Demonstrate and Evaluate Saturated Buffers at Field Scale to Reduce Nitrates and Phosphorus from Subsurface Field Drainage Systems

Mississippi River Basin - Water Management

PROJECT COLLABORATORS:

Agricultural Drainage Management Coalition Member Companies

Agricultural Drainage Management Systems Task Force

Dr. Dan Jaynes, National Laboratory for Agricultural & the Environment

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A Saturated Buffer in Illinois (IL-3)

Demonstrate and Evaluate Saturated Buffers at Field Scale to Reduce Nitrates and Phosphorus from Subsurface Field Drainage Systems

Project Director:
Stephen W. Baker
Agricultural Drainage Management Coalition
Springfield Plastics, Inc. 7300 W State Rte. 104
Auburn, IL 62615

Primary Authors:
Nathan Utt, Lead Engineer, Ecosystem Services Exchange
Dan Jaynes, Research Soil Scientist, USDA-ARS
Jessica Albertsen, Biological Science Research Technician, USDA-ARS

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Project Duration: September 15, 2011 – September 15, 2014, a 1-year, no-cost extension was granted for the project that extended until September 15, 2015. The final report is due 90 days after the last day of the project (December 15, 2015).
Number of Sites: 9

FSA Order Number: AG-64SS-P-12-0051 and AG-3151-P-15-0168

Project Duration: September 28, 2012 – September 28, 2015
Number of Sites: 6

Date of Submission: December 15, 2015

List of deliverables/products of project activities:

1. Fifteen (nine CIG-funded, six FSA-funded) field evaluations using saturated buffers in four states (IA, IL, IN, MN) to evaluate the environmental effectiveness and performance as part of a drainage management system.
2. Field evaluations that include operation timing, climatic conditions, nutrient reductions, and reduced drainage outflows.
3. Optimize nutrient management, reduce downstream loads, maintain agricultural productivity, and enhance wildlife habitat using water management in the Midwest.
4. Establish outreach materials to distribute to producers and technical agencies using print and electronic communications to increase awareness and availability of drainage systems water management data and information.

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Demonstrate and Evaluate Saturated Buffers at Field Scale to Reduce Nitrates and Phosphorus from Subsurface Field Drainage Systems

Executive Summary

Nutrient loss through subsurface drainage systems is a major concern throughout the Midwest. This project sought to demonstrate and evaluate the effectiveness of a new conservation practice commonly referred to as a Saturated Buffer (SB). By hydrologically reconnecting a subsurface drainage outlet with an edge-of-field buffer this practice takes advantage of both the denitrification and plant nutrient uptake opportunities that are known to exist in buffers with perennial vegetation as a way to remove nutrients from the drainage water. The USDA-NRCS developed an interim practice standard (739 – Vegetated Subsurface Outlet) in conjunction with this project.

The objectives, or deliverables, of this project were 1) establish 15 saturated buffers (nine CIG-funded, six FSA-funded) in four states, 2) monitor drain flows, quantify nutrient reductions, and evaluate the impact of climate and operation timing at all 15 sites, 3) optimize management of and reduce nutrient transport from SB systems while maintaining agricultural productivity and enhancing wildlife benefit, 4) establish outreach material and distribute to producers and technical agencies.

Deliverable 1: This project installed a total of 15 SB's in Iowa, Illinois, Indiana, and Minnesota. These sites intentionally included a variety of soil types, buffer vegetation, surface topographies, and ditch/stream channel depths. This variety was included to evaluate the effectiveness of this practice if it were to be adopted on a regional scale. The original timeline included having all nine CIG-funded sites installed in 2012, of which seven were. The remaining two sites, as well as all six FSA-funded sites, were installed by June 2013. This delay in installation caused a delay in the start of full-scale monitoring at all sites.

Deliverable 2: Flow monitoring equipment was installed at all 15 sites. Extensive data logger and sensor malfunctions plagued the project in the initial stages. As a result, consistent flow measurements did not begin until Fall 2014. A one-year, no-cost extension was granted to compensate for this and allow for more data collection. Water sampling was irregular in 2013, but most sites had consistent samples collected during periods of tile flow in 2014 and 2015. The impacts of climate and operation timing were also observed in these years.

Deliverable 3: Data gathered as part of Deliverable 2 were used to calculate nutrient load reductions at the sites for 2014 and 2015. Field observations, with input from the producer, were used to maintain a balance between optimizing SB performance and maintaining agricultural productivity. As a result, the nutrient reduction capability at some SB sites was greatly reduced in order to prevent potential crop damage due to flooding. This was particularly a concern at sites where the buffer and cropped area were at similar ground elevations. While no direct measurements were taken, there was no observed conflict between the ability of the buffer systems to provide enhanced wildlife habitat and also provide water quality treatment.

Deliverable 4: There were 25+ field days and presentations given in association with this project. These events targeted producers, drainage contractors, government and technical agencies, as well as the general public. Magazine and news articles were also published that discussed this project and explained the potential benefits of a SB system. While some handout material was created for the field

days and presentations, a more comprehensive set of publications are planned to be distributed after the submission of this report.

Of the 15 SB sites that were installed and monitored, four of them (IA-1, IA-3, IL-3, and IL-5) showed substantial nitrate removal. IA-1 performed well over 2013-2015 and removed a total of 301 lbs of nitrate-N over 2 ½ years. In 2015, IA-3 removed 408 lbs, IL-3 removed 68 lbs and IL-5 removed 161 lbs of nitrate-N. These locations met our expected requirements for soil characteristics of successful saturated buffers. These project sites had an average installation cost of $3,700. Assuming a 50 year lifespan and 4% inflation rate, the cost of nitrate removal ranged from $0.50 - $4.64/lbs-N with an average cost of $2.13/lbs-N removed. This makes them competitive with other field-edge practices for nitrate load reduction.

Besides these four sites, IL-2, IL-4, and MN-3 showed promising results in at least one year. The site characteristics at IL-2 made tile monitoring difficult and treated flow was estimated using DRAINMOD. Making some simplifying assumptions we computed a sizeable (293 lbs N) nitrate removal at this site in 2014. IL-4 and MN-3 also had good nitrate removal in 2014 but limited removal in 2015. IL-4 also met all of our other criteria for a well-functioning SB and we feel that this site shows promise and may prove to be very effective in removing nitrate if more reliable flow data can be obtained.

Of the remaining sites, we had insufficient data for MN-1, IL-1, and IN-3 to determine their nitrate removal performance. However, given that IN-3 and MN-1 are susceptible to flooding at the control structure, their performance may be difficult to determine using the techniques used in this evaluation. The other five sites, IA-2, IN-1, IN-2, MN-2 and MN-4 did not show positive results for being used as saturated buffers for removing nitrate. Reasons for their failure vary, but could include coarse soil layers at depth which prevented the creation of an elevated water table, inadequate soil carbon levels at the depth of the raised water table, improper design or installation, and high water levels in the ditch that prevented the water from moving through the buffer. Even though these sites failed to demonstrate nitrate removal, they provided valuable information for improving the site selection process.

There were no consistent trends at the monitored buffers that indicated that dissolved phosphorus in the tile water was removed by the saturated buffers. Therefore, we conclude that the saturated buffer practice as implemented in this project cannot appropriately be assumed to treat phosphorus-related water quality concerns.

Soil samples were collected at all sites near the beginning and end of this project. There were no detected changes in soil organic matter or soil phosphorus that were attributable to the SB practice.

Two of the SB sites were selected for monitoring any change in streambank stability as a result of implementing a SB. The ditch channels, which had average depths of 6 and 10 ft, at these sites were intensively surveyed near the start and end of the project. Neither of these ditches, which had relatively stable banks prior to implementing the practice, showed any significant movement as a result of the SB practice. We conclude that on ditches/streams with stable banks the SB will not cause increased sloughing or other stability issues. Ditches/steams with highly unstable banks prior to implementation could still be considered but more thorough planning and design would be warranted.

The data from this study confirm that, when proper site conditions and design considerations are met, the SB practice can be an effective method for reducing nitrate transport from subsurface drainage systems. Phosphorus loads, however, appear to be generally unaffected by this practice. It is recommended that the guidelines in the NRCS Practice 739 be updated to include more refined site selection and design criteria that will lead to practice implementation at sites more likely to provide a water quality benefit. It is also recommended that additional monitoring of some select SB sites be conducted to better quantify nutrient removal effectiveness and refine management strategies. Testing of different SB design methods could also help overcome some of the site-specific hurdles and aid with effective widespread adoption of the practice.

Introduction

Summary of the work to be performed:

Artificial subsurface drainage systems have been in use by farm producers for over 150 years in the Mississippi River Basin. These systems facilitate crop production in areas that would be otherwise unsuitable, and increase yield in others. Almost invariably, they were designed for the sole purpose of quickly removing excess water from the plant root zone to prevent wet stress and to improve crop yields, but with no consideration of their effects on water quality.

In this project we demonstrated diverting tile water through grass buffers along ditches and streams to reduce nutrient transport and improve water quality from agricultural subsurface drainage systems. This demonstration project retrofitted existing buffers to demonstrate the effectiveness of this practice and help develop criteria necessary for widespread adoption, as no such guidance currently exists.

Saturated Buffers (SB) are constructed by installing tile lines under the buffered area perpendicular to the tile drainage outlet. A control structure is installed in the main close to the outlet. The control structure can be managed to raise the water table under the buffer to allow the perennial vegetation to utilize the nutrient rich water and to increase denitrification, which is the conversion of nitrate (NO_3) to atmospheric nitrogen (N_2). Under this system, the buffer can reduce overland flows and sedimentation, while reducing nutrient transport from subsurface outflows.

There were five main focus areas for this project: (1) to engage producers in demonstration of the multiple benefits of saturated buffers on farm economics, soil quality, and water quality and quantity; (2) to test the magnitude of the nutrient reduction benefits that can be achieved with saturated buffers; (3) to improve the water and nutrient accounting for these systems; (4) to assess soil organic matter changes; and (5) to disseminate this information to the farming community.

Field evaluations (Objectives 1 – 4):

In each of the four states, we monitored existing field drainage systems that had been retrofitted for the SB practice to evaluate the environmental effectiveness of saturated or intermittently saturated buffers. All field sites were planted with corn or soybean varieties and with normal pesticides and fertilizer application rates – allowing us to determine the impacts of saturated buffers with a statistically supported methodology.

Flow, water quality, and water table:

Water flow rates from subsurface drainage systems were monitored, and water samples for nitrate (all 15 sites) and phosphorous (10 sites) analysis were taken approximately twice a month during periods of tile flow. Water flow measurements were combined with nitrate and phosphorous concentration measurements to calculate the reduction in nutrient loads resulting from the SB systems. Water quality sample analyses were performed by the National Laboratory for Agriculture and the Environment in Ames, Iowa.

Soil quality:

Sites were monitored for potential changes in soil quality as a result of implementing SB's by measuring soil properties near the beginning and end of the project. The soil quality properties of concern were identified as the % soil organic matter and the soil Phosphorus concentration. Soil texture and pH were also measured to assist with understanding the site characteristics.

Data summary and technology transfer (Objective 4):

A database of the different sites, with their soil, crop, drainage system, slope, climate, and other relevant factors was developed. Results from the different sites were analyzed to explain similarities and differences in effectiveness of the SB practice. One focus was to provide data to NRCS and FSA that will assist them in determining program priorities and payment dollars for SB practices.

The ADMC held a series of field days at producers' farms distributed throughout the region. Local farmers, contractors, industry, and other interested groups were invited to the demonstration site to discuss SB systems in an informal setting. These meetings were held at the actual SB location whenever possible. Additional presentations were given at LICA meetings, government agency training sessions, and other similar events. A full list of recorded field days and presentations is given in Appendix L.

After the final project report has been submitted the ADMC will further develop a comprehensive instructional publication that will be used in conjunction with NRCS efforts, as well as the variety of seminars that will be conducted as a part of this project. However, the publication will be a stand-alone product that will help a producer make SB decisions, evaluate his or her water management efforts, and formulate a solid plan for drainage improvement on their farm. ADMC intends to involve NRCS staff in developing copy, evaluating the message, and in selecting interested parties to develop and distribute the publication. The USDA logo will be prominently displayed on all materials. ADMC will also develop other printed materials to be distributed as columns and inserts to major Midwest farm publications, including, but not limited to the *Farm Journal, Progressive Farmer, Corn/Soybean Digest, Drainage Contractor, and Successful Farming.* These columns will be written from the perspective of a farmer to better convey a variety of Drainage Water Management themes. Finally, ADMC will post on its website where data is gathered and disseminated in a central location. The material will further support the efforts of these practices.

Primary project personnel

Nathan Utt, Lead Engineer, Ecosystem Services Exchange
Andy Mackrill, Conservation Planner, Ecosystem Services Exchange
Dan Jaynes, Research Soil Scientist, USDA-ARS
Kent Heikens, Agricultural Science Research Technician, USDA-ARS
Jessica Albertsen, Biological Science Research Technician, USDA-ARS
Steve Baker, President, Springfield Plastics Inc.
Leonard Binstock, Executive Director (Ret.), ADMC

Water sampling personnel

Ian Olson, Centrol Crop Consulting
Tom Johnston, Dodge County, Minnesota SWCD
Kent Heikens, USDA-ARS
Karen Wilke, The Nature Conservancy
Roy Becker, Becker Tiling
Rich Stewart, Rock Island County, Illinois SWCD
Tim McMahon, The Agriculture Watershed Institute
Dan Baker, Springfield Plastics, Inc.
Josh Cain, Cain's Homelike Farms
Dan Perkins, Perkins' Good Earth Farm

Project collaborators:

Agricultural Drainage Management Coalition (ADMC) member companies
- Advanced Drainage Systems
- Agri Drain Corp
- Ecosystem Services Exchange
- FRATCO
- Northern Natural Gas
- Plastics Pipe Institute
- Prinsco, Inc
- Springfield Plastics, Inc
- Trimble

USDA-ARS, National Laboratory for Agriculture and the Environment (NLAE)

NRCS – CIG Funding

Total project cost: $391,344.00

Total NRCS funds requested: $195,623.00

Total In-Kind and Cash Contributions: $195,721.04

FSA Funding

Total project cost: $274,639.70

Total FSA funds contracted: $204,285.50

Total In-Kind and Cash Contributions: $70,354.20

ARS-USDA-NLAE

Analytical costs: $8,022

Background

Nutrient transport from agriculture lands is of major concern in the upper Midwest. Eutrophication of fresh water bodies, which is primarily attributed to phosphorus, raises concerns in both the urban and rural communities. The hypoxic zone in the Gulf of Mexico has also received national attention. Typically in marine systems eutrophication is associated principally with nitrates.

Many of the row-crop agriculture fields in the Midwest are located adjacent to ditches, streams, rivers and lakes. Producers have used grassed buffers along many of the water systems to protect them from sediment due to overland flows. However, they provide limited protection from subsurface flows that may contain excess nitrates or phosphorus, especially in tile-drained landscapes.

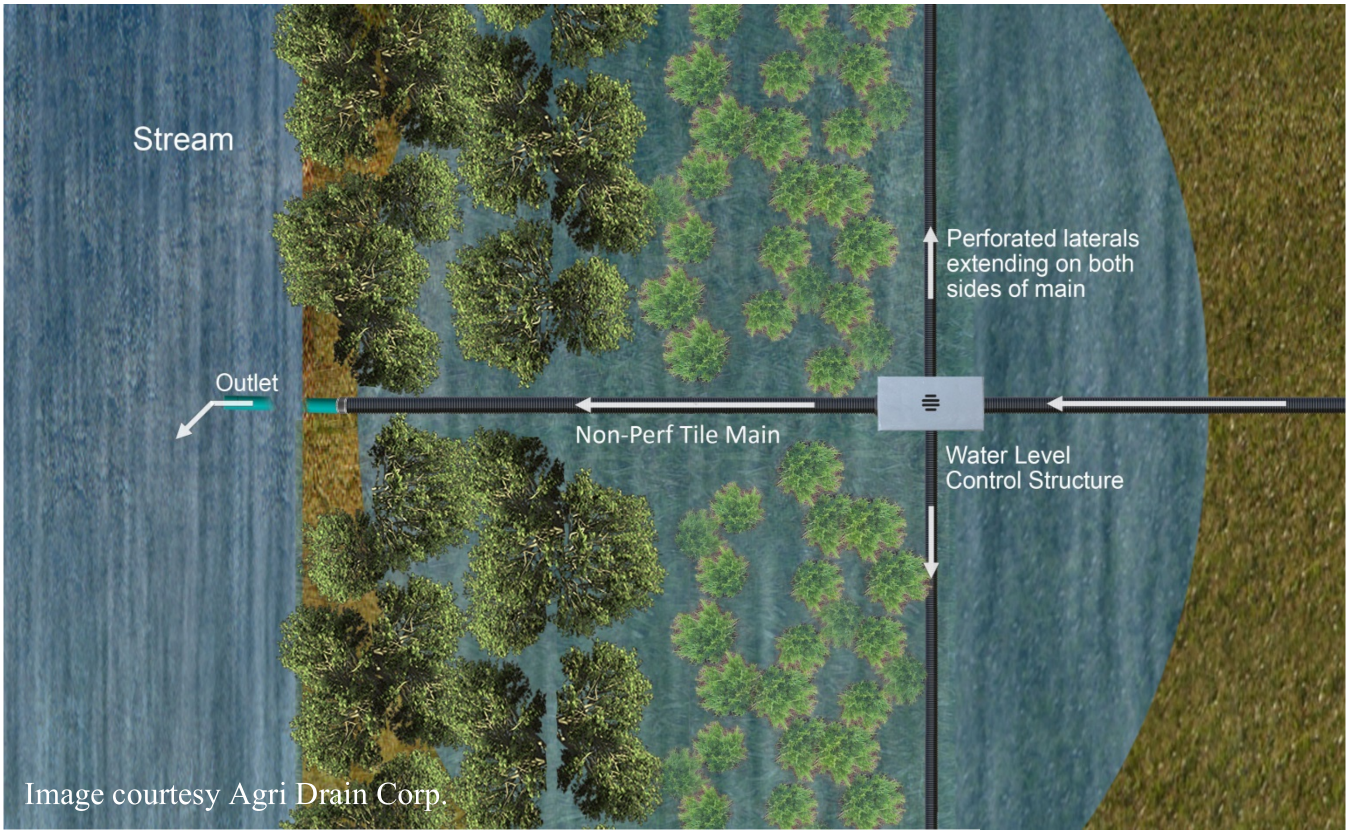
While the first steps to reducing nutrient transport through the tile water are typically accomplished through agronomic-related practices, such as fertilizer rate and timing, in-field and edge-of-field conservation practices related specifically to subsurface drainage water have also been developed. These practices include Drainage Water Management (DWM), denitrifying bioreactors, and enhanced or created wetlands. While these conservation practices have proven to be effective for reducing nutrient loading from tile-drained fields, adoption has been limited due to the cost of implementation, grower knowledge of the practices, and grower confidence on how the practices will fit into their farm operation. Continued development of innovative, lower-cost practices is needed to meet the water quality issues facing the Midwest region. Continued demonstration of these practices will be critical in helping landowners and farm operators build the awareness of and confidence in these practices that will be needed for broad adoption.

The Agricultural Drainage Management Coalition (ADMC) is a nation-wide group of agricultural, industry, and environmental interests that have come together to promote drainage water conservation practices. The ADMC includes over 60 key stakeholders, including individual farmers, industry manufacturers, and environmental groups like The Sand County Foundation. The Agricultural Drainage Management Systems Task Force (ADMSTF) is a multi-agency and university collaboration that has met regularly since 2003 to develop a national effort for implementing improved drainage water management practices and systems that will enhance crop production, conserve water, and reduce adverse off–site impacts on water quality and quantity.

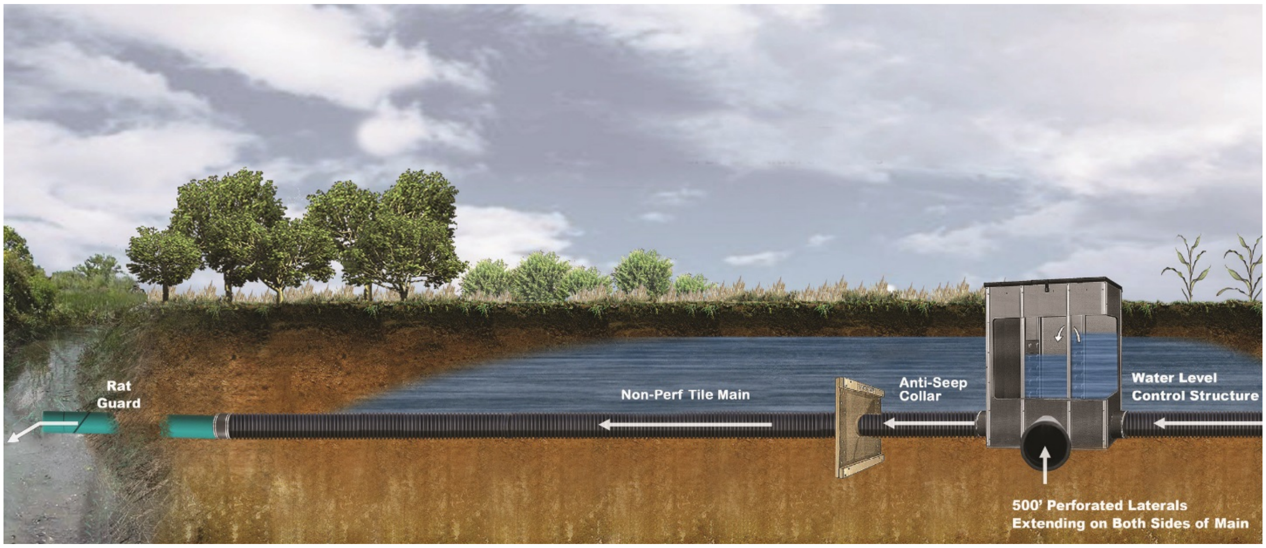
Review of Materials and Methods

Riparian buffers have been shown to remove nitrates from subsurface flow with varying levels of efficiency (Mayer et al, 2005). Large areas of the Midwest are intensively tile drained and it is assumed that many of the vegetated buffers adjacent to waterways are being under-utilized because the tile outlets quickly move large amounts of subsurface flow past the buffer and into the receiving waterway without any opportunity for treatment by the buffer. The goal of a Saturated Buffer (SB) system is to hydrologically reconnect the buffer with the tile flow. By doing this we are able to capitalize on the water treatment capacity of the buffer and use it to remove nutrients from the tile water, thereby improving the water quality in the receiving water bodies. This treatment method is not currently being utilized in the Midwest.

A SB system works by diverting tile water into the subsoil of the buffer and then letting it move horizontally as shallow groundwater through the buffer and into the receiving water body, such as a ditch or stream. In a typical system this is accomplished by intercepting the tile main as it enters the buffer. An additional tile, referred to as a distribution line, intercepts the main and runs underneath the buffer and parallel to the receiving water body. A control structure is used to create an elevated water table within the buffer, which brings the tile water into the more biologically rich area of the soil where nutrient removal is more likely to occur. This raised water table also creates the hydraulic gradient needed to move the water from the distribution area into the receiving water body. As the water moves into the soil in the buffer the nitrates are removed, it is hypothesized, by both plant uptake and denitrification, with the latter being thought to be the more dominant pathway. It is possible that dissolved phosphorus can also be removed by SB systems by either plant uptake or otherwise binding to the soil matrix.



An aerial view of a theoretical saturated buffer



A side view of a theoretical saturated buffer

In terms of nitrate removal through denitrification, a SB operates under the same principles as denitrifying bioreactors (NRCS Practice 605). In both cases tile water is diverted through an area that will encourage denitrification and the speed or rate at which the water moves through the treatment area can be manipulated with water control structures. While a bioreactor utilizes a woodchip trench to provide a carbon food source for the denitrifying microbes a SB uses the carbon already present in the soil as the food source. This allows for potentially similar nutrient removal to occur without the cost of digging the large trench and filling with wood chips that are generally trucked in. The greatly reduced cost of implementation could prove to a significant in allowing this practice to receive widespread implementation.

Prior to beginning this regional SB demonstration project a pilot SB was installed and monitored near Story City, Iowa by USDA-ARS National Laboratory for Agriculture and the Environment (NLAE) and Iowa State University. Early results from this site looked very promising for the practice (Jaynes and Isenhart, 2014). Over a two-year period they observed that over 50% of the tile flow was diverted through buffer, with the remaining flow bypassing the treatment system and exiting through the traditional outlet. Of the water diverted through the buffer all measureable nitrates were completely removed. The goal of this demonstration project was to test if similar results would be obtained at other locations with varying site and climate characteristics.

To accomplish the goals of this demonstration project fifteen monitoring sites were selected in four different states (IA, IL, IN, and MN). When selecting the sites we intentionally chose a variety of site characteristics, recognizing that not all were “ideal”. This allowed us to demonstrate the effectiveness of the practice if implemented at a large scale. This also afforded us the opportunity to explore why some sites had SB systems that were more effective at removing nutrients than others, which could lead to better site selection and design criteria for the NRCS and other agencies.

All SB sites used in this project were retrofits to existing tile and buffer systems. In situations where the field elevation at the site was sufficiently higher than the buffer elevation there was no need for the landowner to change any of the stop log elevations in the SB control structure. At these sites the landowners/operators saw no noticeable change in how they managed their land, except for being careful not to hit the control structure and monitoring equipment with a mower or other implement.

Sites where the field and buffer elevations were more similar required slightly more management by the landowner/operator. In these conditions the stop logs in the SB control structure had to be managed at time intervals similar to a Drainage Water Management system (NRCS Practice 554). Overall, time and management requirements for this practice were fairly minimal.

The following table and map show the locations for the fifteen sites used in this project and summarize some key site characteristics, including the installation date of the SB. More detailed site descriptions and maps are given in Appendix A.

Lessons Learned: Site Selection

One lesson learned was to thoroughly search for all tile outlets that exist within the area of the proposed SB. Failure to properly locate and incorporate these outlets into the SB system resulted in decreased system efficiency. The following list contains some insights about the site selection process that we gained.

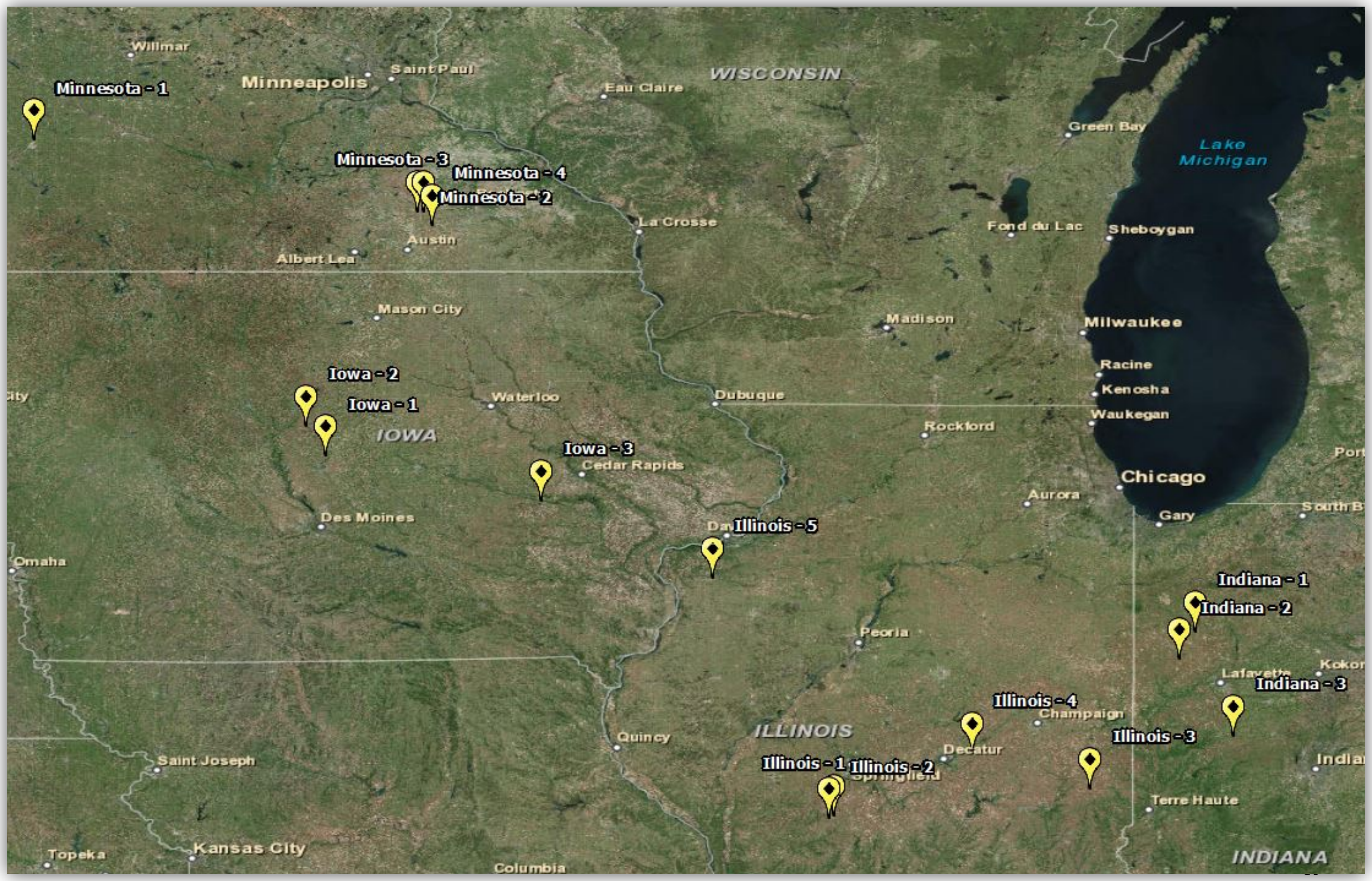
1. Get in the channel and walk the section of ditch/stream where the proposed saturated buffer will go, preferably when the water level is at base flow or lower. Look for and mark all outlets
2. Verify the tile system you are intercepting has a large enough drainage area to justify the cost of installing a saturated buffer treatment system
3. In addition to using soil maps, take soil cores to verify high organic matter and lack of coarse materials within the buffer
4. Sites with shallow ditches that are frequently flooded may not produce satisfactory results

Conservation Innovation Grant (CIG) and Farm Services Agency (FSA) Site Information

Site ID	Project	County	Latitude (N)	Longitude (W)	Installation Date	Well Depth Avg. (ft)	Structure Height (ft)	Outlet Pipe Size (in)	Buffer Length	Drainage area (acres)	Soil Texture	Vegetation Type	Landscape Type (F-field, B-buffer)
IA-1	CIG	Hamilton	42.284949°	93.585772°	11/15/2012	8.29	6	8	1,000	11.6	Clay, Loam	Grass, Some Trees	F –Sloped B- Sloped
IA-2	CIG	Wright	42.510524°	93.731346°	6/14/2013	5.83	6	12	655	48.45	Silty, Clay, Loam	Grass, Some Trees	F- Flat B- Flat
IA-3	FSA	Benton	41.949545°	91.972652°	5/6/2013	6.22	8	6	1,000	148.26	Silty, Clay, Loam	Grass, Some Trees	F –Sloped B- Flat
IL-1	CIG	Sangamon	39.585983°	89.777395°	7/16/2012	6.37	6	8	1,020	26.37	Silty, Clay, Loam	Grass Only	F –Sloped B- Flat
IL-2	CIG	Sangamon	39.566567°	89.814644°	7/2012	6.37	6	12	1,635	62.81	Silty, Clay, Loam	Grass Only	F –Flat B- Flat
IL-3	CIG	Edgar	39.788653°	87.852870°	7/2012	6.88	8	12	585	38.36	Silty, Clay, Loam	Grass Only	F –Flat B- Flat
IL-4	FSA	Piatt	40.054900°	88.740330°	6/2013	6.10	6	5	1,300	17.18	Silty, Clay, Loam	Grass Only	F - Sloped B- Sloped
IL-5	FSA	Rock Island	41.367779°	90.689689°	3/26/2013	6.37	7	12	720	149.33	Silty, Clay, Loam, Complex	Grass Only	F –Sloped B- Sloped
IN-1	CIG	Jasper	40.966909°	87.062940°	7/2012	3.75	6	6	1,155	7.38	Silty, Clay, Loam	Alfalfa, Some Trees	F –Flat B- Flat
IN-2	CIG	Jasper	40.757544°	87.062940°	7/2012	6.48	6	6	1,325	13.99	Silty, Clay, Loam	Grass, Some Tress	F –Flat B- Flat
IN-3	FSA	Montgomery	40.185580°	86.780870°	6/2013	6.40	6	8	1,270	67.23	Silty, Clay, Loam	Grass Only	F –Flat B- Flat
MN-1	CIG	Yellow Medicine	44.654230°	95.778461°	11/1/2012	6.80	8	8	1,085	15.04	Silty, Clay, Loam, Complex	Grass, Shrubs, and Trees	F –Flat B- Flat
MN-2	CIG	Dodge	44.114928°	92.902266°	4/2013	5.33	8	6	920	50.52	Silty, Clay, Loam	Grass Only	F –Sloped B- Flat
MN-3	FSA	Dodge	44.113780°	92.850176°	4/2013	5.68	8	6	1,000	28.26	Silty, Clay, Loam, Complex	Grass, Some Shrubs	F –Sloped B- Flat
MN-4	FSA	Dodge	44.014358°	92.793908°	6/2013	5.99	8	6	850	39.94	Silty, Clay, Loam	Grass Only	F –Sloped B- Flat

**** All sites are on a soybean/corn rotation. A few have a continuous corn rotation**

CIG/FSA Site Locations



Discussion of Quality Assurance

In order to determine the effectiveness of the Saturated Buffer (SB) practice it was essential to monitor the amount of tile water that was diverted into the SB treatment system and then determine the effectiveness of the SB at removing the nutrients (N and/or P) in the tile water as it moved through SB and into the receiving waterway. To do this each site was equipped with monitoring equipment to measure both the amount of tile flow that left the field and the amount of tile flow that bypassed the SB system and discharged into the receiving waters through the existing tile outlet. The difference between these two values represented the amount of tile water that was treated by the SB system.

The effectiveness of the SB at removing the nutrients it received was quantified by first determining the nutrient concentration as it left the field but prior to it entering into the saturated buffer. Additional measurements were taken at set locations within the buffer to measure the change in nutrient concentration as the tile water moved horizontally through the buffer.

In addition to measuring the effectiveness of the SB practice other site parameters were monitored to determine if this practice would cause other changes to occur at the site. These parameters include soil organic matter levels, soil phosphorus concentrations, and streambank stability.

Flow Monitoring:

Sampling Design

Tile flow was monitored using v-notch weirs that were installed inside the three-chambered (two sets of stop logs) water level control structures installed (see image below) as part of the SB practice. The exception to this was the site IL-2, which will be discussed later in this section. The special v-notch stop logs used were manufactured by Agri Drain Corp (ADC). The geometry and thickness of the ADC v-notch is slightly different that a standard 45° v-notch. A rating curve for that specific geometry was developed by Dr. Richard Cooke (University of Illinois Urbana-Champaign). Additional flat-weir rating curves had also been developed for the ADC control structures by Dr. Cooke. During periods when the water level was higher than the top of the v-notch the two equations were combined. The rating curve equations, as well as instructions on to apply them, can be found in Appendix H.

A typical control structure, equipped with water level sensors, v-notch weirs, and splash guard between chambers

The SB distribution line was connected to the chamber between the two sets of stop logs. Tile flow from the field was measured using the v-notch in the first set of stop logs. The v-notch in the second set of stop logs, which was always at least five inches lower the first v-notch, was used to measure the bypass flow. The difference is these two flow values is assumed to equal the amount of flow that was diverted into the SB treatment area. A splash guard was installed between the two sets of stop logs to prevent water from jumping over the middle chamber. It also helped reduce the turbulence in the middle chamber and allowed for more accurate measurements for the bypass flow.

The IL-2 site was set up differently than the other sites. In this field the perforated 12 inch main ran underneath the buffer and was used as the distribution line. A regular two-compartment control structure was used to hold water in the main and encourage water to move through the buffer. While this system could work fine for a typical SB installation, it complicated the monitoring process.

The two-compartment structure used for managing the SB was installed upstream of the final four laterals and used a v-notch stop log as described previously to measure the bypass. An additional structure was installed at the outlet of the tile system and the weir was set such that the bottom of the v-notch was about equal to the top invert of the main. The flow at the outlet structure would then equal the bypass flow from the first structure plus the flow from the final four laterals. It was assumed that all the laterals, which are approximately the same length, would flow the same amount and that the difference in flow between the two structures could be used to estimate the flow from the rest of the system. However, a final review of the flow data from this site yielded no discernable trend between the two structures that could be used to estimate the flow coming from the final four laterals only. As a result we are unable to calculate the amount of flow leaving the field. Nutrient load reductions at this site were calculated using DRAINMOD. Both free draining and managed drainage simulations were run (see Appendix C). The differences between these two scenarios were assumed to represent the amount of flow treated by the SB.

Sampling Procedures

In order to calculate the flow it was important to accurately know the distance from the bottom of control structure to both the water surface (water level) and bottom of the v-notch weir (weir height). The weir height was measured to the nearest 1/16th an inch using a standard tape measure. This distance was measured at the time of installation and whenever the weir height was modified by ESE staff. The weir height was periodically re-measured to ensure that it had not been unknowingly changed. The landowners and other non-ESE support staff were asked to report both the date/time and amount that the weir height changed if they ever made adjustments to their weirs. However, this guidance was not always followed. If a discrepancy was found between the recorded and current weir height the water level data was reviewed to find abrupt changes in the level that were consistent with the change in weir height. If no clear point of change was found, the change in weir height was recorded for the date/time that it was observed by ESE. In cases where unreported weir management were observed it was due to stop logs being removed from the structure. This means that any discrepancy between when the weir height actually change compared to when ESE estimated it changed would result in underestimating flow values.

