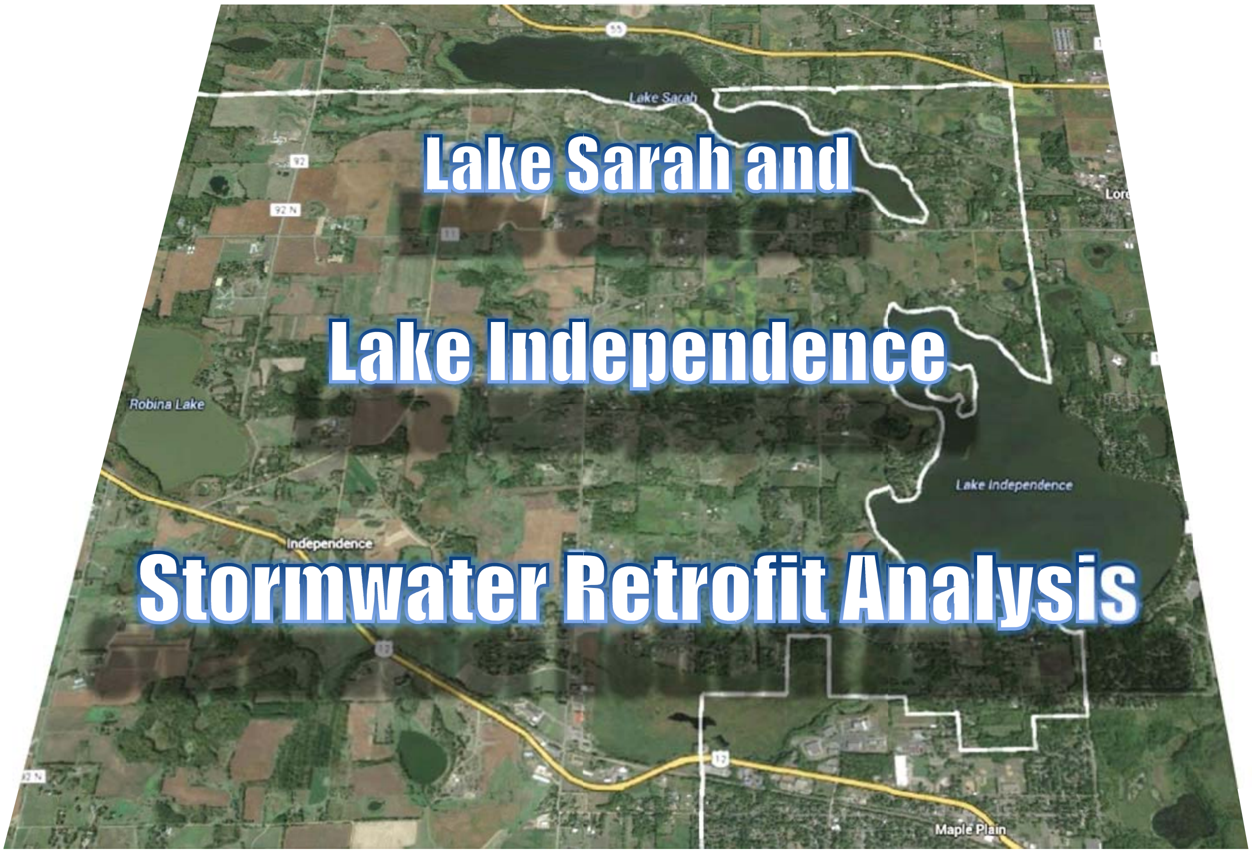
Lake Sarah and Lake Independence Stormwater Retrofit Analysis



Prepared for the

CITY OF INDEPENDENCE

by the

ANOKA CONSERVATION DISTRICT

In partnership with the Hennepin Conservation District

and the

Metro Conservation Districts

Funding provided in part by the Clean Water Fund
from the Clean Water, Land, and Legacy Amendment

May 2014

Cover photos: Google Maps

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Executive Summary

The City of Independence contracted Hennepin Conservation District and Anoka Conservation District to complete this stormwater retrofit analysis for the purpose of identifying and ranking water quality improvement projects in those portions of the City of independence that flow into Lake Sarah and Lake Independence. Both lakes have completed Total Maximum Daily Loads (TMDL) and TMDL implementation plans for impairment by phosphorus. The City of Independence has annual phosphorus reduction goals of 143lbs for Lake Sarah and 535 lbs for Lake Independence. These reductions are likely to be met only with an aggressive pursuit of structural and cultural practices.

This analysis is primarily intended to identify projects in the City of Independence to improve water quality in Lake Sarah and Lake Independence to achieve phosphorus waste load reduction goals identified in local water plans and TMDL implementation plans. Some projects were identified that fall outside of the City of Independence boundaries and are included in this analysis because of their close proximity to the lakes or their likely impact on project selection by the City of Independence.

Before identifying treatment opportunities, the watershed must be understood. Field staff must understand how water moves through the system: where it picks up additional pollutants, where pollutants naturally fall out, and if the water that falls on the landscape ever makes it to the lake. The general strategy when looking for water quality improvement practices was to find opportunities to hold water on the land longer, thereby encouraging infiltration, sediment deposition, and nutrient assimilation. This analysis focuses primarily on structural practices that are not dependent on the annually renewed commitment of landowners. As such, land management practices such as manure management, conservation tillage, contour strip farming, and riparian buffers that can provide significant water quality benefits were down played.

For each type of recommended retrofit, conceptual sketches or photos are provided in the project profiles section. The intent of these figures is to provide an understanding of the approach. If a project is selected, site-specific designs must be prepared. In addition, many of the proposed retrofits (e.g. new ponds) will require engineered plan sets if selected. This typically occurs after committed partnerships are formed to install the project. Committed partnerships must include willing landowners when installed on private property.

Water quality benefits associated with the installation of each identified project were individually modeled using methodologies that varied by project type. Reductions in Total Suspended Solids (TSS), Total Phosphorus (TP), and stormwater volume were modeled. The costs associated with project design, administration, promotion, land acquisition, opportunity costs, construction oversight, installation, and maintenance were estimated. The total costs over the effective life of the project were then divided by the modeled benefits over the same time period to enable ranking by cost-effectiveness.

Figure 1 shows all modeled projects throughout the two contributing watersheds. In addition to the projects within the watershed, the entire shoreline of both lakes was inventoried for lakeshore restoration opportunities. In total, 64 identified projects were modeled with installation cost estimates for ranking purposes. A total of 115 potential projects were considered but 51 were eliminated from additional consideration for various reasons. The associated reductions in TP if all modeled projects were installed exceed identified goals within the TMDL implementation plans. Unfortunately, some of those projects are located outside of the City of Independence. Additionally, with the installation of any single project, treatment train impacts will influence downstream project performance. To address this, it is preferable to develop a watershed wide model that is routinely updated with project parameters as they are installed. Since this may be impractical, other tools for considering overlapping treatment areas and treatment train effects were provided.

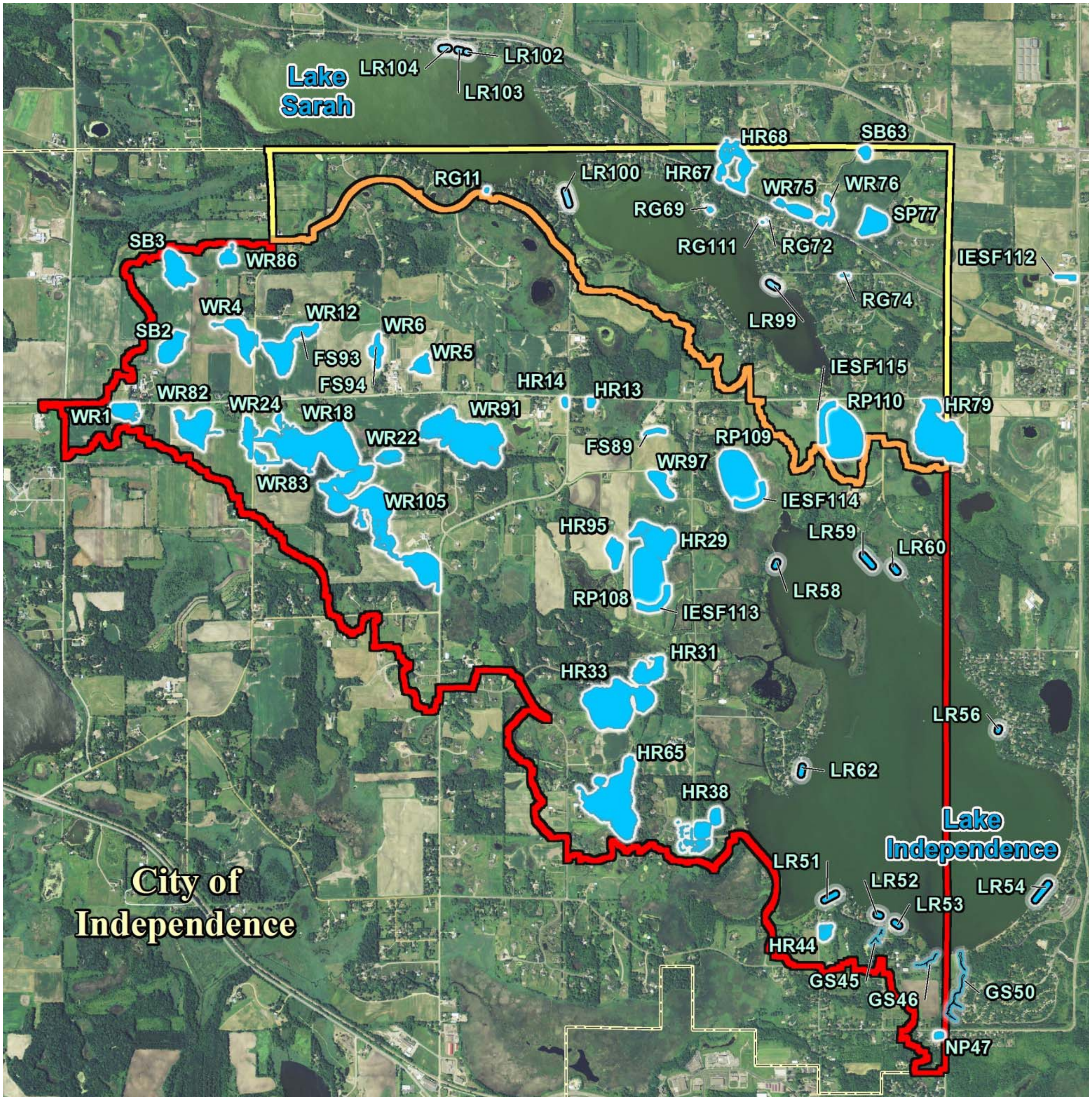


Figure 1: Potential Retrofit Projects Map

Table 1: Potential Retrofit Projects Index

Residential Rain Gardens		Hydrologic Restorations		Filter Strip/ Grassed Waterway
RG11 pg. 30	RG74 pg. 33	HR13 pg. 61	HR44 pg. 67	FS89 pg. 95
RG69 pg. 31	RG111 pg. 34	HR14 pg. 62	HR65 pg. 68	FS93 pg. 96
RG72 pg. 32		HR29 pg. 63	HR67 & 68 pg. 69	FS94 pg. 97
Lakeshore Restorations		HR31 pg. 64	HR79 pg. 70	**Ponds/ IESFs**
LR51 pg. 37	LR60 pg. 44	HR33 pg. 65	HR95 pg. 71	NP47 pg. 103
LR52 pg. 38	LR62 pg. 45	HR38 pg. 66		RP108 pg. 104
LR53 pg. 39	LR99 pg. 46	**Wetland Restorations**		RP109 pg. 105
LR54 pg. 40	LR100 pg. 47	WR1 pg. 72	WR75 pg. 80	RP110 pg. 106
LR56 pg. 41	LR102 pg. 48	WR4 pg. 73	WR76 pg. 81	IESF112 pg. 107
LR58 pg. 42	LR103 pg. 49	WR5 pg. 74	WR82 pg. 82	IESF113 pg. 108
LR59 pg. 43	LR104 pg. 50	WR6 pg. 75	WR83 pg. 83	IESF114 pg. 109
Gully Stabilizations		WR12 pg. 76	WR86 pg. 84	IESF115 pg. 110
GS45 pg. 53	GS50 pg. 55	WR18 pg. 77	WR91 pg. 85	**Seasonal Ponding**
GS46 pg. 54		WR22 pg. 78	WR97 pg. 86	SP77 pg. 113
		WR24 pg. 79	WR105 pg. 87	
		Water & Sediment Control Basins		
		SB2 pg. 90	SB63 pg. 92	
		SB3 pg. 91		

An implementation strategy cannot rely solely on pursuing the most cost-effective projects. Willingness of involved landowners to participate, social acceptability and political support for the type of project, total project budget, ability to leverage outside funds, and opportunities to implement cost saving approaches all play a critical role in project selection. Furthermore, an implementation strategy should include long-term and a short-term elements. While the final implementation strategy is the purview of local resource management professionals and civic leaders, we've included an example in this Executive Summary as a starting point.

Short-Term Implementation Strategy

The City of Independence has a goal of reducing phosphorus by 40% within the next few years (57.2 lbs/yr. reduction to Lake Sarah and 214 lbs/yr. reduction to Lake Independence). The following projects are selected due to the limited number of involved landowners, ease of project promotion, relatively low cost of installation, and likelihood of installation within a two to three year time frame. By lumping similar projects under a single programmatic umbrella, project design, bidding, administration and construction elements can be combined and simplified by doing them simultaneously. We strongly recommend doing a single round of rain garden installations to install all identified rain garden projects simultaneously. Similarly, all lakeshore restorations should be done at once. Although projects are organized according to the receiving water body in this section, lakeshore restorations for both Lake Sarah and Lake Independence should be completed simultaneously.

Lake Sarah projects include residential rain gardens (RG), lakeshore restorations (LR), hydrologic restorations (HR), seasonal ponding (SP), and wetland restoration (WR). The RG and LR projects are likely to be received well by the landowners due to the nature of the project. The HR, SP and WR projects were selected specifically because they would take very little, if any, agricultural land out of production and so may be viable and open the door to partnering with agricultural producers on more aggressive projects in the future. The short-term Lake Sarah projects are sufficient to reduce total phosphorus discharge by 38.55 lbs/yr adjusted with a Pollutant Delivery Ratio (PDR – refer to "Location in Watershed" pg.17 for an explanation of PDR). Additional reductions to reach the 57.2 lbs/yr goal may be achieved through promotion of cultural practices such as conservation tillage, which will require an outreach campaign not included in this report.

Lake Independence projects include residential lakeshore restorations (LR), gully stabilizations (GS), hydrologic restorations (HR), wetland restoration (WR), and vegetated filter strips (FS). The LR and GS projects are likely to be received well by the landowners due to the nature of the projects treating a visible erosion problem. The HR, WR and FS projects were selected specifically because they would take very little, agricultural land out of production and so may be viable and open the door to partnering with agricultural producers on more aggressive projects in the future. The short-term Lake Independence projects are sufficient to reduce total phosphorus discharge by 119.23 lbs/yr adjusted with a Pollutant Delivery Ratio (PDR – refer to "Location in Watershed" pg.17 for an explanation of PDR). Additional reductions to reach the 214 lbs/yr goal may be achieved through promotion of cultural practices such as conservation tillage and nutrient management, which will require an outreach campaign not included in this report.

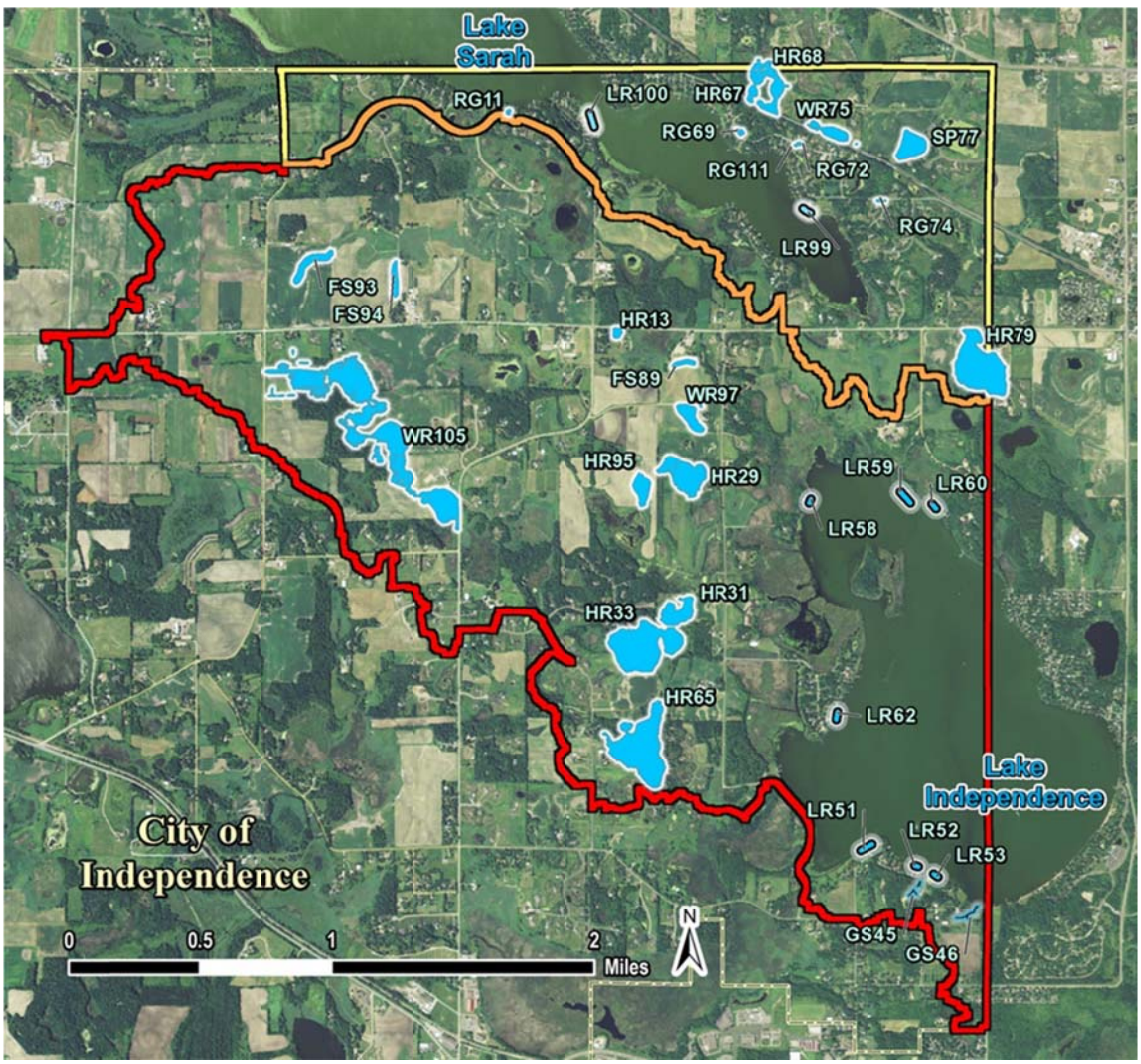


Figure 2: Short-Term Projects

Table 2: Short-Term Lake Sarah Projects

Site ID (pg.)	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Volume Decrease (ac-ft/yr)	Short Term Cost[1]	Project Life Cost[2]	Cost-Benefit ($/lb TP)	TP PDR	Cost-Benefit w/ PDR	TP Decrease w/ PDR
RG11 (30)	0.16	1.11	0.75	$25,055	$26,555	$1,196	0.95	$1,259	1.05
RG69 (31)	0.06	0.54	0.33	$15,055	$16,555	$1,533	0.95	$1,614	0.51
RG72 (32)	0.10	0.71	0.47	$15,055	$16,555	$1,166	0.95	$1,227	0.67
RG74 (33)	0.08	0.62	0.43	$15,055	$16,555	$1,335	0.90	$1,483	0.56
RG111 (34)	0.02	0.13	0.09	$3,055	$3,055	$1,175	0.95	$1,237	0.86
LR99 (46)	.66	1.05	0	$12,805	$14,680	$1,398	1.00	$1,398	1.05
LR100 (47)	1.61	2.58	0	$12,735	$14,600	$566	1.00	$566	2.58
HR67&68 (69)	15.99	15.32	0.70	$61,105	$71,105	$232	0.95	$244	14.55
HR79 (70)	1.90	5.87	8.32	$130,205	$140,205	$1,194	0.90	$1,327	5.28
WR75 (80)	8.41	9.34	2.58	$63,205	$73,205	$392	0.95	$413	8.87
SP77 (113)	1.0	2.85	2.15	$9,920	$10,420	$365	0.90	$406	2.57
Total	**29.99**	**40.12**	**15.82**	**$363,250**	**$403,490**				**38.55**

Table 3: Short-Term Lake Independence Projects

Site ID (pg.)	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Volume Decrease (ac-ft/yr)	Short Term Cost	Project Life Cost	Cost-Benefit ($/lb TP)	TP PDR	Cost-Benefit w/ PDR	TP Decreas e w/ PDR
LR51 (37)	2.73	4.37	0	$23,655	$27,860	$638	1.00	$638	4.37
LR52 (38)	.26	.42	0	$5,555	$5,710	$1,371	1.00	$1,371	0.42
LR53 (39)	2.73	4.8	0	$19,055	$20,560	$428	1.00	$428	4.80
LR58 (42)	1.35	2.15	0	$14,405	$15,440	$717	1.00	$717	2.15
LR59 (43)	7.83	12.52	0	$51,105	$55,700	$445	1.00	$445	12.52
LR60 (44)	2.66	4.26	0	$24,105	$26,000	$611	1.00	$611	4.26
LR62 (45)	1.30	2.07	0	$13,365	$15,360	$740	1.00	$740	2.07
GS45 (53)	1.33	2.1	0	$39,325	$43,385	$1,019	1.00	$1,019	2.10
GS46 (54)	9.77	15.6	0	$79,105	$87,285	$279	1.00	$279	15.60
HR13 (61)	1.74	2.49	0.22	$26,205	$36,205	$727	0.65	$1,118	1.62
HR29 (63)	2.02	5.98	3.29	$25,205	$92,705	$771	0.85	$907	5.08
HR31 (64)	2.92	3.77	1.40	$63,705	$73,705	$978	0.90	$1,087	3.39
HR33 (65)	3.09	9.19	6.52	$141,705	$151,705	$825	0.85	$971	7.81
HR65 (68)	5.49	6.25	2.71	$143,205	$153,205	$1,226	0.85	$1,442	5.31
HR95 (71)	9.44	9.64	1.93	$51,205	$61,205	$316	0.80	$396	7.71
WR97 (86)	1.10	2.53	1.61	$57,705	$67,705	$1,338	0.85	$1,574	2.15
WR105 (87)	26.41	32.13	7.69	$533,205	$543,205	$845	0.60	$1,408	19.28
FS89 (95)	0.65	1.25	0	$4,835	$10,835	$433	0.70	$619	0.50
FS93 (96)	16.28	34.27	0	$10,945	$32,945	$48	0.40	$120	13.71
FS94 (97)	4.51	10.95	0	$10,865	$26,465	$121	0.40	$303	4.38
Totals	**103.61**	**166.74**	**25.37**	**$1,338,460**	**$1,547,185**				**119.23**

[1] Short term costs include project promotion, design, land acquisition and construction. This amount is useful for grant applications. A breakdown of expenses is included in each project profile.
[2] Project life cost includes short term costs plus the cost of long term maintenance and production loss payments if applicable over the life of the project.

Long-Term Implementation Strategy

Several projects with great potential to reduce phosphorus loading to the lakes will take several years to come to fruition and during that time, alternative funding mechanism and creative partnerships can be sought to substantially reduce the cost to the city. The greatest cost savings can be found when pursuing wetland restorations (WR) and ponds (NP and RP). The following table shows project elements that could be paid for by sources other than state grants, or reduced greatly by combining with other projects opportunistically. Additional project funding ideas are presented on page 26.

Table 4: Cost Saving Opportunities

Project	Total Cost	Cost Subject to Reduction/ Reimbursement	Project Element With Potential Savings	Cost Reduction Opportunity
WR1	$92,205	$126,324	Entire Project	Sale of wetland credits on open market provided no state funds are used for restoration ($1/sq. ft.) To sell credits, additional vegetative restoration funds will be needed. If landowners pursue projects themselves, there will be no cost to the public. Acreages subject to verification by wetland delineation. Alternatively, WR projects on agricultural land could be pursued with RIM or NRCS funding.
WR4	$143,705	$239,580	Entire Project	
WR5	$86,205	$87,120	Entire Project	
WR6[3]	$74,205	$60,984	Entire Project	
WR12[4]	$195,205	$313,632	Entire Project	
WR18[5]	$559,205	$831,996	Entire Project	
WR24	$59,705	$82,764	Entire Project	
WR76	$73,705	$47,916	Entire Project	
WR82	$208,705	$196,020	Entire Project	
WR86	$60,205	$65,340	Entire Project	
WR91	$289,205	$344,124	Entire Project	
NP47	$155,140	$77,440	Excavation	Combine with road project or other public works project that requires fill material.
RP108	$3,540,751	$2,337,720	Excavation	
RP109	$3,540,338	$2,323,200	Excavation	
RP110	$3,305,245	$2,323,200	Excavation	
TOTAL	**$12,383,729**	**$9,457,360**		

Projects on agricultural land that remove land from production are also included in this section, assuming the process to promote and secure partners will take longer.

Table 5: Long-Term Lake Sarah Projects

Site ID (pg.)	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Volume Decrease (ac-ft/yr)	Short Term Cost	Project Life Cost	Cost-Benefit ($/lb TP)	TP PDR	Cost-Benefit w/ PDR	TP Decrease w/ PDR
WR76 (81)	3.77	4.63	1.75	$63,705	$73,705	$796	0.95	$838	4.40
SB63 (92)	0.66	1.15	0	$20,205	$30,205	$1,130	0.75	$1,507	0.86
RP110 (106)	194.86	108.62	1.60	$3,269,245	$3,305,245	$1,014	1.00	$1,014	108.62
RP110 adjustment[6]	-115.94	-80.92	-1.19	-$2,435,588	-$2,462,407	$1,014	1.00	$1,014	-80.92
IESF115 (110)	0	145.34	0	$1,381,005	$1,387,005	$275	1.00	$275	145.34
IESF115[6]	0	-108.28	0	-$1,028,849	-$1,033,319	$275	1.00	$275	-108.28
Total	**83.35**	**70.54**	**2.16**	**$1,269,723**	**$1,300,434**				**70.02**

[3] More aggressive alternative to FS94.
[4] More aggressive alternative to FS93.
[5] Second alternative to WR105 but preferable to WR83.
[6] The reason for adjustments is to account for treatment associated with runoff from other municipalities and to reduce the costs to the City of Independence proportionately. This is explained in greater detail on page 100.

Table 6: Long-Term Lake Independence Projects

Site ID (pg.)	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Volume Decrease (ac-ft/yr)	Short Term Cost	Project Life Cost	Cost-Benefit ($/lb TP)	PDR	Cost-Benefit w/ PDR	TP Decrease w/ PDR
WR1 (72)	3.46	8.39	3.39	$82,205	$92,205	$549	0.30	$1,830	2.52
WR4 (73)	17.01	22.09	1.90	$133,705	$143,705	$325	0.40	$813	8.84
WR5 (74)	1.61	4.71	1.78	$76,205	$86,205	$915	0.50	$1,830	2.36
WR6 (75)	2.29	5.11	1.13	$64,205	$74,205	$726	0.45	$1,613	2.30
WR12 (76)	31.43	25.64	4.05	$185,205	$195,205	$381	0.40	$953	10.26
WR18[7] (77)	10.58	39.54	9.96	$549,205	$559,205	$707	0.45	$1,571	17.79
WR24 (79)	1.14	3.41	0.80	$49,705	$59,705	$876	0.40	$2,190	1.36
WR82 (82)	2.90	15.65	5.83	$198,705	$208,705	$667	0.40	$1,668	6.26
WR86 (84)	0.57	4.07	1.67	$50,205	$60,205	$740	0.30	$2,467	1.22
WR91 (85)	8.53	18.29	7.80	$279,205	$289,205	$791	0.60	$1,318	10.97
SB3 (91)	1.50	9.13	0	$21,568	$31,568	$173	0.30	$577	2.74
NP47 (103)	3.63	4.49	0.76	$140,740	$155,140	$1,152	0.90	$1,280	4.04
RP108 (104)	152.11	89.09	1.13	$3,504,751	$3,540,751	$1,325	0.95	$1,395	84.64
RP109 (105)	116.59	72.02	2.07	$3,504,338	$3,540,338	$1,639	0.95	$1,725	68.42
IESF113 (108)	0	105.34	0	$1,381,005	$1,387,005	$275	1.00	$275	105.34
IESF114 (109)	0	72.66	0	$1,042,305	$1,046,805	$480	1.00	$480	72.66
Totals	**353.35**	**499.63**	**42.27**	**$11,263,257**	**$11,470,157**				**401.72**

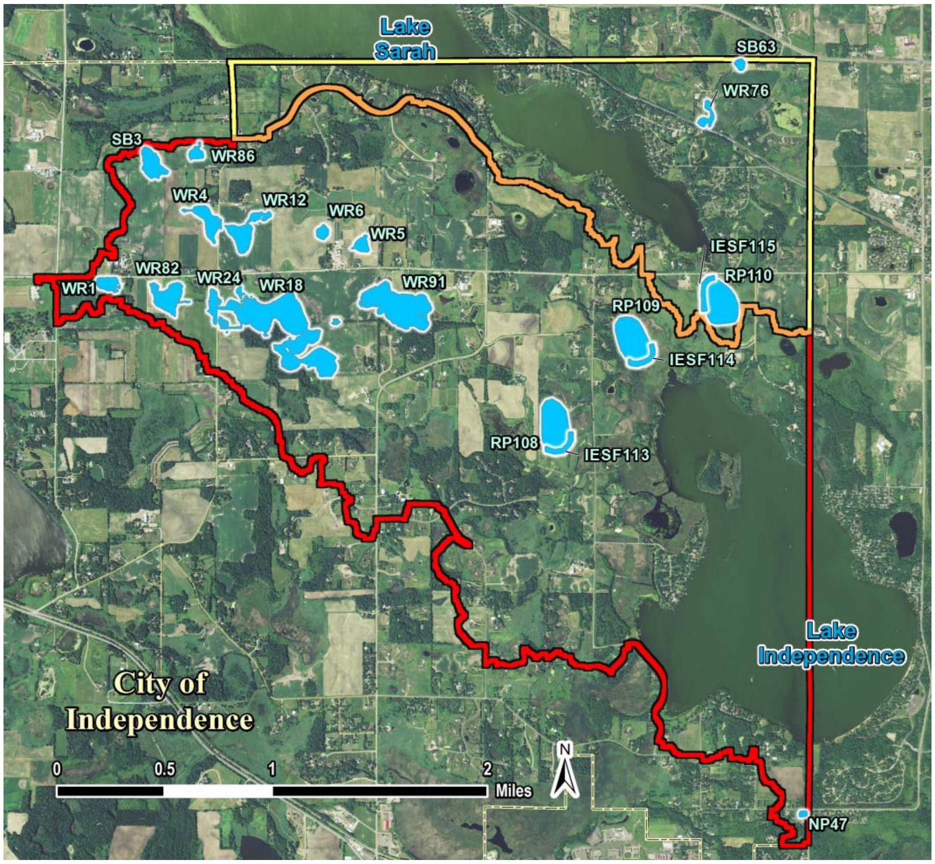


Figure 3: Long-Term Projects

[7] Less preferable alternative to WR105. WR18 is better than WR83 however.

Alternative Projects

All projects with a Cost-Benefit Ratio corrected with a PDR that exceed $2,500/lb-TP are included as alternative projects. As discussed under 'long-term projects,' creative partnerships and cost-saving measures can be sought to bring the overall costs down, and improve the cost-benefit ratio to an acceptable threshold.

Table 7: Alternative Projects

Site ID (pg.)	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Volume Decrease (ac-ft/yr)	Short Term Cost	Project Life Cost	Cost-Benefit ($/lb TP)	PDR	Cost-Benefit w/ PDR	TP Decrease w/ PDR
HR14 (62)	0.92	0.86	2.72	$25,205	$35,205	$2,047	0.65	$3,149	0.56
HR38 (66)	1.56	2.56	2.31	$127,205	$137,205	$2,680	0.95	$2,821	2.43
HR44 (67)	0.29	0.60	0.89	$47,205	$57,205	$4,767	0.95	$5,018	0.57
WR22 (78)	0.11	2.24	1.35	$73,205	$83,205	$1,857	0.50	$3,714	1.12
WR83[7] (83)	0.62	5.57	0.33	$138,705	$148,705	$1,335	0.45	$2,967	2.51
SB2 (90)	0.92	1.5	0	$21,864	$31,864	$1,065	0.30	$3,550	0.45
Totals	**4.42**	**13.33**	**7.60**	**$433,389**	**$493,389**				**7.64**

NOTE: Projects outside the City of Independence are not included in this section. Refer to Table 15 and Table 17 on pages 22 and 23 respectively.

Document Organization

This document is organized into five sections, plus references and appendices. Each section is briefly described below.

Background

The background section provides a brief account of the TMDLs that have been completed and a description of the landscape characteristics and resultant water quality issues.

Analytical Process

The analytical process section overviews the procedures that were followed when analyzing the watershed. It overviews the processes of retrofit scoping, desktop analysis, field investigation, modeling, cost/treatment analysis, project ranking, and project selection. Refer to Appendix A for a detailed description of the methods.

Analytical Elements

The analytical elements section explains a myriad of other considerations that were taken into account when developing this work product. Examples include the target pollutants and their interrelationships, project type and the implication of project selections, cultural as opposed to structural projects, edge of field and network level benefits, pollutant delivery ratios, model calibration, treatment train effects, and multiple treatment alternatives for a given site.

Project Ranking, Selection & Funding

The project ranking, selection and funding section describes the methods and rationale for how projects were ranked. There are many possible ways to prioritize projects, and the list provided in this report is merely a starting point. Local resource management professionals will be responsible to select projects to pursue. Several considerations in addition to project cost-effectiveness for prioritizing installation are included. Project funding opportunities may play a large role in project selection, design and installation.

Project Profiles

For each type of project included in this report, there is a description of the rationale for including that type of project, the modeling method employed, and the cost calculations used to estimate associated installation and maintenance expenses. The project type description concludes with a map of those projects as well as a table summarizing modeled projects, listed in order of cost-effectiveness for phosphorus removal. In addition, for each potential project that was selected for modeling, there is a project profile page that summarizes model results for removal of TP, TSS and volume if applicable. Each page includes model outputs for various potential configurations along with a budget for the configuration that was selected. Maps for each project are included that show the project location in the watershed, the treatment area with aerial photo base, and colored LiDAR with shaded relief to convey topography. The maps also provide parcel lines and property identifications numbers to facilitate outreach to landowners.

References

This section identifies various sources of information synthesized to produce the protocol utilized in this analysis.

Appendices

This section provides supplemental information and/or data used during the analysis.

Background

In accordance with Section 303(d) of the Federal Clean Water Act, Total Maximum Daily Load (TMDL) analyses and Implementation Plans were developed for Lake Sarah and Lake Independence located in western Hennepin County surrounded by the cities of Independence, Greenfield, Medina, Loretto, Corcoran, and Maple Plain. The TMDL identifies water quality goals that must be reached to meet state standards. Each city within the contributing watersheds has been designated a proportionate share of load reductions. The City of Independence is charged with reducing phosphorus waste-loads of 143lbs/year to Lake Sarah and 535 lbs/year to Lake Independence.

The TMDL Implementation Plans and City of Independence Water Resource Management Plan identify the following phosphorus load reductions as possible for the lakes by the City of Independence.

Table 8: TMDL Identified Annual Phosphorus Load Reductions for City of Independence

Phosphorus Source	Strategy	Sarah	Independence
Cropland	• Vegetated filter strip • Water & sediment control basins[8] • Grassed waterways[8] • Seasonal ponding[8] • Wetland restoration[8] • Hydrologic restoration[8]	38	187
Animal Waste	• Manure storage or off-site disposal • Manure application • Runoff management	133	260
Urban Development	• Residential rain gardens • Street sweeping • Shoreline buffers • Shoreline stabilization	89	80
Failing Subsurface Sewage Treatment Systems	• Inspection • Pumping • remediation		6
Goose Removal	• Capture and relocation		8
Stormwater Ponds	• Neighborhood ponds[8] • Regional ponds[8]		
Erosion Correction	• Gully stabilization[8]		
Total		260	541

Lake Sarah and Lake Independence are located in the northeast and eastern portion of the City of Independence respectively. The contributing watersheds are composed of rolling hills with silt soils. Swales and depressions typically supported wetlands historically, which would have served to capture runoff, increase infiltration and evapotranspiration, assimilate nutrients, and trap sediment in runoff. Many of the wetlands have undergone substantial drainage for agricultural purposes. Drainage was achieved through drainage ditches and subsurface drain tile. There is no record of drain tile locations so all hydric soil areas without wetland signatures or visible ditching are presumed to be drain tiled. Wetland ditching and drain tiling increases the volume of water that reaches the lakes, increases the

[8] Added as part of this analysis.

speed with which it makes it there, and increases the pollutant load that it carries. Channelization of natural flowages further exacerbates this problem.

Landuse also greatly impacts the quality and volume of stormwater runoff. Landuses that leave soil bare by removing vegetation, that add nutrient or chemical pollutants, or that increase impervious surfaces all tend to reduce downstream water quality. In the City of Independence, most of the land use is composed of row crops, livestock operations, and medium and low density residential. The agricultural areas increase erosion via artificial drainage and exposed soil and increase nutrient loads from livestock and over application of fertilizers. The winter application of manure to agricultural fields has been identified in some areas as a substantial source of nutrient rich early spring runoff. Residential areas are located in close proximity to the lakes. Impervious surface in residential areas is cited as contributing to increased pollutant loading which is due in part to in-stream erosion accelerated by greater runoff volumes. Lakeshore erosion made worse by on-lake recreational activities and vegetation removal and upslope mowing also contributes to water quality degradation in the lakes. In general, this analysis looked for opportunities to restore natural hydrology, correct active erosion, revegetate denuded areas, and capture and treat polluted stormwater.

Analytical Process

This Stormwater Retrofit Analysis is a watershed management tool to identify and prioritize stormwater retrofit projects by performance and cost effectiveness. This process helps maximize the value of each dollar spent.

Scoping includes identifying the objectives and bounds of the analysis in terms of target pollutant, geography, and practices.

Desktop analysis involves the utilization of high resolution aerial photography, digital elevation data (LiDAR), soils, hydrography, parcels, stream and ditch networks, wetlands, culverts, and landuse to narrow the scope of analysis and facilitate field investigation.

Field investigation involves driving and walking through the watershed along every public road and parcel to observe field conditions in search of problem sites and opportunities. Problem areas include active erosion, land management practices that contribute to water quality degradation, and artificial drainage. Most problem areas present an opportunity for corrective action, including hydrologic restoration, revegetation, ponding, soil stabilization, and land management practice improvements. As part of the field investigation, an erosion inventory of the entire shoreline of both lakes was completed.

Modeling involves several methods to estimate target pollutant removals associated with potential projects. Since no single modeling methodology currently available is suited to model benefits from the variety of project identified in this report, several methodologies had to be employed. They are explained in detail in Appendix A and include; Soil and Water Assessment Tool (SWAT), Source Loading and Management Model for Windows (WinSLAMM), and Board of Water and Soil Resources Pollution Reduction Calculator (BWSR PRC).

Cost estimating is critical for the comparison and ranking of projects, development of work plans, and pursuit of grants and other funds. Project installation costs are only one element included in cost estimates provided in this analysis. Engineering, landowner outreach, construction oversight, project administration, land acquisition, production loss, and long term maintenance costs were also considered. In addition to this, expected project life was incorporated into the estimate. All project costs should be verified against local experience.

Project ranking is essential to identify which projects to pursue to achieve water quality goals. It isn’t as simple as sorting by cost-effectiveness however. Since similar projects in different areas of the watershed will have different impacts on the receiving water body, a correction factor called a Pollutant Delivery Ratio (PDR) was used to further refine ranking.

Project selection involves considerations other than project ranking, including but not limited to total cost, treatment train effects, social acceptability, and political feasibility.

Analytical Elements

Many elements come into play when developing a stormwater retrofit analysis. Each analysis must be customized to the target pollutant, locally acceptable practice type, local fiscal capacity, and watershed characteristics. The following describes how these elements were considered.

Target Pollutants

Although lakes Sarah and Independence are both impaired for phosphorus, other pollutants were also identified for reduction in this report. Table 9 describes the target pollutants and their role in water quality degradation. Projects that effectively reduce loading of multiple target pollutants can provide greater immediate and long term benefits.

Table 9: Target Pollutants

Target Pollutant	Description
Total Phosphorus (TP)	Phosphorus is a nutrient essential to plant growth and is commonly the factor that limits the growth of plants in surface water bodies. Total Phosphorus (TP) is a combination of particulate phosphorus, which is bound to sediment and organic debris, and dissolved phosphorus (DP), which is in solution and readily available for plant growth (active). Excess phosphorus contributes to eutrophication of water bodies. (MPCA website).
Total Suspended Solids (TSS)	Very small mineral and organic particles that can be dispersed into the water column due to turbulent mixing (MPCA website). TSS loading can create turbid and cloudy water conditions and carry with it particulate phosphorus. As such, reductions in TSS will also result in TP reductions.
Volume	Higher runoff volumes and velocities can carry greater amounts of TSS to receiving water bodies. It can also exacerbate in-stream erosion, thereby increasing TSS loading. As such, reductions in volume, will reduce TSS loading and, by extension, TP loading.

Potential Project Types

A variety of stormwater retrofit approaches were identified. Table 10 describes projects included in this analysis.

Table 10: Stormwater Treatment Options

Project Type	Code	Description	Project Life	Modeling Method
Residential Rain Gardens	RG	Small depressions in residential landscapes designed to capture and treat runoff through infiltration and/or filtration.	20	Win SLAMM
Lakeshore Restorations	LR	Stabilization of active lakeshore erosion through structural and bioengineering techniques.	10	BWSR Pollution Reduction Estimator
Gully Stabilizations	GS	Correction of active gully erosion with rock cross vanes or other grade stabilization measures and revegetation.	20	BWSR Pollution Reduction Estimator

Project Type	Code	Description	Project Life	Modeling Method
Hydrologic Restorations	HR/WR	Restoration of hydrology in areas that have been partially (HR) or completely (WR) drained.	20	SWAT
Water and Sediment Control Basins	SB	Structural practice in agricultural fields to detain runoff and stabilize swales subject to erosion.	20	SWAT
Vegetated Filter Strips/ Grassed Waterways	FS	Establishment of permanent vegetative cover along waterways to slow runoff and capture sediment.	20	SWAT
New Ponds **Regional Ponds**	NP RP	Creation of new ponds to capture and treat runoff.	30	SWAT
Iron Enhanced Sand Filters	IESF	A stormwater pond enhancement that filters stormwater through a medium rich in iron, thereby binding dissolved phosphorus.	30	WinSLAMM
Seasonal Ponding	SP	Holding water in drained agricultural areas when not actively in production with control structures that interrupt artificial drainage processes.	10	SWAT

Project Categories

Projects fall into one of three general categories; cultural, vegetative, and structural. Cultural practices are those that must be continued by landuse managers each year in order for the benefits to persist. Vegetative practices are installed and may persist without active management or maintenance but are also easy and inexpensive to remove or denude, either intentionally or inadvertently. Structural practices are physically robust measures that also require maintenance but are difficult and expensive to remove and so the resultant benefits are much less likely to be rapidly lost, barring catastrophic structural failure. The durability of a project, and therefore the persistence of benefits is greatest for structural practices and least for cultural practices. This is not meant to imply that cultural practices should not be pursued with educational and technical assistance outreach programs, but they were not the focus of this report because of their temporal nature and difficulty to model. The table below summarizes the categories, which were included in this report and why.

Table 11: Structural, Vegetative and Cultural Practices

Project Type	Type	Included in Report	Rationale	Cost-Effectiveness
Residential Rain Gardens	Structural	Yes	One of few options for residential areas.	Moderate
Lakeshore Restorations	Structural/ Vegetative	Yes	100% of benefits to lake	High-Low
Gully Stabilizations	Structural/ Vegetative	Yes	Large scale TSS removal	High
Hydrologic Restorations	Structural/ Vegetative	Yes	Multiple target pollutant and habitat benefits	High-Low
Water & Sediment Control Basins	Structural	Yes	Socially feasible option on ag. land that needn’t remove much land from production	High-Low

Project Type	Type	Included in Report	Rationale	Cost-Effectiveness
Vegetated Filter Strips/ Grassed Waterways	Vegetative	Yes	Included for comparative purposes, may be pursued instead of SB but takes land out of production	High
New Ponds Regional Ponds	Structural	Yes	Neighborhood level and regional level treatment for multiple target pollutants, very durable	High-Moderate
Iron Enhanced Sand Filters	Structural	Yes	Specialized method for removing dissolved phosphorus	High for DP
Seasonal Ponding	Structural/ Cultural	Yes	Emerging approach that may be very cost-effective and socially acceptable	High
Goose Removal	Cultural	No	Wholly cultural, can't model benefits, vegetative buffers may deter geese and provide more durable benefits	Unknown
Manure Application	Cultural	No	Wholly cultural, can't model benefits	High
Nutrient Management	Cultural	No	Wholly cultural, can't model benefits	High
Street Sweeping	Cultural	No	Presumed to occur in models based on city correspondence	High
SSTS Remediation	Structural	No	Can't model benefits	Unknown

Cost Estimates

Providing reasonable cost estimates is essential to ranking projects by cost-effectiveness, developing long term work plans, and securing funds. To capture the full cost of projects, construction costs, land acquisition, incentive payments for lost productivity, project design, project maintenance, and project promotion and administration were included. For projects within the railroad right of way, an addition $15,000 was added for permitting.

Project promotion and administration includes local staff efforts to reach out to landowners, administer related grants, and complete necessary administrative tasks.

Design includes site surveying, engineering and construction oversight.

Land or easement acquisition cover the cost of purchasing property or the cost of obtaining necessary utility and access easements from landowners.

Production loss includes payments to landowners to offset income losses from taking land out of production.

Construction calculations are project specific and may include all or some of the following; grading, erosion control, vegetation management, structures, mobilization, traffic control, equipment, soil disposal, and rock or other materials.

Maintenance includes annual inspections and minor site remediation such as vegetation management, structural outlet repair and cleaning, and washout repair.

Table 12: Project Cost Estimating

Project Type	Promo/ Admin (hrs)	Design ($)	Land/ Easement Acquisition	Production Loss	Construction	Annual Maintenance
Residential Rain Gardens	35	$2,500			$20/sq. ft.	$75
Lakeshore Restorations	35	$1,500			$70-$150/lin. ft.	$1.5/lin. ft.
Gully Stabilizations	35	$4,000			$65/sq. ft.	$.50/sq. ft.
Hydrologic Restorations	85	$10,000	$5,000/ac		$4,000-$25,000/ control structure $40/cu. yd. earthwork	$500
Wetland Restoration	85	$10,000	$20,000/ac		$4,000-$25,000/ control structure $40/cu. yd. earthwork	$500
Water and Sediment Control Basins	85	$10,000			$4,000/control structure/4000 cu. meters storage $40/cu. yd. earthwork	$500
Vegetated Filter Strips/ Grassed Waterways	65	$6,000		$800/ ac./yr.[9]	$200/ac.	$300
New Ponds Regional Ponds	85	$25,000- $50,000	$20,000/ac		$5.50/sq. ft.	$100/acre of pond
Iron Enhanced Sand Filters	85	$20,000	$20,000/ac		$15/sq. ft.	$100/acre of filter
Seasonal Ponding	40	$3,000			$4,000/control structure	$50

Location in Watershed

Network level modeling allows calculation of benefits to the receiving water body, not simply at the edge of field. Most projects were modeled to determine their benefits at the edge of the field due to model limitations however. The BWSR Pollutant Reductions Calculators and SWAT are geared toward edge of field modeling in rural landscapes, whereas WinSLAMM is designed to calculate network level benefits in built environments. In order to translate edge of field benefits into benefits to the receiving water body, a pollutant delivery ratio (PDR) is used. PDRs can be highly complex calculations, including factors such as slope, distance to a water course, vegetative cover, distance to the receiving water body, the target pollutant, and intervening water quality treatment along the flow path. Incorporating all of these in a reproducible manner would require complex algorithms that are beyond the scope of this effort. A subjective PDR was provided as an example however. It was intuitively arrived at by a natural resource management professional utilizing maps showing the project location in the watershed,

[9] Assumes 160 bushel/acre corn at $5.00/bushel.

receiving water body, aerial photos, topography and flow paths. Each project was assigned a factor from 0.3 to 1.0, representing the percentage of benefits that would transfer to the receiving water body. Local resource management professionals are encouraged to modify the PDR rankings based on their local knowledge of the landscape. Figure 4 shows the subwatershed boundaries overlaid on LiDAR generated topographic map with shaded relief to aid in visualizing the watersheds.

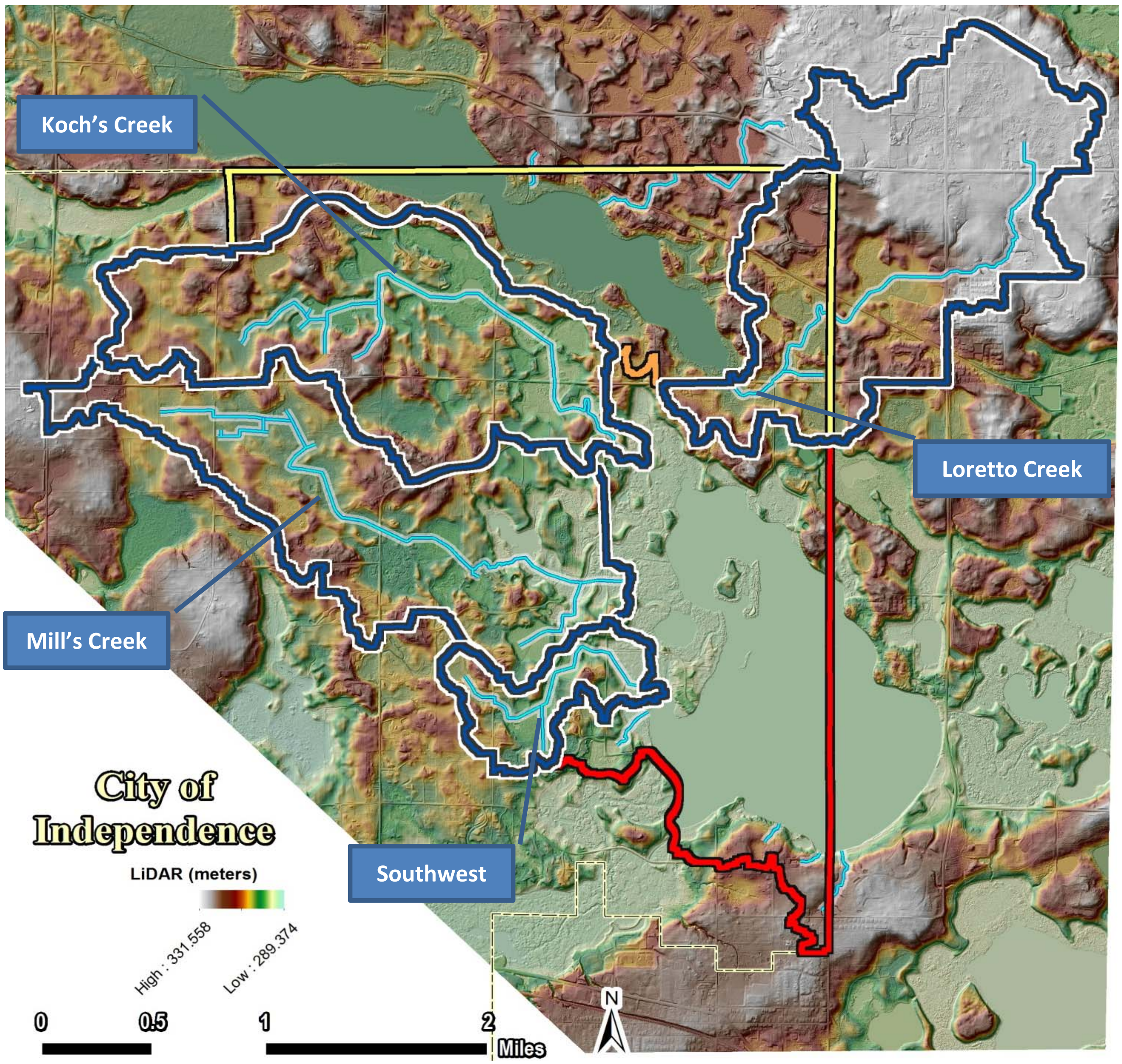


Figure 4: Subwatersheds with LiDAR Base

Models and Calibration

Modeling methodology is provided in detail in Appendix A. The primary model used to estimate project benefits in rural areas was the Soil and Water Assessment Tool (SWAT). This model considers hydrography, soils, vegetation, and topography in a GIS interface. Potential projects can be modeled either by inserting a practice at the downstream limit of a defined subwatershed or by altering landuse and/or topography within that watershed. The latter approach is highly time intensive and does not lend itself well to rapidly modeling multiple scenarios. As such, the use of SWAT was limited to edge of field benefits modeling. SWAT was also used by the Three Rivers Park District (TRPD) to model agricultural areas of the Lake Sarah watershed in the Lake Sarah TMDL. TRPD calibrated and validated the model with field monitoring. Those calibrations were applied to this SWAT model. SWAT was run to calculate base conditions for three regional ponds, which are positioned close to the lakes and treat the vast majority of the contributing subwatershed. SWAT modeling results for these watersheds are compared to SWAT model outputs for the Lake Sarah TMDL and calibrated BATHTUB and FLUX models used in the Lake Independence TMDL. Those comparisons are shown in Table 13.

Table 13: Model Calibration

Annual Loading	TP Modeled (lbs)	TP TMDL (lbs)	TP Variance
Sarah – Loretto Creek and Portion of Other Direct	746	761	98%
Independence - Koch's Creek	336	314	107%
Independence - Mill's Creek	439	482	91%

SWAT was used to model benefits for all but residential rain gardens (WinSLAMM), gully stabilizations (BWSR PRC), lakeshore restorations (BWSR PRC), and iron enhanced sand filters (WinSLAMM). The other models, as noted in Table 10 and Appendix A, were not calibrated but their application was limited to near-lake practices and so their results are less likely to have been skewed by watershed influences.

