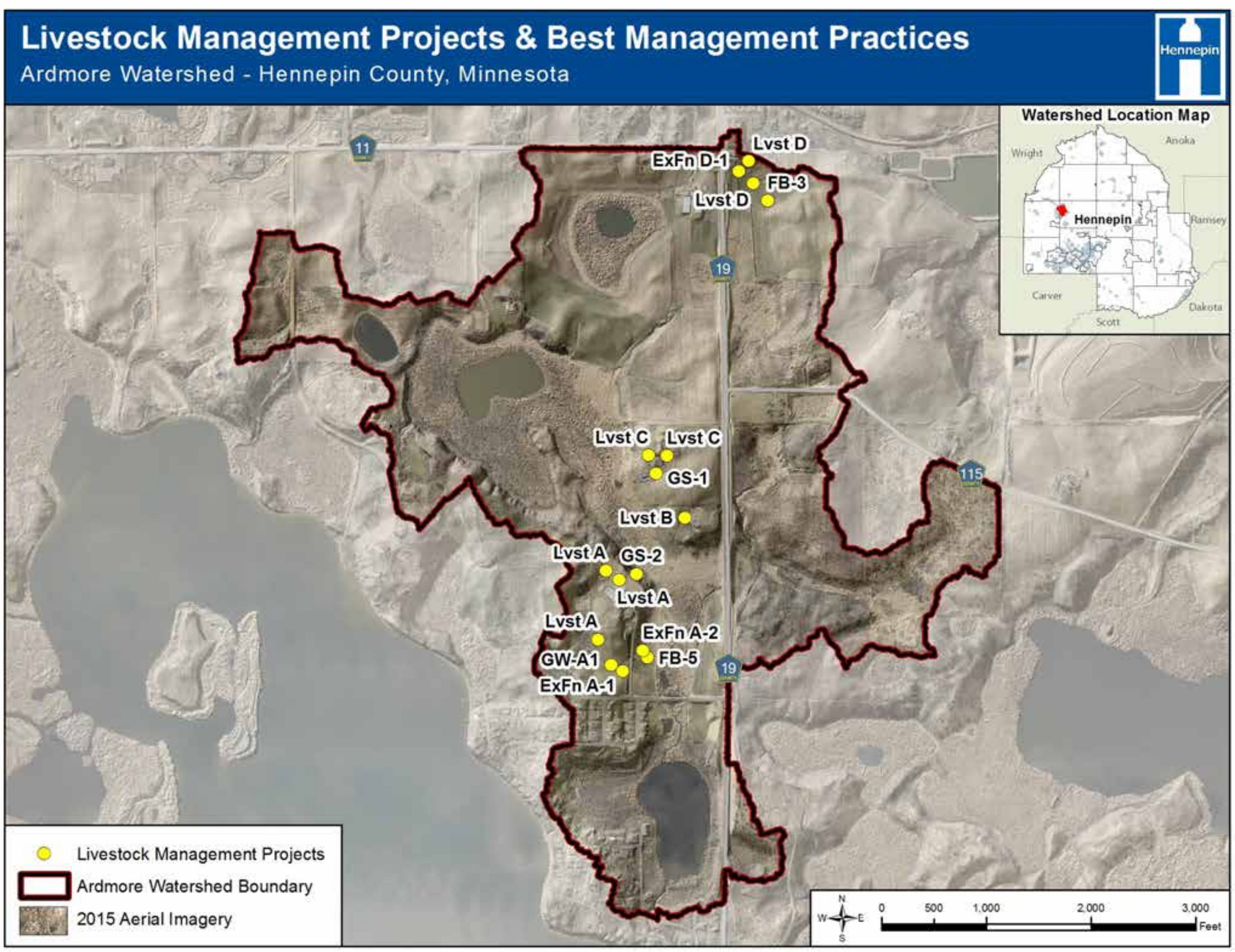
Table 7R: Phosphorous reduction to Lake Ardmore and associated costs of proposed livestock projects

Project rank	Retrofit type (refer to catchment profile pages for additional detail)	Projects identified	TP reduction (lb/yr)	Phosphorus delivery ratio to Lake Ardmore	Phosphorus reduction to Lake Ardmore (lb/yr)	Total project cost (includes 10-year maintenance)	Estimated cost/lb-TP/year (10 year)
1	Nutrient Management System	Lvst D	8.8	0.5	4.4	$4,200	$96
2	Pasture & Paddock Management	Lvst A	2.5	1.0	2.5	$4,750	$190
3	Field Buffer	FB-5 (lvst A)	6.3	1.0	6.3	$12,098	$192
4	Gully Stabilization	G-1 (lvst C)	22.1	0.4	6.7	$19,165	$218
5	Field Buffer	FB-3 (lvst D)	12.7	0.4	5.1	$12,169	$239
6	Exclusion Fencing	EsFn D-1 (lvst D)	4.6	0.5	2.3	$5,875	$255
7	Exclusion Fencing	ExFn A-1 (lvst A)	2.0	1.0	2.0	$5,775	$289
8	Gully Stabilization	G-2 (lvst A)	12.8	0.7	8.9	$36,200	$407
9	Exclusion Fencing	ExFn A-2 (lvst A)	1.8	1.0	1.8	$7,875	$438
10	Grass Waterway	GW-A1 (lvst A)	1.8	1.0	1.8	$9,180	$510
11	Manure Storage System	Lvst C	6.0	0.4	2.4	$14,375	$599

Table 7R: Phosphorous reduction to Lake Ardmore and associated costs of proposed livestock projects (continued)

Project rank	Retrofit type (refer to catchment profile pages for additional detail)	Projects identified	TP reduction (lb./yr.)	Phosphorus delivery ratio to Lake Ardmore	Phosphorus reduction to Lake Ardmore (lb./yr.)	Total project cost (includes 10-year maintenance)	Estimated cost/lb.-TP/year (10 year)
12	Manure Storage System	Lvst B	2.0	0.5	1.0	$7,875	$788
13	Manure Storage System	Lvst A				$66,200	N/A
14	Clean Water Diversion	Lvst A				$7,325	N/A
15	Clean Water Diversion (roof gutters)	Lvst C				$4,000	N/A
16	Manure Storage System	Lvst D				$35,400	N/A

Figure 14R: Location of proposed livestock management BMP projects



Wetland restoration and new pond construction

This report looks for opportunities to reestablish or repair the hydrology, plants and soils of a former or degraded wetland that has been drained, farmed or modified. The goal is to closely approximate the original wetland's natural condition, resulting in multiple environmental benefits, but primarily to store additional water and assimilate nutrients.

This section also looks at new, regional pond opportunities that would maximize nutrient load reductions within this watershed. One new pond was analyzed for these reductions within this watershed. The primary technique to analyze the benefits of wetland and new pond projects is the PondNet model. Three wetland restoration opportunities and one new pond opportunity were analyzed in this study.

