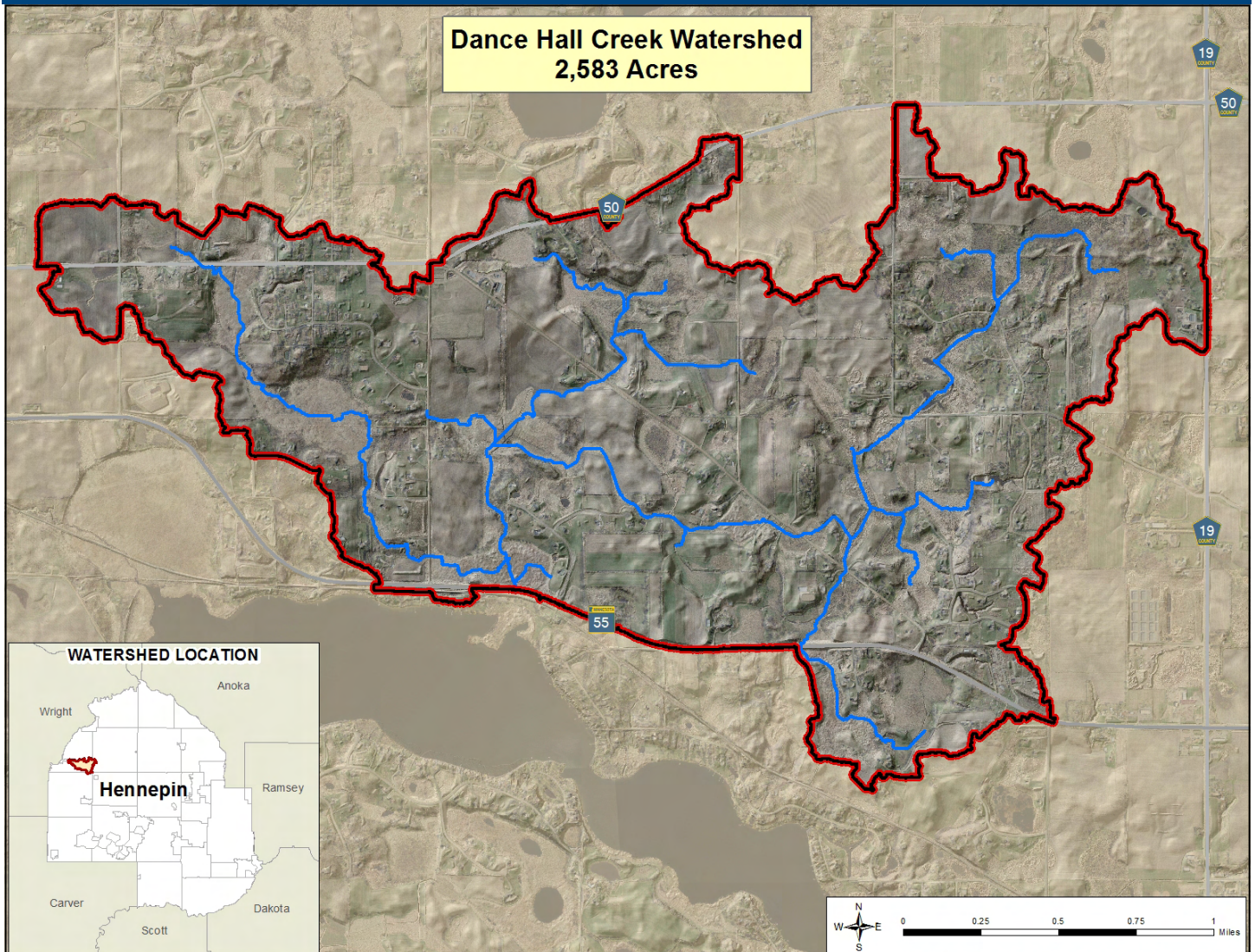


Dance Hall Creek Subwatershed Stormwater Retrofit Assessment



Hennepin County
Public Works
Environmental Services

Prepared for the City of Greenfield
October 2014

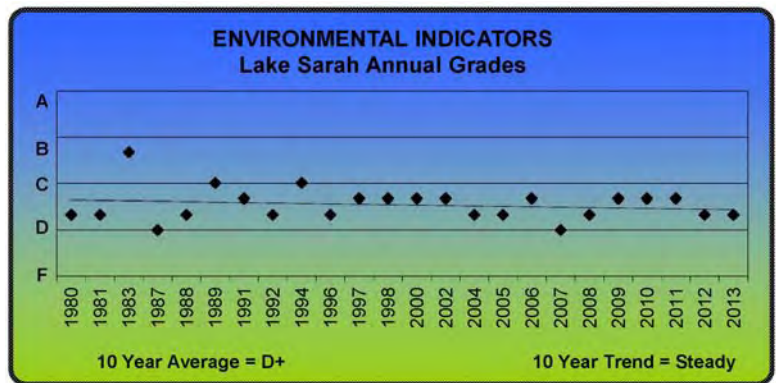
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Executive summary

Lake Sarah is on the Minnesota Pollution Control Agency's (MPCA) 303(d) list of impaired waters for aquatic recreation (swimming). As shown by the Hennepin County lake grades, water quality in Lake Sarah has been poor since monitoring began in the 1980s. The primary cause of impairment is phosphorous, which originate from two main sources – watershed runoff and in-lake loading. The Lake Sarah Total Daily Maximum Load (TMDL) study identified the Dance Hall Creek Watershed as a major source of phosphorous, contributing 975 pounds (46 percent) of phosphorus per year to Lake Sarah.

Figure 1: Lake grades for Lake Sarah



A stormwater retrofit analysis, which identifies and prioritizes retrofit projects by performance and cost-effectiveness, was conducted within the Dance Hall Creek Watershed. This analysis helps maximize the value of each dollar spent. The results recommend cost-effective best management practices (BMPs) that will reduce phosphorus loads into Lake Sarah by 50 percent or more to achieve the goal for the 2011 TMDL study.

The results of this assessment are based on the modeling of various stormwater treatment BMPs within the Dance Hall Creek Watershed. Conceptual drawings and/or photos have been incorporated in this report to provide a better understanding of each BMP and approach for implementation. More detailed, site-specific designs will need to be prepared for each BMP selected prior to implementation. Most projects 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 the recommended BMPs considered a combination of factors, including potential to reduce the target pollutant (phosphorous), the project type and associated cost-benefit analysis, and the location of the project within the watershed. Additional factors that should be considered prior to prioritizing the recommended BMPs include project costs, available funding, economics of scale, landowner willingness, and short- versus long-term impacts on property values and public infrastructure.

Selection of the subwatershed

Lake Sarah was identified as a priority resource in the Pioneer-Sarah Creek Watershed Management Commission's 2nd Generation Watershed Management Plan. A TMDL study and associated implementation plan was completed for Lake Sarah in 2011. The TMDL's implementation plan was developed with a great deal of technical advisory and public involvement and includes projects that will reduce nutrient loads to the lake. Anticipated nutrient reductions are included for each of the projects. The TMDL study determined that the Dance Hall Creek Subwatershed contributed 46 percent of the annual external phosphorus loads to Lake Sarah. Because of this significant contribution, this subwatershed was chosen for additional analysis through cooperative efforts of the City of Greenfield, the former Hennepin Conservation District, Hennepin County Environmental Services and the Metropolitan Association of Conservation Districts.

Document organization

This document presents a brief overview of the processes involved to develop 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, including their rankings based on cost per pound of nutrient reduction and project profiles.

Basic conclusions

This study, which used site-specific observations and measurements, new topographic data (2-foot contour LiDAR data), and current land use and modeling processes, supports the findings from previous studies that show a direct correlation between land use, land management and phosphorus transport to the amount of pollutants discharging from the Dance Hall Creek system to Lake Sarah. The amount of pollutants, in this case phosphorous, reaching Lake Sarah would be greatly reduced by maintaining land cover or implementing BMPs that keep stormwater on-site or slow stormwater leaving a site

The implementation of any land practices that keeps rainfall on the land instead of running off and prevents nutrients that are either attached to soil or dissolved in the runoff water from reaching the creek system will benefit the water quality of Lake Sarah. In addition, disturbances of the land from development, soil exposure, agricultural, livestock and other man-made activities add to the problem and must be properly managed.

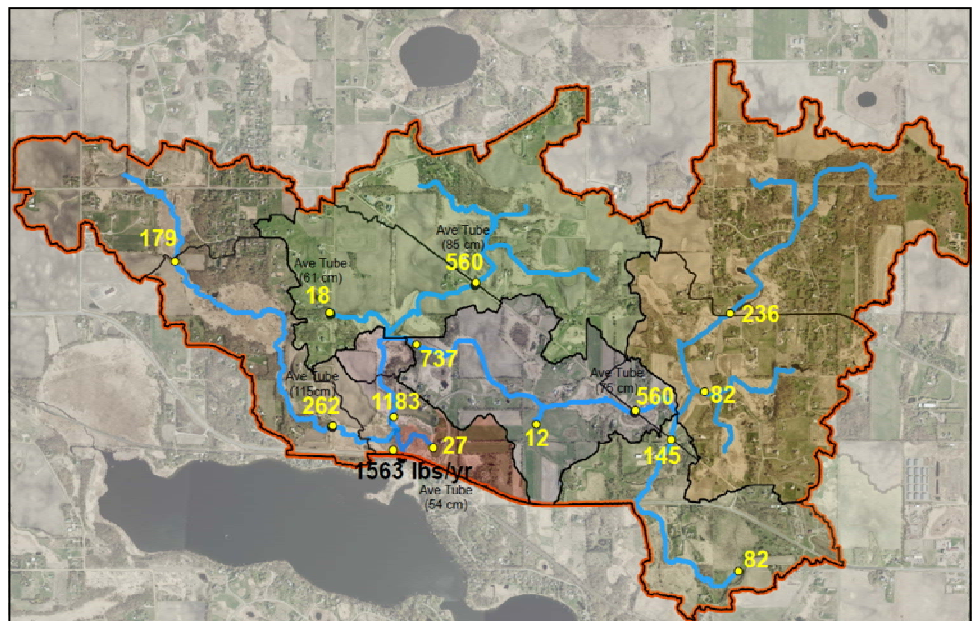
The cost/benefit relationship of putting these practices into place is highly dependent upon how severe the land disturbance is and how close the practice is to Dance Hall Creek and more specifically Lake Sarah.

Figure 2 shows an example of a high runoff season and the phosphorous loads at various locations in the Dance Hall Creek Watershed. Table 1 shows the anticipated total phosphorus (TP) reduction at the location that the practice is implemented and downstream at the lake, total suspended solids (TSS) reduction, stormwater volume reduction, total project cost and cost per pound of TP removed.

The cost effectiveness and nutrient reductions for some conceptual practices were generalized. For example, not every livestock facility was modeled due to the specific site

and management techniques each facility uses. However, the concept of on-site compost systems to treat manure generated by the number of livestock was evaluated, and a delivery ratio of nutrients to Lake Sarah was determined based on distance to the creek and lake. An average load reduction and cost/benefit analysis can then be estimated to locate livestock facilities that warrant additional study. If the landowner is interested in such a study, the exact nutrient reductions would be analyzed on a site-by-site basis.

Figure 2: Dance Hall Creek Watershed nutrient loads (pounds per year of phosphorus)



Recommended projects

Table 1: Dance Hall Creek retrofit projects and rankings

Project rank	Retrofit type	Project ID	Total P reduction	PDR	P reduction to Lake Sarah	TSS reduction	Volume reduction	Total project cost	Estimated cost
			(lb/yr)		(lb/yr)	(lb/yr)	(ac-ft/yr)	(includes 10-yr maintenance)	(lb-TP/year for 10 years)
1	Grassed waterway (1,375 total feet)	Field 4/5-1	41.6	0.8	29.2	58,400	N/A	\$10,750	\$37
2	Grassed waterway (2,365 total feet)	Field 1-1	62.6	0.7	43.8	87,600	N/A	\$17,500	\$40
3	Grassed waterway (1,175 total feet)	Field 1-2	31.1	0.7	21.8	43,600	N/A	\$9,500	\$44
4	Exclusion fence	Livestock 2a	11.5	1.0	11.5	N/A	N/A	\$5,375	\$47
5	Tile intake alternatives	Field 5-2	42	0.1	4.2	8,400	N/A	\$2,400	\$57
6	Exclusion fence	Livestock 7c	48	0.4	19.2	N/A	N/A	\$12,650	\$66
7	Buffer	Field 4/5-1	32.6	0.9	29.3	58600	N/A	\$19,530	\$67
8	Grassed waterway (1,625 total feet)	Field 1-7	43	0.4	17.3	34,525	N/A	\$12,243	\$71
9	Grassed waterway (1,050 total feet)	Field 1-3	28	0.4	11.2	22,400	N/A	\$8,505	\$76
10	Exclusion fence	Livestock 7b	55.4	1	55.4	N/A	N/A	\$42,750	\$78
11	Prescribed grazing	Livestock 7a	1	1	1	N/A	N/A	\$800	\$80
12	Grassed waterway (525 total feet)	Field 1-5	14	0.4	5.6	11,200	N/A	\$5,100	\$91
13	Buffer	Field 2/3/-1	26.8	0.6	16.1	32,200	N/A	\$15,295	\$95
14	Buffer	Field 1-2a	12.8	0.9	11.2	23,000	N/A	\$11,210	\$100
15	Buffer	Field 1-2	27.6	0.6	16.6	33,200	N/A	\$17,830	\$107
16	Nutrient management system	Livestock 7b	17.5	1	17.5	N/A	N/A	\$19,200	\$110
17	Hydrologic restoration	Pond 1	100	1	100	N/A		\$223,500 (20 YRS)	\$112
18	Buffer	Field 1-6	32	0.4	12.8	26,700	N/A	\$14,450	\$113
19	Clean water diversion	Livestock 7b	16.5	0.75	12.4	N/A	N/A	\$15,000	\$121
20	Buffer	Field 5-4	69.0	0.2	13.8	27,600	N/A	\$17,830	129
21	Grassed waterway (225 total feet)	Field 1-6	6	0.4	2.4	4,800	N/A	\$3,150	\$131
22	Hydrologic restoration	Pond 5	--	1	29			\$76,000 (20 Years)	\$131
23	Field 1-7 W&SCB + 2 waterways (850')	Field 1-7	42	0.4	16.8	33,600	N/A	\$22,580	\$134

Implementing the top 23-ranked projects would achieve the phosphorous reduction goals at a total cost of \$583,148.

Table 1: Dance Hall Creek retrofit projects and rankings (continued)

Project rank	Retrofit type	Project ID	Total P reduction	PDR	P reduction to Lake Sarah	TSS reduction	Volume reduction	Total project cost	Estimated cost
			(lb/yr)		(lb/yr)	(lb/yr)	(ac-ft/yr)	(includes 10-yr maintenance)	(lb-TP/year for 10 years)
24	Hydrologic restoration	Pond 2	90	1	91			\$253,500 (20 Years)	\$139
25	Hydrologic restoration	Ponds 1&2	--	1	169			\$477,000 (20 Years)	\$141
26	Pond excavation	Pond 2a	6.8	0.9	6.1	33,000	N/A	\$10,500	\$172
27	Buffer	Field 3-2	8.7	0.5	4.4	8,800	N/A	\$7,690	\$175
28	Buffer	3-4 east	22.9	0.3	6.9	13,800	N/A	\$12,195	\$177
29	Manure storage system//compost bin	Livestock 6a	4	1	4	N/A	N/A	\$7,375	\$185
30	Water and sediment control basin	Field 1-7	19.5	0.4	7.8	15,600	N/A	\$15,375	\$197
31	Buffer	Field 2-2a	5.8	0.9	5.2	8,800	N/A	\$10,355	\$200
32	Manure storage system//compost bin	Livestock 7a	5	1	5	N/A	N/A	\$10,600	\$212
33	Buffer	Field 1-1	11.75	0.6	7.1	14,200	N/A	\$15,295	\$215
34	Manure storage system//compost bin	Livestock 5a	6	0.5	3	N/A	N/A	\$7,375	\$245
35	Manure storage system//compost bin	Livestock 3b	3	1	3	N/A	N/A	\$7,375	\$247
36	Livestock exclusion fencing	Livestock 3b	1	1	1	N/A	N/A	\$2,500	\$250
37	Buffer	Field 1-5	12.25	0.4	4.9	5,800	N/A	\$12,350	\$252
38	Pond scour protection	Pond 1a	2	1	2	4,000	N/A	\$6,000	\$300
39	Manure storage system//compost bin	Livestock 1a	2	1	2	N/A	N/A	\$7,375	\$369
40	Manure storage system//compost bin	Livestock 1b	2	1	2	N/A	N/A	\$7,375	\$369
41	Manure storage system//compost bin	Livestock 1c	2	1	2	N/A	N/A	\$7,375	\$369
42	Manure storage system//compost bin	Livestock 1d	2	1	2	N/A	N/A	\$7,375	\$369
43	Manure storage system//compost bin	Livestock 1e	2	1	2	N/A	N/A	\$7,375	\$369
44	Manure storage system//compost bin	Livestock 1f	2	1	2	N/A	N/A	\$7,375	\$369
45	Manure storage system//compost bin	Livestock 1g	2	1	2	N/A	N/A	\$7,375	\$369
46	Manure storage system//compost bin	Livestock 2b	2	1	2	N/A	N/A	\$7,375	\$369