Project Alternatives and Treatment Trains

Although there are sufficient projects identified in the Lake Independence and Lake Sarah watersheds to individually remove a total of 680 lbs/yr of TP and 110 lbs/yr of TP respectively, the cumulative benefit of all of those projects in the landscape would be an amount far less than that. This is true because the projects overlap substantially in terms of both contributing watershed and downstream benefits. These overlaps impact how much pollutant loading reduction can actually be achieved on the landscape. The most effective way to take these overlaps into account is through a watershed wide model that incorporates all stormwater treatment structures, cultural practices and landuse changes. This is not currently practical due to limits in technology and staffing. As an alternative, local resource managers should consider this overlap intuitively in two general ways when selecting projects for installation; 1) alternative treatment options presented for the same problem, and 2) treatment train effects.

Many projects are alternative treatments for the same problem. A single site may have multiple treatment options presented, such as using a sediment basin, a hydrologic restoration, or a vegetated filter strip to stabilize a critical area in an agricultural field. Figure 5 shows overlapping treatment areas. Catchments with treatment provided by multiple practices are darker. Many projects in the western part of the Lake Independence watershed overlap treatment areas. What's important to acknowledge is that if the most robust and large scale project is installed, it may not be cost-effective to install the smaller projects as well because their marginal benefit will be greatly reduced.

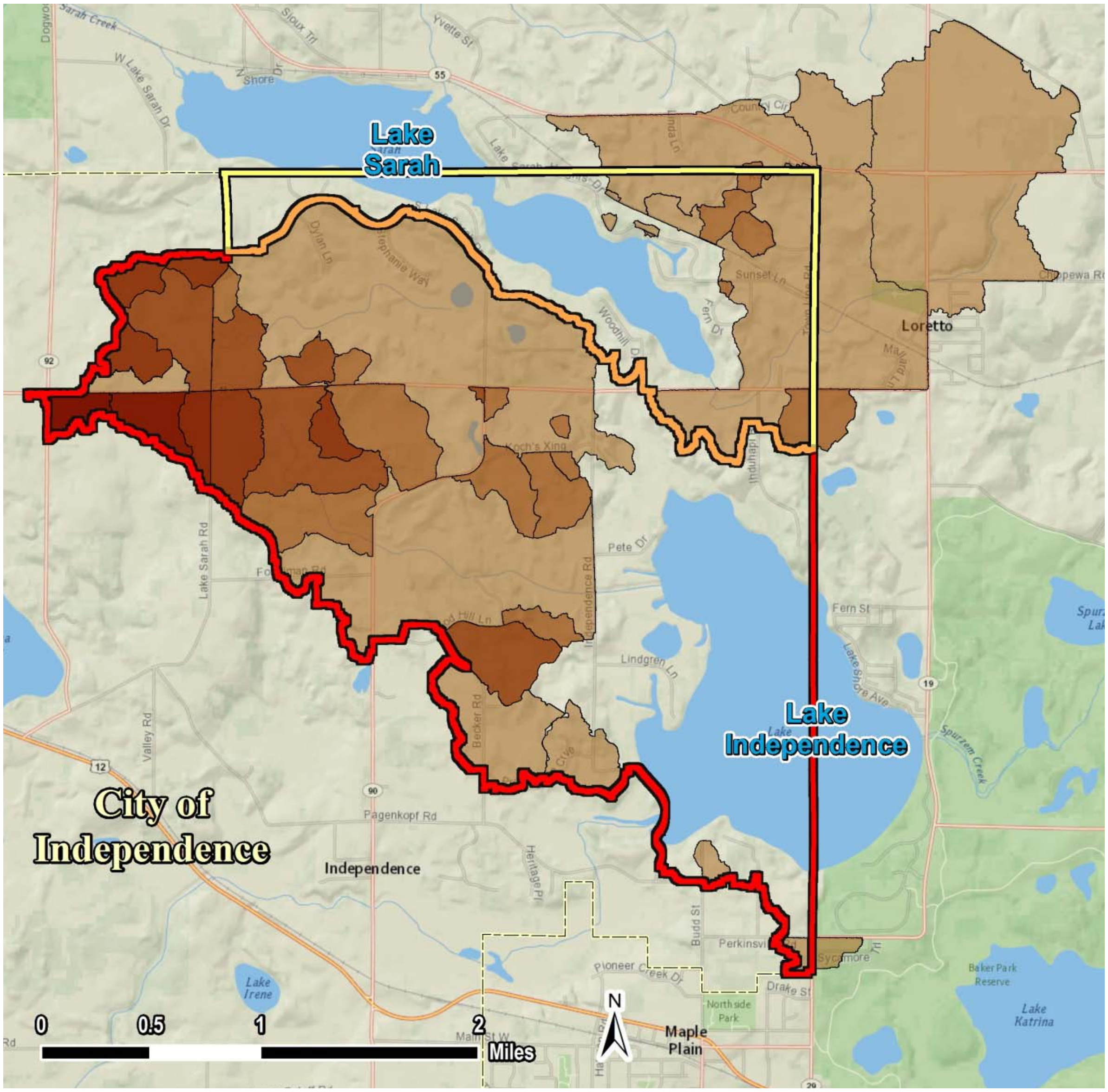


Figure 5: Overlapping Treatment

Treatment trains are another form of overlapping treatment by treating water in series through multiple practices. The clearest examples in this report are the three regional ponds. Each of these ponds treats stormwater runoff from its entire subwatershed. The modeling completed for the regional ponds to ascertain water quality and volume inputs and outflows presumed current landuse conditions. Within each subwatershed, however, numerous other potential projects have been identified. As these other projects are installed and come on-line, the water quality entering the regional ponds will be improved and so the marginal treatment provided by the pond may be lower. The reduction in treatment provided by the regional pond is not likely to be equal to the added treatment provided by the upstream practice however, since needed water quality treatment is greater than the capacity of both practices. As long as the regional pond continues to discharge some pollutant loading into the lake, projects installed further upstream will continue to provide some level of benefit.

Project Ranking, Selection and Funding

The intent of this analysis is to provide the information necessary to enable local natural resource managers to successfully secure funding for the most cost-effective projects to achieve water quality goals. This analysis ranks projects by cost-effectiveness to facilitate project selection. There are many possible ways to prioritize projects, and the list provided in this report is merely a starting point. Local resource management professionals will be responsible to select projects to pursue. Several considerations in addition to project cost-effectiveness for prioritizing installation are included.

Project Ranking

If all identified practices were installed, significant pollution reduction could be accomplished. However, funding limitations and landowner interest will be a limiting factor in implementation. The following tables rank all modeled projects by cost-effectiveness including a Total Phosphorus Pollutant Delivery Ratio (PDR), explained in Location in Watershed on page 17.

Table 14: Lake Sarah Retrofit Projects

Site ID (pg.)	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Volume Decrease (ac-ft/yr)	Project Life (yrs)	Project Life Cost	Cost-Benefit ($/lb TP)	TP PDR	Cost-Benefit w/ PDR	TP Decrease w/ PDR
HR67&68 (69)	15.99	15.32	0.70	20	$71,105	$232	0.95	$244	14.55
IESF115 (110)	0	145.34	0	30	$1,387,005	$275	1.00	$275	145.34
IESF115 adjustment[10]	0	-108.28	0	30	-$1,033,319	$275	1.00	$275	-108.28
SP77 (113)	1.0	2.85	2.15	10	$10,420	$365	0.90	$406	2.57
WR75 (80)	8.41	9.34	2.58	20	$73,205	$392	0.95	$413	8.87
LR100 (47)	1.61	2.58	0	10	$14,600	$566	1.00	$566	2.58
WR76 (81)	3.77	4.63	1.75	20	$73,705	$796	0.95	$838	4.40
RP110 (106)	194.86	108.62	1.60	30	$3,305,245	$1,014	1.00	$1,014	108.62
RP110 adjustment[5]	-115.94	-80.92	-1.19	30	-$2,462,407	$1,014	1.00	$1,014	-80.92
RG72 (32)	0.10	0.71	0.47	20	$16,555	$1,166	0.95	$1,227	0.67
RG111 (34)	0.02	0.13	0.09	20	$3,055	$1,175	0.95	$1,237	0.86
RG11 (30)	0.16	1.11	0.75	20	$26,555	$1,196	0.95	$1,259	1.05
HR79 (70)	1.90	5.87	8.32	20	$140,205	$1,194	0.90	$1,327	5.28
LR99 (46)	.66	1.05	0	10	$14,680	$1,398	1.00	$1,398	1.05
RG74 (33)	0.08	0.62	0.43	20	$16,555	$1,335	0.90	$1,483	0.56
SB63 (92)	0.66	1.15	0	20	$30,205	$1,130	0.75	$1,507	0.86
RG69 (31)	0.06	0.54	0.33	20	$16,555	$1,533	0.95	$1,614	0.51
Total	**113.34**	**110.66**	**17.98**		**$1,703,924**				**108.57**

[10] The reason for adjustments is to account for treatment associated with runoff from other municipalities and to reduce the costs to the City of Independence proportionately. This is explained in greater detail on page 98.

Table 15: Lake Sarah Projects not in City of Independence

Site ID (pg.)	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Volume Decrease (ac-ft/yr)	Project Life (yrs)	Project Life Cost	Cost-Benefit ($/lb TP)	TP PDR	Cost-Benefit w/ PDR	TP Decrease w/ PDR
IESF112 (107) Several	0	75.10	0	30	$354,405	$121	1.00	$121	75.10
RP110 (106) Several	115.94	80.92	1.19	30	$2,462,407	$1,014	1.00	$1,014	80.92
LR104 (50) Greenfield	1.03	1.65	0	10	$18,680	$1,131	1.00	$1,131	1.65
LR103 (49) Greenfield	.26	.41	0	10	$11,370	$2,753	1.00	$2,753	0.41
LR102 (48) Greenfield	.11	.18	0	10	$7,290	$3,994	1.00	$3,994	0.18
Total	**117.34**	**158.26**	**1.19**		**$2,854,152**				**158.26**

Table 16: Lake Independence Retrofit Projects

Site ID (pg.)	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Volume Decrease (ac-ft/yr)	Project Life (yrs)	Project Life Cost	Cost-Benefit ($/lb TP)	PDR	Cost-Benefit w/ PDR	TP Decrease w/ PDR
FS93 (96)	16.28	34.27	0	20	$32,945	$48	0.40	$120	13.71
IESF113 (108)	0	105.34	0	30	$1,387,005	$275	1.00	$275	105.34
GS46 (54)	9.77	15.6	0	20	$87,285	$279	1.00	$279	15.60
FS94 (97)	4.51	10.95	0	20	$26,465	$121	0.40	$303	4.38
HR95 (71)	9.44	9.64	1.93	20	$61,205	$317	0.80	$396	7.71
LR53 (39)	2.73	4.8	0	10	$20,560	$428	1.00	$428	4.80
LR59 (43)	7.83	12.52	0	10	$55,700	$445	1.00	$445	12.52
IESF114 (109)	0	72.66	0	30	$1,046,805	$480	1.00	$480	72.66
SB3 (91)	1.50	9.13	0	20	$31,568	$173	0.30	$577	2.74
LR60 (44)	2.66	4.26	0	10	$26,000	$611	1.00	$611	4.26
FS89 (95)	0.65	1.25	0	20	$10,835	$433	0.70	$619	0.50
LR51 (37)	2.73	4.37	0	10	$27,860	$638	1.00	$638	4.37
LR58 (42)	1.35	2.15	0	10	$15,440	$717	1.00	$717	2.15
LR62 (45)	1.3	2.07	0	10	$15,360	$740	1.00	$740	2.07
WR4 (73)	17.01	22.09	1.90	20	$143,705	$325	0.40	$813	8.84
HR29 (63)	2.02	5.98	3.29	20	$83,705	$771	0.85	$907	5.08
WR12 (76)	31.43	25.64	4.05	20	$195,205	$381	0.40	$953	10.26
HR33 (65)	3.09	9.19	6.52	20	$151,705	$825	0.85	$971	7.81
GS45 (53)	1.33	2.1	0	20	$43,385	$1019	1.00	$1,019	2.10
HR31 (64)	2.92	3.77	1.40	20	$73,705	$978	0.90	$1,087	3.39
HR13 (61)	1.74	2.49	0.22	20	$36,205	$727	0.65	$1,118	1.62
NP47 (103)	3.63	4.49	0.76	30	$155,140	$1,152	0.90	$1,280	4.04
WR91 (85)	8.53	18.29	7.80	20	$289,205	$791	0.60	$1,318	10.97
LR52 (38)	.26	.42	0	10	$5,710	$1,371	1.00	$1,371	0.42
RP108 (104)	152.11	89.09	1.13	30	$3,540,751	$1,325	0.95	$1,395	84.64
WR105[3] (87)	26.41	32.13	7.69	20	$543,205	$845	0.60	$1,408	19.28
HR65 (68)	5.49	6.25	2.71	20	$153,205	$1,226	0.85	$1,442	5.31
WR18[11] (77)	10.58	39.54	9.96	20	$559,205	$707	0.45	$1,571	17.79
WR97 (86)	1.10	2.53	1.61	20	$67,705	$1,338	0.85	$1,574	2.15
WR6 (75)	2.29	5.11	1.13	20	$74,205	$726	0.45	$1,613	2.30
WR82 (82)	2.90	15.65	5.83	20	$208,705	$667	0.40	$1,668	6.26

[11] WR18, WR83 and WR105 are alternative scales of restoration.

RP109 (105)	116.59	72.02	2.07	30	$3,540,338	$1,639	0.95	$1,725	68.42
WR1 (72)	3.46	8.39	3.39	20	$92,205	$549	0.30	$1,830	2.52
WR5 (74)	1.61	4.71	1.78	20	$86,205	$915	0.50	$1,830	2.36
WR24 (79)	1.14	3.41	0.80	20	$59,705	$876	0.40	$2,190	1.36
WR86 (84)	0.57	4.07	1.67	20	$60,205	$740	0.30	$2,467	1.22
HR38 (66)	1.56	2.56	2.31	20	$137,205	$2,680	0.95	$2,821	2.43
WR83[3] (83)	0.62	5.57	0.33	20	$148,705	$1,335	0.45	$2,967	2.51
HR14 (62)	0.92	0.86	2.72	20	$35,205	$2,047	0.65	$3,149	0.56
SB2 (90)	0.92	1.5	0	20	$31,864	$1,065	0.30	$3,550	0.45
WR22 (78)	0.11	2.24	1.35	20	$83,205	$1,857	0.50	$3,714	1.12
HR44 (67)	0.29	0.60	0.89	20	$57,205	$4,767	0.95	$5,018	0.57
Totals	**461.38**	**679.70**	**75.24**		**$13,501,731**				**528.59**

Table 17: Lake Independence Projects Not In City of Independence

Site ID	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Volume Decrease (ac-ft/yr)	Project Life (yrs)	Project Life Cost	Cost-Benefit ($/lb TP)	PDR	Cost-Benefit w/ PDR	TP Decrease w/ PDR
GS50-Medina (55)	233.5	373.7	0	20	$535,789	$72	1.00	$72	373.70
LR54-Medina (40)	6.87	10.99	0	10	$42,990	$391	1.00	$391	10.99
LR56-Medina (41)	.35	.56	0	10	$8,650	$1,539	1.00	$1,539	0.56
Totals	**240.72**	**385.25**	**0.00**		**$587,429**				**385.25**

Project Selection

The City of Independence has an annual TP load reduction goal of 535lbs for Lake Independence and 143 lbs for Lake Sarah from all sources. The combination of projects selected for pursuit should strive to achieve these goals in the most cost-effective manner possible. These goals are not likely to be reached solely through pursuit of projects identified in this analysis, however. A more likely scenario is a combination of structural and vegetative projects included herein along with cultural practices such as increased street sweeping, livestock manure management, crop residue management, goose population management, and septic system maintenance. Figure 6 is provided as an aide for project selection.

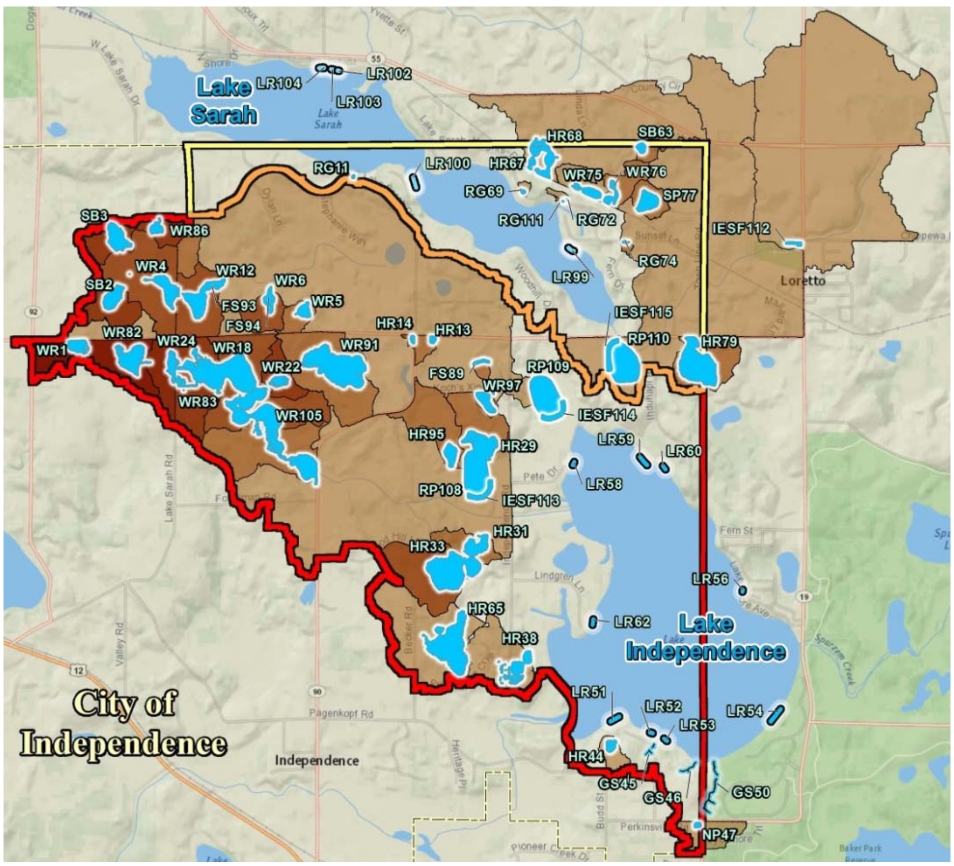


Figure 6: Project Selection Aide

Several other factors affecting project installation decisions should be weighed by resource managers when selecting projects to pursue. These factors include but are not limited to the following;

- Total project costs
- Cumulative treatment
- Availability of funding
- Economies of scale
- Landowner willingness
- Project combinations with treatment train effects
- Non-target pollutant reductions
- Timing coordination with other projects to achieve cost savings
- Stakeholder input
- Number of parcels (landowners) involved
- Project visibility
- Educational value
- Long term impacts on property values and public infrastructure

Because much of the watershed is in agricultural production and commodity prices are very high it may be impractical to install agricultural conservation practices to improve water quality and reduce discharge volumes that remove crop land from production. Strategies to install conservation practices in light of this include:

- Focus on residential areas, where landowners are more likely to view projects as mutually beneficial (lakeshore restoration, gully stabilization and rain gardens).
- Contact owners of large parcels that are for sale as they may be more willing to consider installing practices such as wetland restorations.
- Break all tile lines within areas that are undergoing residential development.
- Promote practices such as sediment basins and seasonal ponding that remove very little land from production.
- Provide compensation for losses in production for projects like filter strips and grassed waterways that do take land out of production. Lost production payments are included in project cost estimates and they are still cost-effective.
- Promote wetland banking projects in marginal agricultural lands, the funds from which may be financially preferable to commodity prices.
- Purchase fee title or easements on land for long term restorations that restore cropland to wetland.

The tables below provide an example of project selection by assigning tiers according to some of the factors and considerations listed above.

Table 18: Lake Independence Tier 1 Project Selection Example

Site ID (pg.)	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Project Life Cost	PDR	Cost-Benefit w/ PDR	TP Decrease w/ PDR	Rationale
FS93 (96)	16.28	34.27	$32,945	0.40	$120	13.71	T1: Very cost-effective
IESF113 (108)	0	105.34	$1,387,005	1.00	$275	105.34	T1: Very cost-effective
GS46 (54)	9.77	15.6	$87,285	1.00	$279	15.60	T1: Very cost-effective
FS94 (97)	4.51	10.95	$26,465	0.40	$303	4.38	T1: Very cost-effective
HR95 (71)	9.44	9.64	$61,205	0.80	$396	7.71	T1: Very cost-effective
LR53 (39)	2.73	4.8	$20,560	1.00	$428	4.80	T1: Very cost-effective
LR59 (43)	7.83	12.52	$55,700	1.00	$445	12.52	T1: Very cost-effective
IESF114 (109)	0	72.66	$1,046,805	1.00	$480	72.66	T1: Very cost-effective
SB3 (91)	1.50	9.13	$31,568	0.3	$577	2.74	T1: Very cost-effective
LR60 (44)	2.66	4.26	$26,000	1.00	$611	4.26	T1: Very cost-effective
LR51 (37)	2.73	4.37	$27,860	1.00	$638	4.37	T1: Very cost-effective
LR58 (42)	1.35	2.15	$15,440	1.00	$717	2.15	T1: Very cost-effective
LR62 (45)	1.3	2.07	$15,360	1.00	$740	2.07	T1: Very cost-effective
WR4 (73)	17.01	22.09	$143,705	0.40	$813	8.84	T1: Very cost-effective
FS89 (95)	0.65	1.25	$10,835	0.70	$619	0.50	T1: Very cost-effective
HR29 (63)	2.02	5.98	$83,705	0.85	$907	5.08	T1: Very cost-effective
HR33 (65)	3.09	9.19	$151,705	0.85	$971	7.81	T1: Cost-effective residential project
GS45 (53)	1.33	2.1	$290,385	1.00	$1,019	2.10	T1: Cost-effective residential project
HR31 (64)	2.92	3.77	$73,705	0.90	$1,087	3.39	T1: Cost-effective residential project
HR13 (61)	1.74	2.49	$36,205	0.65	$1,118	1.62	T1: Cost-effective residential project
NP47 (103)	3.63	4.49	$155,140	0.90	$1,280	4.04	T1: Residential project
LR52 (38)	.26	.42	$5,710	1.00	$1,371	0.42	T1: Cost-effective residential project
RP108 (104)	152.11	89.09	$3,540,751	0.95	$1,395	84.64	T1: Cost-effective – couple with public works projects that need fill material to sharply reduce cost
WR105 (87)	26.41	32.13	$543,205	0.60	$1,408	19.28	T1: Large TP reduction
HR65 (68)	5.49	6.25	$153,205	0.85	$1,442	5.31	T1: Residential project
WR97 (86)	1.10	2.53	$67,705	0.85	$1,574	2.15	T1: Small scale ag. WR as test case.
RP109 (105)	116.59	72.02	$3,540,338	0.95	$1,725	68.42	T1: Cost-effective – couple with public works projects that need fill material to sharply reduce cost
Totals	**394.45**	**541.56**	**$11,630,497**			**465.91**	

Table 19: Lake Independence Tier 2 Project Selection Example

Site ID (pg.)	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Project Life Cost	PDR	Cost-Benefit w/ PDR	TP Decrease w/ PDR	Rationale
WR18 (77)	10.58	39.54	$559,205	0.45	$1,571	17.79	T2: Overlaps w/ WR 105
WR12 (76)	31.43	25.64	$195,205	0.40	$953	10.26	T2: Distant from lake, takes ag. Land out of production, promote wetland banking
WR91 (85)	8.53	18.29	$289,205	0.60	$1,318	10.97	
WR6 (75)	2.29	5.11	$74,205	0.45	$1,613	2.30	
WR82 (82)	2.90	15.65	$208,705	0.40	$1,668	6.26	
WR1 (72)	3.46	8.39	$92,205	0.30	$1,830	2.52	
WR5 (74)	1.61	4.71	$86,205	0.50	$1,830	2.36	
Totals	**60.80**	**117.33**	**$1,504,935**			**52.46**	

Table 20: Lake Independence Tier 3 Project Selection Example

Site ID (pg.)	TSS Decrease (tons/yr)	TP Decrease (lbs/yr)	Project Life Cost	PDR	Cost-Benefit w/ PDR	TP Decrease w/ PDR	Rationale
WR24 (79)	1.14	3.41	$59,705	0.40	$2,190	1.36	T3: Less cost-effective
WR86 (84)	0.57	4.07	$60,205	0.30	$2,467	1.22	T3: Less cost-effective
HR38 (66)	1.56	2.56	$137,205	0.95	$2,821	2.43	T3: Less cost-effective
WR83 (83)	0.62	5.57	$148,705	0.45	$2,967	2.51	T3: Less cost-effective Overlaps w/ WR105
HR14 (62)	0.92	0.86	$35,205	0.65	$3,149	0.56	T3: Less cost-effective
SB2 (90)	0.92	1.5	$31,864	0.30	$3,550	0.45	T3: Less cost-effective
WR22 (78)	0.11	2.24	$83,205	0.50	$3,714	1.12	T3: Less cost-effective
HR44 (67)	0.29	0.60	$57,205	0.95	$5,018	0.57	T3: Less cost-effective
Totals	**6.13**	**20.81**	**$613,299**			**10.22**	

Project Funding

In addition to conventional funding sources such as the Clean Water Land and Legacy Amendment, funding for project construction and other elements may be offset by other sources and partnerships. For example, the Natural Resources Conservation Service can provide project planning and coordination on agricultural lands. Their designs may be installed with funding sources outside of the Farm Bill that may be more cost-competitive with commodity markets. Local Water Plan implementation funding may be well used to tip the scales in favor of federal conservation funding by providing additional incentive payments to agricultural producers to implement conservation. The public and private sector wetland banking markets may provide between $0.25 and $1.25 per square foot for wetland restorations. The Metropolitan Technical Services Area Joint Powers Board may also provide project design assistance through a state funded program. This can help develop the site specific project plans and budgets upon which successful grant applications are built.

There may be several less expensive approaches to achieve the benefits attributed to the potential projects described in this analysis. For example, a wetland restoration may be accomplished by simply breaking tile lines or installing a ditch plug instead of installing a weir or other control structure. It may be possible to purchase an easement over the land instead of fee title, or even partner with a conservation-minded landowner willing to donate the use of their property. Cost estimates in this report are intended to be on the higher end of anticipated costs to hedge against inflation and guard against requesting funds from third parties that are insufficient to complete the project.

Project Profiles

Modeled projects are organized by type instead of subwatershed or catchment. This was done to reduce duplicative reporting within the analysis and facilitate report compilation. For each project modeled, the method of modeling, assumptions made, and cost estimate considerations are described, and are similar for each project type. Furthermore, the mapping conventions and table configurations for each project type are similar but may vary greatly between project types. To facilitate generation of tabular outputs and maps as well as reporting of model and budget elements, a report structured around distinct project types emerged as most efficient. Project types included in the following sections are;

- Residential Rain Gardens
- Lakeshore Restorations
- Gully Stabilizations
- Hydrologic Restorations
- Water and Sediment Control Basins
- Vegetated Filter Strips/ Grassed Waterways
- New Ponds (neighborhood and regional)
- Iron Enhanced Sand Filters
- Seasonal Ponding

Residential Rain Gardens

Residential rain gardens capture and treat stormwater runoff from roads, driveways and roof tops. There are two general types of rain gardens; rain leader disconnect, and curb cut. The former captures stormwater as it discharges from gutter downspouts and can be incorporated into most properties. The latter captures stormwater that is in roadside gutters and redirects it into shallow road-side basins.

Figure 7: Curb Cut Rain Garden Example

Both types of rain gardens can function as infiltration basins (bioretention) or filtrations basins (biofiltration). Filtration basins are designed with a buried perforated drain tile that allows water in the basin to discharge to the stormwater drainage system after having been filtered through the soil. Infiltration basins have no underdrain, ensuring that all water that enters the basins will either infiltrate into the soil or be evapotranspired into the air. Bioretention provided 100% retention and treatment of captured stormwater, whereas biofiltration basins provide excellent removal of particulate contaminants but limited removal of dissolved contaminants, such as dissolved phosphorus.

The treatment efficacy of a particular project depends on many factors, including but not limited to the pollutant of concern, the quality of water entering the project, the intensity and duration of storm events, project size, position of the project in the landscape, existing down watershed treatment, soil and vegetation characteristics, and project type. Optimally, new rain gardens will capture water that would discharge into priority water body untreated. Many rain leader disconnect rain gardens intercept water that would have been filtered through turf grass or other vegetation, or even infiltrated, thereby provided little to no benefit. Because curb cut rain gardens capture water that is already part of the stormwater drainage system, they are more likely to provide higher benefits. The following matrix conveys the general efficacy of rain garden types in terms of the three most common pollutants.

Table 21: Relative Benefit to Downstream Water Resource

Rain Garden Type	TSS Removal	TP Removal	Volume Reduction	Site Selection and Design Notes
Curb Cut - Bioretention	High	High	High	Optimal sites are low enough in the landscape to capture most of the watershed but high enough to ensure adequate separation to the water table for treatment purposes. Higher soil infiltration rates allow for deeper basins and may eliminate the need for underdrains.
Curb Cut - Biofiltration	High	Moderate	Low	
Rain Leader Disconnect - Bioretention	Moderate	Low	Moderate	Optimal sites are those where downspout discharge makes it into the stormwater drainage system, a simple downspout redirection into vegetated areas is not sufficient to treat runoff, concentrated flow occurs, and adequate downstream treatment is absent.
Rain Leader Disconnect - Biofiltration	Low	Low	Low	

For the purpose of this analysis, only opportunities for curb cut rain gardens were sought. Optimal curb cut rain garden sites were difficult to find in the watershed due to silty-loam soils with low infiltration rates, steep slopes, lack of curb and gutter (storm water drainage infrastructure), and high water tables and sewage pump stations in topographic low areas. The photo below shows a sewage pumping station. These are located throughout the Lake Sarah residential neighborhoods near the bottom of most hills, in precisely the location that a rain garden would typically be installed. Their presence makes rain gardens impossible in many areas. Furthermore, in landscapes with heavier silt and clay loam soils, underdrains are typically installed to ensure rain gardens dry within 72 hours. Underdrains must either be day-lighted or connected to a subsurface storm sewer pipe. The Lake Sarah neighborhood lacks storm sewer pipes and so rendered the installation of underdrains impractical in many otherwise well suited locations. Because of these limitations, only a few curb cut rain garden opportunities were identified.

Figure 8: Sewage Pump Station

Each rain garden's pollutant removals were estimated using the stormwater model WinSLAMM. WinSLAMM uses an abundance of stormwater data from the upper Midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It is useful for determining the effectiveness of proposed stormwater control practices. It has detailed accounting of pollutant loading from various land uses, and allows the user to build a model "landscape" that reflects the actual landscape being considered. The user is allowed to place a variety of stormwater treatment practices that treat water from various parts of this landscape. It uses rainfall and temperature data from a typical year, routing stormwater through the user's model for each storm. WinSLAMM is well suited to urban and suburban environments.

In order to determine cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach and promotion, project design, easement acquisition, project administration, and project maintenance over the anticipated life of the practice were considered in addition to actual construction costs. All rain gardens were presumed to have a 12 inch ponding depth, underdrains, amended soils, no pretreatment, mulch, and perennial ornamental and native plants. Street sweeping was entered as occurring once annually per correspondence with City of Independence staff. The useful life of the project was assumed to be 20 years and so all costs are amortized over that time period.

The table below summarizes all potential rain gardens identified during field reconnaissance. Projects are sorted from most cost-effective to least cost-effective in terms of the cost per pound of Total Phosphorus removed from the system. Cost assumptions made to calculate the cost-benefit of each project should be verified against local experience while creating implementation plans. The relative ranking shouldn't vary much even with alterations to the cost formula.

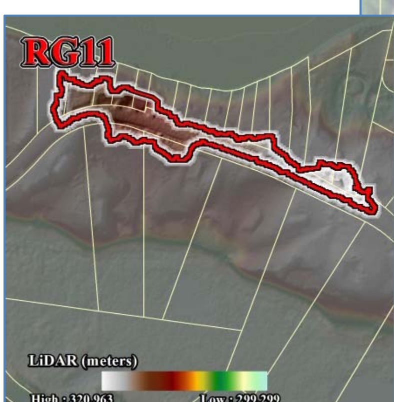
Table 22: Potential Residential Rain Garden Projects

Water Resource	Site ID	TSS Reduction (tons/yr)	TP Reduction (lbs/yr)	Volume Reduction (ac-ft/yr)	20 Yr. Cost[12]	Project Life (yrs)	Cost-Benefit ($/lb TP)
Sarah	RG72	0.10	0.71	0.47	$16,555	20	$1,165.85
Sarah	RG111	0.02	0.13	0.09	$3,055	20	$1,175.00
Sarah	RG11	0.16	1.11	0.75	$26,555	20	$1,196.17
Sarah	RG74	0.08	0.62	0.43	$16,555	20	$1,335.08
Sarah	RG69	0.06	0.54	0.33	$16,555	20	$1,532.87

[12] Assumes 35 hours for promotion and administration at $73/hr, $2,500 for design, $20/square foot installation cost, and $75/year for maintenance.

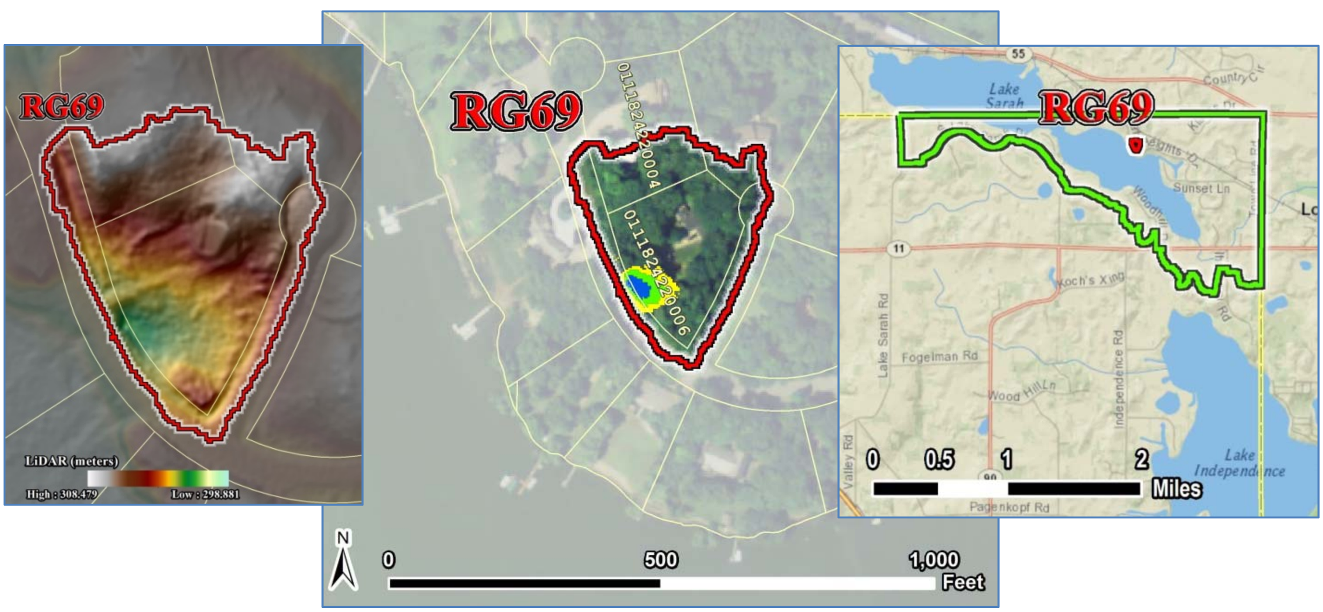
RG11 Size (sq. ft.)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	1.67	426	1.05	N/A	N/A	N/A	N/A	N/A	N/A
1,000	0.56	106	0.30	1.11	315	0.75	66.7%	75.1%	71.4%
2,000	0.35	62	0.17	1.32	359	0.88	79.0%	85.3%	83.8%
4,000	0.00	0	0.00	1.67	421	1.05	100%	100%	100%

Site Summary – RG11 – 1000 sq. ft.	
Water Body	Lake Sarah
Treatment Watershed (ac)	2.0
Dominant Land Cover	Med. Density Residential
Installation Cost ($)	$20,000
Promo/Design/Admin ($)	$5,055
Maintenance ($/20yrs)	$1,500
Total 20 Year Cost ($)	$26,555
Project Life (yrs)	20
$/lb-TP removal/yr	$1,196.17
$/lb-TSS removal/yr	$4.22
$/ac-ft volume removal/yr	$1,770.33



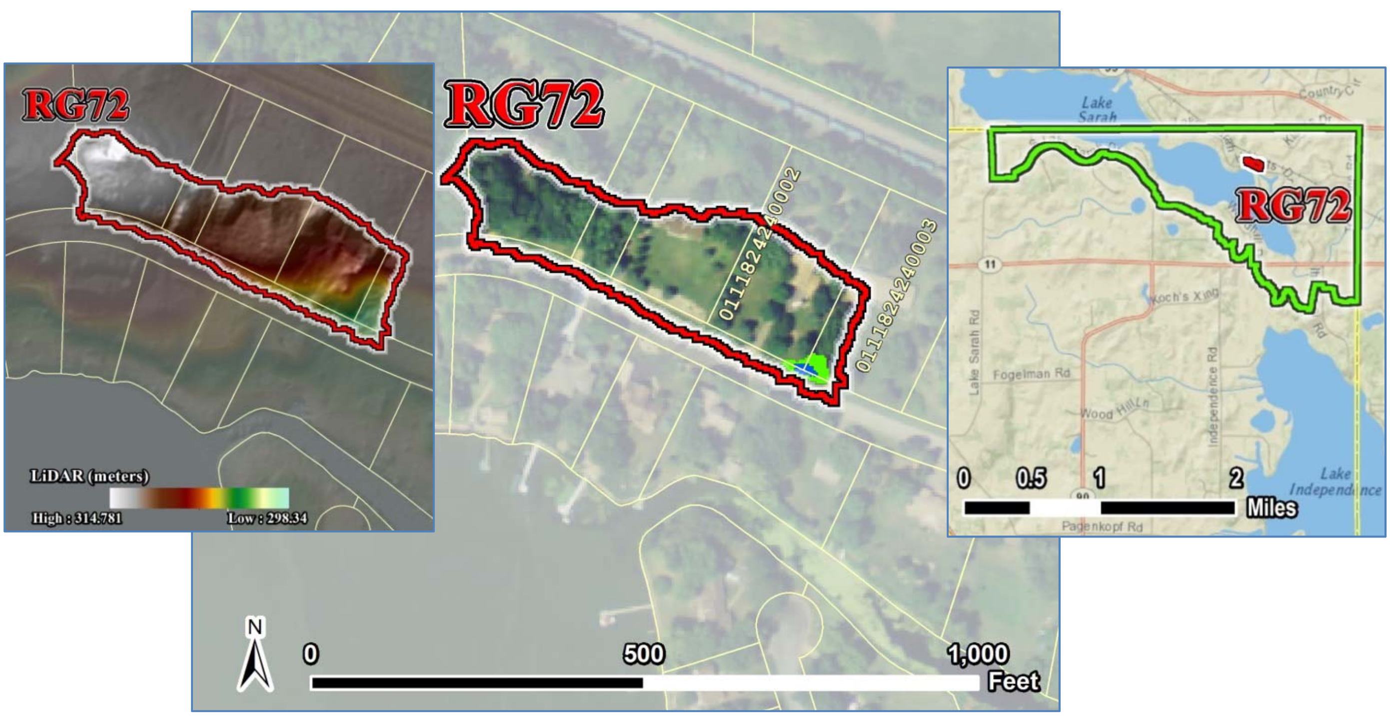
RG69 Size (sq. ft.)	Loading TP lbs/yr	 TSS lbs/yr	 Volume ac-ft/yr	Reductions TP lbs/yr	 TSS lbs/yr	 Volume ac-ft/yr	% Reduction TP lbs/yr	 TSS lbs/yr	 Volume ac-ft/yr
Initial Conditions	1.00	178	0.57	N/A	N/A	N/A	N/A	N/A	N/A
250	0.68	101	0.36	0.32	77	0.21	32.0%	43.3%	36.8%
500	0.46	57	0.24	0.54	121	0.33	54.0%	68.0%	57.9%
1000	0.34	38	0.17	0.66	140	0.40	66.0%	78.7%	70.2%
2000	0.20	21	0.09	0.80	157	0.48	80.0%	88.2%	84.2%

Site Summary – RG69 – 500 sq. ft.	
Water Body	Lake Sarah
Treatment Watershed (ac)	2.27
Dominant Land Cover	Med Density Residential
Installation Cost ($)	$10,000
Promo/Design/Admin ($)	$5,055
Maintenance ($/20yrs)	$1,500
Total 20 Year Cost ($)	$16,555
Project Life (yrs)	20
$/lb-TP removal/yr	$1,532.87
$/lb-TSS removal/yr	$6.84
$/ac-ft volume removal/yr	$2,508.33



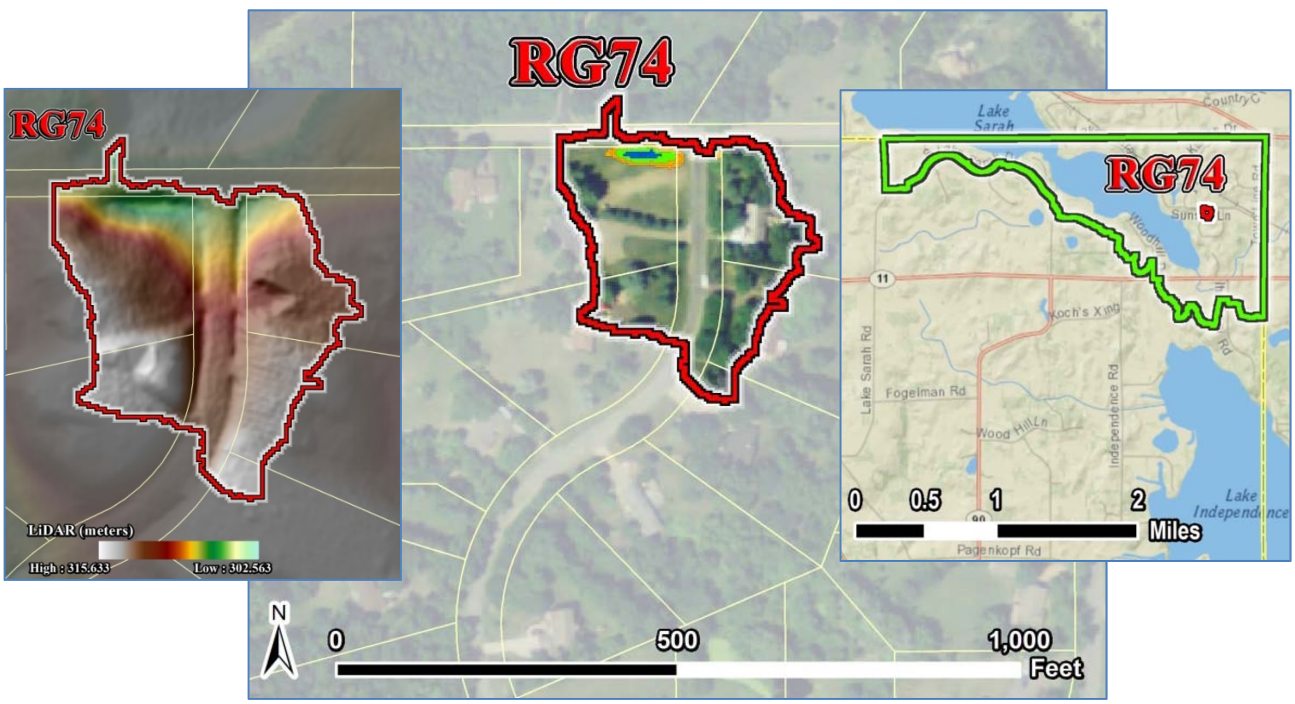
RG72	Loading			Reductions			% Reduction		
	TP	TSS	Volume	TP	TSS	Volume	TP	TSS	Volume
Size (sq. ft.)	lbs/yr	lbs/yr	ac-ft/yr	lbs/yr	lbs/yr	ac-ft/yr	lbs/yr	lbs/yr	ac-ft/yr
Initial Conditions	1.74	397	1.00	N/A	N/A	N/A	N/A	N/A	N/A
250	1.34	284	0.72	0.40	113	0.28	23.0%	28.5%	28.0%
500	1.03	207	0.53	0.71	190	0.47	40.8%	47.9%	47.0%
1000	0.63	111	0.29	1.11	286	0.71	63.8%	72.0%	71.0%

Site Summary – RG72 – 500 sq. ft.	
Water Body	Lake Sarah
Treatment Watershed (ac)	2.3
Dominant Land Cover	Med. Density Residential
Installation Cost ($)	$10,000
Promo/Design/Admin ($)	$5,055
Maintenance ($/20yrs)	$1,500
Total 20 Year Cost ($)	$16,555
Project Life (yrs)	20
$/lb-TP removal/yr	$1,165.85
$/lb-TSS removal/yr	$4.36
$/ac-ft volume removal/yr	$1,761.17



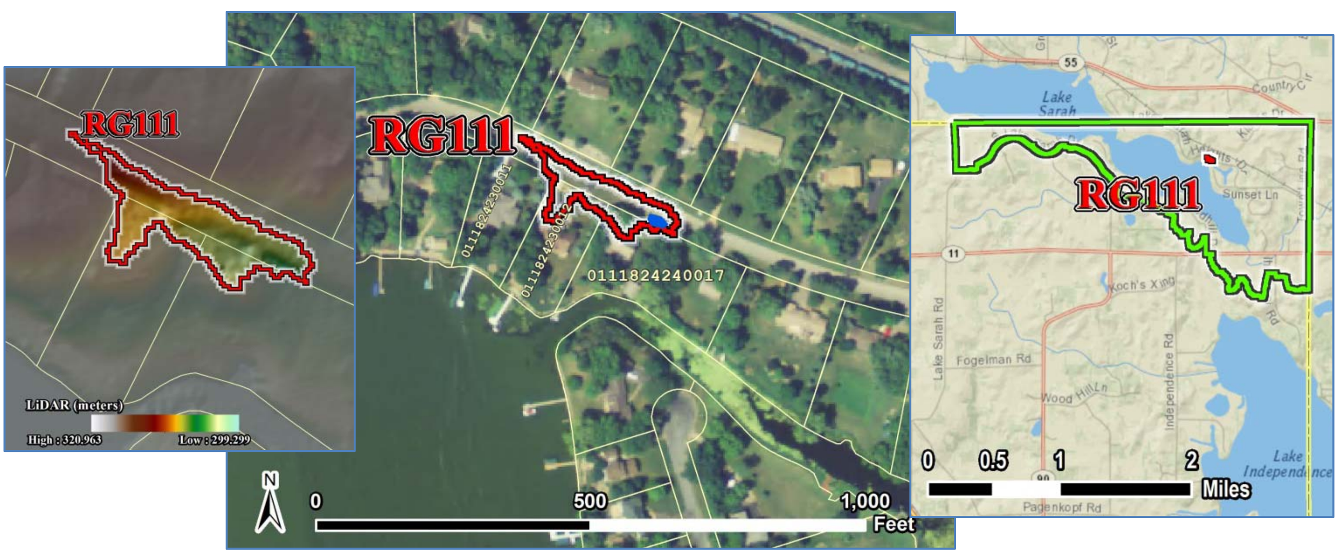
RG74 Size (sq. ft.)	Loading TP lbs/yr	 TSS lbs/yr	 Volume ac-ft/yr	Reductions TP lbs/yr	 TSS lbs/yr	 Volume ac-ft/yr	% Reduction TP lbs/yr	 TSS lbs/yr	 Volume ac-ft/yr
Initial Conditions	1.35	296	0.84	N/A	N/A	N/A	N/A	N/A	N/A
250	0.99	196	0.58	0.36	100	0.26	26.7%	33.8%	31.0%
500	0.73	133	0.41	0.62	163	0.43	45.9%	55.1%	51.3%
1000	0.44	69	0.23	0.91	227	0.61	67.4%	76.7%	72.7%
1500	0.36	54	0.18	0.99	242	0.66	73.3%	81.8%	78.6%

Site Summary – RG74 – 500 sq. ft.	
Water Body	Lake Sarah
Treatment Watershed (ac)	2.15
Dominant Land Cover	Med. Dens. Residential
Installation Cost ($)	$10,000
Promo/Design/Admin ($)	$5,055
Maintenance ($/20yrs)	$1,500
Total 20 Year Cost ($)	$16,555
Project Life (yrs)	20
$/lb-TP removal/yr	$1,335.08
$/lb-TSS removal/yr	$5.08
$/ac-ft volume removal/yr	$1,920.53



RG111	Loading			Reductions			% Reduction		
Size/Depth (sq. ft./inches)	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr
Initial Conditions	0.32	78	0.20	N/A	N/A	N/A	N/A	N/A	N/A
250/6 (no underdrain)	0.19	41	0.11	0.13	37	0.09	40.6%	47.4%	45.0%
500/6 (no underdrain)	0.11	21	0.06	0.21	48	0.14	56.3%	61.5%	60.0%
250/12 (w/underdrain)	0.26	30	0.16	0.06	38	0.04	18.8%	61.5%	20.0%
500/12 (w/underdrain)	0.23	13	0.14	0.09	65	0.06	28.1%	83.3%	30.0%

Site Summary – RG111 – 250/6 sq. ft.	
Water Body	Lake Sarah
Treatment Watershed (ac)	0.4
Dominant Land Cover	Med. Dens. Residential
Installation Cost ($)[13]	$500
Promo/Design/Admin ($)	$2,555
Maintenance ($/20yrs)	$0
Total 20 Year Cost ($)	$3,055
Project Life (yrs)	20
$/lb-TP removal/yr	$1,175.00
$/lb-TSS removal/yr	$4.12
$/ac-ft volume removal/yr	$1,697.22



[13] Cost assumes installation of risers (ProRing or equivalent) on existing outlet to a depth that ponding duration is short enough for turf to continue to survive. No mulch, supplemental plantings, soil amendments or underdrains will be used.

Lakeshore Restorations

Lakeshore restoration involves the correction of active soil erosion at the shoreline. Phosphorus is carried on the eroding sediment into the water body, where, through a series of chemical reactions, it can become available for uptake by plants, contributing to algal blooms. The sediment can also smother fish habitat, reduce water clarity, and reduce lake depth as it fills in lower areas. Pursuing lakeshore stabilizations as a means of improving lake water quality is highly cost-effective since 100% of the pollutants would have made it directly into the lake.

Lakeshore stabilization designs are site specific and need to take into account soil type, existing vegetation, slope, overland flow, wave action due recreational activity, fetch, orientation, and landowner desires. Designs range from a solely vegetative treatment with no site grading, to complete slope grading and hard armoring. Costs also vary widely based on these factors as well as site access, regulatory requirements and the length of treatment area.

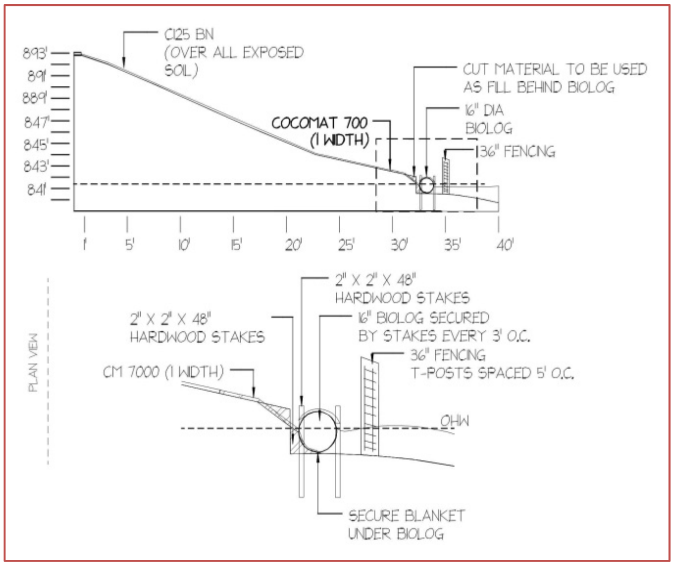


Figure 9: Typical Cross Section - Simple Design

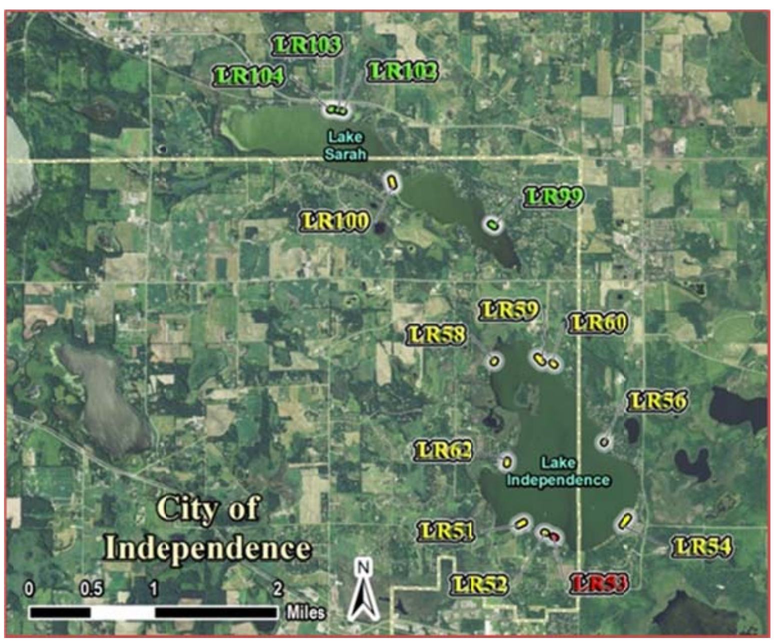
For the purpose of this analysis, cost/linear foot was estimated based on erosion severity and the likely approach to stabilization efforts falling into one of two categories; 1) rock toe restoration with heavy equipment grading, or 2) BioLog with manual grading and plantings. The former was estimated at $150/linear foot and the latter was estimated at $70/linear foot.