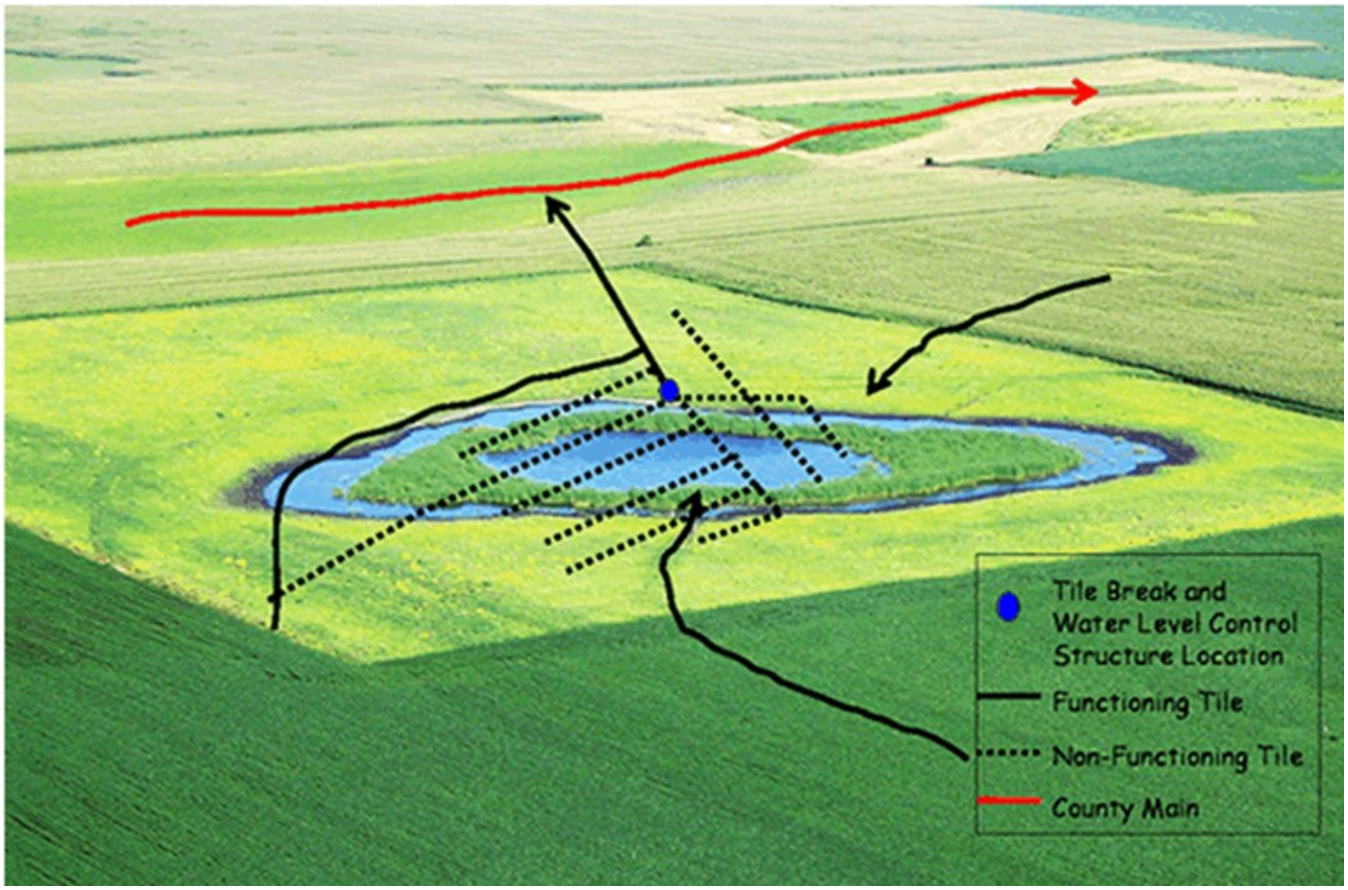


Figure 15R: Drained wetland restoration concept

Wetland Restoration

Wetland Restoration 1 is located in the far NW corner of the Lake Ardmore Watershed. It straddles two properties. This basin is a natural depressional area but has a functioning drain tile that essentially drains all the water after a storm event. The north portion (approximately 0.2 acres) of the basin is farmed. The south portion (approximately 1.7 acres) is grasses and shrubs. Restoration would entail disabling the existing drain tile and installing an outlet control structure at an elevation of somewhere between 978.0 ± and 980.0±.

Wetland Restorations 2W and 2E are existing landlocked wetland basins that are drained with private, pipe outlets. Wetland area 2W drains east, via 7"± pipe into wetland area 2E. Wetland 2E drains south via 12" pipe into the Hidden Lake Wetland Basin. Both basin restorations could be accomplished by disabling the pipes and installing outlet control structures that would regulate the wetlands to their pre-settlement historic elevations. Wetland 2W would be raised approximately 2 feet to 986.0 and wetland 2E would be raised 3 feet to approximately the same elevation as wetland 2W. These higher water levels will have an effect on the property located east of County Road 19. The culvert into this property under CSAH 19 is at an approximate elevation of 985.0.

Wetland restoration cost, phosphorus and volume assumptions are as follows:

Wetland Restoration 1 (WR1)

Treatment watershed = 19.75 acres

Wetland surface area = 1.8 ac.

Wetland depth = 2.5 feet @ 978.0

Wetland pool volume = 4.5 ac. ft.

Structure type = box weir

Total Phosphorus (before) = 6.4 pounds

Total Phosphorus (after) = 3.2

Phosphorus reduction = 3.2 lbs./year

Delivery Ratio = 0.10 x 3.2 = 0.32 lbs./year

Cost for 20 year lifespan

Construction and vegetation restoration cost	$13,500 ($7,500/ac)
Easement Cost	$ 10,250 ($30,000 ac. cropland, $2,500/ac existing wetland)
Design and administration	$10,000
Maintenance	$10,000 over 20 years
Total cost	= $43,750

Total cost per pound of phosphorus reduction to Lake Ardmore = $6,836/lb.

Wetland Restoration 2W (WR2W)

Treatment Watershed = 50 acres.

Wetland surface area = 18.6 acres.

Wetland pool volume = 74 acre feet

Structure type = box weir

Total Phosphorus (before) = 20.7 lbs./year

Total Phosphorus (after) = 15.7 lbs./year

Phosphorus reduction = 5.0 lbs./year

Delivery ratio = 0.40 x 5.0 = 2.0 lbs./year

Cost for 20 year lifespan

Vegetation restoration cost	$20,000 ($5,000/ac on 4 acres of expanded areas)
Construction	$10,000 (structure and pipe)
Easement Cost	$156,500 ($30,000 ac. cropland, $2,500/ac existing wetland)
Design and administration.	$20,000
Maintenance	$20,000 over 20 years
Total cost	= $226,500

Total cost per pound of phosphorus reduction to Lake Ardmore = $5,663/lb.

Wetland Restoration 2E (WR2E)

Treatment Watershed = 117.8 acres

Wetland surface area = 5.5 acres.

Wetland pool volume = 13.75 acre feet

Structure type = Outlet control structure

Total Phosphorus (before) = 78.0 lbs./year

Total Phosphorus (after) =47.2 lbs./year

Phosphorus Reduction = 30.8 lbs/year.at wetland

Phosphorus Delivery Ratio = 0.4 (30.8x0.4=12.3 lbs./yr. to Lake Ardmore)

Cost for 20 year lifespan

Vegetation restoration cost	$8,750 ($2,500/ac on 3.5 acres of expanded area)
Construction costs	$33,125 (925 ft. of 12" pipe @25/ft. and $10,000 for outlet structures)
Easement Cost	$122,500 ($30,000 ac. -cropland 3.5 ac, $2,500/ac existing wetland 7.0 ac.-2 ac on west side of CSAH19 and 5 ac. on east)
Design and administration.	$20,000
Maintenance	$20,000 over 20 years
Total cost	= $204,375

Total cost per pound of phosphorus reduction to Lake Ardmore = $831/lb.

Wetland Restoration 3

Treatment watershed = 472 acres

Wetland surface area = 16.1 acres

Wetland pool volume = 70.6 acre feet

Structure type = Outlet control structure

Total phosphorus (before) = 391 lbs.

Total phosphorus (after) = 343 lbs.

Phosphorus delivery Ratio = 1.0

Phosphorus Reduction to Lake Ardmore = 48 lbs./yr.

Cost for 20 year lifespan

Construction costs

Structure	$25,000
Roadway	$120,000
Easement Cost	$132,500 (17 ac. X $2,500 = 3 ac. X $30,000)
Design and administration.	$58,500
Wetland restoration costs (seed, 5 year intense maintenance)	$20,000
Maintenance	
Roadway (20 years)	$25,000
Wetland (20 years)	$5,000
Total cost	= $386,000

Total cost per pound of phosphorus reduction to Lake Ardmore = $402

Regional Ponds

One new pond was pursued in this study. It would be located adjacent to the existing wetland area where wetland 2E exists. The wetland itself receives water from a 117.8 acre watershed. The wetland would remain the same as it is today, but instead of flowing into the existing 12" pipe that routes it untreated into the Lake Ardmore drainage way, it would overflow into a newly constructed pond. This new pond would treat the phosphorus build up that has accumulated in the wetland throughout the years. Based on NURP analysis, it would decrease phosphorus loads similar to the wetland restoration option shown above, at approximately the same price. The operation and maintenance of a pond like this would be advantageous to the city over a wetland restoration because of ease and access to it.