Table 1: Dance Hall Creek retrofit projects and rankings (continued)

Project rank	Retrofit type	Project ID	Total P reduction	PDR	P reduction to Lake Sarah	TSS reduction	Volume reduction	Total project cost	Estimated cost
			(lb/yr)		(lb/yr)	(lb/yr)	(ac-ft/yr)	(includes 10-yr maintenance)	(lb-TP/year for 10 years)
47	Manure storage system//compost bin	Livestock 3a	2	1	2	N/A	N/A	\$7,375	\$369
48	Manure storage system//compost bin	Livestock 3c	2	1	2	N/A	N/A	\$7,375	\$369
49	Manure storage system//compost bin	Livestock 3d	2	1	2	N/A	N/A	\$7,375	\$369
50	Manure storage system//compost bin	Livestock 3f	2	1	2	N/A	N/A	\$7,375	\$369
51	Manure storage system//compost bin	Livestock 3h	2	1	2	N/A	N/A	\$7,375	\$369
52	Manure storage system//compost bin	Livestock 6b	2	1	2	N/A	N/A	\$7,375	\$369
53	Manure storage system/compost bin	Livestock 2a	2.0	1.0	2.0	N/A	N/A	\$7,375	\$370
54	Buffer	Field 5-3	13.7	0.2	2.74	27,540	N/A	\$10,225	\$373
55	Hydrologic restoration	Ponds 3&4	--	1	40			\$337,000 (20 Years)	\$421
56	Buffer	Field 3-8	8.7	0.2	1.7	3,400	N/A	\$7,690	\$452
57	Pond excavation	Pond 1a	3.5	1.0	3.5	7,000	N/A	\$52,400	\$1,497
58	Pond excavation	Pond 3a	2	0.3	0.6	4,000	N/A	N/A	\$13,800
59	Gully stabilization	GS1	10.1	0.3	3.0	20,190	N/A	\$93,000	\$3,100
60	Gully stabilization	GS3	10.1	0.3	3.0	20,190	N/A	\$93,000	\$3,100
61	Pond excavation	Pond 7b	2.2	0.3	0.7	N/A	N/A	\$23,000	\$3,285
62	Gully stabilization	GS2	2.6	0.3	0.8	5,100	N/A	\$27,500	\$3,400
63	Wetland restoration	WR2	21.6	0.1	2.16	4,400	2.7	\$86,500	\$4,005
64	Gully stabilization	GS4	9	0.2	1.8	18,000	N/A	\$84,000	\$4,665
65	Wetland restoration	WR3	24.3	0.1	2.4	4,800	7.7	\$134,500	\$5,605
66	Gully stabilization	GS5	5	0.1	0.5	N/A	N/A	\$29,000	\$5,800
67	Wetland restoration	WR1	3.8	0.1	0.38	760	1.2	\$49,000	\$12,895
68	Pond excavation	Pond 7a	0.2	0.1	0.02	N/A	N/A	\$17,500	\$87,500
69	Manure storage system//concrete tank	Livestock 7b	2	1	2	N/A	N/A	\$75,000	N/A

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. The analysis identifies opportunities and develops conceptual designs for BMPs for areas that are contributing the largest pollutant loads to the receiving water body. The subwatershed assessment process took the following 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 neighbourhoods of the highest priority sub watersheds 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 (WinnSLAMM), Board of Water and Soil Resources Pollution Reduction Model, Revised Universal Soil Loss Equation Version 2 (RUSLE2) and Minnesota Feedlot Assessment Runoff Model (MinnFARM).
5. **Manage installation** based on landowners’ willingness and funding availability.

The subwatershed retrofit analysis process is a tool that helps to identify and prioritize BMPs based on performance and cost/benefit. The process for the Dance Hall Creek Subwatershed Analysis involved scoping, desktop analysis, field investigation, modeling, cost estimating, and project ranking and selection.

Target elements

The main element considered in this analysis was phosphorous, the target pollutant for Lake Sarah. Volume of water and total suspended solid controls were analyzed as secondary elements as they can affect phosphorous loads.

Table 2: Priority elements analyzed in Dance Hall Creek subwatershed assessment

Priority elements analyzed	Description
Total phosphorous Secondary: Total Suspended Solids and volume of water	<p>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.</p> <p>Total Suspended Solids (TSS) are very small 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 Sarah.</p> <p>Volume of water: Higher runoff volumes and velocities can carry greater amounts of TSS and dissolved phosphorus to Lake Sarah. Reductions in volume will reduce total phosphorus loads to Lake Sarah.</p>
Cost	Each retrofit practice has been analyzed for the annual cost per pound of phosphorous load reduction into Lake Sarah. Cost includes installation, annual maintenance, life expectancy, design and project oversight.
Watershed location	All projects have been analyzed to determine how much they would reduce the phosphorous load into Lake Sarah. The modeling estimates the amount of phosphorous that actually enters the lake by multiplying the modeled phosphorous load at the edge-of-field by a phosphorous delivery ratio. The phosphorous delivery ratio was determined by using maps that show the project location in the watershed, distance to Lake Sarah, 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 than 1.0.

Potential project types

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

Table 3: Potential project types for Dance Hall Creek 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
Water and sediment control basin	An earth embankment or a combination ridge and channel generally constructed across the slope and minor watercourses to form a sediment trap and water detention basin.	RUSLE 2/ BWSR Pollution Reduction Estimator
Wetland restoration	Restoring hydrology to cropland areas that have been partially or completely drained.	SWAT/NURP
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, and storage tanks for type and length of	MinnFARM/modeled average phosphorus yields/ RUSLE2
Pond enhancement	Restoring or enhancing an urban pond to minimum design standards to restore nutrient and sediment removal efficiency.	SWAT/NURP
Hydrologic restoration	Creating new regional or local ponds to capture and treat runoff.	SWAT/NURP

Project profiles

Buffer strips

Buffer strips, sometimes referred to as filter strips, are areas of vegetation situated between a potential source of pollution and a body of water that receives runoff, as shown in Figures 4 and 5. Runoff may carry sediment, organic matter, plant nutrients and pesticides that are either bound to the sediment or dissolved in the water. A properly designed and operating buffer strip protects water quality by reducing the amount of sediment, organic matter, nutrients and pesticides in the runoff at the edge of the field before the runoff enters the body of water.

Buffer strips are often constructed along the boundaries of cropland and streams, lakes, ponds or wetlands. This not only helps remove pollutants from the runoff but also serves as habitat for wildlife and provides an area for field turn rows and haymaking. In some instances, a buffer strip could be used as pasture as long as livestock are fenced out of the stream or lake. Buffer strips also prevent erosion because the vegetation covers an area of soil that otherwise might have a high erosion potential.

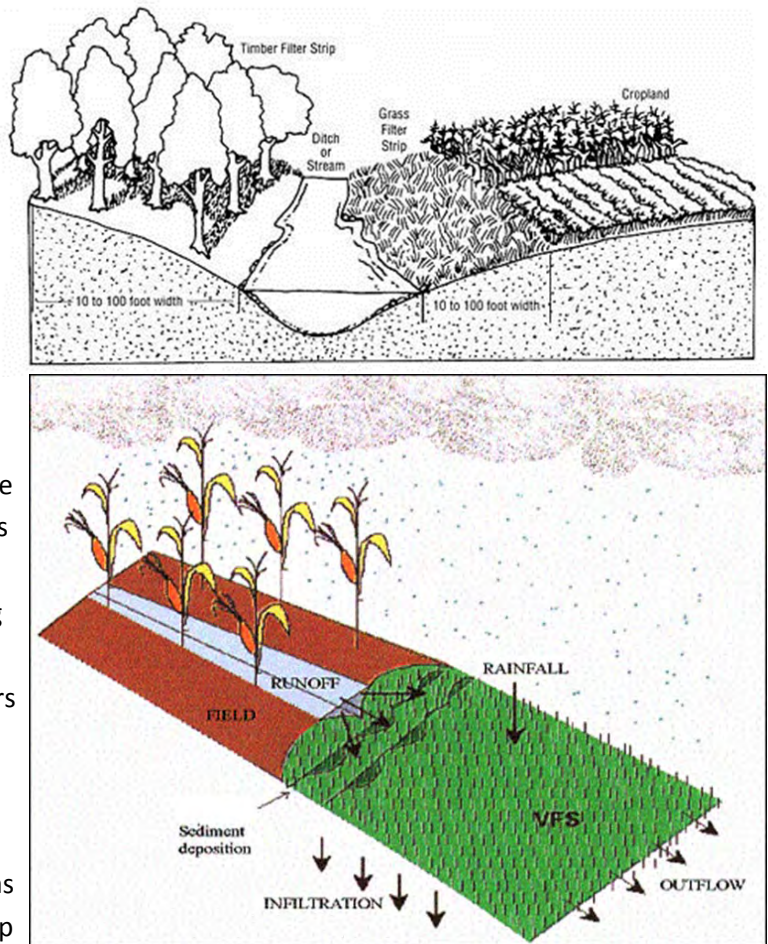
Buffer strips are often used in conjunction with other agricultural and land best management practices, such as contour plowing, pest scouting, conservation tillage, crop rotations, strip cropping, soil testing, and proper nutrient and pest management. Most field research supports the use of buffer strips with widths ranging from 10 to 40 feet depending on the receiving water and amount of flows it is designed to intercept.

Buffer strips are proposed in areas where active agricultural activities are occurring near a body of water 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, the type of vegetation in the strip, the width of the strip, the distance to the stream or wetland, and the distance to Lake Sarah.

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 to 20 years. The life span is determined by the amount of soil or sediment that the grass in the filter strip traps. Eventually the cropland at the edge of the filter strip and the filter strip itself needs 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 in the buffer strip at least once per year. Harvesting should be done after August to protect nesting birds.

Figure 4 and 5: Examples of design and operation of vegetated buffer strips



Dance Hall Creek 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), is calculated in pounds and is measured 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

Some of the phosphorous reduction benefits from the buffer strips will be diminished depending on the distance between the buffer strip and Lake Sarah. The vegetated buffers were further analyzed to determine the reduction of phosphorus that would reach Lake Sarah, which is the phosphorous delivery ratio (PDR). The PDR was estimated for each site by considering the location and distance of the buffer strip from Lake Sarah, flow restrictions, aerial photographs, topography and the type of nutrient available for transport (soluble versus particulate). Each buffer site was assigned a PDR ranging 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 Sarah. The phosphorus load that actually reaches Lake Sarah was estimated by multiplying phosphorus reduction at the edge of the field and the PDR.

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.

Dance Hall Creek specific buffer assumptions

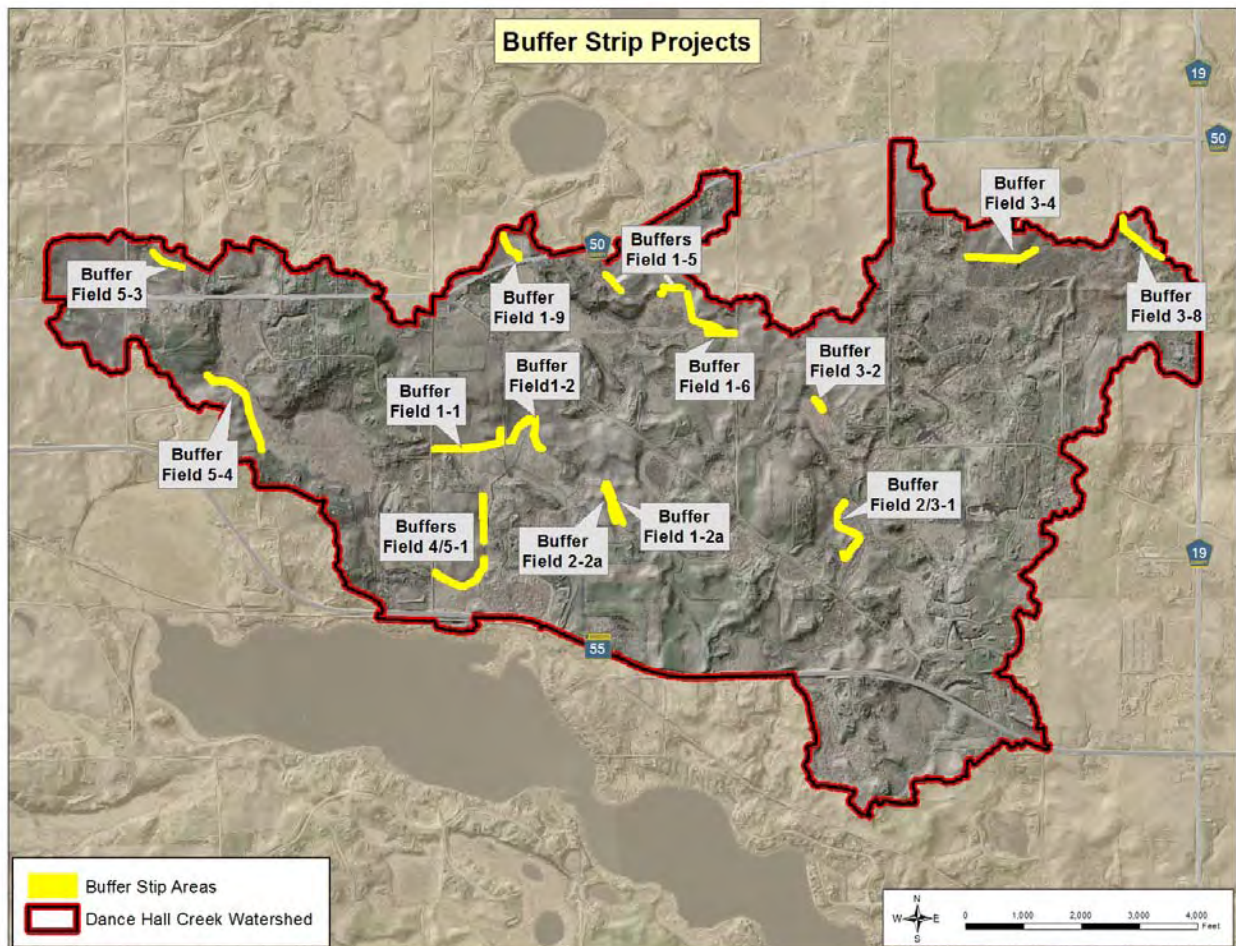
- Buffer width = 35 feet
- Buffer length: varies
- Project lifespan = 10 years
- Cost (estimated by the Metropolitan Association of Conservation Districts' BMP Cost Estimator):
 - Construction cost = \$350/acre
 - 10-year maintenance cost = \$100/acre
 - 1-year production cost lost = \$800/acre
 - Design, 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 4 shows the estimated phosphorus reduction entering Lake Sarah from the fields analyzed and the associated cost for the life span of the project due to the implementation of buffer strips.

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

Field ID	Buffer		Area up-stream of buffer	Total 10-year cost	Average soil loss from contributing field	P reduction	PDR	Phosphorus reduced to Lake Sarah	Cost of P reduction to Lake Sarah for lifespan of practice
	Length	Area							
	(ft)	(acres)							
1-2a	750	0.60	6.9	11,250	4.8	12.80	0.9	11.2	100
2-2a	630	0.51	2.3	10,355	5.1	5.80	0.9	5.2	200
5-4	1,750	1.40	20.0	17,830	11.0	69.00	0.2	13.8	129
1-1	1,400	1.10	7.6	15,295	4.0	11.75	0.6	7.1	215
1-2	1,760	1.40	12.8	17,830	6.1	27.60	0.6	16.6	107
1-5	925	0.75	4.6	12,350	8.0	12.25	0.4	4.9	252
3-2	250	0.20	1.7	7,690	18.0	8.70	0.5	4.4	175
3-8	230	0.20	2.9	7,690	9.2	8.70	0.2	1.7	452
1-6	1,175	1.00	7.4	14,450	14.3	32.00	0.4	12.8	113
3-4e	875	0.7	10.0	12,195	6.1	22.9	0.3	6.9	177
5-3	600	0.5	3.6	10,225	12	13.7	0.2	2.74	373

Figure 6: Location of proposed buffer strips



Grassed waterways

Grassed waterways are constructed, graded channels that are seeded to grass or other suitable vegetation. Grassed waterways are designed to slow the flow of water, conveying it to a stable outlet at a non-erosive velocity. Grassed waterways significantly reduce gully erosion by protecting the soil from concentrated flows. The vegetation may also act as a filter, absorbing some of the chemicals and nutrients in runoff water, and provide cover for small birds and animals.

In the construction of grassed waterways, a natural drainage is graded and shaped to form a smooth, bowl-shaped channel and is seeded with sod-forming grasses. Runoff flows across the grass rather than eroding the soil and forming a larger gully. An outlet is often installed at the base of the drainage to stabilize the waterway and prevent a new gully from forming.

The expected lifespan of a grassed waterway is 10 to 20 years. The lifespan is 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.



Example of well-functioning grassed waterway.



Example of gully erosion that is commonly observed in this watershed.



Example of channelized erosion in cropland where a waterway or water and sediment control basin would be recommended.