The water levels were measured to the nearest 0.1 inch and in-field calibration checks were periodically performed by ESE staff to ensure they were reporting accurate data. The level sensors were connected to data loggers equipped with two-way telemetry. The water levels were recorded every six minutes and then transmitted to an ftp site every hour via a built-in cellular modem. The loggers also had adequate capacity to store data in case the transmission capabilities were temporarily lost.

All the sites except IA-1 were initially instrumented with Ibexis logging and telemetry units supplied by Barker-Lemar Companies (West Des Moines, IA). We had significant reliability issues with these loggers. They also relied on either AT&T or T-Mobile modems, which did not have sufficient signal coverage at many of the SB sites. The Ibexis units were eventually replaced with logger and telemetry units provided by ADC. These units utilized a Unitronics V130-J-TR6 10 bit Data Logger for recording data and a Verizon modem for data transfer to the ftp server. It did take some time to get the bugs worked out of the firmware but once that was accomplished they were very reliable and performed well. The dates that the monitoring equipment were installed are given in the following table.

Dates that monitoring equipment were installed at each site. Also included are the dates that the data loggers were updated and that the ultra-sonic level sensor was replaced with a more reliable pressure transducer.

Site ID	Ibexis Logger	Unitronics Logger	Switch to pressure transducer
IA-1	NA	NA	NA
IA-2	6/15/2013	9/13/2013	10/28/2014
IA-3	5/6/2013	8/13/2014	9/26/2014
IL-1	1/24/2013	10/10/2013	11/26/2014
IL-2	1/24/2013	10/10/2013	11/26/2014
IL-3	1/24/2013	10/9/2013	11/25/2014
IL-4	6/11/2013	8/14/2014	11/25/2014
IL-5	6/22/2013	8/14/2014	12/18/2014
IN-1	1/22/2013	8/29/2014	12/17/2014
IN-2	1/22/2013	10/9/2013	12/17/2014
IN-3	7/13/2013	9/10/2014	12/17/2014
MN-1	6/1/2013	5/1/2014	10/23/2014
MN-2	-	9/26/2013	10/24/2014
MN-3	-	9/25/2013	10/24/2014
MN-4	-	9/26/2013	10/24/2014

All sites except IA-1 were initially instrumented with Banner T30 UIPBQ ultra-sonic sensors (±<0.6 inch) for monitoring the water levels in the structures. When connected to the Ibexis loggers these sensors had a considerable amount of noise in the data that they reported. After switching to the new loggers, the noise still persisted and it was determined that this sensor was unsuitable for measuring water levels in this application. All the ultra-sonic sensors were replaced with APG PT500 0-5psi pressure transducers (±<0.7 inch) in October-December 2014. After the switch to the Unitronics loggers and APG pressure transducers the water level data became very reliable. Water levels at IA-1 were measured with AST4510 pressure transducers (American Sensor Technologies) and recorded every hour with a CR10X data logger (Campbell Scientific).

Data Custody Procedures

The ftp site, hosted by Barker-Lemar Companies, was used to store all the data sent by the logger/telemetry units. The ftp site was connected to a website for real-time viewing of the data and there was a place built on the website for recording the weir height and other details related to the flow calculation. Additionally, data that were manually downloaded from the loggers (for periods when the telemetry portion was not operating properly) were also uploaded to the ftp site for storage and viewing.

Calibration

During periodic site visits the water level recorded by the sensors were compared to manual measurements to ensure that the sensors were recording properly. The pressure transducers were also able to be field-calibrated as needed.

Data Processing, Reduction, and Review

Data processing and reduction was performed by PAQ Interactive (Monticello, IL), a third-party vendor who was contracted by the ADMC to perform this service. With some guidance from ESE staff they filtered the noise from the water level data. Standard filtering methods were attempted but not successful so a more manual approach was used. If the data was too noisy to confidently discern between false and real readings then the data were discarded. This process was used primarily for the data collected by the ultra-sonic sensors as the pressure transducer data was in better condition and extensive processing was not needed. After the initial data processing was complete PAQ reduced the data to daily and hourly average water levels. They used this information to calculate the daily and hourly average flow rates through the v-notch weirs.

After PAQ completed the data processing and reduction it was reviewed by ESE staff. They screened the daily average flow values and flagged all data that appeared to be the result of either sensor malfunction or submerged outlet conditions. These judgements were based on site visit records, rainfall information, estimated maximum flowrates for the intercepted tile, and personal knowledge and experience with the site. A record of the flagged data is given in the Appendix B. All flagged data was removed prior to sending it to Dan Jaynes, USDA-ARS NSERL, who performed the final analysis and load calculations.

Water Quality Sampling

Sampling Design

Water samples were collected at all sites to determine the effectiveness of the practice and calculate nutrient load reductions. All nine CIG-funded sites and one FSA-funded were monitored for both nitrate and total dissolved phosphorus (TDP). The remaining five FSA-funded sites were monitored for nitrate only. Local partners were used to collect bi-monthly grab samples during periods of tile flow. A water sampling protocol was established by the ADMC and an instruction sheet was distributed to all sampling partners. A copy of these instruction sheets are provided in Appendix E. The water sampling partners also received on-site training at the start of the project.

Water samples were collected as the tile left the cropped area to determine the pre-treatment nutrient concentration. This sample was collected from the upstream chamber of the control structures. Groundwater samples were collected to measure any changes in nutrient concentration as the water moved through the buffer and into the receiving ditch or stream. An additional sample was collected in the receiving ditch or stream as a way to put the observed nutrient concentrations in context with the local watershed.

Groundwater monitoring wells

Groundwater sampling wells were installed at each site to monitor the change in nutrient concentration as the water moved laterally underneath the buffer. Three well transects were installed at all sites except IA-3, which had four. The transects were equally spaced along the distribution line. Three monitoring wells were installed for each transect. One well was installed at the edge of the stream bank and the other two were installed at equal intervals between the stream bank and the distribution line. Maps with well locations for each site are included in the site descriptions.

The wells comprised of a 5’ section of slotted 2” PVC pipe that was wrapped in a knitted nylon fabric, as shown in the images below. A non-slotted 2’ section of pipe was used to bring the pipe above the ground surface for access. The wells were typically installed between 5.0 and 6.0 ft deep. Some sites had shallower wells due to excessive stones or rock in the soil sublayers. The depths for each well is included in the individual site description (see Appendix A).

Example slotted PVC well with fabric cover and example installation.

The wells were installed using a 4 inch auger. After the PVC pipe was inserted into the hole it was backfilled with sand until 4 – 6 inches from the surface. At this point bentonite was used to seal the top of the well and prevent surface water from flowing into the well. A ¼ inch diameter tube was installed inside each well for pulling the water samples. A shop-vac with special hose was periodically used to remove built-up sediment from within the well.

Sampling Procedures

Samples were collected on a bi-monthly basis during periods of tile flow. Water samples were collected more frequently at IA-1 as it was close to Ames, IA and could be visited by NLAE staff more frequently. After the samples were collected they were placed in insulated containers with freezer packs and shipped next-day to the ARS lab in Ames, Iowa for analysis. See Appendix E for a more thorough description of how samples were collected.

Custody Procedures

All water quality data was processed and stored by staff at the NLAE.

Calibration

No in-field calibration was performed for collecting samples. Laboratory equipment was properly maintained and calibrated using standard procedures.

Sample Analysis

When the water samples arrived at NLAE, the boxes were opened, logged in, and stored in a refrigerator before analysis. Water samples were analyzed for nitrite (NO_2) using a Lachat 8000/8500 (Formally the Zellweger Analytics. Lachat Instrument Division from Milwaukee, WI, now known as HACH from Loveland CO.) Wherein NO_3 was quantitatively reduced to NO_2 concentration determined colorimetrically (Kenney and Nelson, 1982). The method quantitation limit was 0.3 mg N L^{-1} as NO_3. NO_3 and NO_2 are reported together as NO_3. Total dissolved phosphorus (TDP) was measured with a Lachat QuickChem 8000 using QuickChem Method 10-115-01-1F after digestion following EPA method laboratory operations can be found in Appendix D.

Data reduction, analysis, and review

All water quality data were compiled and reviewed by NLAE staff.

Nutrient Load Calculations

Annual mass load of nitrate leaving the field via the tile outlet was calculated by multiplying the nitrate concentration measured in the control box times the volume of water that flowed from the box between water sampling dates and summing over all samples in a calendar year. Nitrate removal within the buffer was computed by taking the nitrate concentration entering the buffer (within the control box) minus the nitrate concentration averaged for the wells in each transect closest to the stream times the flow volume of water that was redirected into the buffer. Annual mass loss of total dissolved phosphorus (TDP) was not computed as there was not a consistent trend in TDP concentration across the buffer at most sites indicating no systematic change in TDP within the buffer.

Soil Measurements

Sampling Design

One objective of the project was to monitor any changes in soil quality that could occur as a result of implementing the SB practice. It was determined that the key parameter of concern was the soil organic matter. The soil phosphorus concentrations were also measured to track any changes. Soil texture analyses were also completed in 2014 to give additional information about the physical conditions at each site. Soil samples were collected in 2014 and again in 2015.

Sampling Procedures

A 4-ft soil core, in 1-ft intervals, was collected at each well location using a 0.688 inch diameter JMC soil probe. Three composite samples were made for each depth interval, one for each of the three well transects. The IA-3 site, which had four well transects, had two composite samples made for each depth interval with the two transects east of the control structure grouped into one sample and the two west transects grouped into the other.

Additional samples were collected in the fall of 2015. All sites were visited and soil cores taken to 8 ft at locations near the three well transects within each buffer. Soil cores were taken with a Giddings hydraulic probe using a 1.5 inch diameter sampling tube fitted with a clear acrylic liner. Intake cores were taken from 0-4 feet and 4-8 feet within each monitoring well transect. Cores were capped, returned to NLAE and refrigerated until analysis. Cores were opened, described by soil layer, and sampled for total N and C and soil texture. Carbon, total N, and texture results were not available for this report, but profile descriptions are included under each site description. The laboratory results from these additional soil samples will be made available at a later time.

Custody Procedures

After the 1-ft composite samples were collected they were placed in a Ziploc bag and stored by ESE staff at room temperature until samples at all sites had been collected. The samples were then delivered to the University of Wisconsin Soil and Forage Analysis Laboratory (Verona, WI) for analysis. The results from the lab analysis were delivered electronically to ESE and were then stored on computers that were regularly backed up.

Calibration and Sample Analysis

The UW soil lab uses the Bray test for determining soil phosphorus concentrations and the Weight-Loss-On-Ignition method for determining the % organic matter. The soil texture was determined using the hydrometer method. More detailed information about the laboratory methods are found in Appendices I-K.

Data Analysis and Review

After the lab measurements were completed they were sent to ESE staff that compiled the data into summary spreadsheets for analysis and review. The change in soil phosphorus concentration and % organic between 2014 and 2015 were compared using the Paired Two-Sample for Means t-Test, which was run using Excel. The data for all sites and transects were pooled together to increase statistical power and then blocked by depth.

Streambank Stability

Detailed transects of the drainage ditches at two of the saturated buffer sites were measured to determine if implementation of the practice had any effect on stream bank stability. These two sites were selected because the ditches were relatively deep and the banks were steep but uniformly sloped, making accurate mapping of the banks feasible. The ditch banks were also free of trees and other shrubs that could block the GPS signal needed for the survey.

A typical section of the IN-2 ditch

Sampling Design

At both locations three ditch transects within the saturated buffer area were intensively surveyed. The transects were equally spaced along the length of the buffer and corresponded to the well transects. Three additional transects were surveyed outside of the saturated buffer so that bank movement resulting from the SB practice could be separated from bank movement that occurs under normal conditions.

The ditch transects were surveyed by ESE staff using an RTK GPS system with Sokkia GRX-1 antennas and Carlson SurvCE software on the Juniper Systems Mesa controller. When the RTK signal is locked, these antennas have a positioning accuracy of Horizontal: 10mm and Vertical 15mm. The sampling dates and locations are given in Table.

Site ID	Survey Date	
	Before	After
IN - 2	8/24/2013	9/5/2015
IL - 3	8/22/2013	9/4/2015

Sampling Procedures

When the initial surveys were completed the survey shots were taken at a high enough frequency to accurately map the shaped of the ditch. This resulted in a higher point density near the bottom of the ditch where bank movement was also thought to be more pronounced.

The second survey was taken using the “Stake Points” feature in the software, which allows the surveyor to accurately find the X,Y,Z position of a previously surveyed point. Using this feature ESE was able to locate the exact X,Y location of the all points in the original survey. When the point was found (accuracy of <0.10 ft) the current elevation of that location was recorded.

Custody Procedures

After each survey was completed the data were exported as a shape file from the GPS control unit and stored on ESE computers that were regularly backed up.

Calibration

When performing the first survey four benchmarks were installed around the survey area. The RTK base station was set up over a designated corner of the SB control structure. Additional permanent structures, such as bridges and culverts, were used as additional benchmarks.

These same benchmarks were also located during the second survey and any shift in location was noted using the “Stake Points” feature. The X,Y locations of all benchmarks were consistent between the surveys within 0.10ft. The vertical offset between the two surveys was <0.05ft and considered negligible.

Data Analysis and Review

The X,Y,Z positions from both surveys were imported into an Excel spreadsheet. Using Pythagorean’s Theorem the X,Y positions were converted into points along a straight line. For visual comparison the elevations from both surveys were then plotted.

The stream bank movement that was potentially a result of the SB practice was determined by first separating the data collected from SB side of the ditch within their three transects from the rest of the data. All other data were treated as the control group. The differences between the data from the two surveys were compared using the Paired Two-Sample for Means t-Test, which was run using Excel.

Results/Findings

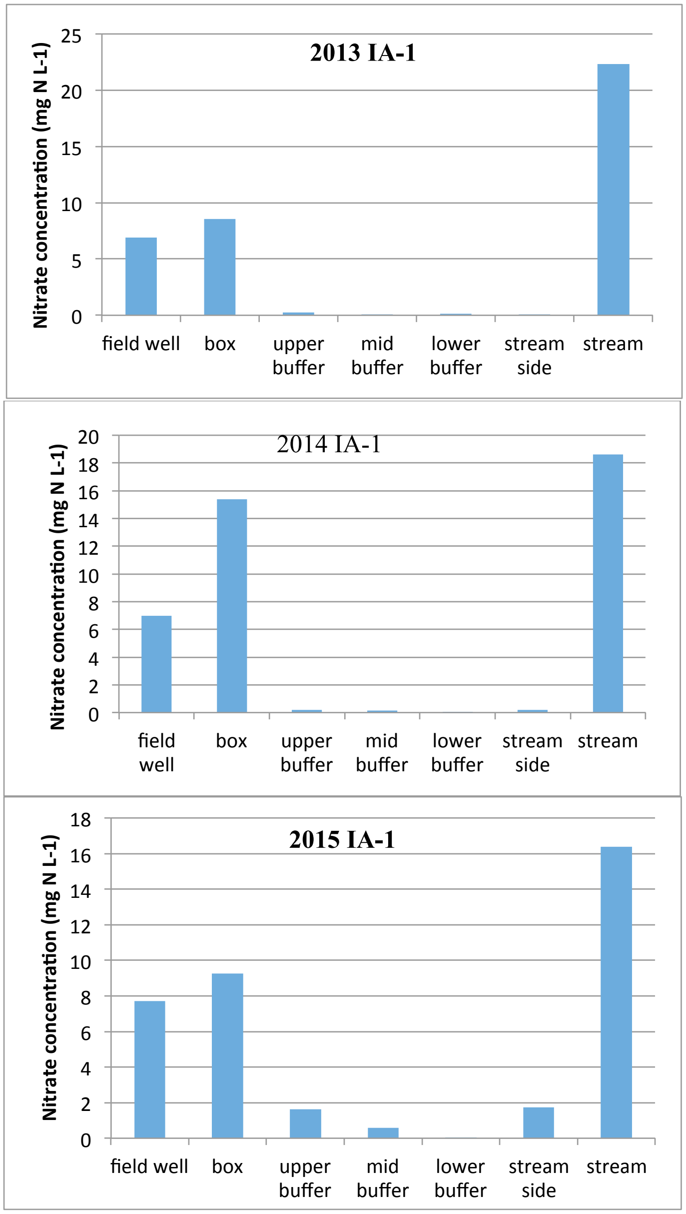
Nitrate concentration:

Water samples were generally collected bi-monthly at each site and analyzed for nitrate and total dissolved phosphorus (TDP). For the IA-1 site ortho-phosphorus was analyzed in 2013 instead of TDP, but TDP was analyzed in 2014, and no P measurements were made in 2015. For the other CIG sites and one FSA site, TDP was measured in 2014 and 2015. Most locations had water samples collected in 2014 and 2015 with a few sites having multiple water samples collected during 2013 as well.

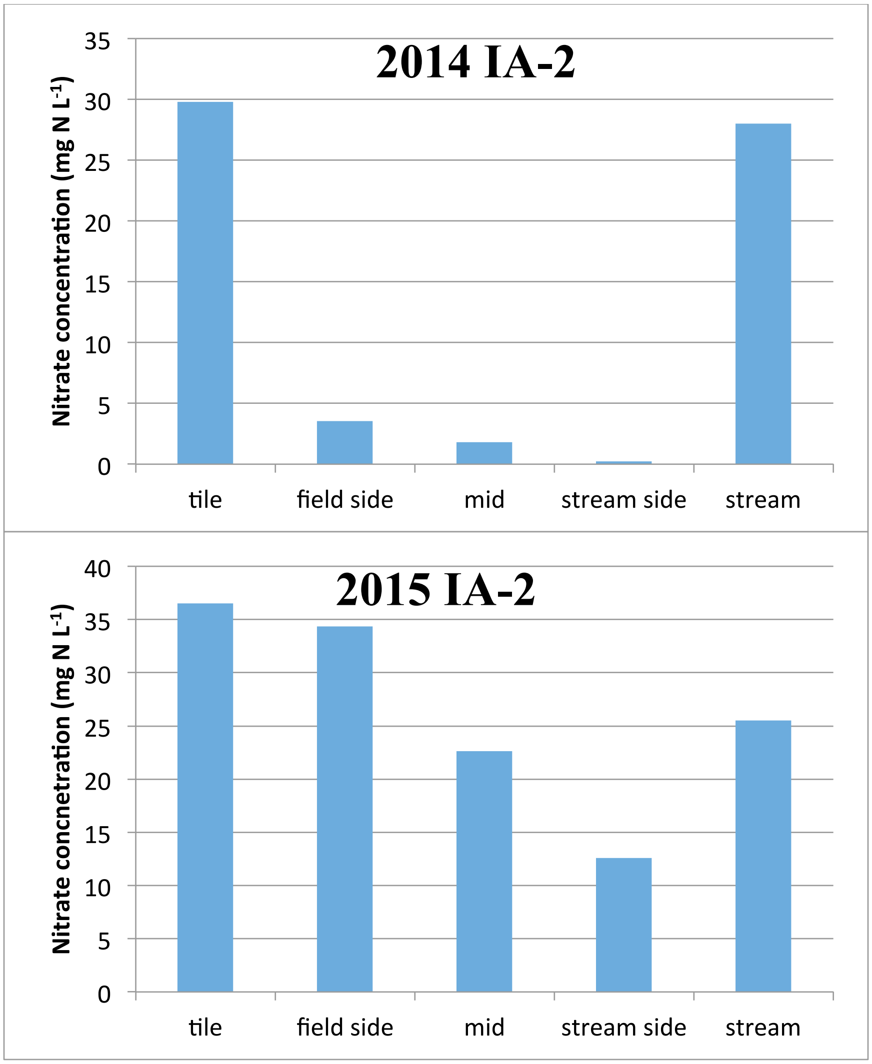
For this report, we graph the nutrient concentrations in the control box at the tile outlet averaged over the entire year. Yearly average concentrations within the stream are also graphed. We also averaged the nutrient concentrations for each well position over the entire year of observation. Thus, average concentrations for the observation wells in the buffer closest to the field and the distribution pipe, averages for the observation wells closest to the stream, and averages for the observation wells in the middle of the buffer are reported.

Nitrate

In general, individual nitrate concentrations ranged from below our detection limit (<0.3 mg L^{-1}) to over 40 mg L^{-1} for some samples. When computing concentration averages, nitrate concentrations less than our detection limit of 0.3 mg L^{-1} were set to 0. For most of the sites, average nitrate concentrations followed the pattern of highest at the tile outlet, decreasing across the buffer, and then higher again in the stream. This decreasing trend in nitrate concentrations across the buffer is what was found at the first saturated buffer in Bear Creek (Jaynes and Isenhart, 2014) and what we would expect if nitrate was being denitrified or sequestered as it flows through the buffer towards the stream. Yearly results for each saturated buffer site are detailed below.

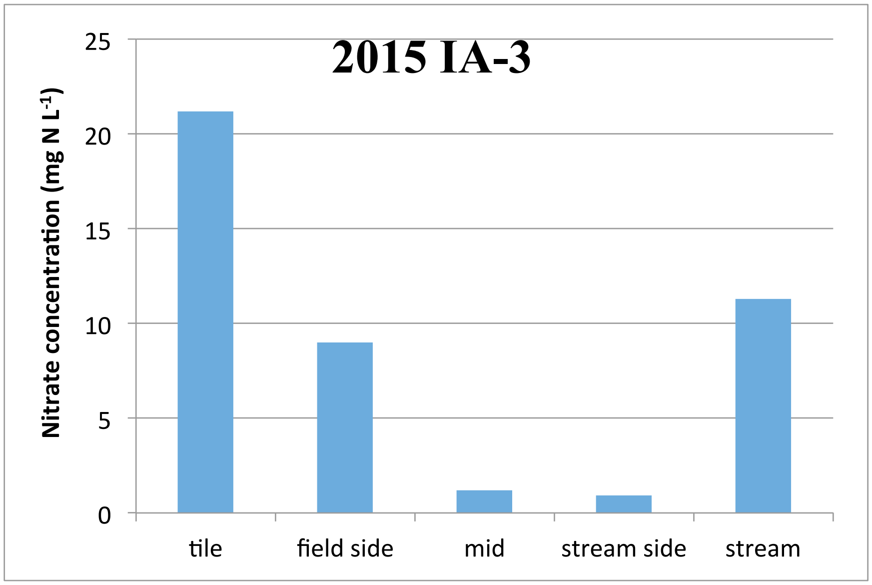


IA-1. Average nitrate concentrations by well position were computed for 2013-2015. This site had additional wells on the field side of the distribution pipe and observation wells at four positions between the stream and the distribution pipe. Average nitrate concentrations in the stream were greater than 16 mg L^{-1} each year indicating considerable nitrate contamination in this small stream. At the control box at the tile outlet, average nitrate concentration exceeded 8 mg L^{-1} in the tile outlet for all years. The observation wells to the field side of the distribution pipe had average nitrate concentrations exceeding 6 mg L^{-1} – not as high as in the tile, but still indicating substantial nitrate leaching below the root zone of the row crop. Average nitrate concentrations decreased sharply to near 0 in the observation wells within the buffer. Only in 2015 did average nitrate concentrations in the buffer wells exceed 1 mg L^{-1}. Thus, this buffer appears to be removing nitrate from the shallow groundwater as it flows through the buffer.



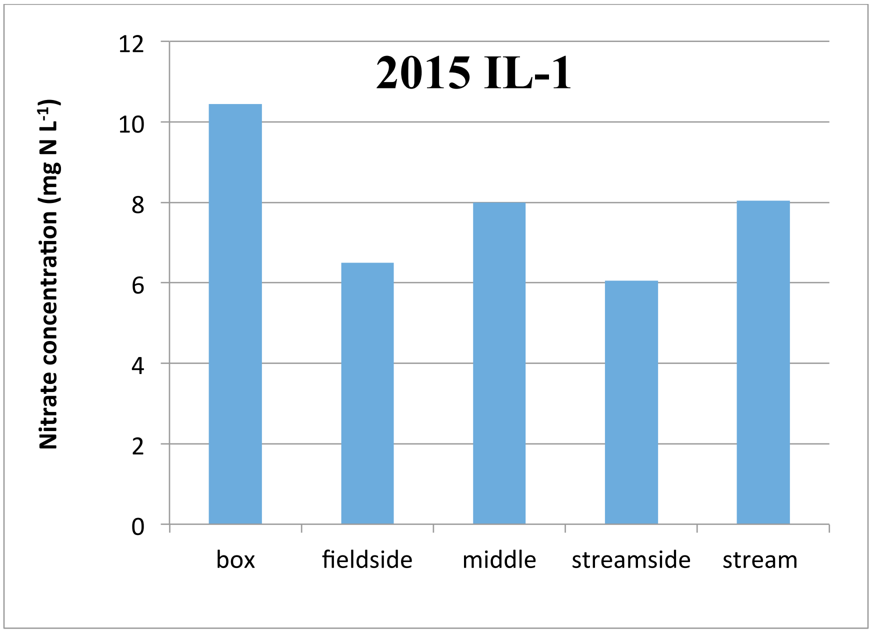
IA-2. Average nitrate concentration in the tile outlet was near or greater than 30 mg L^{-1} in 2014 and 2015. Average stream nitrate concentrations were also high exceeding 25 mg L^{-1} both years. In 2014, average nitrate concentrations in the buffer observation wells were less than 5 mg L^{-1} and decreased from field side to stream side of the buffer indicating nitrate removal. In 2015, concentrations in the buffer wells also decreased although they were considerably greater than in 2014. Thus, while nitrate was being removed, not all the nitrate was removed within the buffer in 2015.

2014 IA-3
No data

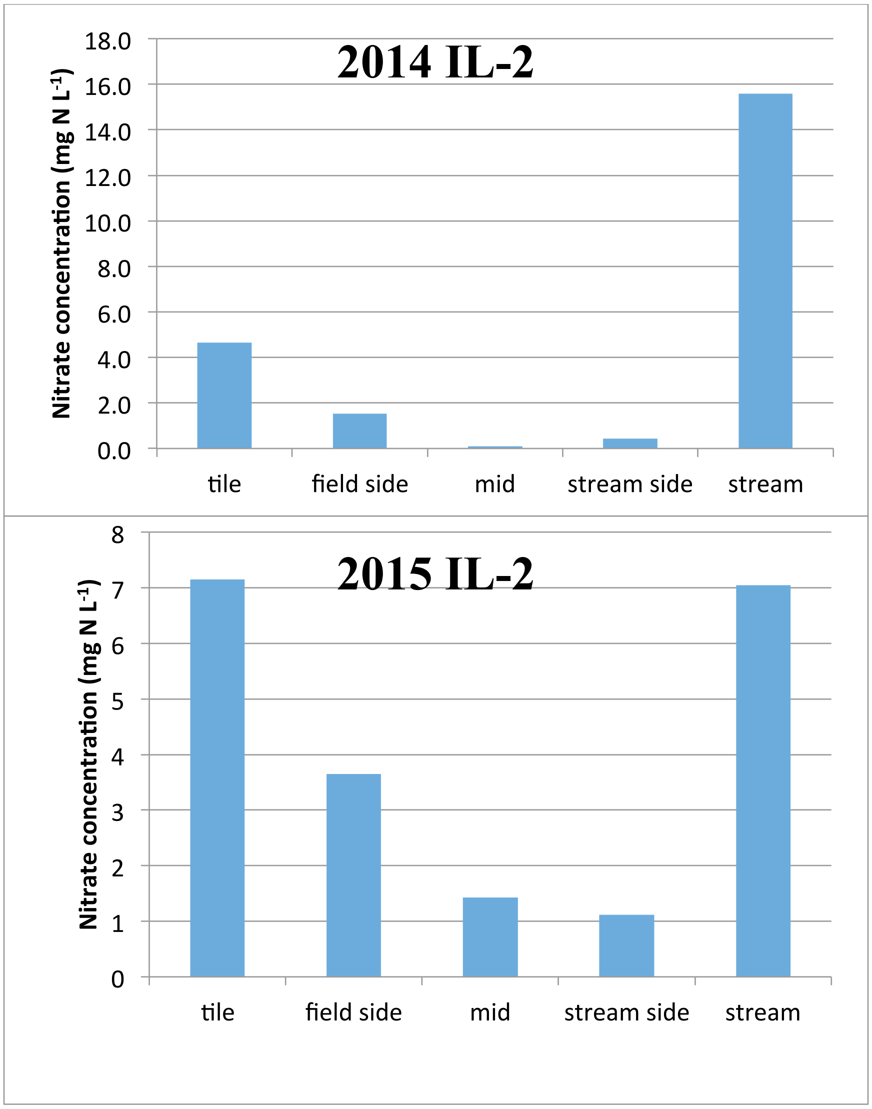


IA-3. No water samples were collected in 2014 due to the short period in which tile flow actually occurred and some complications experienced by the water sampling personnel. In 2015, average nitrate concentrations in the observation wells decreased from the field side to the stream side of the buffer and were much lower than in the tile outlet of the stream indicating nitrate removal within the buffer.

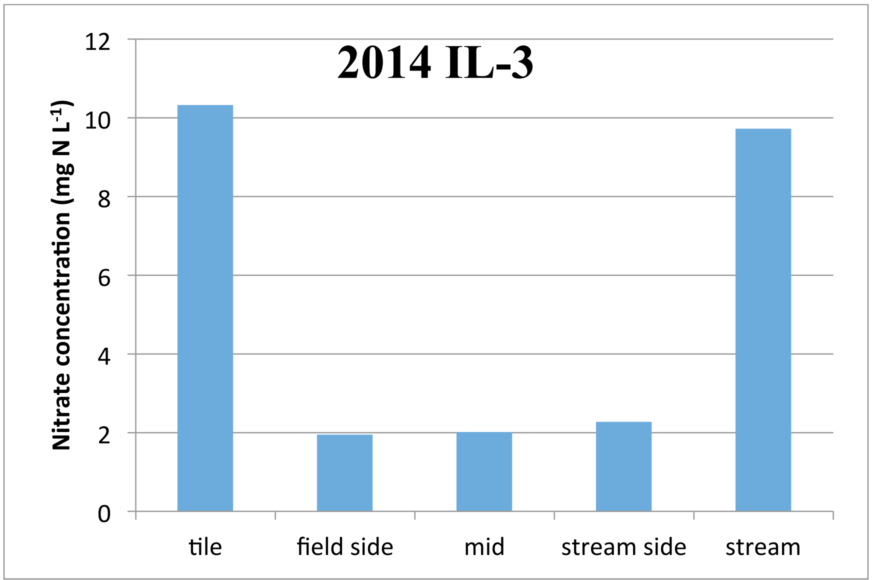
2014 IL-1
No data

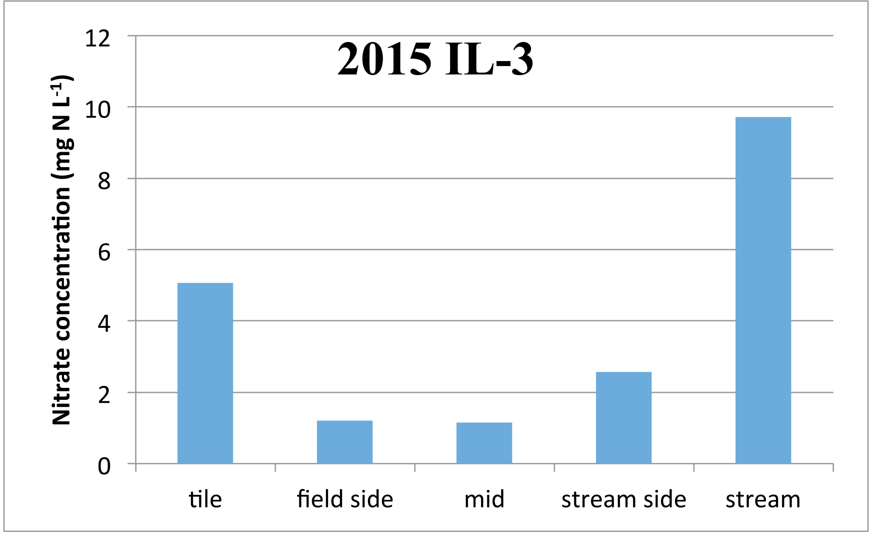


IL-1. This site experienced little tile flow in 2014, resulting in only one water sample being collected in September. Average nitrate concentrations were not computed for that year. In 2015, average nitrate concentration decreased somewhat in the buffer wells compared to the tile outlet and the stream, but no consistent trend was observed across the buffer. Thus, while some nitrate may have been removed within the buffer, there was not a consistent decrease of nitrate concentration across the buffer.

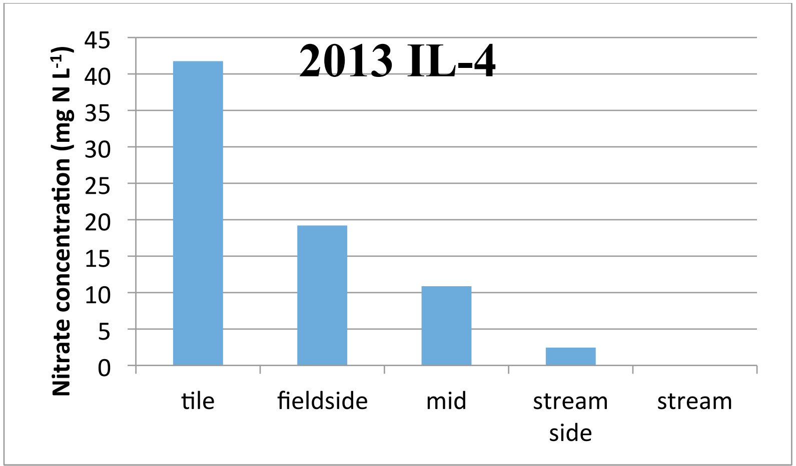


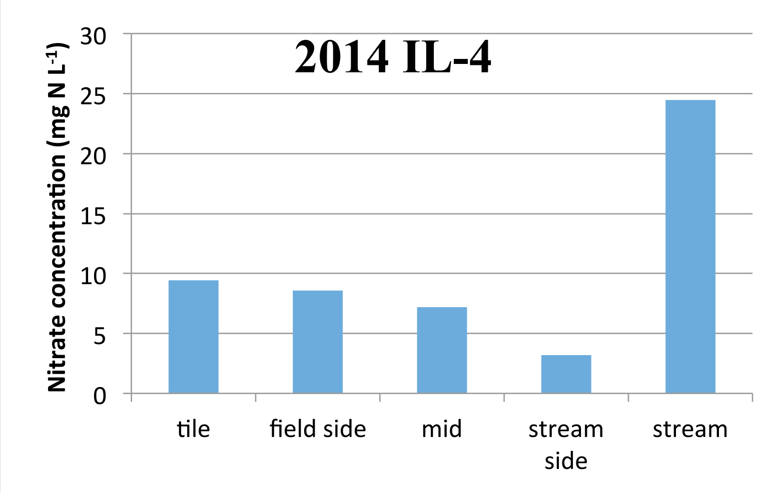
IL-2. In both 2014 and 2015 the average nitrate concentration decreased from the field side to stream side of the buffer and were much less than concentrations in the tile outlet or the stream. Thus, there appears to be the potential for nitrate removal within this buffer.

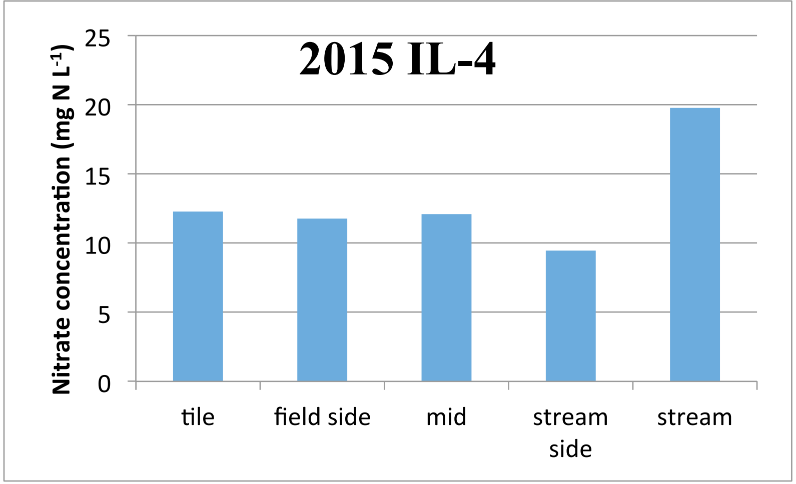




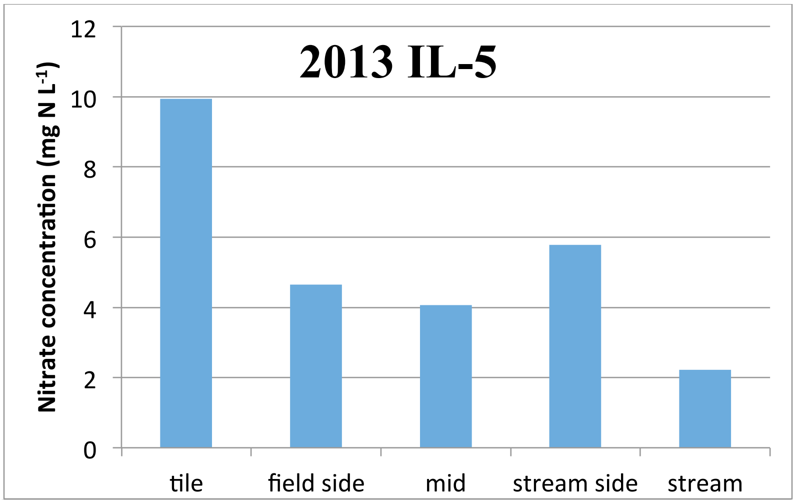
IL-3. Average nitrate concentrations in the buffer wells did not show any consistent trend with position within the buffer in 2014 or 2015. The streamside wells often had average nitrate concentrations greater than at the mid-buffer locations. This may have been due to bank storage of high nitrate stream water infiltrating the stream bank during high water conditions and being sampled by the stream-side wells. This condition was a common occurrence at other sites as well. However, nitrate concentrations in the buffer were much lower than in the field outlet of stream. Thus, nitrate removal may be taking place in the buffer, but if removal is occurring most is taking place within the first few feet of the buffer between the distribution pipe and the field side wells. From this data alone, we cannot be sure if nitrate is being removed at this site.