Figure 16R: Photo of constructed stormwater pond

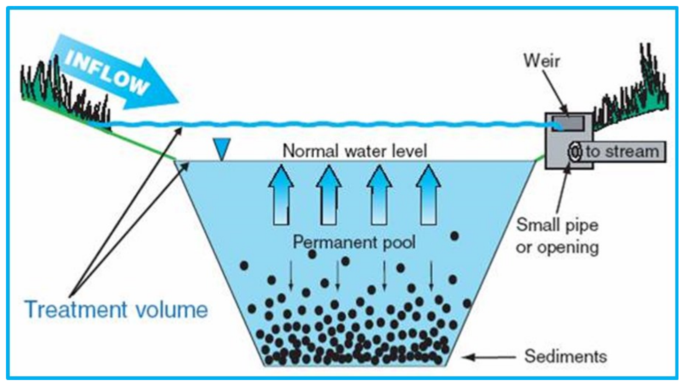


Figure 17R: Stormwater treatment pond section

Regional Pond 1 (RP-1) adjacent to existing wetland 2E.

Treatment Watershed = 117.8 acres

Pond surface area = 2.0 acres.

Pond pool volume = 8 acre feet

Structure type = Outlet control structure

Total Phosphorus (before) = 78.0 lbs./year

Total Phosphorus (after) =47.1 lbs./year

Phosphorus Reduction = 30.9 lbs./year.

Phosphorus Delivery Ratio = 0.4 (30.9x0.4=12.4 lbs./yr. to Lake Ardmore)

Cost for 20 year lifespan

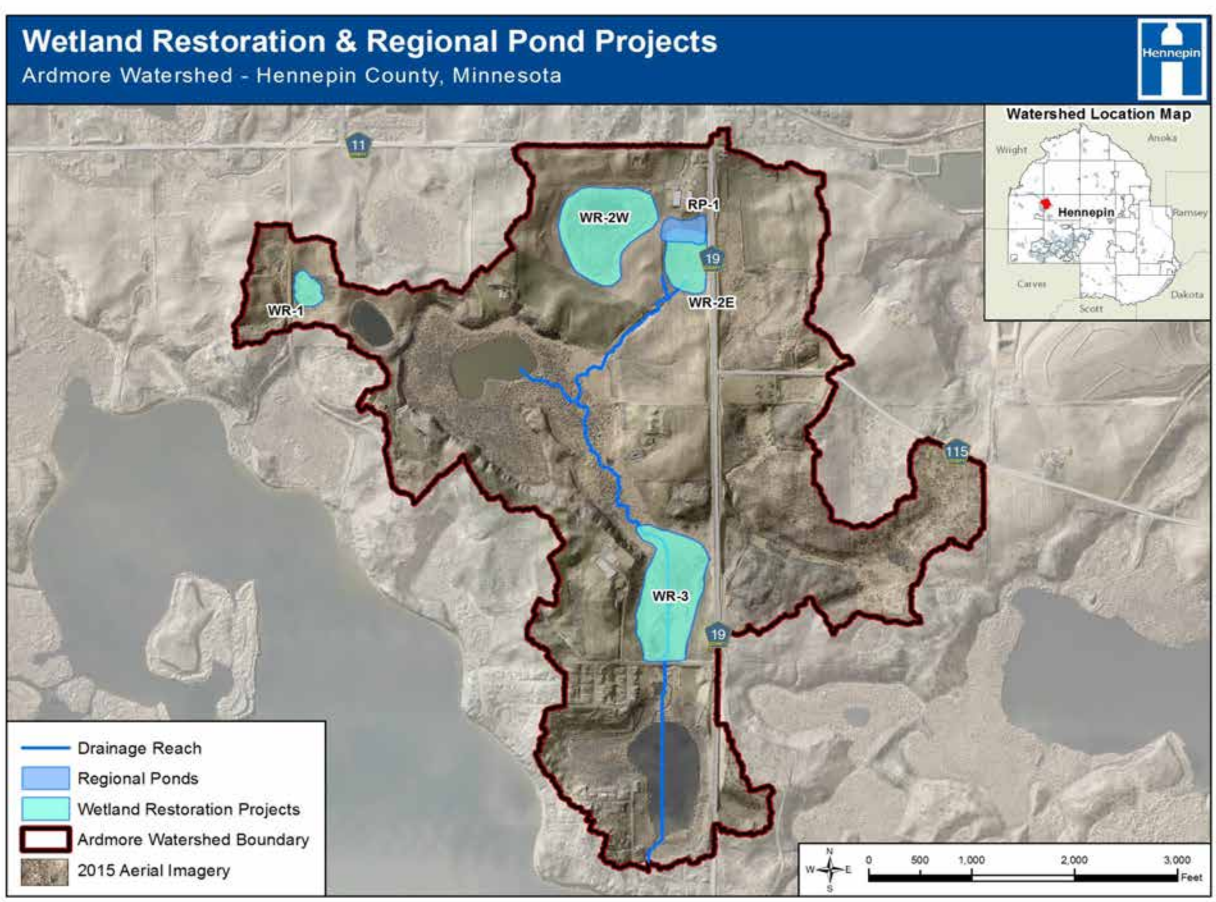
Vegetation restoration cost and erosion control (lump sum)	$5,000
Construction costs	$103,125
Pipe and structure	$33,125 (925 feet of 12" pipe @25/ft. and $10,000 for outlet control structures)
Excavation	$65,000 (13,000 cu. yd. @ $5 cu. yd. assuming on site disposal)
Wetland rip-rap overflow to NURP pond	$5,000 (50 cu. yd. @ $100/CY= $5,000)
Easement Cost	$65,000 ($30,000 ac. -cropland 2.0 ac, $2,500/ ac existing wetland 2.0 ac.)
Design and administration	$20,000
Maintenance	$20,000 over 20 years
Total cost	$208,125

Total cost per pound of phosphorus reduction to Lake Ardmore = $846/lb.

Table 8: Phosphorous reduction to Lake Ardmore and associated costs of proposed wetland restoration and regional pond projects