Dance Hall Creek grassed waterway analysis parameters

Grassed waterway siting

Areas that would benefit from a grassed waterway were determined by in-field site observations, topographic information (LiDAR) and analysis of aerial photographs. Visual evidence was gathered by observations of the sites in the spring of 2014 during and after runoff-generating rainfall events.

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

In areas that could not be observed in the field, photographic evidence of erosion scars in cropland for two out of four years, along with the LiDAR indicators mentioned above, were used.

Phosphorus reductions

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

- Soil type: Silt was used for all sites
- Soil loss (volume) per year: For all waterways, it was assumed that the channel erosion consisted of a 3-inch deep and 5-foot wide triangular shape (0.625 cubic foot per foot of waterway) on an annual basis.
- Gully (waterway) condition:
 - It was assumed that the sediment from the waterway would fan out before entering the receiving waters; therefore, they were considered to be non-channelized for the purpose of the model.
 - Distance to receiving surface water, calculated in feet to main ditch or wetland (receiving water). This varies from site to site but was determined from measurements between the waterway and the receiving ditch system.
 - For the purpose of the model inputs, there was no filter/buffer strip upstream of waterway installation.

Phosphorus delivery ratio

The phosphorus delivery ratio is built into the gully stabilization program that incorporates items b and c above. No additional reductions to Lake Sarah were assumed beyond what the program calculated.

Cost basis for grassed waterways

Construction costs were estimated at \$4 per foot of waterway and include excavation and distribution of the material on-site, seeding and mulching.

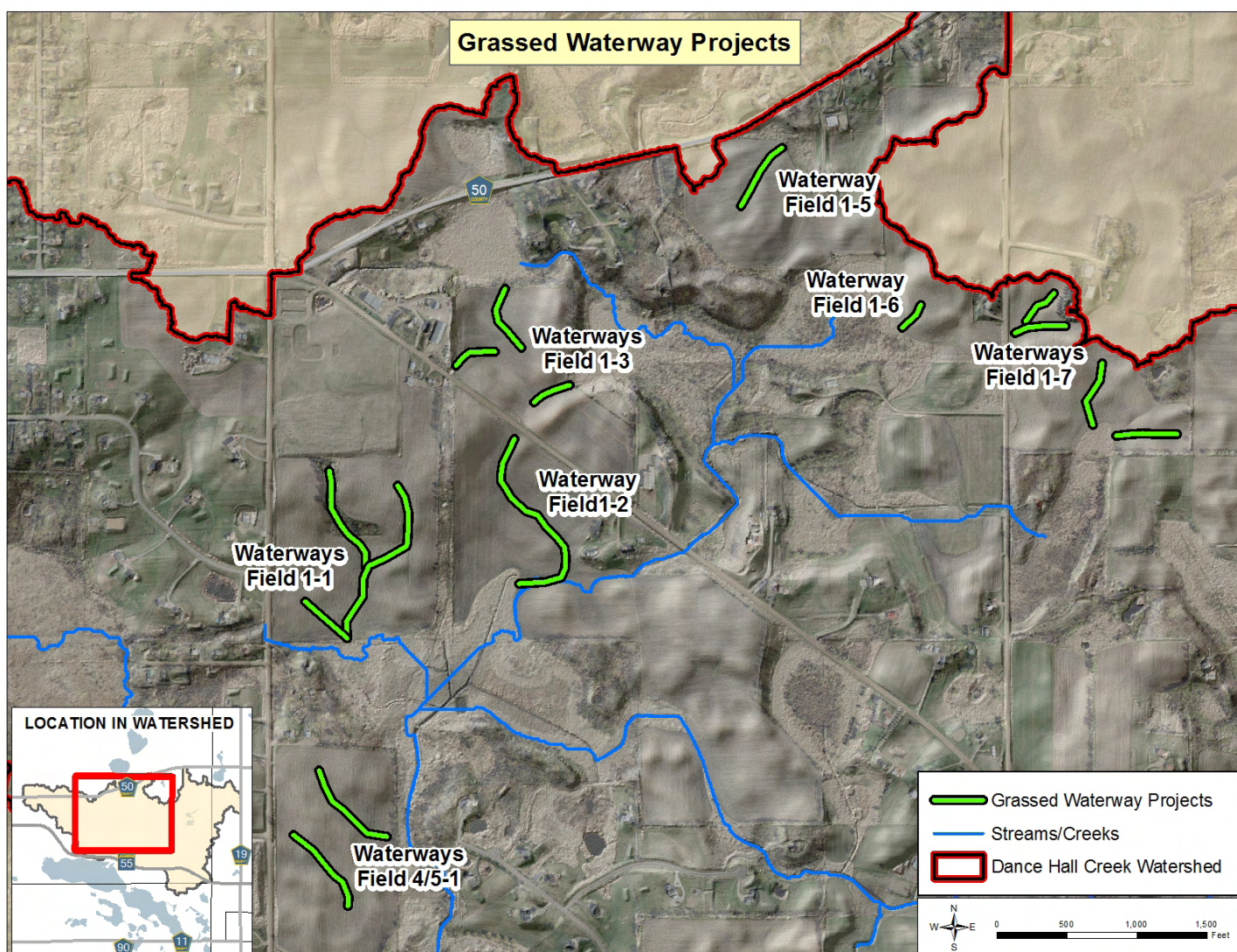
Maintenance costs were estimated at \$0.25 per year per foot of waterway and include repair, reseeding and weed controls. The lifespan of vegetated waterways is a minimum of 10 years.

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

Table 5: Phosphorous reduction to Lake Sarah 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 Sarah	Cost of P reduction to Lake Sarah for the life span of the practice
	(ft)	(\$)	(lbs/year)	(ft)	(lbs/year)	(\$/lbs)
1-1	2,365	17,500	18.7	350	18.7	94
1-2a	1,450	11,105	14.9	100	14.9	75
4 & 5-1	1,375	10,750	14.1	100	14.1	76
1-3	1,050	8,505	9.1	800	9.1	94
1-5	525	5,100	3.1	1,350	3.1	165
1-6	225	3,150	1.9	250	1.9	166
1-7	1,625	12,243	10.3	1,000	10.3	120

Figure 7: Location of proposed grassed waterway projects



Gully stabilization

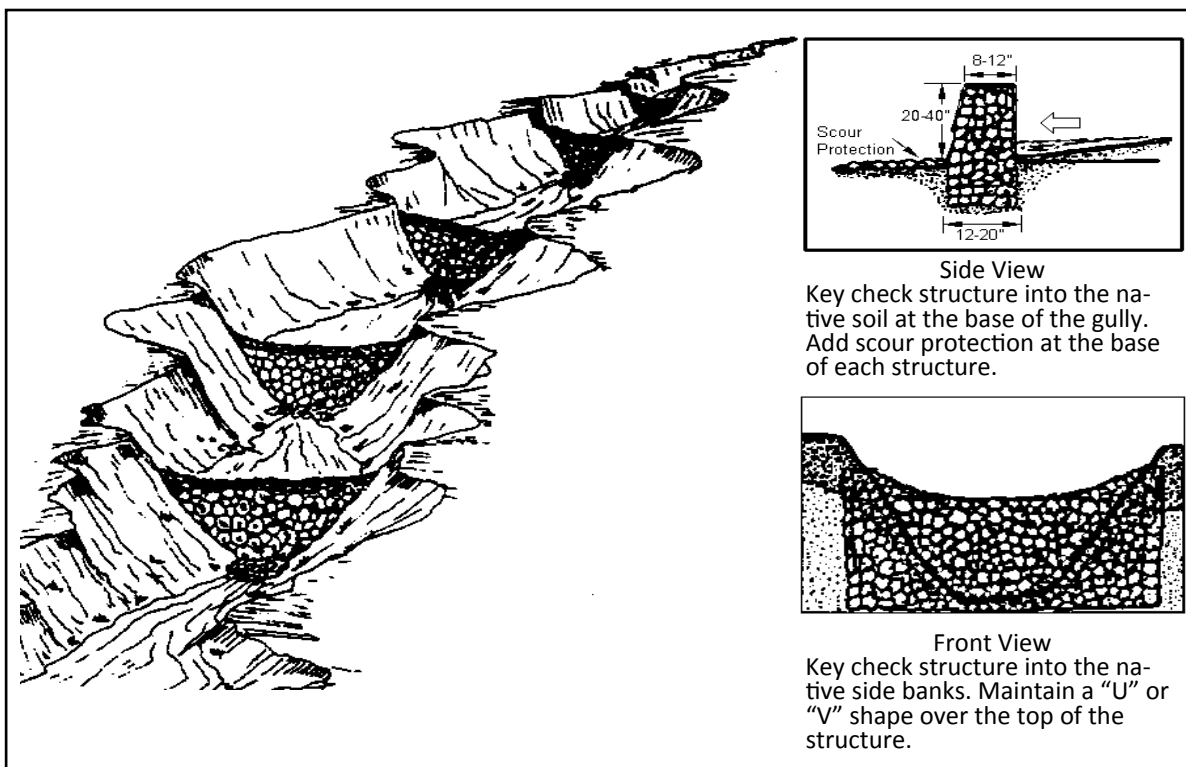
Gullies are a specific form of severe erosion typically caused by concentrated water flow on erosive soils. Concentrated water flow may begin as minor sheet flow that produces rills and eventually results in major gully formation. Gullies can have major impacts on an area by taking land out of production, 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.



Example of gully formation in a farm field.

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 measures for physical protection as well as additional long-term root support and aesthetics.

Figure 8: Example of construction of a gully stabilization project



Dance Hall Creek gully stabilization analysis parameters

Gully locations

Gully erosion sites in the Dance Hall Creek Watershed that would benefit from gully stabilization projects were determined by in-field site observations, topographic information (LiDAR) and analysis of aerial photographs. Visual evidence was gathered during observations in the spring of 2014. Topographic evidence was based on LiDAR indicators, including incised topographic settings and well-defined drainage areas leading to water collection flowage areas. In areas we could not observe in the field, photographic evidence of erosion scars, sediment fans and the LiDAR indicators mentioned above were used.

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), is calculated in pounds and is 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.) Two distinct gully formations were observed within the watershed:
 - Slight yearly recession rate: Generally described as a gully with some bare banks but where active erosion is not readily apparent. Some rills and minimal tree root exposure are evident. Slight recession rates vary from 1/2 to 3/4 inch per year along the wetted perimeter of the gully. The annual average slight gully recession rate was assumed to be 5/8 inch (0.05 feet) per year.
 - Moderate yearly recession rate: Generally described as a gully with predominantly bare banks with some rills and vegetative overhang. Some exposed tree roots are evident. Moderate recession rates vary from 3/4 inch to 3 1/2 inches per year along the wetted perimeter of the gully. The annual average moderate gully recession rate was assumed to be 1 inch (0.083 feet) per year.
- Gully conditions: Assumed to be channelized with no filter/buffer strips upstream.
- Wetted perimeter of the gully: Assumed to be 5 feet for all gullies. Assumed to have rectangular shape, 2-foot bottom, and 1.5-foot vertical side banks.

Phosphorus delivery ratio

Some of the phosphorous reduction benefits from the gully stabilization projects will be diminished depending on the distance between the gully and Lake Sarah. The gully stabilization projects were analyzed to determine the reduction of phosphorus reaching Lake Sarah, which is the phosphorous delivery ratio (PDR). The PDR was estimated for each site by considering the location and distance of the gully from Lake Sarah, 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 Sarah. The phosphorous load that actually reaches Lake Sarah was estimated by multiplying the phosphorus reduction at the bottom of the gully and the PDR.

Cost basis for gully stabilization

Construction costs were estimated at \$90 per linear foot for moderate recession rate gully controls and \$50 per linear foot for slight recession rate gully controls. Moderate recession rate projects would generally consist of clearing, grubbing, shaping, installing riprap-lined channels, constructing check dams and completing restoration work. Projects with slight recession rate gullies usually involve constructing check dams, minimal placing of riprap and more restoring vegetation.

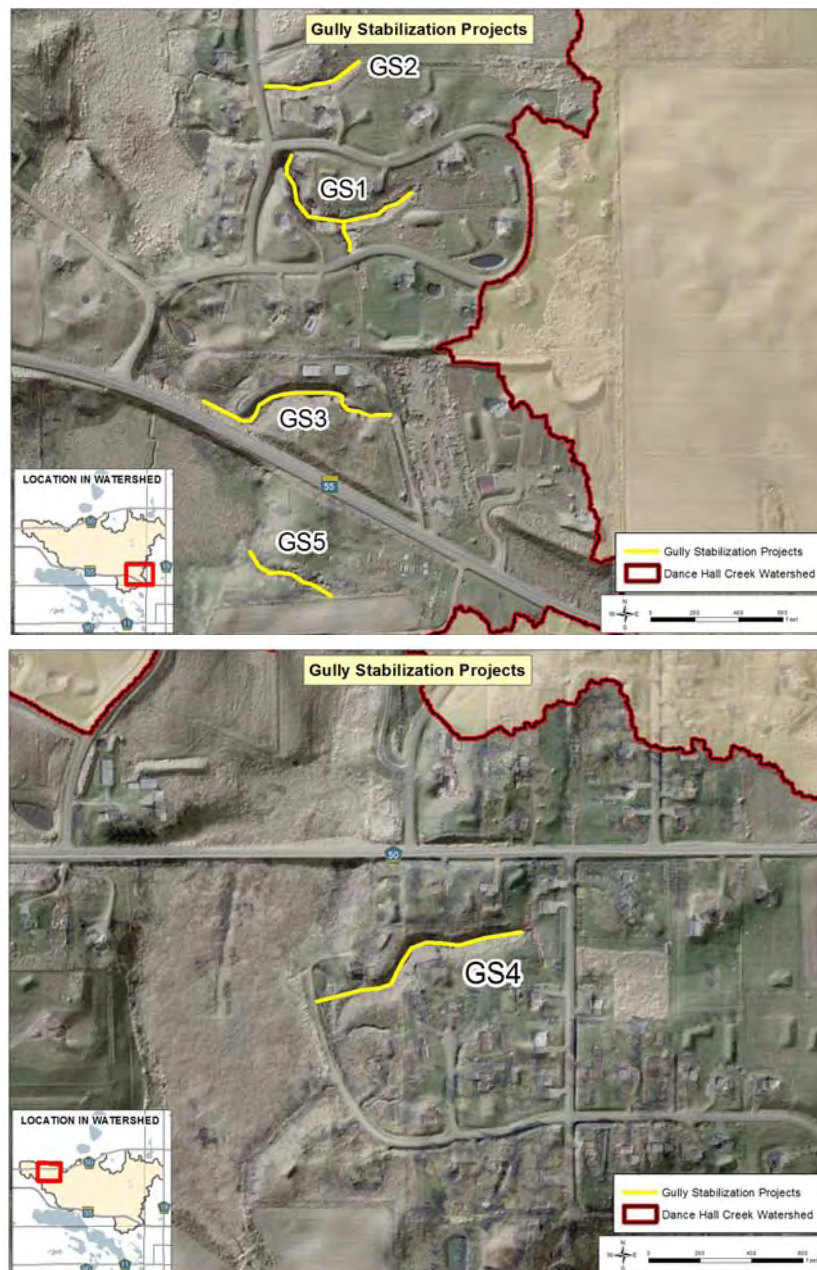
Design and oversight costs were estimated at a \$5,000 lump sum per gully site and include scoping work, survey, staking, design and construction inspection.

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 6: 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 Sarah	Cost of P reduction to Lake Sarah for lifespan of the practice
	(ft)	(ft ³ /year)	(lbs/yr)	(\$)		(lbs/yr)	(\$/lbs)
GS1	950	Moderate	16.75	\$93,000	0.3	5.0	\$1,860
GS2	400	Slight	4.25	\$27,500	0.3	1.3	\$2,115
GS3	950	Moderate	16.75	\$93,000	0.3	5.0	\$1,860
GS4	850	Moderate	15.00	\$84,000	0.2	3.0	\$2,800
GS5	430	Slight	4.60	\$29,000	0.1	0.5	\$5,800

Figure 9: Location of proposed gully stabilization projects



Water and sediment control basins

Water and sediment control basins are a series of small embankments built perpendicular to concentrated flow paths on cropland. Sediment-laden runoff entering the basin is stored and then slowly released through an underground outlet. The sediment settles out in the basin.

Water and sediment control basins are commonly built in a parallel series crossing the watercourse in several places in order to trap runoff and sediment while preventing the watercourse from becoming a gully.

The basins can be designed to be farmed. The intakes that meter the water out are typically a plastic perforated stand pipe about 4 feet high.



Example of a typical water and sediment control basin layout.