An inventory of all active erosion sites was completed for the entire shoreline of both Lake Sarah and Lake Independence. Instances of erosion were classified according to severity. Erosion severity determinations and soil loss estimates were calculated utilizing the Wisconsin NRCS direct volume method recession rate classifications. Methodologies are described in greater detail in the appendix.

The table below summarizes all potential lakeshore restoration projects identified during field reconnaissance. Projects are sorted from most cost-effective to least cost-effective in terms of the cost per pound of Total Phosphorus removed from the system. Cost assumptions made to calculate the cost-benefit of each project should be verified against local experience while creating implementation plans. The relative ranking shouldn't vary much even with alterations to the cost formula.

Table 23: Potential Lakeshore Restoration Projects

Water Resource	Site ID	TSS Reduction (tons/yr)	TP Reduction (lbs/yr)	Install Cost[14] ($)	Promo/ Design/ Admin/ Maint. ($)[15]	Project Life (yrs)	Cost-Benefit ($/lb TP)
Independence	LR54	6.87	10.99	$32,060	$1,093	10	$391
Independence	LR53	2.73	4.8	$15,000	$556	10	$428
Independence	LR59	7.83	12.52	$46,950	$875	10	$445
Sarah	LR100	1.61	2.58	$8,680	$592	10	$566
Independence	LR60	2.66	4.26	$19,950	$605	10	$611
Independence	LR51	2.73	4.37	$19,600	$826	10	$638
Independence	LR58	1.35	2.15	$10,350	$509	10	$717
Independence	LR62	1.3	2.07	$9,310	$605	10	$740
Sarah	LR104	1.03	1.65	$12,040	$664	10	$1,131
Independence	LR52	.26	.42	$1,500	$421	10	$1,371
Sarah	LR99	.66	1.05	$8,750	$593	10	$1,398
Independence	LR56	.35	.56	$3,780	$487	10	$1,539
Sarah	LR103	.26	.41	$6,020	$535	10	$2,753
Sarah	LR102	.11	.18	$2,660	$463	10	$3,994

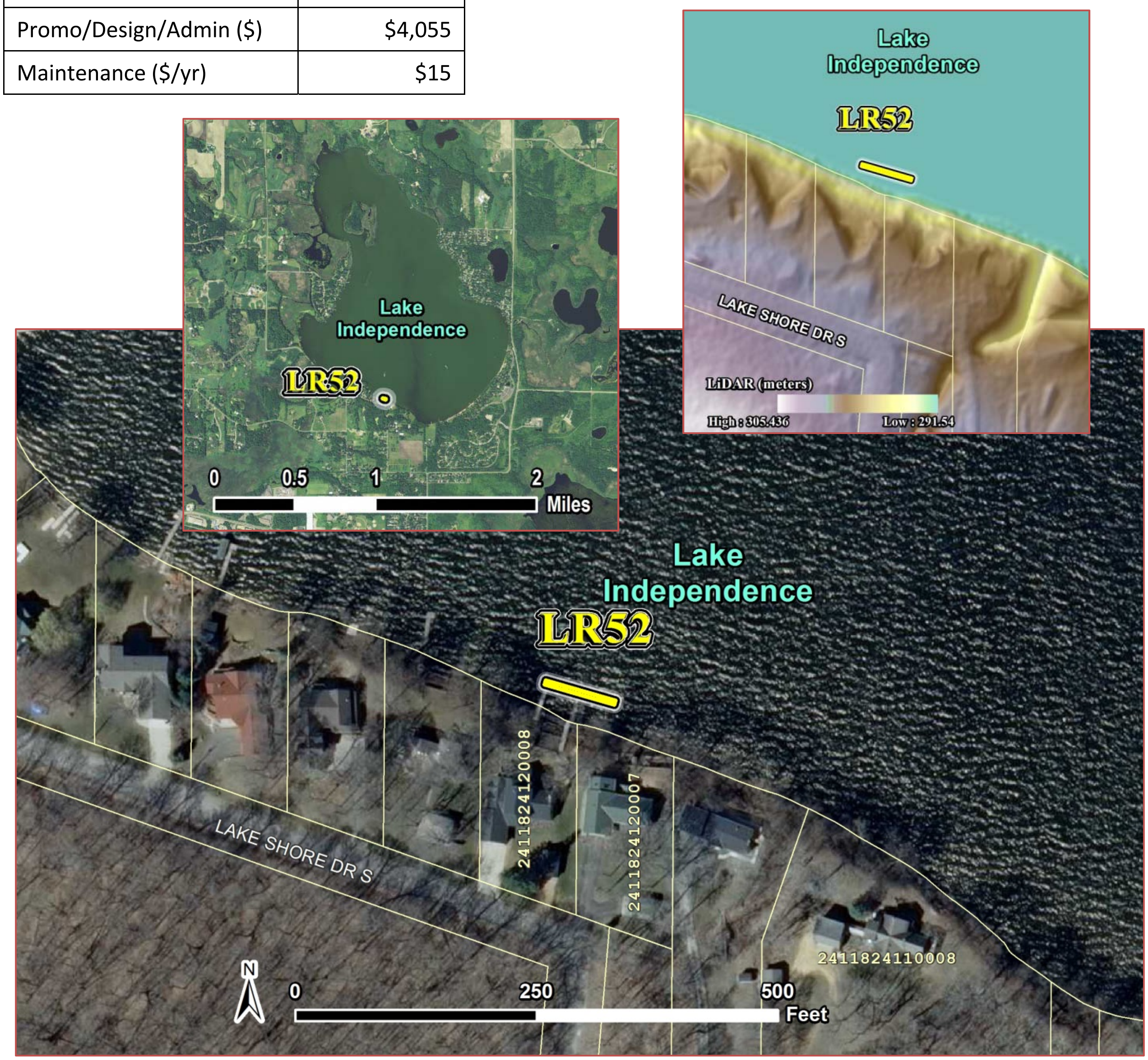


[14] $70/lin. ft. for biolog and manual grading, $150/lin. ft. for rock toe and heavy equipment grading.

[15] Assumes 35 hours for promotion and administration at $73/hr., $1,500 for design, and $1.5/linear-foot/year for maintenance.

Site Summary – LR51	
City	Independence
Erosion Severity	Moderate
Shoreline (ft)	280
Eroding Face (ft)	1.5
Recession Rate (ft/yr)	.13
Sediment Loss (tons/yr)	2.73
TP Loading (lbs/yr)	4.37
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	BioLog
Installation Cost ($)	$19,600
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$420

Site Summary – LR52	
City	Independence
Erosion Severity	Moderate
Shoreline (ft)	10
Eroding Face (ft)	4
Recession Rate (ft/yr)	.13
Sediment Loss (tons/yr)	.26
TP Loading (lbs/yr)	.42
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	Rock Toe
Installation Cost ($)	$1,500
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$15



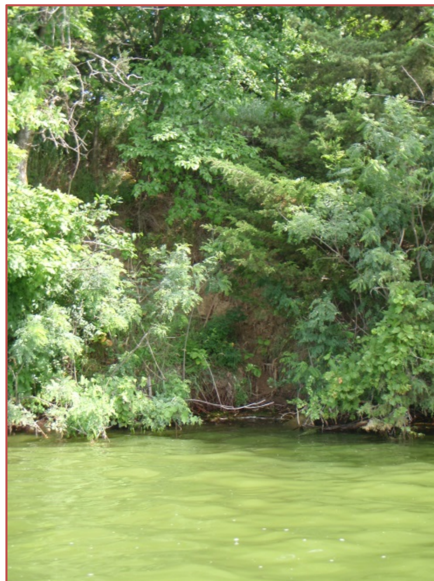
Site Summary – LR53	
City	Independence
Erosion Severity	Severe
Shoreline (ft)	100
Eroding Face (ft)	2
Recession Rate (ft/yr)	.3
Sediment Loss (tons/yr)	3.00
TP Loading (lbs/yr)	4.80
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	Rock Toe
Installation Cost ($)	$15,000
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$150

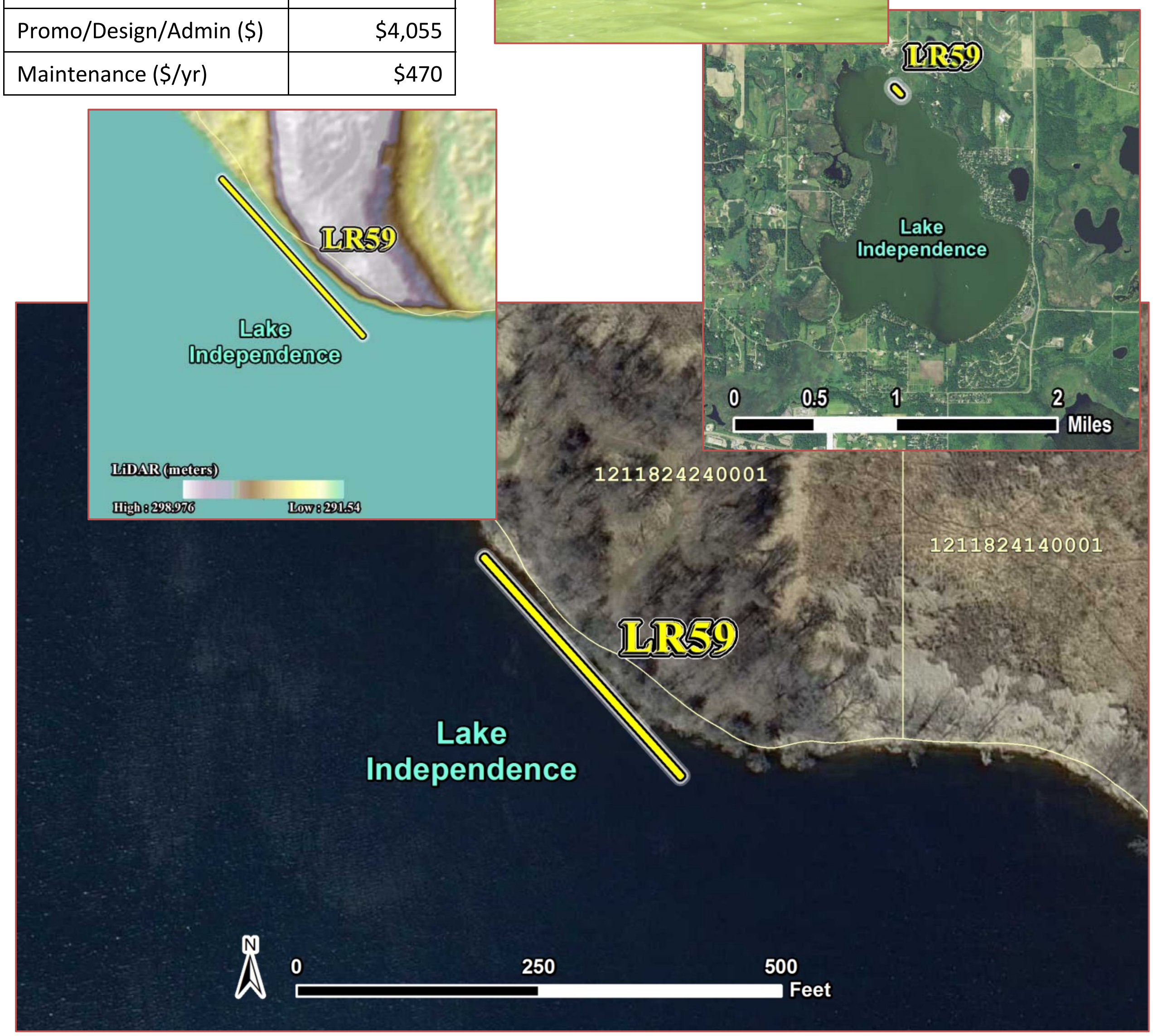
Site Summary – LR54	
City	Medina
Erosion Severity	Moderate
Shoreline (ft)	458
Eroding Face (ft)	1.5
Recession Rate (ft/yr)	.2
Sediment Loss (tons/yr)	6.87
TP Loading (lbs/yr)	10.99
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	BioLog
Installation Cost ($)	$32,060
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$687

Site Summary – LR56	
City	Medina
Erosion Severity	Moderate
Shoreline (ft)	54
Eroding Face (ft)	1
Recession Rate (ft/yr)	.13
Sediment Loss (tons/yr)	.35
TP Loading (lbs/yr)	.56
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	BioLog
Installation Cost ($)	$3,780
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$81

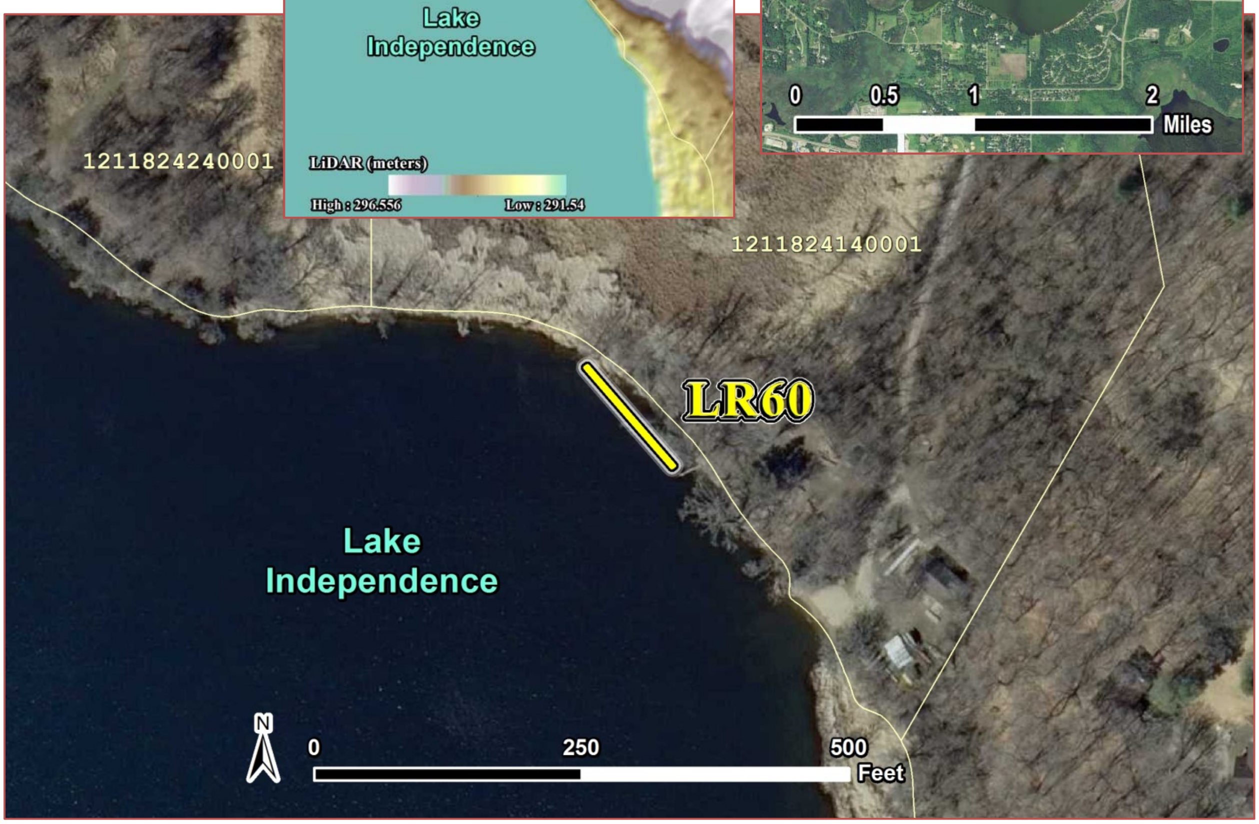
Site Summary – LR58	
City	Independence
Erosion Severity	Moderate
Shoreline (ft)	69
Eroding Face (ft)	3
Recession Rate (ft/yr)	.13
Sediment Loss (tons/yr)	1.35
TP Loading (lbs/yr)	2.15
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	Rock Toe
Installation Cost ($)	$10,350
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$104

Site Summary – LR59	
City	Independence
Erosion Severity	Moderate
Shoreline (ft)	313
Eroding Face (ft)	2.5
Recession Rate (ft/yr)	.2
Sediment Loss (tons/yr)	7.83
TP Loading (lbs/yr)	12.52
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	Rock Toe
Installation Cost ($)	$46,950
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$470

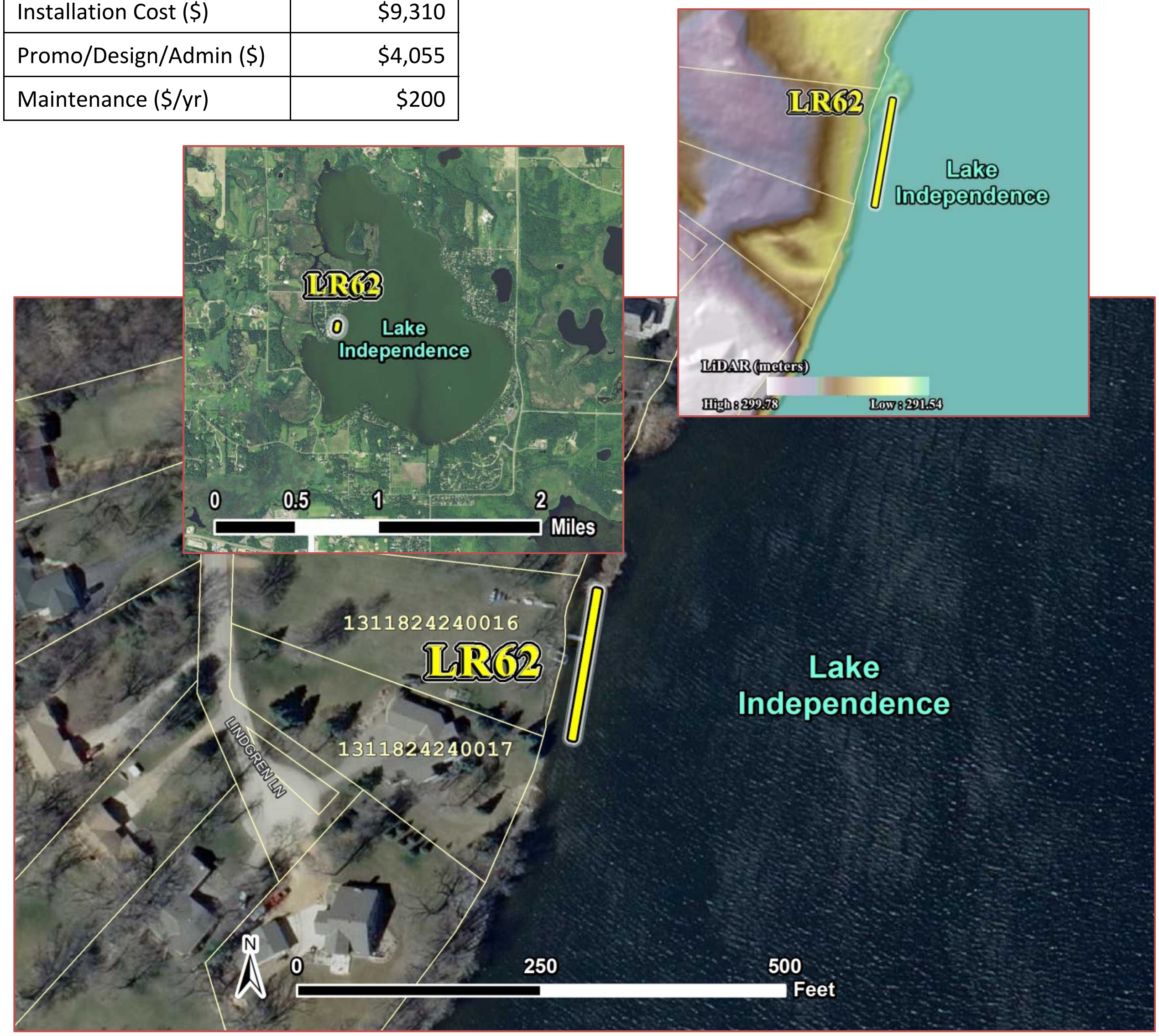




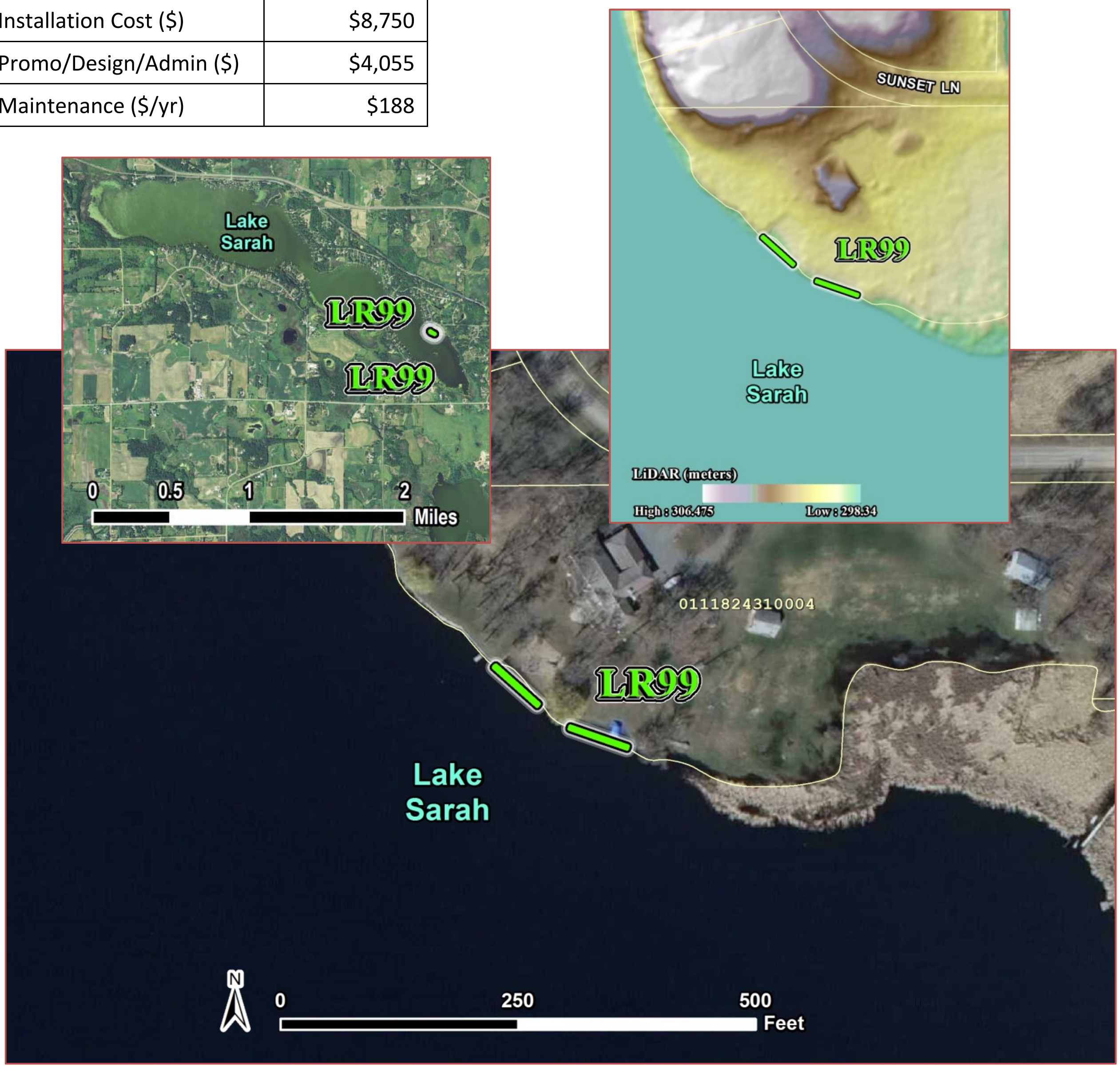
Site Summary – LR60	
City	Independence
Erosion Severity	Moderate
Shoreline (ft)	133
Eroding Face (ft)	2
Recession Rate (ft/yr)	.2
Sediment Loss (tons/yr)	2.66
TP Loading (lbs/yr)	4.26
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	Rock Toe
Installation Cost ($)	$19,950
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$200



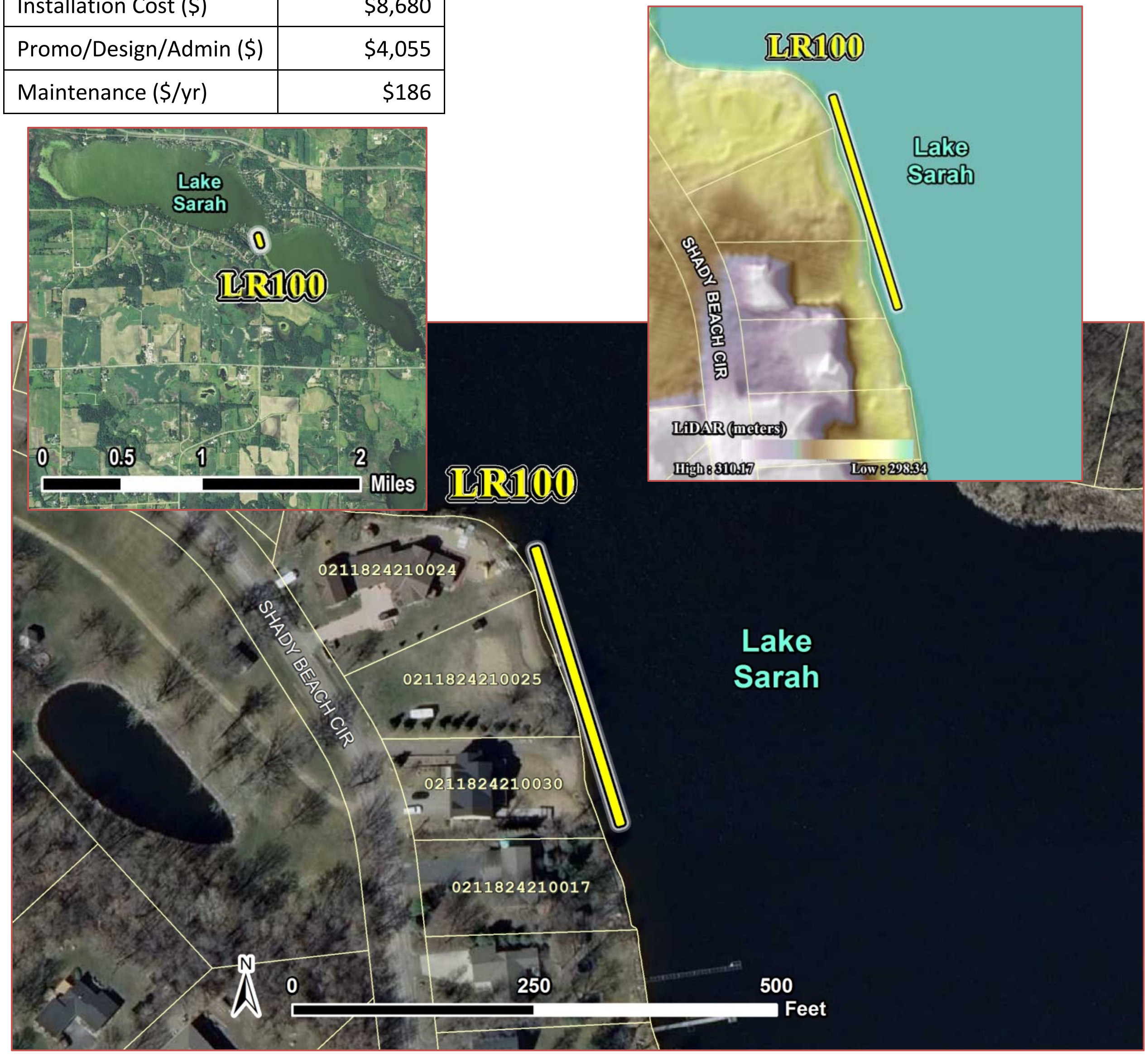
Site Summary – LR62	
City	Independence
Erosion Severity	Moderate
Shoreline (ft)	133
Eroding Face (ft)	1.5
Recession Rate (ft/yr)	.13
Sediment Loss (tons/yr)	1.30
TP Loading (lbs/yr)	2.07
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	BioLog
Installation Cost ($)	$9,310
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$200



Site Summary – LR99	
City	Independence
Erosion Severity	Slight
Shoreline (ft)	125
Eroding Face (ft)	3.5
Recession Rate (ft/yr)	.03
Sediment Loss (tons/yr)	.66
TP Loading (lbs/yr)	1.05
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	BioLog
Installation Cost ($)	$8,750
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$188

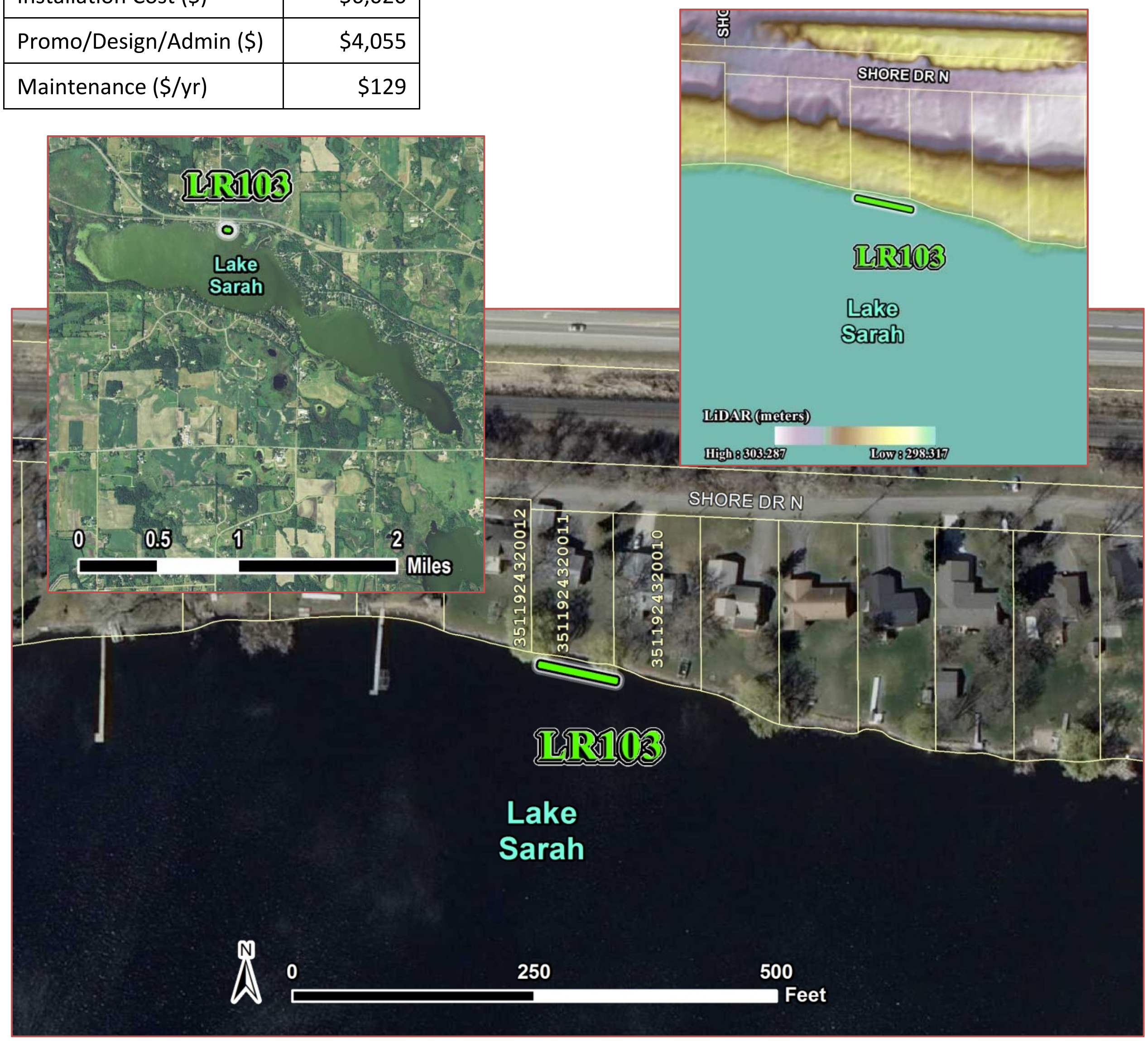


Site Summary – LR100	
City	Independence
Erosion Severity	Moderate
Shoreline (ft)	124
Eroding Face (ft)	2
Recession Rate (ft/yr)	.13
Sediment Loss (tons/yr)	1.16
TP Loading (lbs/yr)	2.58
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	BioLog
Installation Cost ($)	$8,680
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$186

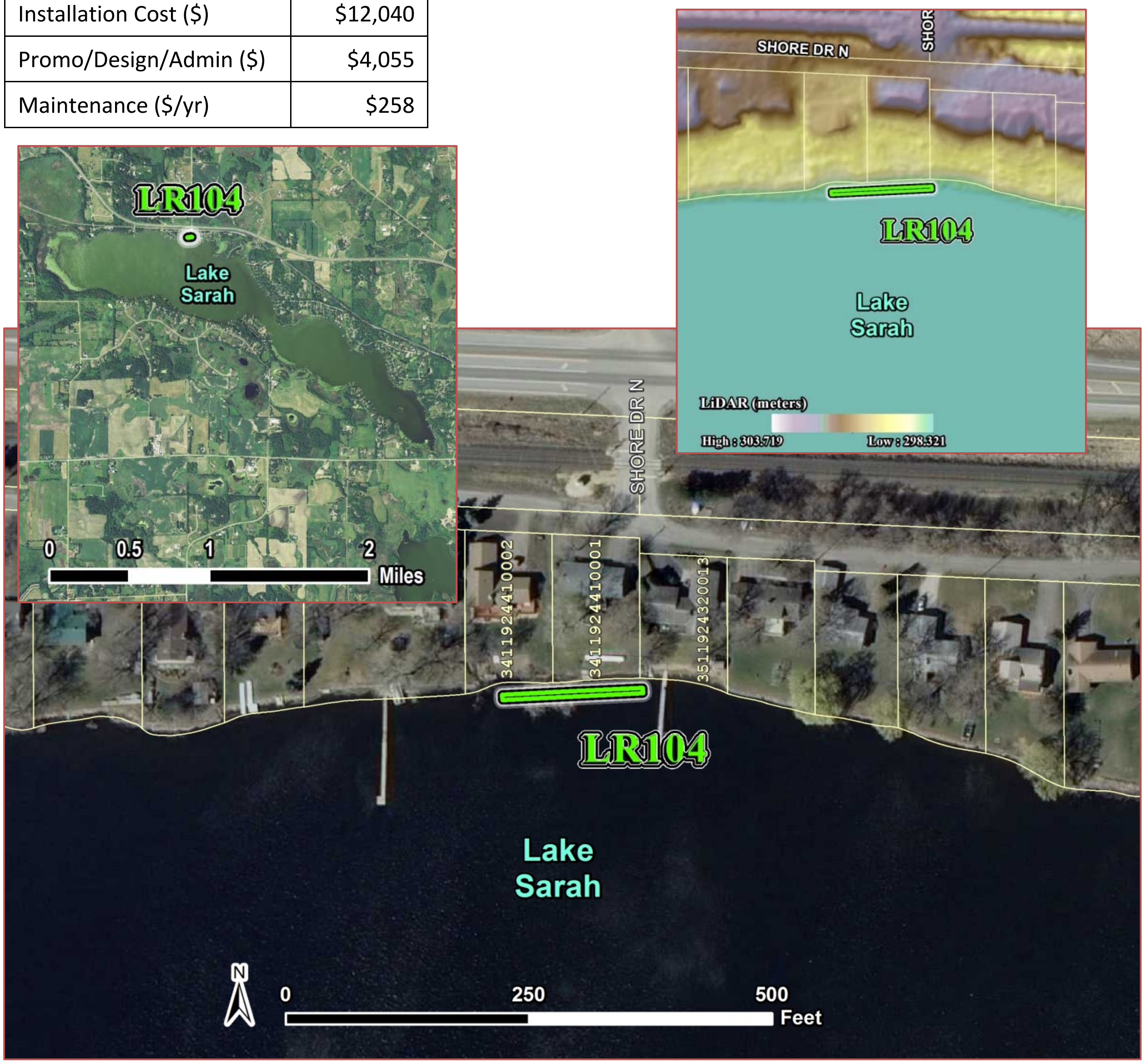


Site Summary – LR102	
City	Greenfield
Erosion Severity	Slight
Shoreline (ft)	38
Eroding Face (ft)	2
Recession Rate (ft/yr)	.03
Sediment Loss (tons/yr)	.11
TP Loading (lbs/yr)	.18
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	BioLog
Installation Cost ($)	$2,660
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$57

Site Summary – LR103	
City	Greenfield
Erosion Severity	Slight
Shoreline (ft)	86
Eroding Face (ft)	2
Recession Rate (ft/yr)	.03
Sediment Loss (tons/yr)	.26
TP Loading (lbs/yr)	.41
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	BioLog
Installation Cost ($)	$6,020
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$129



Site Summary – LR104	
City	Greenfield
Erosion Severity	Slight
Shoreline (ft)	172
Eroding Face (ft)	4
Recession Rate (ft/yr)	.03
Sediment Loss (tons/yr)	1.03
TP Loading (lbs/yr)	1.65
Estimated Reduction (%)	100
Life of Project (yrs)	10
Restoration Type	BioLog
Installation Cost ($)	$12,040
Promo/Design/Admin ($)	$4,055
Maintenance ($/yr)	$258



Gully Stabilizations

Concentrated overland flow will result in the formation of gullies over time if the erosive force of the flowing water exceeds soil cohesion. Gullies typically erode from downstream to upstream, with the greatest erosion occurring at knickpoints. A knickpoint is a vertical face in the bottom of the gully that is undergoing accelerated erosion. Figure 10: Gully Knickpoint shows a knickpoint in a small gully.

Figure 10: Gully Knickpoint

As soil is eroded from the bottom of the gully, it cuts deeper into the landscape, creating steeper side slopes that are unstable and subject to sloughing. The side slopes slump into the gully where subsequent stormwater will carry the deposited sediment down gradient. The sediment carries with it nutrients such as phosphorus as well as other pollutants commonly found in soil.

Gully stabilization designs vary greatly depending on the size of the gully, soil texture, vegetative cover, contributing watershed size, slope and landuse characteristics, site access, and cultural features. The first element of gully stabilization is to arrest the advancement of knickpoints. This is done using grade stabilization practices such as check dams and cross vanes. Grade stabilization practices prevent further down cutting of the gully bottom.

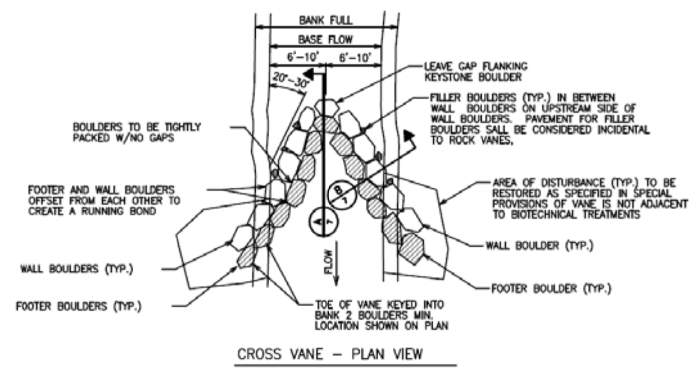


Figure 12: Cross Vane - Typical Plan View

Once grade stabilization has been achieved, smaller portions of the gully may be filled in and revegetated. Where filling the gully is impractical, the side slopes may be graded to a stable slope of not more than 2:1 and appropriate erosion control and vegetation can be applied to the side slopes and bank toe. Engineered designs are critical to ensure the practices are suitable for anticipated water velocities and volumes, soil types, and other characteristics previously mentioned. Costs vary greatly depending on the engineered practice as well as site access, regulatory requirements and the size of the treatment area.

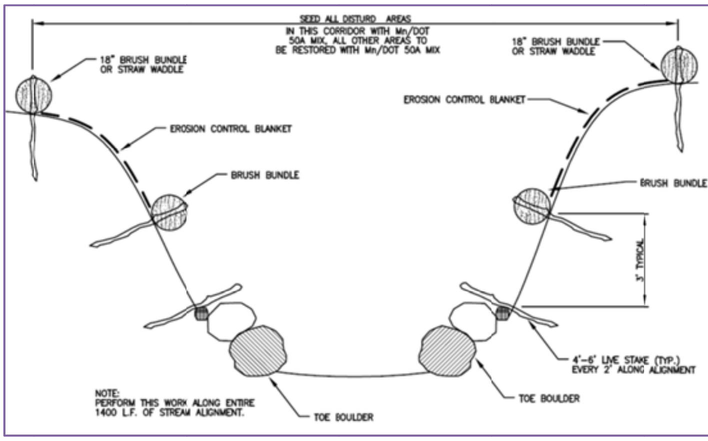


Figure 11: Various Stabilization Practices Cross Section

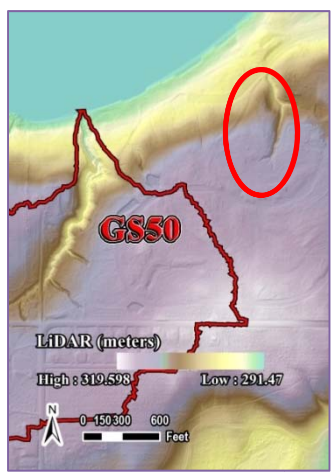
An inventory of readily identifiable gullies immediately adjacent to the lakes was completed for both Lake Sarah and Lake Independence. Near lake gullies were prioritized because they have a higher sediment delivery rate to the lake and so more benefit to lake water quality will be realized by stabilizing them as opposed to gullies farther from the lakes. Instances of erosion were classified according to severity along each distinct gully segment. Erosion severity determinations and voided soil volumes were estimated utilizing RAP-M (Windhorn, R. D., 2000). Total sediment and phosphorus reduction estimates were based upon the Board of Water and Soil Resources Pollution Reduction Estimator which estimates loading based upon a correlation between voided sediment volume and type with soil density averages and phosphorus concentrations. The appendix includes more detail on modeling methods.

To estimate cost-benefit, installation cost, annual maintenance, as well as project promotion, design, and administration were all estimated. The installation cost was estimated at $65/square foot of erosive area. All gully sections were assumed to be stabilized with a combination of rock cross vanes, rip rap, bioengineering, and revegetation. Total cost over the 20 year anticipated project life was divided by the total reduction in Total Phosphorus over the same time span.

The table below summarizes all potential gully stabilization projects identified during field reconnaissance. Projects are sorted from most cost-effective to least cost-effective in terms of the cost per pound of Total Phosphorus removed from the system. Cost assumptions made to calculate the cost-benefit of each project should be verified against local experience while creating implementation plans. The relative ranking shouldn't vary much even with alterations to the cost formula.

Table 24: Potential Gully Stabilization Projects

Water Resource	Site ID	TSS Reduction (tons/yr)	TP Reduction (lbs/yr)	Install Cost ($)[16]	Promo/ Design/ Admin/ Maint. ($)[17]	Project Life (yrs)	Cost-Benefit ($/lb TP)
Independence	GS50	233.5	373.7	$425,789	$110,000	20	$72
Independence	GS46	9.77	15.6	$53,105	$26,409	20	$279
Independence	GS45	1.33	2.1	$26,325	$17,060	20	$1019



Substantial work has already been completed on GS50, with the installation of grade control structures. Much of the gully remains bare of vegetation and erosion appears to persist, however. It may be part of the plan to allow the site to reach equilibrium and revegetate naturally. The site should be monitored to ensure continued progress. Another potential project within the park east of the other sites was identified but not modeled because it is entirely within the City of Medina (see inset above). Project planners should consider addressing this site in conjunction with GS50.

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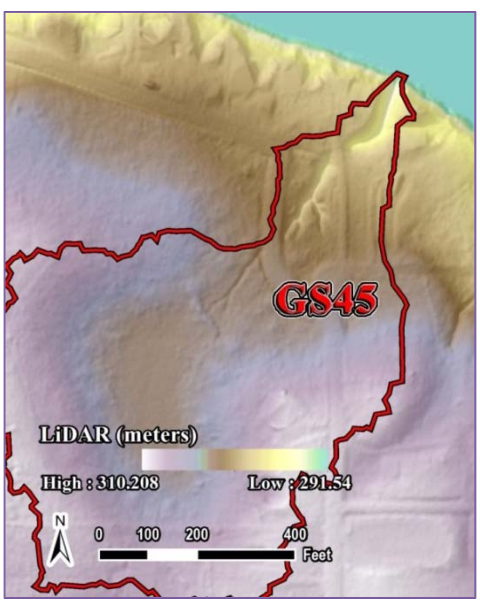
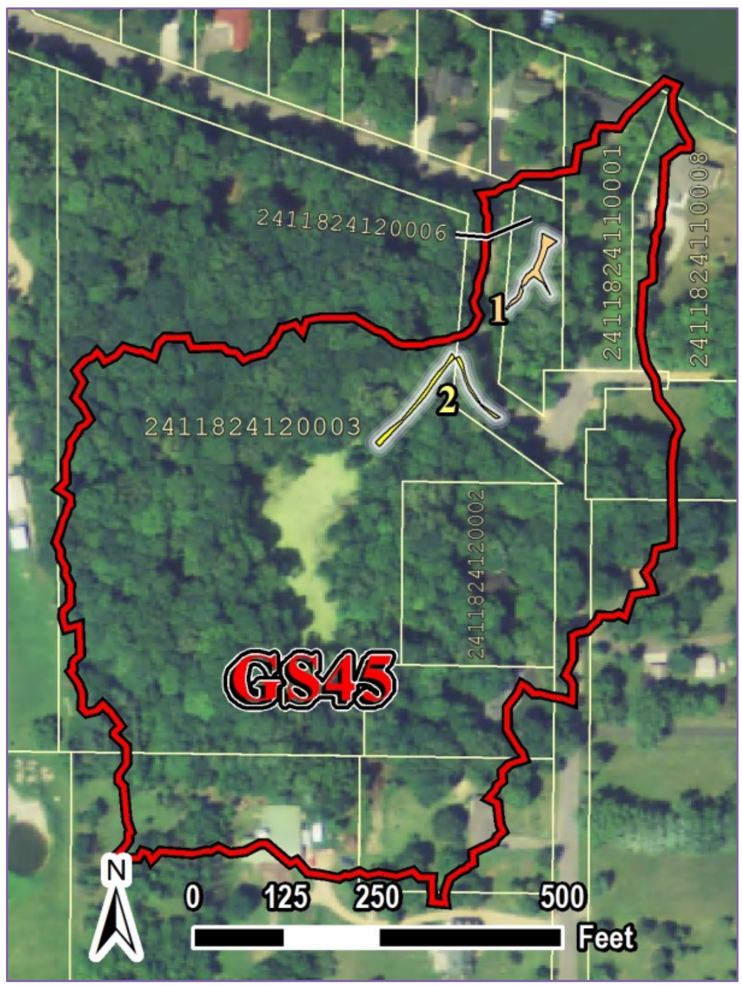
[16] Installation was estimated at $65/sq-ft of erosive area.

[17] Maintenance was estimated at $.50/sq- ft/yr of erosive area for the life of the project. Promotion/ administration/ design was estimated at $6,500 per gully section.

Site Detail – GS45 – Rock cross vanes, rip rap, bioengineering, revegetation			
Gully Segment	1	2	Total
Erosion Severity	Moderate	Slight	
Recession Rate (ft/yr)	0.13	0.03	
Lower Gully Area (sq ft)	957	1068	2025
Erosive Gully Area (sq ft)	191	214	405
Sediment Loss (tons/yr)	1.06	0.27	1.33
TP Loading (lbs/yr)	1.7	0.4	2.1
$/lb-TP removal/yr	$616	$2,584	$1,019
$/lb-TSS removal/yr	$493	$2,067	$815

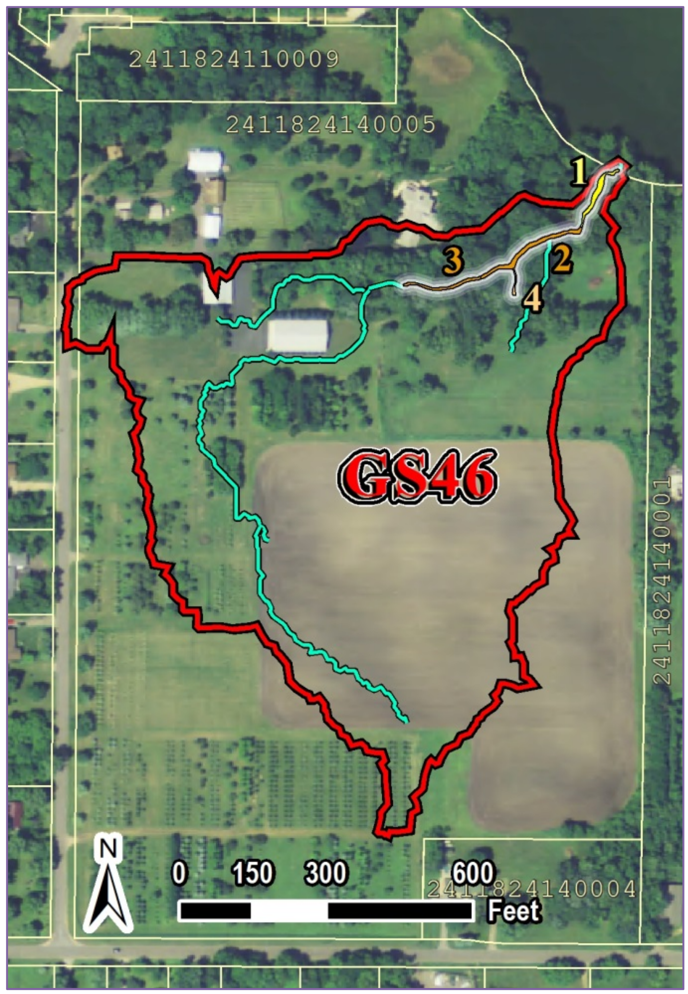
Site Summary – GS45	
Water Body	Lake Independence
Watershed (acres)	12.6
City	Independence
Dominant Land Cover	Residential, Open space
Average Slope (%)	7.4
Sediment Delivery Rate (%)	100
Project Life (yr)	20
Installation Cost ($)	$26,325
Promo/Design/Admin ($)	$13,000
Maintenance ($)	$4,060





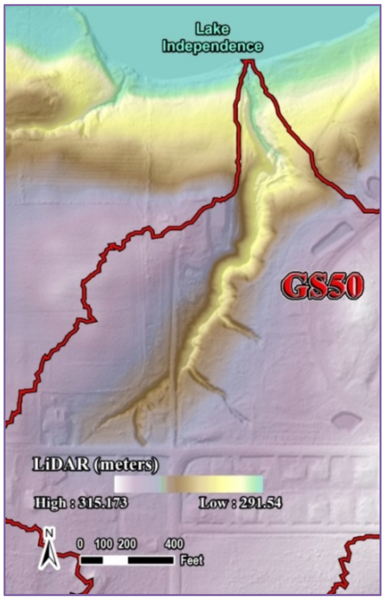
Site Detail – GS46 – Rock cross vanes, rip rap, bioengineering, revegetation					
Gully Segment	1	2	3	4	Total
Erosion Severity	Slight	Severe	Severe	Moderate	
Recession Rate (ft/yr)	0.05	0.4	0.4	.13	
Lower Gully Area (sq ft)	1166	1893	828	198	4085
Erosive Gully Area (sq ft)	233	379	166	40	817
Sediment Loss (tons/yr)	0.3	6.44	2.82	0.22	9.77
TP Loading (lbs/yr)	0.5	10.3	4.5	0.4	15.6
$/lb-TP removal/yr	$2,521	$169	$210	$1,353	$279
$/lb-TSS removal/yr	$2,017	$136	$168	$1,082	$223

Site Summary – GS46	
Water Body	Lake Independence
Watershed (acres)	19.1
City	Independence
Dominant Land Cover	Crop, Pasture
Average Slope (%)	7.2
Sediment Delivery Rate (%)	100
Project Life (yr)	20
Installation Cost ($)	$53,105
Promo/Design/Admin ($)	$26,000
Maintenance ($)	$8,180



Site Detail – GS50 – Rock cross vanes, rip rap, bioengineering, revegetation								
Gully Segment	1	2	3	4	5	6	7	Total
Erosion Severity	Very Severe	Severe	Very Severe	Moderate	Severe	Slight	Severe	
Recession Rate (ft/yr)	1.5	0.4	1.5	.13	0.4	0.03	0.4	
Lower Gully Area (sq ft)	6965	2106	7966	3197	3562	3209	5748	32753
Erosive Gully Area (sq ft)	1393	421	1593	639	712	642	1150	6551
Sediment Loss (tons/yr)	88.8	7.2	101.6	3.5	12.1	.8	19.5	233.5
TP Loading (lbs/yr)	142.1	11.5	162.5	5.7	19.4	1.3	31.3	373.7
$/lb-TP removal/yr	$39	$166	$39	$482	$155	$2,086	$148	$72
$/lb-TSS removal/yr	$31	$133	$31	$385	$124	$1,669	$119	$57

Site Summary – GS50	
Water Body	Lake Independence
Watershed (acres)	76
City	Medina
Dominant Land Cover	Residential, Park
Average Slope (%)	7
Sediment Delivery Rate (%)	100
Project Life (yr)	20
Installation Cost ($)	$425,789
Promo/Design/Admin ($)	$45,500
Maintenance ($/yr)	$65,500



Hydrologic Restorations

The natural hydrologic system throughout the study area has been altered by ditching, tiling, channelizing, impounding and piping as shown in the figures to the right. Many features of the drainage system were design to shed water from the landscape quickly to prevent property damage due to flooding and to bring marginal land into crop production. Little thought was put into how such projects would impact downstream water quality, flooding, or erosion. Furthermore, partially drained wetlands with organic soils can become large sources of phosphorus because of bio-chemical processes if their hydrologic regime involves the right degree and duration of water level fluctuations.

Figure 13: Drain Tile Outlet from Ag. Field

Public projects undertaken to achieve drainage goals often involved fees and/or taxes charged to landowners. Upon payment of those taxes, landowners secure long term drainage rights. These rights are described in Minnesota's Public Drainage Law (MN Stat. 103e). The foundation of this law dates back to the late 1800s. When undergoing project planning and design, it is critical not to infringe on a landowner's drainage rights by installing a project that negatively impacts off-site drainage functions.