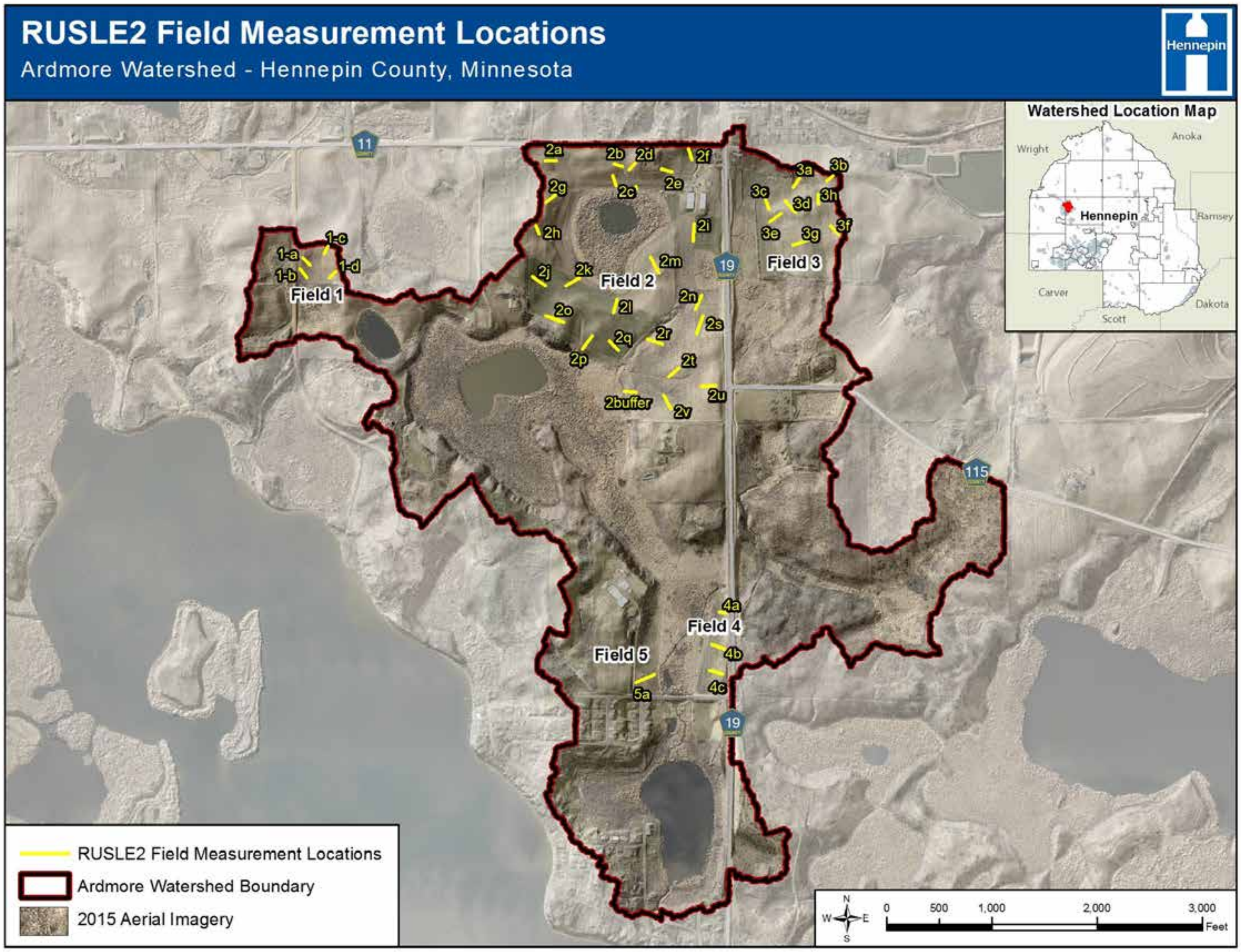
Wetland restoration and regional ponding	Total area of wetland or pond	Average pool elevation an depth	Structure	Volume of storage (ac. ft.)	Phosphorus reduction	Phosphorus delivery ratio	Pounds of phosphorus reduced going to Lake Ardmore per year	Cost per pound of phosphorus reduction to Lake Ardmore for a 20 year lifespan
WR-2E	5.5	986.0/2.5	Structure	13.75	30.8	0.4	12.3	$831
RP-1	2.0	982.0/4.0	Structure	8.0	30.9	0.4	12.4	$846
WR-2W	18.6	986.0/4.0	Box weir	74.0	5.0	0.4	2.0	$5,663
WR-1	1.8	978.0/2.5	Box weir	4.5	3.2	0.1	0.32	$6,836
WR-3	16.1	984.0/4.3	Structure	70.0	48.0	1.0	48.0	$402

Figure 18R: Location of proposed wetland restoration and regional pond projects



Appendix

Figure 1: RUSLE2 field measurement locations



Modeling Methods

The following information describes each water quality model applied in this analysis and the inputs used to run the model.

Soil and Water Assessment Tool (SWAT)

The Soil and Water Assessment Tool (SWAT) was used to model runoff from the Lake Ardmore subwatershed draining to Lake Ardmore. SWAT is a partially physically-based and partially empirically-based watershed model (Neitsch et al., 2005) developed at the U.S. Department of Agriculture Agricultural Research Service (SWAT is currently supported by the Blacklands Research and Extension Center at Texas A&M University). The SWAT model runs on a daily time step and is intended to model large agricultural watersheds. The model has been calibrated and validated to many watersheds in the United States and around the world

SWAT has progressed through several development releases. The release selected for this project was ArcSWAT2012 for ArcGIS version 10.1. All SWAT modeling and field assessments were conducted by Hennepin County Environment and Energy staff during the Lake Ardmore Subwatershed Assessment. The SWAT model simulates the hydrologic cycle accounting for the following processes: precipitation, overland runoff, infiltration, percolation through one or more soil layers, evaporation, plant transpiration, interaction with the shallow aquifer, and loss to a deep aquifer (Arnold et al., 1998). Water is delivered to the stream as overland runoff, lateral flow, and groundwater flow and is routed through defined stream channels to the watershed outlet. SWAT also models off-channel, surface-water bodies such as wetlands and ponds and on-channel bodies such as reservoirs.

Sediment export from uplands is calculated in SWAT with the Modified Universal Soil Loss Equation (MUSLE; Williams, 1975). Factors that control sediment export predicted by the MUSLE are surface runoff, peak flow, soil erodibility, biomass and residue present, cropping practices, slope length, and percentage of coarse fragments (i.e., stones) of soil.

Simulation of phosphorus and nitrogen cycles in SWAT uses inputs of inorganic fertilizer, organic fertilizer, plant residue, and, for nitrogen, rainwater. Nitrogen is partitioned between five mineral and organic pools within the soil and is transferred between and out of these pools through export, decay, mineralization, nitrification and denitrification, volatilization, and plant uptake. Similarly, SWAT models five soil phosphorus pools, with transfer between and out of these pools through export, decay, mineralization, immobilization and plant uptake. Nitrogen and phosphorus are exported via overland runoff, lateral flow, and groundwater flow to the stream channel, though they are only tracked through overland runoff and lateral flow. In the stream reaches, in-stream nutrient processes can be simulated with the imbedded QUAL2E submodel, or the nutrients can be delivered to the reach outlet unprocessed. Given the channelized nature of most streams and that the primary driver of nutrient dynamics throughout the Lake Ardmore subwatershed is wetland processing, in-stream process subroutines were not utilized in this analysis. Plant growth is modeled directly in SWAT based on simplified crop growth equations from the Erosion Productivity-Impact Calculator (EPIC) with controlling inputs including temperature, solar radiation, nutrient availability, and water.

SWAT Spatial Inputs

Spatial inputs for the Lake Ardmore SWAT model included digital elevation, land use, and soils. All data for the Lake Ardmore watershed were projected into the Universal Transverse Mercator Zone 15, with the North American Datum, 1983. The Lake Ardmore watershed and subbasins were delineated from the Hennepin County 2 Foot contour intervals derived from the spring 2012 Minnesota DNR LIDAR digital elevation model (DEM). This delineation was updated with water routing information from field observations. Soil Survey Geographic (SSURGO) soil data were downloaded from the US Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) Soil Data Mart website. These data are organized by county and are the most detailed available for the watershed. *(continued)*

The SSURGO dataset included 61 soils in the Lake Ardmore watershed. Land use input for the model was generated from the 2014 Hennepin County parcel dataset, which includes land use as it relates to the tax code. These land uses were updated and subdivided using 2012 high-resolution Hennepin County aerial photographs and field observations. The resulting land use dataset was converted to a grid.

Subbasins in the Lake Ardmore subwatershed were refined using field observations and known locations of stream channels, culverts and ponds. The final subbasin configuration included 6 subbasins ranging from 3.4 to 112 hectares. The watershed had 484 HRUs.

Agriculture

The major land use in the Lake Ardmore watershed is fairly well divided between large lot residential/hobby farms, woodland and wetlands. Agriculture cropland accounts for approximately 20% of the total watershed area. There are also four farms in this study that grow corn (for grain), soybeans, alfalfa, and corn (for silage) for a mix of grain crops and animal consumption. Hay and alfalfa are grown within the watershed for animal consumption. The number of animal units in the subwatershed was based on the results from aerial 3D high resolution photographs from 2015, 2011, and 2008. Four parcels within the subwatershed were identified in the 2015 survey as having farm animals. Three had horses and one had beef cattle. There were 33 horses and 15 cattle counted in the photo reviews. The specific manure management activities of the horse and beef producer are unknown. For that reason, the HCEED did not model a manure component in this SWAT run.

Residential and Urban Land Uses

A variety of urban and residential land uses are present in the Lake Ardmore watershed. The percentage of impervious area in each of the land uses guided how the land use type was represented in the SWAT model. Most was large lot, rural residential with low impervious percentages.