Water and sediment control basin specific site analysis

Field 1-7

- Drainage area above and below basin = 6.5 acres
- Soil loss reduction = 19.5 tons/year
 - Before average soil loss in field (measurement 1 and 2) = 6.6 tons/ac/yr = 42.25 t/year (Based on RUSLE)
 - Average soil loss above and below basin after install = 3.5 tons/ac/yr=22.75. (Based on RUSLE2)
 - Per BWSR guidance, assume 1 pound of phosphorus per ton of soil loss = 19.5 lbs of phosphorus reduction
- Cost is based on Metropolitan Association of Conservation Districts BMP cost estimator for water and sediment control basin 0-10 acre drainage area

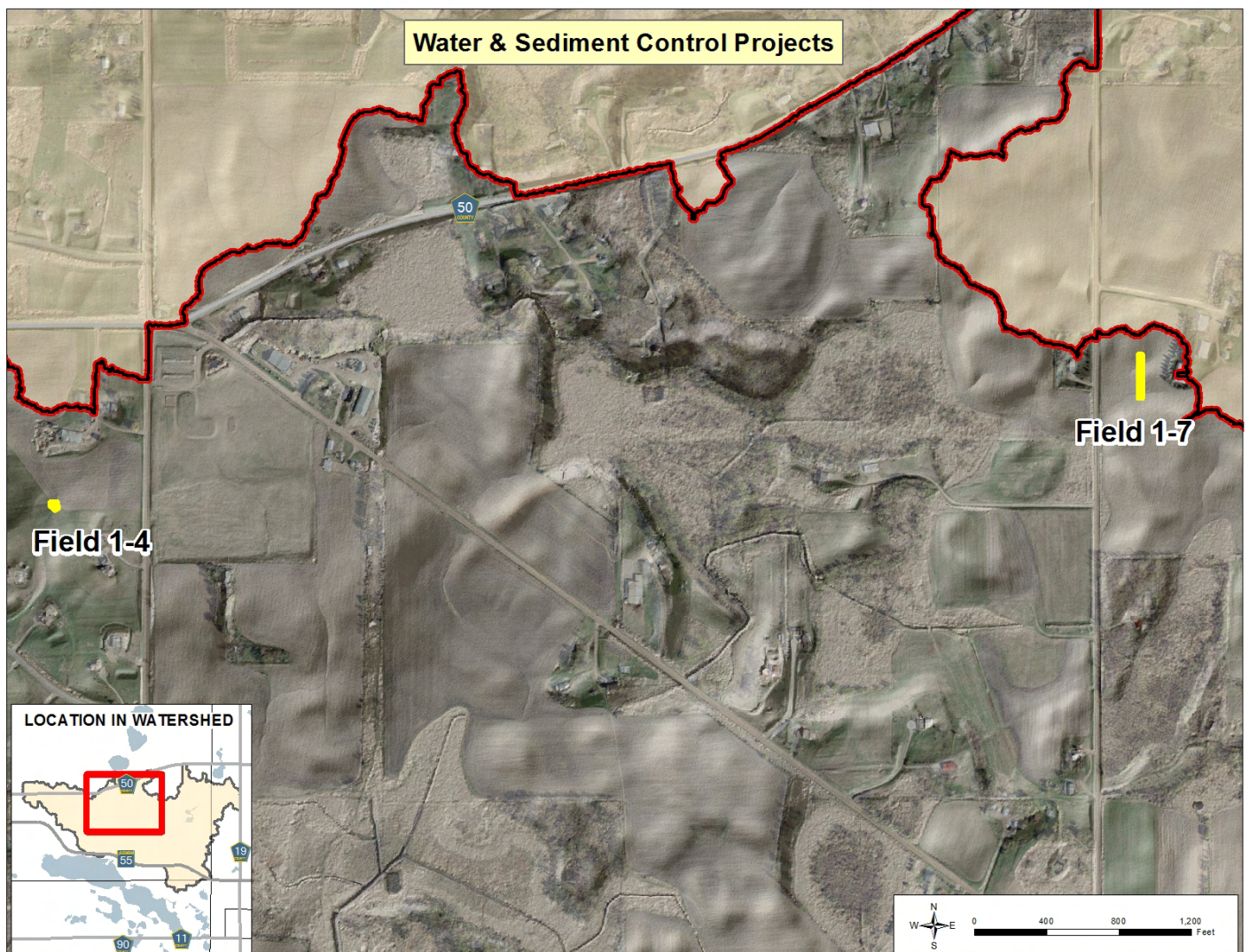
Field 1-4

- Drainage area above basin = 11.3 acres
- Soil loss reduction = 0 tons/year. No soil reduction because existing off-site grass areas act as buffer.
 - Before average soil loss in field = 3.8 tons/ac/year
 - Average soil loss above and below basin after install = 3.8 tons/acre per year

Table 7: Phosphorous reduction to Lake Sarah and associated costs of proposed water and sediment control basins

Field ID	Total area of protection above and below W&SCB	Total 10-year cost	P reduction	PDR	P reduced to Lake Sarah	Cost of P reduction to Lake Sarah for lifespan of the practice
	(acres)	(\$)	(lbs/year)		(lbs/year)	(\$/lb)
1-7	6.5	\$15,375	19.5	0.4	7.8	\$197
1-4	11.3	\$14,478	0	N/A	N/A	N/A

Figure 10: Location of proposed water and sediment control basins



Wetland restoration and enhancement

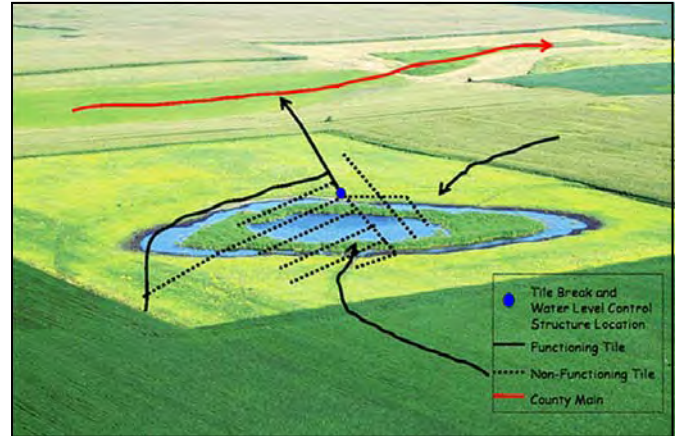
Wetland restorations involve reestablishing or repairing the hydrology, plants and soils of a former or degraded wetland to as close to the original natural condition as possible. These are wetlands that have been drained, farmed or otherwise modified. Restoring wetlands has numerous environmental benefits, especially to store water and absorb nutrients. The PondNet model was the primary tool used to analyze the proposed wetland projects.

Wetland restoration analysis parameters

Lifespan was assumed to be 10 years.

Cost assumptions

- Installation = \$7,500 lump sum
- Easement = \$20,000/acre
- Design and administration = \$15,000 lump sum
- Maintenance = \$10,000 over 10-year lifespan

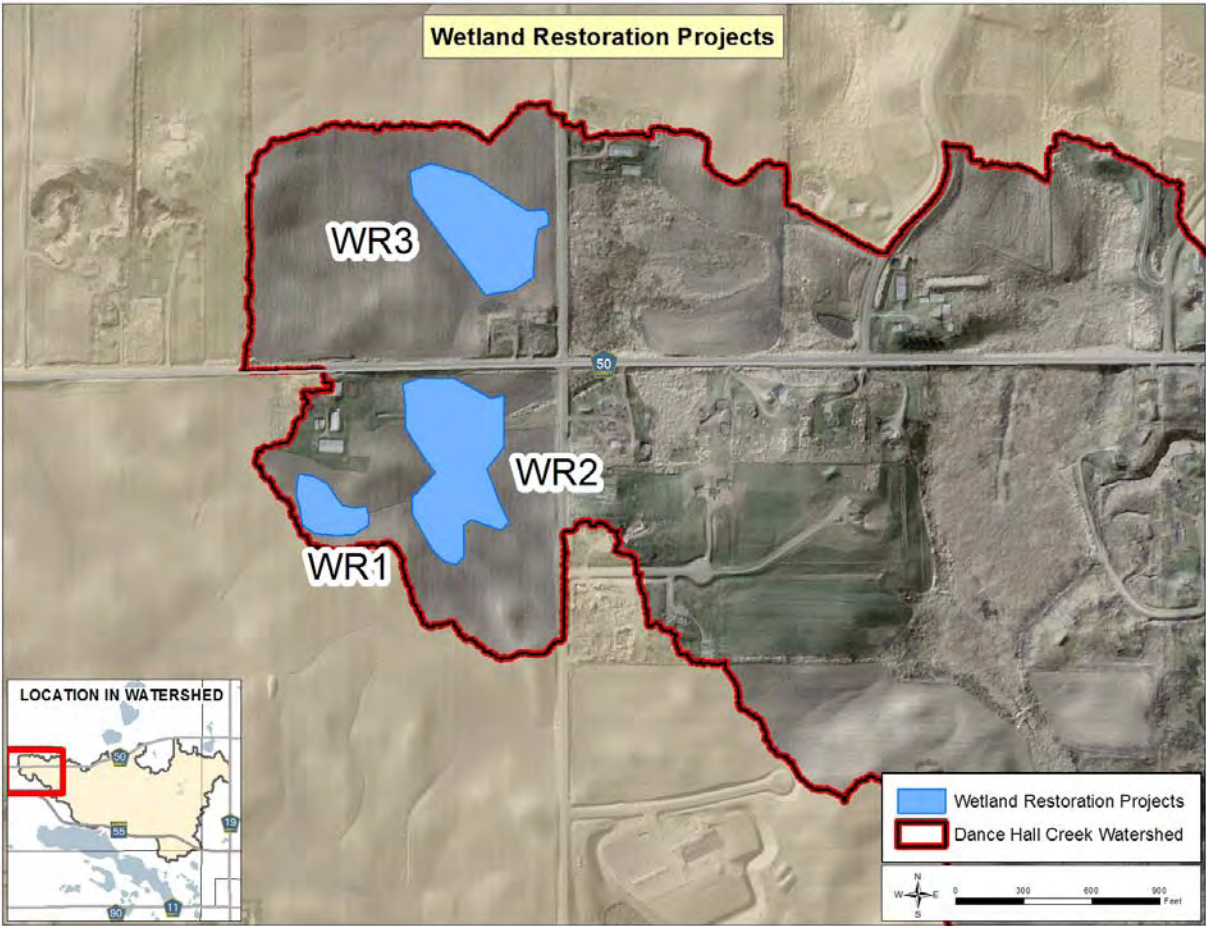


Example of wetland restoration project.

Table 8: Phosphorous reduction to Lake Sarah and associated costs of proposed wetland restorations

Wetland ID	Total area of wetland	Avg. pool elevation and depth	Structure	Volume of storage	P reduction	PDR	P reduction to Lake Sarah	Cost of P reduction to Lake Sarah for lifespan of the practice
	(acres)	(feet)		(acre-feet)	(lbs/yr)		(lbs/yr)	(\$/lbs)
WR/HR 1	1.2	1034.0-2.0	Box weir	2.4	3.8	0.1	0.25	\$1,290
WR/HR 2	2.7	1026-1.0	Box weir	2.7	21.6	0.1	2.16	\$4,005
WR/HR 3	5.1	1025	Water control	7.65	24.3	0.1	2.43	\$5,534

Figure 11: Location of proposed wetland restorations



Livestock best management practices

The Dance Hall Creek Subwatershed has both production and non-production livestock facilities, which differ in the numbers and needs of the animals as well as the management practices and goals. A primary distinction is that production animals are raised for commercial purposes for meat and milk while non-production animals are raised primarily for hobby. Table 8 characterizes the similarities and differences between production and non-production livestock facilities.

Each livestock facility is unique in its needs and requirements, and each producer or landowner may have different operational procedures and expectations from their operation. To understand the needs and objectives of producers, a detailed analysis of the facilities must be conducted in cooperation with the producer before specific projects are implemented. This would be done by surveying and interviewing the producers and then following up with a site investigation before.

MinnFARM, RUSLE2 and BWSR water pollution calculators were used to model the nutrient loads to Dance Hall Creek and Lake Sarah from livestock facilities based on the site conditions, field observations, topography and aerial photo analysis.

It was assumed that non-production livestock facilities (i.e., horses) would not have a managed manure storage or disposal system. Manure storage primarily consisted of onsite stacking with no protections. However, disposal of manure may occur if the opportunity arose.

Production facilities (i.e., dairy, beef) were assumed to have managed, short-term (1 or 2 month) storage and disposal systems. It was further assumed that manure, crop and land nutrient needs were analyzed infrequently by the landowner (every 4 or more years).

Table 9: Parameters for livestock facilities

Facility parameters	Production livestock	Non-production livestock
Livestock health needs		
Animal nutrition	✓	✓
Animal housing	✓	✓
Animal type/size/ location of facility	✓	✓
Critical natural resource issues		
Wetlands	✓	✓
Streams	✓	✓
Lakes	✓	✓
Floodplains	✓	✓
Pasture management		
Area available	✓	✓
Food and nutrient requirements	✓	✓
Supplemental food/ forage	✓	✓
Timing and rotation	✓	✓
Manure storage and disposal		
Storage slab/pit	✓	✓
Manure spreading	✓	✓
Length of storage	✓	✓
Compost facility		✓
Scrape and haul services		✓
Nutrient management		
Nutrient management	✓	
Manure testing	✓	
Cropland soil testing	✓	
Crop fertility requirements	✓	
Application/spreading requirements	✓	
Application/spreading timing	✓	

Dance Hall Creek livestock facility analysis parameters

Non-production facilities

Unless otherwise noted, phosphorus and costs associated with non-production facilities are assumed as follows.

- Phosphorus assumptions:
 - Pasture management and exclusion fencing is adequate for each site based on aerial photo analysis.
 - Storage of waste materials, although uncontrolled, occurs on upland areas with minimal potential of surface water contamination.
 - An average of 2 lbs of phosphorus reduction entering Lake Sarah per site per year was assumed based on standard export models for phosphorus loads from uncontrolled storage facilities.
 - Compost bins were assumed to be the method of controlling nutrient loads from the existing non-production facilities. Compost bins were assumed to decrease phosphorus exports to Lake Sarah by 2 lbs. per year per facility unless otherwise noted.



Example of a compost bin for non-production or small site livestock facility.

- Cost assumptions for compost storage facility:

– Compost bin material and construction costs =	\$4,500
– Yearly compost bin maintenance cost =	\$ 250
– Design and oversight (5 hours at \$75/hour) =	<u>\$ 375</u>
– Total =	\$7,375

Production facilities

The watershed contains three larger production facilities. One facility was not analyzed because pasture, storage and nutrient management appeared to be adequate. The facility is located on the far eastern edge of the watershed outside of the City of Greenfield and the legal boundary of the Pioneer-Sarah Creek Watershed and has a very low phosphorus delivery. The other two facilities were analyzed separately using MinnFARM, RUSLE2 and standard model export coefficients. Based on these export coefficients, it was assumed that production pastures would export about 2 pounds per acre of phosphorus per year. Refer to Figure 12 for the locations of the livestock facilities;

Figure 12: Location of proposed livestock management projects

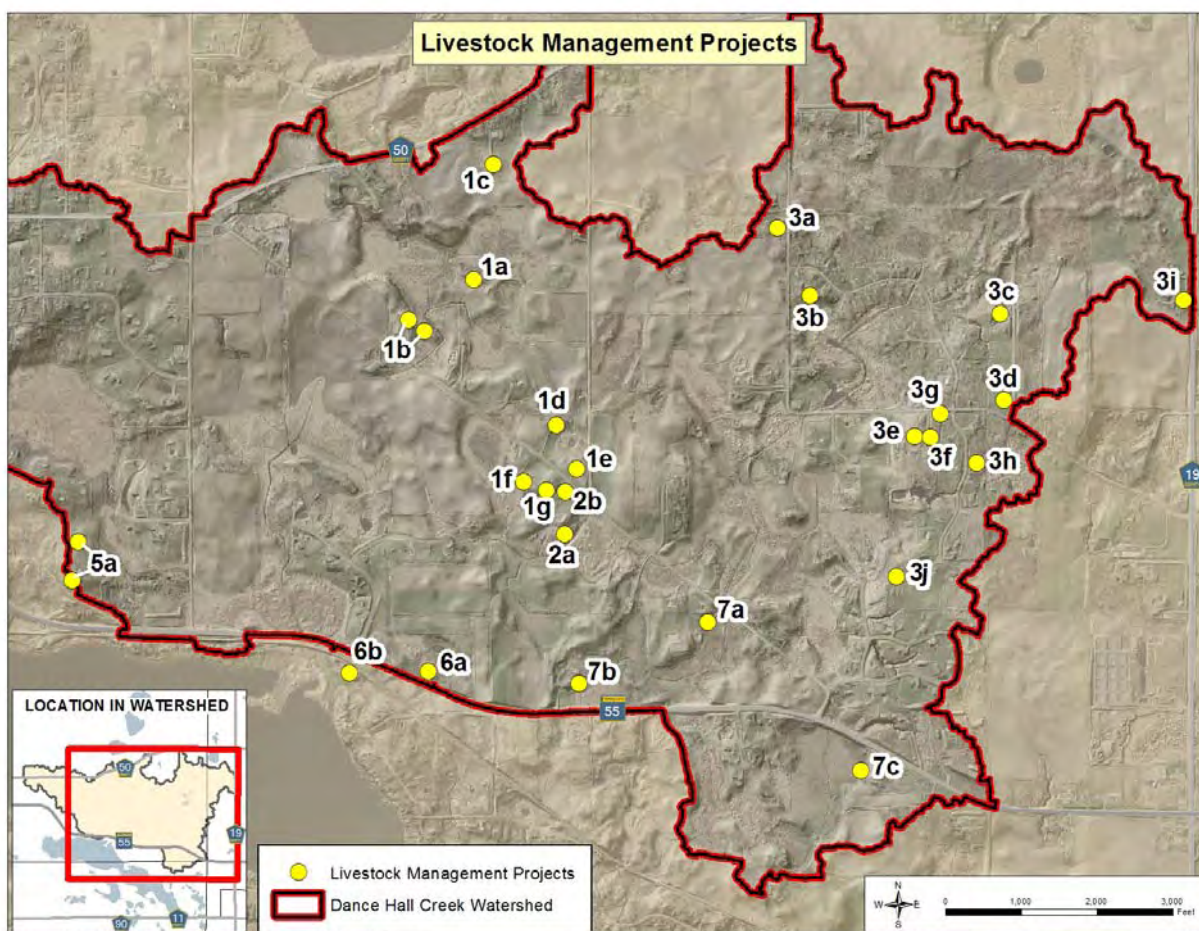


Table 10: Phosphorous reduction to Lake Sarah and associated costs of proposed livestock projects