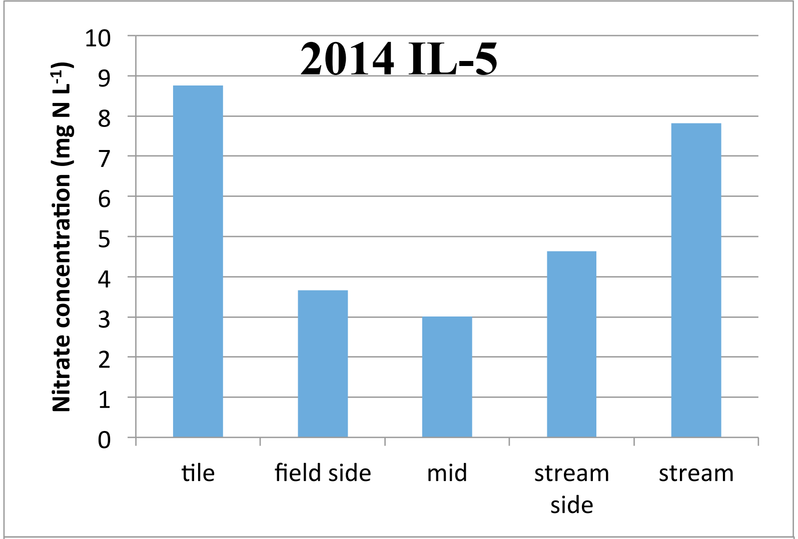


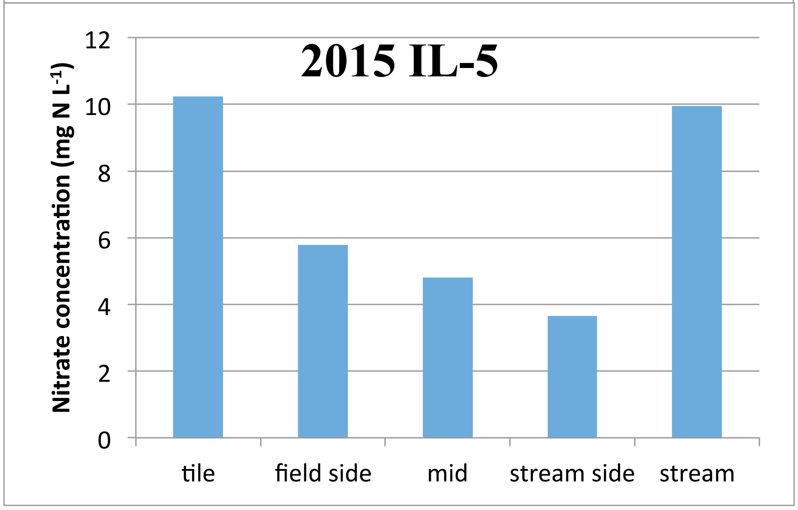




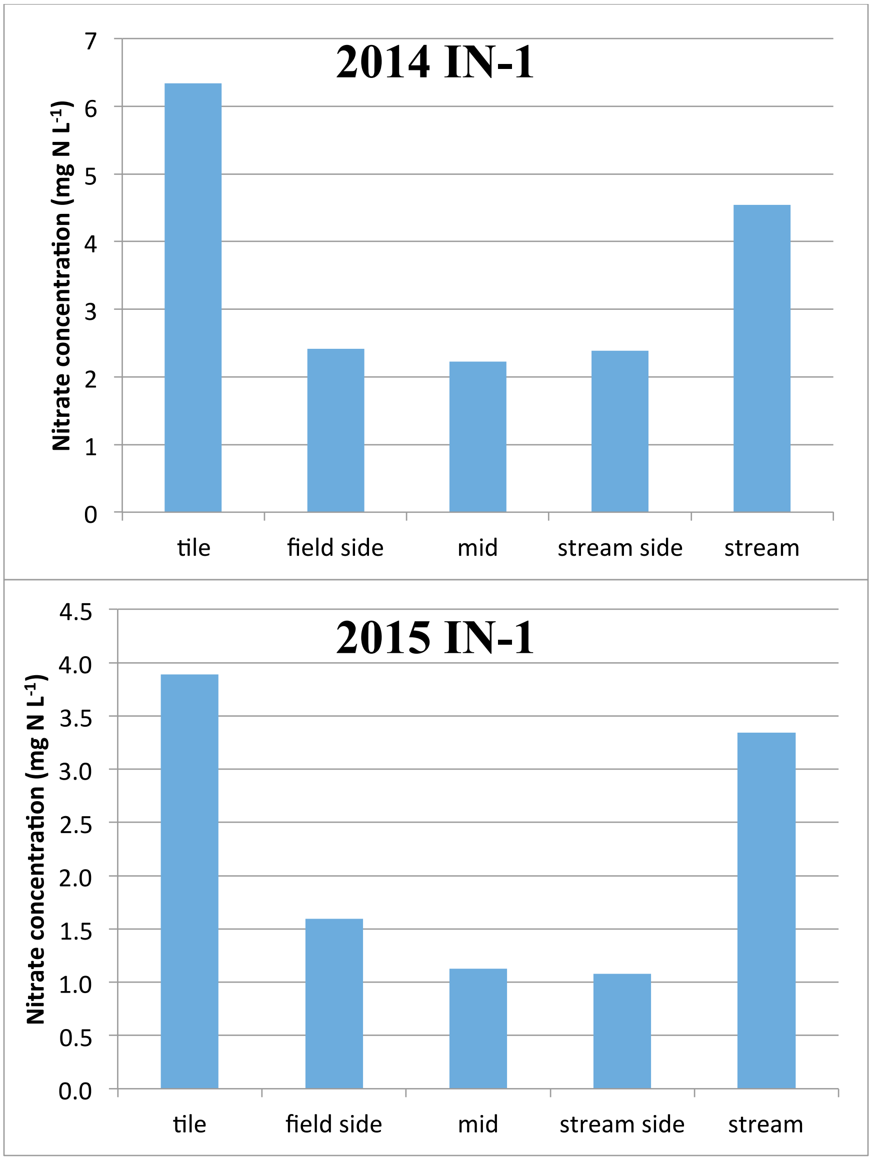
IL-4. Water samples were collected at this site in 2013-2015. In 2013, no stream samples were collected. Nitrate concentrations leaving the field were greater than 40 mg L^{-1} in 2013, but considerably lower in 2014 and 2015. Average nitrate concentrations in 2013 for the buffer wells showed a marked decrease across the buffer indicating that nitrate removal may be taking place. A decreasing trend was also observed in 2014 although not as strong as in 2013, while very little trend was evident in the well observations for 2015. Thus, this site appeared to remove nitrate more effectively in 2013 and 2014 than in 2015.



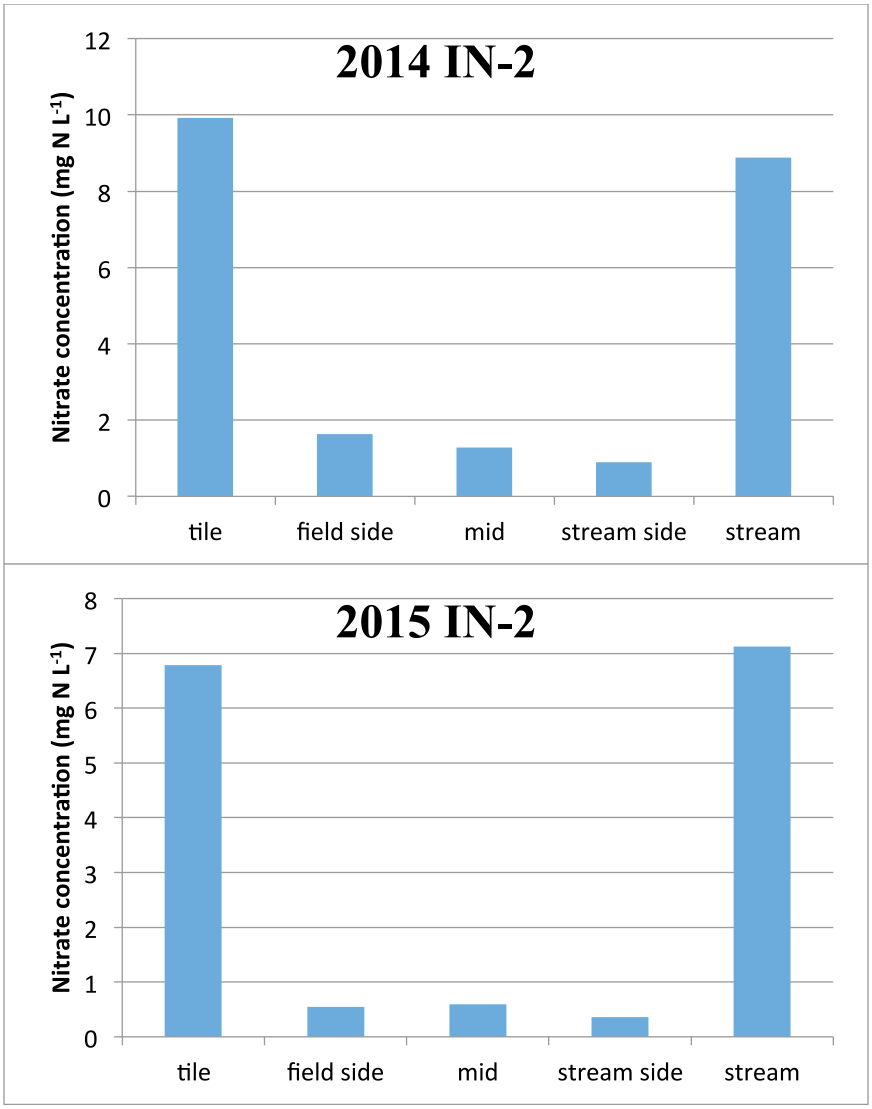




IL-5. This site had water samples collected in 2013-2015. Average nitrate concentrations in the tile outlet were around 10 mg L^{-1} all three years. While the buffer wells had average nitrate concentrations less than in the tile outlet the wells showed an inconsistent trend across the buffer except in 2015. Thus, nitrate removal through this buffer may have been inconsistent across this buffer.

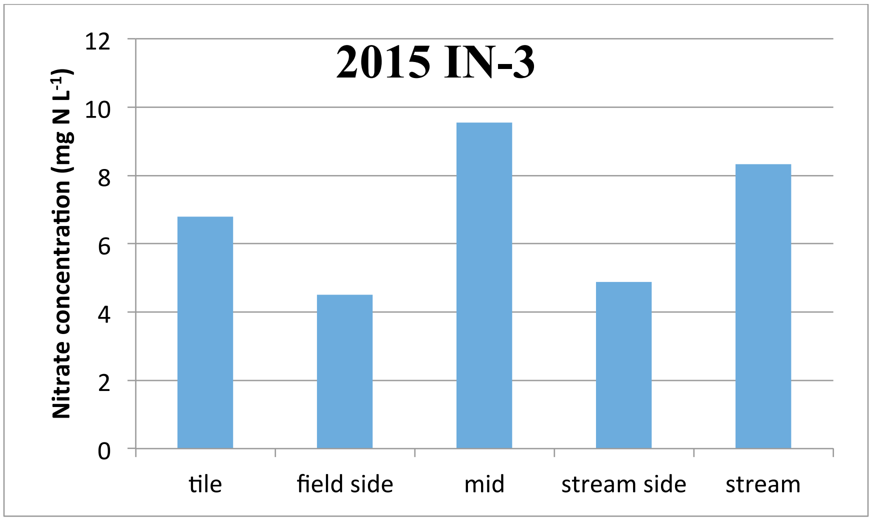


IN-1. Average nitrate concentrations in the buffer wells were considerably lower that the concentrations in the tile outlet. At this site there was little trend in nitrate concentrations across the buffer with most of the decrease occurring between the distribution pipe and the field side wells. Nitrate concentrations from this field were very modest not exceeding 7 mg L^{-1} in either year. From this data we are not certain if there was substantial nitrate removal at this site, because the tile flow carried little nitrate to start with.



IN-2. Average nitrate concentrations at this site were similar to IN-1 where concentrations were greatest in the tile outlet and the stream and much less in the buffer wells, but there was little trend in concentration across the buffer. Thus, most of the nitrate removal would have had to take place between the distribution pipe and field side wells or the water within the buffer.

2014 IN-3
No data

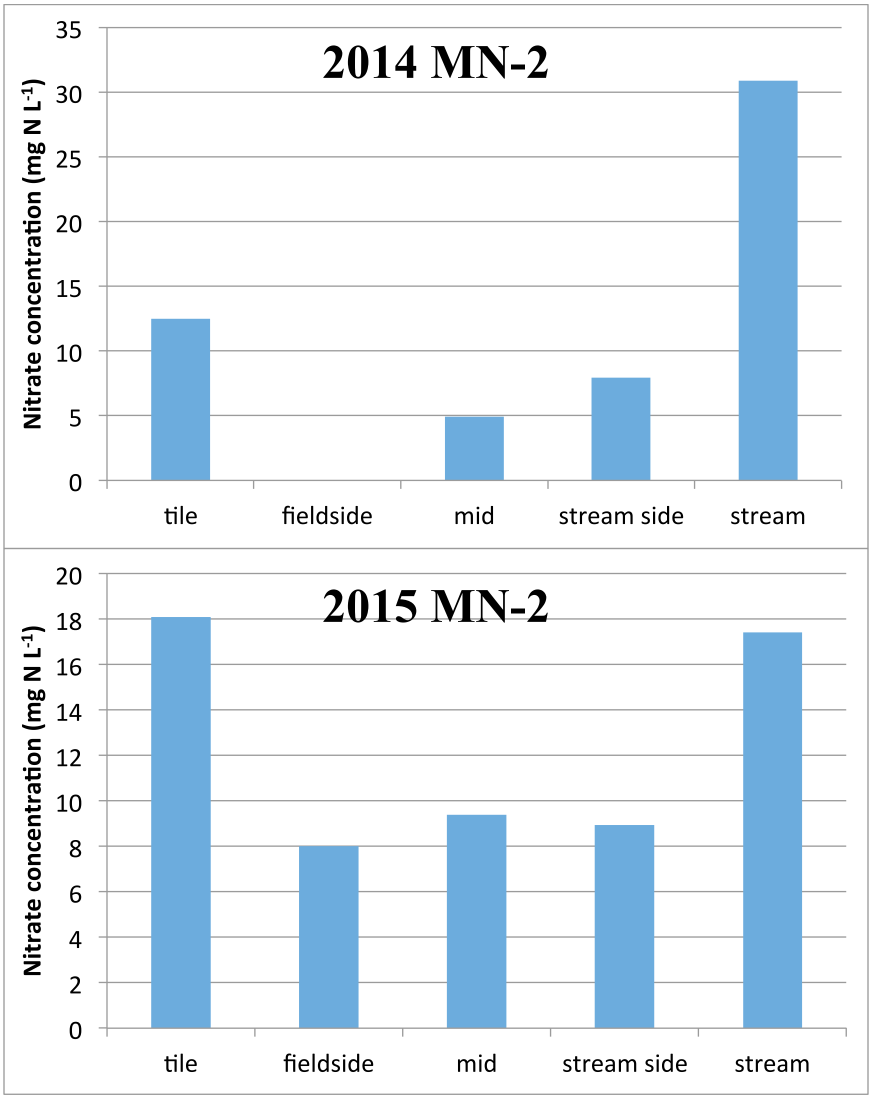


IN-3. No water samples were collected from IN-3 in 2014 and only samples from 3 dates in 2015, thus the results are based on few samples. Average nitrate concentrations showed no consistent trend across this buffer indicating no measureable nitrate removal within the buffer.

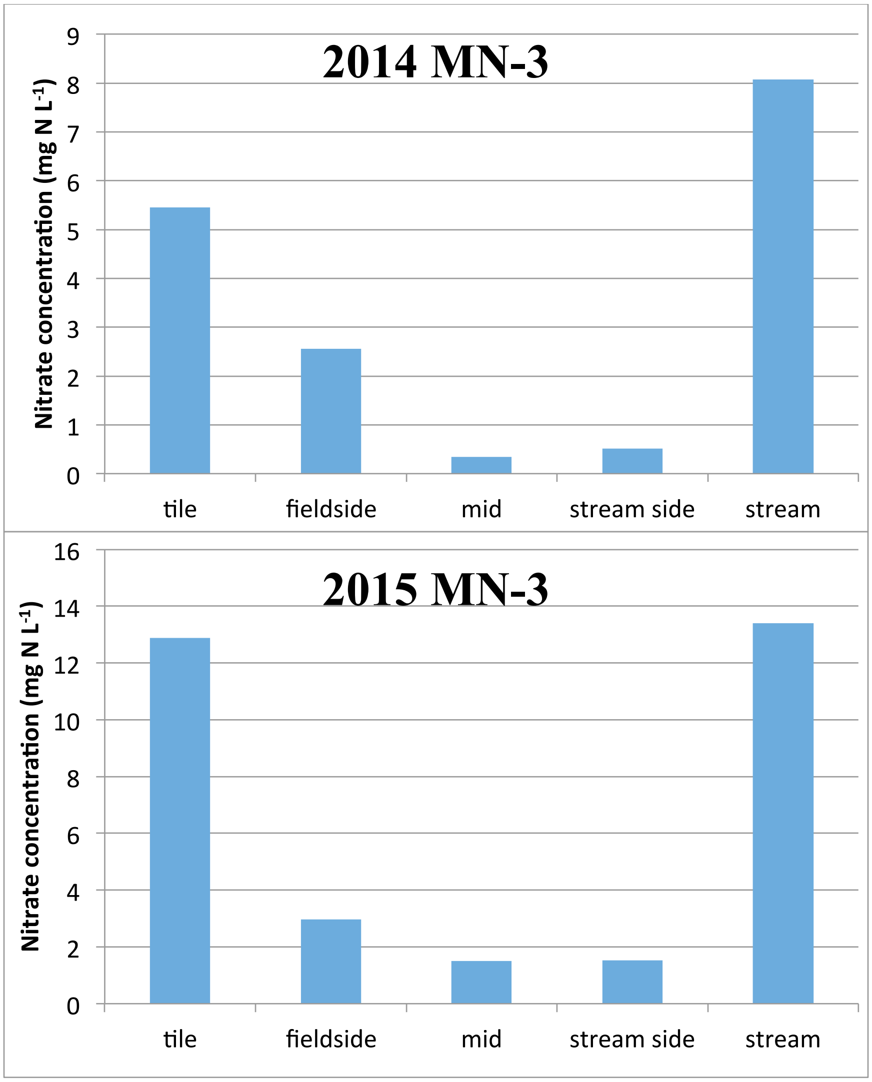
2014 MN-1
No data

2015 MN-1
No data

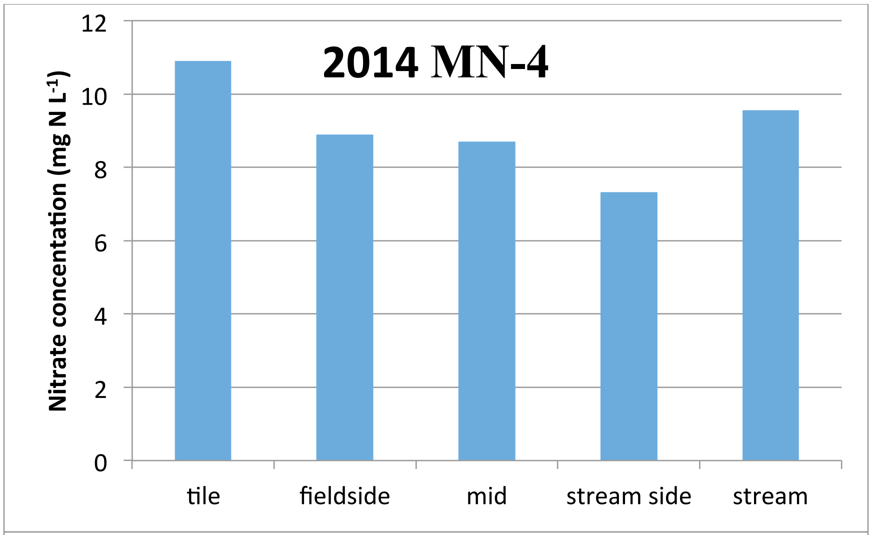
MN-1. No water samples were ever turned in from this site. After installation it was discovered that an extensive sand lens connected the field with the adjacent river. When the water level in the river was high there would be water in the groundwater monitoring wells. As soon as the river dropped, however, the water would quickly escape through the sand. There was a brief period of flow in 2014, but the site was flooded and inaccessible so no samples were collected. There was no observed tile flow in 2015 so no sampling was possible.

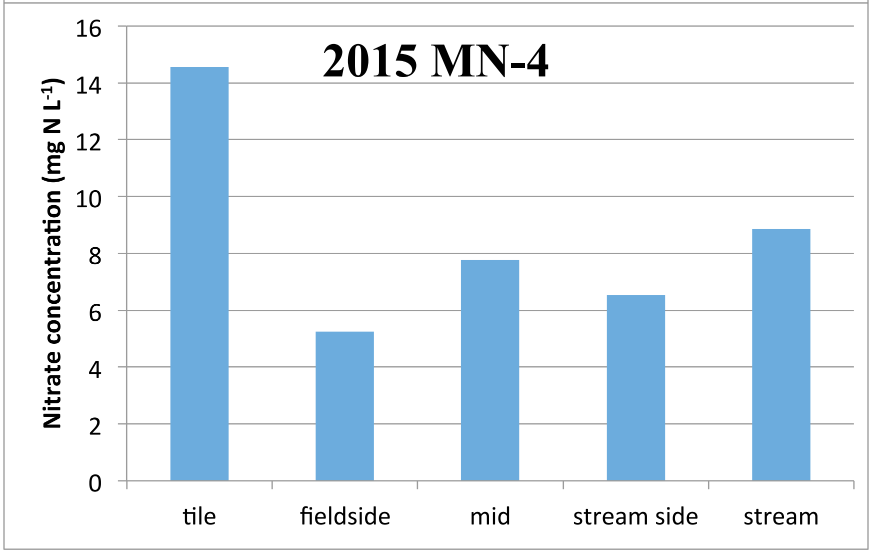


MN-2. Although water samples were collected for 7 dates in 2014, no samples were collected from transect 3, well 11, and only 1 sample from wells 21 and 22 (see appendix A for well locations). Only well 13 had consistent samples, thus the results are very incomplete and difficult to interpret for 2014. Similarly, no water samples were submitted for well 31 and only samples from 2 of the 5 sample dates for wells 11, 21, 32, and 33 in 2015 leading to sparse sampling results. The lack of water samples from well 31 was most likely due to the shallow depth of installation of this well (3.38'), but we are uncertain as to why the other wells were often dry. As a result it is difficult to discern any consistent pattern for 2014 data, while in 2015 it appears that average nitrate concentration increased in wells moving from the field side to stream side of the buffer. Thus, although we can compute a nitrate removal load (below) the results are very tentative and most likely this site was ineffective in removing nitrate.



MN-3. Average nitrate concentrations showed decreasing nitrate concentrations from the field to stream side observation wells demonstrating substantial nitrate removal. Well concentrations were much less than concentrations in the tile outlet or stream. Thus, this site appears to be effective in removing any nitrate that was introduced through the distribution pipe.





MN-4. Water samples were routinely collected from all wells at this site except for well 23 that was dry half the time in both years. This well was installed about a foot shallower than the other wells at this site and this may have contributed to less frequent collection of samples. In 2014, the average nitrate concentrations showed a modest decreasing trend across the buffer compared to the other sites, indicating some nitrate removal but by no means complete removal. In 2015, there was little evidence of trend across the buffer although nitrate concentrations were lower in the buffer than at the tile outlet, thus we conclude that nitrate removal may have been uneven and modest at this site.

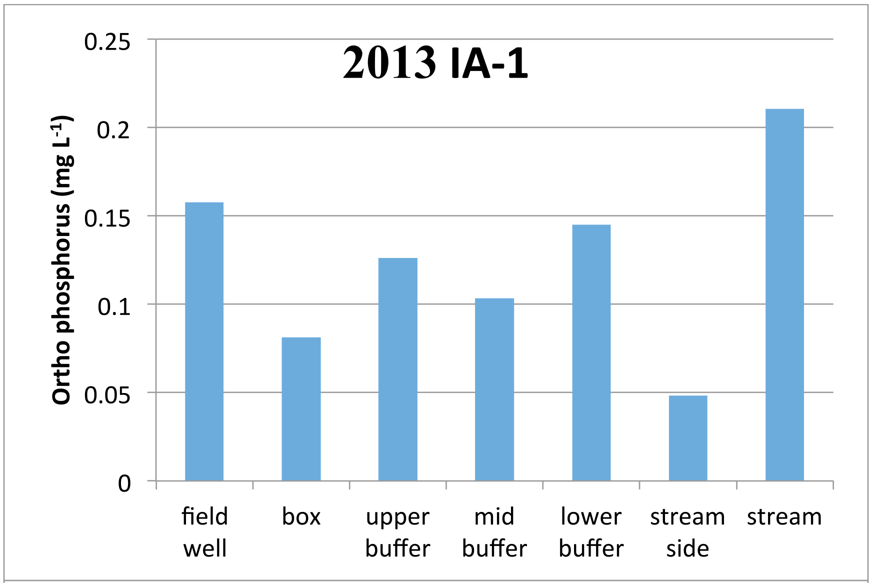
Summary of nitrate concentration data

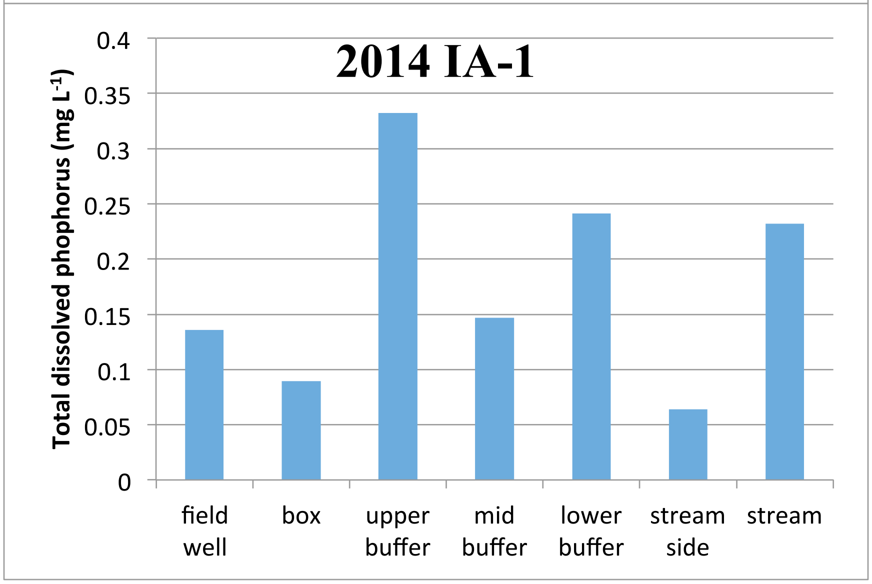
Overall, the average nitrate concentrations across the buffers indicated substantial nitrate removal in about 17 of the 27 field-years where data was collected. Nitrate may have been removed during the other 10 field-years as well, but the removal was not consistent across the buffer as would be expected if nitrate was being removed by denitrification as it moved in groundwater through the high organic matter soil layers of the buffers. We should note that monitoring for nitrate removal with fully penetrating wells has its limitations. For example, the wells may be tapping into groundwater in the buffer that is more regional in nature and not being impacted by the saturated buffer infrastructure. Thus, these wells may be sampling water that is introduced by the saturated buffer infrastructure as well as water that in not impacted giving a mixed signal in the water sample. Also as noted above, the wells closest to the stream may be sampling some of the stream bank storage of water. As the nitrate concentrations in the streams were always greater than what was in the buffer, this bank storage would serve to increase the average nitrate concentration being sampled by the well closest to the stream. A third possible complication is that flow paths in the shallow groundwater within riparian buffers can be quite complicated. While not part of this study, a tracer study at the saturated buffer in Bear Creek, IA showed that while tracer added through the distribution pipe showed up in all of the buffer observations wells, the travel times were variable with tracer arriving at some wells further from the distribution pipe sooner than wells closer to the pipe. This could impact the expected decreasing trend in nitrate concentrations across the buffer that we are using to determine nitrate removal in this project leading to misinterpretation of some of the well data. Thus, while we based our assessment on the presence of a decreasing trend in nitrate concentration across the buffer, nitrate removal may still be taking place at sites without this trend, we just could not measure it accurately.

Total dissolved phosphorus

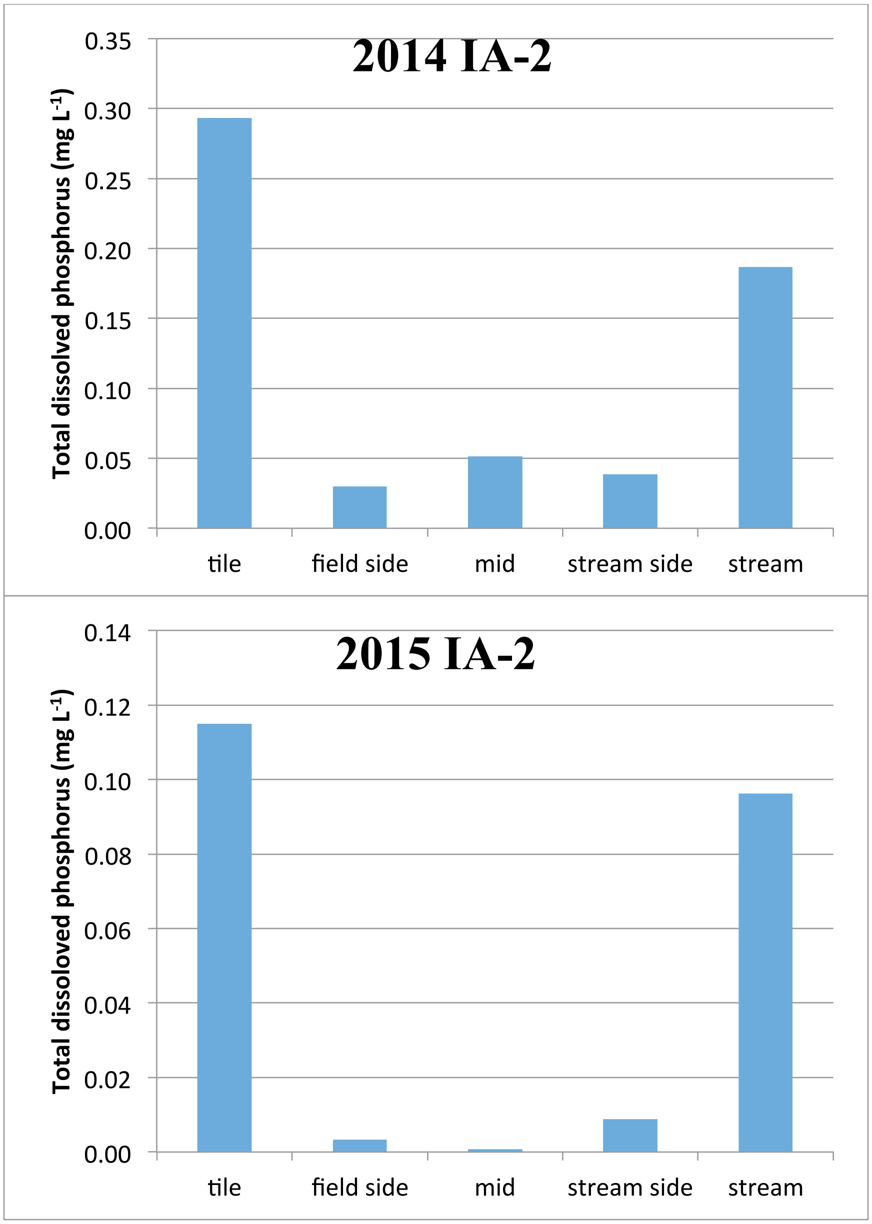
Saturated buffers were designed as a nitrate removal practice with nitrate being removed primarily via denitrification. However, there is the possibility that the practice could remove some phosphorus as well if the soils within the buffer have an adsorption affinity for P and if this adsorption potential is not already saturated with P. Thus, P, in the form of total dissolved P (TDP) was measured in the tile outlet, stream and observations wells at each saturated buffer site. To protect against eutrophication, the EPA (1986) recommends an upper limit of 0.1 mg L^{-1} as the standard for total phosphorus in streams. In this study, we were primarily measuring TDP with ortho-P measured at 1 site in 1 year (2014 IA-1). While total P would be greater than ortho-P or TDP in most waters, in tile drainage that has little suspended solids, TDP should be very close to total P measurements. Thus, the results here are compared to the EPA recommendation to help put the numbers into perspective.

Water samples from sites IA-3, IL-5, IN-3, MN-2, and MN-3 were not filtered and thus we did not analyze these for TDP. Results for the remaining sites are detailed below.



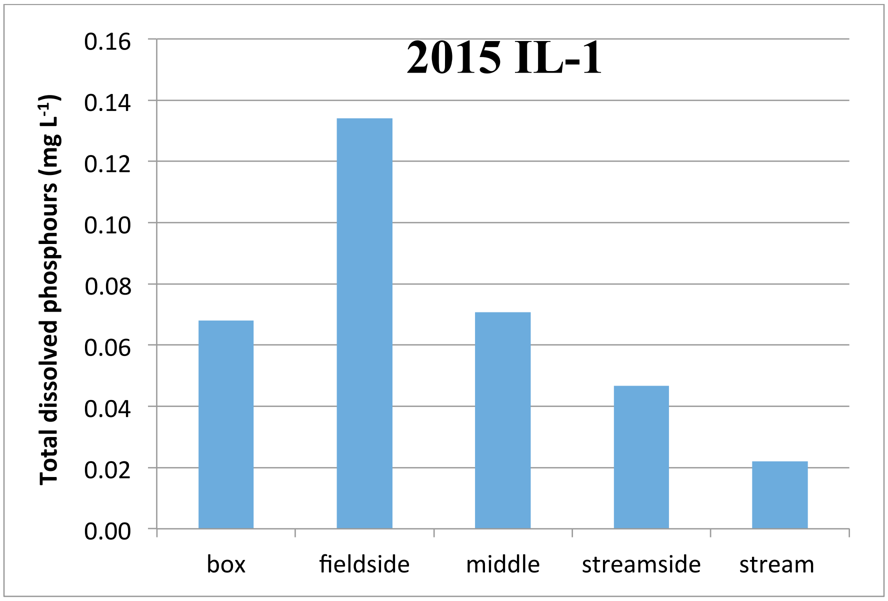


IA-1. At IA-1, ortho-P was measured in 2013, while TDP was measured in 2014 as it was at the other saturated buffer sites. We would expect a high correlation between ortho-P and TDP in tile drainage and if anything for the ortho-P to be slightly less as ortho-P is included in the TDP measurement. No P measurements were made at this site in 2015. Ortho-P and TDP concentrations in the tile outlet (box) averaged below 0.1 mg L^{-1}, which is below the EPA recommendation for total P in flowing water, and about what we would expect for tile drainage from row cropped fields where manure is not used. TDP concentrations in the stream averaged about twice as great and may reflect an overland or manure component for the source water for this stream. For both years, there was no consistent trend in TDP in the observation wells across the buffer. Thus, we would conclude that there is no consistent removal of P across this buffer.

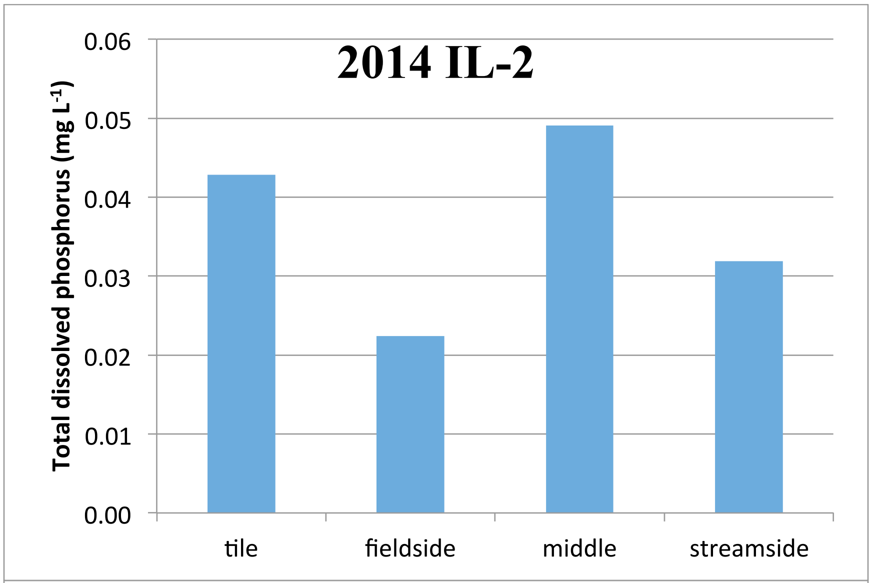


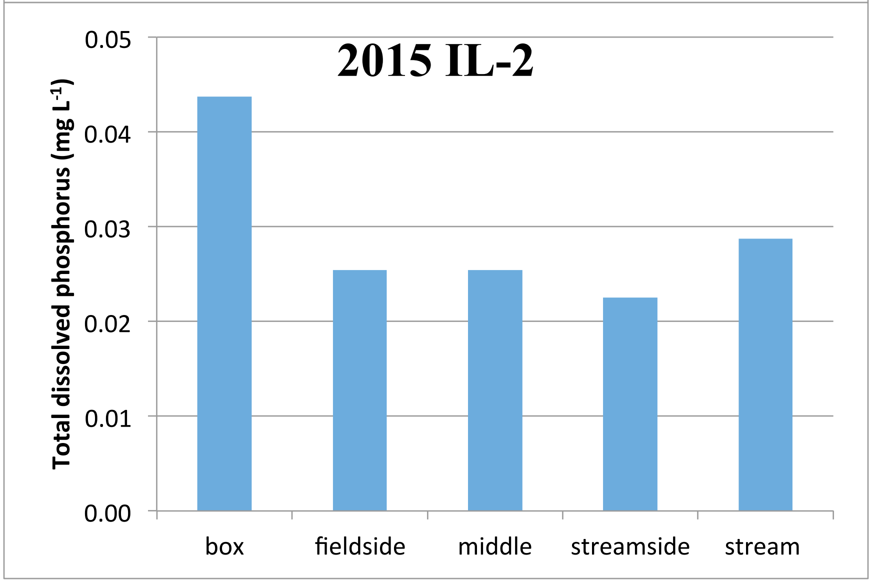
IA-2. TDP concentrations from this field tile outlet were above the 0.1 mg L^{-1} EPA recommendation for total P. There is a marked reduction in TDP within the buffer compared to the source water from the field tile outlet. Thus, it appears that much of the TDP being introduced into the buffer is being retained in the buffer soil.