Wetlands

Wetlands exert a large influence in the Lake Ardmore watershed, detaining water, and settling out nutrients. However, wetland cannot be explicitly modeled in SWAT, instead, on-channel wetlands were modeled as “reservoirs” in SWAT. Each “reservoir” was assigned to a subbasin and individually parameterized according to the normal surface area/ volume. Wetlands and ponds were parameterized with a number of days to return to the normal pool volume after exceeding the emergency pool volume.

Calibration

Using the Curve Number method, SWAT is a daily time step model and precipitation is input as daily values. Precipitation, as recorded by the cooperative observer station at Rockford, is recorded as an 8 a.m. to 8 a.m. day. Streamflow is averaged as a midnight to midnight day.

Buffer Strip Analysis

Buffer strips were analyzed using the Board of Water and Soil Resources' *Pollution Reduction Calculator for Filter Strips* (*www.bwsr.state.mn.us/outreach/eLINK/indes.html*).

Existing conditions were modeled utilizing the USDA, NRCS Revised Universal Soil Loss Equation (RUSLE2).

Input parameters and assumptions used for the BWSR' Calculator for Filter Strips:

1. Parameters for the Filter Strip Area (Buffer);

   A. Pre-existing soil loss in Filter Strip Area = 1.33 tons/acre

   B. Post-construction soil loss in Filter Strip Area = 0.044 tons/acre

   C. Soil type = Silt (85 lbs/cu.ft.)

   D. Buffer Width = 35 feet

   E. Filter Strip Area is variable (Length of Filter Strip x 35' buffer width.

2. Parameters for Upland Runoff treatment

   A. Filter strip watershed areas are variable for each site. Surface area drainage across the filter strip was measures from two-foot (2') topographic data (LiDAR) overlaid on aerial photographs of the areas being analyzed. Areas are measured in acres.

   B. Upland Soil Loss Before treatment is based on the average soil loss within the contributing area leading to the filter strip. Average soil loss was estimated using the USDA NRCS RUSLE2 program on all farm fields with in the watershed. Where filter strips are located, the average soil loss from the upland surface area from the contributing field area draining to the filter strip was used

   C. Filter strip function as designed (yes or no input in the BWSR Calculator for Filter Strips) was considered yes on all filter strips.

Grassed Waterway and Gully Stabilization Analysis

The estimates for reductions in soil loss, sediment, and attached phosphorus delivery for gully stabilization and grassed waterways are based on estimation of soil volume voided per year. The estimate assumes that once the practice is in place, the stabilized condition controls gully erosion. Soil loss reduction from the practice is equal to soil erosion before the project was put in place. A sediment delivery ratio (SDR) is assigned based on characteristics of flow from the gully or waterway and is applied to estimate sediment reduction. Sediment-attached phosphorus reduction is estimated from the sediment reduction, default phosphorus content of 1.0 lb. of phosphorus per 1 ton of soil, and a correction for soil texture. The inputs and assumptions used for this calculator were as follows: (http://www.bwsr.state.mn.us/practices/pollution_reduction.html)

A. Soil type. (in this watershed we used silt on all sites)
B. Soil volume voided per year (cubic feet). For gullies GS1 and GS3 this report assumes a 4" deep gully in a 3 feet wide parabolic shape. For gully GS 2, we assumed 4" deep by 5 foot wide.
C. Number of years to form the gully. This report assumes a yearly occurrence.
D. Gully condition. This report assumes the gully fans out before entering the receiving water. For the calculator the input is 'non-channelized'.
E. Distance to receiving surface water (feet to main ditch or wetland) measured along the route the water takes to get to the receiving water.
F. Presence of a filter strip before waterway instillation (in all cases there were no filter strips)

Wetland Restoration/Enhancement and Pond Excavation/Maintenance

These sites were analyzed utilizing the National Urban Runoff Program, Design Calculations for Wet Detention Ponds developed by Wm. Walker (http://www.wwwalker.net/pdf/spwudes.pdf). This program estimates nutrient loads from existing ponds and wetlands based on the land use (% impervious area and phosphorus concentration), watershed area and average mean pond depth. Surface area was measured from 2012 aerial photographs. Impervious areas for agriculture watershed were adjusted to 25% impervious area to account for an average phosphorus load of 1.0 pounds per acre based on average nutrient loads produced from agriculture production fields from research and the Elm Creek WMC and Pioneer-Sarah Creek WMC water quality standards. (http://elmcreekwatershed.org/files/342.pdf) (http://pioneersarahcreek.org/files/455.pdf) (http://www.pca.state.mn.us/index.php/view-document.html?gid=3977) (http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=280936) Pre- construction average mean depth was measured by photographic and in-field evidence of emergent vegetation or lack thereof (cattails-2 feet, sedges-6 inches, reed canary grass- less than 6 inches, open water-3.0 feet or greater). Watershed areas varied for each pond/wetland area but were based on LiDAR topographic delineations. Post construction average mean depth for the NURP program input was 1.5 meters for the new pond and and For Wetland restorations/enhancements specific depths and average volumes were based on LIDAR information.. Wetlands 1 and 2E restoration was assumed with a mean average depth of 2.5 feet after construction. Pond 2W was assumed at 4.0 feet after construction.

Livestock

We utilized a variety of programs for our analysis of soil loss and nutrient loads for the livestock section of this report. Nutrient and storage management analysis for utilized the recent Sauk River nutrient management program and University of Wisconsin Discovery Farms results which showed an average reduction in phosphorus loads to the Sauk River and other study farms of 0.25 lbs/ac. per acre of cropland nutrient management enrolled in their program.

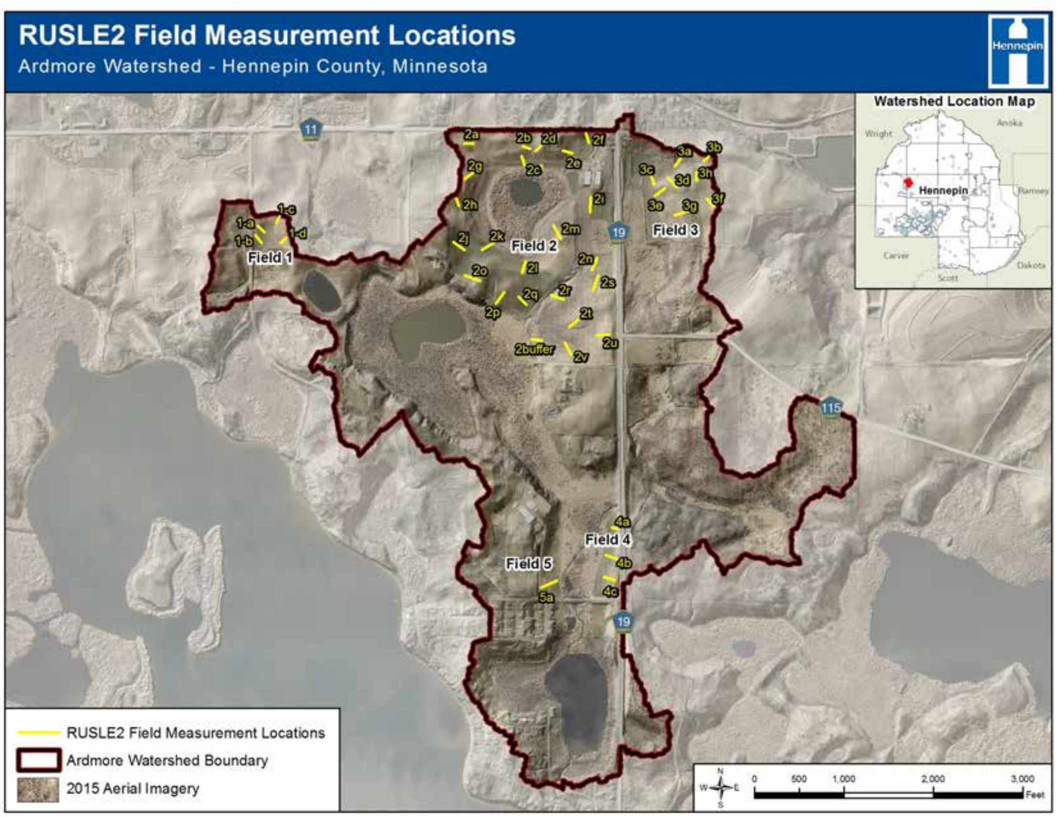
For all pasture land nutrient assumptions for exclusion fencing, an average phosphorus load of 2.0 pounds per acre of phosphorus export was used as the base average nutrient load produced on pasture land. This amount of load was based on research into studies identifying nutrient loads from various sources (http://www.pca.state.mn.us/index.php/view-document.html?gid=3977) For the waterway load reductions, we assumed a higher rate of 6.0 lbs/ac because of the concentrated flows that occur in this waterway.