Project ID	Retrofit type	P reduction	PDR	P reduction to Lake Sarah	TSS reduction	Volume reduction	Total project cost	Cost of P reduction to Lake Sarah for lifespan of the practice
	(refer to catchment profile pages for additional detail)	(lb/yr)		(lb/yr)	(lb/yr)	(ac-ft/yr)	(includes 10-year maintenance)	(\$/lbs)
Livestock 2a	Exclusion fence	11.5	1.0	11.5	N/A	N/A	\$5,375	\$47
Livestock 7c	Exclusion fence	48	0.4	19.2	N/A	N/A	\$12,650	\$66
Livestock 7b	Exclusion fence	55.4	1	55.4	N/A	N/A	\$42,750	\$78
Livestock 7a	Prescribed grazing	1	1	1	N/A	N/A	\$800	\$80
Livestock 7b	Nutrient management system	17.5	1	17.5	N/A	N/A	\$19,200	\$110
Livestock 7b	Clean water diversion	16.5	0.75	12.4	N/A	N/A	\$15,000	\$121
Livestock 6a	Manure storage system/compost bin	4	1	4	N/A	N/A	\$7,375	\$185
Livestock 7a	Compost bin/storage for 10-15 horses	5	1	5	N/A	N/A	\$10,600	\$212
Livestock 5a	Compost bin for 4 or less horses	6	0.5	3	N/A	N/A	\$7,375	\$245
Livestock 3b	Manure storage system/compost bin	3	1	3	N/A	N/A	\$7,375	\$247

Table 10: Phosphorous reduction to Lake Sarah and associated costs of proposed livestock projects

Project ID	Retrofit type	P reduction	PDR	P reduction to Lake Sarah	TSS reduction	Volume reduction	Total project cost	Cost of P reduction to Lake Sarah for lifespan of the practice
	(refer to catchment profile pages for additional detail)	(lb/yr)		(lb/yr)	(lb/yr)	(ac-ft/yr)	(includes 10-year maintenance)	(\$/lbs)
Livestock 3b	Livestock exclusion fencing	1	1	1	N/A	N/A	\$2,500	\$250
Livestock 1a	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 1b	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 1c	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 1d	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 1e	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 1f	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 1g	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 2b	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 3a	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 3c	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 3d	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 3f	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 3h	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 6b	Manure storage system/compost bin	2	1	2	N/A	N/A	\$7,375	\$369
Livestock 2a	Manure storage system/compost bin	2.0	1.0	2.0	N/A	N/A	\$7,375	\$370
Livestock 7b	Manure storage system/concrete tank	2	1	2	N/A	N/A	\$75,000	N/A

Dance Hall Creek livestock facility individual site analysis

Area 1 livestock sites

- Livestock facility site 1a was considered a typical non-production facility with three horses based on of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.
- Livestock facility site 1b was considered a typical non-production facility with three horses in 2012 and five horses in 2006 and 2011 based on of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.
- Livestock facility site 1c was considered a typical non-production facility with four horses in 2012 and six to 10 horses in 2006, 2008 and 2011 based on of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.
- Livestock facility site 1d was considered a typical non-production facility with three horses based on of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.
- Livestock facility site 1e was considered a typical non-production facility with four horses based on review of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.
- Livestock facility site 1f was considered a typical non-production facility with two horses based on aerial of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.
- Livestock facility site 1g was considered a typical non-production facility with no animals but evidence of livestock from trails near barn based on of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.

Area 2 livestock sites

- Livestock facility site 2a was not considered a typical non-production facility because current and pasture and manure handling appears to be limited and current pasture/paddocks are within a floodplain and wetlands. The facility has two horses based on review of aerial photos.
 - The site has two main sources of phosphorus:
 1. Yearly flushing of livestock waste nutrients due to the flooding of the creek adjacent to the paddock/pasture area. According to the University of Minnesota Extension Service, two horses would yield about 100 pounds of phosphorus load per year. It was assumed that 10% of that load (10 pounds of phosphorous per year) would reach Lake Sarah.
 2. Yearly flushing from flooding also causes erosion scour and transfers nutrients into the creek system. About 3.4 acres of paddock area would be affected by erosion. This would result in 0.45 tons per acre of soil loss (RUSLE2 analysis) or a total of 1.53 tons soil loss per year. One ton of soil loss is equivalent to 1 pound of phosphorus per year, resulting in 1.53 pounds of phosphorus per year from this site.
 - Recommended BMP controls are:
 - o Exclusion fencing around the paddock and pasture areas from the wetland and floodplain of the creek.
 - o Compost bin for the manure storage system
 - Cost assumptions for Livestock site 2a:
 - o Exclusion fencing from wetland and floodplain areas:
 - Installation cost: 1,000 feet @ \$2.50/ft. = \$2,500
 - Design and oversight: 5 hours @ \$75/hr. = \$375
 - Maintenance: 0.25/ft./yr = \$250/year (\$2,500 for 10 years)
 - Total cost for exclusion fence = \$5,375
 - o Composting storage facility (typical) = \$7,375
- Livestock facility site 2b was considered to be a typical non-production facility with one to three horses based on review of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.

Area 3 livestock sites

- Livestock facility site 3a was considered a typical non-production facility with one horse based on review of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.
- Livestock facility site 3b was not considered a typical non-production facility because manure is currently stacked in a wetland so was not analyzed with different assumptions. The facility has one horse based on review of aerial photos.
 - Recommended BMP controls are:
 - Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 3 lbs/year.
 - Installing exclusion fencing around the wetland. Fencing out 0.5 acres of wetland would reduce phosphorous to Lake Sarah by 1 lb/year.
 - Cost assumptions for livestock site 3b:
 - Exclusion fencing from wetland:
 - Installation cost: 445 ft @ \$2.50/ft = \$1,113
 - Design and oversight: 5 hours @ \$75/hr = \$375
 - Maintenance: 0.25/ft./yr = \$111/year (\$1,110 for 10 years)
 - Total cost for exclusion fence = \$2,600
 - Composting storage facility (typical) = \$7,375
- Livestock facility 3c was considered a typical non-production facility with one or two horses based on review of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.
- Livestock facility site 3d was considered a typical non-production facility with two horses based on review of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.
- Livestock facility site 3e had no horses based on review of aerial photos.
- Livestock facility site 3f was considered a typical non-production facility with one or two horse based on review of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.
- Livestock facility site 3g had no horses based on review of aerial photos.
- Livestock facility site 3h was considered a typical non-production facility with two horses based on review of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.
- Livestock facility site 3i was a production facility but was non evaluated.
- Livestock facility 3j had no horses based on review of aerial photos.

Area 4 livestock sites

This area had no apparent livestock facilities.

Area 5 livestock sites

- Livestock facility site 5a was considered a typical non-production facility with three horses based on review of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.

Area 6 livestock sites

- Livestock facility site 6a was not considered a typical non-production facility because manure is currently stacked in a wetland so was analyzed with different assumptions. The facility has five horses based on review of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 4 lbs/year because it would both properly dispose of manure and eliminate the existing manure pile.
- Livestock facility site 6b was considered a typical non-production facility with five horses based on review of aerial photos. Implementing a compost bin BMP would reduce phosphorous to Lake Sarah by 2 lbs/year.

Area 7 livestock sites

- Livestock facility site 7a was not considered a typical non-production facility because current pasture and manure handling appears to be very limited. The facility has 11 animal units and four acres of pasture appears to be over-grazed based on review of aerial photos. Manure is stock piled adjacent to a wetland/stream area. The MinnFARM model estimates a yield of 1 lb of soluble phosphorus per year from the feedlot.
 - Recommended BMPs are:
 - o Properly storing manure with a larger compost bin and better manure storage location would reduce phosphorous to Lake Sarah by 4 lbs/year.
 - o Converting 4 acres of pasture to prescribed grazing would reduce phosphorous to Lake Sarah by 1 lb/year.
 - Cost assumptions for livestock site 7a:
 - o Compost bin and storage facility:
 - Compost bin and storage facility = \$6,000
 - Design and oversight: 8 hours @ \$75/hr = \$600
 - Maintenance: \$400/year (\$4,000 for 10 years)
 - Total cost for compost bin and storage facility = \$10,600
 - o Prescribed grazing
 - Plan development and installation: \$200/ac = \$800

- Livestock facility site 7b was considered a production facility with 80 animal units according to MPCA permit. It was assumed that this site had limited manure storage adequate for less than one month, limited nutrient management and excessive feedlot erosion. It was assumed that manure is spread over 70 acres of cropland and existing manure spreading is based on transportation time, field conditions and cropping convenience and time between applications, but not so much on soil nutrient needs.
 - The site has three main sources of phosphorus:
 1. Feedlot erosion: Soil loss prior to the BMP was estimated at 55 tons per acre (RUSLE2), and soil loss after the BMP was estimated at 33 tons per acre (RUSLE2). Total soil loss reduction would be 22 tons per acre. Using BWSR standard of 1 ton soil loss yielding 1 pound of total phosphorus, implementing feedlot BMPs would reduce phosphorous to Lake Sarah by 22 lbs/year.
 2. Pasturing in wetland: The site currently has 27 acres of pasture in wetlands under with a total annual phosphorous load of 54 pounds. Using exclusion fencing to remove 27 acres of wetland from pasturing would reduce phosphorous to Lake Sarah by 54 lbs/year.
 3. Nutrient and storage management on 70 acres of cropland: Average soil loss in the fields where manure was spread was assumed to be 2.4 to 3.2 tons per acre per year (RUSLE2). Nutrient and storage management would not reduce soil loss but would reduce soluble phosphorous by 0.25 lbs/acre annually . This would result in a total phosphorous reduction to Lake Sarah of 17.5 lbs/year from 70 acres of cropland. A storage system is essential to prevent winter spreading of manure and associated spring runoff. Benefits of storage system improvements were not analyzed as part of this report.
 - Recommended BMPs for site 7b:
 - o Feedlot clean water diversion system
 - o Livestock exclusion fence
 - o Storage system and nutrient management plan
 - Cost assumptions for livestock site 7b:
 - o Feedlot clean water diversion system = \$14,072.50
 - Underground pipe system from wooded/grove area:
 - 12" HDPE pipe: 325 feet @ \$15/ft = \$4,875
 - Oversight and design = \$1,000
 - Maintenance: \$0.10/ft/yr = \$325 for 10-year lifespan
 - Total = \$6,200
 - Berm that is 75 feet long:
 - Construction: \$10/ft = \$750
 - Oversight and design = \$500
 - Maintenance: \$0.25/ft./yr. = \$187.50
 - Total = \$1,437.50

- Diversion and waterway outlet from feedlot to east of pole shed. 325 feet of diversion and 125 feet of waterway:
 - Construction of 325-foot diversion: $\$7/\text{ft} = \$2,275$
 - Design and oversight of diversion = \$850
 - Maintenance of diversion: $\$0.50/\text{ft.}/\text{yr} = \$1,625$ for 10-year lifespan
 - Total for diversion = \$4,750
 - Construction of 125-foot waterway: $\$4/\text{ft} = \500
 - Design and oversight of waterway = \$560
 - Maintenance of waterway: $\$0.50/\text{ft.}/\text{yr.} = \625
 - Total for waterway = \$1,685
 - Total for diversion and waterway = \$6,435
 - o Livestock exclusion fence
 - Construction of 8,400 feet of fencing: $\$2.50/\text{ft.} = \$21,000$
 - Design and oversight: 10 hours @ $\$75/\text{hr.} = \750
 - Maintenance: $\$0.25/\text{ft.}/\text{yr.} = \$21,000$
 - Total cost for livestock exclusion fence = \$42,750
 - o Storage system and nutrient management plan
 - Storage system for 80 animal units for 6 months. Assume 28,800 cubic feet of concrete tank. Total cost = \$75,000 - \$100,000
 - Nutrient management plan for 70 acres of cropland.
 - Crop consultant charge: $\$4,800/\text{yr.}$ for the first 2 years = \$9,600
 - Crop consultant charge: $\$1,200/\text{yr}$ for the remaining 8 years = \$9,600
 - Total cost = \$19,200
 - Total cost for storage system and nutrient management plan = \$94,200 - \$119,200
- Livestock facility site 7c was considered a production facility with 15 animal units based on review of aerial photos. Assume a yield of 2 lbs/acre of phosphorus per year from the pasture. Installing 2,425 feet of fencing to exclude livestock from 24 acres of wetland would reduce phosphorous to Lake Sarah by 48 lbs/year.
 - Cost assumptions for site 7c:
 - o Construction cost for 2,425 feet of fence: $\$2.50/\text{ft} = \$6,062.50$
 - o Oversight and design: 7 hours @ $75/\text{hr} = \$525$
 - o Maintenance: $\$0.25/\text{ft}/\text{yr} = \$6,062.50$
 - o Total cost = \$12,650

Pond excavation and maintenance

In the rural residential areas of the Dance Hall Creek Watershed, stormwater is conveyed to ponds through road ditches, culverts and storm sewer pipes. The receiving ponds were sized to achieve predefined water quality goals and are designed with controlled outflows to manage discharge rates. Water discharging from ponds flows through wetlands and/or stream channels before entering Lake Sarah.

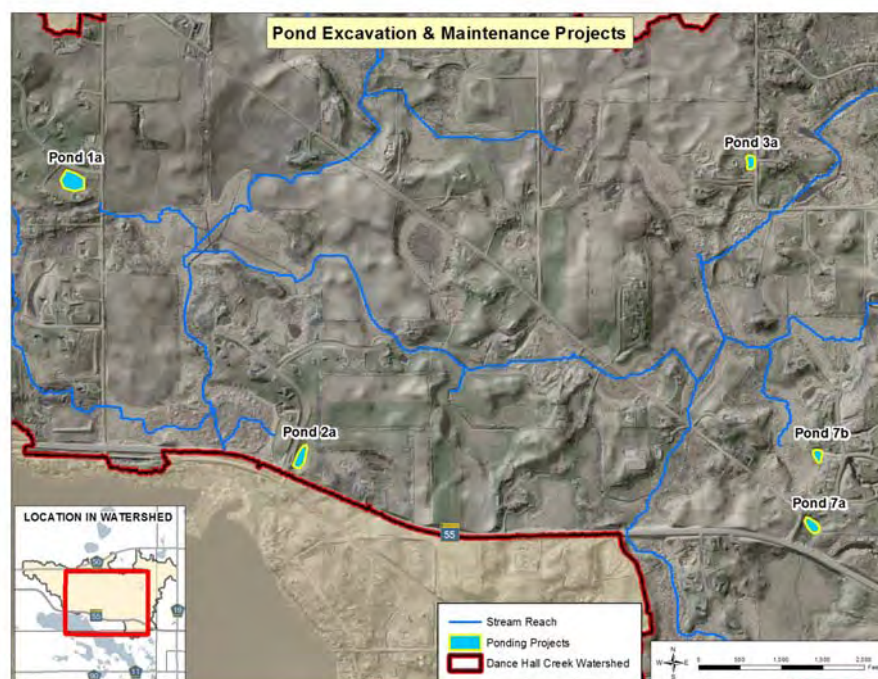
In undeveloped areas or areas developed prior to the establishment of ponding requirements, generally no ponding occurs except in existing wetland and depressed areas.

This reports analyzes opportunities to reduce phosphorus through new ponding or wetland restorations. It also examines opportunities to improve maintenance of or enhance existing stormwater ponds to reduce downstream pollutants. Before and after nutrient loads associated with pond excavations and maintenance were analyzed using the SWAT and NURP models.