Figure 14: Channelized Flow in Wetland

Current water management practices put greater emphasis on downstream impacts. Contemporary water management projects encourage holding water on the landscape long enough to encourage infiltration, achieve water quality benefits such as nutrient uptake and sediment detention, and control discharge rates and time of downstream concentration to reduce downstream flooding and erosion. Restoration of the hydrologic system is advantageous because it can achieve multiple benefits. This is done by plugging ditches, breaking tile lines, installing water level control structures, and realigning drainage ways. The figures below illustrate two structure concepts frequently used to restore hydrology.

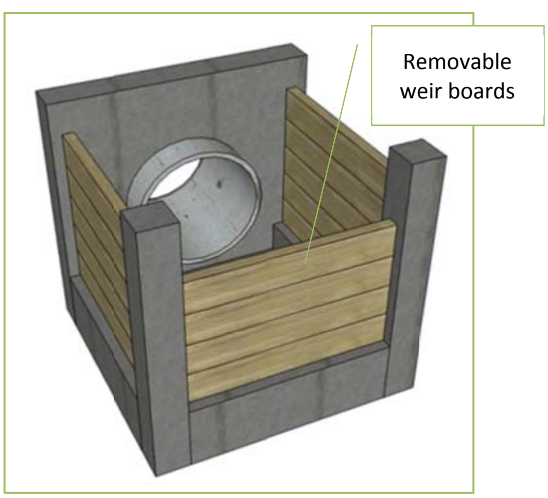


Figure 16: Box Weir Around Culvert

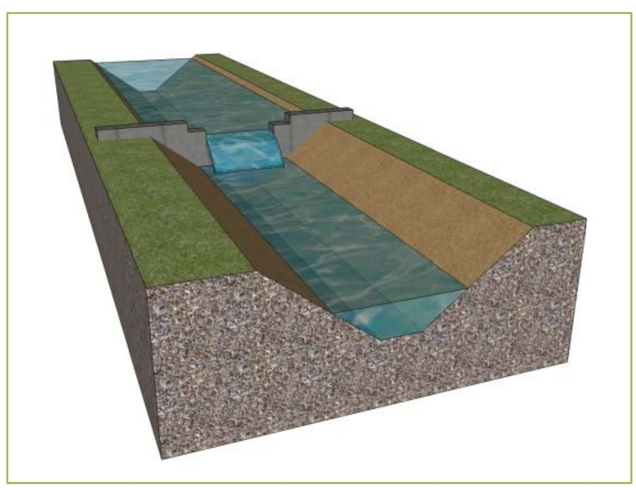


Figure 15: Channel Weir

For the purpose of this analysis, field reconnaissance focused on finding opportunities to restore natural hydrology or impound water on properties where few property owners would be involved, no impacts to upstream hydrology were anticipated, and limited negative impacts to residential and agricultural landuses were likely. Identification of surface ditching and channelized water ways is easy. Unfortunately, buried drain tile is much more difficult to identify and there are no public records of their location. To address this, all areas with hydric (wetland) soils that did not show wetland indicators were assumed to be drained with perforated drain tile.

In some instanced, hydrologic restoration can restore hydrology to partially drained systems without significantly expanding the size of the wetland. In other cases, hydrologic restoration will convert effectively drained wetland back into wetland. The former scenarios were classified as hydrologic restoration and identified with an 'HR,' while the latter scenarios were classified as wetland restorations and identified with a 'WR.' This distinction is important for two reasons; 1) wetlands fall under the jurisdiction of several federal and state laws, and 2) there are additional private and public funding mechanisms and incentives for wetland restoration. Examples of the latter include the state wetland bank, which pays $10,000 per acre for wetland credits to offset impacts due to road projects or the private sector wetland bank, in which wetland credits typically sell for $.75-$1.25/square foot.

Many wetland restoration opportunities have been identified. In many cases wetland restoration is not practical as it would take farmland out of production. There are several cases, however where wetland restoration can be accomplished on residential properties, properties held by development companies, properties owned by absentee owners, estates managed by trusts, properties that are for sale, and on marginal crop land at the edge of agricultural field. Local resource managers should consider these factors when vetting projects.

Hydrologic restoration has also been identified as a tool. Wetlands that are subject to frequent cycles of wetting and drying can become a large source of phosphorus due to some complex bio-chemical processes. If wetland hydrology can be managed to maintain saturated conditions without drastically increasing the ponding depth, phosphorus discharge can be dramatically reduced. This can be achieved without making the wetland much larger in landscapes with steep slopes. The degree to which this is effective is highly dependent on each wetland's chemistry. Pre-project and post-project monitoring is strongly recommended to verify project success.

Benefits of hydrologic restoration projects were modeled utilizing the ArcView extension of the Soil & Water Assessment Tool (ArcSWAT). This model combines inputs of hydrography, topography, soils, and land cover in a GIS interface and determines runoff volume and pollutant loading based on these inputs. The model was run with and without the identified project and the difference in pollutant discharge was noted. Each site was modeled at multiple pool restoration depths. The greatest depth that could be achieved without significantly flooding adjacent properties was selected. A detailed account of the methodologies used is included in Appendix A. Professionally engineered designs will be necessary for all hydrologic restoration projects to ensure drainage rights are not infringed upon.

Because modeling was done on very small land units, water quality data were not available to calibrate the model. Model outputs are best estimates based on available data but may vary greatly from observed field conditions. Furthermore, the models predicted benefits at the field edge, not benefits to the receiving water body. For pollutants held in suspension in the water column such as TSS, projects that are closer to the lake or main tributaries to the lake may be preferred to projects farther away even if the project benefits in the table shows greater cost effectiveness for the farther projects. For dissolved pollutants such as dissolved phosphorus or chlorides, the distance from the receiving water body is less critical. Rather than estimate the pollutant delivery ratio for each pollutant type, we focused our investigation on sites near the lakes and/or immediately adjacent to the drainage system. This approach will ensure that all identified projects have merit. Ultimately, it will be the purview of watershed management professionals to select projects to pursue. To facilitate this process, maps for each project showing the location in the watershed are provided.

In order to determine cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach and promotion, project design, easement acquisition, project administration, and project maintenance over the anticipated life of the practice were considered in addition to actual construction costs. As an example, the outlet control retrofit shown in Figure 17 cost only $8,450 to install, but design engineering, hydraulic modeling, project bidding, construction oversight, landowner outreach and education, and project reporting cost an additional $8,500.

Figure 17: Outlet Control Retrofit

All projects were assumed to use one of three structure types;

- box weirs (Figure 16)
- channel weirs (Figure 15)
- outlet control structure (Figure 18)

Channel weirs are used where flow is through an open ditch. Box weirs are used where flow is through a culvert. Water control structures allow landowners to dynamically manage subsurface drainage and surface ponding to achieve hydrologic goals by raising or lowering the flow mechanism. To pond water, control structures must be coupled with an earthen berm. The installation costs of these practice vary greatly but the cost of design, hydraulic modeling, landowner outreach, project administration, and construction oversight are comparable regardless of the structure type.

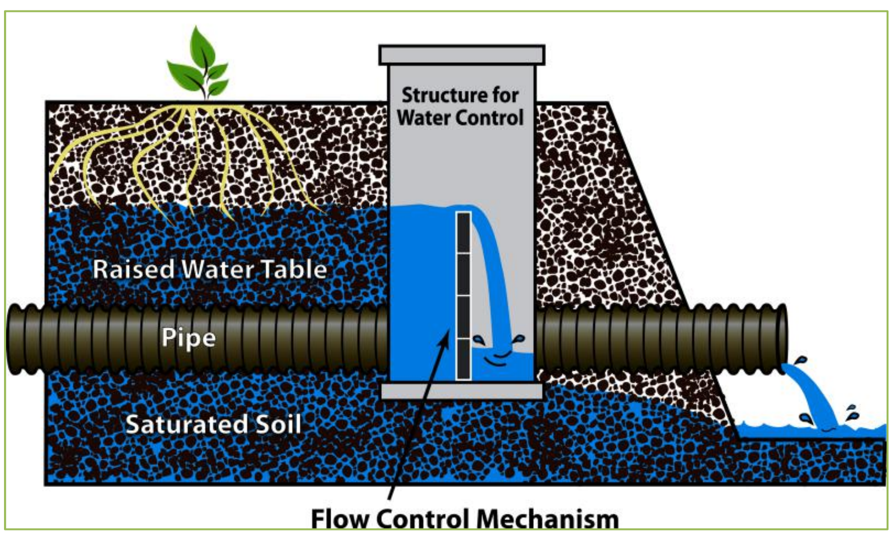


Figure 18: Water Control Attached to Drain Tile (illustration courtesy of Illinois NRCS)

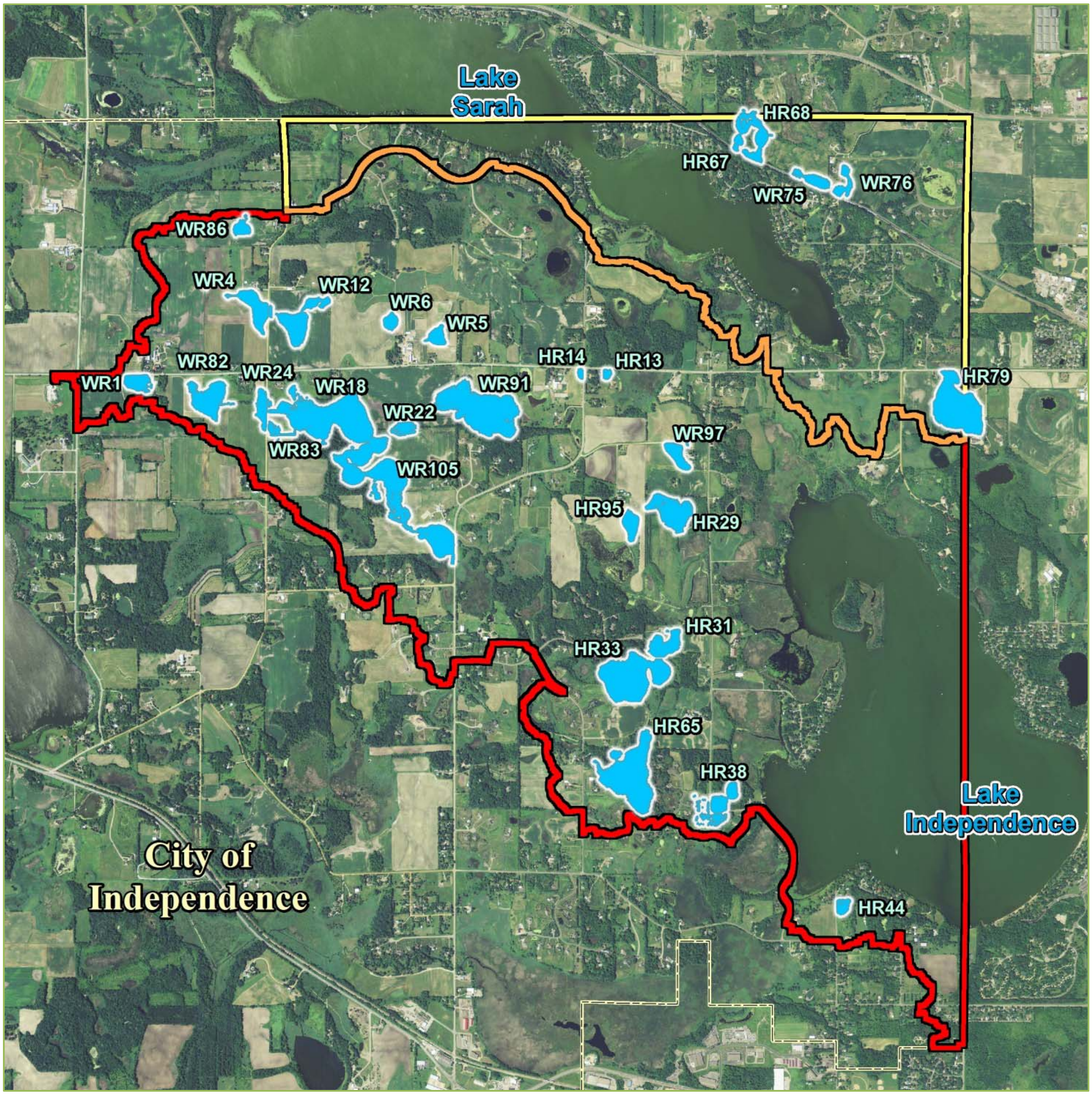
The table on the next page summarizes all potential hydrologic restoration projects identified during field reconnaissance. Projects are sorted from most cost-effective to least cost-effective in terms of the cost per pound of Total Phosphorus removed at the edge of field. Cost assumptions made to calculate the cost-benefit of each project should be verified against local experience while creating implementation plans. The relative ranking shouldn't vary much even with alterations to the cost formula.

Table 25: Potential Hydrologic Restoration Projects

Water Resource	Site ID	Structure Type	Pool Elev.	TSS Reduction (tons/yr)	TP Reduction (lbs/yr)	Volume Reduction (ac-ft/yr)	20 Yr Cost[18]	Project Life (yrs)	Cost-Benefit ($/lb TP)
Sarah	HR67& 68	Box Weir	999	15.99	15.32	0.70	$71,105	20	$232
Independence	HR95	Box Weir	964	9.44	9.64	1.93	$61,205	20	$317
Independence	WR4	Box Weir	985	17.01	22.09	1.90	$143,705	20	$325
Independence	WR12	Channel Weir	981	31.43	25.64	4.05	$195,205	20	$381
Sarah	WR75	Box Weir	990	8.41	9.34	2.58	$73,205	20	$392
Independence	WR1	Control Structure & Berm	1009	3.46	8.39	3.39	$92,205	20	$549
Independence	WR82	Channel Weir	987	2.90	15.65	5.83	$208,705	20	$667
Independence	WR18[19]	Channel Weir	981	10.58	39.54	9.96	$559,205	20	$707
Independence	WR6	Channel Weir	988	2.29	5.11	1.13	$74,205	20	$726
Independence	HR13	Box Weir	972	1.74	2.49	0.22	$36,205	20	$727
Independence	WR86	Control Structure	992	0.57	4.07	1.67	$60,205	20	$740
Independence	HR29	Channel Weir	963	2.02	5.98	3.29	$83,705	20	$771
Independence	WR91	Channel Weir	980	8.53	18.29	7.80	$289,205	20	$791
Sarah	WR76	Box Weir	995	3.77	4.63	1.75	$73,705	20	$796
Independence	HR33	Channel Weir	973	3.09	9.19	6.52	$151,705	20	$825
Independence	WR105[20]	Box Weir	980	26.41	32.13	7.69	$543,205	20	$845
Independence	WR24	Box Weir	983	1.14	3.41	0.80	$59,705	20	$876
Independence	WR5	Channel Weir	1011	1.61	4.71	1.78	$86,205	20	$915
Independence	HR31	Channel Weir	964	2.92	3.77	1.40	$73,705	20	$978
Sarah	HR79	Box Weir	987	1.90	5.87	8.32	$140,205	20	$1,194
Independence	HR65	Channel Weir	973	5.49	6.25	2.71	$153,205	20	$1,226
Independence	WR83[20]	Channel Weir	980	0.62	5.57	0.33	$148,705	20	$1,335
Independence	WR97	Box Weir	980	1.10	2.53	1.61	$67,705	20	$1,338
Independence	WR22	Channel Weir	982	0.11	2.24	1.35	$83,205	20	$1,857
Independence	HR14	Box Weir	982	0.92	0.86	2.72	$35,205	20	$2,047
Independence	HR38	Channel Weir	967	1.56	2.56	2.31	$137,205	20	$2,680
Independence	HR44	Channel Weir	974	0.29	0.60	0.89	$57,205	20	$4,767

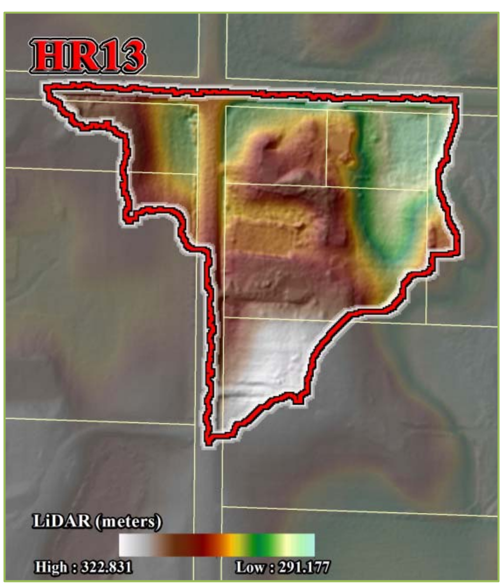
[18] Total cost over twenty years was calculated assuming easement costs were $5,000/acre for hydrologic restorations and $20,000/acre for wetland restorations, project design and construction oversight were $10,000, easement administration and coordination, landowner outreach, and general project coordination would take 85 hours total at $73/hr, annual inspection and maintenance costs $500/yr. Structure installation is $25,000 for channel weirs, $7,500 for box weirs, and $4,000 for control structures without berms. Earthen berms cost $40/cu. yd. installed. An additional $15,000 is added for projects impacting the railroad ROW for permitting.

[19] WR18, WR83 and WR105 are alternative scales of restoration.


Lake
Sarah
HR68
HR67
WR75
WR76
WR86
WR4
WR12
WR6
WR5
HR14
HR13
WR82
WR24
WR1
WR18
WR91
HR79
WR22
WR83
WR97
WR105
HR95
HR29
HR31
HR33
HR65
HR38
Lake
Independence
City of
Independence
HR44

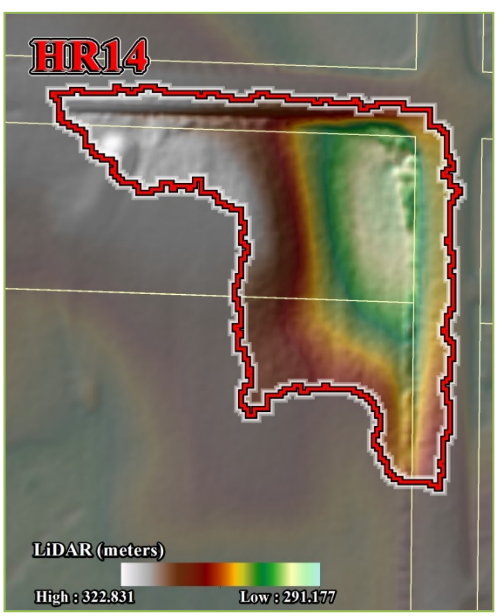
HR13	Pool Area	Loading			Reductions			% Reduction		
Restoration Elev.	(acres)	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr
Initial Conditions	0.0	3.34	6449	7.29	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 971 ft	0.3	2.39	5812	7.21	0.95	637	0.08	28.4%	9.9%	1.1%
Pool to 972 ft	0.5	0.85	2975	7.07	2.49	3474	0.22	74.6%	53.9%	3.0%

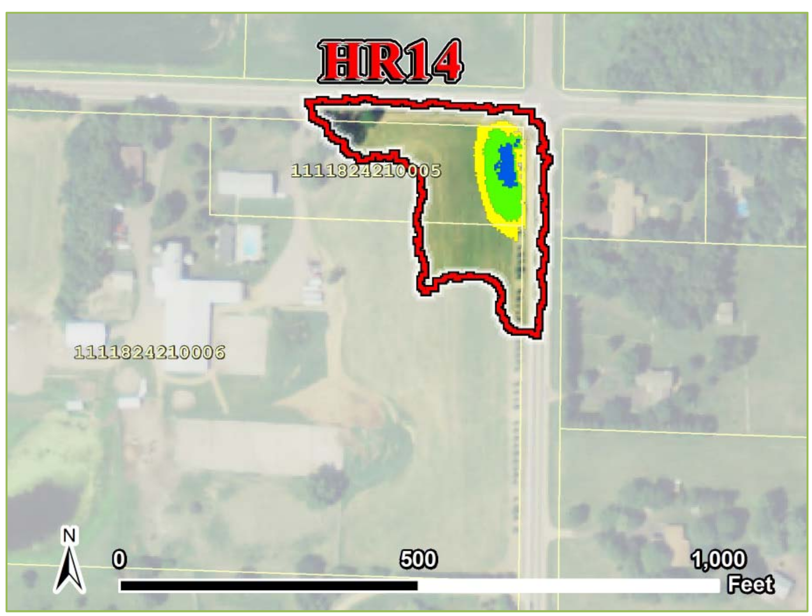
Site Summary – HR13 – 972 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	9.6
Dominant Land Cover	Low Dens. Residential
Installation Type	Box Weir
Installation Cost ($)	$7,500
Easement Cost ($)	$2,500
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$36,205
Project Life (yrs)	20
$/lb-TP removal/yr	$727
$/lb-TSS removal/yr	$0.52
$/ac-ft volume removal/yr	$8,228



HR14 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.0	1.07	2210	3.72	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 981 ft	0.2	0.51	1735	1.17	0.56	475	2.55	52.3%	21.5%	68.6%
Pool to 982 ft	.03	.021	364	1.00	0.86	1846	2.72	80.4%	53.5%	73.1%

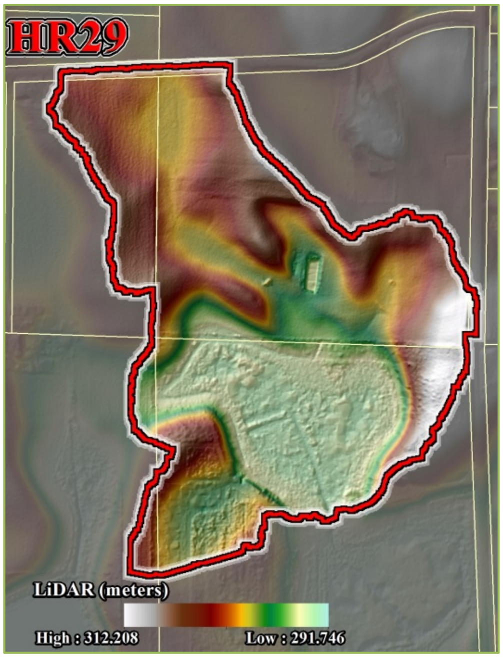
Site Summary – HR14 – 982 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	1.7
Dominant Land Cover	Pasture
Installation Type	Channel Weir
Installation Cost ($)	$7,500
Easement Cost ($)	$1,500
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$35,205
Project Life (yrs)	20
$/lb-TP removal/yr	$2,047
$/lb-TSS removal/yr	$0.95
$/ac-ft volume removal/yr	$647

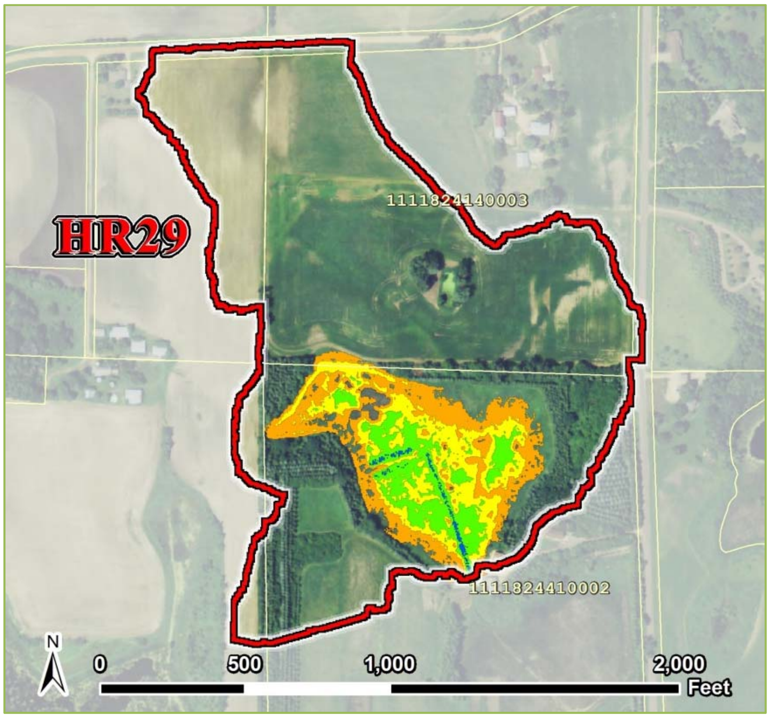




HR29 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	.1	8.93	7,495	38.55	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 961 ft	2.1	6.99	6,990	37.56	1.94	505	0.99	21.7%	6.7%	2.6%
Pool to 962 ft	4.9	4.72	5,727	36.47	4.21	1768	2.08	47.1%	23.6%	5.4%
Pool to 963 ft	8.2	2.95	3,453	35.26	5.98	4042	3.29	67.0%	53.9%	8.5%

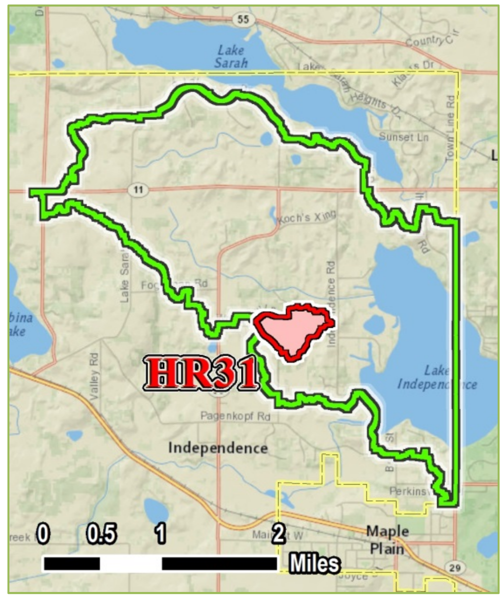
Site Summary – HR29 – 963 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	47.2
Dominant Land Cover	Crop, Pasture
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$41,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$92,205
Project Life (yrs)	20
$/lb-TP removal/yr	$771
$/lb-TSS removal/yr	$1.14
$/ac-ft volume removal/yr	$1,401

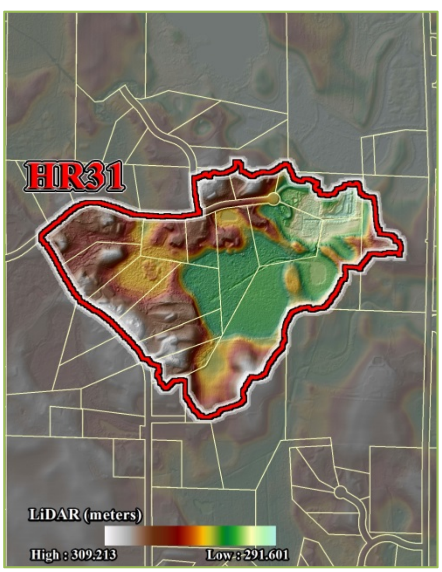


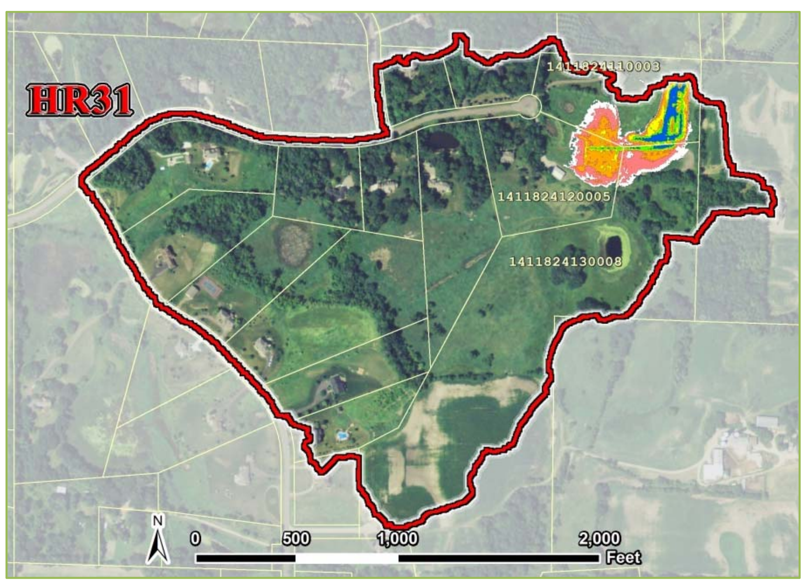


HR31 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.0	11.49	8132	67.78	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 959 ft	0.4	11.26	7955	67.75	0.23	177	0.03	2.0%	2.2%	0.04%
Pool to 960 ft	0.8	10.40	6894	67.65	1.09	1238	0.13	9.5%	15.2%	0.19%
Pool to 961 ft	1.3	9.07	4773	67.51	2.42	3359	0.27	21.1%	41.3%	0.40%
Pool to 962 ft	2.4	8.87	4419	67.15	2.62	3713	0.63	22.8%	45.7%	0.93%
Pool to 963 ft	3.6	8.19	3182	66.82	3.30	4950	0.96	28.7%	60.9%	1.42%
Pool to 964 ft	4.5	7.72	2298	66.38	3.77	5834	1.40	32.8%	71.7%	2.07%

Site Summary – HR31 – 964 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	99
Dominant Land Cover	Agriculture
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$22,500
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$73,705
Project Life (yrs)	20
$/lb-TP removal/yr	$978
$/lb-TSS removal/yr	$.63
$/ac-ft volume removal/yr	$2,632

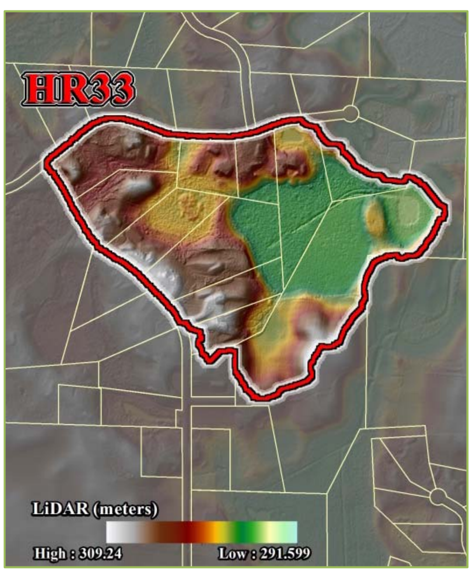


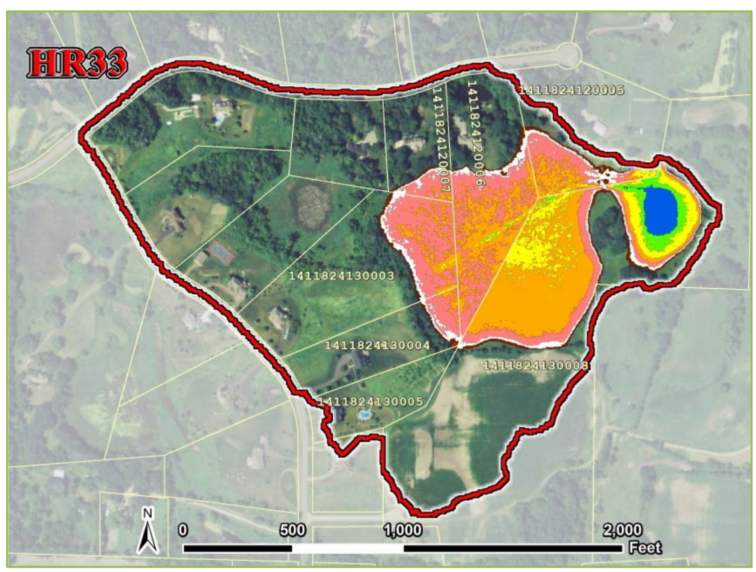




HR33 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	.7	9.19	6,719	52.17	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 968 ft	1.4	8.40	5,896	51.98	0.79	823	.19	8.6%	12.3%	.36%
Pool to 969 ft	3.5	7.82	5,622	51.39	1.37	1,097	.78	14.9%	16.3%	1.50%
Pool to 970 ft	11.1	6.72	5,074	49.79	2.47	1,645	2.38	26.9%	24.5%	4.56%
Pool to 971 ft	17.6	4.39	3,291	48.28	4.80	3,428	3.89	52.2%	51.0%	7.46%
Pool to 972 ft	19.2	3.57	1,371	47.08	5.62	5,348	5.09	61.2%	79.6%	9.76%
Pool to 973 ft	20.1	3.02	549	45.65	9.19	6,170	6.52	67.1%	91.8%	12.5%

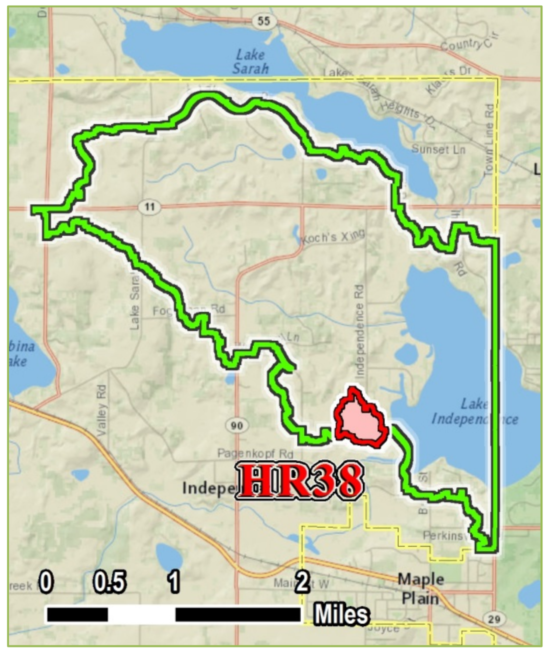
Site Summary – HR33 – 973 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	76.85
Dominant Land Cover	Low Density Residential
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$100,500
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$151,705
Project Life (yrs)	20
$/lb-TP removal/yr	$825
$/lb-TSS removal/yr	$1.23
$/ac-ft volume removal/yr	$1,163

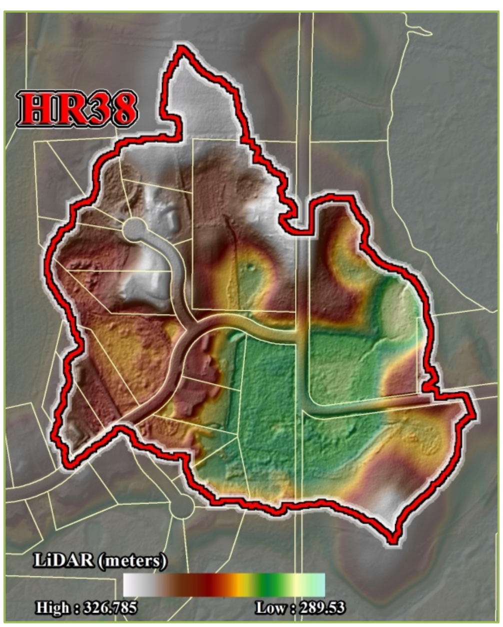


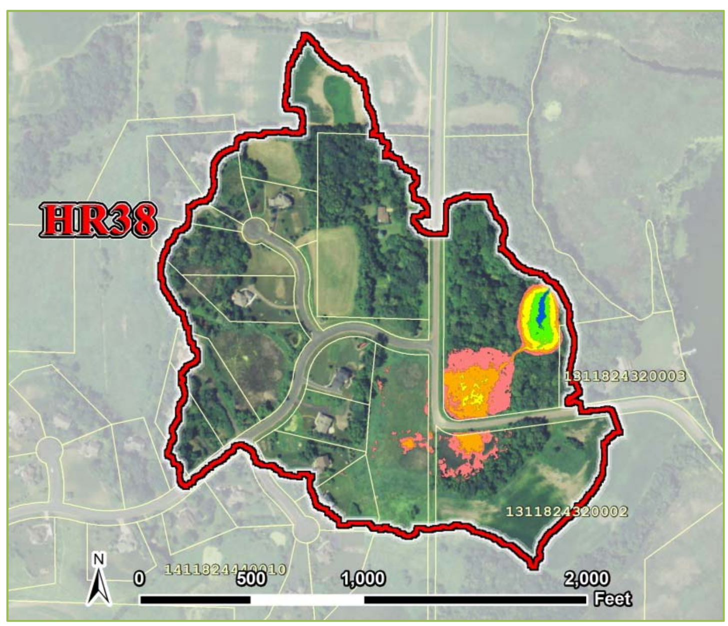


HR38 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.1	6.80	9147	50.39	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 964 ft	0.4	6.36	8924	50.34	0.44	223	0.05	6.5%	2.4%	0.1%
Pool to 965 ft	1.0	5.91	8032	50.15	0.89	1115	0.24	13.1%	12.2%	0.5%
Pool to 966 ft	2.2	5.24	7028	49.31	1.56	2119	1.08	22.9%	23.2%	2.1%
Pool to 967 ft	4.3	4.24	6024	48.08	2.56	3123	2.31	37.7%	34.1%	4.6%

Site Summary – HR38 – 967 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	62.5
Dominant Land Cover	Low Density Residential
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$86,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$137,205
Project Life (yrs)	20
$/lb-TP removal/yr	$2,680
$/lb-TSS removal/yr	$2.20
$/ac-ft volume removal/yr	$2,970

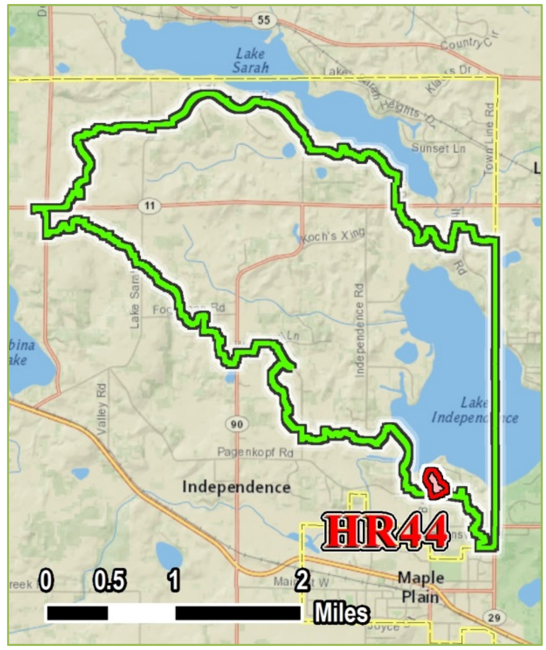


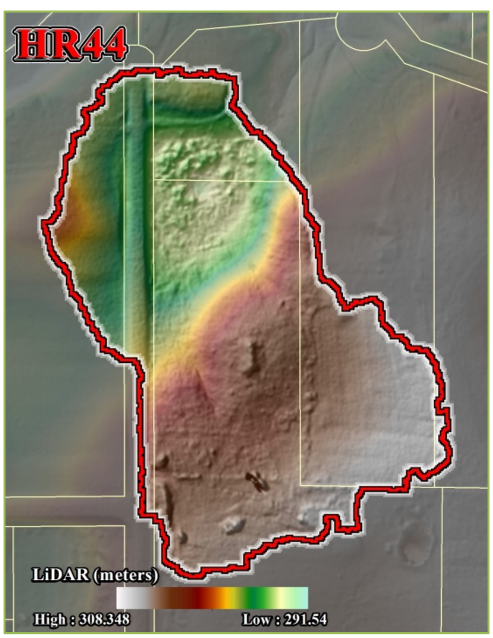


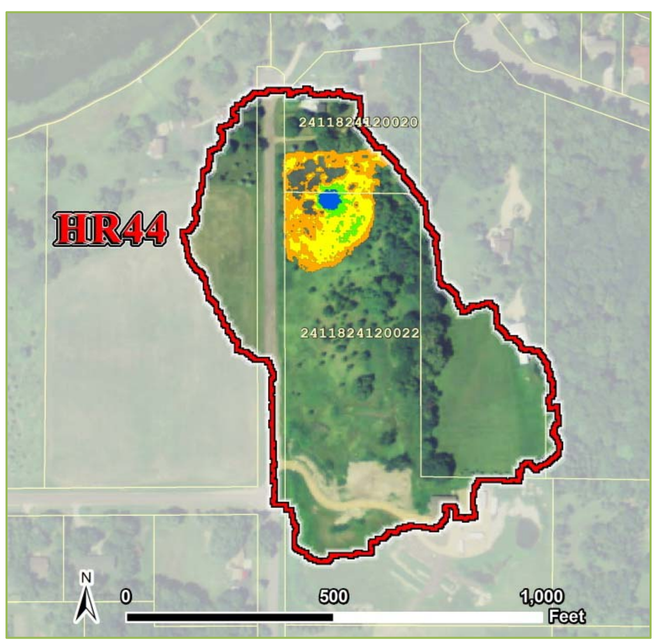


HR44 Restoration Elev.	Pool Area (acres)	Loading			Reductions			% Reduction		
		TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr
Initial Conditions	0.045	0.90	1261	10.90	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 972 ft	0.1	0.82	1213	10.84	0.08	48	0.06	8.9%	3.8%	0.55%
Pool to 973 ft	0.6	0.70	1116	10.39	0.20	145	0.51	22.2%	11.5%	4.68%
Pool to 974 ft	1.2	0.30	679	10.01	0.60	582	0.89	66.7%	46.2%	8.17%

Site Summary – HR44 – 974 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	13.6
Dominant Land Cover	Agriculture
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$6,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$57,205
Project Life (yrs)	20
$/lb-TP removal/yr	$4,761
$/lb-TSS removal/yr	$4.91
$/ac-ft volume removal/yr	$3,214

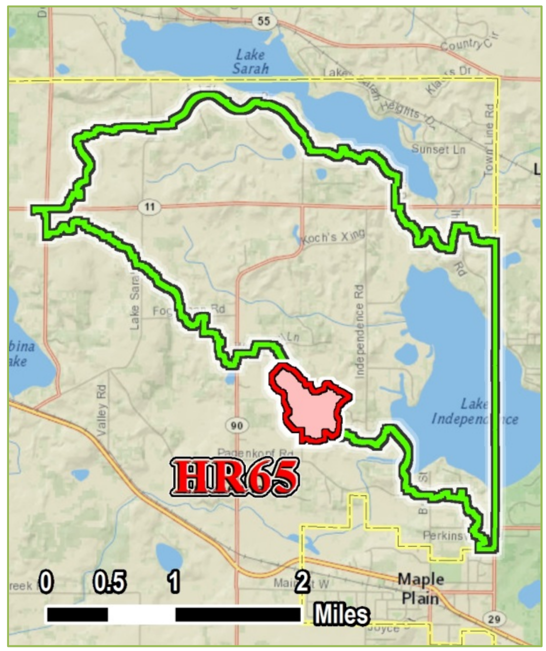


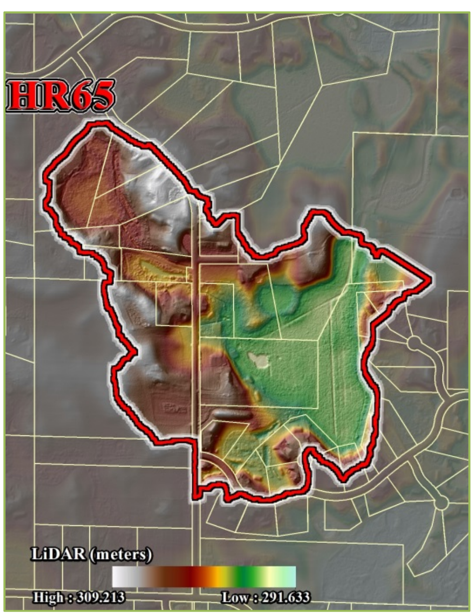


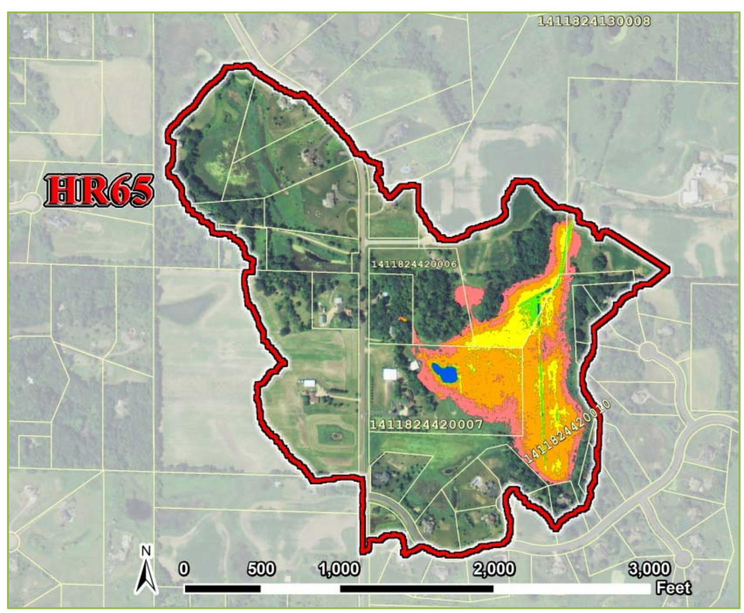


HR65 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.3	16.09	17930	86.67	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 970 ft	1.1	15.19	16955	86.60	0.90	975	.07	5.6%	5.44%	.08%
Pool to 971 ft	4.7	14.18	15434	86.38	1.91	2496	.29	11.9%	13.92%	.33%
Pool to 972 ft	14.3	12.82	13043	85.24	3.27	4887	1.43	20.3%	27.26%	1.65%
Pool to 973 ft	20.4	9.84	6956	83.96	6.25	10974	2.71	38.8%	61.20%	3.13%

Site Summary – HR65 – 973 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	121.8
Dominant Land Cover	Med. Density Residential
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$102,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$153,205
Project Life (yrs)	20
$/lb-TP removal/yr	$1,226
$/lb-TSS removal/yr	$.70
$/ac-ft volume removal/yr	$2,827

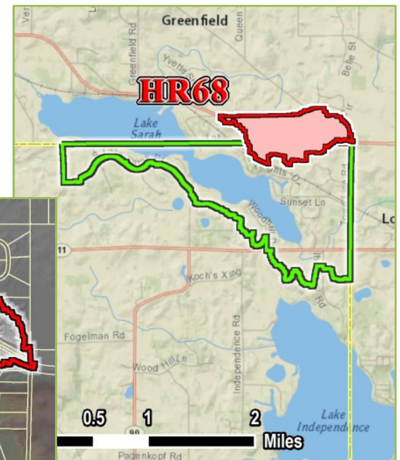


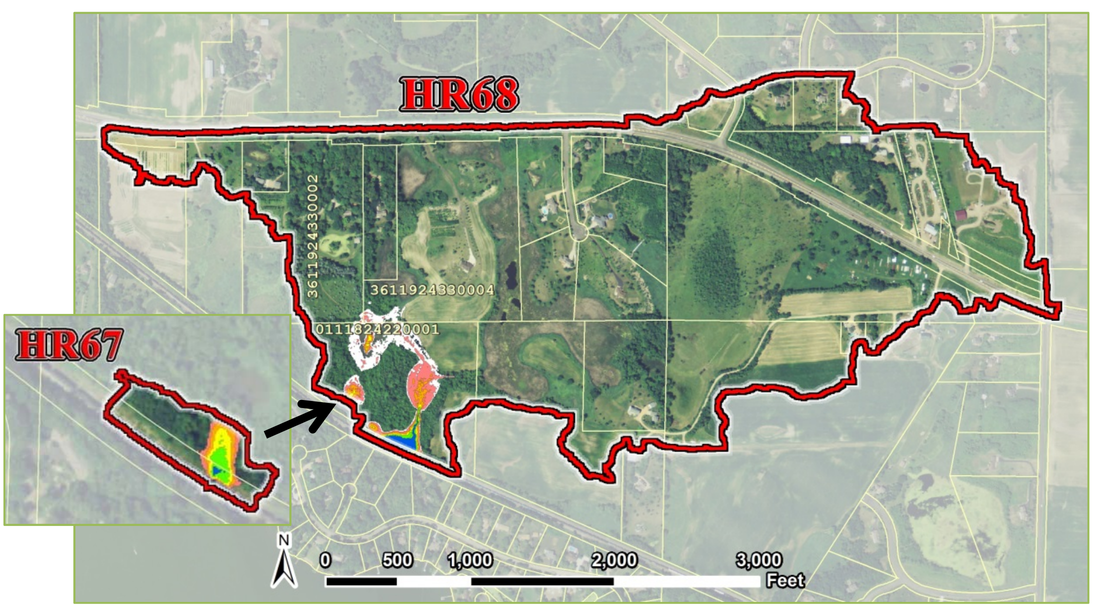




HR67 & 68 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.0	50.74	58824	166.06	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 996 ft	0.61	48.32	56560	165.99	2.42	3351	0.07	4.9%	5.8%	0.04%
Pool to 997 ft	0.87	44.26	54885	165.82	6.48	10946	0.24	12.8%	18.8%	0.22%
Pool to 998 ft	1.44	39.65	47343	165.45	11.09	21006	.061	21.6%	36.1%	0.65%
Pool to 999 ft	2.98	35.42	26814	165.36	15.32	31971	0.70	30.0%	54.9%	0.72%

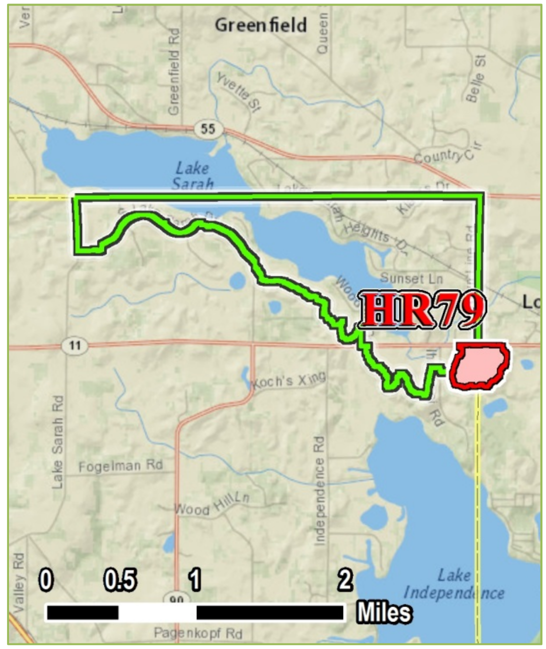
Site Summary – HR67 & 68 999 Pool elev.	
Water Body	Lake Sarah
Treatment Watershed (ac)	235.9
Dominant Land Cover	Agriculture
Installation Type	Box Weir
Installation Cost ($)	$15,000
Easement Cost ($)	$29,900
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$71,105
Project Life (yrs)	20
$/lb-TP removal/yr	$232
$/lb-TSS removal/yr	$.11
$/ac-ft volume removal/yr	$5,079

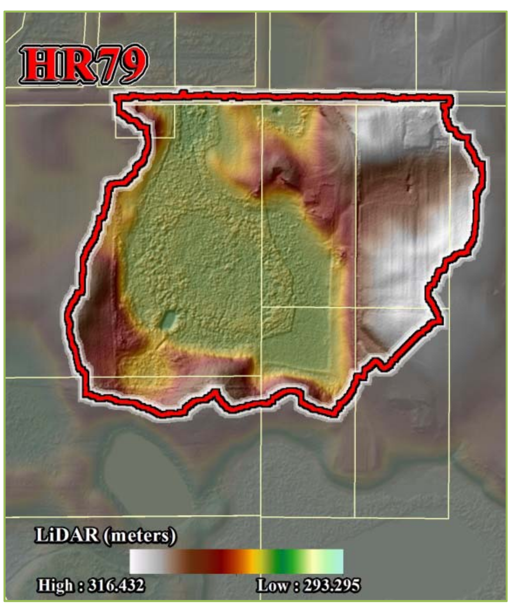


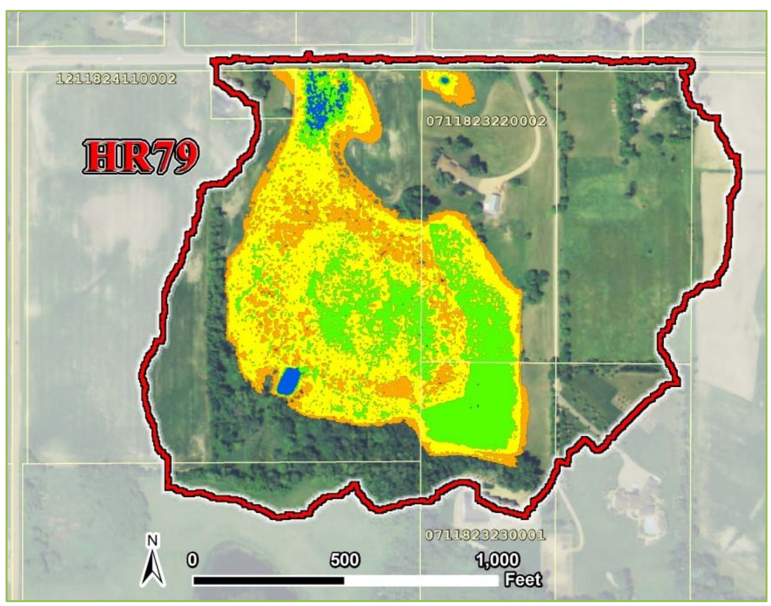


HR79 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.3	8.15	5214	37.84	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 985 ft	5.3	5.21	5024	34.95	2.94	190	2.89	36.1%	3.6%	7.6%
Pool to 986 ft	14.6	2.94	4171	31.31	5.21	1043	6.53	63.9%	20.0%	17.3%
Pool to 987 ft	18.3	2.28	1422	29.52	5.87	3792	8.32	72.0%	72.7%	22.0%

Site Summary – HR79 – 987 Pool elev.	
Water Body	Lake Sarah
Treatment Watershed (ac)	53.1
Dominant Land Cover	Agriculture
Installation Type	Box Weir
Installation Cost ($)	$7,500
Easement Cost ($)	$106,500
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$140,205
Project Life (yrs)	20
$/lb-TP removal/yr	$1,194
$/lb-TSS removal/yr	$1.85
$/ac-ft volume removal/yr	$843