http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=280936 and the loads the Pioneer-Sarah Creek and Elm Creek Watersheds water quality standard for pasture areas. (http://elmcreekwatershed.org/files/342.pdf) (http://pioneersarahcreek.org/files/455.pdf) (http://www.pca.state.mn.us/index.php/view-document.html?gid=3977) (http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=280936)

Cropland RUSLE2

The Revised Universal Soil Loss Equation was used on all cropland within the Lake Ardmore Watershed. This in turn was incorporated into various other models to determine before and after nutrient loads. The existing conditions were measured using LiDAR topographic information to determine the average length and steepness of slope. The Soil Survey for Hennepin County was used to determine the soil type in the field being analyzed.
Crop abbreviations used were c for corn, sb for soybean, sg for small grain and h for hay.
Climate location parameters for the program were from the NRCS Climate database website http://fargo.nserl.purdue.edu/rusle2_dataweb/NRCS_Climate_Database.htm. Minnesota, Hennepin County averages were used. Base crop management parameters used Climate Management Zone 4 from the NRCS Climate Database (http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Program.htm). General crop management used conventional tillage and an average 150 bushels per acre for corn. Mulch tillage and 45 bushels per acre was used for soybeans.

The following map corresponds to the preceding table that lists the field identifiers and input parameters used for each measurement in each field.



Farm field ID	Line ID	Length (ft.)	Fall (ft.)	Average slope (%)	RUSLE2 soil loss	Total field soil loss	Soils	Average field soil loss	Gully erosion	Field acreage	Crop rotation
1	1a	102	11	10.8	9.6		L41D2			3.6 acres	continuous corn
3.6 ac in watershed	1b	107	6	5.6	5.5		L36A				
	1c	87	10	11.5	9.2		L41D2				
	1d	87	16	18.4	20.0	44.3	L41E	11.1			
2	2a	108	13	12.0	8.8		L41D2			70 acres	c-sb
70 acres	2b	82	6	7.3	3.6		L26B				c-sb
	2c	108	15	13.9	9.4		L132A				c-sb
	2d	88	16	18.2	14.0		L41C2				c-sb
	2e	108	15	13.9	11.0		L41C2				c-sb
	2f	109	8	7.3	4.1		L132A				c-sb
	2g	115	16	13.9	11.0		L41D2				c-sb
	2h	95	18	18.9	15.0		L41D2				c-sb
	2i	162	7	4.3	2.6		L36A				c-sb
	2j	153	15	9.8	7.6		L41D2				c-sb
	2k	152	14	9.2	6.5		L41C2				c-sb
	2l	141	13	9.2	6.3		L41C2				c-sb
	2m	176	9	5.1	3.8		35A				c-sb
	2n	151	9	5.9	4.1		35A				c-sb
	2o	185	16	8.6	9.0		L41C2				c-sb
	2p	155	13	8.4	5.8		L41C2				c-sb
	2q	125	10	8.0	5.4		L41C2				c-sb
	2r	156	12	7.7	5.6		L41C2				c-sb
	2s	180	12	6.7	5.0		L41C2				c-sb

Farm field ID	Line ID	Length (ft.)	Fall (ft.)	Average slope (%)	RUSLE2 soil loss	Total field soil loss	Soils	Average field soil loss	Gully erosion	Field acreage	Crop rotation
	2t	128	9	7.0	5.2		L41C2				c-sb
	2u	139	12	9.4	6.7		L41C2				c-sb
	2v	151	10	6.6	4.6	155.1	L41C2	7.1			c-sb
	2buffer	115	14	12.1	7.8		L36A	7.8			
3	3a	111	14	12.6	5.2		L41D2			17 acres	c-csilage-w-alf-alf-alf
17 acres	3b	80	6	7.5	4.7		L41C2				c-csilage-w-alf-alf-alf
	3c	98	6	6,1	1.0		L49A				c-csilage-w-alf-alf-alf
	3d	145	22	15.2	7.6		L41D2				c-csilage-w-alf-alf-alf
	3e	135	13	9.6	3.3		L36A				c-csilage-w-alf-alf-alf
	3f	110	11	10.0	2.8		L40B				c-csilage-w-alf-alf-alf
	3g	170	25	14.7	7.2		L41C2				c-csilage-w-alf-alf-alf
	3h	89	8	9.0	3.0	34.8	L41C2	3.9			c-csilage-w-alf-alf-alf
4	4a	61	6	9.8	4.4		L36A			4.2 acres	c-c-sb
4.2 acres	4b	135	14	10.4	6.0		L36A				c-c-sb
	4c	131	18	13.7	8.8	19.2	L41D2	6.4			c-c-sb
	average soil loss in all buffer strips										
		35	2	use 3%							
5	5a	186	17	9.1	2.3	2.3	L41C2		pasture cont graze, mod overuse	pasture cont graze, mod overuse	

Project Budget Estimates

Unless otherwise mentioned in the individual practice, this section includes the tables used to calculate the cost estimates for the practices in this report. The project budget estimates are as follows;