Table 11: Phosphorous reduction to Lake Sarah and associated costs of proposed pond projects

Project ID	Retrofit type	P reduction	PDR	P reduction to Lake Sarah	TSS reduction	Volume reduction	Total project cost	Cost of P reduction to Lake Sarah for lifespan of the practice
	(refer to catchment profile pages for additional detail)	(lb/yr)		(lb/yr)	(lb/yr)	(ac-ft/yr)	(includes 10-year maintenance)	(\$/lbs)
Pond 1a	Pond 1a scour protection	2	1.0	2	4,000	N/A	\$6,000	\$300
Pond 1a	Pond excavation	3.5	1.0	3.5	7,000	N/A	\$52,400	\$1,497
Pond 3a	Pond excavation	2	0.3	0.6	4,000	N/A	\$13,800	\$2,300
Pond 7b	Pond excavation	2.2	0.3	0.7	N/A	N/A	\$23,000	\$3,285
Pond 7a	Pond excavation	0.2	0.1	0.02	N/A	N/A	\$19,200	\$87,500

Figure 13: Location of proposed pond excavation and maintenance



Pond excavation and maintenance site specific information

Pond 1a

- Assumptions:
 - Surface area = 0.73 acres
 - Mean average depth = 1.5 feet
 - Volume = 47,700 cubic feet
- Wet pond
 - To meet wet pond volume requirement:
 - o Surface area = 0.73 acres
 - o Excavate to a mean depth of 3.3 feet
 - o Volume at 3.3 feet depth = 104,950 cu ft
 - o Volume of excavation = 57,250 cu ft (2,120 cu yd)
 - o Assume MPCA level 1 dredge material (suitable for reuse on residential property)
 - o Assume replacement of outlet control structure
 - Cost assumptions:
 - o Testing of pond sediments = \$2,000
 - o Excavation: \$20.00/cu yd = \$42,400
 - o Restoration and erosion controls = \$5,000
 - o Outlet control structure modifications = \$3,000 w/ NURP pond, \$6,000 without
 - o Totals = \$52,400
- Scour
 - Scour occurs at outlet pipe to pond. Assume scour and re-suspension of soil materials at scour point to be approximately 2 lbs. of phosphorus per year (4,000 lbs soil displacement).
- Phosphorus reductions
 - Excavation: 6.4 lbs pre-excavation - 4.9 lbs post-excavation = 1.5 lb/year
 - Scour/re-suspension = 2 lbs/year



Pond 1a



Channel Scour at outlet to Pond 1a.

Pond 2a

- Assumptions
 - Surface area = 0.45 acres
 - Mean average depth = 0.5 feet
 - Volume = 9,800 cu. ft. (363 cu. yd.)
- To meet wet pond requirements:
 - Surface area = 0.45 acres
 - Excavate to a mean depth of 3.3 feet
 - Volume at 3.3 feet depth = 64,650 cu. ft. (2,395 cu. yd.)
 - Volume of excavation = 54,850 cu ft (2,032 cu yd)
 - Existing wetland- type 1 or type 2. Excavation is permissible per MN WCA.
 - Assume waste soil material on site.
- Costs
 - MPCA testing of material not necessary (level 1 material)
 - Excavation costs: \$3.5/cu yd = \$7,112
 - Restoration = \$750 lump sum
 - Operation and maintenance: \$250/year = \$2500 for 10-year lifespan
 - Total cost = \$10,500
- Phosphorus reduction: 25 lbs/yr pre-excavation - 18.2 lbs/yr post-excavation = 6.8 lbs/yr

Pond 7a

- Assumptions
 - Surface area = 0.25 acres
 - Mean average depth = 1.5 feet
 - Volume = 16,335 cu. ft.
- To meet wet pond requirements:
 - Surface area = 0.25 acres
 - Excavate to a mean depth of 3.3 feet
 - Volume at 3.3 feet depth = 635,950 cu. ft. (2,395 cu. yd.)
 - Volume of excavation = 19,615 cu ft (725 cu yd)
 - Assume MPCA level 1 dredge material (suitable for reuse on residential property)
 - Assume no replacement of outlet control structure

- Costs
 - Testing of pond sediment = \$2,000
 - Excavation \$20.00/c.y. = \$14,500
 - Restoration and erosion controls = \$1,000
 - Total = \$17,500
- Phosphorus reduction: 0.7 lbs/yr pre-excavation - 0.5 lbs/yr post-excavation = 0.2 lbs/yr

Pond 7b

- Assumptions
 - Surface area = 0.20 acres
 - Mean average depth = 2.0 feet
 - Volume = 17,425 cu. ft.
- To meet wet pond requirements
 - Surface area = 0.20 acres
 - Excavate to a mean depth of 5 feet
 - Volume at 5-foot depth = 43,560 cu. ft.
 - Volume of excavation = 26,135 cu ft (1,810 cu yd)
 - Assume MPCA level 1 dredge material (suitable for reuse on residential property)
 - Assume no replacement of outlet control structure
- Costs
 - Testing of pond sediment—\$2,000
 - Excavation \$20/cu yd = \$20,000
 - Restoration and erosion control = \$1,000 lump sum
 - Total cost = \$23,000
- Phosphorus reduction: 9.1 lbs/yr pre-excavation - 6.9 lbs/yr post-excavation = 2.2 lbs/yr

Pond 3a

- Assumptions
 - Surface area = 0.40 acres
 - Mean average depth = 0.5 feet
 - Volume = 8,712 cu. ft. (323 cu yd)
- To meet wet pond requirements:
 - Surface area = 0.40 acres
 - Excavate to a mean depth of 3.3 feet
 - Volume at 3.3 feet depth = 57,500 cu. ft. (2,130 cu. yd.)
 - Volume of excavation = 48,800 cu ft (1,810 cu yd)
 - Existing wetland type 1 or type 2. Excavation is permissible per MN WCA.
 - Assume waste soil material on site
- Costs
 - MPCA testing of material not necessary (level 1 material)
 - Excavation \$5/cu yd = \$9,050
 - Berm removal, add 0.1 acre forebay and riprap overflow into pond = \$1,500
 - Restoration = \$750 lump sum
 - Operation and maintenance: \$250/year = \$2,500 for 10-year lifespan
 - Total cost = \$13,800
- Phosphorus reduction: 4.3 lbs/yr pre-excavation - 2.3 lbs/yr post-excavation = 2.0 lbs/yr

Hydrologic restorations

The hydrologic system in most of the Dance Hall Creek Watershed has been altered by ditching and channelizing. Based on review of historic aerial photos, these altered conditions were created years ago. Most of these changes were made to improve drainage of water from the land in order to prevent flooding and increase crop production on marginal land. These practices are currently one of the major contributors to the poor quality of the water that drains to Lake Sarah from the Dance Hall Creek Watershed.



Additionally, recent monitoring shows that partially drained wetlands with organics soils can become large sources of phosphorous due to biochemical processes. This impact has been observed more in organic-soil wetlands with frequent wet and dry cycles. Managing wetland hydrology to maintain saturated conditions can reduce phosphorous discharge.

Current water management practices put greater emphasis on holding water on the landscape long enough to encourage infiltration, increase nutrient uptake, capture sediment and control discharge rates. Restoring hydrologic systems provides numerous benefits such as providing wildlife habitat, floodwater retention, groundwater recharge.



Example of a hydrologic restoration.

Restorations in the Dance Hall Creek Watershed typically involve plugging ditches and/or installing structures to control water levels. Depending on the site conditions, restorations can be straight-forward in both engineering and determining outcomes. Some may be more complex depending on the number of landowners that need to be involved.

Leadership from the City of Greenfield is needed to accomplish these large restoration products as most of the wetland restorations identified would take farmland or pastureland out of production. Although this provides additional water quality benefits, they cannot be accomplished without buy-in from and appropriate compensation to the property owner. Direct discussions with the landowners to identify their interest level and determine the necessary compensation are needed before moving forward with detailed engineering. Hennepin County staff is available to provide the technical information for these discussions to ensure that everyone clearly understands the decisions being made and the vision for the land after restoration.

The Dance Hall Creek Watershed has the space and conditions to incorporate restorations while involving a relatively limited number of property owners. Additionally, the extreme precipitation and water levels observed in 2014 gave landowners a vision of what conditions may be like in the future.

Costs for restorations can be variable and were estimated assuming a 20-year lifespan. Cost estimates for each restoration are assumed to be:

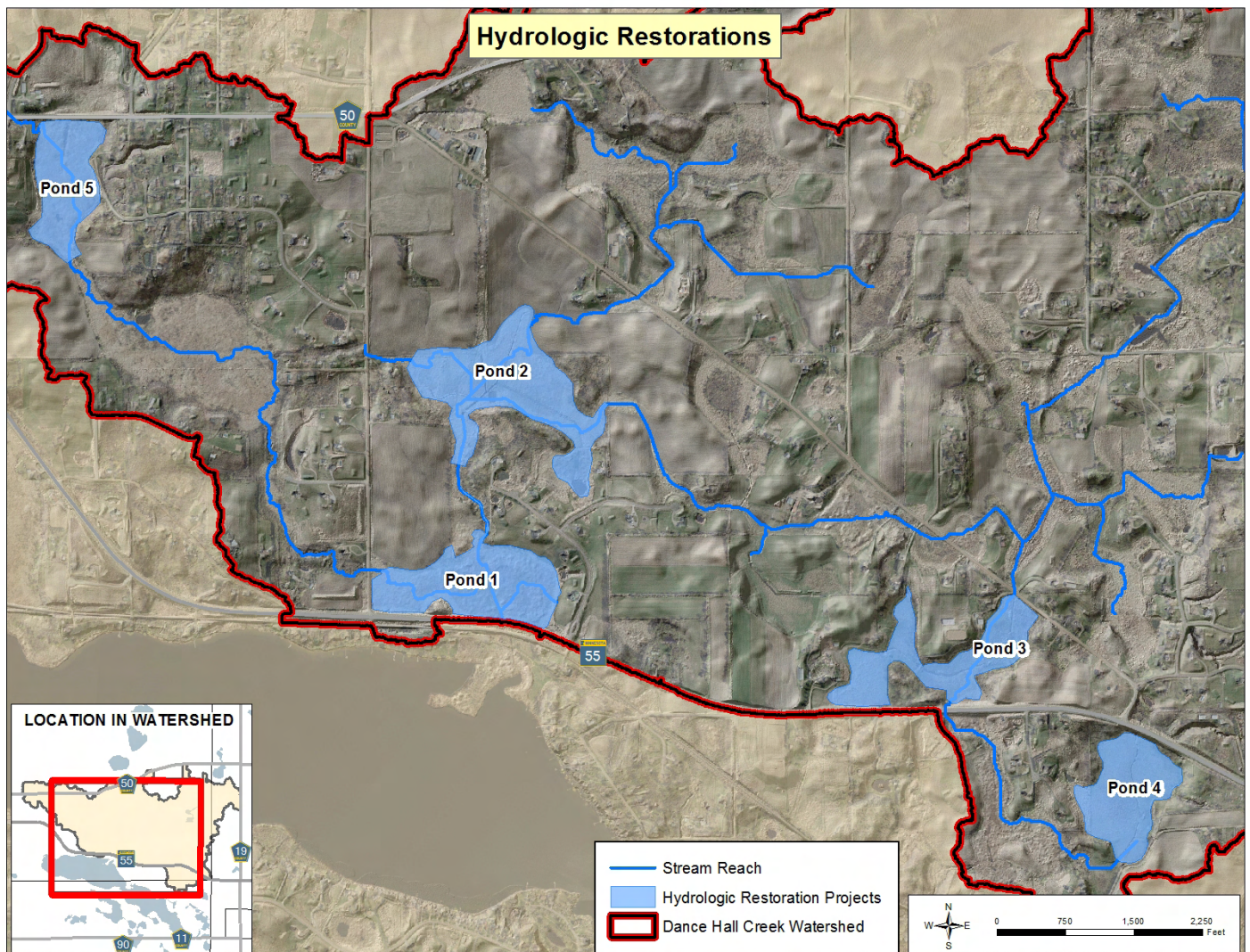
- Easement costs = \$5,000
- Project design and construction oversight = \$10,000
- Easement administration, coordination, outreach and project coordination = \$6,000
- Inspection and maintenance costs = \$500/yr
- Structural installation = \$25,000

The restorations identified can provide a funding mechanism and incentive by earning wetland credits. The Board of Water and Soil Resources currently pays around \$10,000 per acre for wetland credits to offset impacts due to road projects or to add to the private sector wetland bank in which wetland credits typically sell for \$0.75-\$1.25/sq. ft.

Table 12: Phosphorous reduction to Lake Sarah and associated costs of proposed hydrologic restorations

Pond ID	Area (acres)	Volume of storage (ac-ft)	Soils	Area of watershed draining to pond (acres)	Misc.	P reduction (lbs/yr)	Cost estimate (20 yr lifespan)	P reduction to Lake Sarah (lbs/yr)	Cost of P reduction to Lake Sarah for practice lifespan (\$/lbs)
1	30	60	Organic	2,564	Hwy 55	100	\$223,500	100 (10%)	\$112
2	31	62	Organic & loam	1,884	Channel erosion not included	90	\$253,500	91 (9%)	\$139
1 & 2	61	122	Organic & loam	2,564		*	\$477,000	169 (17%)	\$141
3 & 4	37	74	Organic & loam	244	Would require livestock removal, not included in TP reduction	*	\$337,000	40 (4%)	\$421
5	30	60	Organic	261	DNR land	*	\$76,000	29 (3%)	\$131

Figure 14: Location of proposed hydrologic restorations



Appendix

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 Dance Hall Creek subwatershed draining to Lake Sarah. 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 (Gassman, 2007). The release used for this project was ArcSWAT2012 for ArcGIS version 10.1. All SWAT modeling and field assessments were conducted by Three Rivers Park District staff during the Lake Sarah TMDL and Hennepin County staff during the Dance Hall Creek 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 Dance Hall Creek 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 Dance Hall Creek SWAT model included digital elevation, land use and soils. All data for the Dance Hall Creek watershed were projected into the Universal Transverse Mercator Zone 15 with the North American Datum, 1983. The Dance Hall Creek watershed and sub-basins 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 the Greenfield department of public works and 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. The SSURGO dataset included 61 soils in the Dance Hall Creek 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.

Sub-basins in the Dance Hall Creek subwatershed were refined using field observations and known locations of stream channels, culverts and ponds. The final sub-basin configuration included seven sub-basins ranging from 21 to 330 hectares. The watershed had 132 HRUs.

Agriculture

The major land use in the Dance Hall Creek Watershed is agriculture. The majority of producers grow corn (for grain), soybeans and occasionally wheat in rotation. There are also several farms 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 on other fields throughout the watershed for animal consumption.

The number of animal units in the subwatershed was based on survey results used in the Three River Park District's Lake Sarah Watershed Total Daily Maximum Load model. The 2008 survey found that 38 parcels within the subwatershed had farm animals, the majority of which were horses (33). Seven parcels had cattle and three had goats. These totals include several parcels that had more than one type of animal. There were 129 horses, 103 cattle, four goats and a donkey observed. Manure from the goats and donkey were not included in the watershed model.

Most animal operations in the Lake Sarah watershed are hobby horse farms with between one and 11 horses. The majority of these operations include a small, dirt feedlot and an area of associated pasture. Manure on small horse farms is not collected from the pasture. Manure is collected out of the barn and occasionally scraped from the feedlot and stockpiled. Stockpiled manure was not modeled directly in SWAT; rather, half of the manure from each operation was applied to the feedlot and the other half to the pasture. The feedlot manure was assumed to include both the dirt feedlot and the manure stockpile. In the three operations without obvious pastures, the entire quantity of manure was applied to the feedlot. The continuous fertilization function in SWAT applied manure to the landscape daily.

The specific manure management activities of the dairy and beef producers are unknown. For modeling purposes, the Three Rivers Park District assumed that 50 percent of the manure from these operations was collected based on a herd size of fewer than 25 animals (Powell et al., 2005). The collected manure was applied to nearby agricultural fields. Solid manure and bedding application to agricultural fields was observed in the watershed from February to April 2009. The remaining uncollected manure was assumed to remain – half to each the pasture and the feedlot associated with the operation.

Residential and urban land uses

A variety of urban and residential land uses are present in the Dance Hall Creek watershed. The percentage of impervious area in each of the land uses guided how the land use type was represented in the SWAT model.

Wetlands

Wetlands exert a large influence in the Dance Hall Creek watershed by detaining water and settling out nutrients. Because wetlands cannot be explicitly modeled in SWAT, on-channel wetlands were modeled as “reservoirs.” Each “reservoir” was assigned to a sub-basin and individually parameterized according to the normal surface area/volume (which corresponds to bank-full conditions) and the emergency surface area/volume (which correspond with maximum flooded conditions) to match the monitored hydrograph and water quality data. Each wetland was 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. The SWAT model(s) was calibrated to monitored phosphorus concentrations. Calibration parameters that affect landscape phosphorus export were set to the same value. The Three Rivers Park District TMDL SWAT model lowered the USLE P factor to reduce landscape phosphorus loads to expected quantities. Other parameters altered were the phosphorus soil partitioning coefficient and the width of vegetated field edges. The phosphorus sorption coefficient and the soil labile phosphorus concentration were calculated based on soil parameters in the Lake Sarah watershed (Vadas and White, unpublished). The phosphorus concentration in the groundwater was set to 50 µg/L, which corresponds to observations of regional surficial Quaternary groundwater reported by MPCA (1999). Finally, wetlands were assumed to settle phosphorus from August to May and release phosphorus in June and July based on inspection of the monitoring data by Three Rivers Park District. Final land use phosphorus exports are consistent with corresponding literature estimates (see land use-modeled average phosphorus yields table).

Model validation

The Three Rivers Park District SWAT model developed for the Lake Sarah TMDL was calibrated to two years of monitoring data for the two largest inputs into the stream, the east and west tributaries. The calibrated parameters were used for BMP models in the Dance Hall Creek sub-basin as this watershed shares very similar land use, soils and topographic characteristics. The parameters used in the model validation by the Three Rivers Park District are noted in Appendix Table 2.