2014 IL-1
No data

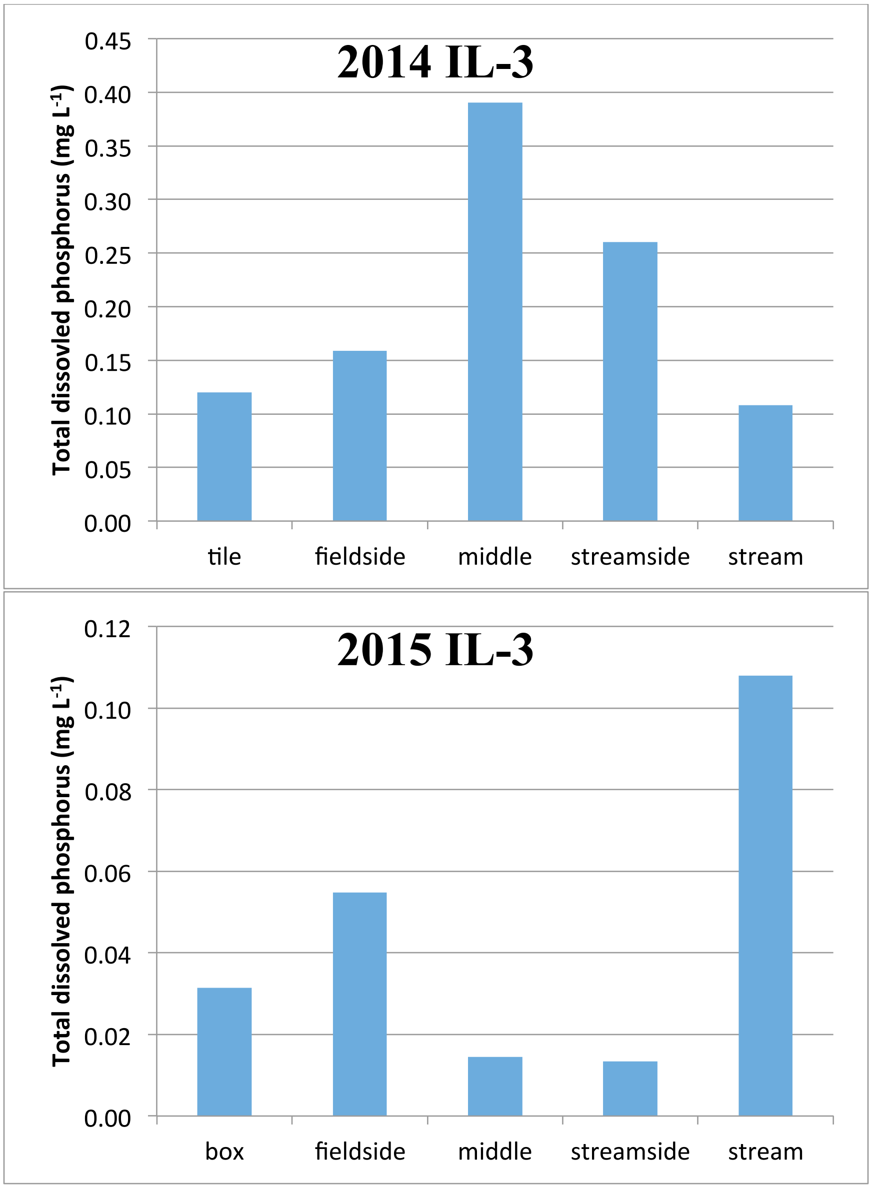


IL-1. Only one water sample was collected in September of 2014 for this site (see section on Nitrate for explanation), so average TDP concentrations were not computed for 2014. In 2015, there appeared to be a trend across the buffer, but the average TDP concentration within the buffer on the field side, was greater than the average TDP coming from the tile outlet. This may be due to some legacy practice within the field, but complicates the interpretation of the pattern. This site maybe removing some TDP as shallow groundwater flows across through the buffer. The average TDP concentration in the field tile outlet was well below the 0.1 mg L^{-1} EPA recommendation.

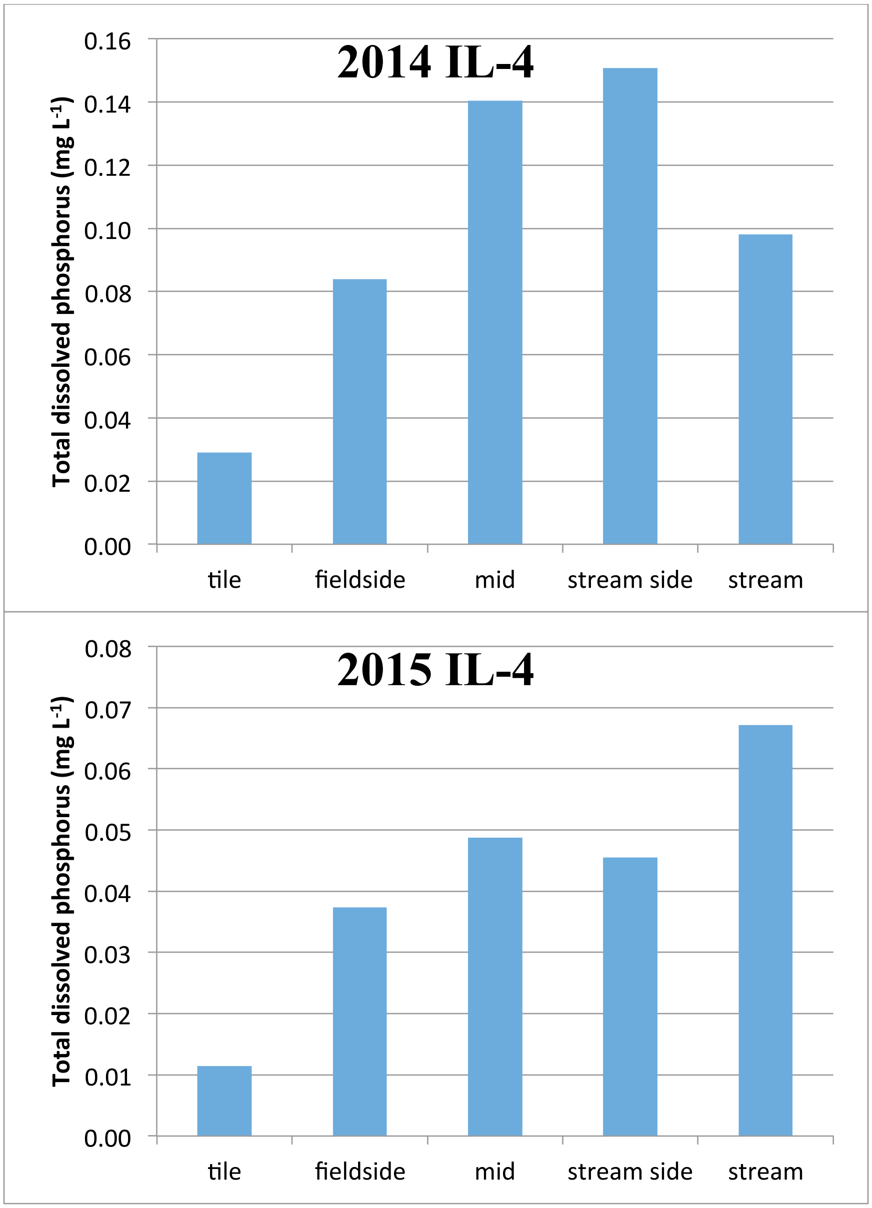




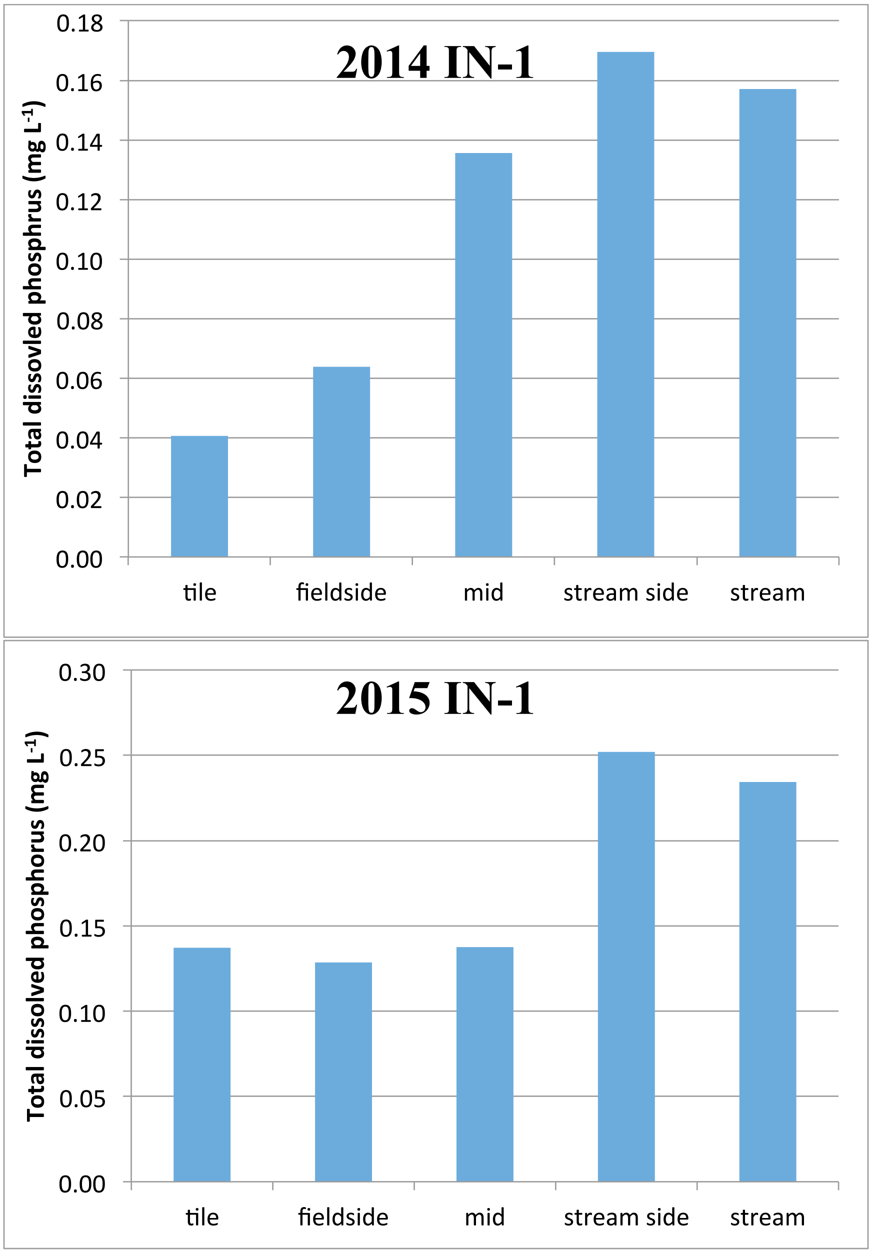
IL-2. There was no trend in TDP across this buffer in 2014, while there does appear to be some reduction in TDP within the buffer in 2015, but again little trend. Our conclusion is that this site is not effective in removing P. The average TDP concentration within the tile outlet did not exceed 0.05 mg L^{-1}, well below the EPA recommendation, thus this tile contributes little to eutrophication of the stream.



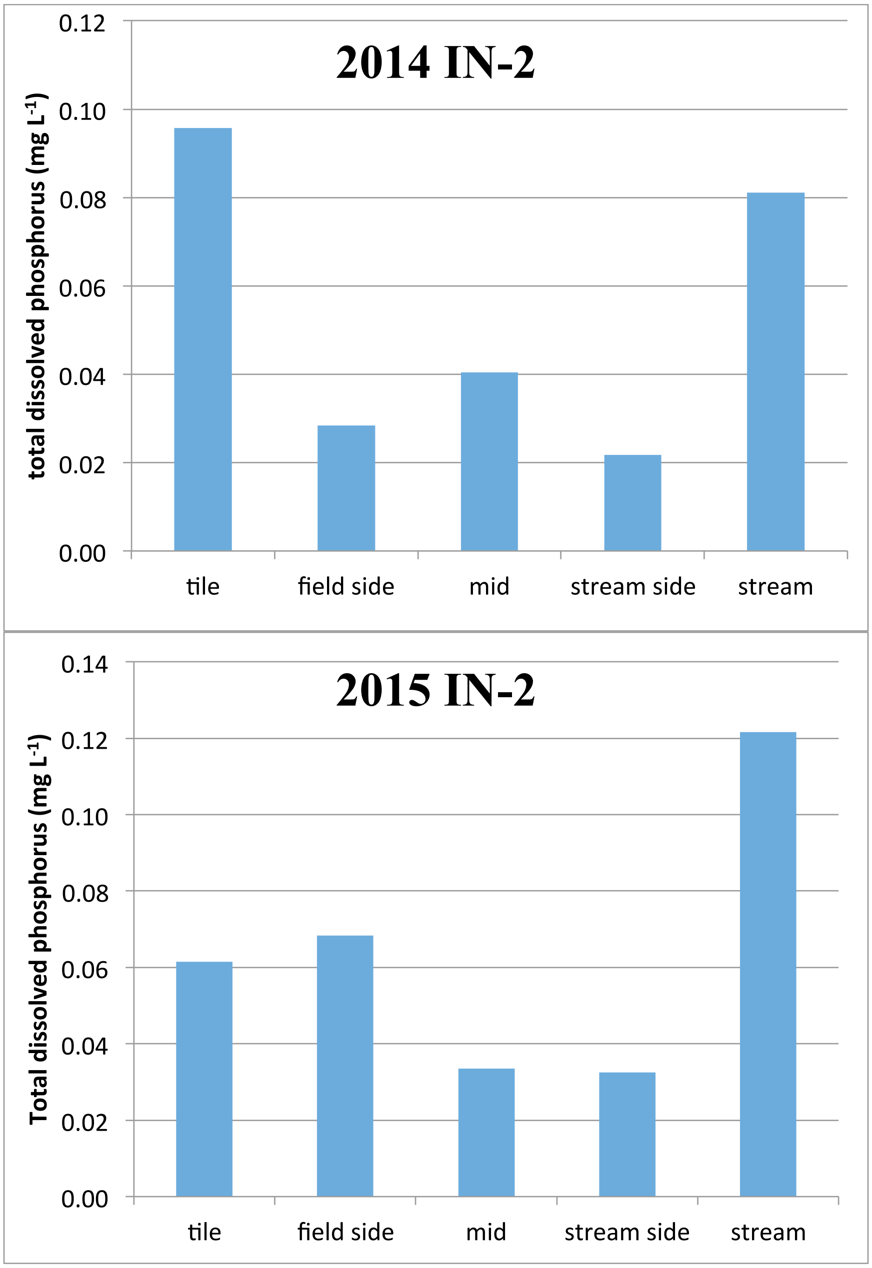
IL-3. Much lower average TDP concentrations were leaving this field in the tile outlet in 2015 than in 2014. However, there was no trend in TDP across the buffer indicating that the buffer was probably not acting as an effective sink for P at this site.



IL-4. Average TDP concentrations in the tile outlet at this site were very low in 2014 and 2015 – much lower than in the stream. Average TDP concentrations in the buffer showed an increasing trend across the buffer, thus this site was not an effective sink for P.



IN-1. Average TDP concentration in the field outlet was higher in 2015 than 2014 and exceeded the EPA recommendation for flowing water as did average TDP concentrations in the stream. Across the buffer, average TDP concentrations remained constant or increased, indicating no removal of P within this buffer.

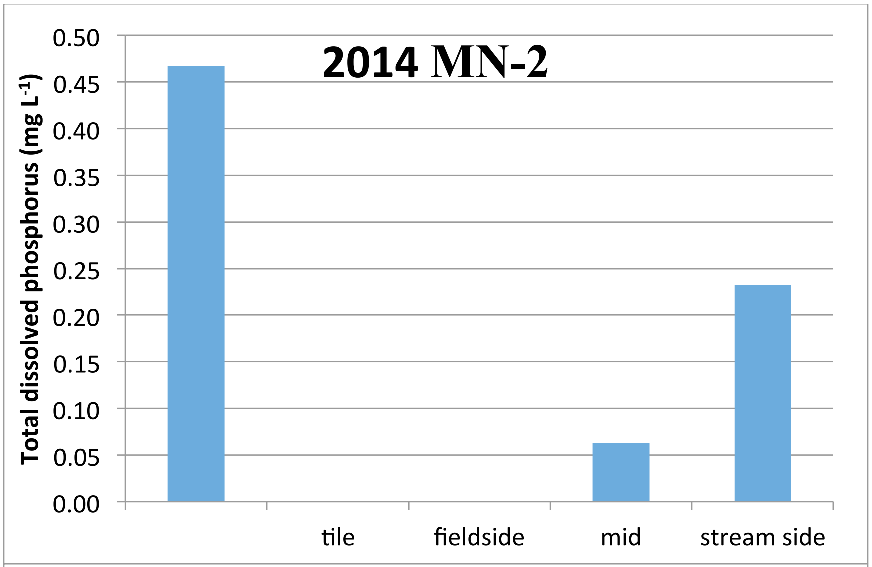


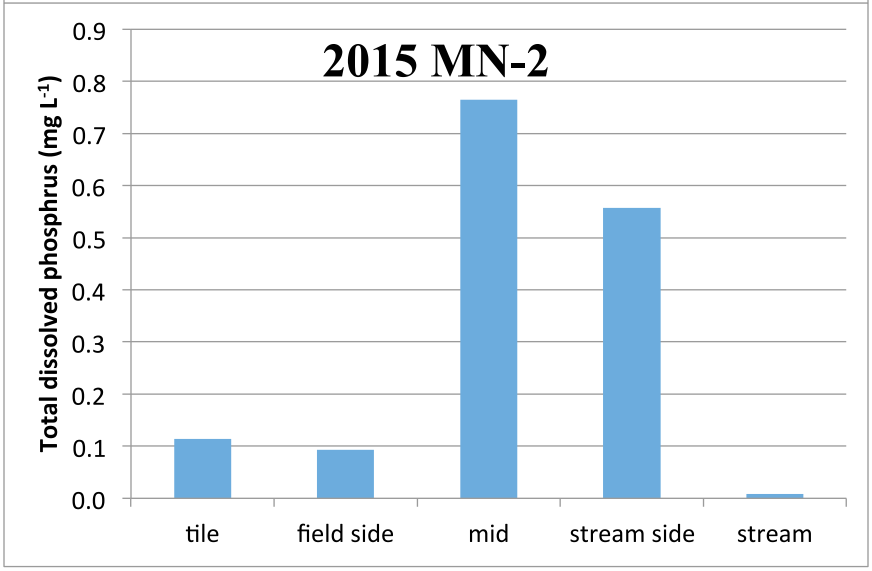
IN-2. Average TDP concentration leaving the field in the tile outlet was below the EPA recommended concentration for total P in both years. Average TDP concentrations within the buffer showed no trend or consistent pattern between the two years. We conclude that this buffer was probably not removing P.

2014 MN-1
No data

2015 MN-1
No data

MN-1. No water samples were ever turned in from this site. After installation it was discovered that an extensive sand lens connected the field with the adjacent river. When the water level in the river was high there would be water in the groundwater monitoring wells. As soon as the river dropped, however, the water would quickly escape through the sand. There was a brief period of flow in 2014, but the site was flooded and inaccessible so no samples were collected. There was no observed tile flow in 2015 so no sampling was possible





MN-2. Although water samples were collected for 7 dates in 2014, no samples were collected from transect 3 or well 11 and only 1 sample from wells 21 and 22. Only well 13 consistent had water samples, thus the results are very incomplete and difficult to interpret for 2014. Similarly, no water samples were submitted for well 31 and only samples from 2 of the 5 sample dates for wells 11, 21, 32, and 33 in 2015 leading to sparse sampling results. The lack of water samples from well 31 was most likely due to the shallow depth of installation of this well (3.38'), but we are uncertain as to why the other wells were often dry. As a result we could not determine a pattern for average TDP concentrations in the buffer wells for 2014. In 2015, average TDP concentrations were higher for some of the buffer well positions than for the tile or stream. We conclude that there was no P removal in this buffer.

Summary of phosphorus concentration data

In a survey of phosphorus concentrations in unconsolidated aquifers in Iowa, Burkart et al. (2004) found average TDP concentrations ranging from 0.077 to .212 mg L^{-1} with maximum individual samples exceeding 1 mg L^{-1} in shallow groundwater. TDP concentrations in the buffer wells in this study mostly fell within this range for many of the sites. Exceptions were at sites IA-3, IN-3, IL-5, and MN-2 through MN-4. Reasons for the high P concentrations in the shallow groundwater in these buffers is not clear, but does not seem to be related to the TDP coming from the field outlet which is usually much lower. These higher TDP concentrations may be related to past field practices at these sites.

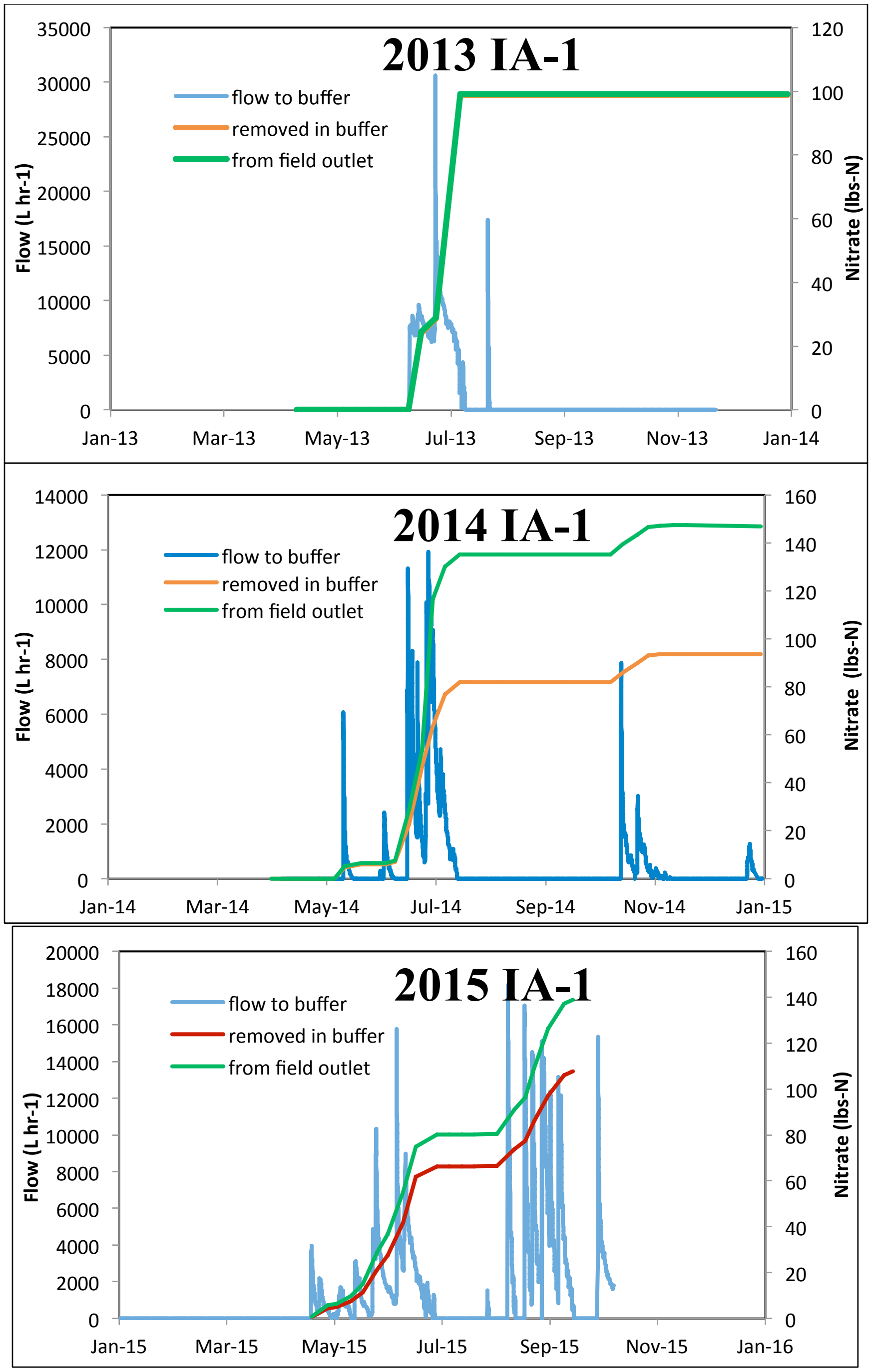
For the removal of P in saturated buffers, our data seems to indicate that in only 1 site (IA-2) was there good evidence of P removal. However, our results may be biased by the method by which we determined P removal within the buffer. Some of the high TDP concentrations we measured in the buffer observation wells may be attributable to the fine sediment that is often collected with the water samples as indicated by the turbidity of many of the samples. Even though these samples were filtered after collection through a 0.45 micron filter, there is the possibility that some fines were still in the sample before determination of TDP and would have contributed to the total P value. We suspect that this accounts for many of the high TDP values we measured in the well samples as there is P in the buffer soil and this P would contribute to the TDP measurement if soil fines are not completely removed. Filtering through an even finer filter may have prevented some of this suspected contamination of the well water samples, but would not have been practical given the difficulties of using finer meshed filters and the inexperience of the water collection volunteers we had to rely on for this study. Given this limitation of our methods, we would still conclude that there is little evidence of P removal in the saturated buffers examined in this study primarily because TDP within the groundwater of the buffers had concentrations greater than TDP concentrations coming from the field tile outlets.

Flow and nitrate load

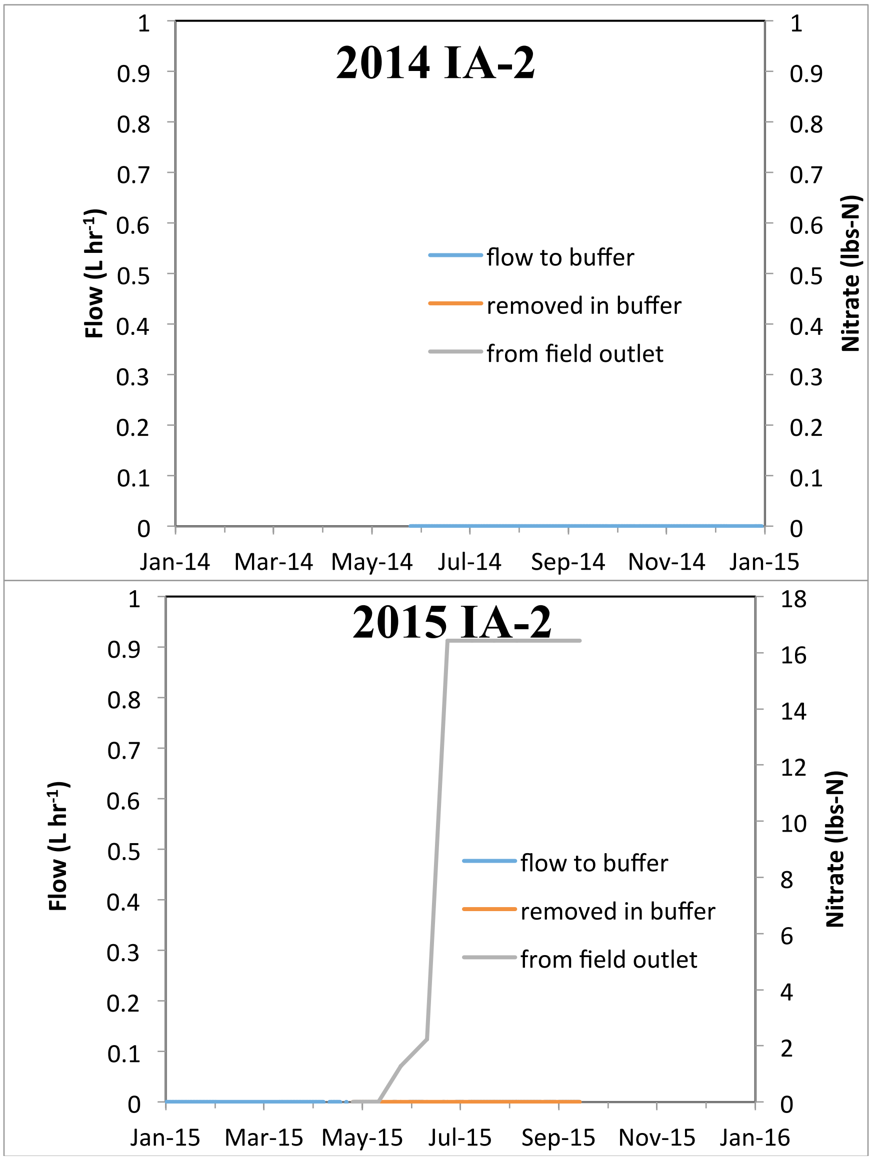
Flow to the buffer was determined at most sites by measuring tile flow leaving the field at the tile outlet where it was intercepted by the control box. This flow was calculated from the measured height of the water column above the flashboards separating the 1st from the 2nd chamber of the control box. Flow from the outlet that did not go to the buffer was discharged directly to the stream and this flow was calculated by measuring the height of the water column in the 2nd chamber as it flowed over the flashboards separating the 2nd from the 3rd chambers of the control box. Flow rates over both sets of flashboards were computed by using a rating equation that converted height above the flashboards to flow rate in gallons per minute. Flow to the buffer is computed as the difference between the flow from the field minus the flow to the stream. This difference method is a cost effective method for determining flow both from the field and out to the buffer. However, any errors or inaccuracies in measuring flow within the control box will be magnified in the computed flow to the buffer. Given the design of the 3-chamber control box, computed negative flows to the buffer are not possible unless the stream is in flood stage or as a result of errors in the flow measurements over the two sets of flashboards. Thus, for this analysis, we set any negative flows to 0, and only computed nitrate removal when water is flowing from the control box out to the buffer.

Nitrate load that went out to the buffer was determined by multiplying the flow to the buffer over a given time period by the nitrate concentration in the tile outlet for the same period. At sites where flow was measured for times when nitrate concentration was not measured, the nitrate concentration for the time closest to the flow measurement period was used. Thus, we can compute the total load of nitrate being delivered by the tile outlet for each year. To compute the nitrate removal within the buffer, the nitrate load that entered the buffer computed above was multiplied by the average nitrate reduction found within the monitoring wells placed in the buffer. To compute the nitrate reduction within the buffer, we took the average nitrate concentration in the tile outlet minus the average nitrate concentration within the wells closest to the stream. While simple, this method could be in error. For example, there were many sites where the nitrate concentrations in the wells closest to the stream were higher than nitrate concentrations in the middle of the buffer. As noted in the nitrate concentration section above, the higher concentrations in streamside wells may have reflected stream bank storage where the high nitrate concentration stream water infiltrated the soil next to the stream raising the concentration in the streamside wells. In this case, our calculation of nitrate removal within the buffer may have been conservative.

Flow and nitrate load removal calculations are shown below for each site-year. In the figures, we show the flow rate out to the buffer where we expect denitrification to remove some of the nitrate. Also shown is the cumulative mass of nitrate that is being removed within the buffer and the cumulative mass of nitrate that was leaving the field through the tile outlet.



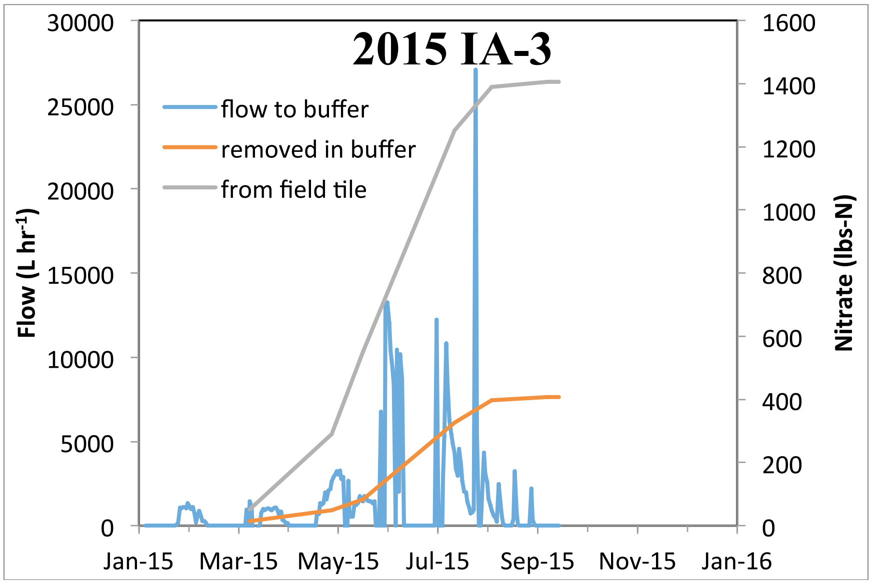
IA-1. Nitrate was removed in the buffer each year. In 2013, flow was not measured until mid-June so only nitrate removal within the buffer for the 2nd half of the year was computed that year. For the 2nd half of 2013, 100% of the nitrate entering the buffer was removed which totaled 99 lbs of nitrate N (green and red lines fall on top of each other). In 2014, 94 lbs of N as nitrate or 64% of the 147 lbs of nitrate-N delivered to the field outlet was removed in the buffer. In 2015, 139 lbs of N as nitrate was carried to the outlet and 107 lbs or 77% of nitrate-N was removed in the buffer. For these years 100, 64, and 91% of the flow from the field was redirected into the buffer. Thus, over the 2½ years at this site 301 lbs of nitrate was removed in the buffer – nitrate that would have otherwise discharged directly into the stream.



IA-2. No flow to the buffer was measured in either 2014 or 2015, thus we computed no nitrate removal within the buffer for these years. Lack of flow to the buffer is very likely due to inaccuracies in the flow measurements over the control box flashboards rather than there being no physical flow to the buffer distribution pipe. In addition, no usable flow were recorded in 2014, while in 2015 we computed only 16 lbs of N as nitrate leaving through this field tile outlet.

2014 IA-3

No load calculated



IA-3. Water samples for only 1 date were collected at this site in 2014 so no load estimates were computed. In 2015, about 30% of the tile flow was redirected into the buffer. A total of 1408 lbs N as nitrate was discharged at the field tile outlet and 408 lbs or 29% of nitrate-N was removed in the buffer. This was nitrate that would have otherwise discharged directly into the stream.

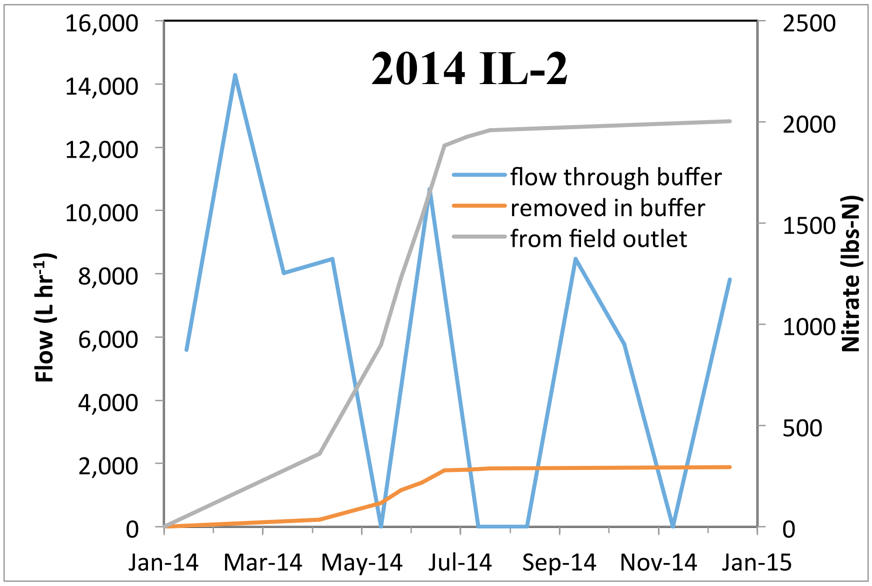
2014 IL-1

No flow data

2015 IL-1

No flow data

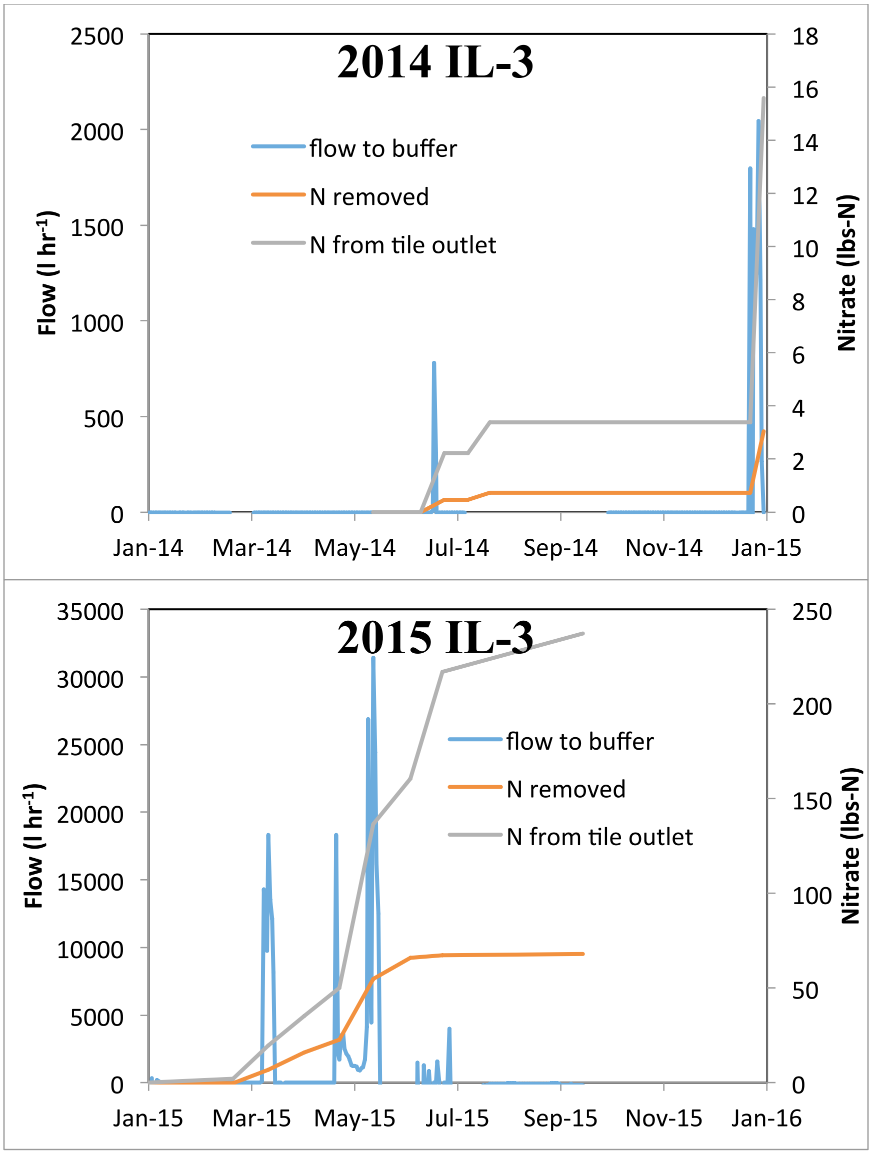
IL-1. There was no usable flow data for 2014 or 2015 for this site, thus we were unable to compute nitrate loss either through the field tile outlet or in the buffer.