BMP	ID	Initial Construction Cost ($/unit)	Contracted Maintenance Cost ($/unit)	O & M Term (yr)	Design Cost for Average Site ($70/hr)	Installation Oversight Cost for Average Site ($70/hr)	Size of Proposed BMP (USER ENTERED)	Total Installation Cost (Includes design & 1-yr maintenance)	10 Year Cost (Includes installation cost & 10 years of maintenance)
Contour Buffer Strips (AC)	CBS	$ 500.00	$ 10.00	10	$ 560.00	$ 280.00	10	$ 5,940.00	$ 6,840.00
Contour Farming (AC)	CF	$ 25.00	$ -	10	$ 560.00	$ 280.00	10	$ 1,090.00	$ 1,090.00
Cover Crop (AC)	CC	$ 25.00	$ -	10	$ 560.00	$ 280.00	40	$ 1,840.00	$ 18,400.00
Diversions (LF)	D	$ 7.00	$ 0.25	10	$ 560.00	$ 280.00	500	$ 4,465.00	$ 5,590.00
Filter Strip (AC)	FS	$ 500.00	$ 10.00	10	$ 1,120.00	$ 560.00	10	$ 6,780.00	$ 7,680.00
Grade Stabilization Structure - drainage area of 0 to 10 acres (NO)	GSS	$ 9,250.00	$ 100.00	10	$ 925.00	$ 462.50	1	$ 10,737.50	$ 11,637.50
Grade Stabilization Structure - drainage area of 10 to 20 acres (NO)	GSS	$ 15,000.00	$ 150.00	10	$ 1,500.00	$ 750.00	1	$ 17,400.00	$ 18,750.00
Grade Stabilization Structure - drainage area of 20 to 40 acres (NO)	GSS	$ 28,125.00	$ 200.00	10	$ 2,812.50	$ 1,406.25	1	$ 32,543.75	$ 34,343.75
Grade Stabilization Structure - drainage area of 40 to 80 acres (NO)	GSS	$ 37,500.00	$ 250.00	10	$ 3,750.00	$ 1,875.00	1	$ 43,375.00	$ 45,625.00
Grade Stabilization Structure - drainage area of 80 to 250 acres (NO)	GSS	$ 56,250.00	$ 300.00	10	$ 5,625.00	$ 2,812.50	1	$ 64,987.50	$ 67,687.50
Grade Stabilization Structure - drainage area of 250 to 500 acres (NO)	GSS	$ 112,500.00	$ 350.00	10	$ 11,250.00	$ 5,625.00	1	$ 129,725.00	$ 132,875.00
Grade Stabilization Structure - drainage area of greater than 500 acres (NO)	GSS	$ 150,000.00	$ 400.00	10	$ 15,000.00	$ 7,500.00	1	$ 172,900.00	$ 176,500.00
Grassed Waterway (LF)	GW	$ 4.00	$ 0.25	10	$ 1,120.00	$ 560.00	1,000	$ 5,930.00	$ 8,180.00
Nutrient Management (AC)	NM	$ 11.00	$ -	10	$ 560.00	$ 280.00	10	$ 950.00	$ 950.00
Nutrient Management (NO)	NM	$ 3,375.00	$ -	10	$ 560.00	$ 280.00	1	$ 4,215.00	$ 4,215.00
Prescribed Grazing (AC)	PG	$ 93.00	$ -	10	$ 560.00	$ 280.00	10	$ 1,770.00	$ 1,770.00
Residue Management (AC)	RM	$ 58.00	$ -	10	$ 560.00	$ 280.00	1	$ 898.00	$ 898.00
Restoration and Management of Declining Habitats (AC)	RMDH	$ 1,500.00	$ 500.00	15	$ 1,120.00	$ 560.00	10	$ 21,680.00	$ 66,680.00
Streambank and Shoreline Protection (SF)	SSP	$ 7.00	$ 0.25	10	$ 2,240.00	$ 1,120.00	1,000	$ 10,610.00	$ 12,860.00
Stripcropping (AC)	Strip	$ 98.00	$ -	10	$ 560.00	$ 280.00	10	$ 1,820.00	$ 1,820.00
Terrace (LF)	Ter	$ 8.00	$ 0.25	10	$ 1,120.00	$ 560.00	1,000	$ 9,930.00	$ 12,180.00
Water and Sediment Control Basin - drainage area of 0 to 10 acres (NO)	SB	$ 12,500.00	$ 100.00	10	$ 1,250.00	$ 625.00	1	$ 14,475.00	$ 15,375.00
Water and Sediment Control Basin - drainage area of 10 to 20 acres (NO)	SB	$ 11,250.00	$ 150.00	10	$ 1,125.00	$ 562.50	1	$ 13,087.50	$ 14,437.50
Water and Sediment Control Basin - drainage area of 20 to 40 acres (NO)	SB	$ 16,875.00	$ 200.00	10	$ 1,687.50	$ 843.75	1	$ 19,606.25	$ 21,406.25
Wetland Creation (AC)	WetC	$ 7,000.00	$ 45.00	10	$ 2,800.00	$ 1,400.00	10	$ 74,650.00	$ 78,700.00
Wetland Enhancement (AC)	WetE	$ 3,000.00	$ 45.00	10	$ 2,800.00	$ 1,400.00	10	$ 34,650.00	$ 38,700.00
Wetland Restoration (AC)	WetR	$ 3,000.00	$ 45.00	10	$ 2,800.00	$ 1,400.00	10	$ 34,650.00	$ 38,700.00
Windbreak - per foot of single row, planted (LF)	Wind	$ 2.00	$ -	10	$ 560.00	$ 280.00	1,000	$ 2,840.00	$ 2,840.00
Septic fix (NO)	Sep	$ 15,000.00	$ -	n/a	$ -	$ -	1	$ 15,000.00	$ 15,000.00
Feedlot Fix - Pit - first 500,000 CF of storage (CF)	FF	$ 1.55	$ 0.01	10	$ 11,200.00	$ 5,600.00	500,000	$ 795,050.00	$ 824,300.00
Feedlot Fix - Pit - additional above 500,000 CF of storage (CF)	FF	$ 1.13	$ 0.01	10	$ 11,200.00	$ 5,600.00	500,000	$ 585,050.00	$ 614,300.00
Feedlot Fix - Treatment Swale (SF)	FF	$ 4.00	$ 0.25	10	$ 2,800.00	$ 1,400.00	1,000	$ 8,450.00	$ 10,700.00
Feedlot Fix - Relocation (NO)	FF	$ 50,000.00	$ -	n/a	$ 11,200.00	$ 5,600.00	1	$ 66,800.00	$ 66,800.00

BMP	ID	Description	Materials/Labor (Installation)	Unit	Annual Maintenance Cost (contracted)	Design Cost ($70/hr)	Installation Oversight Cost ($70/hr)	Promotion & Administration	O & M Term
Rain Leader Disconnect Rain Garden	BRS	Simple (residential, some commercial)	$7.56	Square Foot	$0.25/ft^2	$280/100 ft^2	$210 (3 visits)	minimum 10% const. costs	10
Infiltration Basin (Turf)	BRT	amended soils with under-drains	$15.10	Square Foot	$2000/acre	$1120/acre	$210 (3 visits)	minimum 10% const. costs	10
Simple Bioretention	BR	(no engineered soils or under-drains, but w/curb cuts and forebays)	$14.20	Square Foot	$0.75/ft^2	$840/1000 ft^2	$210 (3 visits)	minimum 10% const. costs	10
Moderately Complex Bioretention	BR	(incl. engineered soils, under-drains, curb cuts, forebays but no retaining walls)	$17.01	Square Foot	$0.75/ft^2	$1120/1000 ft^2	$420 (6 visits)	minimum 10% const. costs	10
Complex Bioretention	BR	(as MCB but with 1.5-2.5 ft partial perimeter walls)	$21.50	Square Foot	$0.75/ft^2	[4]$1400/1000ft^2	$420 (6 visits)	minimum 10% const. costs	10
Highly Complex Bioretention	BR	(as CB but with partial perimeter 2.5-5 ft walls or shorter, complete perimeter walls)	$23.50	Square Foot	$0.75/ft^2	[4]$1400/1000ft^2	$420 (6 visits)	minimum 10% const. costs	10
Curb-Cut		simple cut or with apron	$80.00	Linear Foot					
Impervious Cover Conversion	DeP		$21.71	Square Foot	$500/acre	$1120/acre	$210 (3 visits)	minimum 10% const. costs	10
Grass/Gravel Permeable Pavement	PP	(sand base)	$18.95	Square Foot	$0.75/ft^2	[1]40% above construction	$210 (3 visits)	minimum 10% const. costs	10
Permeable Asphalt	PP	(granite base)	$10.80	Square Foot	$0.75/ft^2	[1]40% above construction	$210 (3 visits)	minimum 10% const. costs	10
Permeable Concrete	PP	(granite base)	$15.00	Square Foot	$0.75/ft^2	[1]40% above construction	$210 (3 visits)	minimum 10% const. costs	10
Permeable Pavers	PP	(granite base)	$35.75	Square Foot	$0.75/ft^2	[1]40% above construction	$210 (3 visits)	minimum 10% const. costs	10
Extended Detention	PP		(12.98)*(CU-FT^0.75)	Cubic Foot	$1000/acre	[5]$2800/acre	$210 (3 visits)	minimum 10% const. costs	10
Pond Retrofits	PR		$4.54	Square Foot	$500/acre	[1]40% above construction	$210 (3 visits)	minimum 10% const. costs	10
Pond Excavation - (MPCA Dredge Class) Level 1 Material	PE		$32.40	Cubic Yard				minimum 10% const. costs	
Pond Excavation - (MPCA Dredge Class) Level 2 Material	PE		$43.20	Cubic Yard				minimum 10% const. costs	
Pond Excavation - (MPCA Dredge Class) Level 3 Material	PE		$64.80	Cubic Yard				minimum 10% const. costs	
Stormwater Wetland	WetC		(4,800)*(D.A.acres^0.484)		$1000/acre	[5]$2800/acre	$210 (3 visits)	minimum 10% const. costs	10
Wet Pond	P		(277.89)*(CU-FT^0.553)	Cubic Foot	$1000/acre	[5]$2800/acre	$210 (3 visits)	minimum 10% const. costs	10
Perimeter Sand Filter	SF		$259.20	Linear Foot				minimum 10% const. costs	
Structural Sand Filter	SF	(including peat, compost, iron amendments, or similar)	$22.04	Square Foot	$250/25 ln ft	$300/25 ln ft	$210 (3 visits)	minimum 10% const. costs	10
Underground Sand Filter	SF		$99.08	Square Foot	$0.75/ft^2	[1]40% above construction	$210 (3 visits)	minimum 10% const. costs	10
Rain Barrels	RE	Does not include pump or distribution	$25.00	Cubic Foot	[3]$25	NA	$210 (3 visits)	minimum 10% const. costs	10
Cisterns	RE	Does not include pump or distribution	$16.00	Cubic Foot	[3]$100	NA	$210 (3 visits)	minimum 10% const. costs	10
Dry Swale	DS		$7.13	Square Foot	$0.75/ft^2	$280/100 ft^2	$210 (3 visits)	minimum 10% const. costs	10
Water Quality Swale[6]	WS		$15.01	Square Foot	$0.75/ft^2	$1120/1000 ft^2	$210 (3 visits)	minimum 10% const. costs	10
French Drain/Dry Well			$15.00	Cubic Foot	[3]$100	20% above construction	$210 (3 visits)	minimum 10% const. costs	10
Lakeshore Restoration (simple)	Lrest	average 25' buffer width, no shoreline toe protection, no emergents	$75.00	Linear Foot	$0.75/ft^2	10% above construction	$210 (3 visits)	minimum 10% const. costs	10
Lakeshore Restoration (moderate)	Lrest	average 25' buffer width with minimal bioengineering, some emergent plantings	$100.00	Linear Foot	$0.75/ft^2	10% above construction	$210 (3 visits)	minimum 10% const. costs	10
Lakeshore Restoration (complex)	Lrest	average 25' buffer with emergent plantings extensive hard armoring or bioengineering for : steep slopes, high erosion potential, ice heave protection, long fetch	$190.00	Linear Foot	$0.75/ft^2	10% above construction	$210 (3 visits)	minimum 10% const. costs	10
Stormwater Planter (commercial/ultra urban)	SP	Usually a stormwater disconnect BMP	$35.86	Square Foot	$0.75/ft^2	20% above construction	$210 (3 visits)	minimum 10% const. costs	10
Stormwater Tree Pits (ultra urban, linear projects)	STP	6' x 12 ' pit with concete vault (central corridor project - st. paul)	$10,000	Each	$0.75/ft^2	[1]40% above construction	$210 (3 visits)	minimum 10% const. costs	10
Extensive Green Roof (ultra urban)	GR	less than 6" in soil media depth	project specific - structural, roof membrane considerations needed	Square Foot	$500/1000 ft^2	[1]40% above construction	$210 (3 visits)	minimum 10% const. costs	10
Intensive Green Roof (ultra urban)	GR	6" or greater in soil media depth	project specific - structural, roof membrane considerations needed	Square Foot	$750/1000 ft^2	[1]40% above construction	$210 (3 visits)	minimum 10% const. costs	10
Stormwater Reuse	RE	look for ponds collecting large drainage areas (>100 acres?) near greenspace with existing irrigation distribution or can be retrofitted for irrigation distribution)							