Appendix Table 1: Modeled average phosphorous yields

Average annual phosphorus exports from different land use types in the SWAT model. Reported values represent the range of averages predicted by SWAT across different soil types and topography throughout the Dance Hall Creek watershed.

Land use	Modeled average phosphorous yields lbs/acre
Agriculture	
Row crop agriculture	0.71 - 1.87
Forage crops	0.16 - 0.33
Horse and cattle feedlots	0.47 - 8.83
Horse and cattle pasture	0.18 - 0.98
Developed	
Low and medium density residential	0.61 - 0.94
Commercial and industrial	0.82 - 0.96
County and state highways	0.53 - 0.74
Undeveloped	
Forest	0.04 - 0.05
Wetland	0.15 - 0.19

Appendix Table 2: Dance Hall Creek SWAT input parameters

Value	Parameter	Description	Units	Default value	Explanation	File
3	SMTMP	Snow melt base temperature	°C	1	Used to delay snowpack melting	.bsn
2	SMFMX	Melt factor for snow on June 21	mmH ₂ O/°C-day	4.5	Used to slow snow melting	.bsn
2.5	SMFMN	Melt factor for snow on December 21	mmH ₂ O/°C-day	4.5	Used to slow snow melting	.bsn
0.25	TIMP	Snow pack temperature lag factor		1	Used to delay snowpack melting	.bsn
Priestly-Taylor	IPET	PET method		-	Selection of potential evapotranspiration method	.bsn
0.92	ESCO	Soil evaporation compensation factor		0.95	Adjusts soil evaporation	.bsn
1	SURLAG	Surface runoff lag time	days	4	Increased surface runoff travel time to stream	.bsn
0.0001	SPCON	Linear parameter for calculating the maximum amount of sediment that can be re-entrained during channel sediment routing		0.0001	No channel erosion or deposition	.bsn
1.5	SPEXP	Exponent parameter for calculating sediment re-entrained in channel sediment routing		1	No channel erosion or deposition	.bsn
0.23	PWP	Phosphorous sorption coefficient		0.4	Changed partitioning between soluble and particulate phosphorous export	.bsn
0	IWQ	In-stream water quality		1 = model in-stream water quality	In-stream water quality was not modeled	.bsn
15	GW_DELAY	Groundwater delay	Days	30	Used to calibrate baseflow response	.gw
0.99	ALPHA_BF	Base flow alpha factor	Days	0.048	Used to calibrate stormflow recession	.gw
0.05	GWSOLP	Concentration of soluble phosphorous in groundwater	mg P / L	0	Adjusted to literature value	.gw
Default—10%	CN2	Initial SCS curve number II value			Adjusted to increase infiltration	.mgt
.025	USLE_P	USLE support practice factor		varies	Adjusted to decrease phosphorous	.mgt
0.1 for roadways	FILTERW	Width of edge of field filter strip	meters	0	Adjusted to match roadside swale phosphorous trapping	.mgt
2	IURBAN	Urban simulation code; 1-USGS, 2—build up/wash off		1	Changed method to build up / wash off	.mgt
Varies	USLE_C	Minimum C _{USLE}		varies	Increased C _{USLE} for alfalfa and brome to increase phosphorous loss to literature values	crop.dat

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/index.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:

- Parameters for the filter strip area (buffer):
 - Pre-existing soil loss in filter strip area = 1.0 tons/acre
 - Post-construction soil loss in filter strip area = 0.027 tons/acre
 - Soil type = Silt (85 lbs/cu.ft.)
 - Buffer width = 35 feet
 - Filter strip area is variable (Length of filter strip x 35' buffer width)
- Parameters for upland runoff treatment.
 - Filter strip watershed areas are variable for each site. Surface area drainage across the filter strip was measured from two-foot (2') topographic data (LiDAR) overlaid on aerial photographs of the areas being analyzed. Areas are measured in acres.
 - 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 within 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.
 - 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 pound of phosphorus per 1 ton of soil and a correction for soil texture. The inputs and assumptions used for this calculator (www.bwsr.state.mn.us/practices/pollution_reduction.html) were as follows:

- Soil type = silt for all sites
- Soil volume voided per year (cubic feet): For all waterways, a 3-inch deep gully in a 5-foot wide parabolic shape (0.625 cubic foot per foot of waterway) formed every year was assumed.
- Number of years to form the gully: yearly occurrence was assumed
- Gully condition: assumed that the gully fans out before entering the receiving water. For the calculator, the input is non-channelized.
- Distance to receiving surface water (feet to main ditch or wetland) measured along the route the water takes to get to the receiving water.
- Presence of a filter strip before waterway installation (in all cases there were no filter strips)

Water and sediment control basins

The Water and Sediment Control Basin for field 1-7 was analyzed based on the USDA NRCS RUSLE2 calculator (http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm) The existing conditions were measured using LiDAR topographic information to determine the average length and steepness of slope where the water and sediment basin would be placed. The Soil Survey for Hennepin County was used to determine the soil type in the field being analyzed. Crop management for field 1-7 was assumed as a corn-soybean rotation based on historic aerial photographic analysis for the years 2000, 2002, 2004, 2006, 2009 and 2012. Cropping directions were straight row, non-contoured. The water and sediment control basin was positioned in the middle of the slope for this analysis.

Wetland restoration and enhancement and pond excavation and maintenance.

These sites were analyzed utilizing the National Urban Runoff Program, Design Calculations for Wet Detention Ponds developed by Wm. Walker (www.walker.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 pound 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>, www.pca.state.mn.us/index.php/view-document.html?gid=3977, 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 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 3.3 feet for pond maintenance and excavation and outlet elevations on wetland restorations

and enhancements. For pond maintenance and excavation, 3.3 feet average mean depth is recommended for the greatest pollutant (phosphorus) removal efficiency based on research and development of the PondNet (NURP) program by Walker used in this sub watershed assessment.

Livestock

We utilized a variety of programs for our analysis of soil loss and nutrient loads for the livestock section of this report.

RUSLE2 (Revised Universal Soil Loss Equation)

In the case of sites 2a erosion scour and 7b feedlot erosion, the Revised Universal Soil Loss Equation (RUSLE 2) was used as the basis for soil loss and load reductions before and after BMP implementation within the feedlots. 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. Base management in RUSLE 2 on both sites was considered single year rotation of forage, pasture, continuously grazed with severe overuse and a low pasture yield. A supporting practice of a diversion in the post development RUSLE 2 analysis, placed in the middle of the slope was considered on site 7b. For post BMP site 2a erosion scour, the BMP pasture exclusion fencing and stable vegetation conditions with no scour and no phosphorus loads was assumed for the RUSLE 2 analysis

Nutrient and storage management analysis for pre-BMP nutrient loss on the cropland areas where manure disposal occurs from site 7b used RUSLE2. The disposal area for manure within the Dance Hall Creek Watershed was assumed to be 70 acres. Our analysis used a 6-year crop rotation of: corn, soybeans, small grain, alfalfa, alfalfa, alfalfa, before and after nutrient management occurred on this cropland. After-BMP analysis for nutrient management on 70 acres used parameters for RUSLE2 as the existing inputs but utilized the recent Sauk River nutrient management program results that showed an average reduction in phosphorus loads to the Sauk River of 0.25 lbs/ac. per acre of cropland nutrient management enrolled in their program.

MinnFARM (Minnesota Feedlot Annualized Runoff Model)

The MinnFARM model was used for livestock site 7a to determine feedlot runoff. MinnFARM was developed to calculate the annual pollutant loading from a feedlot in Minnesota. The model is based in part on algorithms from the Feedlot Evaluation Model (1982) model developed by the Agricultural Research Service for prioritizing feedlot pollution potential based on a single 25-year, 24-hour event. MinnFARM estimates annual pollutant loadings for COD, phosphorus, nitrogen, BOD and fecal coliforms at the end of a defined treatment area.

For livestock site 7a the following input parameters were used in determining annual pollutant loads from this feedlot.

- Total feedlot area = 0.60 acres
- Roof area = 0.10 acres
- Total area 2 = 0.82 acres
- Total buffer area = 0.77 acres
- Total area 3 = 5.51 acres
- Ratio of buffer to feedlot area (includes Area 2) = 0.54

For all pastureland 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 pastureland. This amount of load was based on research into studies identifying nutrient loads from various sources (www.pca.state.mn.us/index.php/view-document.html?gid=3977, 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>, www.pca.state.mn.us/index.php/view-document.html?gid=3977, www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=280936)

Cropland RUSLE2

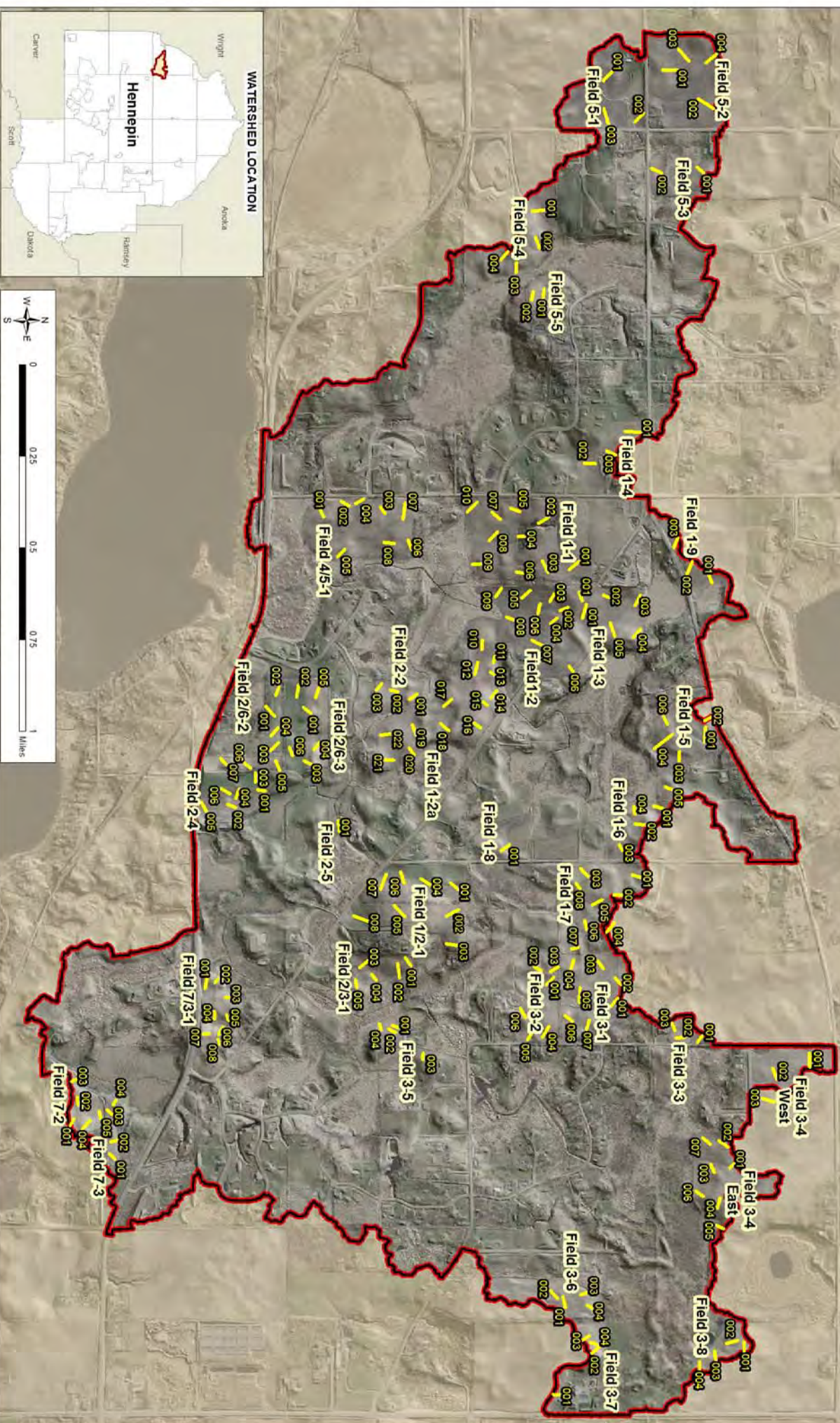
The Revised Universal Soil Loss Equation was used on all cropland within the Dance Hall Creek Watershed. This in turn was incorporated into various other models (to determine before and after nutrient loads; the existing conditions were measured using LiDAR topographic information to determine the average length and steepness of slope). The Soil Survey for Hennepin County was used to determine the soil type in the field being analyzed. Appendix Table 1 lists the field identifiers and input parameters used for each measurement in each field.

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.

Dance Hall Creek Watershed - RUSLE2 Field Measurement Locations



Appendix Table 3: Field identifiers and input parameters used

Farm field ID	Line ID	Length	Fall	Average slope	RUSLE2 soil Loss	Soil	Field size	Crop rotation
		(ft.)	(ft.)	(%)			(acres)	
04/05-01	001	110	10	9	5.8	41 lester		
	002	135	11	8	5.5	41 lester		
	003	113	12	11	7.8	41 lester		
	004	140	8	6	4.1	41 lester		
	005	150	12	8	5.7	41 lester		
	006	140	16	11	6.4	40 angus		
	007	240	7	3	2.3	35 lerdahl		
					37.6		30	c-sb
01-01	001	180	6	3	1.6	40 angus		
	002	165	6	4	2.1	40 angus		
	003	185	5	3	1.6	40 angus		
	004	90	13	14	8.7	36 Hamel		
	005	140	12	9	5.5	36 Hamel		
	006	110	12	11	7.8	41 lester		
	007	150	8	5	2.6	40 angus		
	008	170	10	6	3.2	40 angus		
	009	125	13	10	5.3	24 Glenco		
	010	200	8	4	2.6	36 Hamel		
					41		33	c-sb
01-02	001	140	8	6	4.1	41 lester		
	002	125	16	13	11	41 lester		
	003	120	20	17	14	41 lester		
	004	120	12	10	7	41 lester		
	005	170	20	12	10	41 lester		
	006	150	12	8	5.7	41 lester		
	007	165	13	8	5.2	25 LeSeuer		
	008	160	11	7	5	41 lester		
	009	150	12	8	5.7	35 lerdahl		
	010	130	12	9	6.1	41 lester		
	011	90	3	3	1.7	36 Hamel		
	012	175	11	6	4.4	41 lester		
	013	105	8	8	5	41 lester		
	014	140	15	11	8.6	41 lester		
	015	90	7	8	4.8	41 lester		
	016	110	7	6	3.8	41 lester		
(actual field 2)	017	150	13	9	6.4	41 lester		
(actual field 2)	018	150	20	13	11	41 lester		
(actual field 2)	019	165	14	8	5.8	41 lester		
(actual field 2)	020	120	17	14	11	41 lester		
(actual field 2)	021	120	10	8	5.3	22 lester		
(actual field 2)	022	170	10	6	3.8	36 Hamel	63	c-sb
					145.4			
01-03	1	200	23	12	8.3	41 lester		

Appendix Table 3: Field identifiers and input parameters used (*continued*)

Farm field ID	Line ID	Length	Fall	Average slope	RUSLE2 soil Loss	Soil	Field size	Crop rotation
		(ft.)	(ft.)	(%)			(acres)	
	2	90	13	14	10	41 lester		
	3	160	12	8	5.8	41 lester		
	4	150	23	15	14	41 lester		
	5	200	12	6	4.5	41 lester		
	6	100	6	6	3.7	41 lester	22	c-sb
					46.3			
01-04	1	230	7	3	2.3	41 lester		
	2	160	9	6	3.7	36 Hamel		
	3	140	11	8	5.5	41 lester		
					11.5		11	c-sb
01-05	1	210	17	8	6.3	41 lester		
	2	100	11	11	7.5	41 lester		
	3	140	18	13	11	41 lester		
	4	330	26	8	7.4	41 lester		
	5	120	16	13	10	41 lester		
	6	130	12	9	6.1	41 lester		
					48.3		20	c-sb
01-06	1	130	18	14	12	41 lester		
	2	160	21	13	11	41 lester		
	3	90	7	8	9.1	41 lester		
	4	110	18	16	13	41 lester		
					45.1		10	c-sb
01-07	1	150	14	9	6.4	41 lester		
	2	110	11	10	6.8	41 lester		
	3	160	21	13	11	41 lester		
	4	170	5	3	2.1	41 lester		
	5	150	12	8	5.9	41 lester		
	6	140	9	6	4.1	41 lester		
	7	100	8	8	4.3	44 nessel		
	8	90	6	7	4.9	44 nessel		
					45.5		25	c-sb
01-08	1	160	15	9	4.1	41 lester		
					4.1		5.8	c-sb-sg-h
01-09	1	130	18	14	10	36 Hamel		
	2	190	11	6	3.3	40 angus		
	3	150	8	5	3.5	35 lerdahl		
					16.8		7.4	c-sb
01/02-1	1	170	13	8	3.7	44 nessel		
	2	200	14	7	2.5	36 Hamel		
	3	190	19	10	3.3	37 angus		
	4	180	13	7	2.5	41 lester		
	5	220	16	7	2.6	41 lester		
	6	170	15	9	3.2	41 lester		

Appendix Table 3: Field identifiers and input parameters used (*continued*)