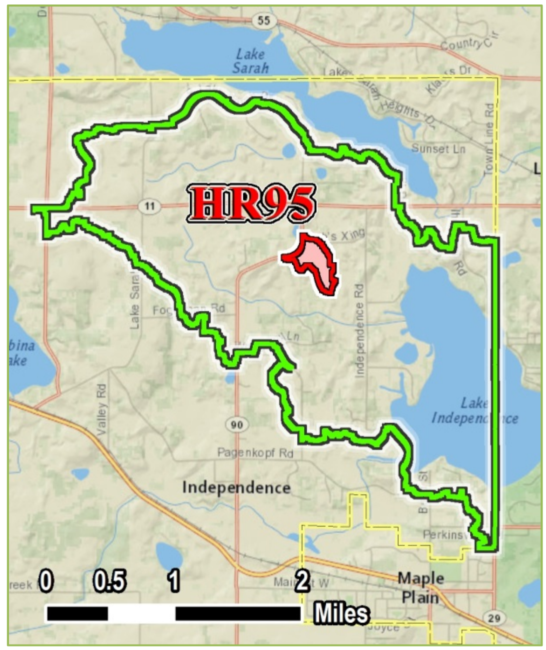


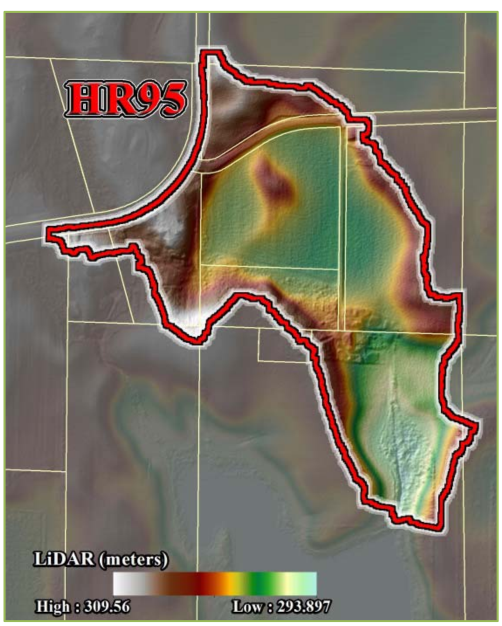




HR95 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0	27.87	23334	40.85	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 961 ft	1.1	23.71	16738	40.12	4.16	6596	0.73	14.9%	28.3%	1.8%
Pool to 962 ft	1.9	21.52	12121	39.47	6.35	11213	1.38	22.8%	48.1%	3.4%
Pool to 963 ft	2.4	19.46	7421	39.15	8.41	15913	1.70	30.2%	68.2%	4.2%
Pool to 964 ft	2.8	18.23	4452	38.92	9.64	18882	1.93	34.6%	80.9%	4.7%

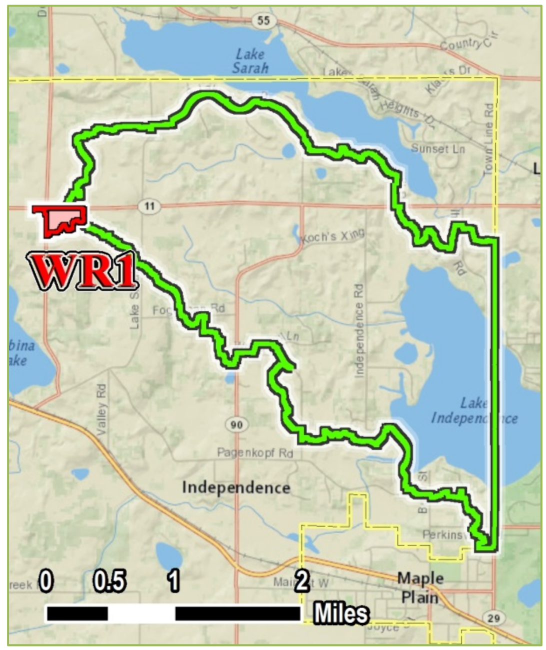
Site Summary – HR95 – 964 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	46.2
Dominant Land Cover	Agriculture
Installation Type	Box Weir
Installation Cost ($)	$7,500
Easement Cost ($)	$27,500
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$61,205
Project Life (yrs)	20
$/lb-TP removal/yr	$317
$/lb-TSS removal/yr	$.16
$/ac-ft volume removal/yr	$1,586

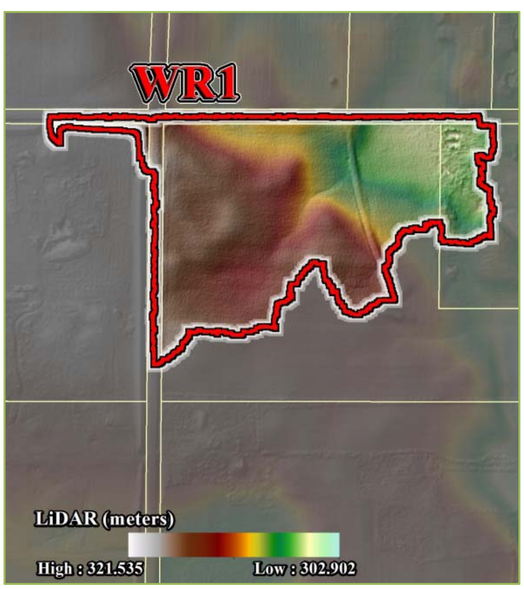


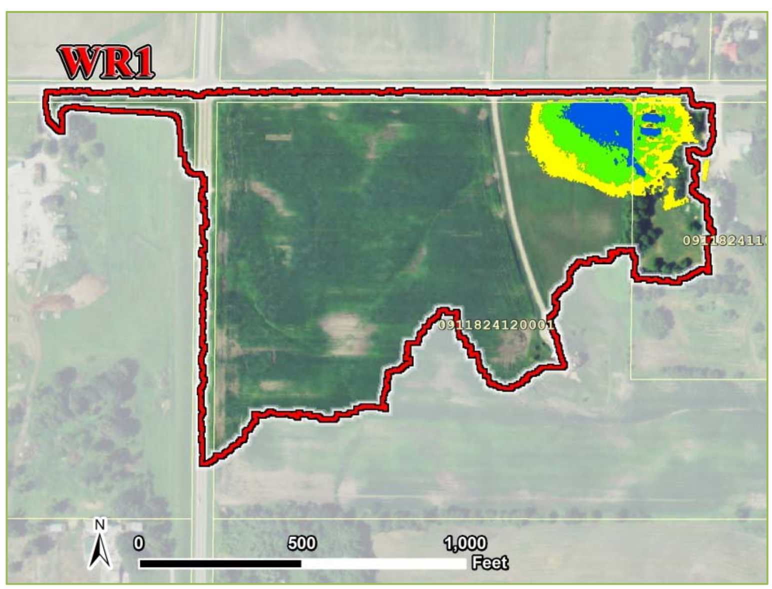


WR1 Restoration Elev.	Pool Area (acres)	Loading			Reductions			% Reduction		
		TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr
Initial Conditions	0	15.37	13,695	26.34	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 1007 ft	0.7	11.54	13,013	25.17	3.83	682	1.17	24.9%	5.0%	4.4%
Pool to 1008 ft	1.7	8.97	10,861	23.90	6.40	2,834	2.44	41.6%	20.7%	9.3%
Pool to 1009 ft	2.9	6.98	6,769	22.95	8.39	6,926	3.39	54.6%	50.6%	12.9%

Site Summary – WR1 – 1009 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	29.4
Dominant Land Cover	Agriculture
Installation Type	Box Weir
Installation Cost ($)	$8,000
Easement Cost ($)	$58,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$92,205
Project Life (yrs)	20
$/lb-TP removal/yr	$549
$/lb-TSS removal/yr	$.67
$/ac-ft volume removal/yr	$1,360

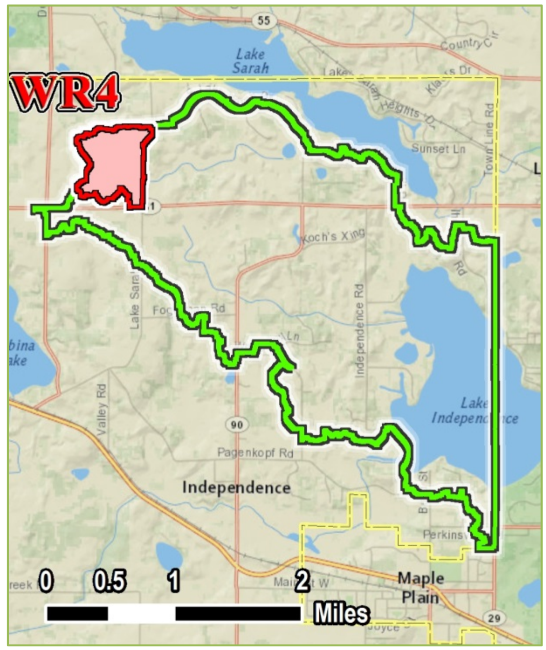


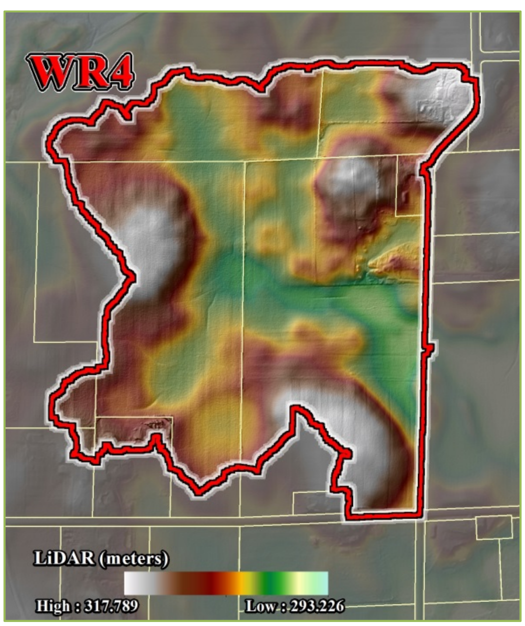


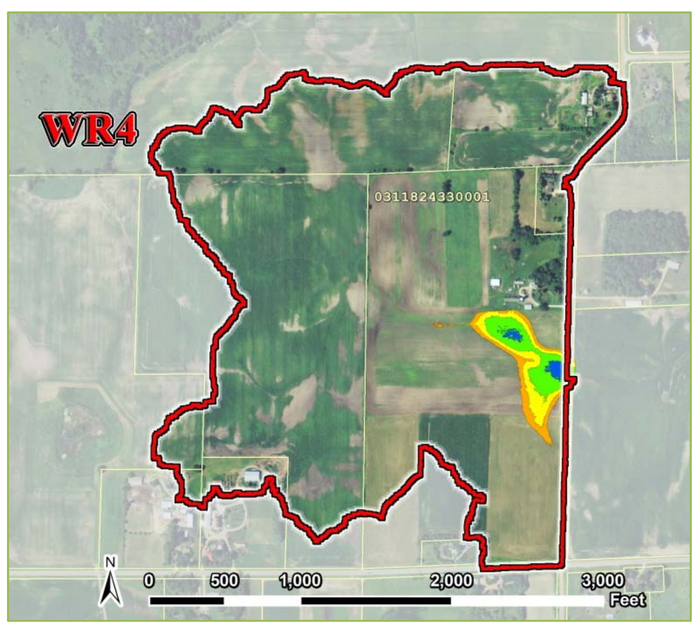


WR4 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0	90.45	63,283	141.28	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 982 ft	0.4	84.78	62,686	141.20	5.67	597	0.08	6.3%	0.9%	0.06%
Pool to 983 ft	2.3	82.67	61,791	140.85	7.78	1,492	0.43	8.6%	2.4%	0.30%
Pool to 984 ft	4.1	75.22	47,164	140.20	15.23	16,119	1.08	16.8%	25.5%	0.76%
Pool to 985 ft	5.5	68.36	29,254	139.38	22.09	34,029	1.90	24.4%	53.8%	1.34%

Site Summary – WR4 – 985 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	167.3
Dominant Land Cover	Agriculture
Installation Type	Box Weir
Installation Cost ($)	$7,500
Easement Cost ($)	$110,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$143,705
Project Life (yrs)	20
$/lb-TP removal/yr	$325
$/lb-TSS removal/yr	$.21
$/ac-ft volume removal/yr	$3,782

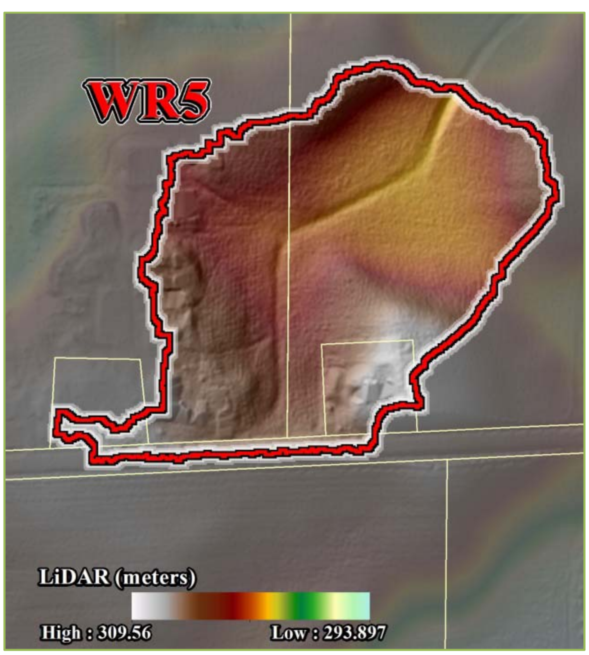


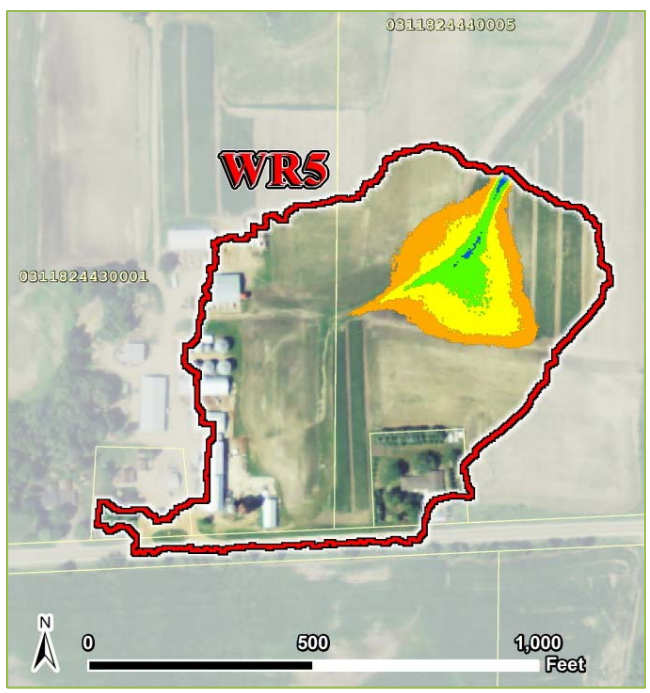




WR5 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.0	7.64	5893	11.63	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 1009 ft	0.4	5.82	5626	10.99	1.82	267	0.64	8.6%	2.4%	0.30%
Pool to 1010 ft	1.2	4.12	4705	10.30	3.52	1188	1.33	16.8%	25.5%	0.76%
Pool to 1011 ft	2.0	2.93	2668	9.85	4.71	3225	1.78	24.4%	53.8%	1.34%

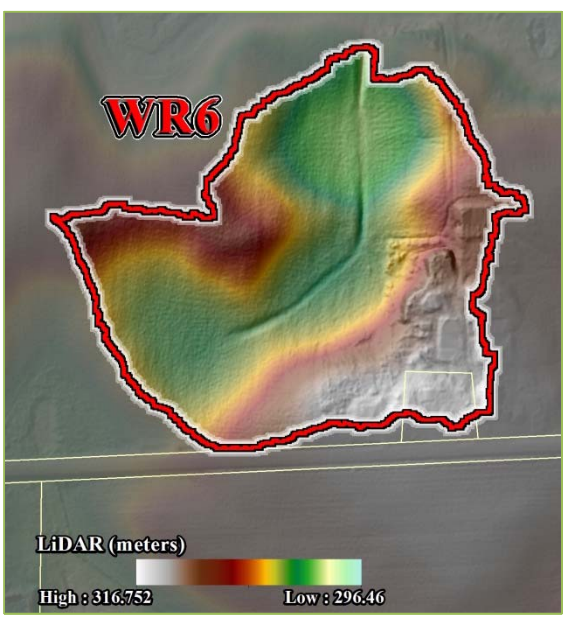
Site Summary – WR5 – 1011 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	13.6
Dominant Land Cover	Agriculture
Installation Type	Channel Weir
Installation Cost ($)	$20,000
Easement Cost ($)	$40,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$86,205
Project Life (yrs)	20
$/lb-TP removal/yr	$915
$/lb-TSS removal/yr	$1.34
$/ac-ft volume removal/yr	$2,421

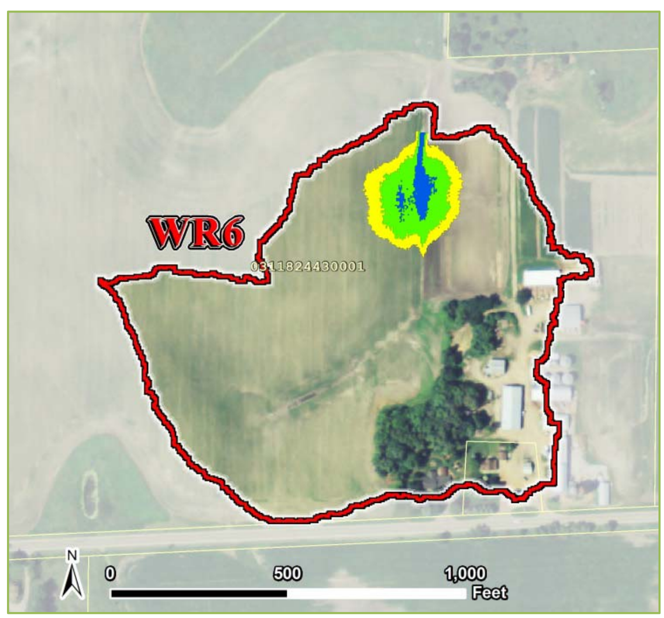




WR6 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions		16.06	11399	19.83	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 986 ft	0.2	15.94	11318	19.80	0.12	81	0.03	0.8%	0.7%	0.15%
Pool to 987 ft	0.9	12.62	10628	18.98	3.44	711	0.85	21.4%	6.8%	4.29%
Pool to 988 ft	1.4	10.95	6815	18.70	5.11	4584	1.13	31.8%	40.2%	5.70%

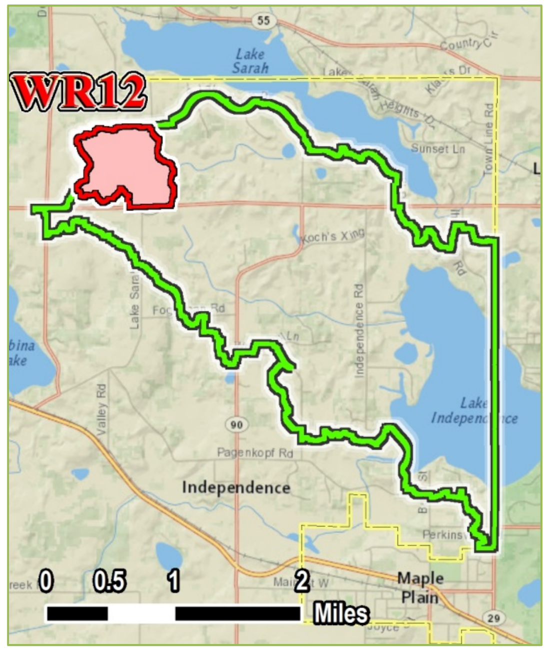
Site Summary – WR6 – 988 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	22.7
Dominant Land Cover	Agriculture
Installation Type	Channel Weir
Installation Cost ($)	$20,000
Easement Cost ($)	$28,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$74,205
Project Life (yrs)	20
$/lb-TP removal/yr	$726
$/lb-TSS removal/yr	$0.81
$/ac-ft volume removal/yr	$3,283

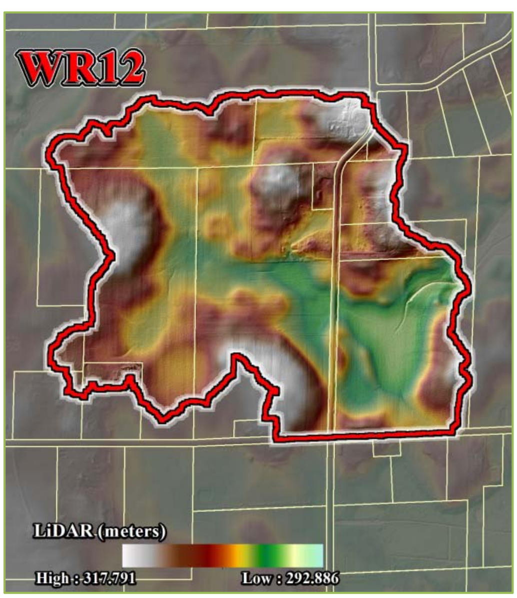


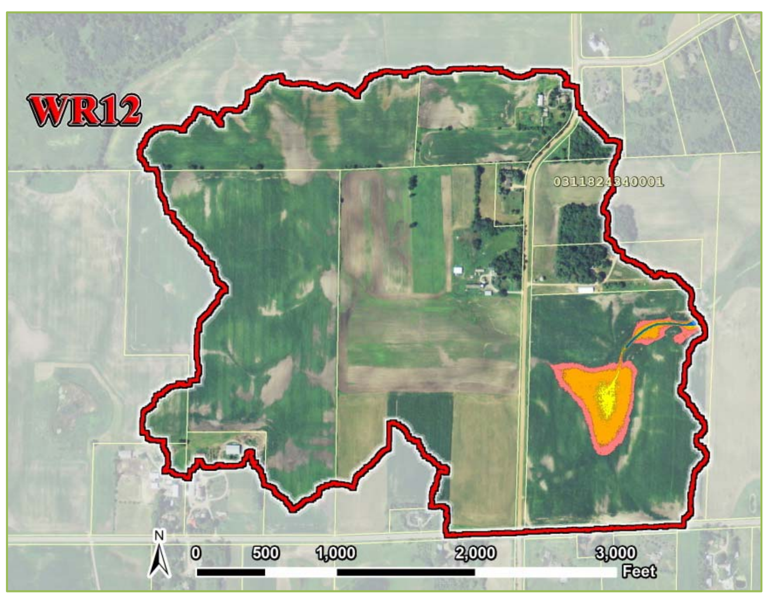


WR12 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0	206.8	152613	199.22	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 978 ft	0.2	206.0	151786	199.17	0.79	827	0.05	0.4%	0.5%	0.03%
Pool to 979 ft	1.0	204.2	148891	198.69	2.63	37.22	0.53	1.3%	2.4%	0.27%
Pool to 980 ft	4.6	193.1	139379	196.77	13.65	13234	2.45	6.6%	8.7%	1.23%
Pool to 981 ft	7.2	181.2	89748	195.17	25.64	62865	4.05	12.4%	41.2%	2.03%

Site Summary – WR12 – 981 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	231.8
Dominant Land Cover	Agriculture
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$144,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$195,205
Project Life (yrs)	20
$/lb-TP removal/yr	$381
$/lb-TSS removal/yr	$.16
$/ac-ft volume removal/yr	$2,410

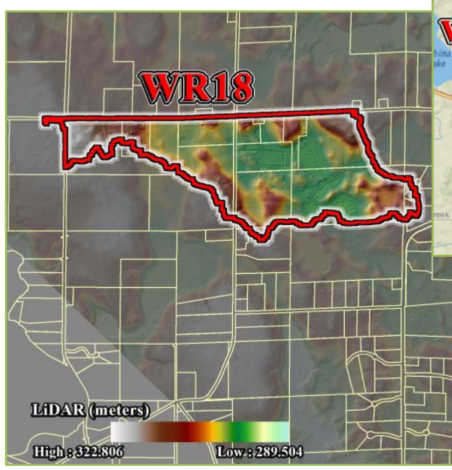


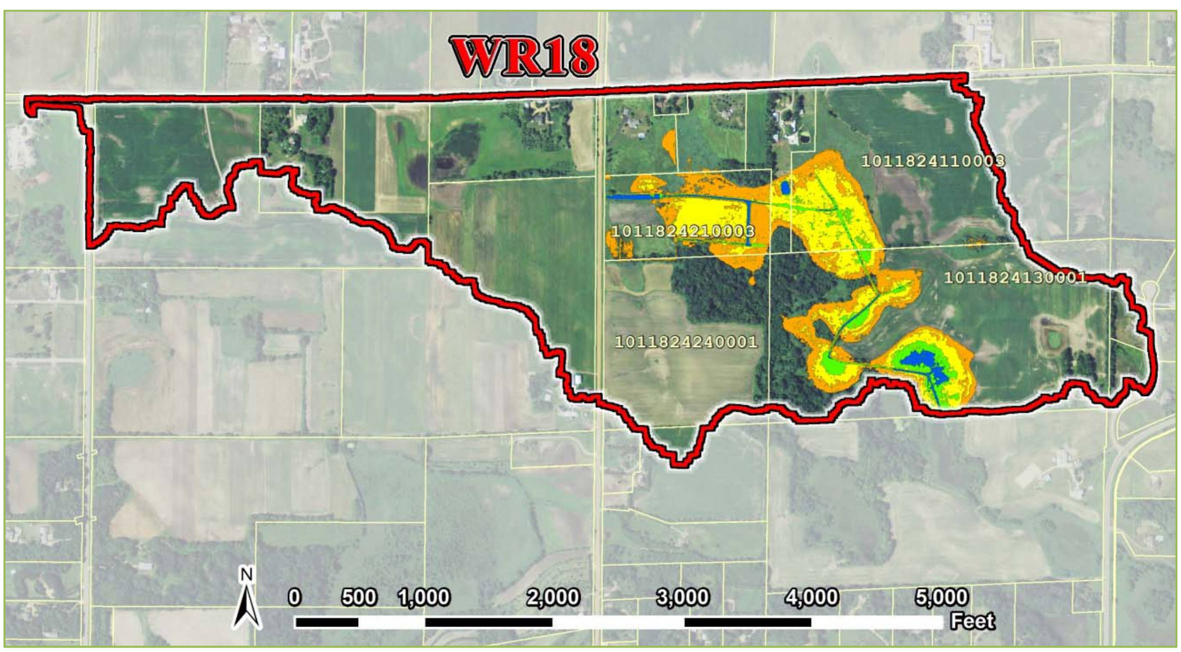




WR18 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0	101.35	70725	230.93	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 978 ft	2.0	94.11	70168	230.78	7.24	557	0.15	7.1%	0.8%	0.06%
Pool to 979 ft	6.9	87.99	68497	229.94	13.36	2228	0.99	13.2%	3.2%	0.43%
Pool to 980 ft	25.2	72.40	60701	225.94	28.95	10024	5.05	28.6%	14.2%	2.19%
Pool to 981 ft	44.3	61.81	49563	220.97	39.54	21162	9.96	39.0%	29.9%	4.31%

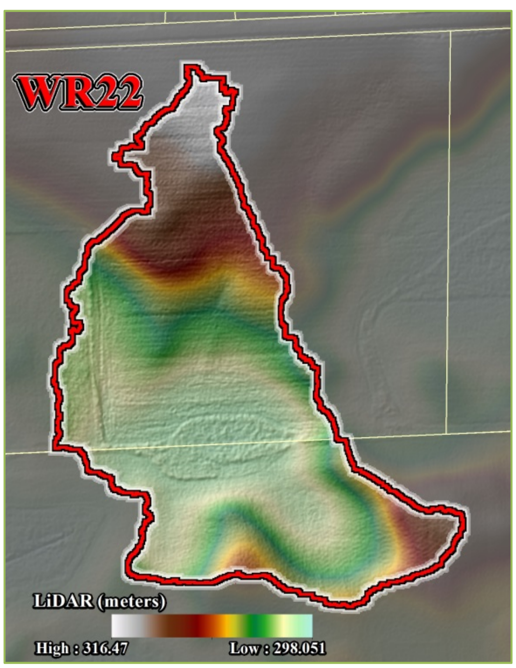
Site Summary – WR18 – 981 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	312.1
Dominant Land Cover	Agriculture
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$508,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$559,205
Project Life (yrs)	20
$/lb-TP removal/yr	$707
$/lb-TSS removal/yr	$1.32
$/ac-ft volume removal/yr	$2,807

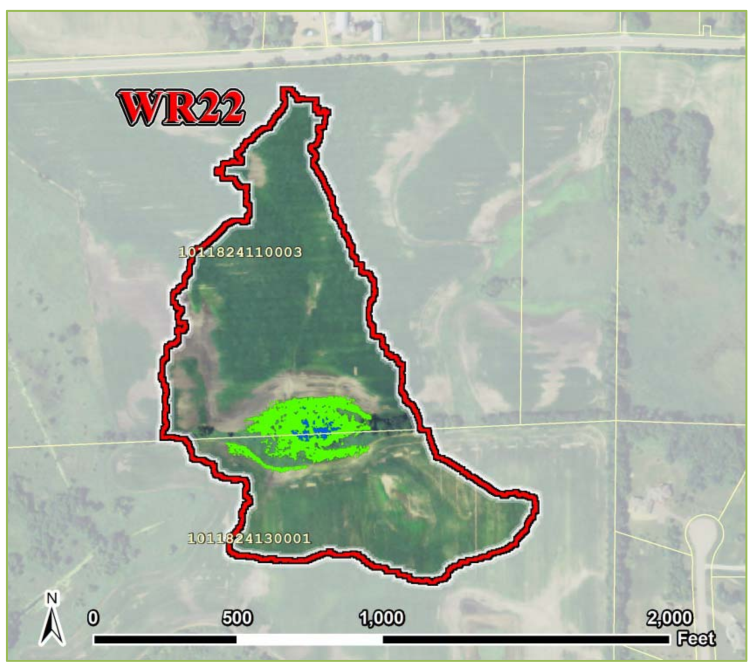




WR22 Restoration Elev.	Pool Area (acres)	Loading			Reductions			% Reduction		
		TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr
Initial Conditions	0	6.35	3894	18.74	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 981 ft	0.1	5.97	3894	18.73	0.38	0	0.01	6.0%	0.0%	0.05%
Pool to 982 ft	1.6	4.11	3683	17.39	2.24	211	1.35	35.3%	5.4%	7.20%

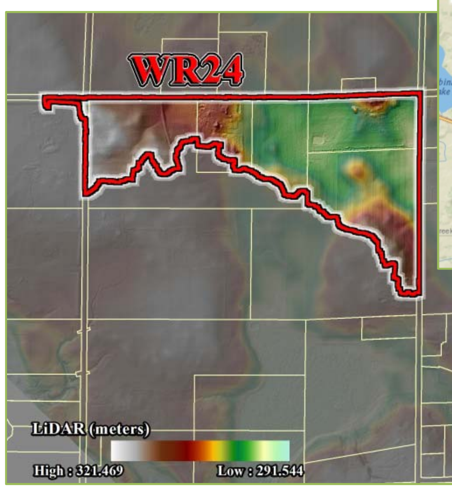
Site Summary – WR22 – 982 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	23.7
Dominant Land Cover	Agriculture
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$32,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$83,205
Project Life (yrs)	20
$/lb-TP removal/yr	$1,857
$/lb-TSS removal/yr	$19.72
$/ac-ft volume removal/yr	$3,082

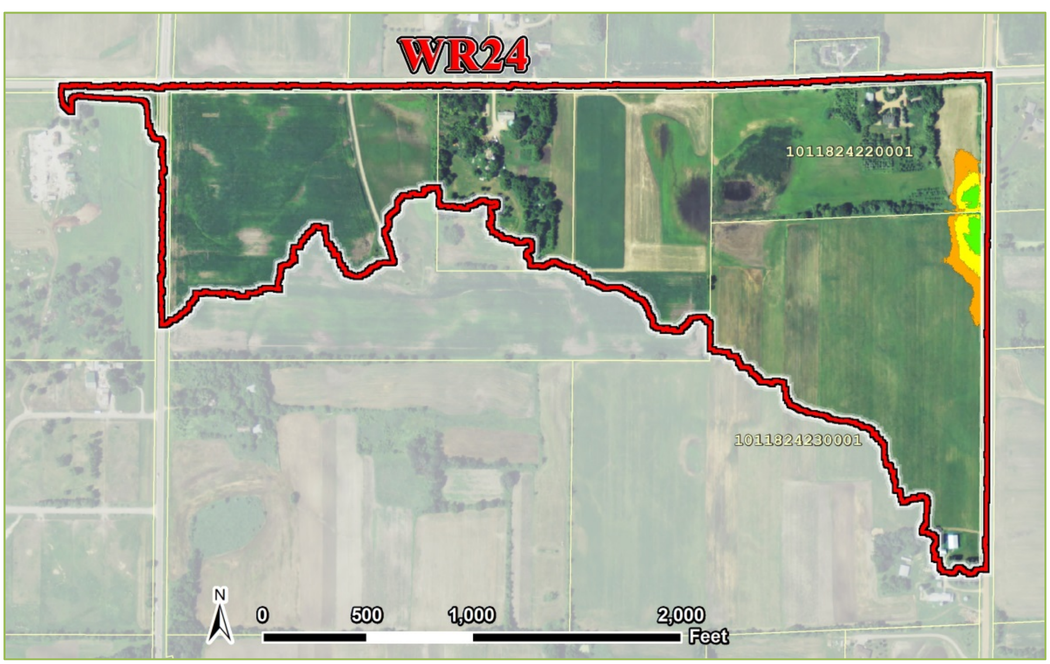




WR24 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.04	36.13	25536	83.47	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 982 ft	0.5	35.89	25347	83.47	0.24	189	0.00	0.7%	0.7%	0.0%
Pool to 983 ft	1.3	32.72	23266	82.67	3.41	2270	0.80	9.4%	8.9%	0.96%
Pool to 984 ft	2.4	Risk of road flooding								

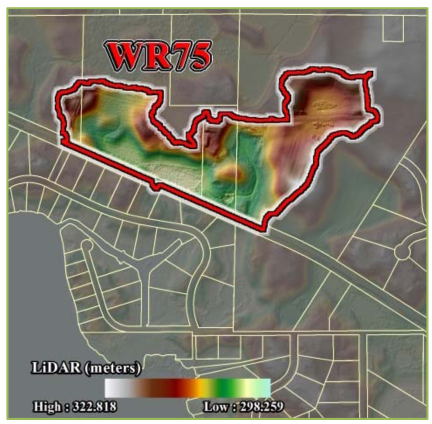
Site Summary – WR24 – 983 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	42.9
Dominant Land Cover	Agriculture
Installation Type	Box Weir
Installation Cost ($)	$7,500
Easement Cost ($)	$26,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$59,705
Project Life (yrs)	20
$/lb-TP removal/yr	$876
$/lb-TSS removal/yr	$1.32
$/ac-ft volume removal/yr	$3,732

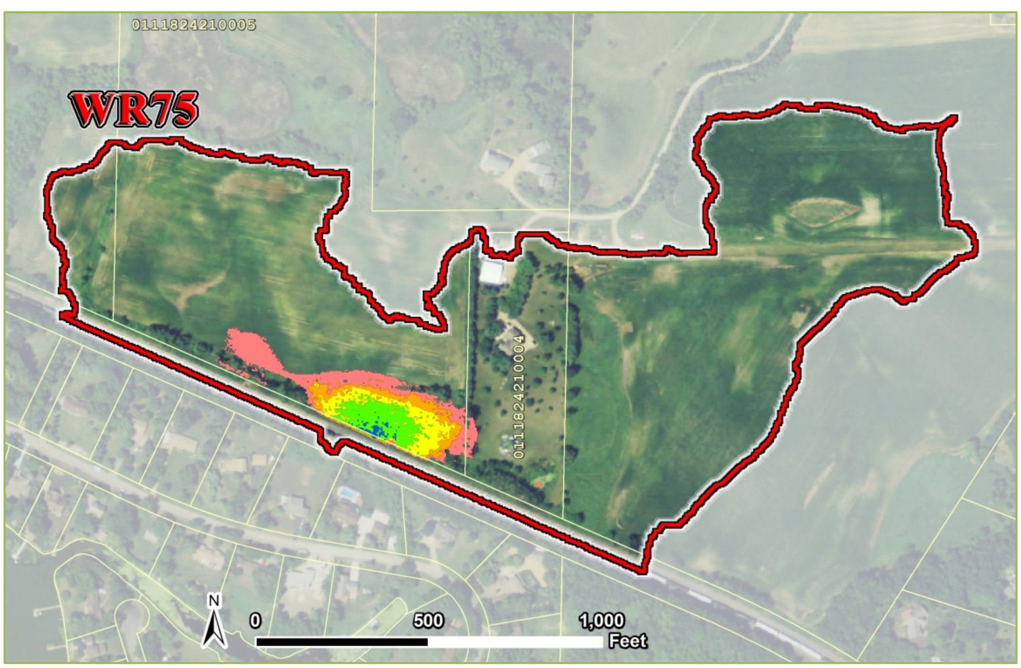




WR75 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.0	24.94	25155	35.32	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 987 ft	0.5	23.07	24795	34.84	1.87	360	0.48	7.5%	1.4%	1.4%
Pool to 988 ft	0.9	19.65	16243	34.39	5.29	8912	0.93	21.2%	35.4%	2.6%
Pool to 989 ft	1.3	16.61	9415	33.47	8.33	15740	1.85	33.4%	62.6%	5.2%
Pool to 990 ft	2.2	15.60	8337	32.74	9.34	16818	2.58	37.4%	66.9%	7.3%

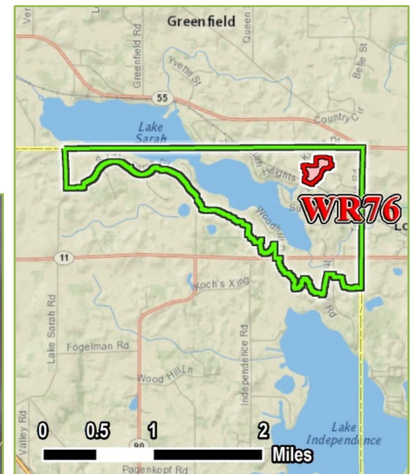
Site Summary – WR75 – 990 Pool elev.	
Water Body	Lake Sarah
Treatment Watershed (ac)	40.3
Dominant Land Cover	Agriculture
Installation Type	Box Weir
Installation Cost ($)	$7,500
Easement Cost ($)	$39,500
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$73,205
Project Life (yrs)	20
$/lb-TP removal/yr	$392
$/lb-TSS removal/yr	$0.22
$/ac-ft volume removal/yr	$1,419

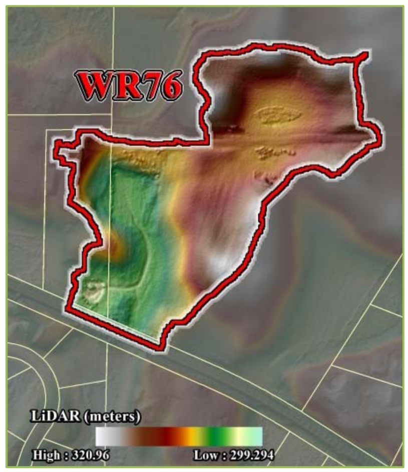


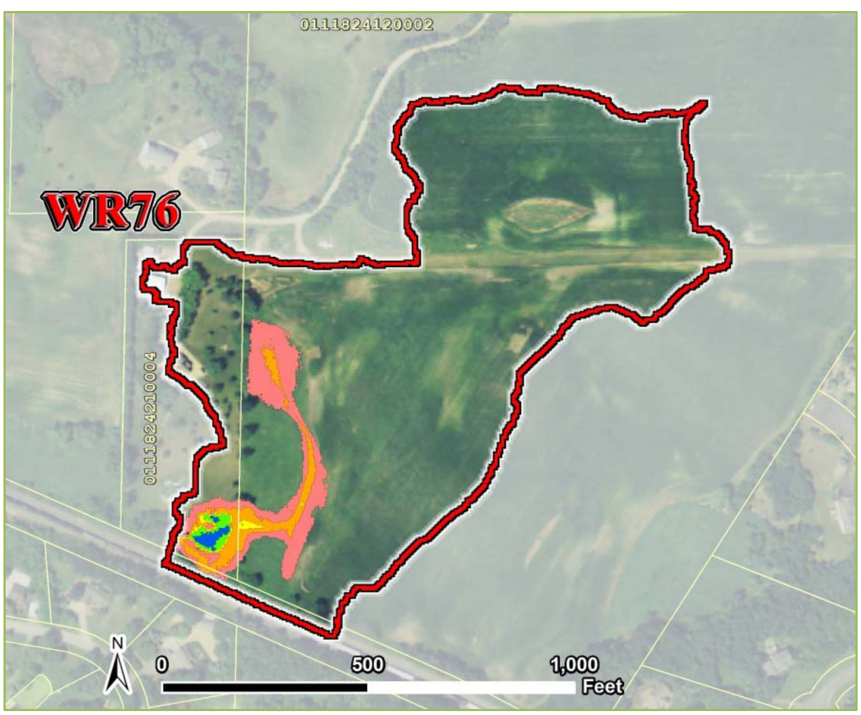


WR76 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Condition	0.12	9.81	11777	18.24	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 993 ft	0.2	8.98	10892	18.21	0.83	885	0.03	8.5%	7.5%	0.2%
Pool to 994 ft	0.6	7.28	8236	17.78	2.53	3541	0.46	25.8%	30.1%	2.5%
Pool to 995 ft	1.7	5.18	4234	16.49	4.63	7543	1.75	47.2%	47.2%	9.6%

Site Summary – WR76 – 987 Pool elev.	
Water Body	Lake Sarah
Treatment Watershed (ac)	21.6
Dominant Land Cover	Agriculture
Installation Type	Box Weir
Installation Cost ($)	$7,500
Easement Cost ($)	$40,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$73,705
Project Life (yrs)	20
$/lb-TP removal/yr	$796
$/lb-TSS removal/yr	$0.49
$/ac-ft volume removal/yr	$2,106

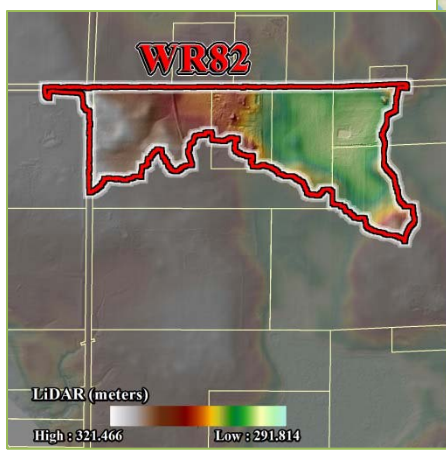


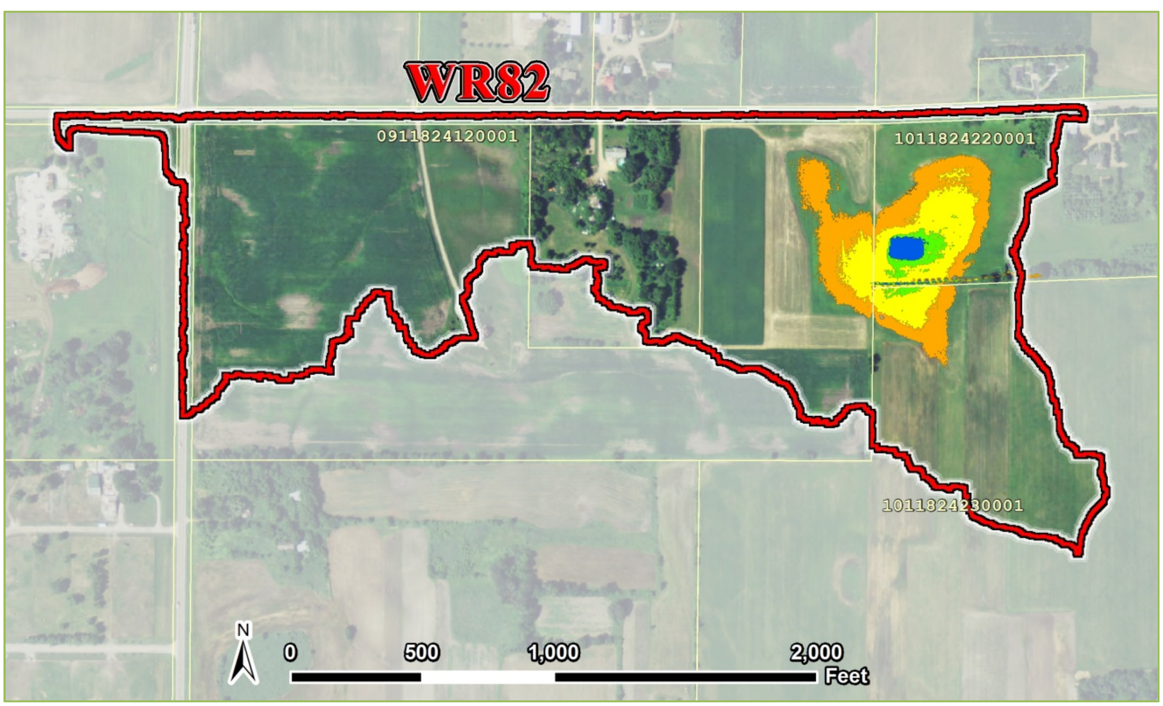




WR82 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.3	32.11	23746	61.69	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 985 ft	0.7	30.36	22127	61.12	1.75	1619	0.57	5.5%	6.8%	0.92%
Pool to 986 ft	3.6	23.21	20373	58.61	8.90	3373	3.08	27.7%	14.2%	4.99%
Pool to 987 ft	8.1	16.46	17945	55.86	15.65	5801	5.83	48.7%	24.4%	9.45%

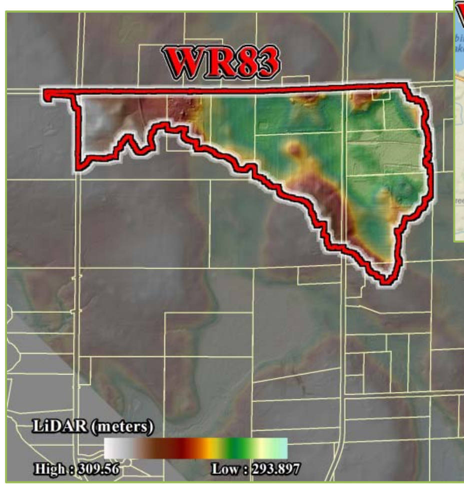
Site Summary – WR82 – 987 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	75.6
Dominant Land Cover	Agriculture
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$157,500
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$208,705
Project Life (yrs)	20
$/lb-TP removal/yr	$667
$/lb-TSS removal/yr	$1.80
$/ac-ft volume removal/yr	$1,790

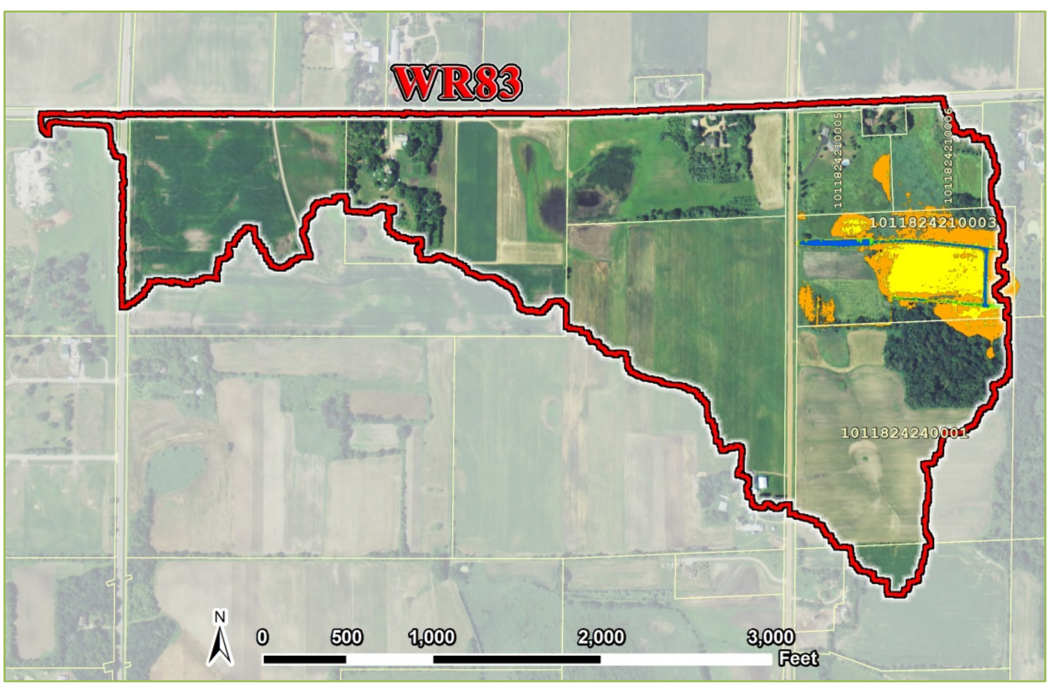




WR83 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0	50.76	39001	125.09	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 978 ft	0.7	49.83	38691	125.09	0.93	310	0.00	1.8%	0.8%	0.00%
Pool to 979 ft	1.1	49.20	38382	124.98	1.56	619	0.11	3.1%	1.6%	0.09%
Pool to 980 ft	5.4	45.19	37762	124.76	5.57	1239	0.33	11.0%	3.2%	0.26%
Pool to 981 ft		Too many parcels involved								

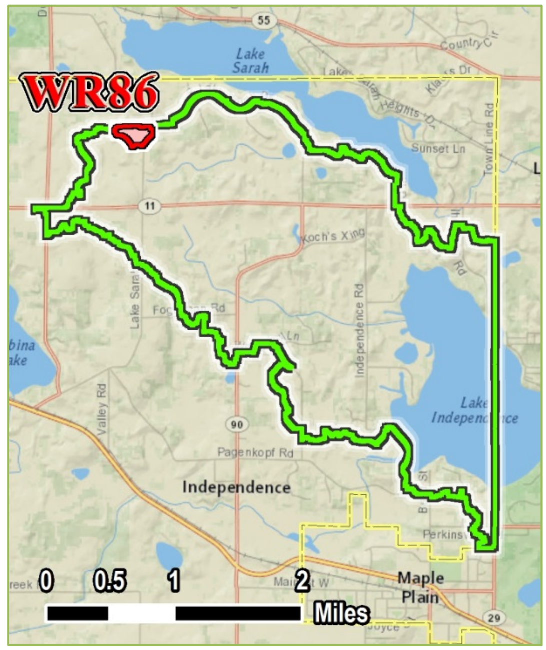
Site Summary – WR83 – 980 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	173.5
Dominant Land Cover	Agriculture
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$97,500
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$148,705
Project Life (yrs)	20
$/lb-TP removal/yr	$1,335
$/lb-TSS removal/yr	$6.00
$/ac-ft volume removal/yr	$22,531

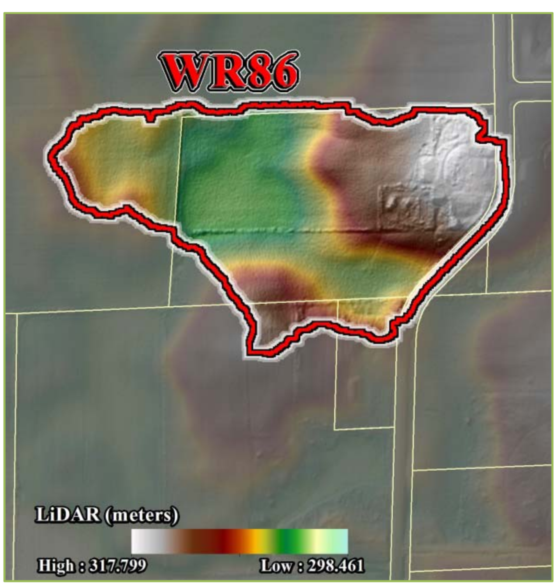


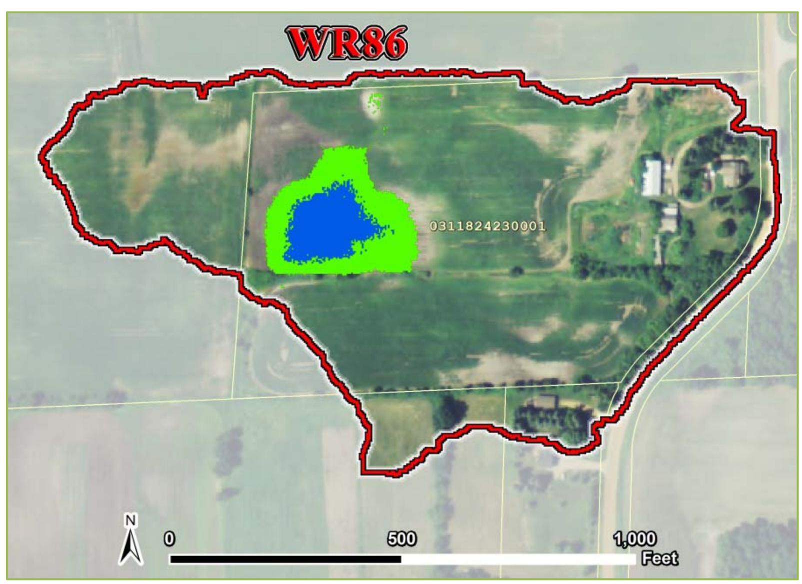


WR86 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0	8.71	6536	16.91	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 991 ft	0.5	6.04	6179	15.95	2.67	357	0.96	30.7%	5.5%	5.7%
Pool to 992 ft	1.5	4.64	5393	15.24	4.07	1143	1.67	46.7%	17.5%	9.9%

Site Summary – WR86 – 992 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	20.0
Dominant Land Cover	Agriculture
Installation Type	Control Structure
Installation Cost ($)	$4,000
Easement Cost ($)	$30,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$60,205
Project Life (yrs)	20
$/lb-TP removal/yr	$740
$/lb-TSS removal/yr	$2.63
$/ac-ft volume removal/yr	$1,803

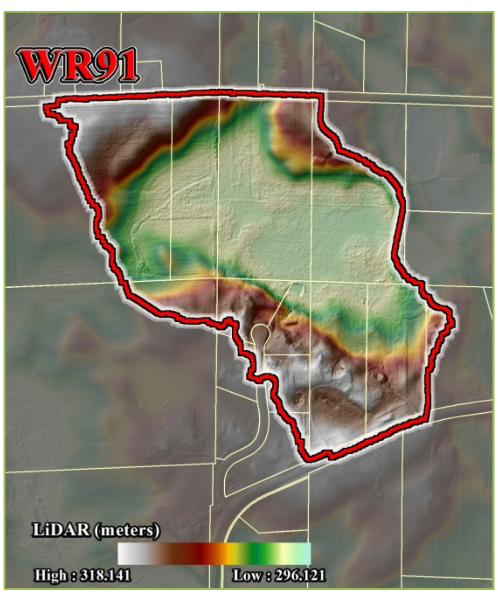


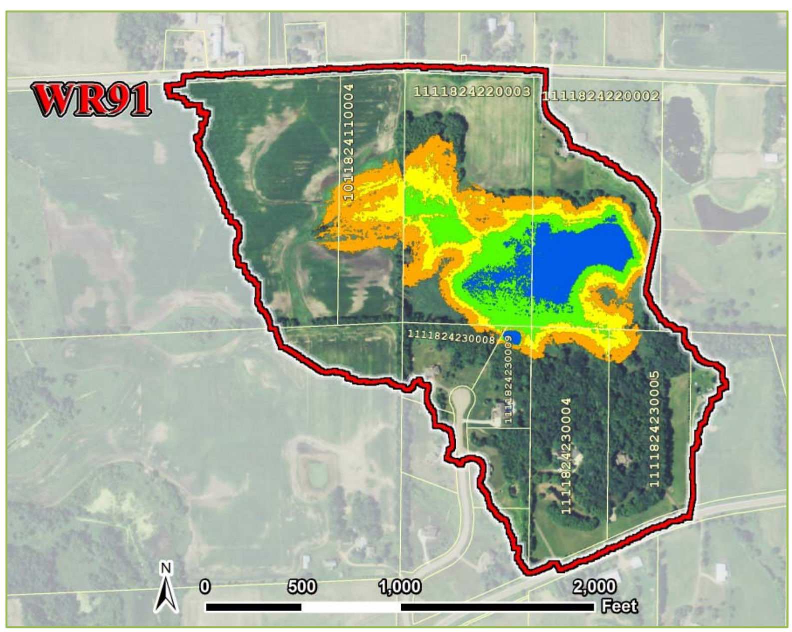




WR91	Pool Area	Loading			Reductions			% Reduction		
		TP	TSS	Volume	TP	TSS	Volume	TP	TSS	Volume
Restoration Elev.	(acres)	lbs/yr	lbs/yr	ac-ft/yr	lbs/yr	lbs/yr	ac-ft/yr	lbs/yr	lbs/yr	ac-ft/yr
Initial Conditions	0	36.75	25776	77.44	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 977 ft	4.4	31.70	25602	75.69	5.05	174	1.75	13.7%	0.7%	2.3%
Pool to 978 ft	10.4	26.82	23512	74.17	9.93	2264	3.27	27.0%	8.8%	4.2%
Pool to 979 ft	16.0	21.95	14107	72.20	14.80	11669	5.24	40.3%	45.3%	6.8%
Pool to 980 ft	23.9	18.46	8708	69.64	18.29	17068	7.80	49.8%	66.2%	10.1%

Site Summary – WR91 – 980 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	97.6
Dominant Land Cover	Agriculture
Installation Type	Channel Weir
Installation Cost ($)	$25,000
Easement Cost ($)	$238,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$289,205
Project Life (yrs)	20
$/lb-TP removal/yr	$791
$/lb-TSS removal/yr	$0.85
$/ac-ft volume removal/yr	$1,854

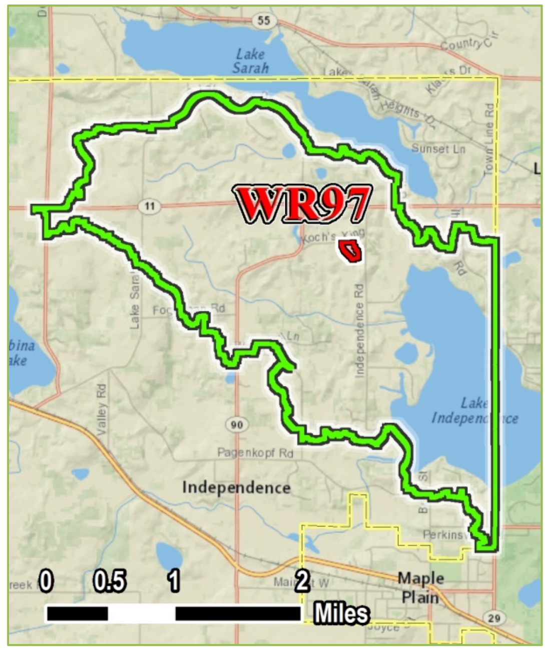


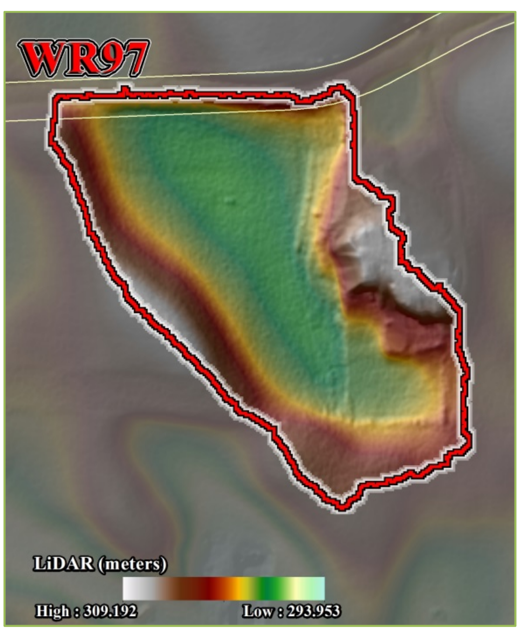


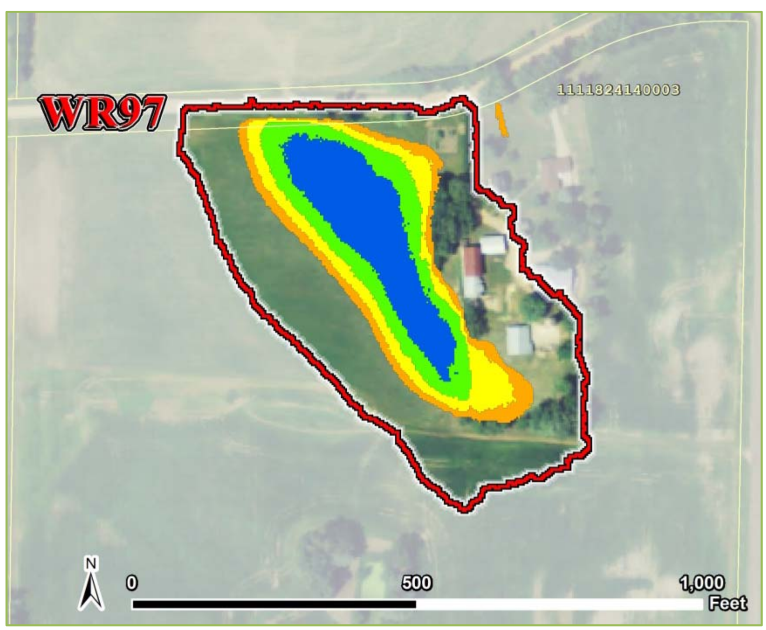
WR97 Restoration Elev.	Pool Area (acres)	Loading			Reductions			% Reduction		
		TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr
Initial Conditions	0	3.04	3146	6.32	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 979 ft	1.0	1.27	2314	5.27	1.77	832	1.05	58.2%	26.5%	16.6%
Pool to 980 ft	1.7	0.51	946	4.71	2.53	2200	1.61	83.2%	69.9%	25.5%
Pool to 981 ft	2.3	0.26	332	4.45	2.78	2814	1.87	91.5%	89.5%	29.6%
Pool to 982 ft	2.8	.018	166	4.32	2.86	2980	2.00	94.1%	94.7%	31.7%

Barn foundation at approximately 985. To maintain adequate separation, 980 elevation was selected.