References

- Best Management Practices Construction Costs, Maintenance Costs and Land Requirements, BARR Engineering, Prepared for MN Pollution Control Agency June 2011
- Board of Water and Soil Resources Pollution Reduction Estimator, Microsoft Excel Version, 2010
- Centers for Watershed Protection, Urban Subwatershed Restoration Manual, August 2007
- Center for Watershed Protection & Chesapeake Stormwater Network. Runoff Reduction Methods, Appendices A to G April, 2008.
- Environmental Protection Agency, 1983. Results of the Nationwide Urban Runoff Program, Volume 1: Final Report. http://www3.epa.gov/npdes/pubs/sw_nurp_vol_1_finalreport.pdf.
- Fact sheet, Ohio State University Extension, Food, Agricultural and Biological Engineering, 590 Woody Hayes Dr., Columbus, Ohio 43210
- HydroCAD, 2011. HydroCAD Stormwater Modeling. http://www.hydrocad.net/.
- Impacts of Cattle Grazing Management on Sediment and Phosphorus Loads in Surface Waters. Iowa State University 2004 Animal Industry Report. Haan, M.M., J.R. Russell, W. Powers, J.L. Boehm, S. Mickelson, and R. Schultz Iowa State University, Ames, IA J.L. Kovar, USDA National Soil Tilth Laboratory, Ames, IA
- Johnson, James et. al., 2007. Lake Independence Phosphorus TMDL. https://www.pca.state.mn.us/sites/default/files/wq-iw8-03e.pdf.
- Lake Independence Phosphorus TMDL, January 2007. Three Rivers Park District,
- Lake Independence Nutrient TMDL Implementation Plan, March 12, 2007, Three Rivers Park District, Minnesota Pollution Control Agency
- Maestre, A. and Pitt, R., 2005. The National Stormwater Quality Database, Version 1.1: A Compilation and Analysis of NPDES Stormwater Monitoring Information. Dept. of Civil and Environmental Engineering, University of Alabama.
- Minnesota Board of Water & Soil Resources, 2010. Pollution Reduction Estimator Worksheet. Conservation Implementation: Tools for calculating pollution reduction estimates. http://www.bwsr.state.mn.us/practices/pollution_reduction.html.
- Minnesota Pollution Control Agency, 2015. Calculating credits for iron enhanced sand filter. Minnesota Stormwater Manual. http://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_iron_enhanced_sand_filter.
- Minnesota Pollution Control Agency, 2015. MIDS Calculator. Minnesota Stormwater Manual. http://stormwater.pca.state.mn.us/index.php/MIDS_calculator
- Minnesota Pollution Control Agency, 2016. Calculating credits for biorention. Minnesota Stormwater Manual. http://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_bioretention.
- Minnesota Pollution Control Agency, Minnesota Stormwater Manual
- Minnesota Department of Agriculture. The Agricultural BMP Handbook for Minnesota, September 2012.
- Minnesota Pollution Control Agency, Best Management Practices Construction Costs, Maintenance Costs, and Land Requirements, June 2011.

References (continued)

- Minnesota Feedlot Annualized Runoff Model (MinnFARM) Version 2.1, October 2008 University of Minnesota Extension - Manure Management and Air Quality Education and Research.
- Model Simulation of Soil Loss, Nutrient Loss, and Change in Soil Organic Carbon Associated with Crop Production, June 2006, NRCS
- Phosphorus Run off Reduction and Annual Ongoing Cost Estimates for common Vermont Agronomic Practices. Dr. Kent E Henderson, FNLC Chair
- PONDNET, Flow and Phosphorus Routing in Pond Networks, William W. Walker, March 1989.
- Potential phosphorus and sediment loads from sources within a dairy farmed catchment. G. M. Lucci, ,R.W.Mcdowell & L.M.Condron. AgResearch, Invermay Agricultural Centre, Private Bag 50034 Mosgiel, New Zealand, and Agriculture and Life Sciences, Lincoln University, P.O. Box 84 Lincoln 7647, New Zealand.
- Quantifying Phosphorus Loss In Runoff From Grazing Cattle. Peter Vadas: USDA-ARS Dairy Forage Research Center, Madison, WI Dennis Busch: UW-Platteville Pioneer Farm, Platteville, WI Mark Powell: USDA-ARS Dairy Forage Research Center, Madison, WI Geoff Brink: USDA-ARS Dairy Forage Research Center, Madison, WI
- Storm Water Assessment Tool (SWAT) USDA Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research. 2014.
- USDA Agriculture Research Service Revised Universal Soil Loss Equation (RUSLE2) April 2010.
- Vegetated filter strip image, University of Florida, Department of Agricultural and Biological Engineering.
- Walker, William W. Jr., 1990. P8 Urban Catchment Model. http://wwwalker.net/p8/.

Hennepin County
Public Works
Environment and Energy

Hakanson Anderson