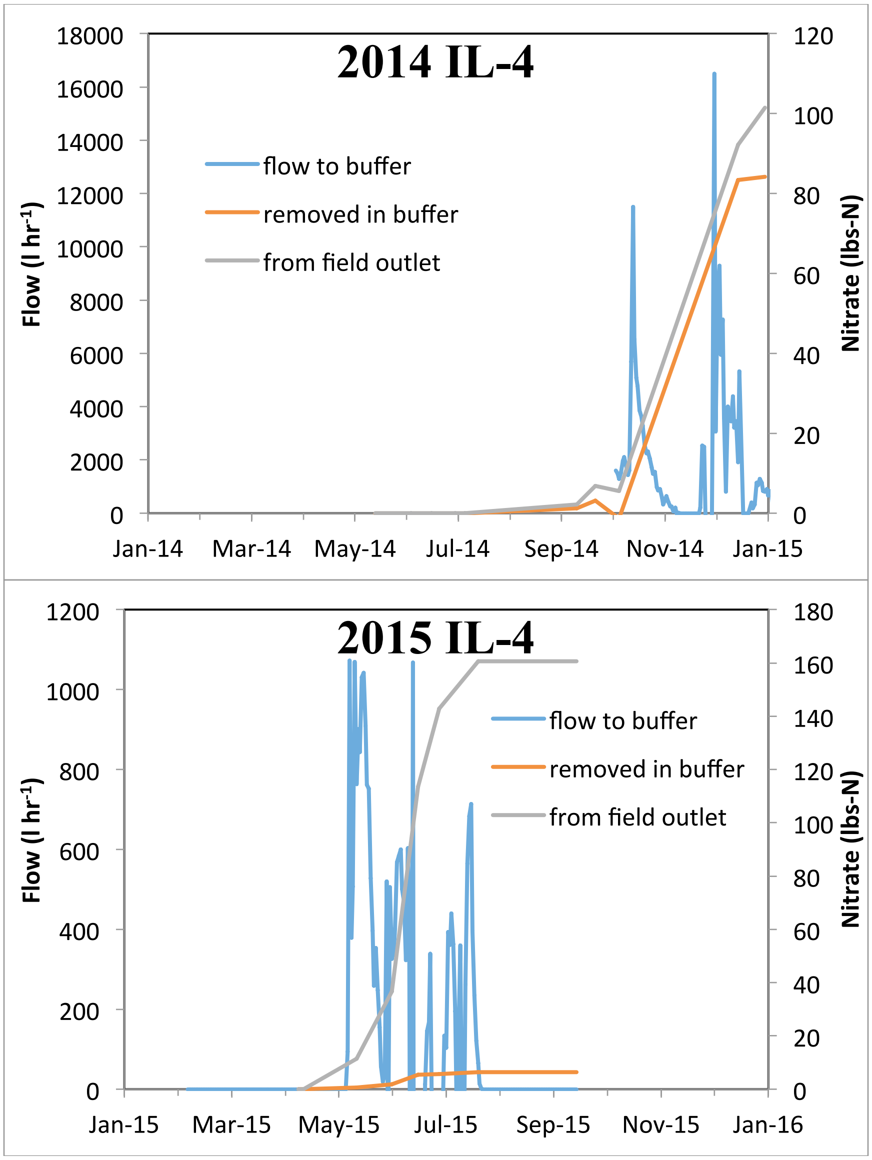
2015 IL-2

Flow data unavailable

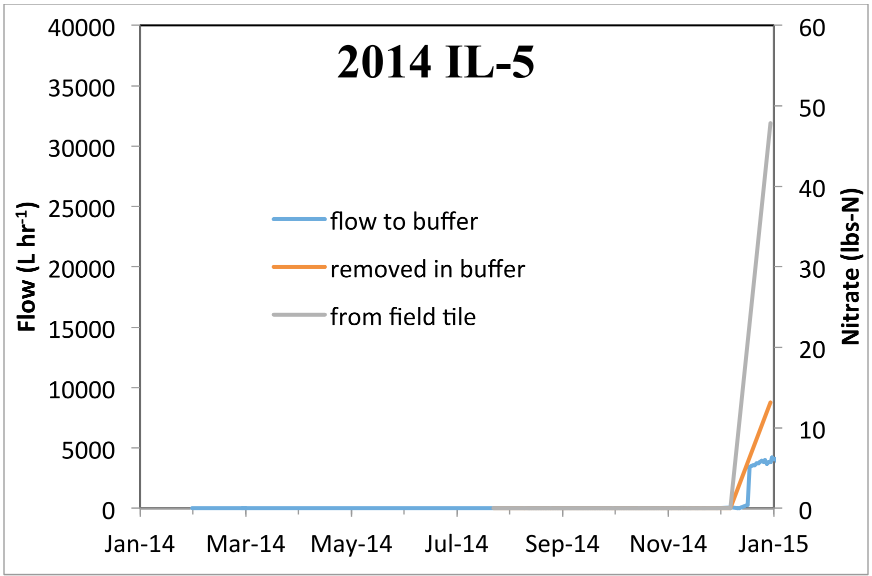
IL-2. As previously explained the flow data generated from this site did not allow the same load calculations as the other sites. Using the results of the DRAINMOD simulations we estimated the flow through the buffer for 2014. Assuming that this flow passed through the riparian buffer, we computed the mass of nitrate removed. In 2014, 64% of the flow that would have left the field at the field outlet was redirected as groundwater through the buffer. We computed that the buffer removed 293 lbs of nitrate-N or 15% of the nitrate that would have left the field through the tile outlet. No DRAINMOD modeling results were available for 2015 to make similar calculations.

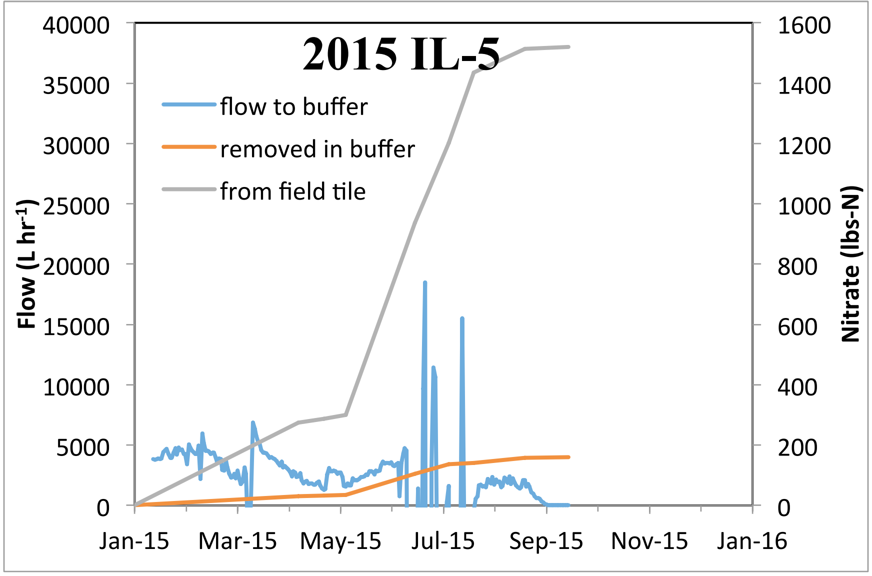


IL-3. In 2014 only a couple of flow events to the buffer were recorded and there were breaks in the flow measurement record. Total nitrate-N loss through the field tile outlet for these periods was 15.6 lbs of which 3 lbs were removed in the buffer for a 19.5% removal rate. In 2015, a longer flow period was recorded and nitrate-N removal within the buffer totaled 68 lbs, which was 28.7% of the 237 lbs of nitrate-N leaving through the field tile outlet. For the two years, 71 lbs of nitrate-N was removed in the buffer that would have otherwise discharged directly into the stream.

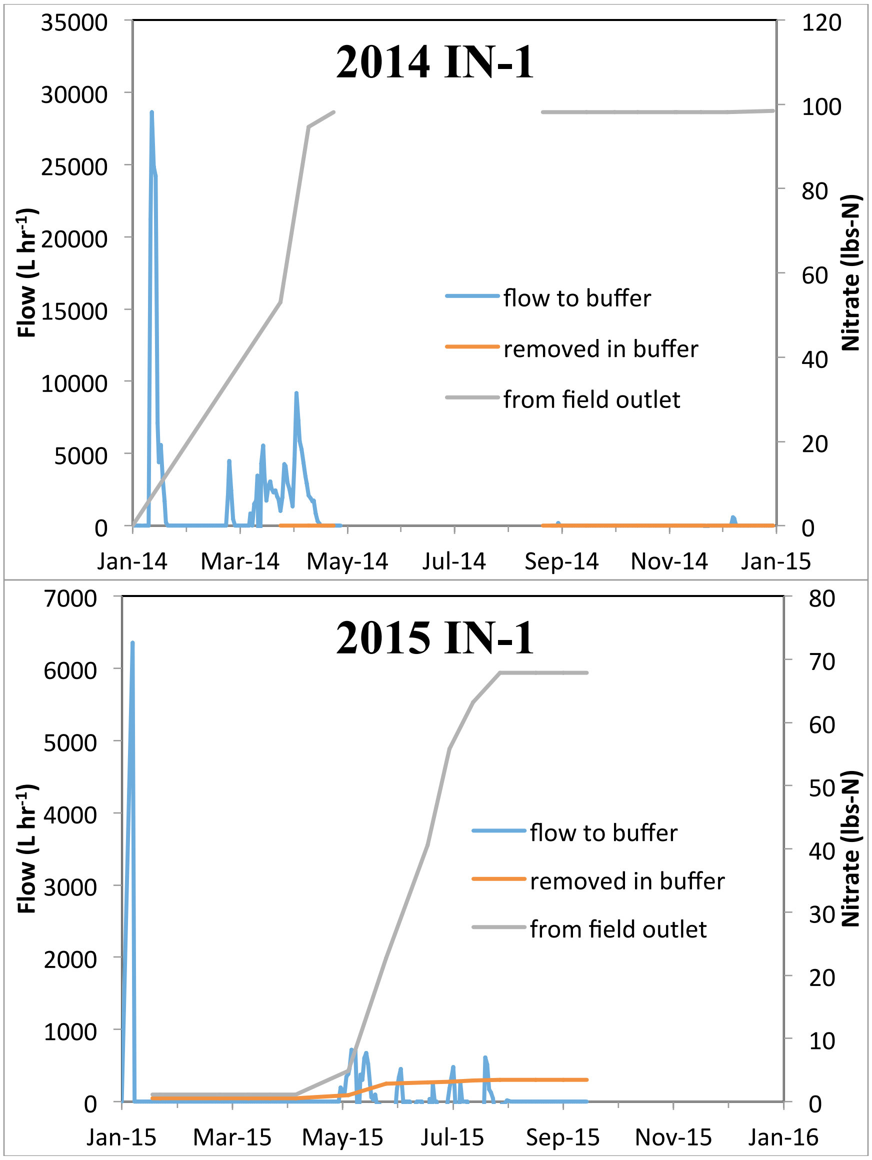


IL-4. In 2014, we were able to measure flow for only the latter quarter of the year. During this time, 91% of the tile flow was redirected into the buffer and the buffer removed 84 lbs of nitrate-N compared to the 101 lbs lost through the tile outlet, for an 83% removal rate. We appeared to have better flow measurements in 2015 which showed over 160 lbs of nitrate-N leaving the tile outlet, but only 6.4 lbs being removed in the buffer. This 4% removal rate was due in part to only 13% of the tile flow being redirected into the buffer and only about a 50% nitrate removal rate within the buffer as determined by the decrease in nitrate concentrations in the observation wells across the buffer.

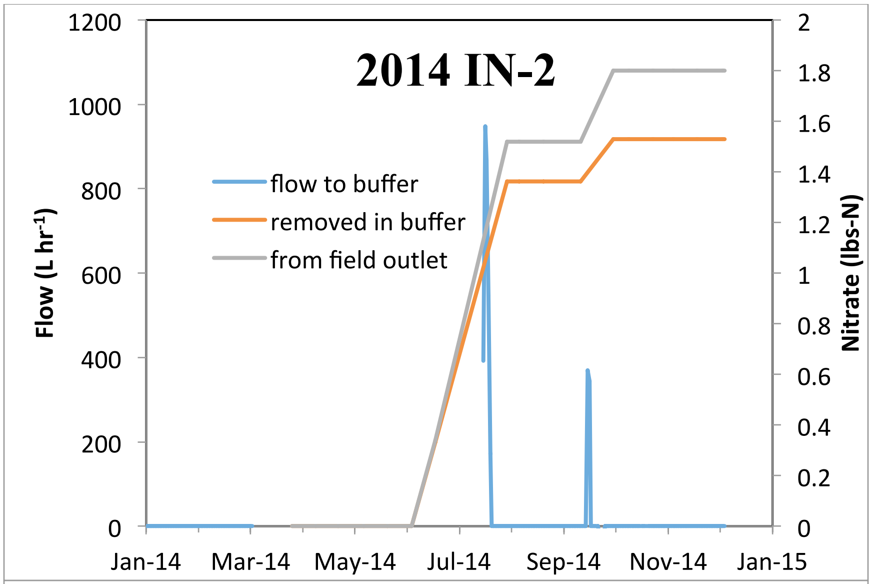


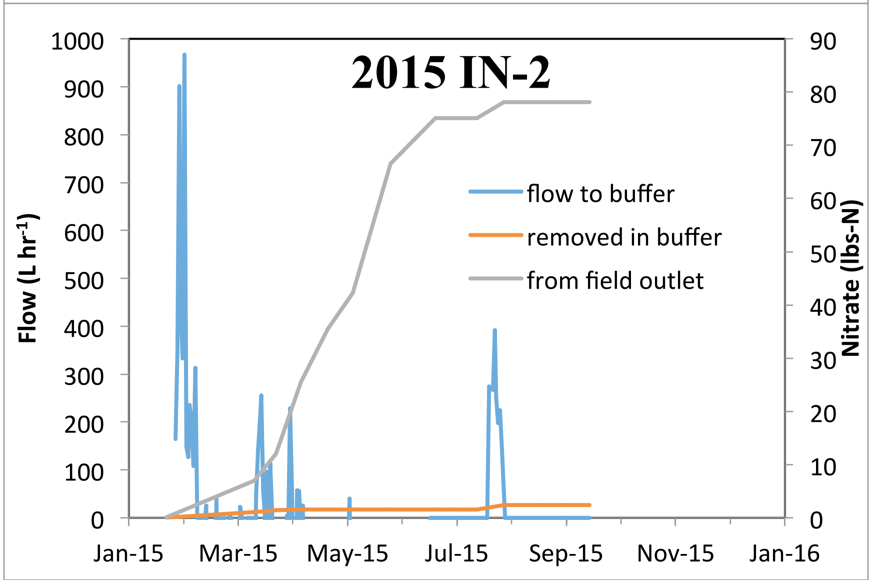


IL-5. The only usable flow recorded in 2014 was in December where 91% of the field tile flow was redirected into the buffer. From this flow we computed that 13 lbs of nitrate-N was removed in the buffer of a possible 48 lbs lost through the field tile outlet. This was a removal rate of 27.6%. In 2015, a longer record of flow helped us determine that 26% of the flow was redirected into the buffer and that the buffer removed 161 lbs of a possible 1520 lbs of nitrate-N that left the field through the tile outlet. This was a removal rate of 11%. Thus, over the two year period, 174 lbs of nitrate-N was removed by this buffer that would have otherwise discharged directly into the stream.



IN-1. Flow values measured in the spring and fall of 2014 indicated that 81% of the discharge from the tile outlet was redirected through the buffer. The field tile discharged a total of 98 lbs of nitrate-N to the control box in 2014. However, nitrate concentrations in the buffer wells indicated that none of this nitrate was removed in the buffer. In 2015, only 6% of the tile flow was redirected into the buffer. A total of 3.5 lbs of nitrate-N was removed within the buffer that year out of a total of 68 lbs that was delivered to the control box. This gave a nitrate removal of 5%. Thus, this buffer was not effective in removing nitrate from field tile flow.





IN-2. There was a gap in flow data during March through June in 2014. However, of this flow 99% was redirected into the buffer. The buffer removed 85% of this nitrate or 1.5 lbs nitrate-N of the total 1.8 lbs delivered to the field tile outlet. 1n 2015, there were also gaps in the measured flow primarily due to stream flooding events raising the water level higher than the flashboards in the control box. We were able to measure that 4% of the flow that entered the control box was redirected into the buffer. The total nitrate load to the control box that year was 78 lbs nitrate-N of which 2.3 lbs or 3% was removed in the buffer. Thus in two years this buffer removed 3.8 lbs of nitrate-N – thus this site was not effective in removing nitrate.

2014 IN-3

No usable flow data

2015 IN-3

No usable flow data

IN-3. No water samples were collected from this site in 2014. In 2015, water samples from only three dates were collected. We measured no flow to the buffer primarily because when flow occurred the water level in the ditch was higher than the flashboards in the control box preventing any measurement. As a consequence, there was no measured nitrate removal within the buffer. Thus, this site did not function effectively for nitrate removal.

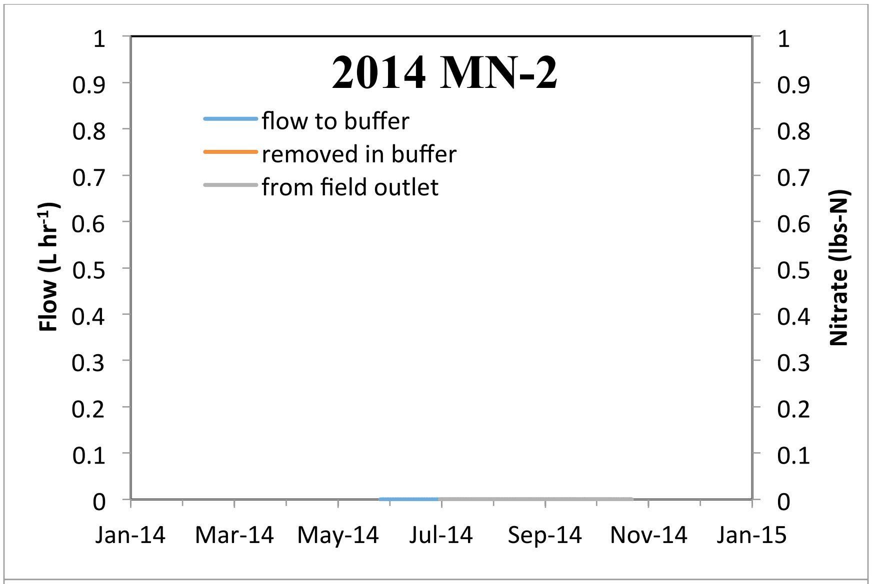
2014 MN-1

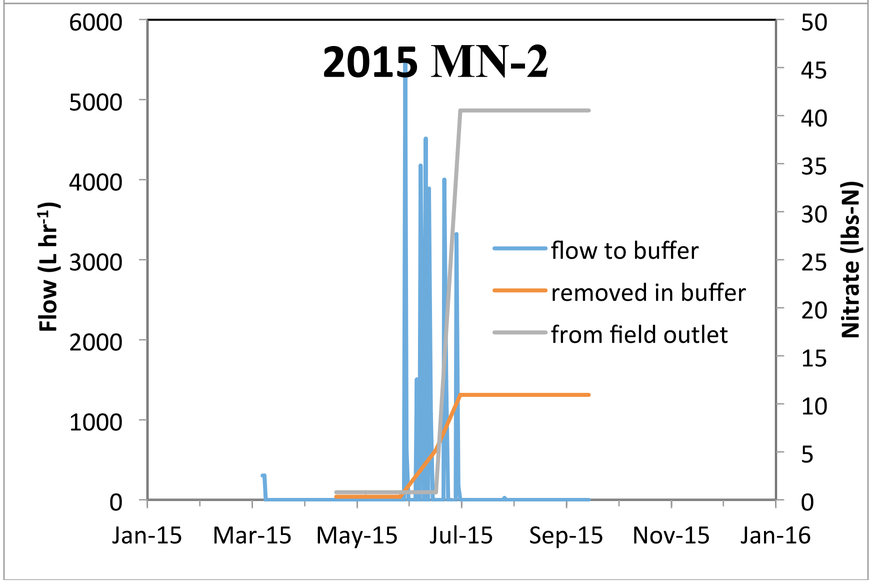
No usable flow data

2015 MN-1

No water data

MN-1. No water samples were ever turned in from this site. After installation it was discovered that an extensive sand lens connected the field with the adjacent river. When the water level in the river was high there would be water in the groundwater monitoring wells. As soon as the river dropped, however, the water would quickly escape through the sand. There was a brief period of flow in 2014, but the site was flooded and inaccessible so no samples were collected. There was no observed tile flow in 2015 so no sampling was possible.





MN-2. No flow to the buffer was recorded in 2014 primarily due to flooding. In 2015, 22% of the flow leaving the field at the tile outlet was redirected through the riparian buffer. The total nitrate-N mass leaving the field in 2015 was 162 lbs. Of this mass, 26 lbs of nitrate-N was removed within the buffer which is equivalent to 16% of the total nitrate mass. Thus, this site showed a moderate ability to remove nitrate.

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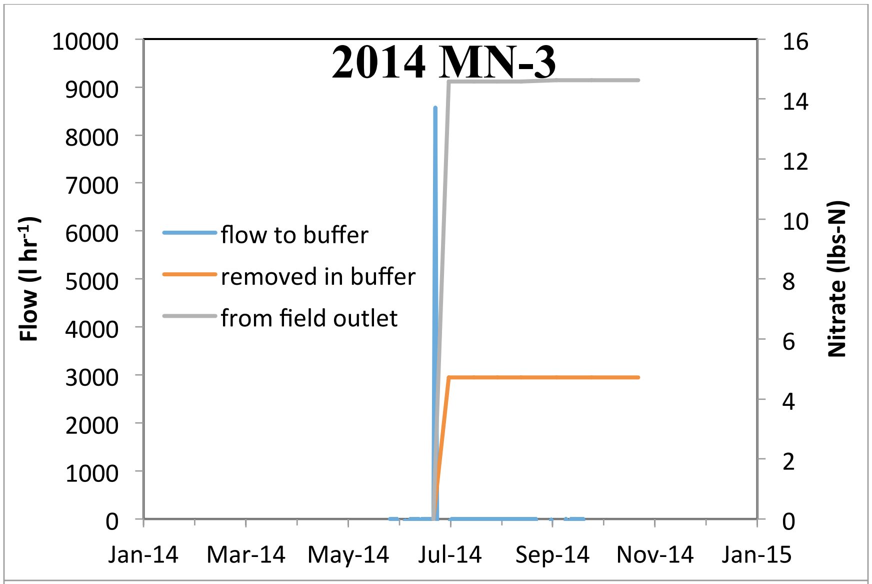
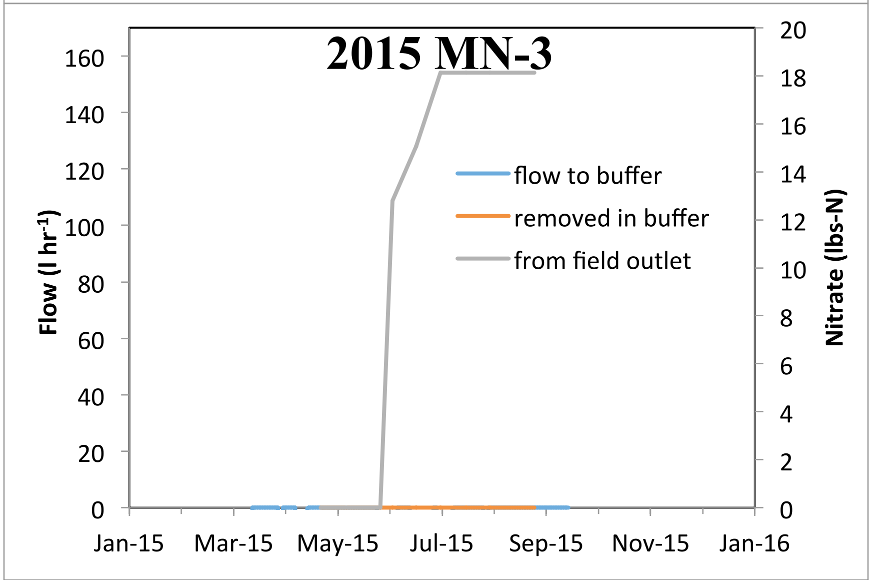
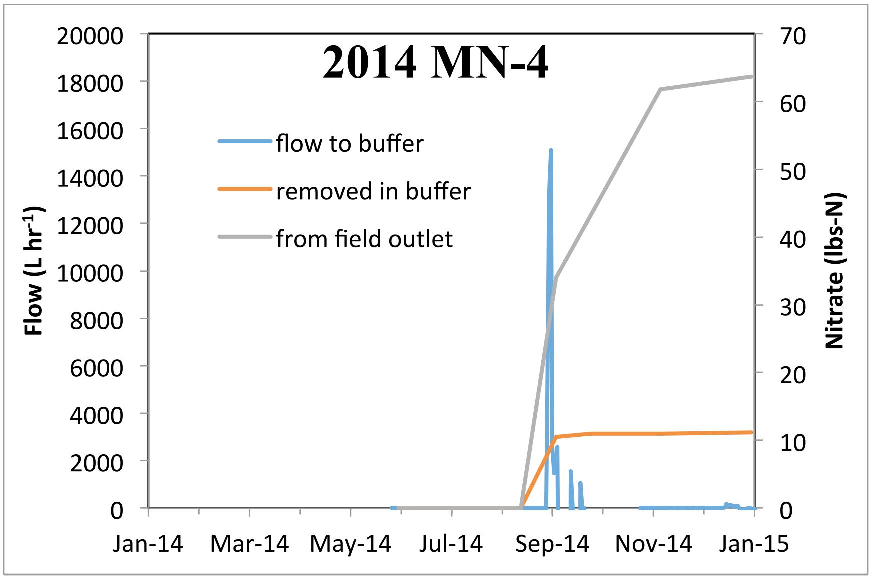
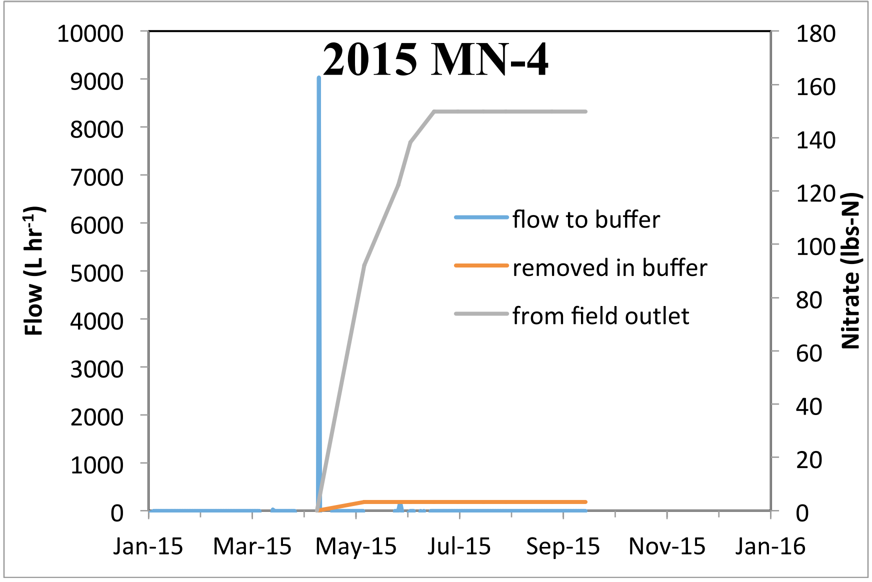




MN-3. Because of flooding only a brief period of flow to the buffer was recorded in 2014 representing 40% of the total flow from the field outlet that year. Five lbs or 32% of nitrate-N was removed within the buffer of the total 15 lbs nitrate-N carried to the field tile outlet. In 2015, no flow to the buffer was recorded and very little flow to the field tile outlet. Thus, none of the 18 lbs of nitrate-N lost from the field was removed in the tile. This site was not very effective in removing nitrate mainly because we recorded very little flow from the field tile outlet.





MN-4. Flow to the buffer was recorded for a brief period in September of 2014. This flow represented 58% of the total discharge from the field tile outlet. In 2014, 11 lbs of nitrate-N was removed in the buffer of the total 64 lbs nitrate-N discharged from the field tile outlet which was 18% of the total nitrate mass. In 2015, flow to the buffer was recorded for only a brief period in May because much of the tile flow period was dominated by flooding, and this period accounted for only 4% of the total field tile discharge to the outlet. Flow to the buffer removed 2.3% or 3.4 lbs of 150 lbs of nitrate-N that entered the control box from the field tile outlet. Over two years this site removed 15 lbs out of a possible 214 lbs of nitrate-N discharged from the field tile outlet. Thus, this site was not very effective in removing nitrate.

Nitrate Removal Summary

For there to be effective nitrate removal within the buffers two things are required. First, there must be flow of tile drainage into the buffer that contains measureable amounts of nitrate. And second, the nitrate that enters the buffer must be removed either by denitrification or sequestration within the growing buffer biomass. At all of the sites, the tile drainage contained plenty of nitrate with typical concentrations ranging from 7 to 40 mg L^{-1}. However, we did not record consistent flow from the control structure into the distribution pipe taking water into the buffer. In 2014, problems with some of the measurement sensors often prevented accurate flow measurement. These were corrected for the most part late in 2014 and all of 2015. Still many of the sites did not have recorded flow to buffer in 2015. At some sites and times this may have been due to flooding where the ditch or stream was higher than the flashboards within the control structure preventing flow measurement. Often flow over the second set of flashboards was computed to be greater than over the first set of flashboards resulting in negative flows being computed into the buffer. This makes little sense other than in flood conditions. Perhaps the flashboards were not always set as we had intended them to be thus affecting the computed flow. The negative flow findings need to be further assessed and improved during future monitoring.

Even given the difficulties in measuring flow into the buffers, several of the sites recorded good nitrate removal capabilities. IA-1 was not plagued by flow measurement issues and showed good nitrate removal in 2013 - 2015. This site removed 301 lbs of nitrate-N over 2 ½ years – nitrate that would have discharged directly into the stream if it had not been redirected into the buffer. In 2014, sites IL-4, IL-5 and MN-4 also showed substantial nitrate removal. However, only IL-5 showed considerable nitrate removal in 2015 as well. At this time we do not understand the lack of consistency in nitrate removal for the IL-4 and MN-4 sites. IA-3 showed considerable nitrate removal in 2015, but unfortunately had no water samples collected in 2014. IL-3 and MN-2 also showed considerable nitrate removal in 2015. These sites failed to show significant nitrate removal in 2014, but this may have been due more too missing or errant flow measurements in 2014 than to a lack of performance by the buffers. Summed together, 5 sites (IA-1, IA-3, IL-3, IL-5, and MN-2) removed 770 lbs of nitrate-N in 2015 that would have otherwise discharged directly into surface waters.

Soil Properties

Soil samples were collected in near the beginning (Set 1) and again at the end (Set 2) of the project to measure any change in soil quality parameters that could be influence by the implementation of a saturated buffer. A comparison of soil organic matter found a significant difference (alpha = 0.10) between the years with an average increase of 0.20% organic matter at the 0 – 1 ft depth only. There was no significant difference in soil organic matter at the other depths. Table lists the average %organic matter for all the sites. The full data for each site is given in Appendix F.

Changes in % Soil Organic Matter were tested (alpha = 0.10) for areas within the saturated buffer.

Depth	n	Mean (%)		Difference	P(T<=t) two-tail
		Set 1	Set 2		
0 - 1 ft	41	4.01	4.21	0.20	0.01
1 - 2 ft	41	3.34	3.37	0.03	0.70
2 - 3 ft	41	2.82	2.85	0.03	0.80
3 - 4 ft	39	2.47	2.27	-0.20	0.12

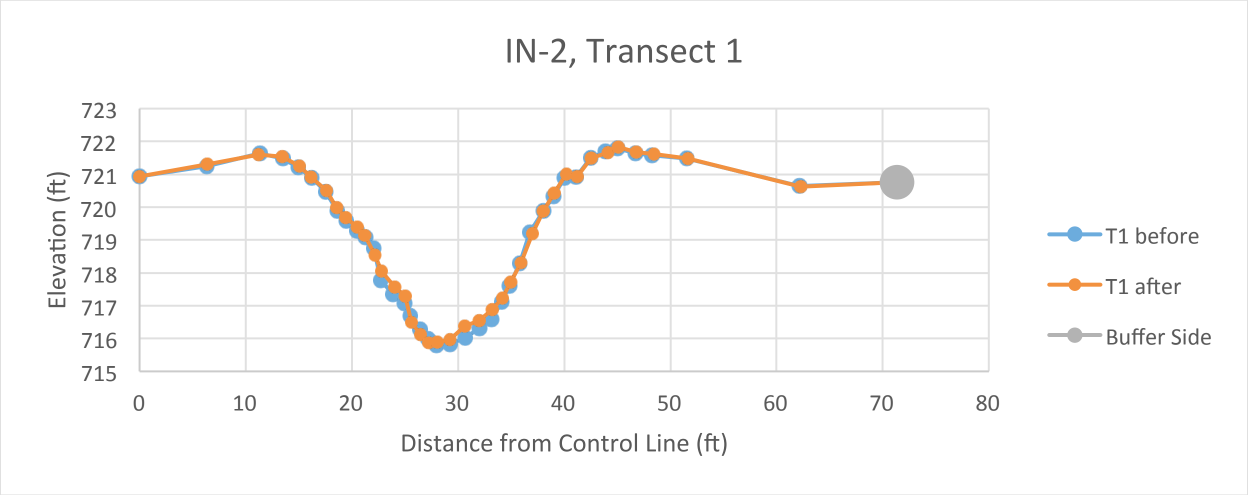
The soil phosphorus concentration was also measured. It was found that the phosphorus concentrations at all depths were significantly higher (alpha = 0.10) in 2014 than they were in 2015. Soil samples were not collected outside the saturated buffer area so it is unclear whether this change was a result of the practice or due to other circumstances.

Changes in Bray-1 soil phosphorus concentration (ppm) were tested (alpha = 0.10) for areas within the saturated buffer.

Depth	n	Mean (ppm)		Difference	P(T<=t) two-tail
		Set 1	Set 2		
0 - 1 ft	41	25.7	23.0	-2.7	0.02
1 - 2 ft	41	12.2	10.3	-2.0	0.02
2 - 3 ft	41	10.4	8.2	-2.2	0.01
3 - 4 ft	39	10.7	8.7	-2.0	0.01

Streambank Stability

A series of ditch transects were intensively surveyed at two of the saturated buffer sites near the start of the project. These same transects were then surveyed a second time at the conclusion of the project to determine if adoption of the practice had any measurable impact on stream bank stability. An example graphical comparison of the “before” and “after” surveys is given below. Plots of all transects are given in Appendix G.



To distinguish between natural changes in the streambank versus those resulting from the SB practice three transects were surveyed outside of the SB area (labeled “Control”) in addition to the three transects that were surveyed within the SB area (labeled as Treatment”). The data labeled “Test” were collected on the same side of ditch as the saturated buffer. As such, only data that are labeled “Test” and “Treatment” actually occurred within the SB area and would have been influenced by the practice. The summary of the results, given below in Table, indicate that, while some measurable changes in the streambank did occur, they cannot be fully attributed to the installation and use of the SB practice.

Site	Transect	Type	n		P(T<=t) two-tail	
			Test*	Control*	Test*	Control*
IL - 3	1	Treatment	20	26	0.31	0.36
	2	Treatment	19	25	0.61	0.83
	3	Treatment	23	23	0.39	1.00
	4	Control	25	14	0.32	0.41
	5	Control	21	18	0.26	0.83
	6	Control	18	17	0.03	0.21
IN - 2	1	Treatment	21	19	0.00	0.24
	2	Treatment	13	26	0.22	0.00
	3	Treatment	17	16	0.21	0.09
	4	Control	18	22	0.05	0.01
	5	Control	18	19	0.38	0.06
	6	Control	12	27	0.07	0.36

* “Test” refers to the side of the ditch where the saturated buffer was installed. This same designation is applied to the areas that are either upstream or downstream of the saturated buffer area. Similarly, the “Control” designates the side of the ditch opposite to the saturated buffer.