Site Summary – WR97 – 980 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	7.16
Dominant Land Cover	Agriculture
Installation Type	Box Weir
Installation Cost ($)	$7,500
Easement Cost ($)	$34,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$67,705
Project Life (yrs)	20
$/lb-TP removal/yr	$1,338
$/lb-TSS removal/yr	$1.54
$/ac-ft volume removal/yr	$2,103

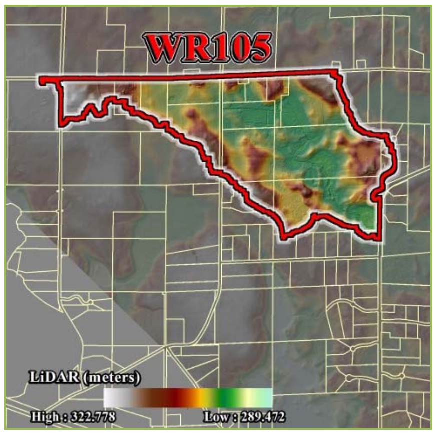


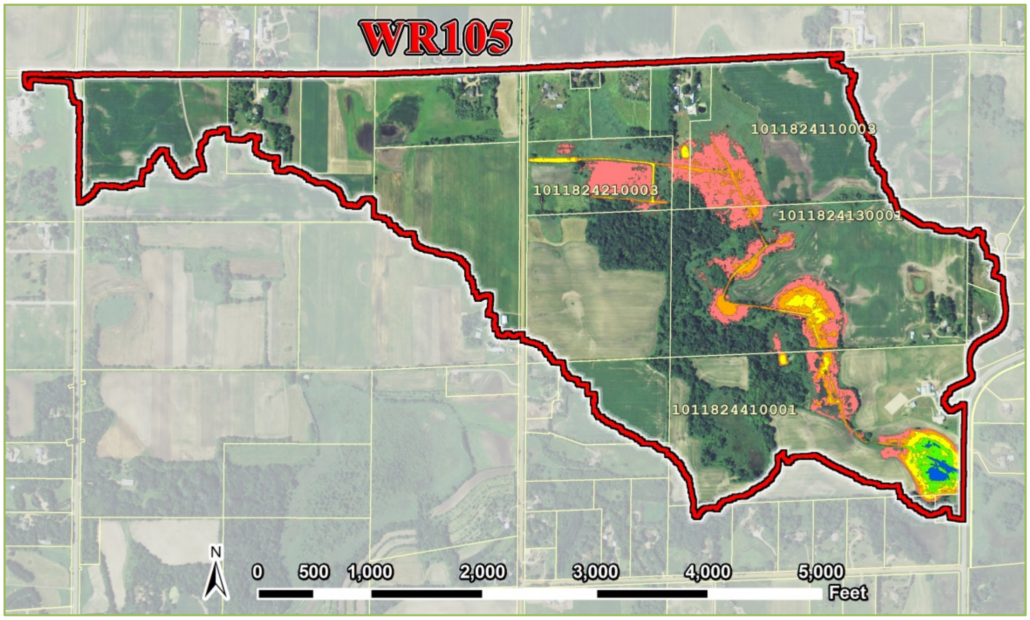




WR105 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.0	144.2	113503	299.84	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 976 ft	0.7	143.5	112789	299.84	0.70	714	0.0	0.5%	0.6%	0.0%
Pool to 977 ft	2.7	140.1	107078	299.84	4.07	6425	0.0	2.8%	5.7%	0.0%
Pool to 978 ft	7.1	134.1	93515	298.91	10.09	19988	0.93	7.0%	17.7%	0.31%
Pool to 979 ft	13.9	127.9	77096	297.04	16.30	36407	2.80	11.3%	32.1%	0.93%
Pool to 980 ft	35.9	112.1	60678	292.15	32.13	52825	7.69	22.3%	46.5%	2.56%

Site Summary –WR105– 980 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	400
Dominant Land Cover	Agriculture
Installation Type	Box Weir
Installation Cost ($)	$7,500
Easement Cost ($)	$509,500
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$543,205
Project Life (yrs)	20
$/lb-TP removal/yr	$845
$/lb-TSS removal/yr	$.51
$/ac-ft volume removal/yr	$3,532





Water and Sediment Control Basins

Water and sediment control basins (WASCOBs) are designed to detain water long enough for the sediment in suspension to drop out of the water column. This is typically done by creation of an earthen embankment across a natural flowage along with an underdrain and riser to allow water to pass under the berm. Water in sediment control basins should not pond more than 12 inches and for no more than 24 hours to ensure that crops are not overly stressed. This allows all but the berm to remain in production. There are many alternative designs including using a washed stone berm that allows water to pass through it or allowing a portion of the basin to remain ponded to gain additional water quality benefits.

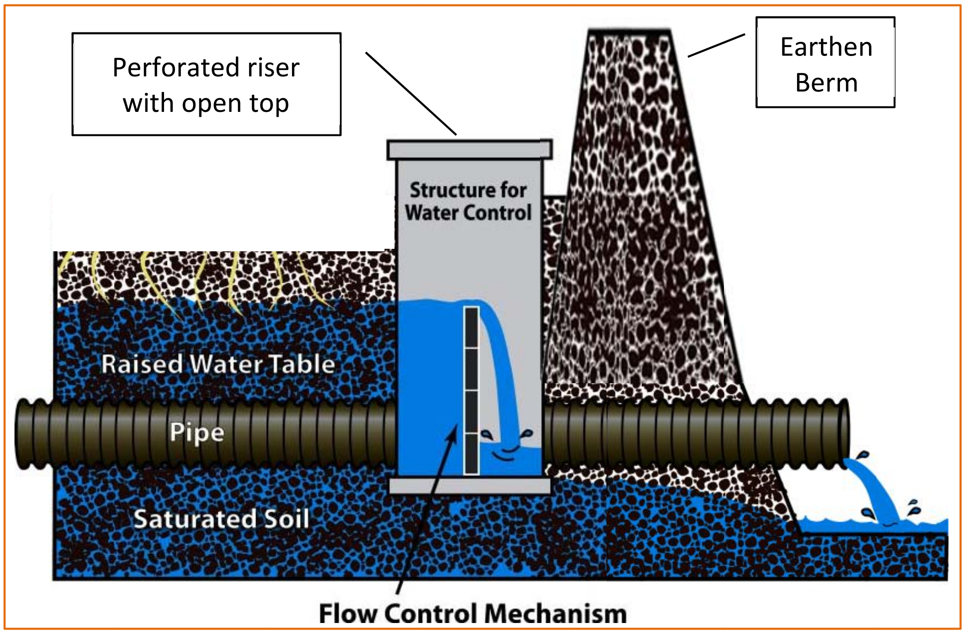


Figure 19: Water Control Attached to Drain Tile (illustration courtesy of Illinois NRCS - modified)

Benefits of water and sediment control basins were modeled utilizing the ArcView extension of the Soil & Water Assessment Tool (ArcSWAT). This model combines inputs of hydrography, topography, soils, and land cover in a GIS interface and determines runoff volume and pollutant loading based on these inputs. Projects were modeled as ponds with pollutant loads associated with volume reductions negated. The model was run with and without the identified project and the difference in pollutant discharge was noted. Each site was modeled at multiple pool depths. An average depth of one foot was selected to avoid extensive crop stress. A detailed account of the methodologies used is included in Appendix A. Professionally engineered designs will be necessary for all WASCOBs to ensure appropriate drainage is achieved. USDA Natural Resource Conservation Service staff may be able to provide design services.

Because modeling was done on very small land units, water quality data were not available to calibrate the model. Model outputs are best estimates based on available data but may vary greatly from observed field conditions. Furthermore, the models predicted benefits at the field edge, not benefits to the receiving water body. For pollutants held in suspension in the water column such as TSS, projects that are closer to the lake or main tributaries to the lake may be preferred to projects farther away even if the project benefits in the table shows greater cost effectiveness for the farther projects. For dissolved pollutants such as dissolved phosphorus or chlorides, the distance from the receiving water body is less critical. Rather than estimate the pollutant delivery ratio for each pollutant type, we focused our investigation on sites near the lakes and/or immediately adjacent to the drainage system. This approach will ensure that all identified projects have merit. Ultimately, it will be the purview of watershed management professionals to select projects to pursue. To facilitate this process, maps for each project showing the location in the watershed are provided.

In order to determine cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach and promotion, project design, easement acquisition, project administration, and project maintenance over the anticipated life of the practice were considered in addition to actual construction costs.

All projects were assumed to use a water control structure. Although more expensive to install, they guarantee that the landowner will be able to manage water levels and ponding durations to achieve the multiple benefits of crop production and water quality improvement. The installation costs of WASCOBs vary depending on the number of structures and the size of earthen berms. The cost of design, hydraulic modeling, landowner outreach, project administration, and construction oversight are comparable regardless of the structure size and so those costs are held constant between projects. The table below summarizes all potential WASCOBs identified during field reconnaissance. Cost assumptions made to calculate the cost-benefit of each project should be verified against local experience while creating implementation plans. The relative ranking shouldn't vary much even with alterations to the cost formula.

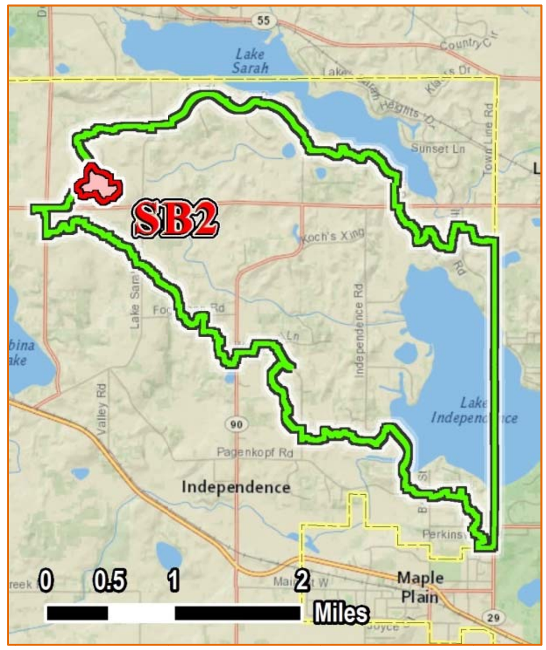
Table 26: Potential Water and Sediment Control Basin Projects

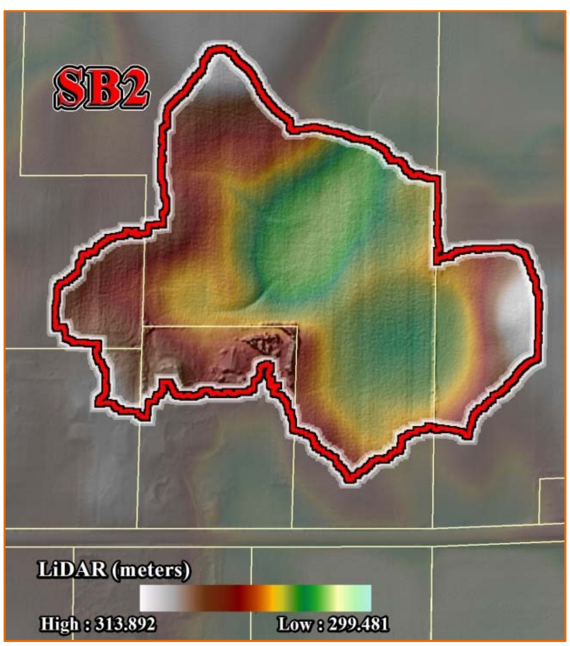
Water Resource	Site ID	Pool Elev.	TSS Reduction (tons/yr)	TP Reduction (lbs/yr)	Volume Reduction (ac-ft/yr)	20 Yr Cost[20]	Project Life (yrs)	Cost-Benefit ($/lb TP)
Independence	SB3	989	1.50	9.13	0.0	$31,568	20	$173
Independence	SB2	991	0.92	1.5	0.0	$31,864	20	$1,065
Sarah	SB63	1015	0.66	1.15	0.0	$30,205	20	$1,130

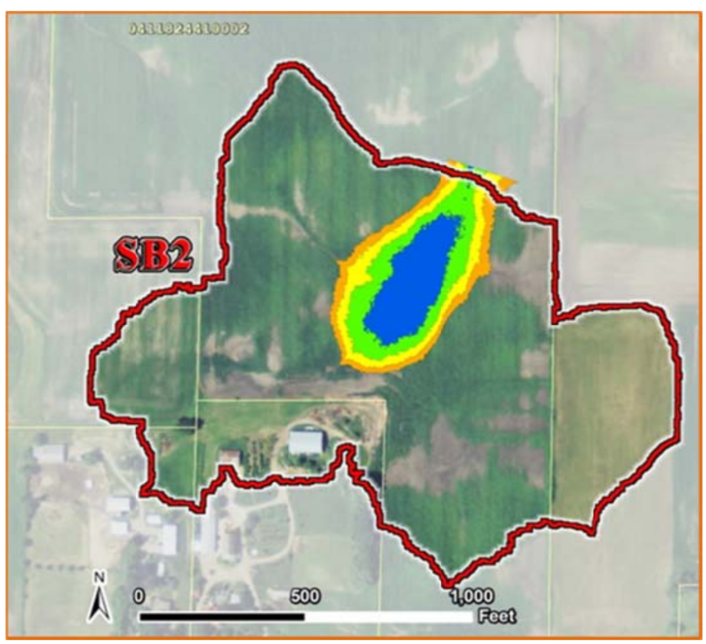
[20] Total cost over twenty years was calculated assuming project design and construction oversight were $10,000, easement administration and coordination, landowner outreach, and general project coordination would take 85 hours total at $73/hr, annual inspection and maintenance costs $500/yr. Structure installation is $4,000 per control structures/4000 cu. meters of storage . Earthen berms cost $40/cu. yd. installed.

SB2 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.0	22.86	14464	31.01	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 991 ft	1.4	21.36	12625	31.01	1.50	1839	0.00	6.5%	12.7%	0.0%
Pool to 992 ft	2.7	18.88	8213	31.01	3.98	6251	0.00	17.4%	43.2%	0.0%
Pool to 993 ft	3.7	16.81	3922	31.01	6.05	10542	0.00	26.5%	72.9%	0.0%
Pool to 994 ft	4.5	15.82	1716	31.01	7.04	12748	0.00	30.8%	88.1%	0.0%

Site Summary – SB2 – 991 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	34.3
Dominant Land Cover	Agriculture
Installation Type	Control Structure & Berm
Installation Cost ($)	$5,659
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$31,864
Project Life (yrs)	20
$/lb-TP removal/yr	$1,065
$/lb-TSS removal/yr	$.87
$/ac-ft volume removal/yr	NA

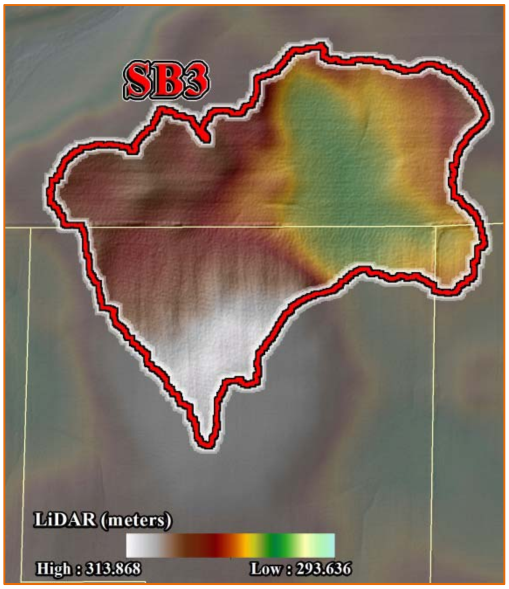


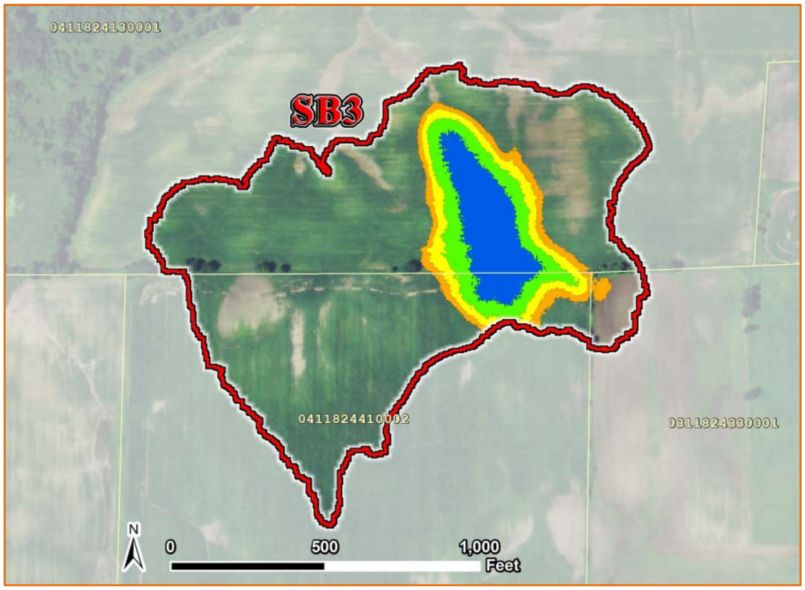




SB3 Restoration Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.0	18.99	11806	26.76	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 989 ft	2.0	16.78	8815	26.76	2.21	2991	0.00	11.6%	25.3%	0.0%
Pool to 990 ft	3.6	14.41	4355	26.76	4.58	7451	0.00	24.1%	63.1%	0.0%
Pool to 991 ft	4.8	13.35	2151	26.76	5.64	9655	0.00	29.7%	81.8%	0.0%
Pool to 992 ft	5.9	13.06	1522	26.76	5.93	10284	0.00	31.2%	87.1%	0.0%

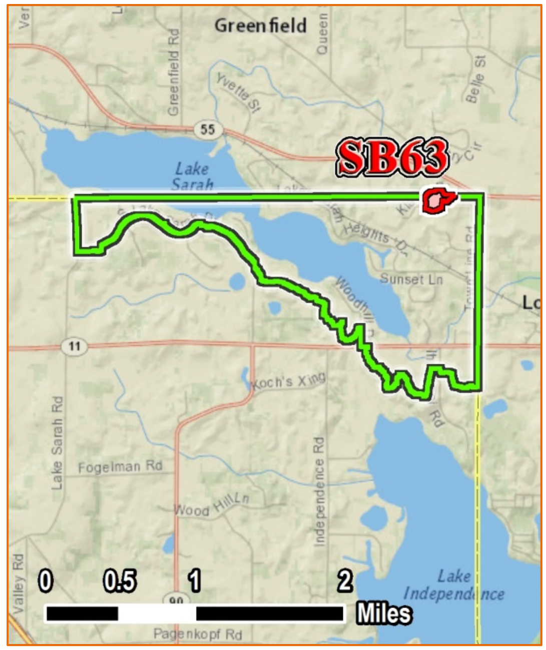
Site Summary – SB3 – 989 Pool elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	29.4
Dominant Land Cover	Agriculture
Installation Type	Control Structure & Berm
Installation Cost ($)	$5,363
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$31,568
Project Life (yrs)	20
$/lb-TP removal/yr	$715
$/lb-TSS removal/yr	$.53
$/ac-ft volume removal/yr	NA

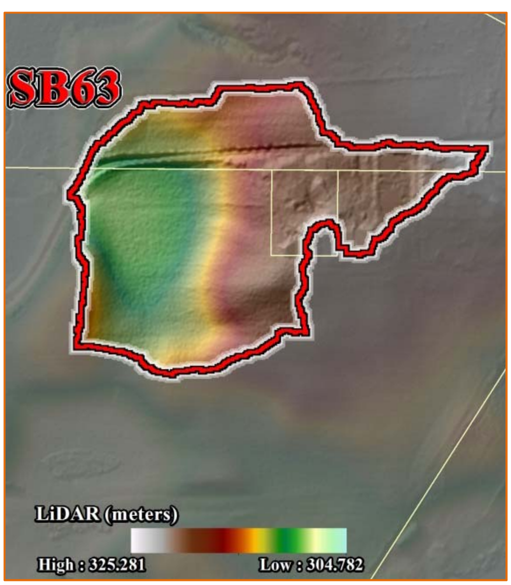


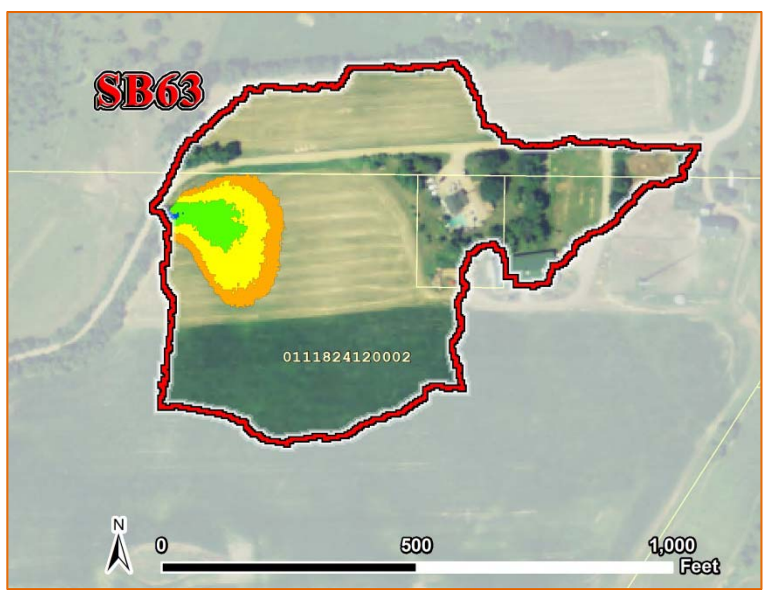


SB63 Restoration Elev.	Pool Area (acres)	Loading			Reductions			% Reduction		
		TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr
Initial Conditions	0.0	4.77	6699	9.02	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 1014 ft	0.2	4.42	6400	9.02	0.35	299	0.0	7.3%	4.5%	0.0%
Pool to 1015 ft	0.6	3.62	5371	9.02	1.15	1328	0.0	24.2%	19.8%	0.0%
Pool to 1016 ft	1.0	2.08	2863	9.02	2.69	3836	0.0	56.5%	57.3%	0.0%

Site Summary – SB63 – 1015 Pool elev.	
Water Body	Lake Sarah
Treatment Watershed (ac)	10.5
Dominant Land Cover	Agriculture
Installation Type	Control Structure
Installation Cost ($)	$4,000
Promo/Design/Admin ($)	$16,205
Maintenance ($/20yrs)	$10,000
Total 20 Year Cost ($)	$30,205
Project Life (yrs)	20
$/lb-TP removal/yr	$1,310
$/lb-TSS removal/yr	$1.14
$/ac-ft volume removal/yr	NA







Vegetated Filter Strips & Grassed Waterways

Vegetated filter strips are areas of vegetation planted between agricultural fields and surface waters to trap sediment, nutrients, organics and other contaminants in runoff. Grassed waterways function similarly but are vegetated flowages within a farm field. The effectiveness of filters strips and grassed waterways is well documented. Efficacy varies depending on factors such as the slope, soil type and vegetative cover of the contributing drainage area as well as the width and vegetation type of the practice. The Agricultural BMP Handbook of Minnesota provides a thorough description of available research.

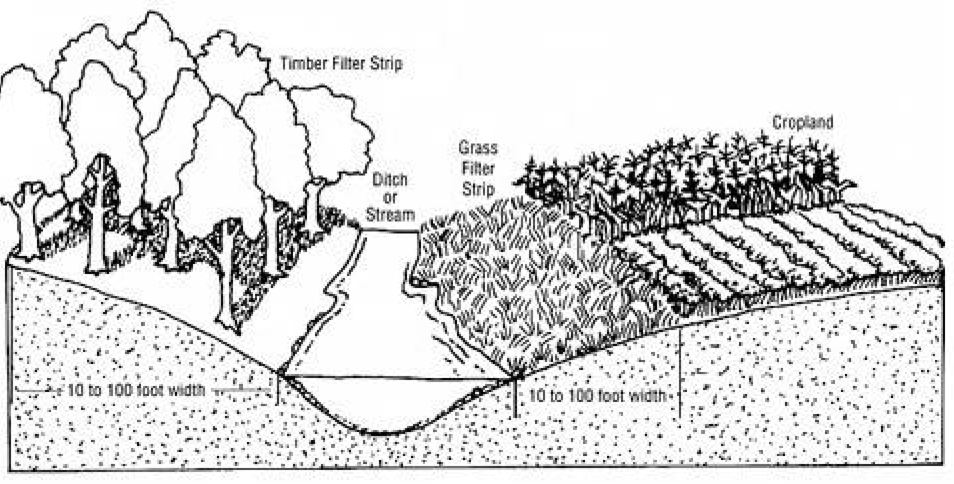


Figure 20: Filter Strip (illustration courtesy of Ohio State University Extension, web)

Filter strips and grassed waterways were only proposed in areas where active agricultural activities were occurring within 30 feet of a water course. Approximately 80% of TSS is removed within the first 7.5 meters of filter strip. Dissolved constituents are much less and so the marginal value rapidly decreased compared to the opportunity cost of not have the land in production. This is the only non-structural practice to be presented in this analysis. While non-structural practices tend to be more cost-effective in the short term, they also tend not to remain as long on the landscape since they are easy for landowners to inadvertently remove.

Benefits of filter strips/grassed waterways were modeled utilizing the ArcView extension of the Soil & Water Assessment Tool (ArcSWAT). This model combines inputs of hydrography, topography, soils, and land cover in a GIS interface and determines runoff volume and pollutant loading based on these inputs. ArcSWAT includes a filter strip tool that facilitates rapid modeling of multiple scenarios. The model was run with and without the identified project and the difference in pollutant discharge was noted. Each site was modeled at multiple widths of vegetated. The narrowest width that achieved the greatest relative benefit was selected to avoid taking land out of production. A detailed account of the methodologies used is included in Appendix A.

Because modeling was done on very small land units, water quality data were not available to calibrate the model. Model outputs are best estimates based on available data but may vary greatly from observed field conditions. Furthermore, the models predicted benefits to the adjacent water course but not necessarily benefits to the receiving water body. For pollutants held in suspension in the water column such as TSS, projects that are closer to the lake may be preferred to projects farther away even if the project benefits in the table shows greater cost effectiveness for the farther projects. For dissolved pollutants such as dissolved phosphorus or chlorides, the distance from the receiving water body is less critical. Ultimately, it will be the purview of watershed management professionals to select projects to pursue. To facilitate this process, maps for each project showing the location in the watershed are provided.

In order to determine cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach and promotion, project design, easement acquisition, project administration, and project maintenance over the anticipated life of the practice were considered in addition to actual installation costs. The cost of lost agricultural production was also considered. The installation costs vary depending on area of practice to be installed. The cost of design, landowner outreach, project administration, and construction oversight are comparable regardless of the project size and so those costs are held constant between projects. The following table summarizes the potential filter strips/grassed waterways identified during field reconnaissance. Cost assumptions made to calculate the cost-benefit of each project should be verified against local experience while creating implementation plans. The relative ranking shouldn't vary much even with alterations to the cost formula.

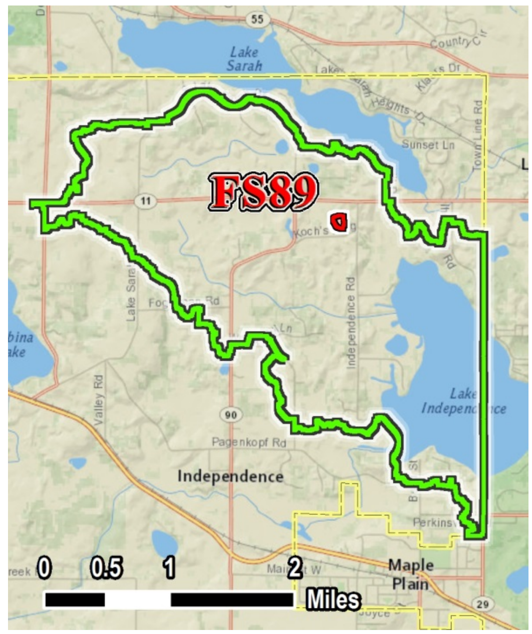
Table 27: Potential Filter Strip/Grassed Waterway Projects

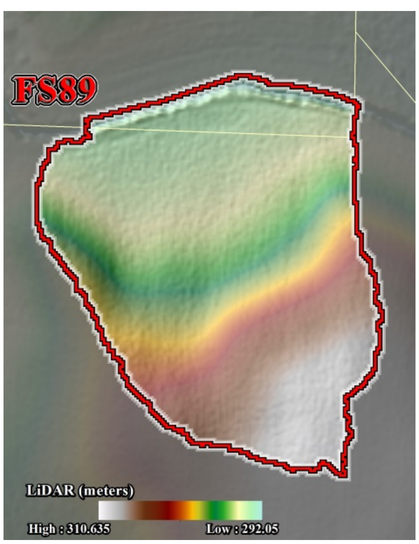
Water Resource	Site ID	Width (ft)	TSS Reduction (tons/yr)	TP Reduction (lbs/yr)	Volume Reduction (ac-ft/yr)	20 Yr Cost[21]	Project Life (yrs)	Cost-Benefit ($/lb TP)
Independence	FS93	20	16.28	34.27	0.0	$32,945	20	$48.07
Independence	FS94	10	4.51	10.95	0.0	$26,465	20	$120.84
Independence	FS89	50	0.65	1.25	0.0	$10,835	20	$433.40

[21] Total cost over twenty years was calculated assuming project design and construction oversight were $6,000, landowner outreach, and general project coordination would take 65 hours total at $73/hr. Lost production costs were valued at $800/acre/year, while filter strip establishment cost was estimated at $200/acre, annual inspection and maintenance costs $300/yr.

FS89 Filter Width	Filter Area (acres)	Loading TP lbs/yr	 TSS lbs/yr	Reductions TP lbs/yr	 TSS lbs/yr	% Reduction TP lbs/yr	 TSS lbs/yr	20 Yr Cost[22] TP $/lbs/yr	 TSS $/lbs/yr
Initial Conditions	0.04	2.13	1778	N/A	N/A	N/A	N/A	N/A	N/A
10 ft	0.08	1.79	1414	.34	364	16.0%	20.5%	$1583	$1.48
20 ft	0.18	1.29	905	.84	873	39.4%	49.1%	$642	$0.62
30 ft	0.28	1.01	598	1.12	1180	52.6%	66.4%	$482	$0.46
50 ft	0.45	0.88	477	1.25	1301	58.7%	73.2%	$433	$0.42

Site Summary – FS89 – 50 ft. filter	
Water Body	Lake Independence
Treatment Watershed (ac)	4.53
Dominant Land Cover	Agriculture
Installation Type	Filter Strip
Installation Cost ($)	$90
Promo/Design/Admin ($)	$4,745
Maintenance ($/20yrs)	$6,000
Production Loss ($/20 yrs)	$0
Total 20 Year Cost ($)	$10,835
Project Life (yrs)	20
$/lb-TP removal/yr	$433.40
$/lb-TSS removal/yr	$.42
$/ac-ft volume removal/yr	NA

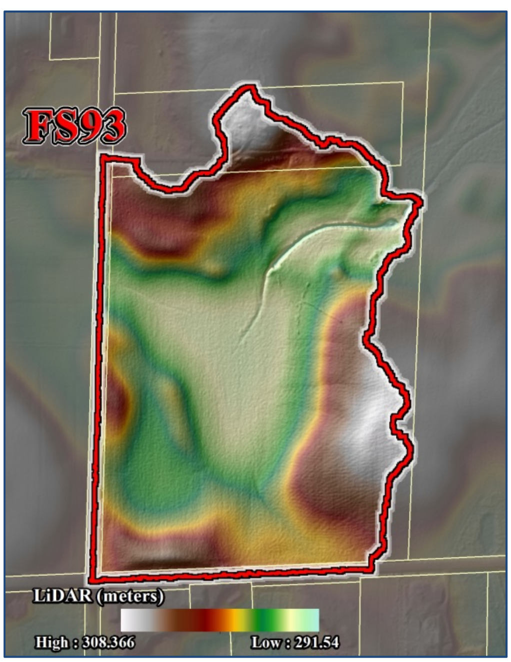


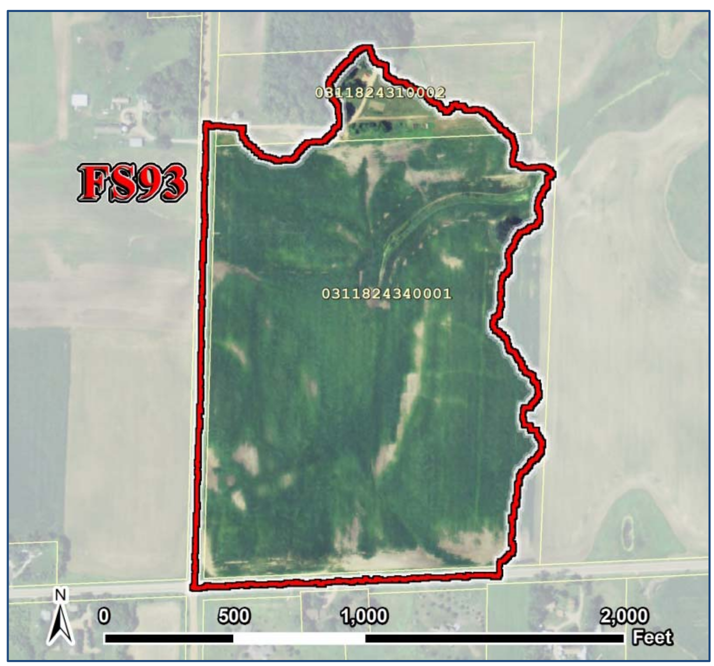


[22] This project involves a producer cultivating land owned by an adjacent landowner. Costs presume that the owner of the property would simply request the riparian area no longer be cultivated and allowed to go fallow. No production loss or project design costs are included. Some outreach, maintenance and seeding funds are included.

FS93 Filter Width	Filter Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	% Reduction TP	% Reduction TSS	20 Yr Cost TP $/lbs/yr	20 Yr Cost TSS $/lbs/yr
Initial Conditions	0.17	42.73	33641	N/A	N/A	N/A	N/A	N/A	N/A
20 ft	1.0	8.46	1079	34.27	32562	80.2%	96.8%	$48	$0.05
30 ft	1.5	8.01	810	34.72	32831	81.3%	97.6%	$59	$0.06
50 ft	2.5	7.92	360	34.81	33281	81.5%	98.9%	$82	$0.09

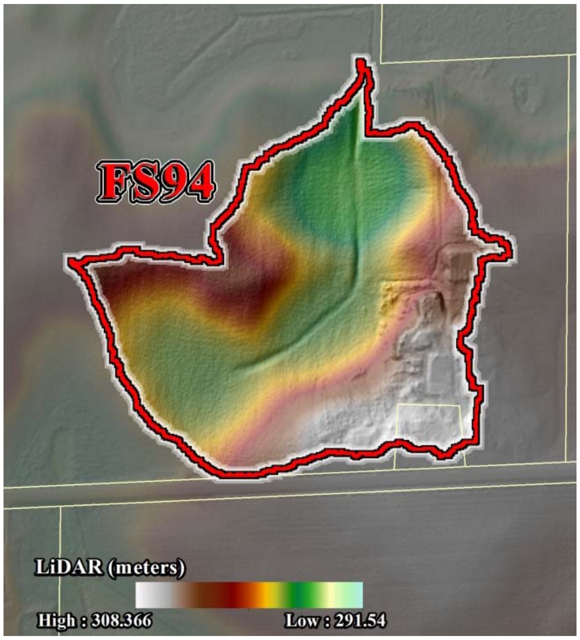
Site Summary – FS93 – 20 ft. filter	
Water Body	Lake Independence
Treatment Watershed (ac)	50.4
Dominant Land Cover	Agriculture
Installation Type	Grassed Waterway
Installation Cost ($)	$200
Promo/Design/Admin ($)	$10,745
Maintenance ($/20yrs)	$6,000
Production Loss ($/20 yrs)	$16,000
Total 20 Year Cost ($)	$32,945
Project Life (yrs)	20
$/lb-TP removal/yr	$48.07
$/lb-TSS removal/yr	$.05
$/ac-ft volume removal/yr	NA





FS94 Filter Width	Filter Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	20 Yr Cost TP $/lbs/yr	20 Yr Cost TSS $/lbs/yr
Initial Conditions	0.1	16.16	11528	N/A	N/A	N/A	N/A	N/A	N/A
10 ft	0.6	5.21	2502	10.95	9026	67.7%	78.3%	$120.84	$0.15
20 ft	1.0	5.13	2338	11.03	9190	68.3%	79.7%	$149.34	$0.18
30 ft	1.6	5.09	2256	11.07	9272	68.5%	80.4%	$192.71	$0.23
50 ft	2.8	5.01	2174	11.15	9354	69.0%	81.1%	$278.50	$0.33

Site Summary – FS94 – 10 ft. filter	
Water Body	Lake Independence
Treatment Watershed (ac)	23.0
Dominant Land Cover	Agriculture
Installation Type	Grassed Waterway
Installation Cost ($)	$120
Promo/Design/Admin ($)	$10,745
Maintenance ($/20yrs)	$6,000
Production Loss ($/20 yrs)	$9,600
Total 20 Year Cost ($)	$26,465
Project Life (yrs)	20
$/lb-TP removal/yr	$120.84
$/lb-TSS removal/yr	$0.15
$/ac-ft volume removal/yr	NA



New Ponds & Iron Enhanced Sand Filters

In urban settings stormwater is conveyed to ponds through pipes. Once in the pipe, water is transported rapidly to its destination. The receiving ponds are designed with controlled outflows to manage discharge rates and are sized to achieve predefined water quality goals. In rural setting, such as the Lake Sarah and Lake Independence watersheds, stormwater flows off roadsides into road side ditches. The road side ditches are typically well vegetated. As the water flows downhill toward the low spot in the landscape, much of the sediment may be trapped in the vegetated ditch and some of the water is infiltrated into the soil. Micro depressions along the way will allow water to pool and effectively be traped until it infiltrates, evaporates or is taken up by plants. At the bottom of the hill, in areas that may or may not have formally been wetland, there may be an area dug out to receive the stormwater. These dugouts are rural stormwater ponds and provide an additional level of treatment: trapping sediment and assimilating nutrients and other pollutants. Water discharging from the pond may flow through adjacent wetlands and down long stretches of stream channel before entering either Lake Sarah or Lake Independence. Along the entire course, there are opportunities for pollutants to be removed from the water columns, or added through additional discharges or erosion.

Areas that have transitioned to residential land uses in the last 30 years are often dotted with small stormwater ponds, whereas some of the older neighborhoods around the lakes lack stormwater ponding. The figure to the right illustrates this point, showing ponds (primarily in red) clustered in newer medium density residential neighborhoods to the west of Lake Independence .

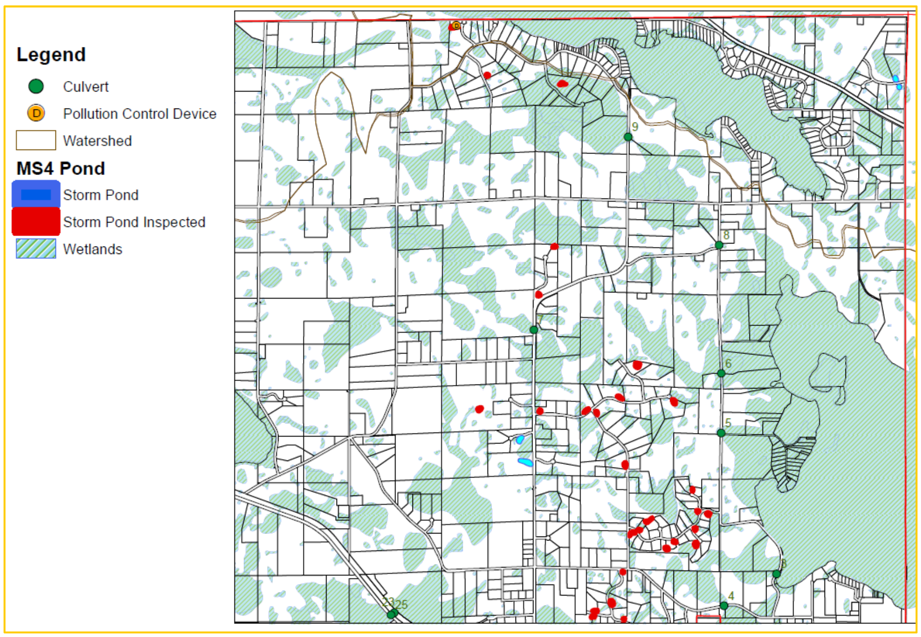


Figure 21: MS4 Ponds (courtesy of Hakanson Anderson and Assoc., Inc.)

Stormwater ponds improve water quality by retaining water for a sufficient length of time to allow sediment to fall out of the water column and to some extent for nutrients to be assimilated. Furthermore, they regulate discharge rates which can reduce downstream in-channel erosion. Pond design is important to ensure that pond maintenance intervals are long, re-suspension of sediment doesn't occur, and collateral flooding does not occur as a result of their installation. For these reasons, ponds must be designed by professional engineers. This report provides a rudimentary description of ponding opportunities and cost estimates for project planning purposes.

Unfortunately, stormwater ponds are less effective at treating dissolve nutrients such as phosphorus. To address this deficiency, researchers in Minnesota developed a feature called an Iron Enhanced Sand Filter (IESF). IESFs rely on the properties of iron to bind dissolved phosphorus as it passes through an iron rich medium. Depending on topographic characteristics of the installation sites, IESFs can rely on gravitational flow and natural water level fluctuation, or water pumping to hydrate the IESF. IESFs must be designed to prevent anoxic conditions in the filter medium because such conditions will release the bound phosphorus. Since IESFs are intended to remove dissolved phosphorus and not organic phosphorus, they are typically constructed just downstream of stormwater ponds, minimizing the amount of suspended solids that could compromise their efficacy and drastically increase maintenance. As an alternative to an IESF, a ferric-chloride injection system could be installed to bind dissolved phosphorus into a flocculent, which would settle in the bottom of the new pond.

The illustration to the right shows an IESF that is installed at an elevation slightly above the normal water level of the pond so that following a storm event the increase in depth of the pond would be first diverted to the iron enhanced sand filter. The filter would have drain tile installed along the base of the trench and would outlet downstream of the current pond outlet. Large storm events that overwhelm the iron enhanced sand filter's capacity would exit the pond via the existing outlet.

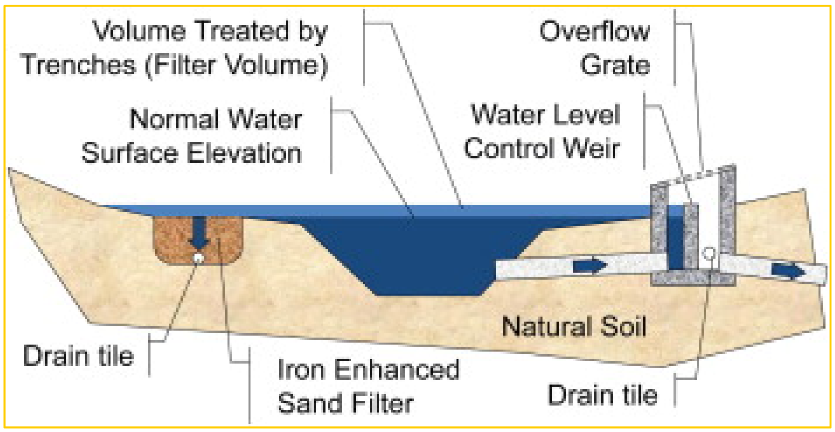


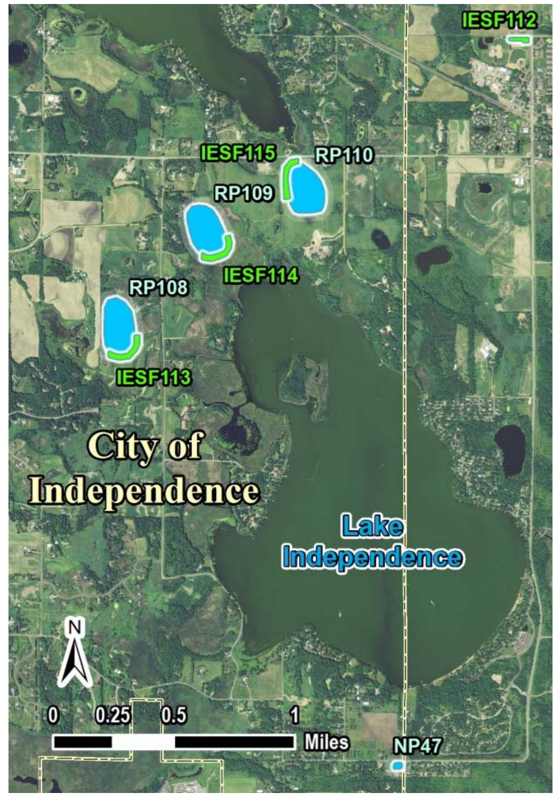
Figure 22: Iron Enhanced Sand Filter Concept (Erickson & Gulliver, 2010)

Benefits of storm water ponds were modeled utilizing the ArcView extension of the Soil & Water Assessment Tool (ArcSWAT). This model combines inputs of hydrography, topography, soils, and land cover in a GIS interface and determines runoff volume and pollutant loading based on these inputs. The model was run with and without the identified project and the difference in pollutant discharge was noted. Each site was modeled at multiple pond sizes and depths. After selecting an optimal pond configuration in terms of cost-benefit, modeling for an IESF was completed in WinSLAMM. WinSLAMM is able to calculate flow through constructed features such as rain gardens with underdrains, soil amendments and controlled overflow elevations. An IESF works much the same way. Storm event based discharge volumes and phosphorus concentrations estimated by SWAT after construction of the pond were entered into WinSLAMM as inputs into the IESF (baseflow was discounted as it would bypass the IESF). Various iterations of IESFs were modeled to identify an optimal treatment level compared to construction costs. A detailed account of the methodologies used is included in Appendix A.

In addition to one small pond (without an IESF), three opportunities for regional ponds with IESFs were identified as well as an IESF addition to an existing pond. The ponds were positioned in the landscape to treat water from the entire subwatershed. At this scale of modeling, it was possible to compare SWAT model outputs with the calibrated FLUX and BATHTUB model outputs in the Lake Independence and Lake Sarah TMDL implementation plans. SWAT outputs were within 10% and so the results were deemed adequate for the purpose of this report. All ponds are located within close proximity to the lakes and so the reported benefits should be close to those actually experienced by the lakes.

Ultimately, it will be the purview of watershed management professionals to select projects to pursue. To facilitate this process, maps for each project showing the location in the watershed are provided.

In order to determine cost-benefit, the cost of each project had to be estimated. All new storm water ponds and IESF projects were assumed to involve excavation and disposal of soil, installation of inlet and outlet control structures and emergency overflow, land acquisition, erosion control and vegetation management. High volume pump stations and annual energy costs were included for the regional ponds with IESFs. Additionally, project engineering, promotion, administration, construction oversight and long term maintenance had to be considered in order to capture the true cost of the effort. Unlike other projects identified in this report, ponds are presumed to have a 30 year functional life and so costs and benefits are amortized over that duration.