Farm field ID	Line ID	Length	Fall	Average slope	RUSLE2 soil Loss	Soil	Field size	Crop rotation
		(ft.)	(ft.)	(%)			(acres)	
	7	230	20	9	3.4	36 Hamel		
	8	270	36	13	6.2	41 lester		
					27.4		28	c-sb-sg (z4-use ww aft. Sb)
02/03-1	1	140	24	17	15	41 lester		
	2	210	35	17	18	41 lester		
	3	150	20	13	11	41 lester		
	4	100	8	8	5	41 lester		
	5	120	14	12	9.1	41 lester		
					58.1		10	c-sb
02-01		see field 1-2						
02-2	1	130	13	10	7.2	41 lester		
	2	110	9	8	5.1	41 lester		
	3	120	7	6	3.9	41 lester		
					16.2		6.3	c-sb
2/6-1								
2/6-2	1	180	10	6	1.8	37 angus		
	2	130	6	5	1.4	37 angus		
	3	170	8	5	1.5	37 angus		
	4	150	8	5	1.9	41 lester		
	5	150	8	5	1.4	37 angus		
	6	130	8	6	1.7	37 angus		
	7	120	18	15	6.8	41 lester		
					16.5		10	c-sb-sg-h-h-h
2/6-3	1	140	18	13	5.9	41 lester		
	2	180	8	4	1.2	37 angus		
	3	110	11	10	3.8	41 lester		
	4	130	14	11	4	36 hamel		
	5	190	7	4	1.4	36 hamel		
	6	120	8	7	1.9	37 angus		
					18.2		18	c-sb-sg-h-h-h
2-4	1	110	5	5	1.8	41 lester		
	2	130	8	6	4.5	36 hamel		
	3	130	8	6	1.9	41 lester		
	3	140	10	7	2.7	41 lester		
	5	160	12	8	2.8	25 Le Sueur		
	6	150	18	12	5.4	41 lester		

Appendix Table 3: Field identifiers and input parameters used (*continued*)

Farm field ID	Line ID	Length	Fall	Average slope	RUSLE2 soil Loss	Soil	Field size	Crop rotation
		(ft.)	(ft.)	(%)			(acres)	
					19.1		15	c-sb-sg-h-h-h
2-5	pasture?							
03-01	1	160	5	3	2.2	26 shore-wood		
	2	130	6	5	3.4	26 shore-wood		
	3	130	8	6	3.9	37 angus		
	4	140	10	7	6.7	44 nessel		
	5	210	10	5	3.4	37 angus		
	6	130	12	9	7.2	22 lester		
	7	140	8	6	3.6	37 angus		
					30.4		25	c-sb
03-02	1	150	10	7	5.8	22 lester		
	2	150	9	6	4.9	22 lester		
	3	130	5	4	2.4	37 angus		
	4	180	13	7	7.3	44 nessel		
	5	140	11	8	4.9	37 angus		
	6	150	6	4	3.3	22 lester		
	buffer1	160	29	18	18	22 lester		
					28.8			
03-03	1	120	7	6	4.6	41 lester		
		130	4	3	1.8	37 angus		
		120	6	5	2.9	37 angus		
					84.7		18	c-sb
03-04west	1	200	9	5	4.5	35 lerdal		
	2	170	8	5	3.2	37 angus		
	3	170	5	3	2.6	35 lerdal		
					10.3		14	c-sb
03-04east	1	140	5	4	3.2	35 lerdal		
	2	160	14	9	7.8	41 lester		
	3	130	10	8	6.4	41 lester		
	4	160	9	6	3.8	37 angus		
	5	110	12	11	9.2	41 lester		
	6	140	12	9	7.4	41 lester		
	7	140	10	7	5.7	41 lester		
					43.5		20	c-sb
03-05	1	110	7	6	3.8	22 lester		
	2	100	4	4	2.5	22 lester		
	3	90	6	7	3.7	36 hamel		
	4	90	12	13	9.1	22 lester		
					19.1		5.5	c-sb

Appendix Table 3: Field identifiers and input parameters used (*continued*)

Farm field ID	Line ID	Length	Fall	Average slope	RUSLE2 soil Loss	Soil	Field size	Crop rotation
		(ft.)	(ft.)	(%)			(acres)	
03-06	1	170	10	6	5.1	44 nessel		
	2	150	10	7	4.9	22 lester		
	3	100	8	8	5	22 lester		
	4	100	8	8	5	22 lester		
					20		15	c-sb
03-07	1	110	8	7	2.4	22 lester		
	2	150	16	11	4.6	22 lester		
	3	120	7	6	2.1	22 lester		
	4	110	10	9	3.1	22 lester		
					12.2		6.7	c-sb-sg
03-08	1	140	7	5	4.2	22 lester		
	2	170	10	6	5.3	22 lester		
	3	140	18	13	13	22 lester		
	4	130	9	7	6.8	44 nessel		
					29.3		7.3	c-sb
05-01	1	180	10	6	4.1	40 angus		
	2	180	6	3	2.7	35 lerdal		
	3	220	6	3	3.3	40 angus		
					10.1		22	c-sb
05-02	1	225	12	5	3.6	40 angus		
	2	250	14	6	6	22 lester		
	3	230	16	7	7	41 lester		
	4	210	10	5	4.1	23 cordova		
					20.7		27	c-sb
05-03	1	130	16	12	12	22 lester		
	2	160	9	6	5.3	35 lerdal	16	c-sb
					17.3			
05-04	1	190	13	7	5.7	36 hamel		
	2	170	18	11	11	41 lester		
	3	140	23	16	18	41 lester		
	4	150	15	10	9.3	41 lester		
					44			
							23	c-sb
05-05	1	140	15	11	11	41 lester		
	2	130	12	9	7.6	41 lester		
					18.6		3.5	c-sb
7/3-1	1	150	13	9	3.4	41 lester		
	2	90	11	12	4.4	41 lester		
	3	90	16	18	7.4	41 lester		
	4	100	15	15	6.1	41 lester		
	5	80	12	15	5.7	41 lester		
	6	130	20	15	5.9	36 hamel		
	7	90	10	11	4	22 lester		

Appendix Table 3: Field identifiers and input parameters used (*continued*)

Farm field ID	Line ID	Length	Fall	Average slope	RUSLE2 soil Loss	Soil	Field size	Crop rotation
		(ft.)	(ft.)	(%)			(acres)	
	8	80	6	8	2.6	22 lester		
					39.5		9.4	c-sb-sg
7-2	1	110	12	11	5	41 lester		
	2	120	12	10	4.5	41 lester		
	3	80	6	8	3	41 lester		
	4	170	22	13	7.4	41 lester		
	5	110	6	5	1.8	36 hamel		
					21.7		7.8	c-sb-sg-h-h-h
7-3	1	110	7	6	1.9	40 angus		
	2	100	6	6	2.8	44 nessel		
	3	100	6	6	2.4	41 lester		
	4	80	6	8	3	41 lester	3.1	c-sb-sg-h-h-h
					10.1			
							537.8	
Lvst7b	1	80	9	11	43	22 lester		
	2	100	12	12	55	41 lester		
with diversion	2	100	11	11	33			

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.

Appendix Table 4: Project budget estimates — rural

BMP	ID	Initial construction cost	Contracted maintenance cost	O & M term	Design cost for average site	Installation cost for average site	Size of proposed BMP	Total installation cost	10-year cost
		(\$/unit)	(\$/unit)	(yr)	(\$70/hr)	(\$70/hr)	(user-entered)	(includes design & 1-yr maintenance)	(includes installation & 10 yrs maintenance)
Contour buffer strips	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	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	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	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	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	GSS	\$28,125.00	\$200.00	15	\$2,812.50	\$1,406.25	1	\$32,543.75	\$34,343.75
Grade stabilization structure, drainage area of 40 to 80	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	GSS	\$56,250.00	\$300.00	10	\$5,625.00	\$2,812.50	1	\$64,987.50	\$67,687.50

Appendix Table 4: Project budget estimates — rural (*continued*)

BMP	ID	Initial construction cost	Contracted maintenance cost	O & M term	Design cost for average site	Installation cost for average site	Size of proposed BMP	Total installation cost	10-year cost
		(\$/unit)	(\$/unit)	(yr)	(\$70/hr)	(\$70/hr)	(user-entered)	(includes design & 1-yr maintenance)	(includes installation & 10 yrs maintenance)
Grade stabilization structure, drainage area of 250 to 500	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	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	NM	\$11.00	-	10	\$560.00	\$280.00	10	\$950.00	\$950.00
Nutrient management	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		10	\$1,770.00	\$1,770.00
Residue management (AC)	RM	\$58.00	-	10	\$560.00		1	\$898.00	\$898.00
Restoration and management of declining habitats (AC)	RMD H	\$1,500.00	\$500.00	10	\$1,120.00		10	\$21,680.00	\$66,680.00
Streambank and shoreline protection (SF)	SSP	\$7.00	\$0.25	n/a	\$2,240.00		1,000	\$10,610.00	\$12,860.00
Stripcropping (AC)	Strip	\$98.00	-	10	\$560.00		10	\$1,820.00	\$1,820.00
Terrace (LF)	Ter	\$8.00	\$0.25	10	\$1,120.00		1,000	\$9,930.00	\$12,180.00
Water and sediment control basin, drainage area of 0 to 10	SB	\$12,500.00	\$100.00	10	\$1,250.00		1	\$14,475.00	\$15,375.00

Appendix Table 4: Project budget estimates — rural (*continued*)

BMP	ID	Initial construction cost	Contracted maintenance cost	O & M term	Design cost for average site	Installation cost for average site	Size of proposed BMP	Total installation cost	10-year cost
		(\$/unit)	(\$/unit)	(yr)	(\$70/hr)	(\$70/hr)	(user-entered)	(includes design & 1-yr maintenance)	(includes installation & 10 yrs maintenance)
Water and sediment control basin, drainage area of 10 to 20 acres (NO)	SB	\$11,250.00	\$150.00	n/a	\$1,125.00		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	6	\$1,687.50		1	\$19,606.25	\$21,406.25
Wetland creation (AC)	WetC	\$7,000.00	\$45.00	6	\$2,800.00		10	\$74,650.00	\$78,700.00
Wetland enhancement (AC)	WetE	\$3,000.00	\$45.00	8	\$2,800.00		10	\$34,650.00	\$38,700.00
Wetland restoration (AC)	WetR	\$3,000.00	\$45.00		\$2,800.00		10	\$34,650.00	\$38,700.00
Windbreak , per foot of single row, planted (LF)	Wind	\$2.00	-		\$60.00		1,000	\$2,840.00	\$2,840.00
Septic fix (NO)	Sep	\$15,000.00	-		-		1	\$15,000.00	\$15,000.00
Feedlot fix, pit, first 500,000 CF of storage (CF)	FF	\$1.55	\$0.01		\$11,200.00		500,000	\$795,050.00	\$824,300.00
Feedlot fix, pit, additional above 500,000 CF of storage (CF)	FF	\$1.13	\$0.01		\$11,200.00		500,000	\$585,050.00	\$614,300.00
Feedlot fix, treatment swale (SF)	FF	\$4.00	\$0.25		\$2,800.00		1,000	\$8,450.00	\$10,700.00
Feedlot fix, relocation (NO)	FF	\$50,000.00	-		\$11,200.00		1	\$66,800.00	\$66,800.00

Appendix Table 5: Project budget estimates — urban

BMP	ID	Description	Material/ labor	Unit	Annual maintenance cost	Design cost	Installation oversight cost	Promo & admin	O & M term
			(installatio n)		(contracted)	(\$70/hr)	(\$70/hr)		
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)	min. 10% const. costs	10
Infiltration basin, turf	BRT	amended soils with under-drains	\$15.10	Square Foot	\$2,000/acre	\$1,120/ acre	\$210 3 visits)	min. 10% const. costs	10
Bioretention, simple	BR	(no engineered soils or under-drains, but w/curb cuts and forebays)	\$14.20	Square Foot	\$0.75/ft ²	\$840/ 1,000 ft ²	\$210 (3 visits)	min. 10% const. costs	10
Bioretention, moderately complex	BR	(incl. engineered soils, under-drains, curb cuts, forebays but no retaining walls)	\$17.01	Square Foot	\$0.75/ft ²	\$1,120/ 1,000 ft ²	\$420 (6 visits)	min. 10% const. costs	10
Bioretention, complex	BR	(as MCB but with 1.5 -2.5 ft partial perimeter walls)	\$21.50	Square Foot	\$0.75/ft ²	\$1,400/ 1,000ft ²	\$420 (6 visits)	min. 10% const. costs	10
Bioretention, highly complex	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	\$1,400/ 1,000ft ²	\$420 (6 visits)	min. 10% const. costs	10
Curb-cut		simple cut or with apron	\$80.00	Linear Foot				min. 10% const. costs	
Impervious cover conversion	DeP		\$21.71	Square Foot	\$500/acre	\$1,120/ acre	\$210 (3 visits)	min. 10% const. costs	10
Grass/gravel permeable Pavement	PP	(sand base)	\$18.95	Square Foot	\$0.75/ft ²	40% above construction	\$210 (3 visits)	min. 10% const. costs	10
Permeable asphalt	PP	(granite base)	\$10.80	Square Foot	\$0.75/ft ²	40% above construction	\$210 (3 visits)	min. 10% const. costs	10
Permeable concrete	PP	(granite base)	\$15.00	Square Foot	\$0.75/ft ²	40% above const.	\$210 (3 visits)	min. 10% const.	10

Appendix Table 5: Project budget estimates — urban (*continued*)

BMP	ID	Description	Material/ labor	Unit	Annual maintenance cost	Design cost	Installation oversight cost	Promo & admin	O & M term
			(installatio n)		(contracted)	(\$70/hr)	(\$70/hr)		
Permeable pavers	PP	(granite base)	\$35.75	Square Foot	\$0.75/ft ²	40% above const.	\$210 (3 visits)	min. 10% const. costs	10
Extended detention	PP		(12.98)* (CU- FT^0.75)	Cubic Foot	\$1,000/acre	\$2,800/acre	\$210 (3 visits)	min. 10% const. costs	10
Pond retrofits	PR		\$4.54	Square Foot	\$500/acre	40% above const.	\$210 (3 visits)	min. 10% const. costs	10
Pond excavation, MPCA dredge class, level 1	PE		\$32.40	Cubic Yard				min. 10% const. costs	
Pond excavation, MPCA dredge class, level 2 material	PE		\$43.20	Cubic Yard				min. 10% const. costs	
Pond excavation, MPCA dredge class, level 3 material	PE		\$64.80	Cubic Yard				min. 10% const. costs	
Stormwater wetland	Wet C		(4,800)* (D.A.acres ^0.484)		\$1,000/acre	\$2,800/ acre	\$210 (3 visits)	min. 10% const. costs	10
Wet pond	P		(277.89)* (CU- FT^0.553)	Cubic Foot	\$1,000/acre	\$2,800/ acre	\$210 (3 visits)	min. 10% const. costs	10
Perimeter sand filter	SF		\$259.20	Linear Foot				min. 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)	min. 10% const. costs	10

Appendix Table 5: Project budget estimates — urban (*continued*)

BMP	ID	Description	Material/ labor	Unit	Annual maintenance cost	Design cost	Installation oversight cost	Promo & admin	O & M term
			(installatio n)		(contracted)	(\$70/hr)	(\$70/hr)		
Underground sand filter	SF		\$99.08	Square Foot	\$0.75/ft ²	40% above const.	\$210 (3 visits)	min. 10% const. costs	10
Rain barrels	RE	Does not include pump or distribution	\$25.00	Cubic Foot	\$25	N/A	\$210 (3 visits)	min. 10% const. costs	10
Cisterns	RE	Does not include pump or distribution	\$16.00	Cubic Foot	\$100	N/A	\$210 (3 visits)	min. 10% const. costs	10
Dry swale	DS		\$7.13	Square Foot	\$0.75/ft ²	\$280/ 100 ft ²	\$210 (3 visits)	min. 10% const. costs	10
Water quality swale	WS		\$15.01	Square Foot	\$0.75/ft ²	\$1,120/ 1,000 ft ²	\$210 (3 visits)	min. 10% const. costs	10
French drain/dry well			\$15.00	Cubic Foot	\$100	20% above const.	\$210 (3 visits)	min. 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 const.	\$210 (3 visits)	min. 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 const.	\$210 (3 visits)	min. 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 const.	\$210 (3 visits)	min. 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 const.	\$210 (3 visits)	min. 10% const. costs	10

Appendix Table 5: Project budget estimates — urban (*continued*)

BMP	ID	Description	Material/ labor	Unit	Annual maintenance cost	Design cost	Installation oversight cost	Promo & admin	O & M term
			(installatio n)		(contracted)	(\$70/hr)	(\$70/hr)		
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	40% above const.	\$210 (3 visits)	min. 10% const. costs	10
Extensive green roof, ultra urban	GR	less than 6" in soil media depth	project specific - structural, roof membran e considera tions needed	Square Foot	\$500/ 1,000 ft ²	40% above const.	\$210 (3 visits)	min. 10% const. costs	10
Intensive green roof, ultra urban	GR	6" or greater in soil media depth	project specific - structural, roof membran e considera tions needed	Square Foot	\$750/ 1,000 ft ²	40% above const.	\$210 (3 visits)	min. 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)							

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