Conclusions, Recommendations and Lessons Learned

Saturated Buffer Performance: Nitrate Load Reductions

As documented in Jaynes and Isenhart (2014), at least two conditions are necessary for nitrate removal in a saturated buffer. First, the soil in the buffer must have a sufficient soil carbon content to serve as an energy source for the denitrifying bacteria. Burford and Bremner (1975), showed that soil with organic carbon contents of at least 2% can easily sustain denitrification To be inclusive we used a threshold 1% organic carbon needs to be present in the soil at 2.5 ft deep to support denitrification. The second criteria is that the watertable in the buffer can be raised to submerge the high carbon soil layer, therefore restricting oxygen diffusion and leading to an anaerobic condition conducive for denitrification. Thus, there must be evidence of either a historically high water table at the depth of the high soil carbon layer, or the presence of a hydraulically restricting layer in the buffer soil that would allow us to raise the watertable by re-directing tile drainage into the buffer. A sandy or gravelly soil layer, the lack of a restricting soil layer at depth, or evidence of historically unsaturated conditions would not be conducive for raising the watertable to increase denitrification, limiting the nitrate removal performance of the buffer.

With the above conditions in mind, we evaluated the nitrate removal performance of the installation at each site based on several criteria. First, we used the measured nitrate removal from redirecting tile flow into the buffer by the control structure. Because we did not have reliable flow measurements for all site-years, we also looked at the trend in average nitrate concentrations across the buffer as measured in the observation wells each year. A decreasing trend in nitrate concentration from the field-side to the stream-side of the buffer was considered an indicator of potential nitrate removal. Also if the nitrate concentration in the buffer wells were consistently lower than in the field outlet tile water, we assumed that the buffer had the potential to remove nitrate. We also examined the soil properties of the buffer to assess the presence of sufficient soil carbon at depth and signs of being able to raise the watertable above this layer as indicated by reduced or gleyed soil and high chroma redoximorphic features.

Table 1. Matrix showing results and suitability of each site for nitrate removal. A “+” means the site meets the criteria, a “-” means it does not and a 0 means it is intermediate. Missing data are indicated by n.d.

Site	2014 lbs Nitrate removed	2014 %NO3 removed	2015 lbs Nitrate removed	2015 %NO3 removed	2014 %flow diverted	2015 %flow diverted	promising [NO3] trend	Need to adjust boards	soil carbon >2% @ 2.5 ft	High water table	Saturated buffer performance			comment
											performing	promising	not performing	
IA-1	94	64	107	77	64	91	+		+	+	+			
IA-2	0	0	0	0	0	0	+	-	-	+			+	no flow, coarse soil, low C
IA-3	n.d.	n.d.	408	29		30	+		+	+	+			
IL-1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-		+	+			+	no flow to buffer
IL-2	293	15	n.d.	n.d.	64	n.d.	+	-	+	+		+		as controlled drainage
IL-3	3	19	68	28	19	33	0	-	+	+	+			
IL-4	84	83	6.4	4	91	13	+/-		+	+		+		need better flow data
IL-5	13	28	161	11	91	26	+/0		+	+	+			
IN-1	0	0	3.5	5	81	6	0	-	-	-			+	low C, coarse soil
IN-2	1.5	85	2.3	3	99	4	+/0	-	-				+	low C
IN-3			0	0	n.d.	n.d.	-	-	+	+/-			+	flooding, coarse soil layer
MN-1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-	+	n.d.			+	flooding
MN-2	0	0	26	16	0	22	0/-		+	+			+	coarse soil layer
MN-3	5	32	0	0	40	0	+		+	-		+		coarse soil layer
MN-4	11	18	3.4	2	58	4	0/-	-	+	-			+	coarse soil layer

The above table summarizes the nitrate removal and site characteristics criteria we used to evaluate each site. Sites that showed substantial nitrate removal included IA-1, IA-3, IL-3, and IL-5. IA-1 performed well over 2013-2015 removing at total of 301 lbs of nitrate-N over 2 ½ years. We only had water quality data for 2015 at IA-3, but this site removed 408 lbs of nitrate-N that year and all of our other criteria indicate that this site should perform well. IL-3 removed 68 lbs in 2015 and IL-5 removed 161 lbs of nitrate-N. These two locations also met our expected requirements for soil characteristics of successful saturated buffers. Both sites had limited nitrate removal in 2014 (3 and 13 lbs nitrate-N, respectively) but these calculated removal rates may have been due to less reliable flow values in that year.

Besides these four sites, IL-2, IL-4, and MN-3 showed promising results in at least one year. For IL-2, this site functioned more as a controlled drainage site rather than a saturated buffer due to the way it was installed and the landscape characteristics at this site. Making some simplifying assumptions and relying on Drainmod modeling results, we computed a sizeable (293 lbs N) nitrate removal at this site in 2014. IL-4 and MN-3 had good nitrate removal in 2014 but limited removal in 2015. IL-4 also met all of our other criteria for a well-functioning saturated buffer. Thus, we feel that this site shows promise and may prove to be very effective in removing nitrate if more reliable flow data can be obtained.

Of the remaining sites, we had insufficient data for MN-1, IL-1, and IN-3 to determine their nitrate removal performance. However, given that IN-3 and MN-1 are susceptible to flooding at the control structure, their performance may be difficult to determine using the techniques used in this evaluation. The other five sites, IA-2, IN-1, IN-2, MN-2 and MN-4 did not show positive results for being used as saturated buffer for removing nitrate. Reasons for their failure to perform could be related to several factors. For example all of these sites except IN-2 were underlain by coarse materials below the high organic carbon layers. These coarse materials may have prevented the watertable from rising high enough in the buffer to reach the high organic carbon layers in the soils to drive denitrification. Sites IA-2, IN-1, and IN-2 also had organic carbon contents less than 1% at 2½ feet and thus may have been carbon limited for effective denitrification.

Cost of Removing Nitrate with Saturated Buffer

For comparison purposes we can compute the cost of a saturated buffer over its lifetime and divide this cost by its expected annual removal of nitrate to compare to other nitrate removal practices. Using the costs of installation for the four sites that proved effective in removing nitrate (IA-1, IA-3, IL-3, and IL-5), assuming a 50 year effective lifespan for these installations, and a 4% inflation rate or cost of money, we compute costs ranging from $0.55 to $4.64/lbs-N with an average of $2.13/lbs-N removed for the four sites. This compares to estimates of $0.92/lbs-N for denitrification bioreactors, $1.38/lbs-N for nitrate removal wetlands, and $5.96/lbs-N for rye cover crops (Iowa Nutrient Reduction Strategy, 2014**)**. Thus, the effective saturated buffers in this study have a cost range similar to these other field-edge practices and much less than fall-planted cover crops. In addition, the practice takes no more land out of production than already used for the riparian buffer.

Saturated Buffer Performance: Phosphorus Load Reductions

There were no consistent trends at the monitored buffers that indicated that dissolved phosphorus in the tile water was removed by the saturated buffers. Therefore, we conclude that the saturated buffer practice as implemented in this project cannot appropriately be assumed to treat phosphorus-related water quality concerns.

Saturated Buffer Performance: Soil Organic Matter (Carbon)

Soil organic matter in the 1 – 4 ft depth range were not shown to change over the course of this project. While it is possible that increased denitrification in the subsoil could have an impact on the amount of organic matter present, it is likely that the length of time that the soil was monitored was insufficient to detect a measurable change. This may have also been confounded by the wide variety of management elevations employed at the different sites. The increase in soil carbon within the top foot of the soil profile is likely a result of the vegetation growing on the buffer in general and not the saturated buffer practice itself.

Saturated Buffer Performance: Impacts on Soil Phosphorus Levels

The soil data collected did show, on average, that soil phosphorus levels decreased over course of our study. However, adequate soil samples were not collected outside of the saturated buffers so we cannot say with any certainty that the decrease was a result of this practice. While the phosphorus testing performed on the water samples indicates the possibility that some dissolved phosphorus could be leaving the buffer through increased lateral water movement into the ditch or stream, the magnitude of the decrease in soil phosphorus cannot be fully accounted for through this pathway.

Saturated Buffer Performance: Streambank Stability

Intensive surveys were performed on multiple ditch transects at two sites, IL-3 and IN-2. The IL-3 ditch was selected because, at 10 ft deep, it is the deepest ditch at any of the sites in this project. This ditch, which appeared to have stable banks prior to implementing the practice, showed no significant changes due to the saturated buffer. IN-2, which similarly had fairly stable banks prior to the study, also showed no bank movement that could be attributed to the saturated buffer. We conclude that on ditches/streams with stable banks the SB will not cause increased sloughing or other stability issues. Ditches/steams with highly unstable banks prior to implementation could still be considered but more thorough planning and design would be warranted.

Appendix A - Site Descriptions

This section contains detailed descriptions of each site. It is designed such that each site description can stand alone as a separate document.

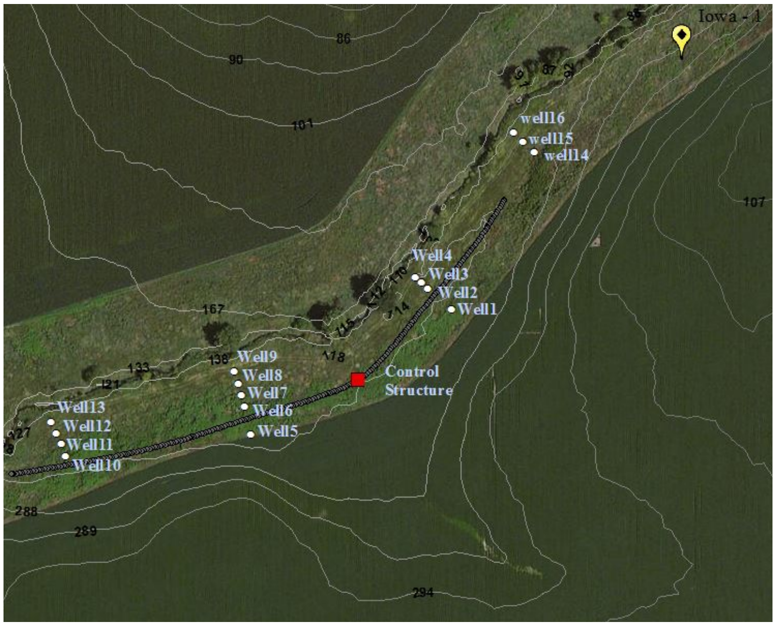
IA – 1 (CIG)

Location: Hamilton Co. IA.
S1 T86N R24W 5th Meridian (Ellsworth Township)
42.284948°N 93.585772°W
Watershed HUC12 # 070801050402

Drained Area and Tile System:
The saturated buffer was installed on an existing 8” clay tile outlet. There was no tile map available for this site, but we estimated the drainage area to be approximately 4.7 ha or 11.6 acres based on local topography (right fig.). The field itself is gently sloping, with a gently sloping buffer. The field is in a corn-soybean rotation by the landowner.

Buffer Dimensions, and Characteristics:
The existing CRP buffer width is ~120 feet wide and was installed as a “Bird Buffer” in the mid 1990’s. The Buffer zone is mainly hardy perennial grasses with a few trees along the stream bank (left fig.).

Installation Date: November 15, 2012



Installation Cost:
The overall cost for this project site was $3,802.32. The cost can easily be divided into three categories; Materials, tile pipe costs etc., Labor and Structure Costs. The total cost for materials and tile pipe was $2,145. Labor came to a total of $125 with approximately 4 hours of backhoe work, and 4 hours of labor. Finally, the structure cost was $1,532.32.

Installation and Management Information:
The saturated buffer was installed by NLAE staff using a back hoe and trencher by intercepting the 8” clay tile. Distribution pipe was ~1,000 feet long, with `600 feet of the tile going towards the West and another ~400 feet going to the East and was installed dead level. There is a riser placed every ~100 feet along the main tile line to help monitor the flow and observe any roots plugging the tile. . The East end of the distribution pipe was wrapped in perforated fabric in attempt to exclude roots entering the pipe. The West end was not wrapped to serve as a check. Flow monitoring was via V-Notch weirs installed as the top flash boards of a three chamber control structure. Flow calibration for these weirs was conducted by NLAE personnel. Flow depth was measured via

pressure transducers installed June 2013. Water samples were collected approximately weekly when the tile was flowing by NLAE personal.

Well Setup and Management

Each site has one control structure set up which contains a control box, and a series of well transects. The 6 foot control box intercepted an 8 in. main. A 4 inch perforated field tile was connected at the flowline of the main and installed ~2 feet below the surface on a flat grade. The control box is designed to hold and retain water while diverting it from the field tile outlet and displacing it into the saturated buffer. Pressure transducers in the control structure box allow for continuous monitoring of the water flow which get sent back to the NLAE building in Ames IA daily. A series of shallow, fully penetrating wells were installed at each location in the buffer zone. Currently, there are 16 observation wells on site to help monitor the nitrate concentrations as the drainage water leaves the field in the tile outlet, and enters the buffer zone on the way to the stream. The wells are set up so there is a group of four to make a transect. The well depths and ID's can be found in the table to the right, which also corresponds to the image above.

Well ID	Depth (ft.)
IA – 1	8.75
IA - 2	8.32
IA – 3	8.46
IA – 4	8.65
IA – 5	8.52
IA – 6	8.53
IA – 7	8.46
IA – 8	8.38
IA – 9	8.50
IA – 10	8.46
IA – 11	8.46
IA – 12	8.55
IA – 13	8.52
IA – 14	7.67
IA – 15	7.42
IA – 16	6.90

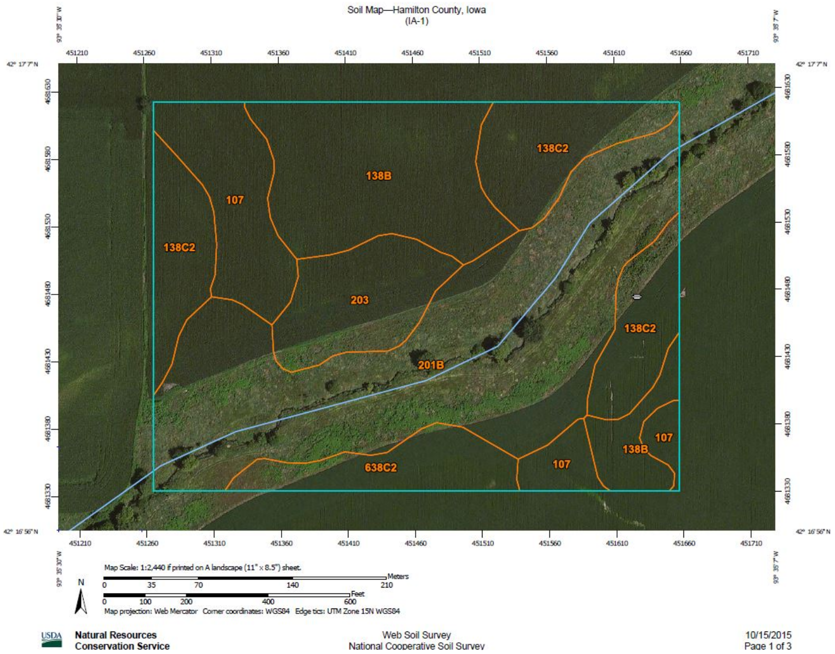
Ditch Characteristics:

This is an unnamed 1st – order stream about 72" below the bank top that flows directly into the South Skunk River.

Soil Description (type, texture, etc.):

Soil map and soil series are below.

Map Symbol	Unit Name
107	Webster Clay Loam, 0-2 % slopes
138B	Clarion Loam, 2-6 % slopes
138C2	Clarion Loam, 6-10 % slopes, moderately eroded
201B	Coland-Terril Complex, 1-5 % slopes
203	Cylinder Loam, 32-40 inches to sand and gravel, 0-2 % slopes
638C2	Clarion-Storden Loams, 5-9 % slopes, moderately eroded



Soils in the buffer are mapped as Coland-Terril. Soil cores showed the soil to be loam or clay loam down to 80 cm (70 inches). Below this depth the soil is loamy sand with frequent stones and pebbles with indications of reducing (saturated) conditions.

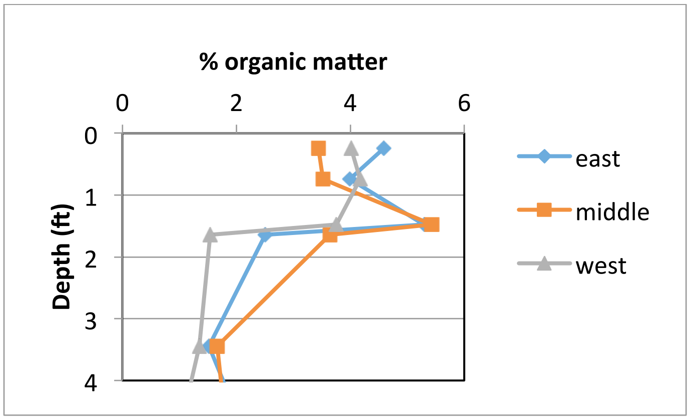
Soil Chemical Profiles

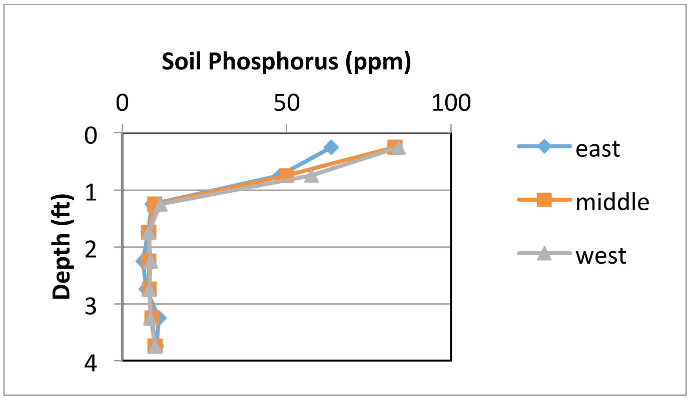
Soil organic matter was greater than 3% in the top 24 inches, and decreased to 1-2% at 48 inches depth and was below 0.5% below 60 inches (not shown). Mehlich III soil P decreased sharply from 60-80 ppm at the surface to about 10 ppm at 1 foot depth. Soil pH was not measured at this site.

Other Important or notable site features: None.

Any Changes in Conditions During the Project?

A second transect of wells were added in 2014 (wells #14-#16) to serve as checks as these were placed within the riparian buffer but outside the area covered by the distribution pipe. In 2013, ortho P was determined on all water samples. In 2014, total dissolved P was determined to parallel what was being measured in the other saturated buffers. No P was measured in 2015.

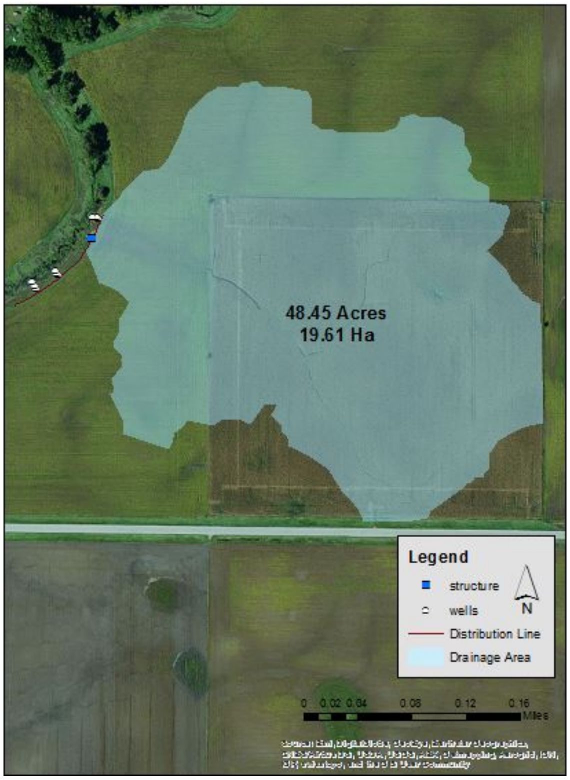




IA – 2 (CIG)

Location: Wright Co. IA.
S19 T89N R24W 5th Meridian (Blairsburg Township)
42.510524°N 93.731346°W
Watershed HUC12 # 07100050701

Drained Area and Tile System:
The saturated buffer was installed on an existing 12” clay tile outlet. There was no tile map available for this site, but the estimated the drainage area is 48.45 acres or 19.61 ha based on local topography (right fig.). The bottom of the drainage area is at a similar elevation as the buffer. The field was in a corn-soybean rotation for the duration of this project.



Buffer Dimensions, and Characteristics:
The existing CRP buffer width is ~75 feet and is planted to hardy perennial grasses with some trees along the stream bank (below fig.).

Installation Date: June 14, 2013

Installation Cost:
The overall installation cost for this site was $3,266, with the structure cost being $1,514.

Installation and Monitoring Information:
The saturated buffer was installed by a local contractor who used a backhoe and plow to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. An existing 20” county main was located along the buffer and 20’ of non-perforated pipe was used on either side of the county main to prevent water from entering this pipe instead of moving through the buffer. The distribution pipe was ~655 feet long, with ~500 feet of the tile going towards the South on a 0.05% grade and another ~155 feet going to the North on a 0.10% grade. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.

Ditch Characteristics: This field is the headwater for Lyons Creek. The stream channel was less than 6' deep in the saturated buffer area. The side slopes were steep with bare soil and some sloughing occurring.

Other Important or Notable Site Features:
A major tile blowout was repaired at the time of installation. Prior to repair this opening allowed a large amount of sediment to enter into the main. As a result, the structure at this site typically had a few inches of sediment in the bottom of the upstream chamber. This made it difficult to get the bottom stop logs to seal properly, which allowed flow to escape without being measured.

Any changes in conditions during the project?
Most of the trees along the buffer were removed in late fall 2013.

Well Setup and Management:
A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the stream bank and the other two equally spaced between the stream and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the stream. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Well ID	Depth (ft.)
IA – 2 - 11	5.75
IA – 2 - 12	6.58
IA – 2 - 13	6.58
IA – 2 - 21	5.83
IA – 2 - 22	5.83
IA – 2 - 23	5.33
IA – 2 - 31	5.58
IA – 2 - 32	5.33
IA – 2 - 33	5.67

Structure Management:
The stop logs were not moved for the duration of the project.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	1152.9	1151.8
6/14/2013	18.50	13.07	1150.7	1150.3

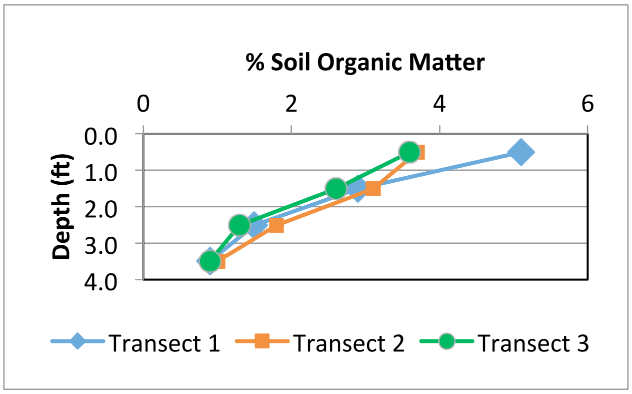
The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

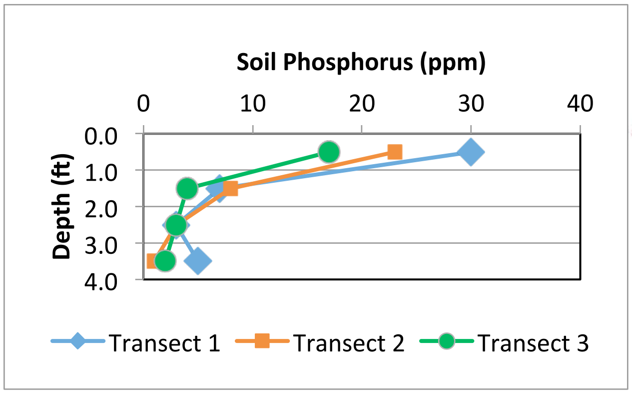
Soil Description (type, texture, etc.):
Soil map and soil series are below. Soils in the buffer are mapped as Kossuth silty clay loam. Soil cores showed the soil to be loam or clay loam down to at least 42 inches. Below this depth the soil was gleyed indicating reducing (saturated) conditions. The soil was calcareous and sandy below about 51 inches.

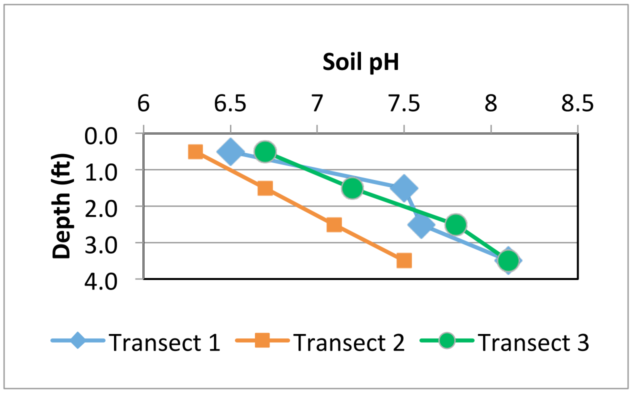
Map Symbol	Unit Name
52B	Bode Clay Loam, 2-5 %slopes
52C2	Bode Clay Loam, 5-9 % slopes, moderately eroded
288	Ottosen Clay Loam, 1-3 % slopes
388	Kossuth Silty Clay Loam, 0-2 % slopes

Soil Chemical Profiles:

Soil organic matter was greater than 2.5% in the top 24 inches, and decreased to 1% at 48 inches. Bray-1 soil P decreased sharply from 18-32 ppm at the surface to about 10 ppm at 1½ foot depth. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH became increasingly alkaline with depth reflecting the deeper calcareous soil layers. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.

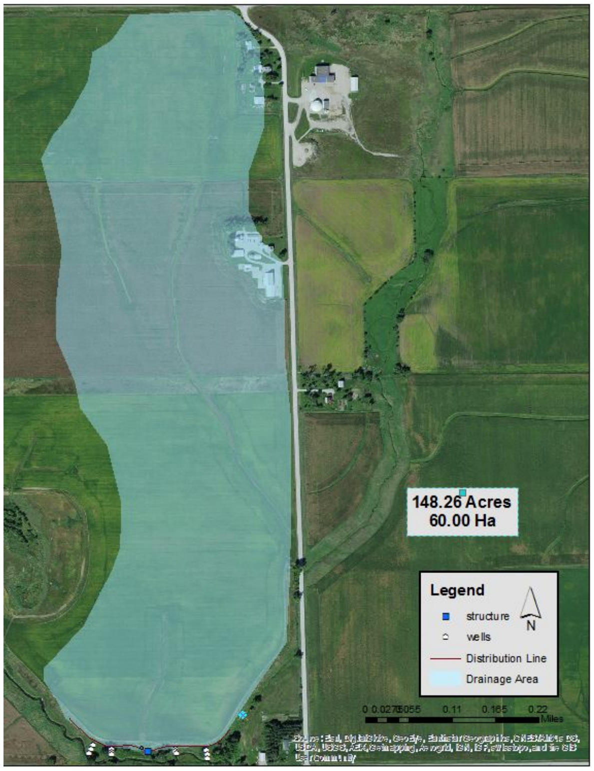






IA – 3 (FSA)

Location: Benton Co. IA.
S35 T83N R10W 5th Meridian (Eldorado Township)
41.949545°N 91.972652°W
Watershed HUC12 # 070802051403



Drained Area and Tile System:

The saturated buffer was installed on a 6” tile outlet. This outlet combined tile lines that drained two separate grassed waterways. There was not a tile map available for this site, but the estimated drainage area is 148 ac. or 60 ha. (right fig.). The field has a fair amount of slope to it and the buffer fairly flat. The field was in a corn- soybean rotation for the duration of the project.

Buffer Dimensions, and Characteristics:

The CRP buffer is ~135 feet wide and is mainly hardy perennial grasses with some trees along the stream bank (below fig.).

Installation Date: May 6, 2013

Installation Cost:

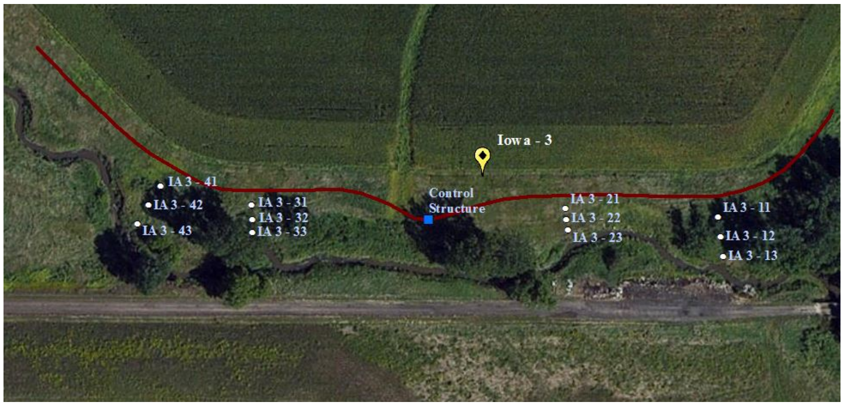
The overall cost for this project site was $5,019 with $1,778 attributed to the control structure.

Installation Management Information:

The saturated buffer was installed by a local contractor who used a backhoe and tile plow to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution line was ~1,200 feet long, with ~600 feet of the tile going in either direction. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.

Ditch Characteristics:

The tile system outlet was into a natural, meandering stream. The channel is less than six feet deep and experiences considerable bank sloughing. This creek is prone to flooding with water commonly coming over the banks.



Other Important or Notable Site Features:

A grassed waterway enters the creek just west of the control structure. As a result, we used non-perforated pipe on the distribution line until past the waterway.

Any Changes in Conditions During the Project?
None.

Well Setup and Management:

A series of four groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the stream bank and the other two equally spaced between the stream and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the stream. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Well ID	Depth (ft.)
IA – 3 - 11	5.88
IA – 3 - 12	6.46
IA – 3 - 13	5.58
IA – 3 - 21	6.43
IA – 3 - 22	6.30
IA – 3 - 23	6.33
IA – 3 - 31	6.38
IA – 3 - 32	6.25
IA – 3 - 33	6.82
IA – 3 - 41	5.93
IA – 3 – 42	6.13
IA – 3 - 43	6.10

Structure Management:
The stop logs were not moved for the duration of the project.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	810.9	810.5
5/10/2013	29.53	24.53	809.2	808.7

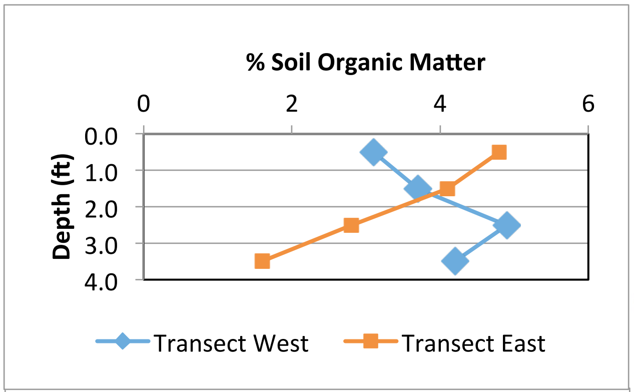
The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

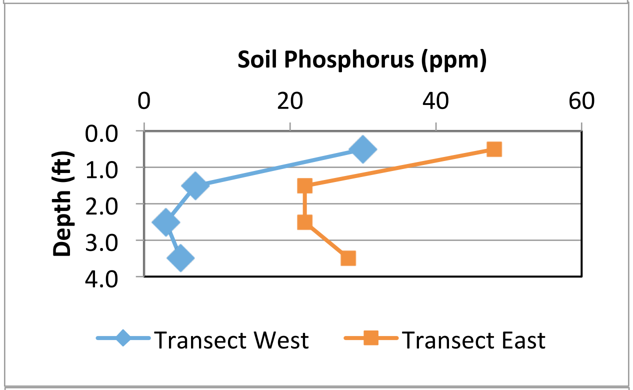
Soil Description (type, texture, etc.):
Soil map and soil series are below. Soils in the buffer are mapped as Colo silty clay loam. Soil cores showed the soil to be loam or clay loam down to 42 inches. Below this depth the soil turns sandier with evidence of continuous saturation (gleying) at 85 inches.

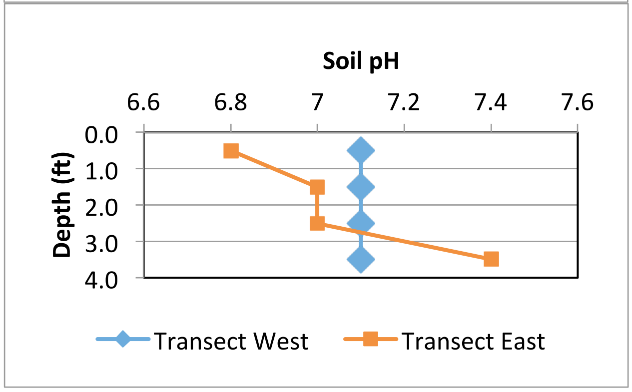
Map Symbol	Unit Name
83B	Kenyon Loam, 2-5% slopes
83C2	Kenyon Loam, 5-9% slopes
83D	Kenyon Loam 9-14% slopes
133	Colo Silty Clay Loam, 0-2% slopes
178B	Waukee Loam, 2-5% slopes
350	Waukegan Silt Loam, 0-2% slopes
350B	Waukegan Silt Loam 2-5% slopes
428B	Ely Silt Loam, 2-5% slopes
1291	Atterberry Silt Loam, Benches 0-2% slopes

Soil Chemical Profiles

Soil organic matter was greater than about 2% in the top 48 inches. Bray-1 soil P decreased with depth with much more soil P present within the east transect. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was neutral throughout the top 48 inches. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.







IL – 1 (CIG)

Location: Sangamon Co. IL
S9 T13N R6W 3rd Meridian (Auburn Township)
39.585983°N 89.777395° W
Watershed HUC12 # 071300070702

Drained Area and Tile System:

The saturated buffer was installed on an existing 8” tile outlet. This tile system drains approximately 26 ac. or 10.7 ha. The buffer is fairly flat and the field slopes upward from the buffer. This field was in a corn- soybean rotation for the duration of the project.

Buffer Dimensions, and Characteristics:

The existing CRP buffer width is ~70 feet wide. The Buffer zone is hardy perennial grasses along the stream bank (left fig.).

Installation Date: July 16, 2012

Installation Cost:

The overall cost for this project site was $3,251 with $1,201 attributed to the structure.

Installation Information:

The saturated buffer was installed by a local contractor who used a backhoe and plow to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution pipe was ~1,020 ft long, with ~740 ft of the tile going towards the South and ~280 ft going to the North. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.

Ditch Characteristics:

The ditch is less than six feet deep with well vegetated, relatively stable banks.

Other Important or Notable Site Features:

None.

Any Changes in Conditions During the Project?

None.

Well Setup and Management:
A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the ditch bank and the other two equally spaced between the ditch and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the ditch. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Well ID	Depth (ft.)
IL-1-11	6.33
IL-1-12	6.42
IL-1-13	6.58
IL-1-21	6.25
IL-1-22	6.67
IL-1-23	6.25
IL-1-31	6.75
IL-1-32	6.08
IL-1-33	6.00

Structure Management:
The stop logs were not moved for the duration of the project.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	630.2	628.7
5/10/2013	41.32	36.32	626.9	626.5

The "Board Height refers to the height of stop logs within the structure and the corresponding "Elevation of the top stop log.

Soil Description (type, texture, etc.):

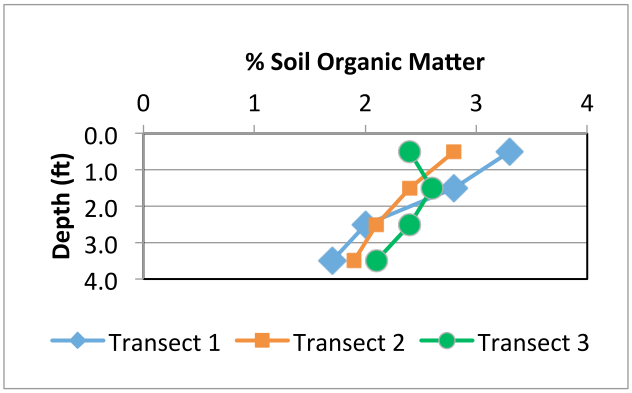
Soil map and soil series are below.

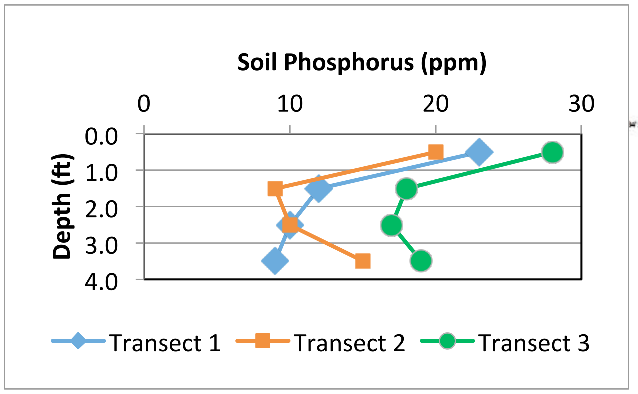
Soils in the buffer are mapped as Sawmill silty clay loam. Soil cores showed the soil to be silty loam to silty clay loam down to 42 inches. A gleyed soil layer with high chroma redoximorphic features indicative of saturated conditions was about 43 inches on the south side going to 67 of the north side. The south side was calcareous starting at 84 inches, but the rest of the buffer was noncalcareous. No sand layers were present.