The installation costs of ponds and IESF vary depending on the size of the project. The cost of design, modeling, landowner outreach, project administration, and construction oversight are comparable regardless of the structure size and so those costs are held constant between projects. The table below summarizes all potential ponds and IESFs identified during field reconnaissance. Cost assumptions made to calculate the cost-benefit of each project should be verified against local experience while creating implementation plans. The relative ranking shouldn't vary much even with alterations to the cost formula.

Table 28: Potential New Ponds and Iron Enhanced Sand Filter Projects

Water Resource	Site ID	TSS Reduction (tons/yr)	TP Reduction (lbs/yr)	Volume Reduction (ac-ft/yr)	30 Yr Cost[23]	Project Life (yrs)	Cost-Benefit ($/lb TP)
Sarah	IESF112	0	75.10	0	$354,405	30	$121
Sarah	IESF113	0	105.34	0	$1,387,005	30	$275
Independence	IESF115	0	145.34	0	$1,387,005	30	$318
Independence	IESF114	0	72.66	0	$1,046,805	30	$480
Sarah	RP110	194.86	108.62	1.60	$3,305,245	30	$1,014
Independence	NP47	3.63	4.49	0.76	$155,140	30	$1,152
Independence	RP108	152.11	89.09	1.13	$3,540,751	30	$1,325
Independence	RP109	116.59	72.02	2.07	$3,540,338	30	$1,639

[23] Total cost over thirty years was calculated assuming project design and construction oversight were $25,000 for the small pond and $50,000 for regional ponds and $20,000 for IESFs, land/easement acquisition at $20,000 per acre, easement administration and coordination, landowner outreach, and general project coordination would take 85 hours total at $73/hr, annual inspection and maintenance costs $100/yr/acre of pond and IESF. Structure installation is $4,000 per control structure/12 ac-ft volume treated. IESF installation was $15/sq-ft.

Lake Sarah Ponds and IESFs Clarification

The Loretto Creek watershed located east of Lake Sarah and that discharges into the southeast end of the lake includes an existing pond that was recently built in the City of Loretto. As part of this analysis, an additional regional ponding opportunity along with two separate IESFs have been identified to treat water from this drainage area. One of the IESFs (IESF112) is proposed in conjunction with the existing Loretto Pond. The other, IESF115 is proposed in conjunction with the new regional pond, RP110. The existing and proposed ponds and IESFs result in treatment train effects that warrant clarification. The watershed also drains portions of five municipalities; Corcoran, Greenfield, Independence, Loretto, and Medina. Since this analysis is designed to aid the City of Independence to reach its loading goals, it was critical to segregate the loading and reduction by city. Table 29 provides the breakdown or relative drainage area and loading. Note that the percentage contribution of the different drainage areas is variable between parameters. This is because the Loretto pond effectively removes a substantial amount of TSS but is less effective at reducing discharge volumes or TP loading. While the drainage area to the Loretto pond continues to contribute approximately 50% of overall TP and Volume, it contributes only 10% of TSS. Variability between target pollutant loading ratios also arises because the algorithms used in the model considers factors such as slope, soil type and landcover that vary between subwatershed drainage areas. The pollutant loading ratios in Table 29 were used to ascertain the relative benefit associated with the contributing watershed within the City of Independence. Since TP is the target pollutant, only 25.5% of the total benefits and costs for RP110 and IESF115 were included in the City of Independence project tables. The remainder is transferred to the table that shows project identified outside the city boundaries.

Loretto Creek Watershed	Acres	% of Total
Corcoran	358	28.8%
Greenfield	27.4	2.2%
Independence	354.7	28.5%
Loretto	109.4	8.8%
Medina	395.1	31.7%

Table 29: Loretto Creek Subwatershed Breakdown

Watershed Size	Cities	Treatment Area (ac)	Area % of Total	TP load (lbs/yr)	TP % of Total	TSS load (lbs/yr)	TSS % of Total	Volume (ac-ft/yr)	Volume % of Total
Entire watershed	Corcoran, Greenfield, Independence, Loretto, Medina	1,245	-	671	-	441,359	-	1,013	-
City of Independence only	Independence	333	26.7%	171	25.5%	178,586	40.5%	257	25.4%
Loretto Pond treatment area	Corcoran, Loretto, Medina	431	34.6%	346	51.6%	44,039	10.0%	477	47.1%
Remainder of watershed	Corcoran, Greenfield, Loretto, Medina	481	38.6%	154	23.0%	218,734	49.6%	279	27.5%

Results include in-line Loretto Pond but DO NOT include proposed conditions

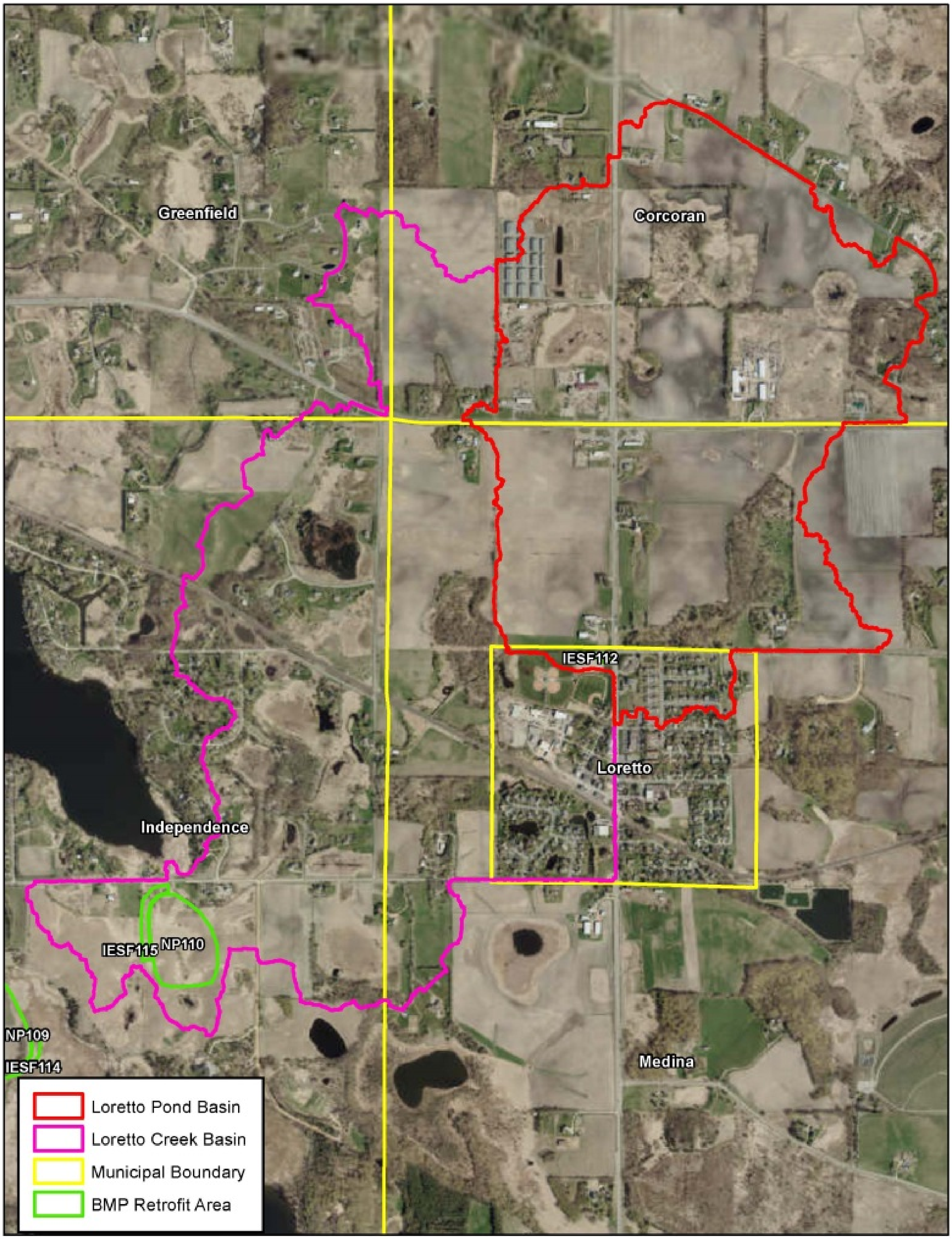
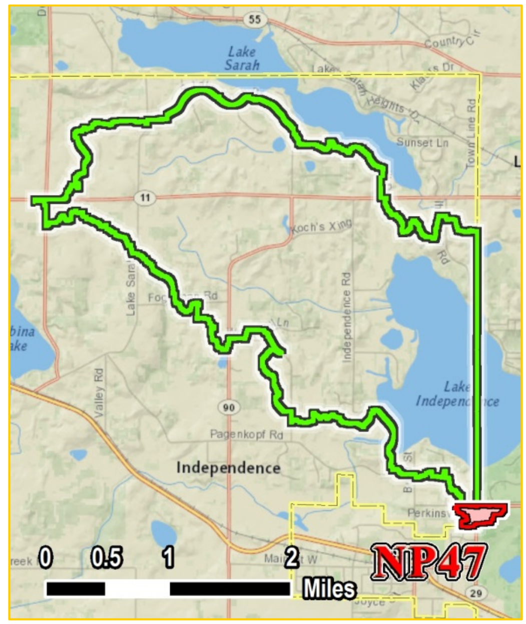
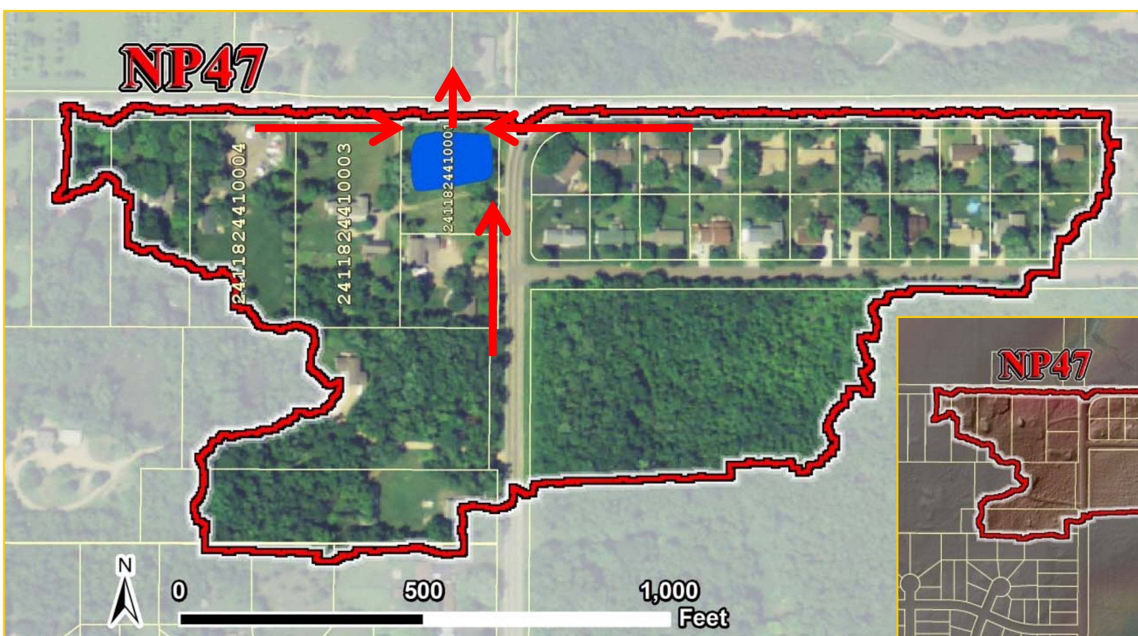


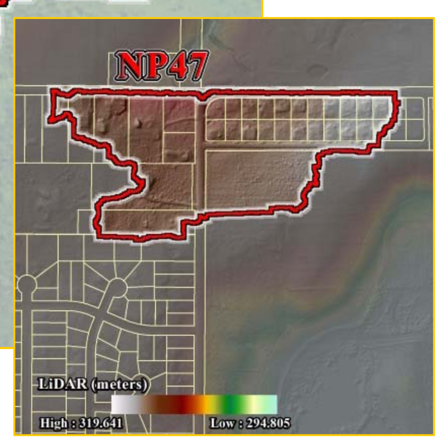
Figure 23: Loretto Creek Subwatershed Breakdown

NP47	Pond Area	Loading			Reductions			% Reduction		
		TP	TSS	Volume	TP	TSS	Volume	TP	TSS	Volume
Pond Depth	(acres)	lbs/yr	lbs/yr	ac-ft/yr	lbs/yr	lbs/yr	ac-ft/yr	lbs/yr	lbs/yr	ac-ft/yr
Initial Conditions	0.0	9.21	8593	22.40	N/A	N/A	N/A	N/A	N/A	N/A
6 ft	0.4	5.23	2353	21.67	3.98	6240	0.73	43.2%	72.6%	3.3%
8 ft	0.4	4.72	1330	26.64	4.49	7263	0.76	48.8%	84.5%	3.4%

Site Summary – NP47 – 0.4 acre 8ft deep	
Water Body	Lake Independence
Treatment Watershed (ac)	28.7
Dominant Land Cover	Residential, Park
Installation Type	New Pond
Installation Cost ($)	$99,935
Promo/Design/Admin ($)	$31,205
Maintenance ($/30yrs)	$14,400
Land Acquisition ($)	$9,600
Total 30 Year Cost ($)	$155,140
Project Life (yrs)	30
$/lb-TP removal/yr	$1,151.74
$/lb-TSS removal/yr	$0.71
$/ac-ft volume removal/yr	$6,804.37

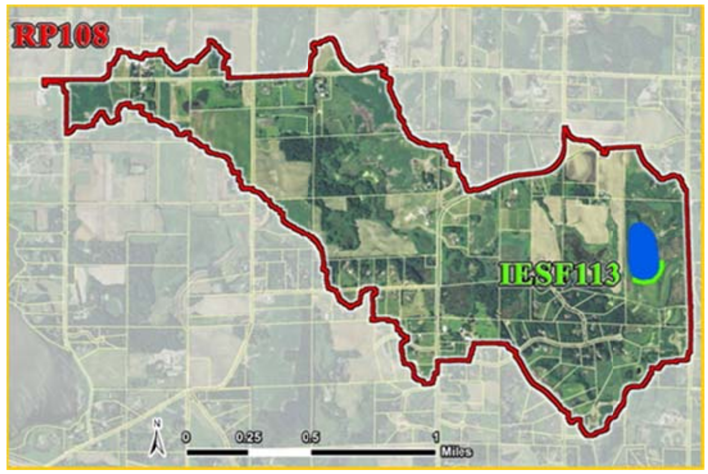


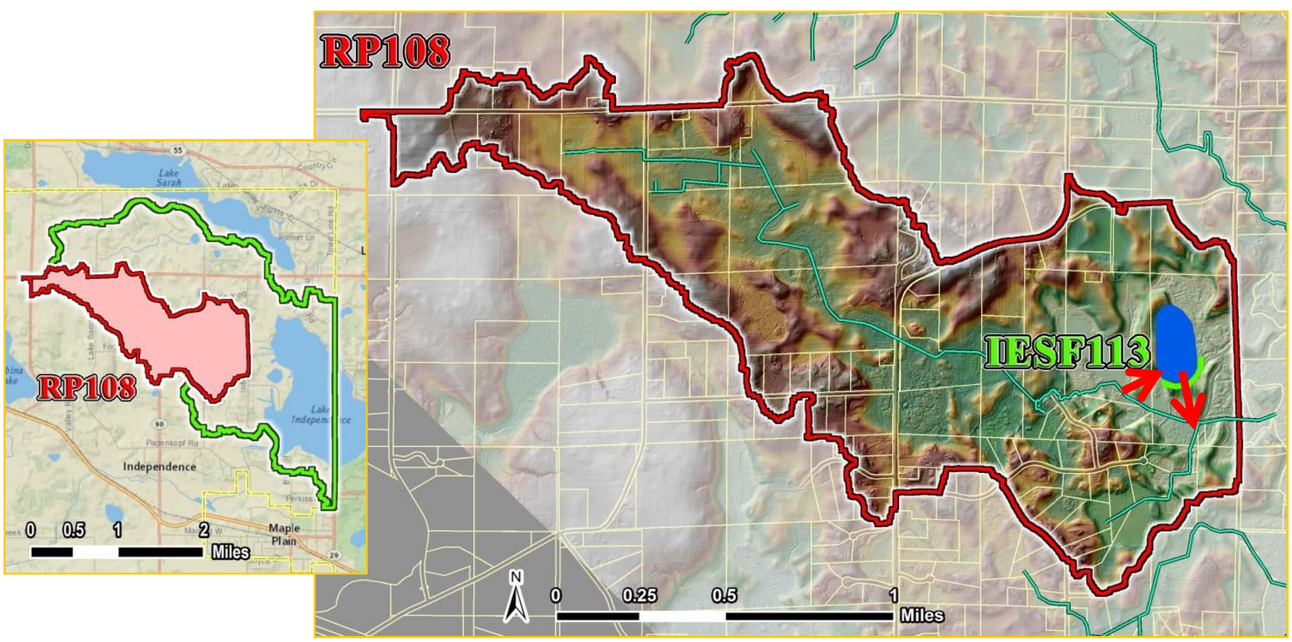




RP108 Pond Area (acre)	Pond Depth (ft)	Loading			Reductions			% Reduction		
		TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr
Initial Conditions	0	439.00	348510	809.39	N/A	N/A	N/A	N/A	N/A	N/A
15	6	351.71	51988	808.14	87.29	296522	1.25	19.9%	85.1%	0.15%
12	8	349.91	44286	808.26	89.09	304224	1.13	20.3%	87.3%	0.14%
15	8	346.31	28882	807.78	92.69	319628	1.61	21.1%	91.7%	0.20%
20	8	345.87	26957	806.78	93.13	321553	2.61	21.2%	92.3%	0.32%

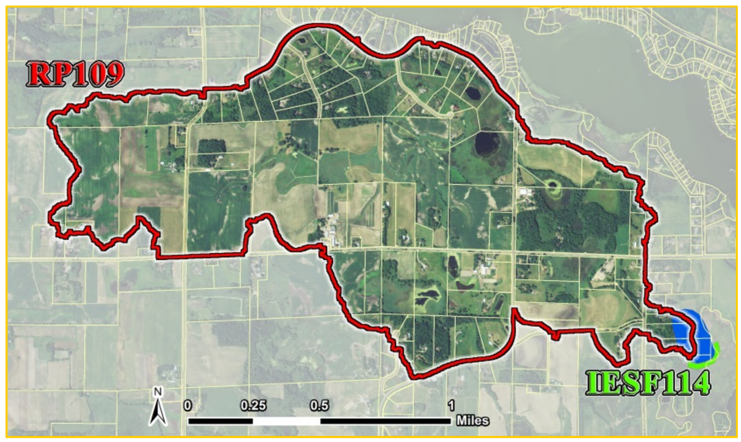
Site Summary – RP108 – 12 acre 8ft deep	
Water Body	Lake Independence
Treatment Watershed (ac)	1079
Dominant Land Cover	Agriculture, Residential
Installation Type	Regional Pond
Installation Cost ($)	$2,872,546
Promo/Design/Admin ($)	$56,205
Maintenance ($/30yrs)	$36,000
Land Acquisition ($)	$288,000
Total 30 Year Cost ($)	$3,540,751
Project Life (yrs)	30
$/lb-TP removal/yr	$1,324.78
$/lb-TSS removal/yr	$0.39
$/ac-ft volume removal/yr	$104,447.92

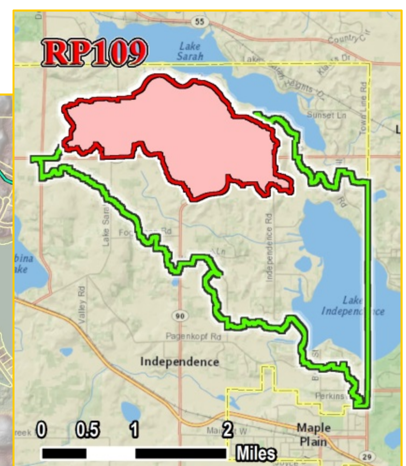


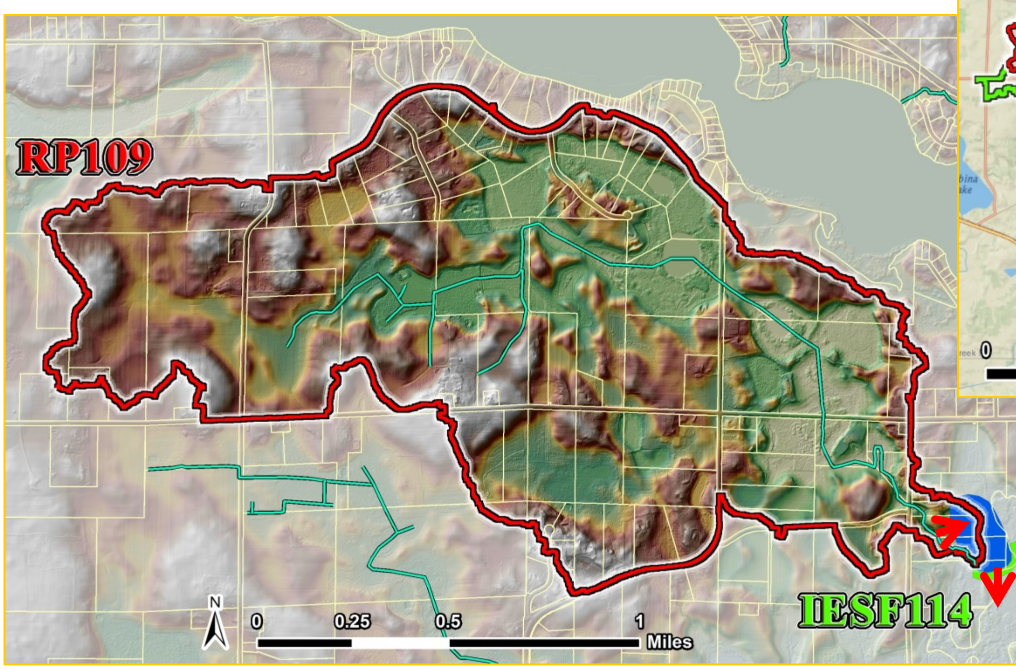


RP109 Pond Area (acre)	Pond Depth (ft)	Loading			Reductions			% Reduction		
		TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr
Initial Conditions	0	336.59	273236	854.35	N/A	N/A	N/A	N/A	N/A	N/A
12	8	264.57	40554	852.28	72.02	233182	2.07	21.4%	85.2%	0.24%
15	8	262.57	32443	851.46	74.02	241293	2.89	22.0%	88.2%	0.34%
20	8	260.59	24332	850.12	76.00	249404	4.23	21.6%	91.1%	0.50%

Site Summary – RP109 – 12 acre 8ft deep	
Water Body	Lake Independence
Treatment Watershed (ac)	1136
Dominant Land Cover	Agriculture, Residential
Installation Type	Regional Pond
Installation Cost ($)	$2,872,133
Promo/Design/Admin ($)	$56,205
Maintenance ($/30yrs)	$36,000
Land Acquisition ($)	$288,000
Total 30 Year Cost ($)	$3,540,338
Project Life (yrs)	30
$/lb-TP removal/yr	$1,638.59
$/lb-TSS removal/yr	$0.51
$/ac-ft volume removal/yr	$57,010.28

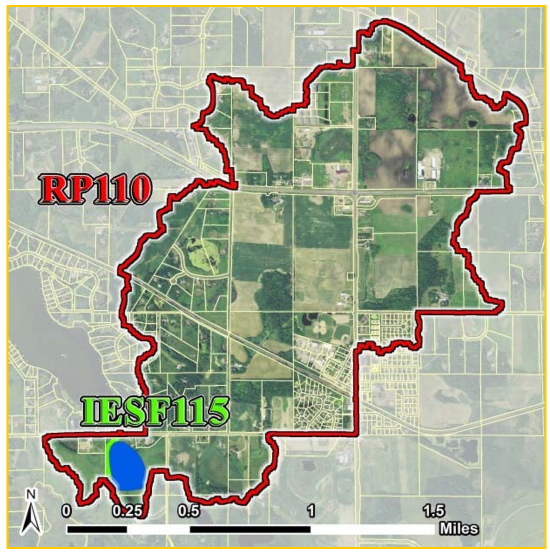


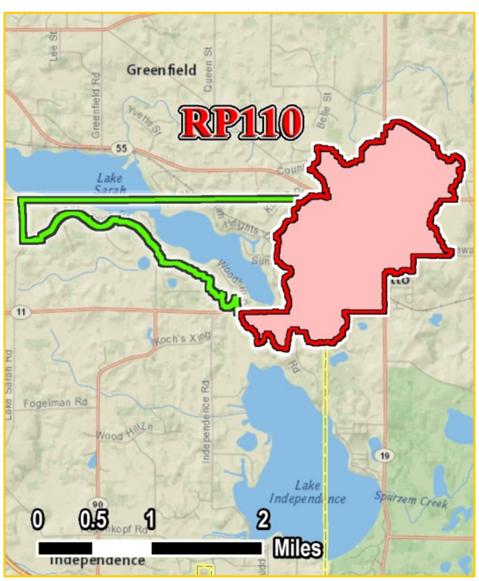


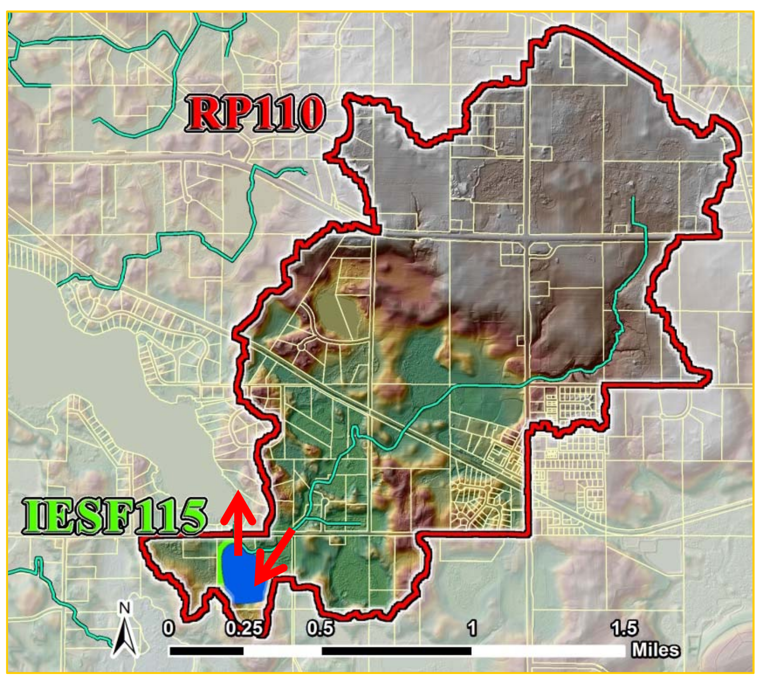


RP110 Pond Area (acre)	Pond Depth (ft)	Loading			Reductions			% Reduction		
		TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr	TP lbs/yr	TSS lbs/yr	Volume ac-ft/yr
Initial Conditions	0	670.60	441359	1012.60	N/A	N/A	N/A	N/A	N/A	N/A
12	8	561.98	51631	1011.00	108.62	389728	1.60	16.2%	88.3%	0.16%
13	8	559.39	39972	1010.76	111.21	401387	1.84	16.6%	90.9%	0.18%
15	8	558.28	34976	1010.22	112.32	406383	2.38	16.8%	92.1%	0.24%
20	8	556.45	26648	1008.39	114.15	414711	4.21	17.0%	94.0%	0.42%

Site Summary – RP110 – 12 acre 8ft deep	
Water Body	Lake Sarah
Treatment Watershed (ac)	1244.5
Dominant Land Cover	Agriculture, Residential
Installation Type	Regional Pond
Installation Cost ($)	$2,925,040
Promo/Design/Admin ($)	$56,205
Maintenance ($/30yrs)	$36,000
Land Acquisition ($)	$288,000
Total 30 Year Cost ($)	$3,305,245
Project Life (yrs)	30
$/lb-TP removal/yr	$1,014.31
$/lb-TSS removal/yr	$0.28
$/ac-ft volume removal/yr	$68,859.27

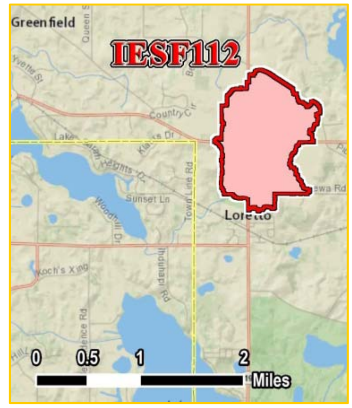




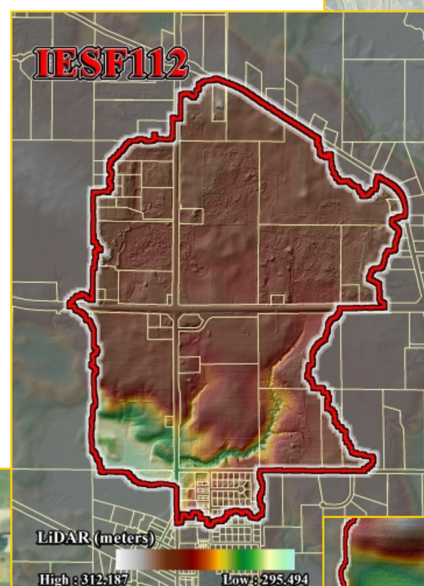


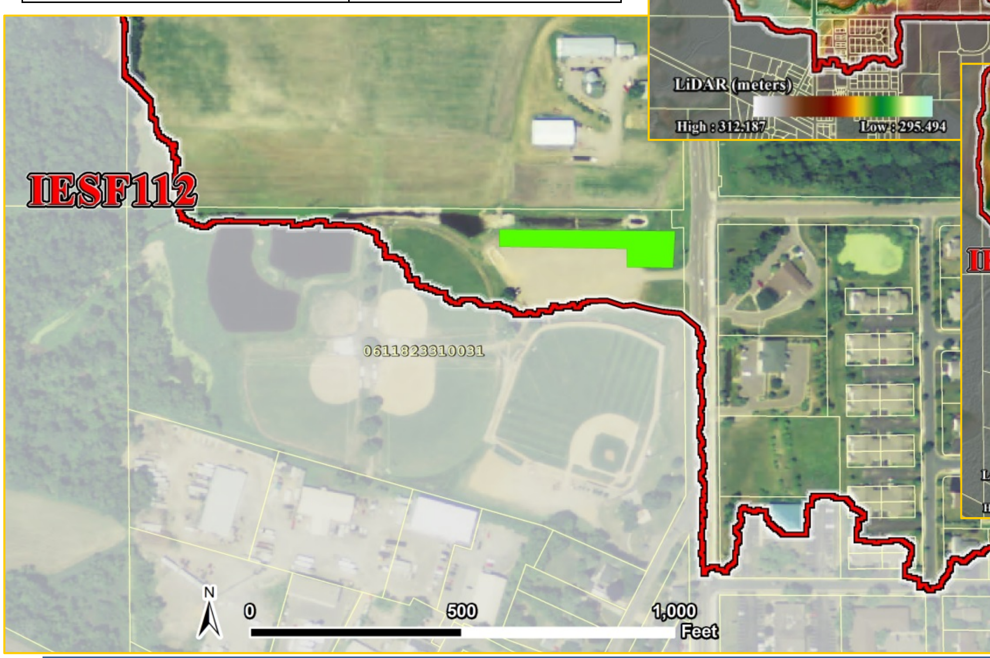
IESF112 Area (acre)	Loading DP lbs/yr	Reductions DP lbs/yr	% Reduction DP lbs/yr
Initial Conditions	148.53	N/A	N/A
0.25	98.03	50.50	42.5%
0.5	73.43	75.10	63.2%
1	51.21	97.32	81.9%

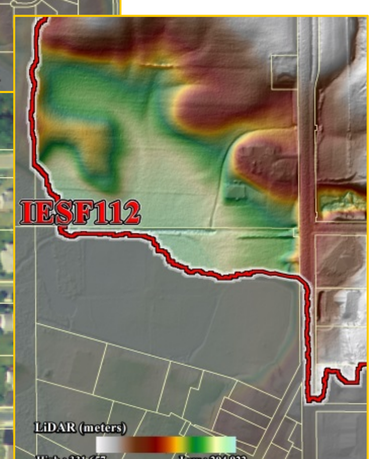
IESFs are typically installed just downstream from treatment ponds to minimize clogging due to particulate matter. High water tables downstream of the Loretto Pond prohibit locating the IESF in that location. Project designers should consider this if the project is pursued.



Site Summary – IESF112 – 0.5 acre	
Water Body	Lake Sarah
Treatment Watershed (ac)	431
Dominant Land Cover	Agriculture, Residential
Installation Type	Iron Enhanced Sand Filter
Installation Cost ($)	$326,700
Promo/Design/Admin ($)	$26,205
Maintenance ($/30yrs)	$1,500
Land Acquisition ($)	(already city owned)
Total 30 Year Cost ($)	$354,405
Project Life (yrs)	30
$/lb-DP removal/yr	$121.39

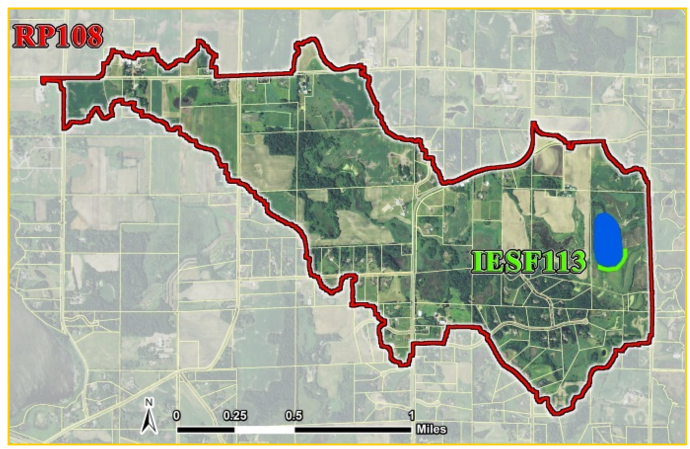


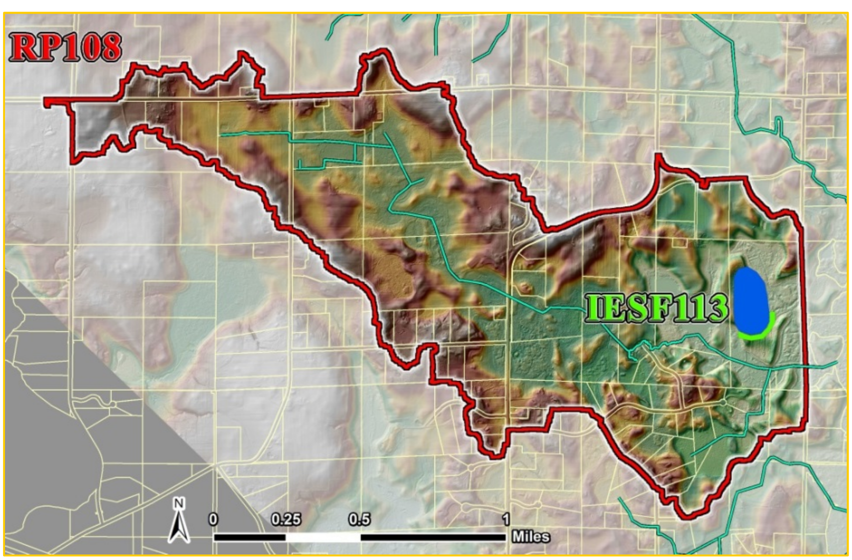




IESF113 Area (acre)	Loading DP lbs/yr	Reductions DP lbs/yr	% Reduction DP lbs/yr
Initial Conditions[24]	153.65	N/A	N/A
0.5	94.03	59.62	48.5%
1	68.47	85.18	69.3%
1.5	54.33	99.32	80.8%
2	48.31	105.34	85.7%

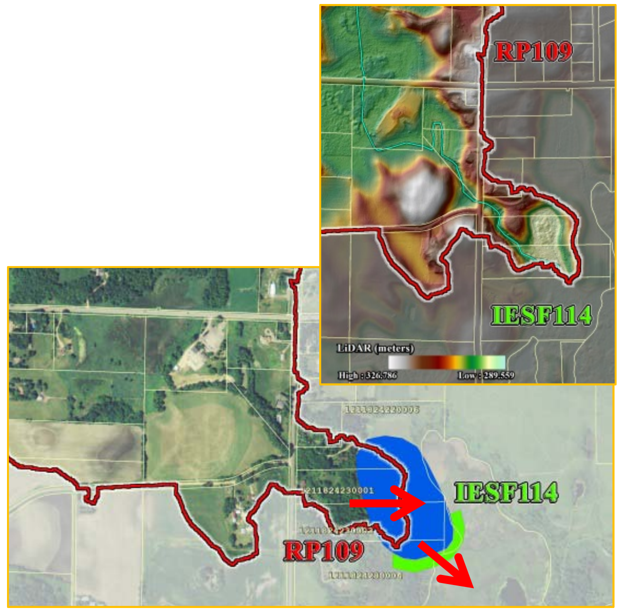
Site Summary – IESF113 – 2 acre	
Water Body	Lake Independence
Treatment Watershed (ac)	1079
Dominant Land Cover	Agriculture, Residential
Installation Type	Iron Enhanced Sand Filter
Installation Cost ($)	$1,306,800
Promo/Design/Admin ($)	$26,205
Maintenance ($/30yrs)	$6,000
Land Acquisition ($)	$48,000
Total 30 Year Cost ($)	$1,387,005
Project Life (yrs)	30
$/lb-TP removal/yr	$275.32



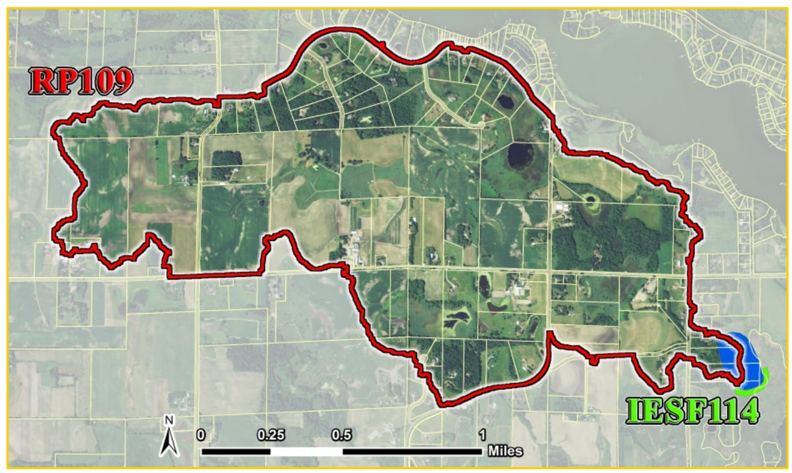


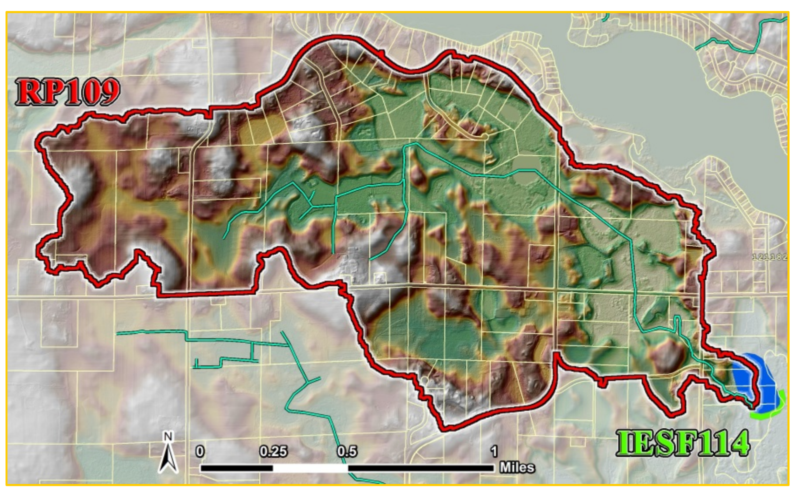
[24] Initial conditions include only the Dissolve Phosphorus (DP) that is associated with storm events as only that DP may be treated by a sufficiently large IESF. TP associated with storm events is 70% of overall TP. DP is 50% of TP.

IESF114 Area (acre)	Loading DP lbs/yr	Reductions DP lbs/yr	% Reduction DP lbs/yr
Initial Conditions[25]	117.81	N/A	N/A
0.5	72.29	45.52	48.3%
1	54.38	63.43	67.3%
1.5	45.14	72.66	77.1%
2	41.47	76.34	81.0%



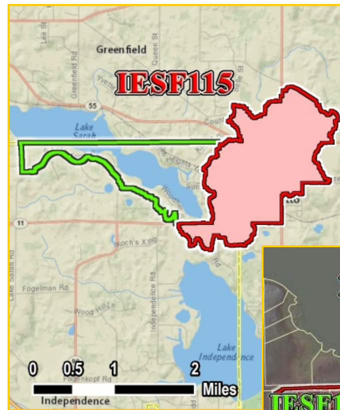
Site Summary – IESF114 – 1.5 acre	
Water Body	Lake Independence
Treatment Watershed (ac)	1136
Dominant Land Cover	Agriculture, Residential
Installation Type	Iron Enhanced Sand Filter
Installation Cost ($)	$980,100
Promo/Design/Admin ($)	$26,205
Maintenance ($/30yrs)	$4,500
Land Acquisition ($)	$36,000
Total 30 Year Cost ($)	$1,046,805
Project Life (yrs)	30
$/lb-DP removal/yr	$480.21

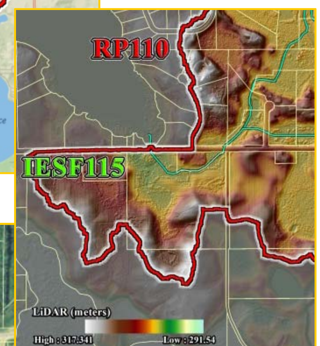




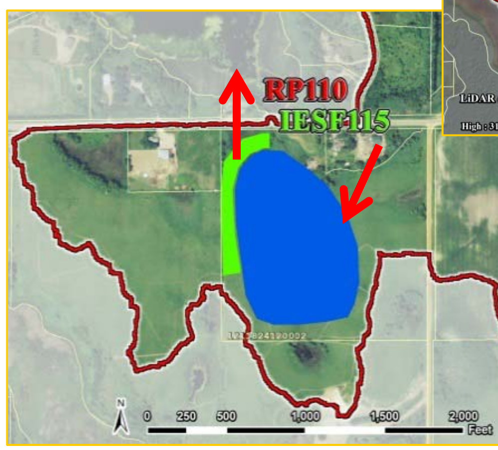
25 Initial conditions include only the Dissolve Phosphorus (DP) that is associated with storm events as only that DP may be treated by a sufficiently large IESF. TP associated with storm events is 70% of overall TP. DP is 50% of TP.

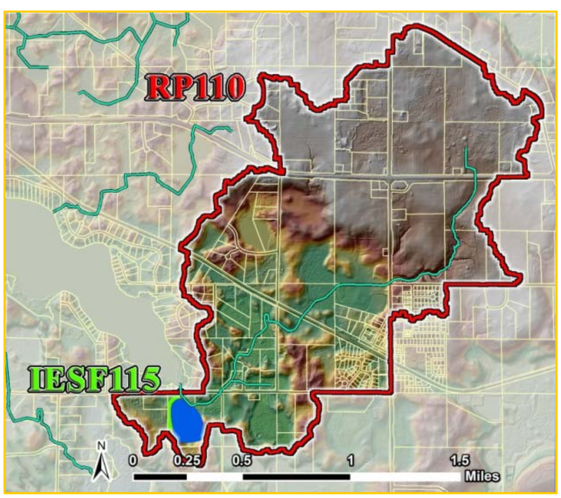
IESF115 Area (acre)	Loading TP lbs/yr	Reductions TP lbs/yr	% Reduction TP lbs/yr
Initial Conditions[26]	234.72	N/A	N/A
0.25	189.28	45.44	24.2%
0.50	159.42	75.30	40.1%
1.0	122.99	111.73	59.5%
1.5	101.96	132.76	70.7%
2.0	89.38	145.34	77.4%

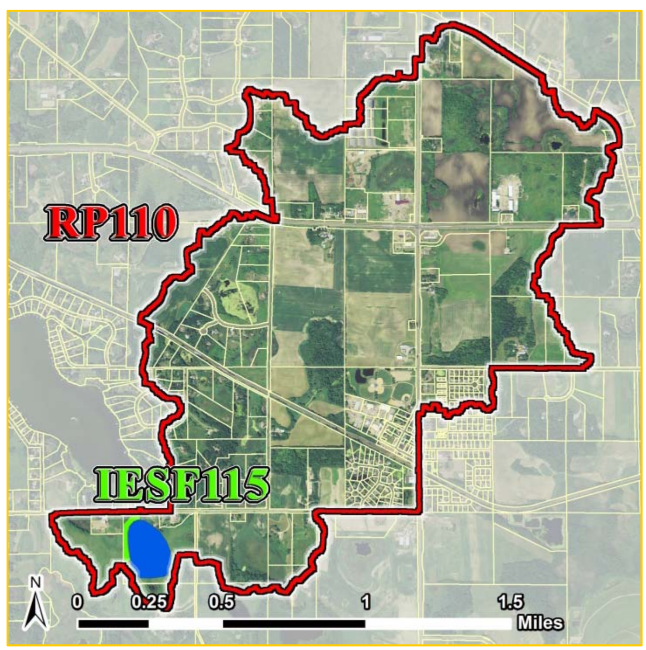




Site Summary – IESF115 – 2 acre	
Water Body	Lake Sarah
Treatment Watershed (ac)	1244.5
Dominant Land Cover	Agriculture, Residential
Installation Type	Iron Enhanced Sand Filter
Installation Cost ($)	$1,306,800
Promo/Design/Admin ($)	$26,205
Maintenance ($/30yrs)	$6,000
Land Acquisition ($)	$48,000
Total 30 Year Cost ($)	$1,387,005
Project Life (yrs)	30
$/lb-TP removal/yr	$318.10







[26] Initial conditions include only the Dissolve Phosphorus (DP) that is associated with storm events as only that DP may be treated by a sufficiently large IESF. TP associated with storm events is 70% of overall TP. DP is 50% of TP.

Seasonal Ponding

During snow melt, early spring rains, and late fall rains, significant runoff and localized erosion can occur. These are particularly sensitive times of year for several reasons. Surface soils can be thawed while frost persists in the subsoil. This prevents infiltration, thereby increasing the amount of runoff over the saturated and highly erodible surface soil. In agricultural areas, these times of year are before and after harvest, when crop and residue covers are at their lowest. Winter application of manure from livestock operations may also greatly increase the nutrient concentration in snowmelt and early spring rains. Finally, disruption to fish spawning from highly turbid and nutrient rich spring runoff can compound the negative environmental impacts. For these reasons, it can be highly beneficial to find opportunities for seasonal ponding on agricultural lands.

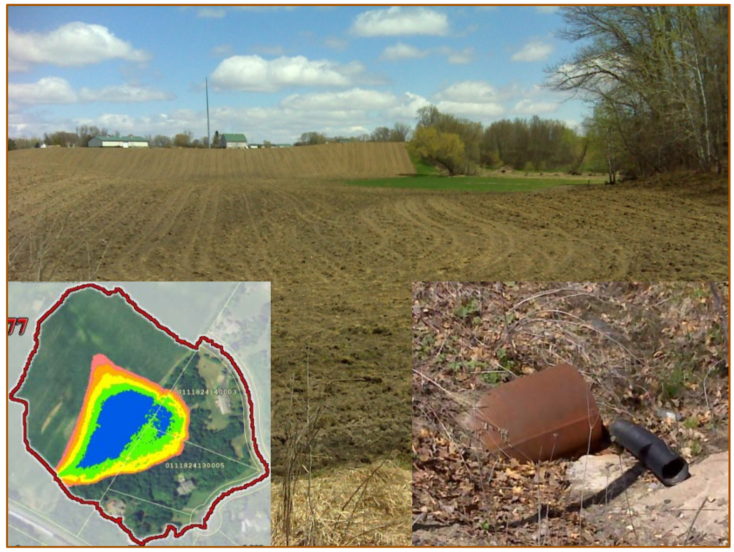


Figure 24: Seasonal Ponding Site
The green area (upper right) has a tile riser which outlets near a culvert (lower right). The aerial photo (lower left) shows potential ponding elevation in different colors.

Seasonal ponding involves temporarily holding back water in areas of the landscape that are otherwise well-drained with drain tile or other artificial means prior to planting and after crop harvest. Not only can this process improve water quality by allowing sediment and organics to settle out in ponded water, but it can help agricultural producers by improving soil nutrients in the ponded area, helping frost go out sooner where pond water is held, and allowing water to be held on the landscape in dry periods to benefit stressed crops. Where deep ponding can be achieved over winter, it may be possible to prevent frost entirely, thereby allowing earlier planting and a longer growing season. A well-managed seasonal ponding project can benefit the agricultural producer and downstream water quality.

Seasonal ponding is achieved by installing a control structure that allows the land operator full control of water levels. Allowing water to pond from after harvest (Oct-November) until before planting (mid to late April) can achieve significant water quality benefits without yield losses (Figure 25). The precise time of water management can be left to the full discretion of the land operator. While longer ponding is preferred, the relatively inexpensive practice proves to be a cost-effective approach even during short duration ponding.

Planting date	Grain yield loss (%)
April 25	0
April 30	0
May 5	1
May 10	2
May 15	5
May 20	8
May 25	13
May 30	18
June 4	24
June 9	31
June 14	39

Figure 25: Corn Planting Date vs. Yield Loss
Data are from planting date trials at Lamberton, MN from 1988-2003 by Bruce Potter and Steve Quiring.

The figure to the right illustrates how a drainage tile could be interrupted with a control structure to manage water levels. By simply removing all or some of the restrictors, water levels could be rapidly dropped.

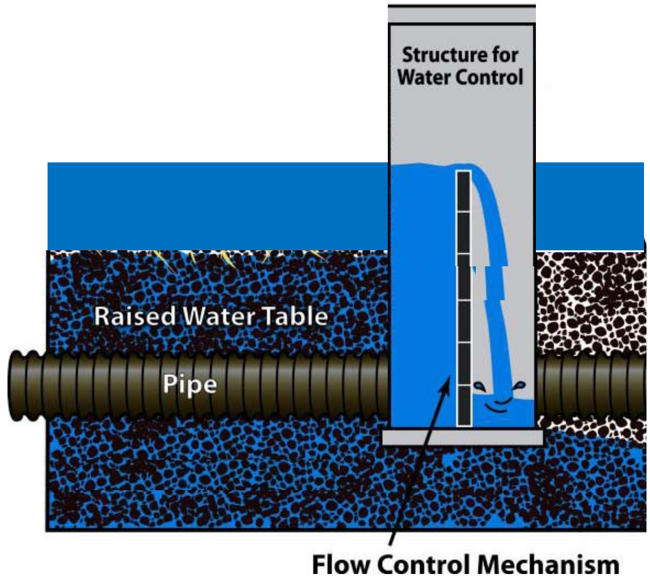


Figure 26: Water Control Attached to Drain Tile (illustration courtesy of Illinois NRCS – modified)

Seasonal pond retrofits were modeled utilizing the ArcView extension of the Soil & Water Assessment Tool (ArcSWAT). This model combines inputs of hydrography, topography, soils, and land cover in a GIS interface and determines runoff volume and pollutant loading based on these inputs. The model was run with and without the identified project and reported in monthly intervals. The difference in pollutant discharge for the months when ponding is anticipated to occur (October – April) were noted. The selected site was modeled at multiple ponding depths. A detailed account of the methodologies used is included in Appendix A.

The seasonal pond is located within close proximity to Lake Sarah and so the reported benefits should be close to those actually experienced by the lake. Ultimately, it will be the purview of watershed management professionals to select projects to pursue. To facilitate this process, maps for each project showing the location in the watershed are provided.

In order to determine cost-benefit, the cost of each project had to be estimated. Seasonal ponding projects were assumed to involve installation of a control structure to retrofit existing drainage features. Additionally, project design, promotion, administration, construction oversight and long term maintenance had to be considered in order to capture the true cost of the effort.

The table below summarizes the seasonal pond project costs and benefits. Cost assumptions made to calculate the cost-benefit should be verified against local experience while creating implementation plans.