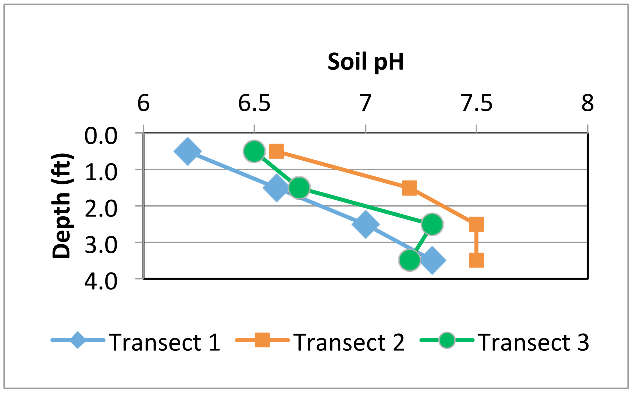
Map Symbol	Unit Name
43A	Ipava Silt Loam, 0-2 % slopes
86B	Osco Silt Loam, 2-5 % slopes
127C2	Harrison Silt Loam, 5-10% slopes, eroded
3107A	Sawmill Silty Clay Loam 0-2% slopes, frequently flooded

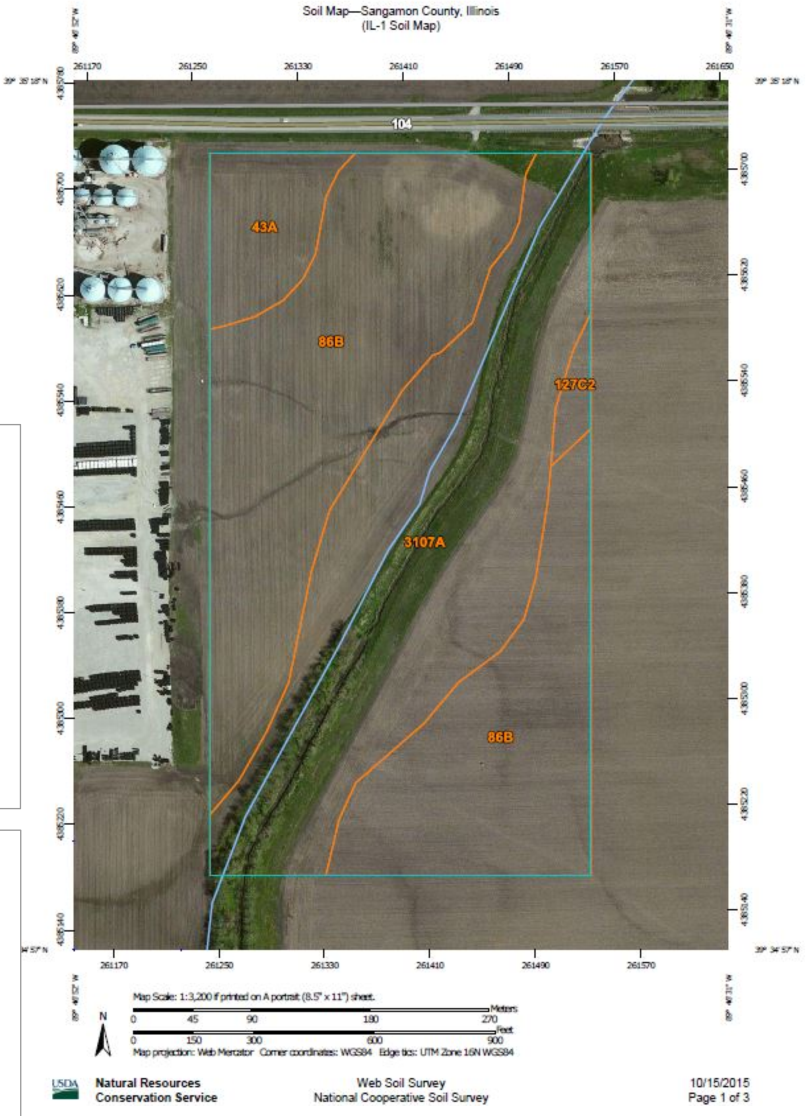
Soil Chemical Profiles:

Soil organic matter was greater than about 2% in the top 48 inches. Bray-1 soil P decreased somewhat with depth with more soil P present transect 3. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was neutral throughout the top 48 inches. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.









Soil Map—Sangamon County, Illinois
(IL-1 Soil Map)

Map Scale: 1:3,200 if printed on A portrait (8.5" x 11") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 16N WGS84

Natural Resources
Conservation Service

Web Soil Survey
National Cooperative Soil Survey

10/15/2015
Page 1 of 3

IL – 2 (CIG)

Location: Sangamon Co. IL
S24 T13N R7W 3rd Meridian (Talkington Township)
39.566567°N 89.814644°W
Watershed HUC12 # 071300070702

Drained Area and Tile System:
The saturated buffer was installed on an existing 12” tile outlet. The drained area treated by the buffer is 63 ac. or 25.4 ha. (right fig.). The field and buffer are at similar elevations and both are fairly flat. The field was in a corn-soybean rotation for the duration of the project.

Buffer Dimensions, and Characteristics:
The existing CRP buffer width is ~80 feet wide and is planted to hardy perennial grasses along the stream bank (left fig.).

Installation Date: July, 2012

Installation Cost:
The overall cost for this project site was $2,440 with $1840 attributed to the structure cost.

Installation Management Information:
The saturated buffer was installed by a local contractor who used a backhoe to do the work in less than one day. The work included installing the control structures and replacing sections of the main near the structures with non-perforated pipe. The upper 1,635 ft of the perforated 12” main was used as the distribution line at this site. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.

Ditch Characteristics:
This ditch begins near the northwest corner of the field. It is fairly shallow, ranging from approximately 2.5 ft – 4.5 ft deep.

Other Important or Notable Site Features: This site is different than the others in that the existing perforated main was used for the distribution line. While this simplified the installation process it did make flow monitoring more difficult.

Any Changes in conditions during the project?
None.

Well Setup and Management:
A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the ditch bank and the other two equally spaced between the ditch and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the ditch. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Well ID	Depth (ft.)
IL-2-11	6.25
IL-2-12	6.25
IL-2-13	6.50
IL-2-21	6.42
IL-2-22	6.25
IL-2-23	6.42
IL-2-31	6.67
IL-2-32	6.50
IL-2-33	6.08

Structure Management:
Because the buffer and cropped area are at similar elevations the stop logs needed to be managed to ensure adequate drainage needs for crop production were satisfied. Due to the conditions at this site there are only one set of stop logs in the control structure, which managed both the buffer and the field.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	640.5	639.1
July 2012	NA	45.32	NA	639.9
6/6/2013	NA	24.38	NA	638.2
5/19/2014	NA	29.38	NA	638.6
6/8/2015	NA	17.38	NA	637.6

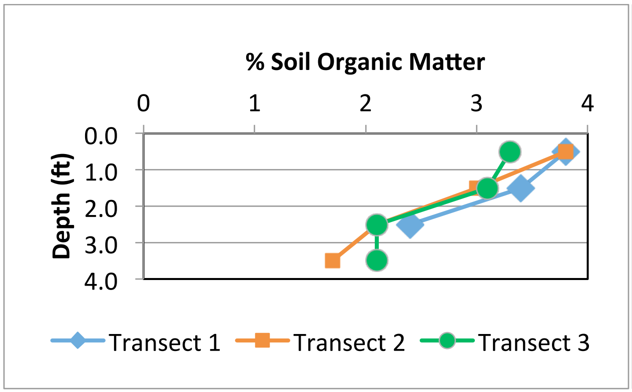
The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

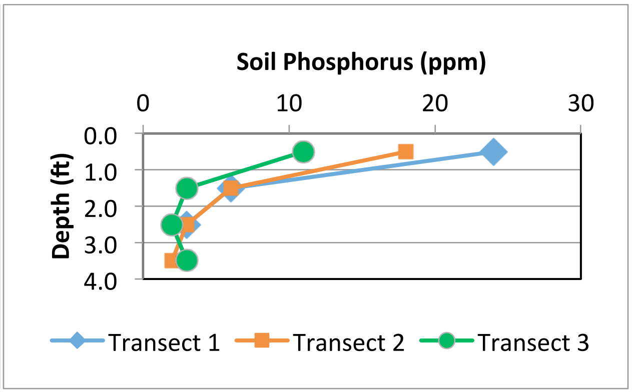
Soil Description (type, texture, etc.):
The soil map and soil series are below. Soils in the buffer are mapped as Virden silty clay loam. Soil cores showed the soil to be a silty clay loam down to 42 inches. Below this depth the soil showed evidence of saturation starting at 30 inches on the east side of the buffer grading to 67 inches on the west side. High chroma redoximorphic concentrations above these depths indicate periodic saturation.

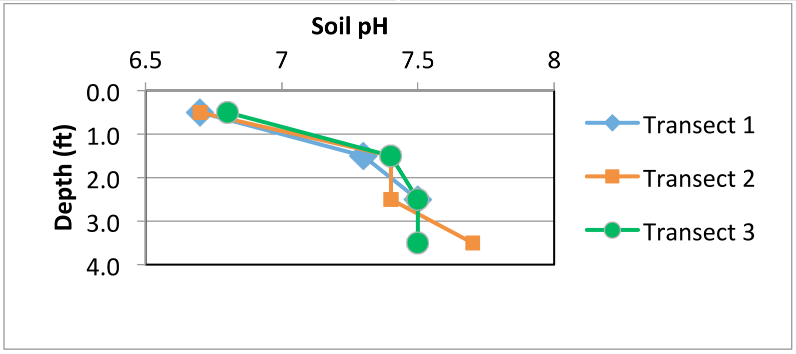
Map Symbol	**Unit Name**
43A	Ipava Silt Loam, 0-2% slopes
50A	Virden Silty Clay Loam, 0-2% slopes

Soil Chemical Profiles

Soil organic matter was greater than about 2% in the top 48 inches. Bray-1 soil P decreased sharply with depth being less than 8 ppm below 1½ feet. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was neutral grading to alkaline at 3½ feet. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.



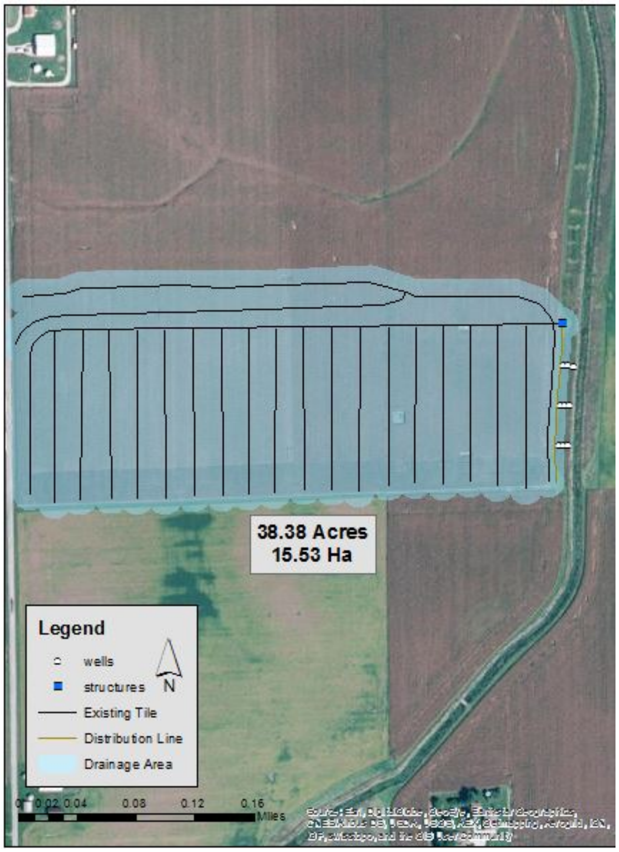




IL-3(CIG)

Location: Edgar Co. IL
S3 T15N R13W 2nd Meridian (Shiloh Township)
39.788653°N 87.852870°W
Watershed HUC12 # 051201120301

Drained Area and Tile System:
The saturated buffer was installed on an existing 12” outlet. The drainage area for this tile system is 38 ac. or 15.5 ha. The field and buffer are at a similar elevation and both are fairly flat. The field was in a corn-soybean rotation for the duration of the project.

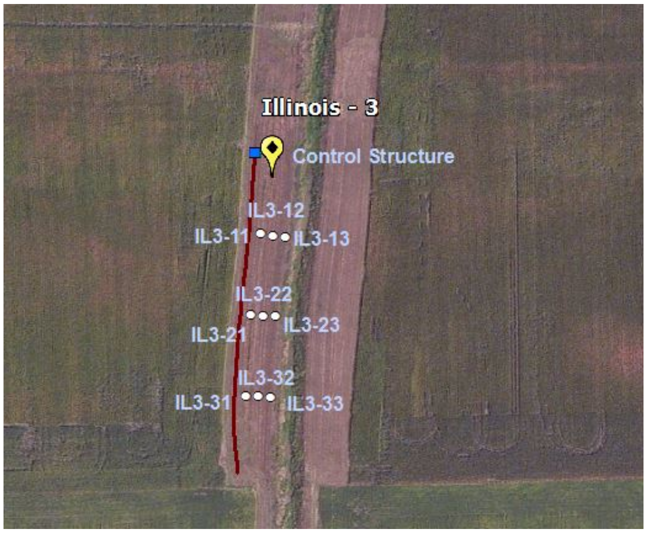


Buffer Dimensions and Characteristics:
The existing CRP buffer width is ~75 feet wide and is planted to hardy perennial grasses.

Installation Date: July, 2012

Installation Cost:
The overall cost for this project site was $3,680, with $1.755 attributed to the control structure.

Installation and Monitoring Information:
The saturated buffer was installed by a local contractor who used a backhoe and plow to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution line is ~585 ft long and extends southward from the control structure. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.



Ditch Characteristics:
This ditch is about 10 ft deep with well-vegetated, sloped, stable banks.

Other Important or notable site features:
None.

Any Changes in conditions during the project?
None.

Well Setup and Management:
A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the ditch bank and the other two equally spaced between the ditch and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the ditch. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Well ID	Depth (ft.)
IL-3-11	6.92
IL-3-12	6.83
IL-3-13	6.00
IL-3-21	7.00
IL-3-22	7.00
IL-3-23	7.00
IL-3-31	6.83
IL-3-32	7.17
IL-3-33	7.17

Structure Management:
Because the buffer and cropped area are at similar elevations the stop logs needed to be managed to ensure adequate drainage needs for crop production were satisfied.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	647.5	647
July 2012	17.44	14.44	643.5	643.3
1/22/2013	65.38	46.32	647.5	645.9
6/6/2013	36.38	31.32	645.1	644.7
11/24/2013	46.38	41.32	645.9	645.5
4/5/2014	29.38	24.32	644.5	644.1
4/7/2013	17.38	12.32	643.5	643.1
6/21/2014	41.25	36.25	645.5	645.1
4/22/2015	5.44	5.44	642.5	642.5
5/13/2015	12.44	17.44	643.1	643.5
5/18/2015	17.44	12.44	643.5	643.1

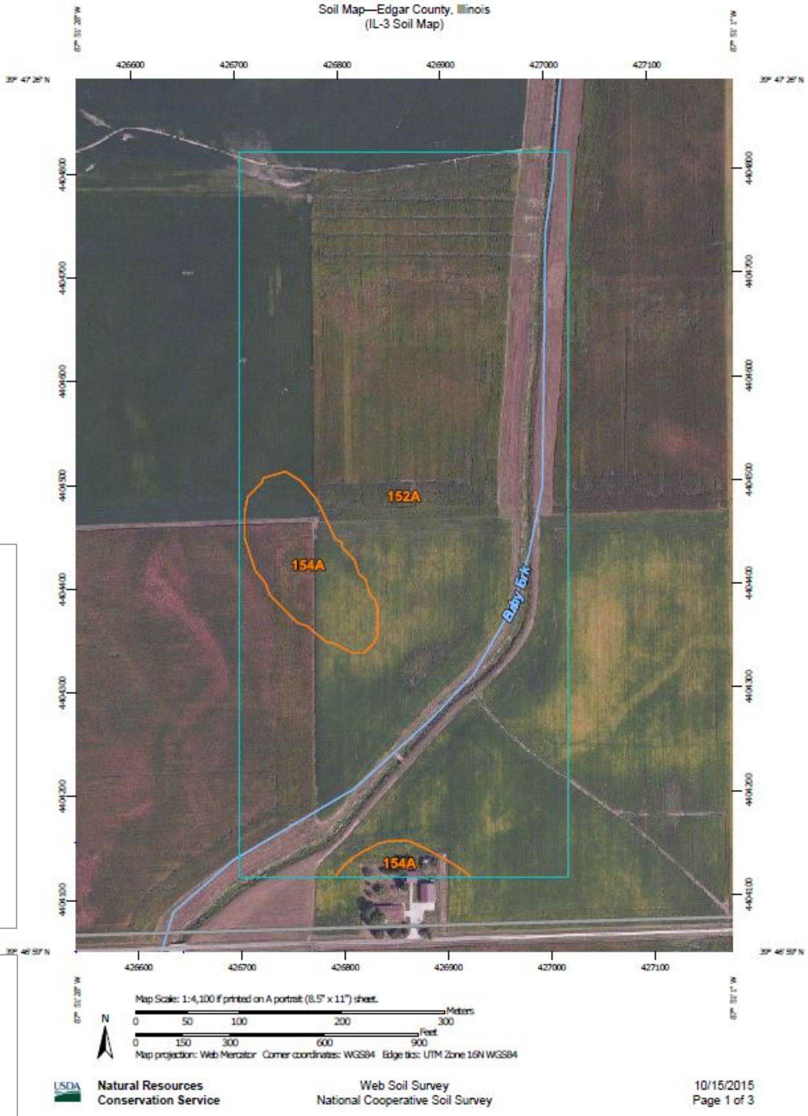
The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

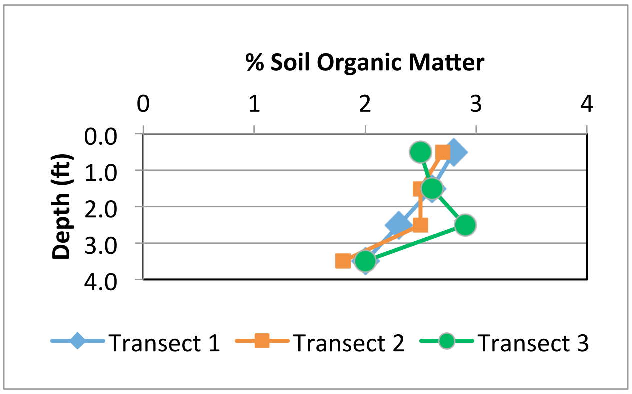
Soil Description (type, texture, etc.):
The soil map and soil series are below. Soils in the buffer are mapped as Drummer silty clay loam. Soil cores showed the soil to be loam to silty clay loam down to 42 inches. Starting at 57 to 81 inches the soil is gleyed with high chroma redoximorphic concentrations indicating periodic saturation. Soil is massive and calcareous starting at 90 inches. No coarse textured soil horizons were present.

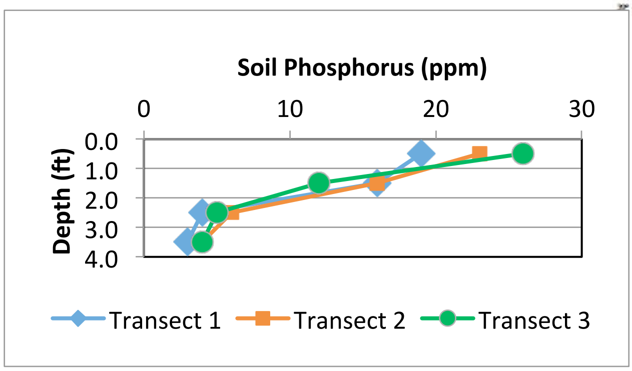
Map Symbol	Unit Name
152A	Drummer Silty Clay Loam 0-2% slopes
154A	Flanagan Silt Loam, 0-2% slopes

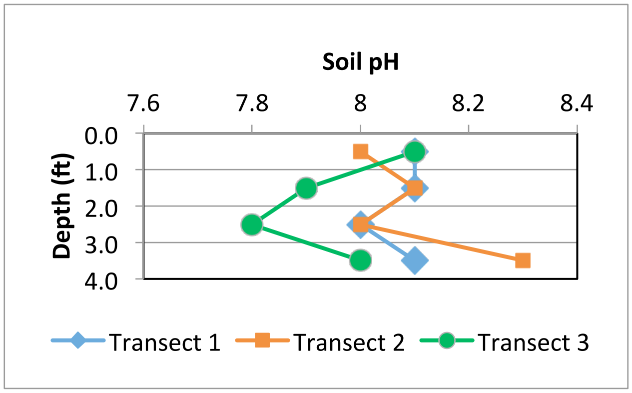
Soil Chemical Profiles

Soil organic matter was greater than about 2% in the top 48 inches. Bray-1 soil P decreased sharply with depth being less than 8 ppm below 2½ feet. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was alkaline throughout the top 3½ feet reflecting the presence of calcareous soils below 75 inches. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.





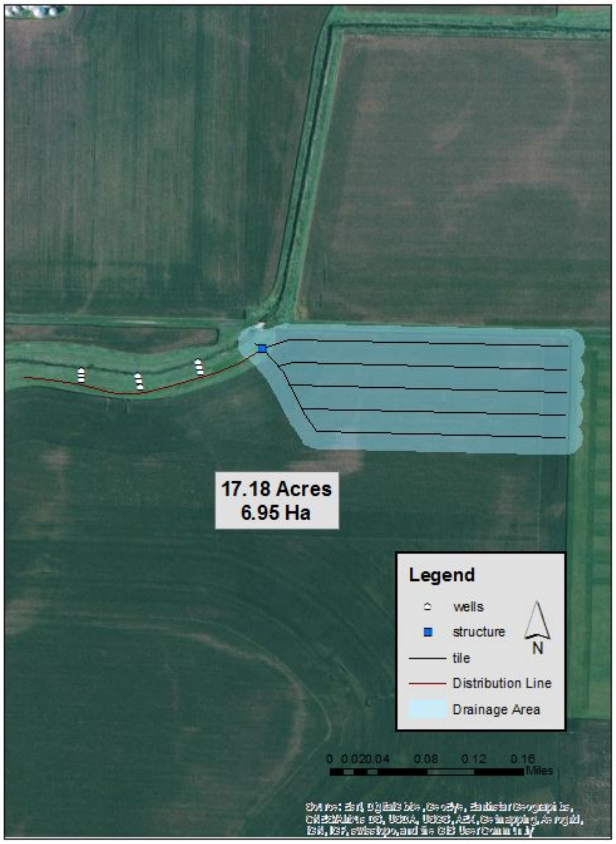




IL – 4 (FSA)

Location: Piatt Co. IL
S3 T18N R4E 3rd Meridian (Willow Branch Township)
40.054900°N 88.740330°W
Watershed HUC12 # 071300060301

Drained Area and Tile System:
The saturated buffer was installed on an existing 5” outlet. The drainage area for this tile system is 18 ac. or 7 ha. The buffer has a small amount of slope and the distribution line was installed along a contour. The field has some slope to it as well. The field was in a corn-soybean rotation for the duration of the project.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Buffer Dimensions and Characteristics:
The existing CRP buffer width is ~105 feet wide and is planted to hardy perennial grasses.

Installation Date: June, 2013

Installation Cost:
The overall cost for this project site was $4,215 with $1,495 attributed to the control structure.

Installation and Monitoring Information:
The saturated buffer was installed by a local contractor who used a backhoe and plow to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution line is ~1,300 ft long and runs roughly westward from the control structure. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.

Ditch Characteristics:
The ditch is about six feet deep with well-vegetated, sloped, and relatively stable banks.

Other Important or Notable Site Features:
None.

Any Changes in Conditions During the Project?
None.

Well setup and Management:
A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the ditch bank and the other two equally spaced between the ditch and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the ditch. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Well ID	Depth (ft.)
IL-4-11	6.08
IL-4-12	6.08
IL-4-13	5.58
IL-4-21	6.50
IL-4-22	6.50
IL-4-23	5.92
IL-4-31	6.08
IL-4-32	6.08
IL-4-33	6.08

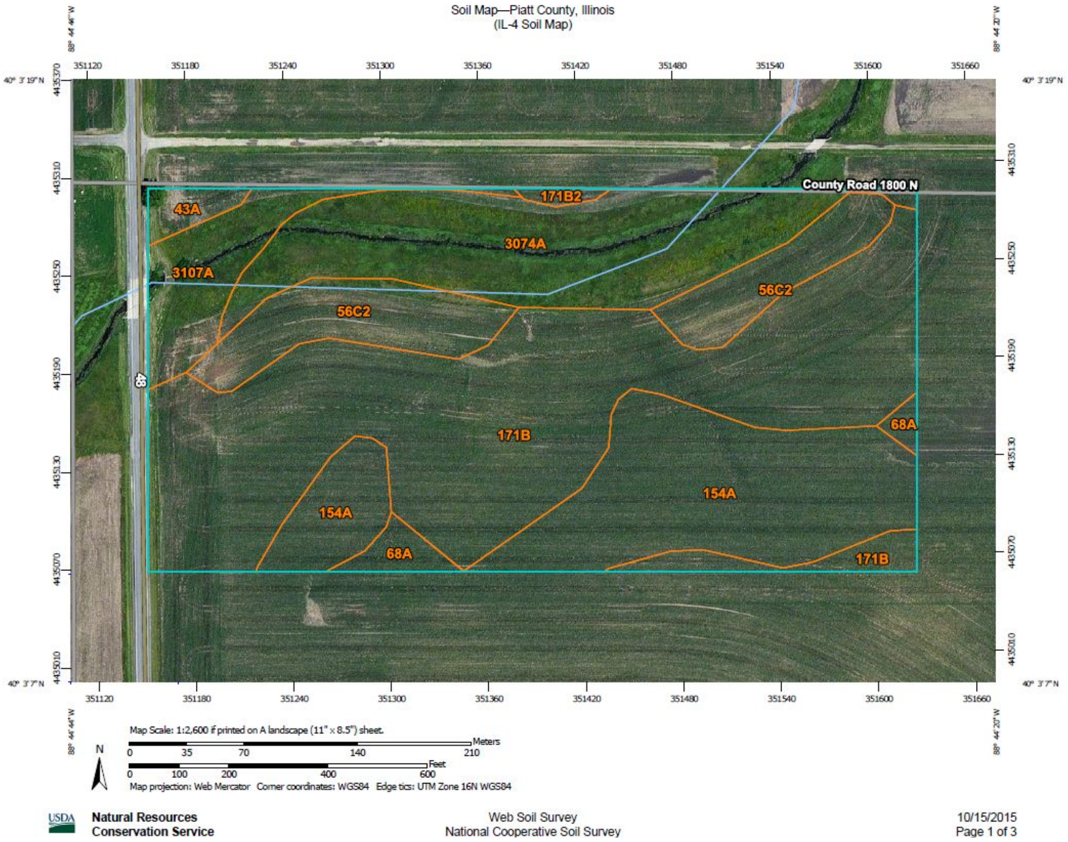
Structure Management:
The stop logs were adjusted shortly after installation. Otherwise, they were not moved for the duration of the project.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	674.0	671.1
June 2013	19.57	13.30	669.7	669.2
8/14/2013	22.57	17.57	670.0	669.5

The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

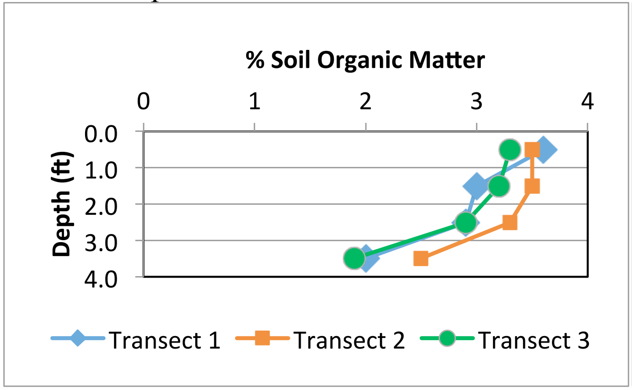
Soil Description (type, texture, etc.):
The soil map and soil series are below. Soils in the buffer are mapped as Radford silt loam. Soil cores showed the soil to be a silt loam to or clay loam down to 42 inches. Below 63 inches the soil was gleyed indicative of saturation. No coarse-textured layers were encountered.

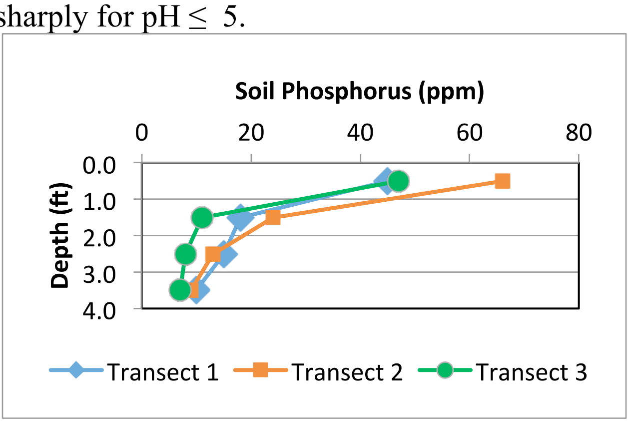
Map Symbol	**Unit Names**
43A	Ipava Silt Loam, 0-2% slopes
56C2	Dana Silty Clay Loam, 5-10% slopes, eroded
68A	Sable Silty Clay Loam, 0-2% slopes
154A	Flanagan Silt Loam, 0-2% slopes
171B	Catlin Silt Loam, 2-5% slopes
171B2	Catlin Silt Loam, 2-5% slopes, eroded
3074A	Radford Silt Loam, 0-2% slopes, frequently flooded
3107A	Sawmill Silty Clay Loam, 0-2% slopes, frequently flooded

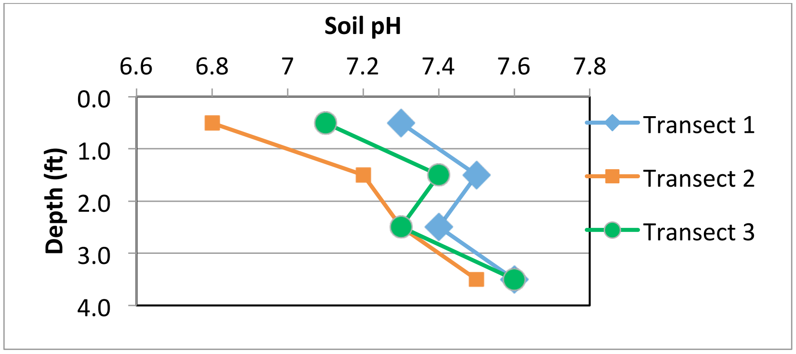


Soil Chemical Profiles:

Soil organic matter was greater than about 2% in the top 48 inches. Bray-1 soil P decreased sharply with depth being less than 10 ppm below 2½ feet. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was neutral trending alkaline with depth. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.

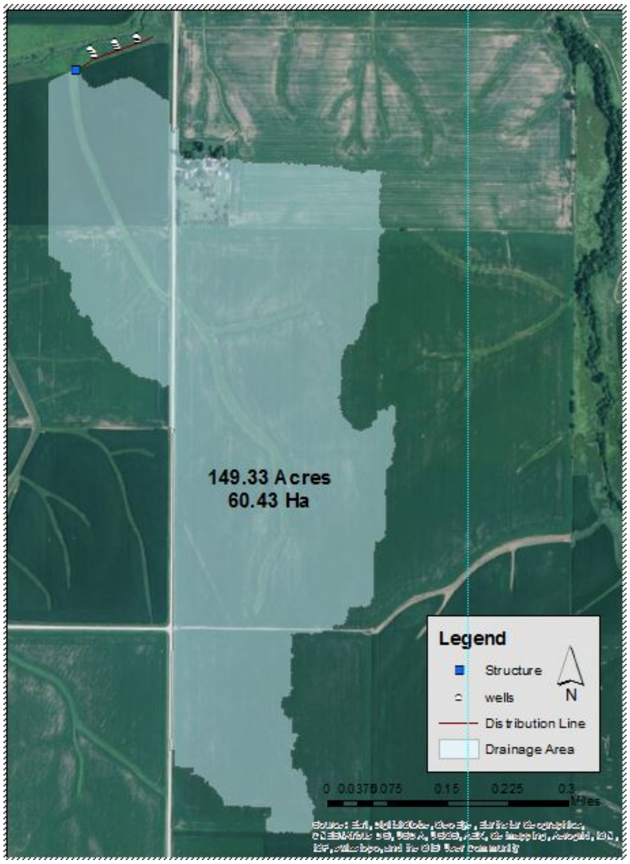






IL – 5 (FSA)

Location: Rock Island Co.
S23 T16N R3W 4th Meridian (Edgington Township)
41.36779°N 90.689689°W
Watershed HUC12 # 070900051201



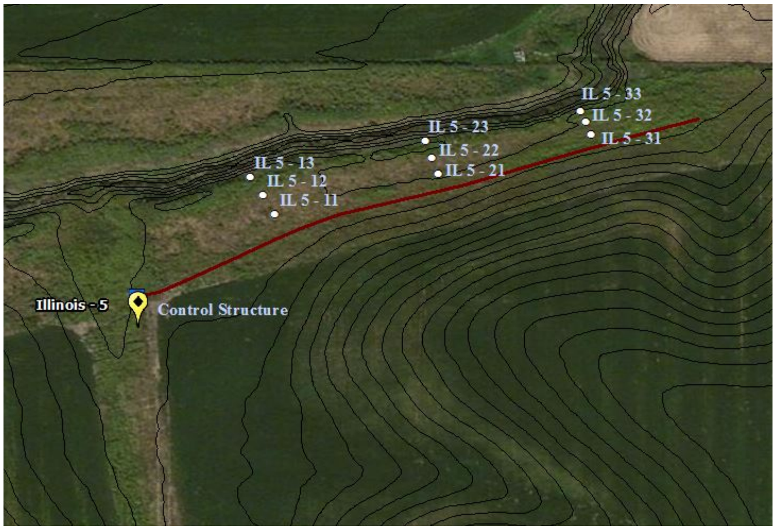
Drained Area and Tile System:
The saturated buffer was installed on an existing 12” outlet. There was not a tile map available for this site, but the estimated drainage area is 149 ac. or 60.4 ha. The buffer is sloped and the distribution line was installed along a contour. The field also has a relatively steep slope. The field was in a corn-soybean rotation for the duration of the project.

Buffer Dimensions and Characteristics:
The existing CRP buffer width is ~120 feet wide and is planted to native prairie grasses.

Installation Date: March 26, 2013

Installation Cost:
The overall cost for this project site was $3,205 with $2,079 attributed to the cost of the control structure.

Installation Management Information:
The saturated buffer was installed by a local contractor who used a backhoe and trencher to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution line was ~720 ft long and runs roughly eastward from the control structure. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.



Ditch Characteristics:
The ditch is approximately eight feet deep with steep, almost vertical sides that are prone to sloughing. The channel has some minor meanders and the banks commonly have exposed soil.

Other Important Site Features:
None.

Any Changes in Conditions During the Project?
None.

Well Setup and Management:

A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the ditch bank and the other two equally spaced between the ditch and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the ditch. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Well ID	Depth (ft.)
IL-5-11	6.33
IL-5-12	6.42
IL-5-13	6.67
IL-5-21	5.92
IL-5-22	6.50
IL-5-23	6.83
IL-5-31	5.67
IL-5-32	6.17
IL-5-33	6.83

Structure Management:

The stop logs were not moved for the duration of the project.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	606.9	605.8
3/26/2013	57.25	50.32	604.4	603.8

The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

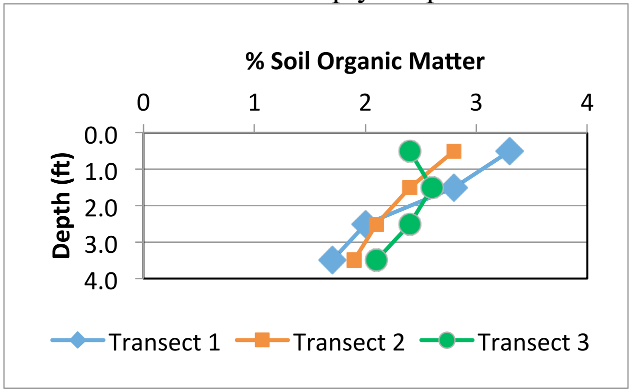
Soil Description (type, texture, etc.):

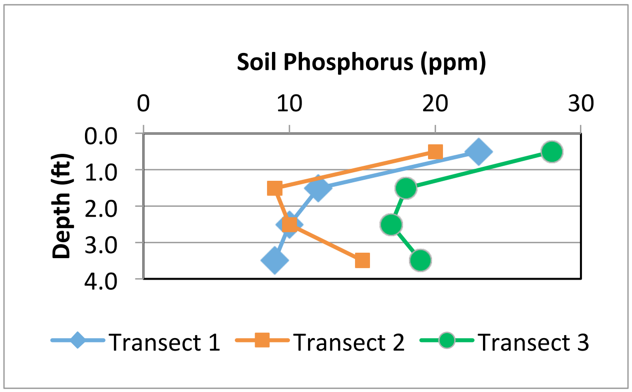
The soil map and soil series are below. Soils in the buffer are mapped as Radford silt loam. Soil cores showed the soil to be silt loam to silty clay loam down to 42 inches. At about 59 inches the sandy soil was gleyed indicative of reducing (saturated) conditions.