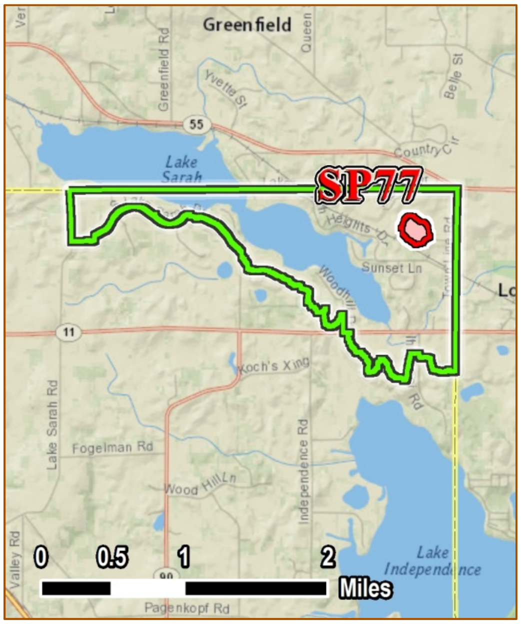
Table 30: Potential Seasonal Ponding Project

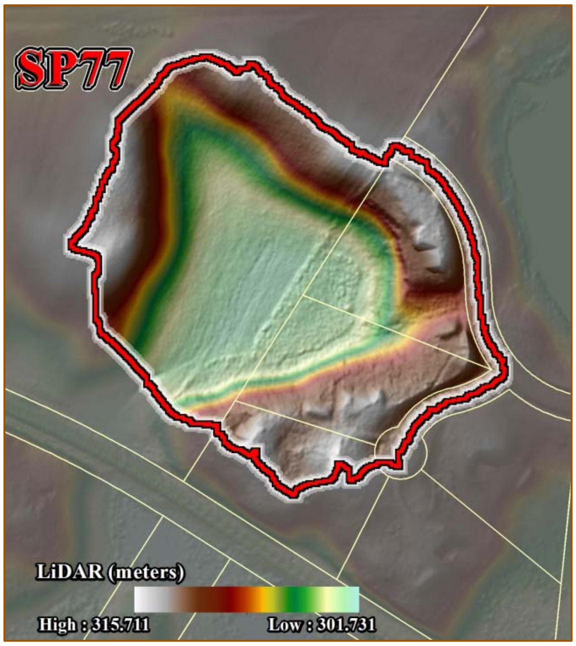
Water Resource	Site ID	Pool Elev.	TSS Reduction (tons/yr)	TP Reduction (lbs/yr)	Volume Reduction (ac-ft/yr)	10 Yr Cost[27]	Project Life (yrs)	Cost-Benefit ($/lb TP)
Sarah	SP77	997	1.0	2.85	2.15	$10,420	10	$365.61

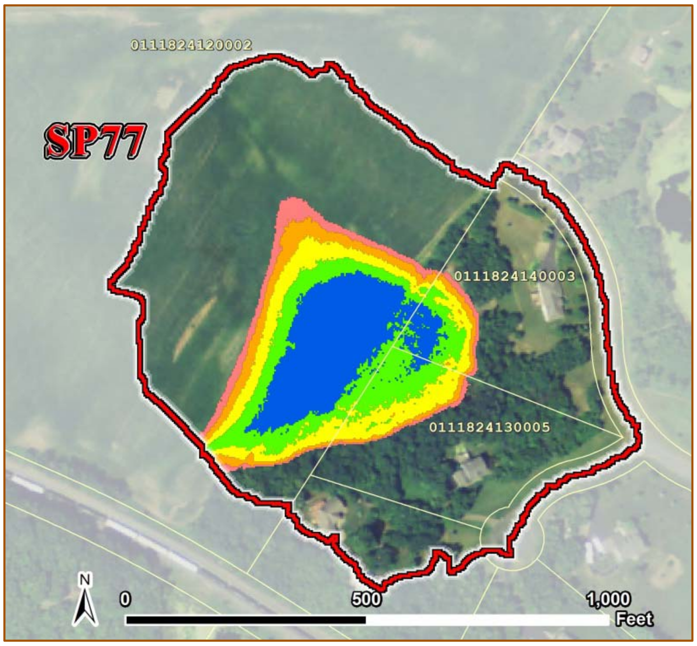
[27] Total cost over ten years was calculated assuming project design and construction oversight were $3,000, landowner outreach, and general project coordination would take 40 hours total at $73/hr, annual inspection and maintenance costs $50/yr. Structure installation is $4,000 per control structures .

SP77 Ponding Elev.	Pool Area (acres)	Loading TP lbs/yr	Loading TSS lbs/yr	Loading Volume ac-ft/yr	Reductions TP lbs/yr	Reductions TSS lbs/yr	Reductions Volume ac-ft/yr	% Reduction TP lbs/yr	% Reduction TSS lbs/yr	% Reduction Volume ac-ft/yr
Initial Conditions	0.0	5.36	4167	14.23	N/A	N/A	N/A	N/A	N/A	N/A
Pool to 993 ft	1.5	4.34	4057	13.63	1.02	110	0.60	19.0%	2.6%	4.2%
Pool to 994 ft	2.7	3.26	3352	12.86	2.10	815	1.37	39.2%	19.6%	9.6%
Pool to 995 ft	3.6	2.84	2632	12.51	2.52	1535	1.72	47.0%	36.8%	12.1%
Pool to 996 ft	4.2	2.57	2287	12.22	2.79	1880	2.01	52.1%	45.1%	14.1%
Pool to 997 ft	4.6	2.51	2162	12.08	2.85	2005	2.15	53.2%	48.1%	15.1%

Site Summary – SP77 – 997 elev.	
Water Body	Lake Independence
Treatment Watershed (ac)	17.56
Dominant Land Cover	Agriculture
Installation Type	Seasonal Pond
Installation Cost ($)	$4,000
Promo/Design/Admin ($)	$5,920
Maintenance ($/10yrs)	$500
Total 10 Year Cost ($)	$10,420
Project Life (yrs)	10
$/lb-TP removal/yr	$365.61
$/lb-TSS removal/yr	$0.52
$/ac-ft volume removal/yr	$484.65







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Appendix – Modeling Methods

Water Quality Models

Pollutant load and removal efficiency at project locations was estimated using a suite of water quality models. Different models were used as each has specialized inputs and features that provide reliable, land use-specific results, but have less utility in other settings. For example, rain gardens are generally installed in urban areas where pollutant runoff and retention are influenced by variables such as impervious surface, development density, traffic volumes, and hydraulic connectivity. The Source Loading and Management Model for Windows (WinSLAMM), is a water quality model for urban areas that is well-suited to evaluate these elements. On the other hand, WinSLAMM has a limited amount of land use inputs. This makes the model poorly-suited for characterizing stormwater flow through a rural landscape that varies from row-crop agricultural to hay and pasture fields to wooded wetlands. In that case, a basin-scale model, such as the Soil & Water Assessment Tool (SWAT), is more appropriate.

The following sections describe each water quality model applied within this analysis, the reason it was chosen for each BMP, and the inputs necessary to run the model. Sections are organized based on the model used and BMPs modeled with the software.

Soil & Water Assessment Tool (SWAT)

Background Information and Input Parameters

Stormwater runoff generated in rural catchments was estimated using the ArcView extension of the Soil & Water Assessment Tool (ArcSWAT) modeling software. This model combines inputs of hydrography, topography, soils, and land cover in a GIS interface and determines runoff volume and pollutant loading based on these inputs. Beginning with a digital elevation model, ArcSWAT delineated basins for both the Lake Sarah and Lake Independence watersheds based on predefined threshold values for minimum basin size. To improve model efficiency, hydrologic response units (HRUs) were derived within each basin based on a unique combination of land cover and soil type. An area was computed for each HRU, as well as an average slope to deliver runoff directly to the basin's outlet. For example, a single 10 acre basin may be split into 20 HRUs, each with a specific land cover and soil type.

DEM data was downloaded as 3.25 mi^2 tiles from the Minnesota Geospatial Information Office (MNGEO) webpage. Tiles were merged using the "Mosaic to New Raster" tool in the ArcView toolbox. To route overland flow under roadways and driveways, culvert locations were determined through desktop analysis and field surveys and "burned" into the landscape.

Land Cover data were provided by the US Geological Survey's National Land Cover Database (NLCD). We used the latest year in which an ArcSWAT look-up table was available: 2006. NLCD 2006 is a 16-class (in the contiguous 48 states) dataset that allowed for compromise between a large and well defined dataset (e.g. Minnesota Land Cover Classification System with >600 classes) and a smaller one which reduces computational time. Because of annual changes to crop coverage, such as rotations between corn and soybeans, all tilled agricultural fields were evaluated similarly. Soils data were provided by the Hennepin County Digital Soil Survey and were characterized in ArcSWAT using the Soil Survey Geographic Database (SSURGO). Precipitation data from 2004-2010 were uploaded from the Weather Generator model within ArcSWAT based on readings from local climatic stations over the given period.

Infiltration and surface runoff were determined within SWAT using a modified version of the SCS curve number (CN) method. Erosion and sediment yield were estimated for each HRU using the Modified Universal Soil Loss Equation (MUSLE). ArcSWAT determined phosphorus transport and transformation using a host of processes in both mineral and organic form, which were summed to determine total phosphorus (TP) load.

BMPs were modeled throughout the Lake Sarah and Lake Independence watersheds. “Initial conditions” were run with current topography and land cover to determine the existing pollutant and volume loads for each project site. The area draining to a specific BMP, called the “treatment area,” was determined for each project by setting the BMP location as the basin confluence within ArcSWAT. All inputs, including the DEM, land cover, and soils datasets, were then clipped to this boundary to determine only the loading at that BMP site.

Table 31: GIS File Sources and Use for ArcSWAT Modeling and Desktop Analysis.

Dataset	Source	Purpose	Notes
Digital elevation model	Minnesota Geologic Information Office (MNGEO)	Model input of topography	Horizontal resolution: meets or exceeds 0.6 m; Vertical resolution: meets or exceeds 0.1 m
Soils	United State Department of Agriculture (USDA) and the Nature Resources Conservation Service (NRCS) - Soils Survey Geographic Database (SSURGO)	Model input, determining BMP viability, locating hydric soils	
Land cover	National Land Cover Dataset (NLCD) 2006	Model input	
Parcel data	Hennepin County	Display homeowner information	Downloaded January 2014
Streams	Minnesota Department of Natural Resources (DNR)	Model input (flow routing), map display	Public waters inventory, watercourse delineations
Lakes and wetlands	Minnesota Department of Natural Resources (DNR)	Map display	Public waters inventory, basin delineations
Aerial photography	USDA National Agriculture Imagery Program (NAIP)	Verify land cover information, map display	
Municipal boundary	MNGEO	Used City of Independence boundary as research area, map display	
Roads	The Lawrence Group, Minnesota Department of Transportation (MNDOT), Metropolitan Council	Map display, BMP description	
Culverts	Desktop analysis and field survey	Model input, BMP siting	

The ArcSWAT model was then run for a seven year period, 2004-2010. The first two years of the model run were used to bring all conditions into equilibrium. Results from years 2006-2010 were analyzed to determine average yearly load of TP, TSS, and volume. Each reported value represents the 5-year average of these model runs.

Model Validation

To better correlate the ArcSWAT model with local conditions, each BMP model was calibrated based on parameters derived in the Lake Sarah TMDL. The SWAT model developed for the 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 both the Lake Sarah and Lake Independence basins, as these watersheds share very similar land use, soils, and topographic characteristics. The parameters used in this analysis are noted in Table 32.

Table 32: ArcSWAT Calibration Parameters

Parameter	Description	Units	Modeled Value[28]	Default Value
SMTMP	Snow melt base temperature	^oC	3	1
SMFMX	Melt factor for snow on June 21	mm $H_20/^oC$-day	2	4.5
SMFMN	Melt factor for snow on December 21	mm $H_20/^oC$-day	2.5	4.5
TIMP	Snow pack temperature lag factor	-	0.25	1
IPET	Potential evapotranspiration method	-	Priestly-Taylor	-
ESCO	Soil evaporation compensation factor	-	0.92	0.95
SURLAG	Surface runoff lag time	days	1	4
SPEXP	Exponent parameter for calculating sediment reentrained in channel sediment routing	-	1.5	1
PSP	Phosphorus sorption coefficient	-	0.23	0.4
IWQ	In-stream water quality	-	Inactive	Active
GW_DELAY	Groundwater delay	days	15	30
ALPHA_BF	Baseflow alpha factor	days	0.99	0.048
GWSOLP	Concentration of soluble phosphorus in groundwater	mg-P/L	0.05	0
CN2	Initial SCS curve number for moisture condition II	-	Default - 10%	Varies
USLE_P	USLE equation support practice factor	-	0.25	1

To validate pollutant loads generated in this analysis with those in the Lake Sarah and Lake Independence TMDLs, separate SWAT models were created for the largest tributaries to each lake within the City of Independence. These are Koch's Creek and Mill's Creek for Lake Independence and the east tributary to Lake Sarah (naming conventions match those from the TMDL study). Results are listed in Table 25 and generally agree across the studies. Only TP is shown as no other stressors (e.g. discharge volume or TSS) are listed in both TMDLs for each watershed.

[28] These parameters are based on those cited in the Lake Sarah TMDL. Default values were used for parameters not shown.

Table 33: TMDL and SRA Model Output Comparison: TP Load and Drainage Areas

	Drainage Area (acres)		TP Load (lbs/yr)		Areal Loading (lbs-TP/ac/yr)	
	TMDL Study	SRA	TMDL Study	SRA	TMDL Study	SRA
Lake Independence Basin						
Koch's Creek	1,342	1,195	314	341	0.23	0.29
Mill's Creek	1,174	1,094	482	441	0.41	0.40
Lake Sarah Basin						
East Tributary[29]	1,245	1,246	761	743	0.61	0.60

Simulating BMPs in SWAT

Hydrologic and Wetland Restorations

Proposed conditions, with installed BMPs, were modeled within the landscape using the 'Pond' parameter dialog. Each proposed hydrologic restoration or wetland restoration increases holding capacity of stormwater runoff, thereby increasing hydraulic residence time and promoting sedimentation. Hydrologic and wetland restorations assume only a change in hydrology to promote ponding to existing topography. This might occur by breaking a tile line, installing a weir, ditch block, or berming across a previously graded land bridge. Ponding area and volume was determined using the NRCS GIS Engineering tools for ArcGIS v10.0 at various elevations. These values were used as the principal spillway height in the Pond dialog of ArcSWAT. Emergency spillway area and volume was determined following empirical equations derived by Almedinger and Ulrich (2010) for the Sunrise River watershed in east-central Minnesota,

Emergency Area = 1.13 * Principal Area
Emergency Volume = 1.18 * Principal Volume

In natural systems, sedimentation is controlled by factors including current velocity, wind speed, fetch, and vegetative coverage around the water body. Within ArcSWAT, sedimentation is controlled by an equilibrium sediment concentration, above which all sediment is presumed to fall out of suspension. This value was derived from Almedinger and Ulrich (2010) where D is the mean depth of the pond in meters and NSED is the equilibrium sediment concentration in mg/L.

$$NSED = 100 * D^{-2}$$

Phosphorus retention generated by the BMP was determined using the phosphorus settling rate (Table 34). The phosphorus settling rate was set at 20 m/year to bring settling values in line with reservoirs throughout east central Minnesota (Almedinger, personal communication). In some cases phosphorus retention was below the amount expected from sedimentation rates. As adsorbed phosphorus is available in nearly all types of sediment, a certain percentage of TP will be removed from the water column as sediment falls out of suspension. The mass of phosphorus bound to sediment was estimated from the Minnesota Board of Water and Soil Resources (BWSR) Pollution Reduction Estimator for sheet and rill erosion, where P_{SED} is the phosphorus content in the sediment in lbs/acre/year and S is the sediment load in tons/acre/year.

$$P_{SED}\ (lbs/ac/yr) = 1.5999 * S^{0.7998}$$

When this value over a given time span was greater than the expected phosphorus retention based on the settling rate, phosphorus reductions were reported solely as phosphorus adsorbed to sediment.

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29 Pollutant estimate and total drainage area combines results from SWAT modeling, P8 modeling (in Loretto only), and export coefficients.

Table 34: ArcSWAT Parameters for the 'Pond' input file (.pnd)

Parameter	Description	Units	Modeled Value[30]	Default Value	Explanation
PND_FR	Fraction of basin area draining into the pond	-	1	0	"Edge-of-field" or "end-of-pipe" BMPs were modeled as a single basin with the entire basin draining to the pond
PND_PSA	Surface area of pond when filled to principal spillway	ha	Variable	0	Determined by NRCS GIS Engineering tools
PND_PVOL	Volume of pond when filled to principal spillway	10^4 m^3	Variable	0	Determined by NRCS GIS Engineering tools
PND_ESA	Surface area of pond when filled to emergency spillway	ha	Variable	0	Emergency spillway area (ha) = 1.13 * Principal spillway area (ha)
PND_EVOL	Volume of pond when filled to emergency spillway	10^4 m^3	Variable	0	Emergency spillway volume (10^4 m^3) = 1.18 * Principal spillway volume (10^4 m^3)
PND_VOL	Initial volume of pond water	10^4 m^3	0	0	initially set at 0 but run with 2-year equilibrium time
PND_SED	Initial sediment concentration of pond water	mg/L	0	0	initially set at 0 but run with 2-year equilibrium time
PND_NSED	Equilibrium sediment concentration in pond	mg/L	Variable	0	NSED = 100 * D^{-2} ; where D = mean depth (m)
PND_K	Hydraulic conductivity through pond bottom	mm/hr	0.4	0	Conductivity for silt and clay soils
PSETL1	Phosphorus settling rate in pond during first period	m/year	20	10	Increased for shallower ponds (1-2 ft. in depth), Settling period not seasonally dependent
PSETL2	Phosphorus settling rate in pond during second period	m/year	20	10	Settling period is year-round (not seasonally dependent)
PND_SOLP	Initial concentration of soluble P in pond	mg-P/L	0	0	initially set at 0 but run with 2-year equilibrium time
PND_ORGP	Initial concentration of organic (particulate) P in pond	mg-P/L	0	0	initially set at 0 but run with 2-year equilibrium time

[30] Default values were used unless otherwise noted.

When assessing the results of these BMP models, please keep in mind that:

1) Proposed ponding for each BMP is based on current topography, which has been greatly altered over the last 150 years through clear-cutting, drainage, grading, and tilling. If the goal were to achieve restoration of an area to its natural, pre-settlement condition, it may be necessary to replicate landscape features long erased by landuse by installing features such as dikes, berms, and weirs that exceed design parameters considered in this analysis. This could result in area and storage conditions that are different from those modeled in this study. The study results can at least be a guideline for restoration activities and pollutant reduction potential.
2) Unfortunately, as there is no existing monitoring data at each prospective BMP location, greater refinement of model calibration could not be performed. If definitive reduction totals are needed for each BMP, then monitoring water quality at the inlet and outlet of installed practices should be pursued where practical. These data could then be used to better calibrate the model to localized conditions and to better design subsequent BMPs.

Filter Strips

ArcSWAT contains a separate submodel for filter strips, which can be initiated by creating a scheduled management operations (.ops) file. This file allows for runoff within specified HRUs to flow through the filter strip prior to reaching the drainage channel. The basin was clipped to include only portions of the landscape draining to the filter strip, which allowed for all HRUs within the submodel to similarly drain to the practice. This also ensures that all land use types are included in pollutant retention calculations.

Four input parameters are available for specifying filter strip characteristics. Recommended values were provided by the *Conservation Practice Modeling Guide for SWAT and APEX*:

1) VFSI: Activates filter strip (1 = active; 0 = inactive).
2) VFSRATIO: Field area to filter strip ratio. Field area was determined from delineating the drainage basin. The proposed filter strip area was measured using ArcGIS. This area included both sides of the waterway.
3) VFSCON: Fraction of the total runoff from the entire field entering the most concentrated 10% of the filter strip (recommended value of 0.25-0.75).
4) VFSCH: Fraction of flow through the most concentrated 10% of the filter strip that is fully channelized (recommended value of 0).

Values for VFSCON and VFSCH were increased to 0.75 and 0.25, respectively, to better mimic regional characteristics of buffers in central Minnesota (Nieber et al., 2011).

Similar to all other BMPs run with ArcSWAT, the model was run for a seven year period, 2004-2010. The first two years of the model run were used to bring all conditions into equilibrium. Results from years 2006-2010 were analyzed to determine average yearly load of TP, TSS, and volume. Each reported value represents the 5-year average of these model runs.

Sediment Basins

Sediment basins are often viewed as depressions (natural or man-made) in the landscape that accept stormwater runoff for the purpose of promoting sedimentation. In this application, standing water would be present for extended periods of time. For this analysis, sediment basins were modeled as structures that slow the runoff of drainage from farm fields but do not hold water indefinitely. When tied to drain tile, these structures (which are often called Water and Sediment Control Basins (WASCOBs)) will reduce the velocity of the drainage enough for sediment to drop out of suspension while allowing for the stormwater to drain slowly from behind the berm into the tile line. ArcSWAT does not have a submodel for this type of practice. As recommended by the *Conservation Practice Modeling Guide for SWAT and APEX*, these structures can be modeled as ponds in ArcSWAT. To be comparative to WASCOBs, though, we assumed no retention of water from the structure. It was assumed all water reaching the structure would be advected downstream through the tile system. Pond parameters set within ArcSWAT are comparative to those listed in Table 34. Equilibrium sediment concentration associated with these structures is still based on ponding depth up to either the berm height or riser overflow height (depending on design).

Similar to all other BMPs run with ArcSWAT, the model was run for a seven year period, 2004-2010. The first two years of the model run were used to bring all conditions into equilibrium. Results from years 2006-2010 were analyzed to determine average yearly load of TP, TSS, and volume. Each reported value represents the 5-year average of these model runs.

New Ponds (Seasonal and Regional)

Ponds were proposed in the landscape where sufficient drainage area could sustain a permanent pool of water (MPCA, 2014). Ponds were proposed following guidance from the Minnesota Pollution Control Agency, in which depths are equal to or less than 8-10 ft. to prohibit stratification and at least 1,800 cu-ft. of pond storage is available for each acre of drainage area.

Ponds were modeled at multiple depths and areas with ArcSWAT, following similar conditions noted in the ‘Hydrologic and Wetland Restorations’ section above. Similar to all other BMPs run with ArcSWAT, the model was run for a seven year period, 2004-2010. The first two years of the model run were used to bring all conditions into equilibrium. Results from years 2006-2010 were analyzed to determine average yearly load of TP, TSS, and volume. Each reported value represents the 5-year average of these model runs.

Seasonal ponds used similar input parameters (Table 34) to both regional and standard wet ponds, but assumed ponding only occurred during non-growing season months, October-April. Reported values for TP, TSS, and volume reduction are averages from these months only.

Simulating BMPs in WinSLAMM

Pollutant removal from rain gardens and iron-enhanced sand filters was estimated using the stormwater model Source Load and Management Model for Windows (WinSLAMM). WinSLAMM uses an abundance of stormwater data from the upper-midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It has detailed accounting of pollutant loading from various land uses, and allows the user to build a model “landscape” that reflects the actual landscape being considered. WinSLAMM uses rainfall and temperature data from a typical year, routing stormwater through the user’s model for each storm. Land use and soils data were from the same files provided in the SWAT modeling section (Table 31) but were clipped within ArcGIS to within the drainage basin boundary (termed the ‘treatment area’). WinSLAMM version 10 was used for this analysis to determine pollutant loading and BMP retention capacity at each project site. Additional inputs for WinSLAMM are provided in Table 35.

Table 35: General WinSLAMM Model Inputs

Parameter	File/Method
Land use acreage	ArcMap
Precipitation/Temperature Data	Minneapolis 1959 – the rainfall year that best approximates a typical year.
Winter season	Included in model. Winter dates are 11-4 to 3-13. Winter dates in
Pollutant probability distribution	WI_GEO01.ppd
Runoff coefficient file	WI_SL06 Dec06.rsv
Particulate solids concentration file	WI_AVG01.psc
Particle residue delivery file	WI_DLV01.prr
Street delivery files	WI files for each land use.

Rain Gardens

Rain Gardens were modeled as drainage area control practices within WinSLAMM. Each was modeled with an underdrain, as the silty soils in this region often lead to lower infiltration rates which can create ponding lasting longer than 48 hours. The underdrain will ensure the garden dries between rain events. If, based on soil tests, it is determined that an underdrain is not necessary, then expected reductions for TP, TSS, and volume will be larger. Table 36 describes specific input parameters for rain gardens in the WinSLAMM model. Figure 27 shows the WinSLAMM biofiltration parameter input screen.

Table 36: WinSLAMM Input Parameters for Rain Gardens

Parameter	Unit	Value
Top Area	sq-ft	varies
Bottom Area	sq-ft	Varies
Total Depth	ft	4.0
Native Soil Infiltration Rate	in/hr	0.3
Infiltration Rate Fraction-Bottom (0-1)	-	1
Infiltration Rate Fraction-Sides (0-1)	-	1
Rock Filled Depth	ft	0.5
Rock Fill Porosity (0-1)	-	0.3
Engineered Media Infiltration Rate	in/hr	2.5
Engineered Media Depth	ft	2.0
Engineerd Media Porosity (0-1)	-	0.3
Inflow Hydrograph Peak to Average Flow Ratio	-	3.8
Broad Crested Weir Length	ft	3.0
Broad Crested Weir Width	ft	0.5
Height From Datum to Bottom of Weir Opening	ft	3.5
Underdrain Pipe Diameter	ft	0.33
Underdrain Invert Elevation Above Datum	ft	0.01
Number of Pipes at invert elevation	-	varies[31]

[31] Additional underdrain pipe added every 250 sq-ft of top area.

All gardens were proposed in residential areas and therefore needed to take into account the effect of street cleaning performed by the City of Independence once per year in the spring. On average, WinSLAMM modeling found that street cleaning removed 1.75 lbs-TSS/ac and 0.004 lbs-TP/ac of drainage area. Street cleaning was not included for the iron-enhanced sand filters or any of the BMPs modeled with SWAT as street cleaning doesn't occur on unpaved roadways and is limited to very few of the paved, rural roadways. Therefore, its impact is negligible outside of the near-lake, residential regions of Independence. Final model results show the potential of the practice to remove pollutants above what is already removed by street cleaning.

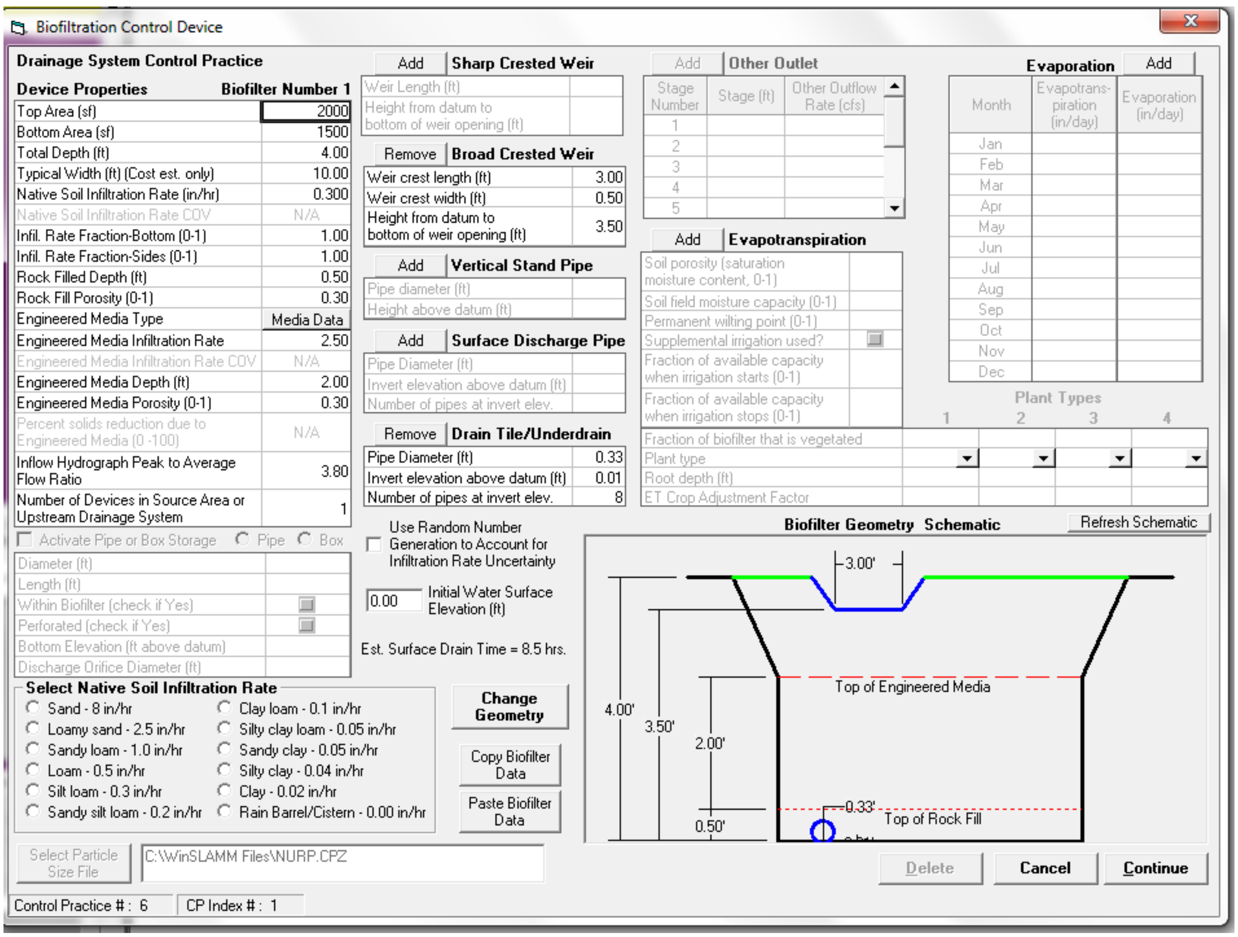


Figure 27: Biofiltration Control Practice Input Screen: Rain Gardens (WinSLAMM)

Iron-Enhanced Sand Filters

Wet ponds, by design, allow for sediments and other bound pollutants to drop out of suspension. This practice, though, often allows dissolved pollutants to advect through the system untreated. Iron-enhanced sand filters (IESF) can be retrofitted to or installed with wet ponds to treat this dissolved load. During a storm event, the pond increases from its permanent-pond stage to its flood stage. The IESF is designed to accept input from the wet pond during storm events, allowing for infiltration of water through its iron rich media, where dissolved pollutants (particularly dissolved phosphorus (DP)) adsorb to the iron filings. DP is then retained within the media while the stormwater can seep into an underdrain. Lastly, the underdrain discharges downstream of the wet pond. IESFs can be installed without ponds, although it is recommended that some form of pretreatment is available to remove sediment, which can deposit within the pore space of the filter and clog the practice over time.

There is currently no drainage practice input for these features in WinSLAMM or SWAT. As they behave similarly to rain gardens, they can be modeled as such. But, as they often operate in tandem with stormwater ponds, estimating when and how much water and pollutants they will receive can be problematic. To estimate flow into the devices, SWAT was utilized to determine the proportion of streamflow contributed from groundwater and overland flow. The IESF is designed to only come online during storm events. SWAT determines flow to stream systems based on contributions from three regions:

Total Flow = Groundwater Input + Overland Flow + Lateral Flow

where lateral flow is input to the stream from the region between the top of the water table and ground surface. It is assumed that overland and lateral flow is supplied by precipitation events. With this in mind, stream baseflow is sustained by groundwater alone. SWAT model runs determined that stormflow contributed 29-35% of total flow across all years. The inputs from overland and lateral flow were used as the volumetric input into the IESF. WinSLAMM was then utilized to determine what percentage of this stormflow could be treated by the filter. Stormflow input into the practice is most dependent upon the volume which can be passed through the system's underdrains. Stormflow treated by the device is a function of total area, depth, infiltration rate, and engineered media characteristics. WinSLAMM input used for this analysis is listed in Table 37.

TP load in stream systems occurs during both baseflow and storm events in two predominant species, dissolved inorganic (usually orthophosphate, generally grouped as DP in this analysis) and particulate organic. The proportion of phosphorus load supplied by storm events was determined by comparing baseflow and storm event TP loads in similar streams of central MN. These data yielded approximately 70% of TP as storm event based (ACD 2013).

To determine what percentage of phosphorus load was in dissolved species (which is what the IESF can treat), a meta-analysis by Hart et al. (2004) was utilized. This study discovered a large range of DP load as a percentage of TP load in stormflow events of rural streams. Their findings for catchments comparable to the Lake Independence and Lake Sarah basins are summarized in Table 38. For a predominantly agrarian (row-crop, hay, and pasture) watershed, DP load is most dependent upon average catchment slope, as greater changes in elevation lead to increases in sediment (and particulate phosphorus) erosion and export as compared to DP export. Thus, for lowland watersheds such as Lake Independence and Lake Sarah, where mean slope is less than 7%, DP can compose between 47-62% of the TP load (Table 38). For simplicity, we used 50% as the fraction of DP in TP load.

Lastly, field tests of installed sand trenches conducted by the University of Minnesota concluded that a sand media mixed with 5% iron filings is capable of retaining 80% (or more) of the DP load of stormwater flowing through the media (Erickson and Gulliver, 2010). Thus, TP retention by the IESF can be determined by the equation,

$$P_{RET} = 0.8 * P_{IN} * q_S$$

where P_{RET} is the DP load removed by the IESF, P_{IN} is the DP input, and q_S is the fraction of stormflow volume passing through the IESF. q_S is a function of the storm event duration and intensity, stormwater pond storage (if in-line with a pond), and IESF storage volume (bottom area, top area, and depth). The 0.8 multiplier assumes the IESF removes only 80% of the DP load. P_{IN} assumes that 70% of the TP load is available during storm events and that only 50% of TP load is in dissolved form, to be treated by the IESF.

Table 37: WinSLAMM Input Parameters for Iron Enhanced Sand Filters

Parameter	Unit	Value
Top Area	sq-ft	varies
Bottom Area	sq-ft	varies
Total Depth	Ft	5.0
Native Soil Infiltration Rate	in/hr	0.0
Infiltration Rate Fraction-Bottom (0-1)	-	1
Infiltration Rate Fraction-Sides (0-1)	-	1
Rock Filled Depth	Ft	0.5
Rock Fill Porosity (0-1)	-	0.3
Engineered Media Infiltration Rate	in/hr	8.0
Engineered Media Depth	Ft	1.5
Engineerd Media Porosity (0-1)	-	0.3
Inflow Hydrograph Peak to Average Flow Ratio	-	3.8
Broad Crested Weir Length	Ft	10
Broad Crested Weir Width	Ft	1.0
Height From Datum to Bottom of Weir Opening	Ft	4.0
Underdrain Pipe Diameter	Ft	0.5
Underdrain Invert Elevation Above Datum	Ft	0.01
Number of Pipes at invert elevation	-	100

Table 38: Composition of In-stream Phosphorus Species Across Various Land Uses and Slopes

		Composition of Total Phosphorus		
Land Use Types	Catchment Slope[32]	% Dissolved	% Particulate	Reference
Mixed land uses	Moderately steep	<15	>85	Cooke (1988)
Pasture, mixed land uses	Moderately steep	9-19	81-91	Quin and Stroud (2002)
Row-crop, pasture	Lowland	47	53	Wilcock (1999)
Pasture, mixed land uses	Lowland	50-76	23-50	Davies-Colley and Nagels (2002)
Dairy pasture	Lowland	48-62	48-62	Fleming and Cox (1998)

[32] Moderately steep catchments have mean slopes >25%. Lowland slopes are <25%.

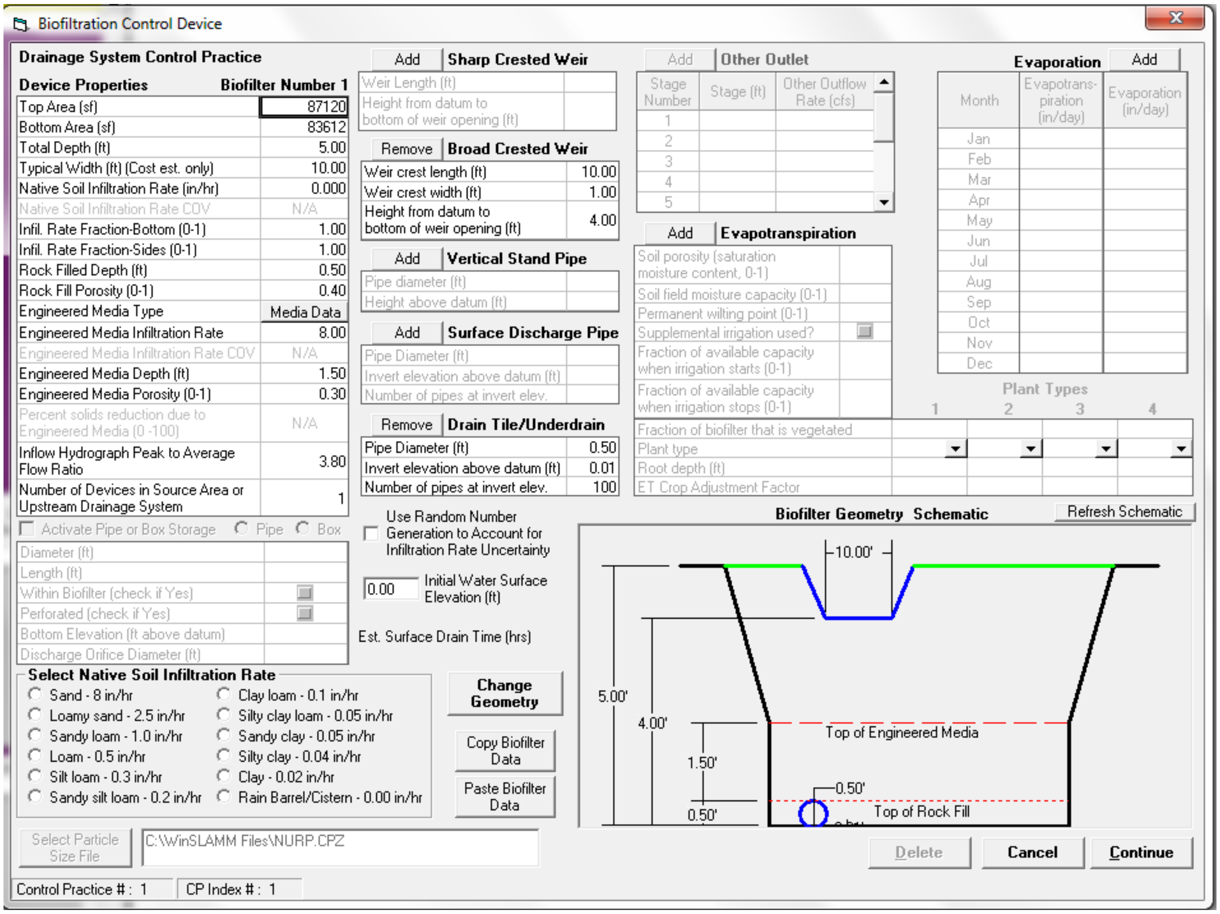


Figure 28: Biofiltration Control Practice Input Screen: IESF (WinSLAMM)

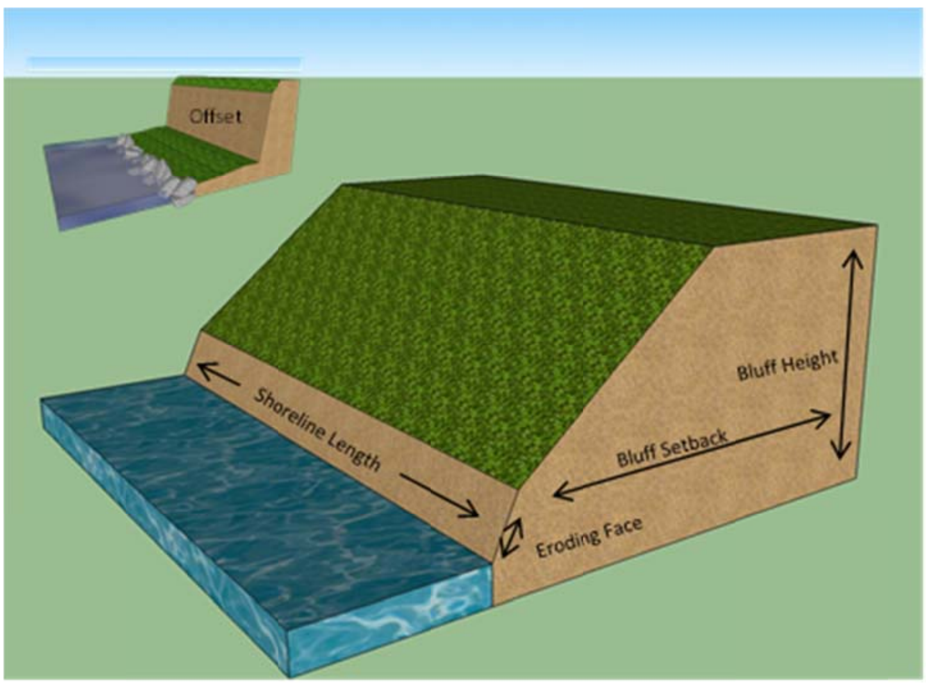
Other Load Estimation Methods

Lakeshore Restorations

An inventory of all active erosion sites was completed in August of 2013 for the entire shoreline of both Lake Sarah and Lake Independence. Instances of erosion were classified according to severity. Erosion severity determinations and soil loss calculations were estimated utilizing the Wisconsin NRCS direct volume method recession rate classifications. Recession rate descriptions were altered slightly to better describe observed field conditions and are shown in Table 39.

Table 39: Lakeshore Recession Rate Classifications

Severity	Lateral Recession Rate (ft/yr)	Description
Offset	<0.01	Erosion offset from the shoreline. Erosion does not appear to be entering water body but bank failure, bluff slumps, and/or seepage visible.
Slight	0.01-0.059	Some bare shore, but active erosion is minimal. Minor or no vegetative overhang. No exposed tree roots.
Moderate	0.06-0.029	Shore is predominantly bare, with some undercutting and vegetative overhang. Some exposed tree roots, but no slumps or slips.
Severe	0.3-0.5	Shore is bare, with vertical slope and/or severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails.
Very Severe	0.5+	Shore is bare, with washouts, vertical slopes, and severe vegetative overhang. Many fallen trees eroding out and changes in cultural features as above. Multiple types of erosion present.



Phosphorus reduction estimates were based upon the Board of Water and Soil Resources Pollution Reduction Estimator, which estimates phosphorus loading based upon a correlation between voided sediment volume and type with soil density averages and phosphorus concentrations.

Soil losses associated with lakeshore restoration projects can be estimated using the equation:

$$\text{Estimated Soil Loss (tons/year)} = \frac{\text{ErodingFace(ft)*RecessionRate(ft/yr)*ShorlineLength(ft)*100(lbs/ft3)}}{\text{2000(lbs/ton)}}$$

For the purpose of this analysis the following assumptions were made;

- Soils were assumed to be silt, the most prevalent type in the area
- Soils had a bulk density of 85 lbs/cu-ft.
- Soils had a TP concentration of 1 lbs/1250 lbs sediment (per page A5 of BWSR manual, BWSR calculator has incorrect correction factor)
- Sediment delivery rates were 100% due to the proximity to the lake

Sediment Type	TSS/TP (lbs/lb)
Sand	1,481
Silt	**1,250**
Clay	1,087
Peat	905

Gully Stabilizations

An inventory of readily identifiable gullies immediately adjacent to the lakes was completed for both Lake Sarah and Lake Independence during the summer and fall of 2013. Near-lake gullies were prioritized because they have a higher sediment delivery rate to the lake and so more benefit to lake water quality will be realized by stabilizing them as opposed to gullies farther from the lakes. Instances of erosion were classified according to severity along each distinct gully segment. Erosion severity determinations and voided soil volumes were estimated utilizing RAP-M Rapids Assessment Point Method: Inventory and Evaluation of Erosion and Sedimentation for Illinois by R. D. Windhorn, Dec. 2000. Recession rate descriptions are shown in the table below.

Table 40: Gully Recession Rate Classifications

Severity	Lateral Recession Rate (ft/yr)	Description
Slight	0.01-0.059	Some bare bank but active erosion not readily apparent. Some rills, but no vegetation overhand. No exposed tree roots.
Moderate	0.06-0.029	Bank is predominantly bare, with some rills and vegetative overhang. Some exposed tree roots. No slumps. Gullies generally V-Shaped.
Severe	0.3-0.49	Bank is bare, with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees. Slumping or rotational slips are present. Some changes in cultural features, such as fencelines out of alignment or pipelines exposed. Gullies become more U-shaped as the lower part of the channel erodes. Knickpoints present in channel bottom.
Very Severe	0.5-2.0	Bank is bare, with rills and severe vegetative overhang. Many exposed tree roots and fallen trees. Slumping of sidewalls quite evident. Gullies are U-shaped, with vertical sidewalls at base of channels. Knickpoints present in channel bottom, with overfalls of 2 feet and greater possible. Soil material often accumulated at base of slopes.

Total sediment and phosphorus reduction estimates were based upon the Board of Water and Soil Resources Pollution Reduction Estimator, which estimates loading based upon a correlation between voided sediment volume and type with soil density averages and phosphorus concentrations. For the purpose of this analysis the following assumptions were made;

- Soils were assumed to be silt, the most prevalent type in the area
- Soils had a bulk density of 85 lbs/cu-ft.
- Soils had a TP concentration of 1 lbs/1250 lbs sediment (per page A5 of BWSR manual, BWSR calculator has incorrect correction factor)
- Sediment delivery rates were 100% due to the proximity to the lake
- Gullies were classified as channelized with no filter strip present

Appendix – Project Budget Estimates

Introduction

The 'Cost Estimates' section on page 16 explains the elements of cost that were considered and the amounts and assumptions that were used. In addition, each project type concludes with budget assumption listed in the footnotes. This appendix is a compilation of tables that shows in greater detail that calculations that were made and quantities used to arrive at the cost estimates for practices where the information provided elsewhere in the document is insufficient to reconstruct the budget. This section includes Gully Stabilizations, Ponds, and Iron Enhanced Sand Filters.

Gully Stabilizations

GS45														
Section	Erosion Severity	Erosion Rate	Gully Lower Area	Erosive Area (20%)	Estimated Sediment Loss	TP	Promo/Admin/Design	Est. Install Cost	Annual Maint.	Project Life	Cost Benefit	Cost Benefit	Restoration Type	cubic feet voided
#		Ft./Yr	Sq.Ft.	Sq.Ft.	Tons/Yr	lbs/Yr	$	$	$	Yrs	$/lb-TP/year	$/1000lb-TSS/year		
1	Moderate	0.13	957	191	1.06	1.7	$ 6,500	$ 12,441	$ 96	20	616	493	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	25
2	Slight	0.03	1068	214	0.27	0.4	$ 6,500	$ 13,884	$ 107	20	2584	2067	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	6
Totals			2025	405	1.33	2.1	$ 13,000	$ 26,325	$ 203	20	1019	815		31
Other: sediment deliver rate of 100%, channelized gully, no filter strip present, silty soil, soil density of 85lbs/cu ft, $65/sq. ft. erosive area cost of treatment														

GS46														
Section	Erosion Severity	Erosion Rate	Gully Lower Area	Erosive Area (20%)	Estimated Sediment Loss	TP	Promo/Admin/Design	Est. Install Cost	Annual Maint.	Project Life	Cost Benefit	Cost Benefit	Restoration Type	cubic feet voided
#		Ft./Yr	Sq.Ft.	Sq.Ft.	Tons/Yr	lbs/Yr	$	$	$	Yrs	$/lb-TP/year	$/1000lb-TSS/year		
1	Slight	0.03	1166	233	0.30	0.5	$ 6,500	$ 15,158	$ 117	20	2521	2017	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	7
2	Severe	0.4	1893	379	6.44	10.3	$ 6,500	$ 24,609	$ 189	20	169	136	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	151
3	Severe	0.4	828	166	2.82	4.5	$ 6,500	$ 10,764	$ 83	20	210	168	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	66
4	Moderate	0.13	198	40	0.22	0.4	$ 6,500	$ 2,574	$ 20	20	1353	1082	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	5
Totals			4085	817	9.77	15.6	$ 26,000	$ 53,105	$ 409	20	279	223		230
Other: sediment deliver rate of 100%, channelized gully, no filter strip present, silty soil, soil density of 85lbs/cu ft, $65/sq. ft. erosive area cost of treatment														

GS50														
Section	Erosion Severity	Erosion Rate	Gully Lower Area	Erosive Area (20%)	Estimated Sediment Loss	TP	Promo/Admin/Design	Est. Install Cost	Annual Maint.	Project Life	Cost Benefit	Cost Benefit	Restoration Type	cubic feet voided
#		Ft./Yr	Sq.Ft.	Sq.Ft.	Tons/Yr	lbs/Yr	$	$	$	Yrs	$/lb-TP/year	$/1000lb-TSS/year		
1	Very Severe	1.5	6965	1393	88.8	142.1	$ 6,500	$ 90,545	$ 697	20	39	31	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	2090
2	Severe	0.4	2106	421	7.2	11.5	$ 6,500	$ 27,378	$ 211	20	166	133	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	168
3	Very Severe	1.5	7966	1593	101.6	162.5	$ 6,500	$103,558	$ 797	20	39	31	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	2390
4	Moderate	0.13	3197	639	3.5	5.7	$ 6,500	$ 41,561	$ 320	20	482	385	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	83
5	Severe	0.4	3562	712	12.1	19.4	$ 6,500	$ 46,306	$ 356	20	155	124	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	285
6	Slight	0.03	3209	642	0.8	1.3	$ 6,500	$ 41,717	$ 321	20	2086	1669	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	19
7	Severe	0.4	5748	1150	19.5	31.3	$ 6,500	$ 74,724	$ 575	20	148	119	Grade stabilization rock cross vanes, rip rap, bioengineering, revegetation	460
Totals			32753	6551	233.5	373.7	$ 45,500	$425,789	$ 3,275	20	72	57		5495
Other: sediment deliver rate of 100%, channelized gully, no filter strip present, silty soil, soil density of 85lbs/cu ft, $65/sq. ft. erosive area cost of treatment														

Ponds

NP47 Pond Budget	Unit	Qty	Rate	Total
Depth	ft	10		
Area	sq ft	17424		
Admin/Promo	hr	85	$ 73.00	$ 6,205.00
Design/const. oversight	ea	1	$ 25,000.00	$ 25,000.00
Annual Maintenance	ea	30	$ 480.00	$ 14,400.00
Installation				$ 99,934.67
Mobilization	ea	0.4	$ 10,000.00	$ 4,000.00
Traffic Control	ea	1	$ 2,000.00	$ 2,000.00
Temp Erosion	ea	1	$ 800.00	$ 800.00
Excavation	cy	6453.33	$ 12.00	$ 77,440.00
Outlet Structure	ea	1.86667	$ 4,000.00	$ 7,466.67
Top Soil	cy	129.067	$ 30.00	$ 3,872.00
Revegetation	sq ft	17424	$ 0.25	$ 4,356.00
Land Acquisition	acre	0.48	$ 20,000.00	$ 9,600.00
IESF	sq ft	0	$ 15.00	$ -
Total cost of project				$ 155,139.67

RP108 Pond Budget	Unit	Qty	Rate	Total
Depth	ft	8		
Area	acre	12		
Admin/Promo	hr	85	$ 73.00	$ 6,205.00
Design/const. oversight	ea	5	$ 10,000.00	$ 50,000.00
Annual Maintenance	ea	30	$ 1,200.00	$ 36,000.00
Land Acquisition	acre	14.4	$ 20,000.00	$ 288,000.00
Installation				$ 2,872,546.00
Mobilization	ea	1	$ 10,000.00	$ 10,000.00
Traffic Control	ea	1	$ 6,000.00	$ 6,000.00
Temp Erosion	ea	1	$ 2,000.00	$ 2,000.00
Excavation	cy	194810	$ 12.00	$ 2,337,720.00
Outlet Structure	ea	67.32	$ 4,000.00	$ 269,260.00
Top Soil	cy	3896	$ 30.00	$ 116,886.00
Revegetation	sq ft	522720	$ 0.25	$ 130,680.00
Total cost of project				$ 3,540,751.00

RP109 Pond Budget	Unit	Qty	Rate	Total
Depth	ft	8		
Area	acre	12		
Admin/Promo	hr	85	$ 73.00	$ 6,205.00
Design/const. oversight	ea	5	$ 10,000.00	$ 50,000.00
Annual Maintenance	ea	30	$ 1,200.00	$ 36,000.00
Land Acquisition	acre	14.4	$ 20,000.00	$ 288,000.00
Installation				$ 2,872,133.33
Mobilization	ea	1	$ 10,000.00	$ 10,000.00
Traffic Control	ea	1	$ 6,000.00	$ 6,000.00
Temp Erosion	ea	1	$ 2,000.00	$ 2,000.00
Excavation	cy	193600	$ 12.00	$ 2,323,200.00
Outlet Structure	ea	71.02	$ 4,000.00	$ 284,093.33
Top Soil	cy	3872	$ 30.00	$ 116,160.00
Revegetation	sq ft	522720	$ 0.25	$ 130,680.00
Total cost of project				$ 3,540,338.33

RP110 Pond Budget	Unit	Qty	Rate	Total
Depth	ft	8		
Area	acre	12		
Admin/Promo	hr	85	$ 73.00	$ 6,205.00
Design/const. oversight	ea	5	$ 10,000.00	$ 50,000.00
Annual Maintenance	ea	30	$ 1,200.00	$ 36,000.00
Land Acquisition	acre	14.4	$ 20,000.00	$ 288,000.00
Installation				$ 2,925,040.00
Mobilization	ea	1	$ 10,000.00	$ 10,000.00
Traffic Control	ea	1	$ 6,000.00	$ 6,000.00
Temp Erosion	ea	1	$ 2,000.00	$ 2,000.00
Excavation	cy	193600	$ 12.00	$ 2,323,200.00
Outlet Structure	ea	84.25	$ 4,000.00	$ 337,000.00
Top Soil	cy	3872	$ 30.00	$ 116,160.00
Revegetation	sq ft	522720	$ 0.25	$ 130,680.00
Total cost of project				$ 3,305,245.00

Iron Enhanced Sand Filters

IESF 112 Budget	Unit	Qty	Rate	Total
Depth	ft	8		
Area	acres	0.5		
Admin/Promo	hr	85	$ 73	$ 6,205
Design/const. oversight	ea	2	$ 10,000	$ 20,000
Annual Maintenance	ea	30	$ 50	$ 1,500
Land Acquisition	acre	0.6	$ -	$ -
IESF	sq ft	21780	$ 15	$ 326,700
Total cost of project				$ 354,405

IESF 113 Budget	Unit	Qty	Rate	Total
Depth	ft	8		
Area	acres	2		
Admin/Promo	hr	85	$ 73	$ 6,205
Design/const. oversigh	ea	2	$ 10,000	$ 20,000
Annual Maintenance	ea	30	$ 200	$ 6,000
Land Acquisition	acre	2.4	$ 20,000	$ 48,000
IESF	sq ft	87120	$ 15	$ 1,306,800
Total cost of project				$ 1,387,005

IESF 114 Budget	Unit	Qty	Rate	Total
Depth	ft	8		
Area	acres	1.5		
Admin/Promo	hr	85	$ 73	$ 6,205
Design/const. oversigh	ea	2	$ 10,000	$ 20,000
Annual Maintenance	ea	30	$ 150	$ 4,500
Land Acquisition	acre	1.8	$ 20,000	$ 36,000
IESF	sq ft	65340	$ 15	$ 980,100
Total cost of project				$ 1,046,805

IESF 115 Budget	Unit	Qty	Rate	Total
Depth	ft	8		
Area	acres	2		
Admin/Promo	hr	85	$ 73	$ 6,205
Design/const. oversigh	ea	2	$ 10,000	$ 20,000
Annual Maintenance	ea	30	$ 200	$ 6,000
Land Acquisition	acre	2.4	$ 20,000	$ 48,000
IESF	sq ft	87120	$ 15	$ 1,306,800
Total cost of project				$ 1,387,005