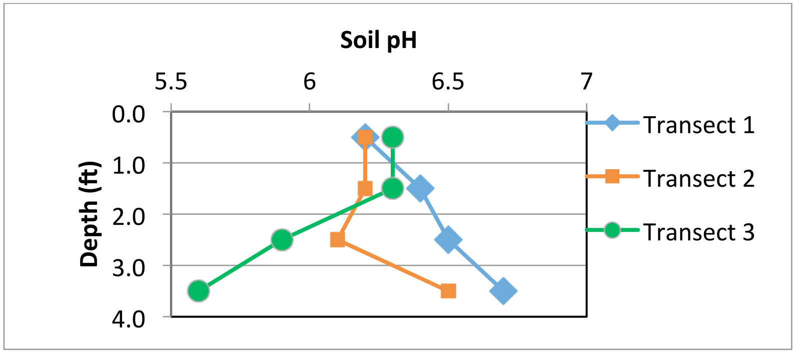
Map Symbol	**Unit Name**
8F	Hickory Silt Loam, 18-35% slopes
19D	Sylvan Silt Loam, 10-18% slopes
86B	Osco Silt Loam, 2-5% slopes
946D3	Hickory-Atlas Complex,10-18% slopes, severely eroded
3074A	Radford Silt Loam,0-2% slopes, frequently flooded

Soil Chemical Profiles

Soil organic matter was greater than about 2% in the top 48 inches. Bray-1 soil P decreased sharply from ½ to 1½ feet and was higher in the 3rd transect. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was neutral in the top 3 ½ feet with Transect 3 going more acid and the other two transects more alkaline with depth. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.







IN – 1 (CIG)

Location: Jasper Co. IN
S13 T29N R6W 2nd Meridian (Barkley Township)
40.966909°N 87.062940°W

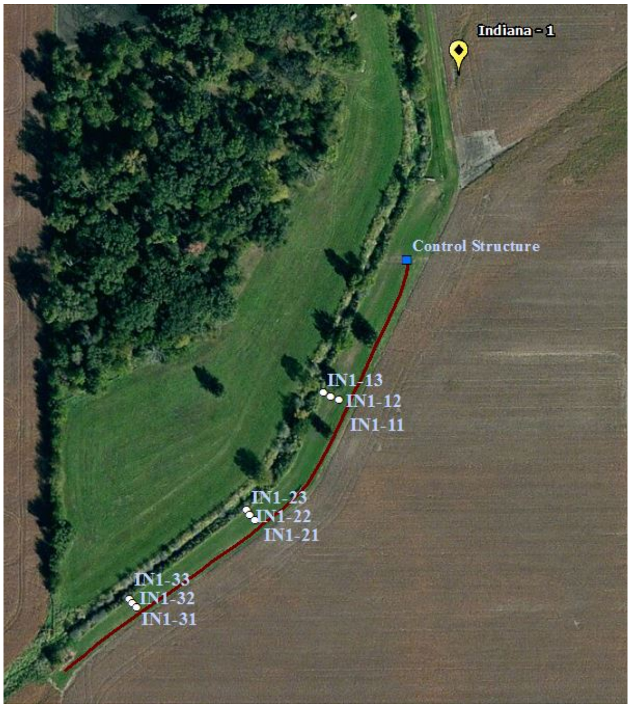
Drained Area and Tile System:
The saturated buffer was installed on an existing 6” outlet. The drainage area for this tile system is 7.4 ac. or 3.0 ha. The field and buffer are both fairly flat with the field being slightly higher than the buffer. The field was in a corn-soybean rotation for the duration of the project.

Buffer Dimensions and Characteristics:
The existing buffer is ~70 feet wide and is used for alfalfa production. There are also some smaller trees along the edge of the ditch.

Installation Date: July, 2012

Installation Cost:
The overall cost for this project site was $5,432 with $1,405 attributed to the control structure.

Installation and Monitoring Information:
The saturated buffer was installed by a local contractor who used a backhoe and trencher to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution line is ~1,155 ft long and runs roughly southward from the control structure. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.



Ditch Characteristics:
The ditch is approximately six feet deep with steep, relatively stable banks.

Other Important Site Features:
None.

Any Changes in Conditions During the Project?
The ditch was cleaned in spring 2015 with the spoil spread over the buffer.

Well Setup and Management:
A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the ditch bank and the other two equally spaced between the ditch and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the ditch. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page. The well tops were specially designed so they would be just below the ground surface to minimize any obstructions in the buffer, which is used for alfalfa production.

Well ID	Depth (ft.)
IN-1-11	2.92
IN-1-12	2.67
IN-1-13	3.17
IN-1-21	4.17
IN-1-22	4.17
IN-1-23	4.17
IN-1-31	4.58
IN-1-32	4.17
IN-1-33	3.75

Structure Management:
Because the buffer and cropped area are at similar elevations the stop logs needed to be managed to ensure adequate drainage needs for crop production were satisfied.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	665.5	664.5
July 2012	36.50	31.50	665.1	664.7
4/26/2013	17.50	12.44	663.5	663.1
6/8/2013	24.45	19.44	664.1	663.7
5/2/2015	12.44	5.44	663.1	662.5

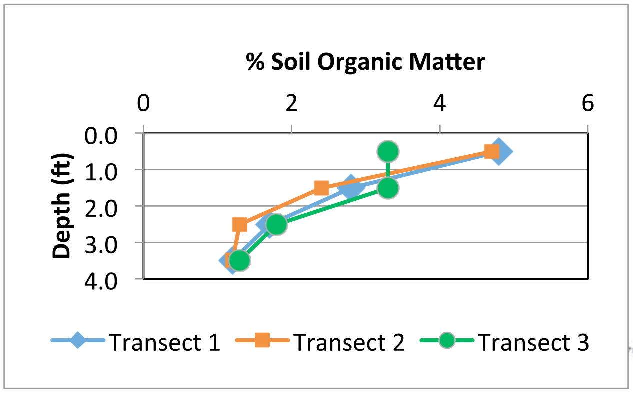
The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

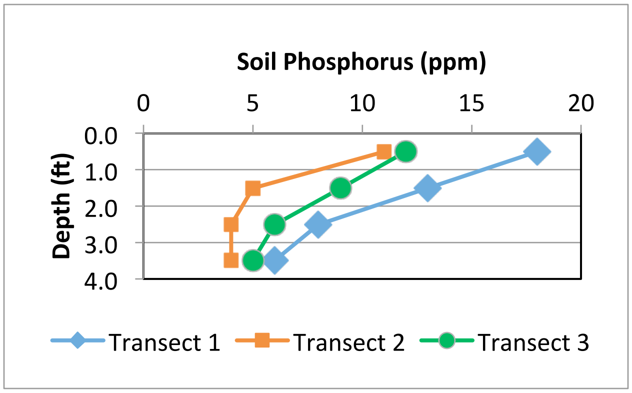
Soil Description (type, texture, etc.):
The soil map and soil series are below. Soils in the buffer are mapped as Rensselaer loam. Soil cores showed the soil to be silt loam to silty clay loam down to 42 inches. A reduced soil layer starting at 29-39 inches was present under the middle and northern end of the buffer. At a depth varying from 35-29 inches a gravely sand layer with large stones was present everywhere.

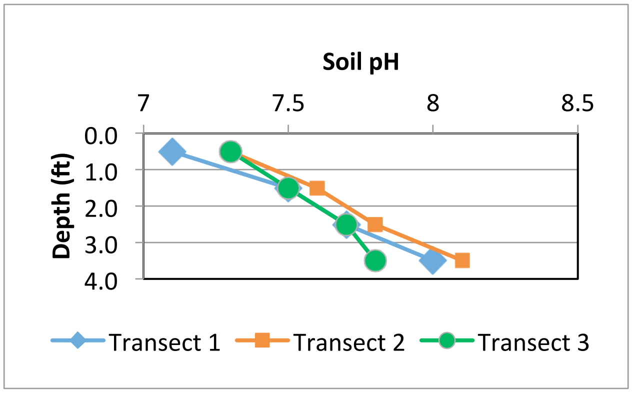
Map Symbol	**Unit Name**
Dc	Darroch Loam
MeB	Metamora Fine Sandy Loam, moderately permeable, 1-4% slopes
Re	Rensselaer Loam

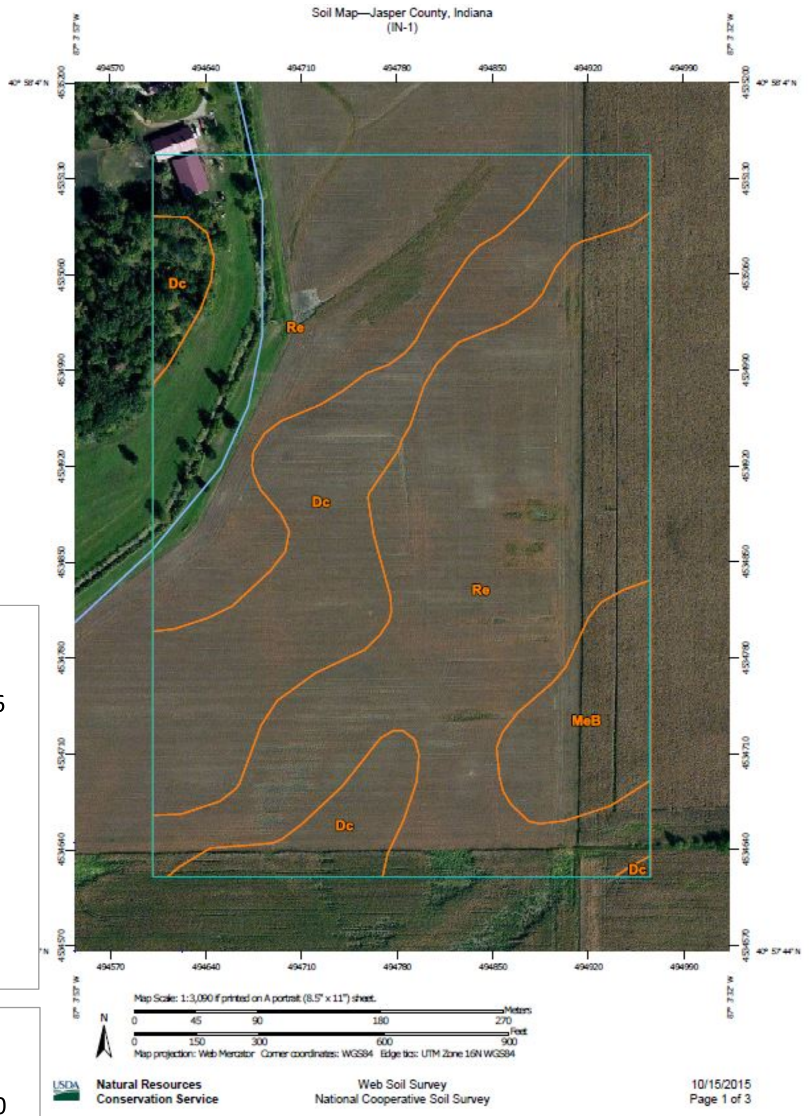
Soil Chemical Profiles:

Soil organic matter was greater than about 1.2% in the top 48 inches. Bray-1 soil P decreased with depth and was greater in the 1st transect. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was neutral at the surface grading more alkaline with depth. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.





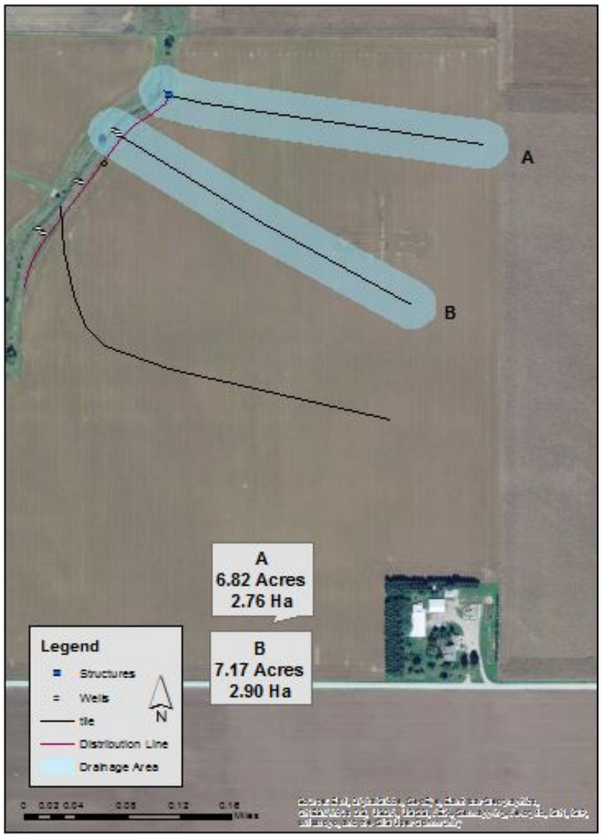




IN – 2 (CIG)

Location: Jasper Co. IN
S26 T27N R7W 2nd Meridian (Carpenter Township)
40.757544°N 87.187460°W

Drained Area and Tile System:
The saturated buffer was installed on an existing 6” outlet. The estimated drained area for this outlet is 6.8 ac. or 2.8 ha. A second 5” tile outlet was possibly tied into the distribution line at the time of installation, but this could not be verified. This second outlet has an estimated drainage area of 7.2 ac. or 2.9 ha. A third outlet also exits the field through the buffer area, but it is likely not physically connected to the distribution line. The field and buffer are both relatively flat, with the field being at a slightly higher elevation than the buffer. The field was in a corn-soybean rotation for the duration of the project.



Buffer Dimensions and Characteristics:
The existing CRP buffer width is ~60 feet wide and is panted to hardy perennial grasses with a few trees and shrubs along the stream bank.

Installation Date: July, 2012

Installation Cost:
The overall cost for this project site was $4,885 with $1,405 attributed to the control structure.

Installation and Monitoring Information:
The saturated buffer was installed by a local contractor who used a backhoe and trencher to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution line is ~1,325 feet long and runs roughly southwest of the control structure. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.

Ditch Characteristics:
The ditch is approximately six feet deep with well-vegetated, relatively stable banks.

Other Important Site Features:
None.

Any Changes in Conditions During the Project?
None.

Well ID	Depth (ft.)
IN-2-11	7.25
IN-2-12	6.42
IN-2-13	6.42
IN-2-21	6.08
IN-2-22	6.08
IN-2-23	6.92
IN-2-31	6.17
IN-2-32	5.75
IN-2-33	7.25

Well Setup and Management:
A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the ditch bank and the other two equally spaced between the ditch and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the ditch. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Structure Management:
Because the buffer and cropped area are at similar elevations the stop logs needed to be managed to ensure adequate drainage needs for crop production were satisfied.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	734.0	733.2
July 2012	24.50	19.50	732.0	731.6
4/29/2014	12.44	5.44	731.0	730.4

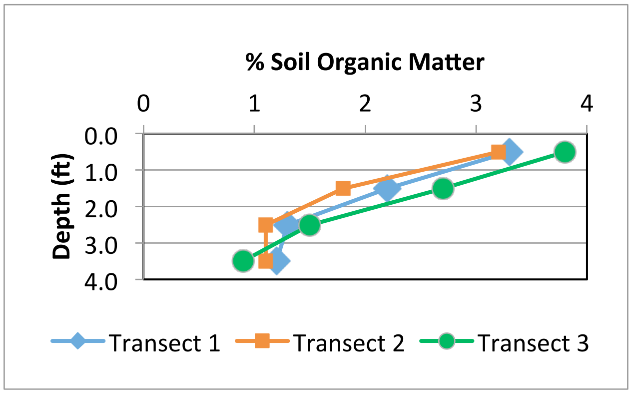
The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

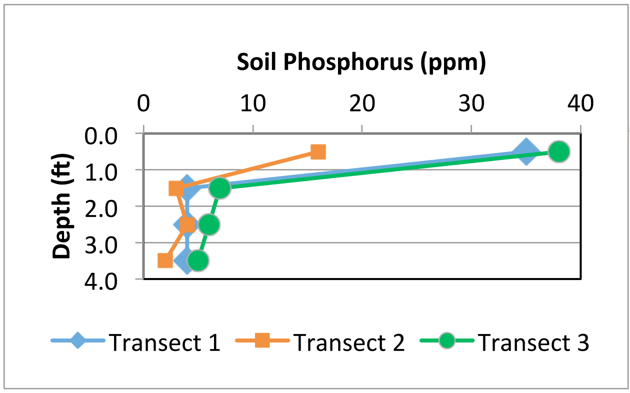
Soil Description (type, texture, etc.):
Soil map and soil series are below.
Soils in the buffer are mapped as Reddick silty clay loam. Soil cores showed the soil to be silty clay loam down to 42 inches. Signs of saturated layers started at 29-39 inches depth. No coarse textured soil horizons were found. Soil was calcareous starting at 75 inches.

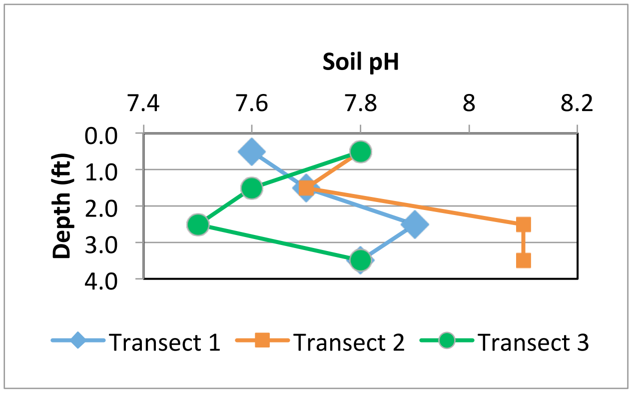
Map Symbol	**Unit Name**
AtA	Andres Loam, 0-2% slopes
Rd	Reddick Silty Clay Loam

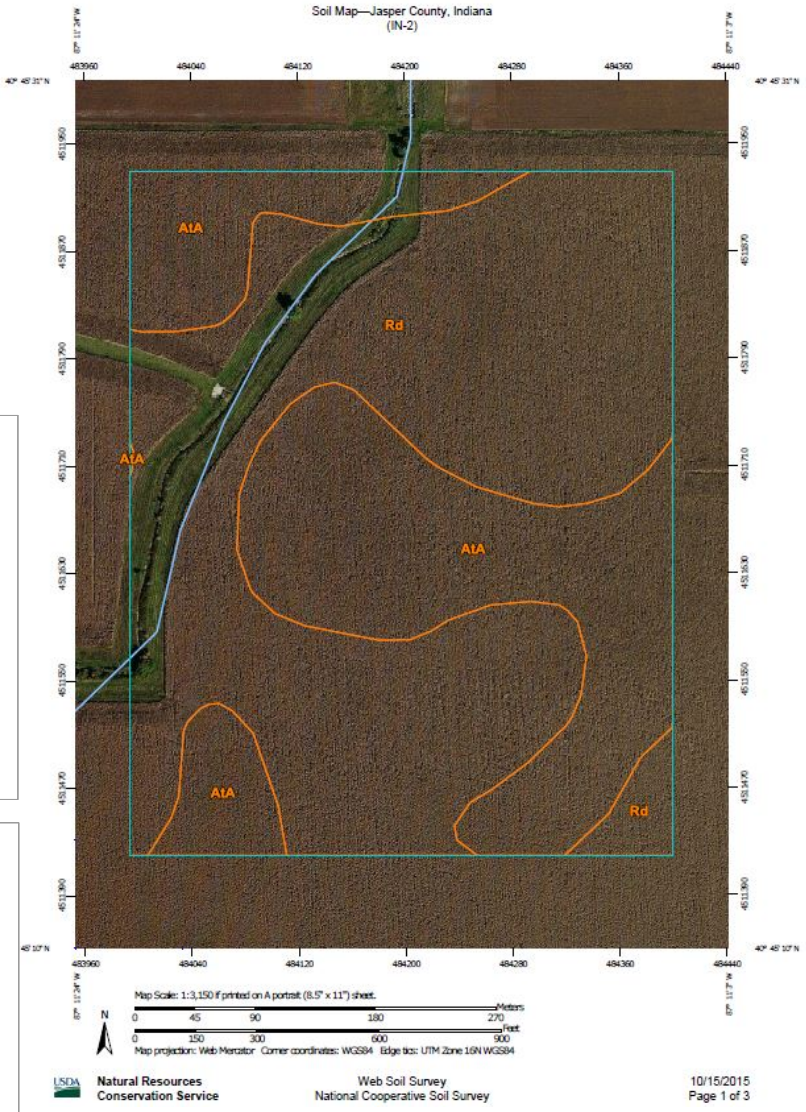
Soil Chemical Profiles

Soil organic matter was greater than about 0.9% in the top 48 inches. Bray-1 soil P decreased sharply with depth and was lower in the 2nd transect. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was neutral to slightly alkaline with depth. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.








Soil Map—Jasper County, Indiana
(IN-2)

Map Scale: 1:3,150 if printed on A portrait (8.5" x 11") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 16N WGS84

Natural Resources Conservation Service

Web Soil Survey
National Cooperative Soil Survey

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IN – 3 (FSA)

Location: Montgomery Co. IN
S17 T20N R3W 2nd Meridian (Sugar Creek Township)
40.185580°N 96.780870°W

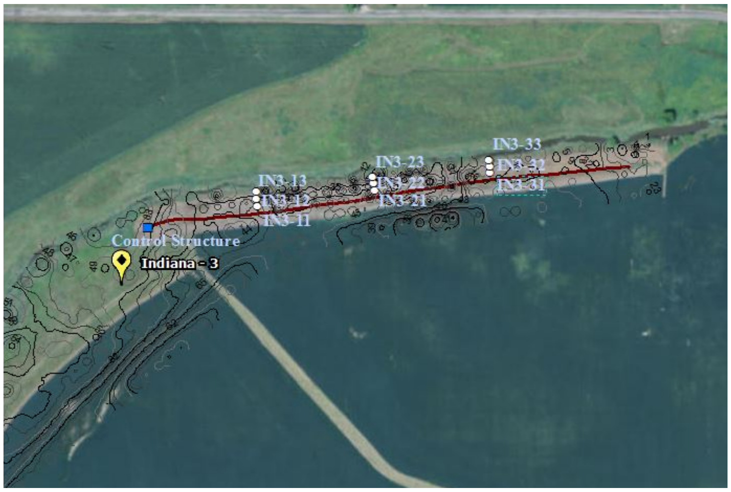
Drained Area and Tile System:
The saturated buffer was installed on an existing 8" outlet. The tile system is estimated to drain 67 ac. or 27.2 ha. The field itself is said to be flat, with a flat buffer. The field was in a corn-soybean rotation for the duration of the project.

Buffer Dimensions and Characteristics:
The CRP buffer is ~85 ft wide. There was some land shaping done in the buffer area near the start of the project. After that work was completed it was re-seeded to a warm/cool season grass mix. There was some difficulty getting the grass to get established and during the project time the soil was often bare or weed-covered. Prior to this it was seeded to native prairie grasses.

Installation Date: June, 2013

Installation Cost:
The overall cost for this project site was $4,170 with $1,495 attributed to the control structure.

Installation and Monitoring Information:
The saturated buffer was installed by a local contractor who used a backhoe and tile plow to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution line is ~1,270 feet long and runs eastward from the control structure. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.



Ditch Characteristics:
The stream is relatively shallow, less than five feet deep. It is well-vegetated and the banks seems relatively stable.

Other Important Site Features:
None.

Any Changes in Conditions During the Project?
None.

Well Setup and Management:
A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the ditch bank and the other two equally spaced between the ditch and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the ditch. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Well ID	Depth (ft.)
IN-3-11	6.42
IN-3-12	6.42
IN-3-13	6.42
IN-3-21	6.33
IN-3-22	6.33
IN-3-23	6.50
IN-3-31	6.50
IN-3-32	6.33
IN-3-33	6.33

Structure Management:
Because the buffer and cropped area are at similar elevations the stop logs needed to be managed to ensure adequate drainage needs for crop production were satisfied.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	776.5	775.5
June 2013	27.44	22.44	774.3	773.9
3/10/2015	22.44	17.44	773.9	773.4
5/4/2015	17.44	12.50	773.4	773.0
5/15/2015	0.00	0.00	772.0	772.0

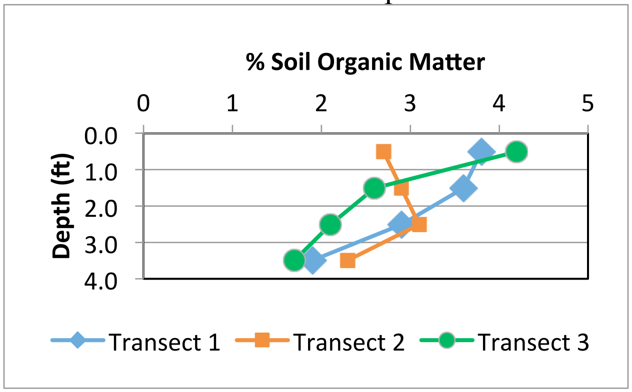
The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

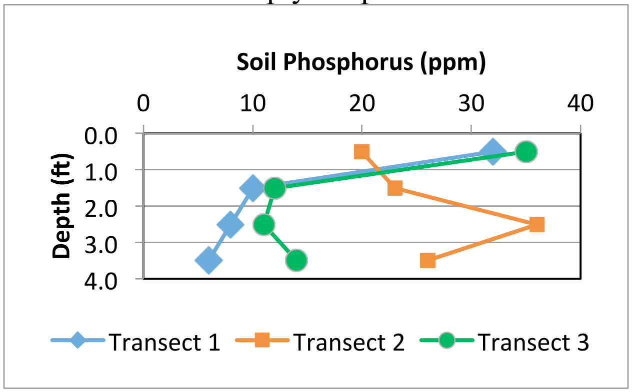
Soil Description (type, texture, etc.):
The soil map and soil series are below. Soils in the buffer are mapped as Cohoctah loam. Soil cores showed the soil to be loam to silt loam down to 42 inches. On the eastern and western ends of the buffer a gleyed layer with high chroma redoximorphic features indicative of saturated conditions was present starting at about 35 inches. At about 67 there appeared to be a calcareous buried A horizon. The middle of the buffer was calcareous starting at 12 inches and had a sandy layer starting at 39 inches. Below the sand was also a buried calcareous A horizon below which was a gleyed clay layer.

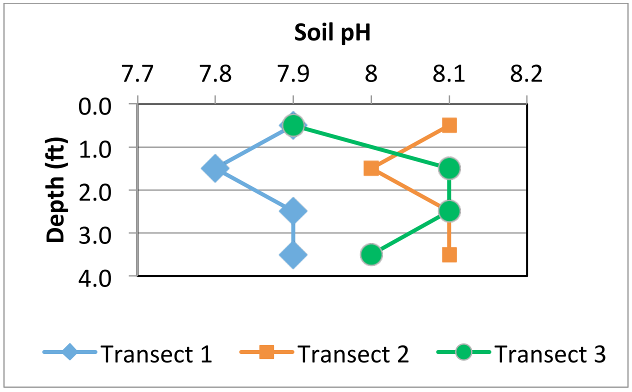
Map Symbol	Unit Name
Ck	Cohoctah Loam, frequently flooded
Du	Drummer Silty Clay Loam
FdA	Fincastle Silt Loam, Tipton Till Plain, 0-2% slopes
FgB2	Fincastle-Miami Silt Loams, 2-6% slopes, eroded
Mb	Mahalasville Silty Clay Loam
SIA	Starks Silt Loam, 0-2% slopes

Soil Chemical Profiles

Soil organic matter was greater than 1.7% in the top 48 inches. Bray-1 soil P decreased sharply with depth at Transects 1 and 3 but increased in Transect 2. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was slightly alkaline throughout the top 3½ feet. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.







MN – 1 (CIG)

Location: Yellow Medicine Co. MN
S27 T114N R41W 5th Meridian (Normania Township)
44.654230°N 95.778461°W
Watershed HUC12 # 070200040602

Drained Area and Tile System:
The saturated buffer was installed on an existing 8" outlet. The drainage area for this tile system is 15 ac. or 6.1 ha. The field and buffer are both flat and at similar elevations. The field was in a corn-soybean rotation for the duration of the project.

Buffer Dimensions and Characteristics:
The existing CRP buffer is ~155 feet wide and is consists of hardy perennial grasses, shrubs, and some trees along the stream bank.

Installation Date: November 1, 2012

Installation Cost:
The overall cost for this project site was $2,758 with $1,483 attributed to the control structure.

Installation Management Information:
The saturated buffer was installed by a local contractor who used a backhoe and tile plow to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution line is ~1,085 feet long and runs southward from the control structure. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.

Ditch Characteristics:
The tile outlets into the Yellow Medicine River. This is a relatively deep, well-developed natural channel.

Other Important or Notable Site Features: There is a bioreactor installed on an adjacent tile outlet.

Any Changes in Conditions During the Project?
None.

Water Setup and Management

A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the river bank and the other two equally spaced between the river and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the river. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Well ID	Depth (ft.)
MN-1-11	~ 6
MN-1-12	~ 6
MN-1-13	~ 6
MN-1-21	~ 6
MN-1-22	~ 6
MN-1-23	~ 6
MN-1-31	~ 6
MN-1-32	~ 6
MN-1-33	~ 6

Structure Management:

Because the buffer and cropped area are at similar elevations the stop logs needed to be managed to ensure adequate drainage needs for crop production were satisfied.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	1052.2	1052.25
11/1/2012	72.07	65.07	1051.8	1051.2
5/3/2013	29.32	29.32	1048.2	1048.2
10/23/2014	29.32	17.32	1048.2	1047.2

The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

Soil Description (type, texture, etc.):

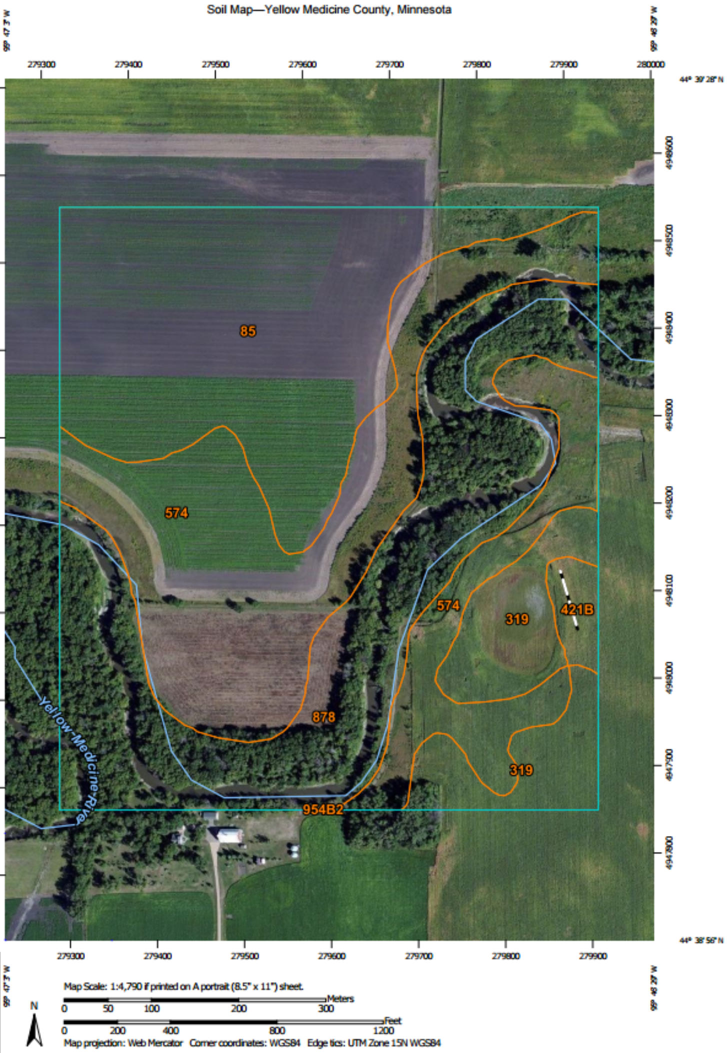
The soil map and soil series are below. Soils in the buffer are mapped as Calco-Du Page complex. Soil cores showed the soil to be silt loam to silty clay loam down to 42 inches.

Map Symbol	Unit Name
85	Calco Silty Clay Loam, occasionally flooded
319	Barbert Silt Loam
421B	Amiret Loam 2-6% slopes
574	Du Page Loam, occasionally flooded
878	Calco-Du Page Complex
954B2	Amiret-Swanklake Loams 2-6% slopes

Soil Chemical Profiles

Soil organic matter was greater than 1.9% in the top 48 inches. Bray-1 soil P decreased with depth at Transects 1 and 3 but increased at the 1½ foot depth before decreasing in Transect 2. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was slightly alkaline throughout the top 3½ feet. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.

Soil Map—Yellow Medicine County, Minnesota



Map Scale: 1:4,790 if printed on A portrait (8.5" x 11") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 15N WGS84

Natural Resources Conservation Service

Web Soil Survey
National Cooperative Soil Survey

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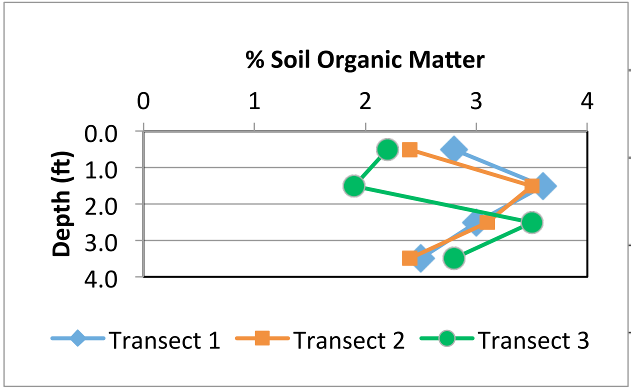
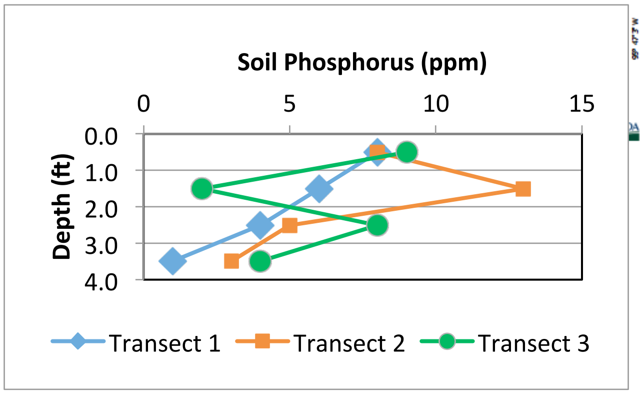
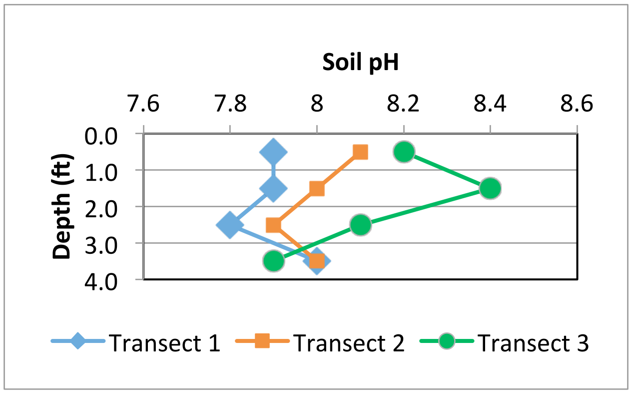






MN – 2 (CIG)

Location: Dodge Co. MN
S31 T08N R17W 5th Meridian (Concord Township)
44.114928°N 92.02266°W
Watershed HUC12 # 070400040304

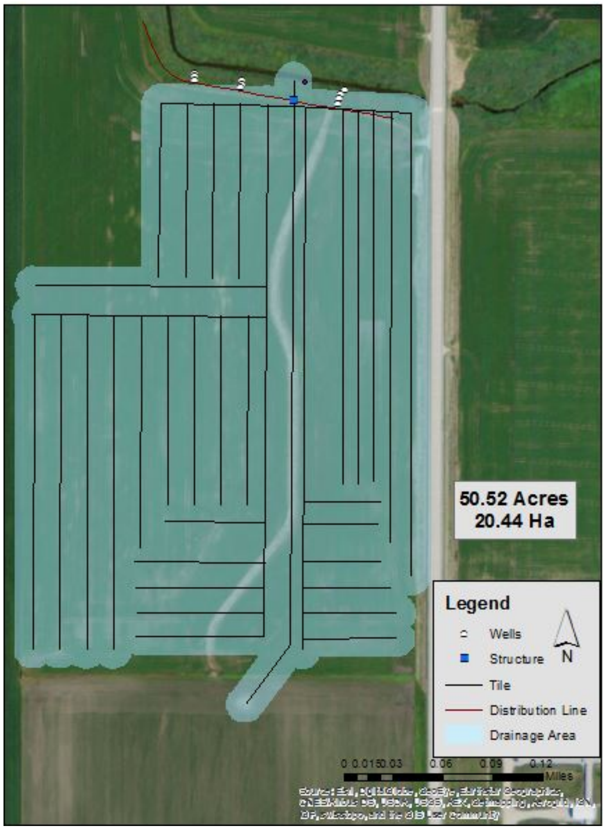
Drained Area and Tile System:
The saturated buffer was installed on an existing 6" outlet. The drainage area, estimated from the provided tile map, is 50.5 ac. or 20.4 ha. The buffer is flat and the field has a gentle slope. The field was in a corn-soybean rotation for the duration of the project.

Buffer Dimensions and Characteristics:
The existing CRP buffer is ~80 feet wide and was planted to hardy perennial grasses.

Installation Date: April, 2013

Installation Cost:
The overall cost for this project site was $3,621.05 with a structure cost of $1,471.05.

Installation and Monitoring Information:
The saturated buffer was installed by a local contractor who used a backhoe and tile plow to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution line is ~920 feet long, with ~610 feet of the tile going towards the West and another ~310 feet going to the East. Flow monitoring was via V-Notch weirs installed as the top stop logs in the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.



Ditch Characteristics:
The ditch is less than six feet deep and well-vegetated with relatively stable banks.

Other Important or Notable Site Features:
None.

Any Changes in Conditions During the Project?
A large main was installed in the draw just east of the control structure in December 2014. The contractor used non-perforated pipe through the width of the buffer.

Well Setup and Management:
A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the stream bank and the other two equally spaced between the stream and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the stream. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Well ID	Depth (ft.)
MN-2-11	4.75
MN-2-12	5.42
MN-2-13	5.00
MN-2-21	5.83
MN-2-22	6.00
MN-2-23	5.46
MN-2-31	3.38
MN-2-32	6.17
MN-2-33	5.96

Structure Management:
The stop logs were not moved for the duration of the project.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	1230.0	1230.6
April 2013	34.38	29.44	1229.5	1229.1

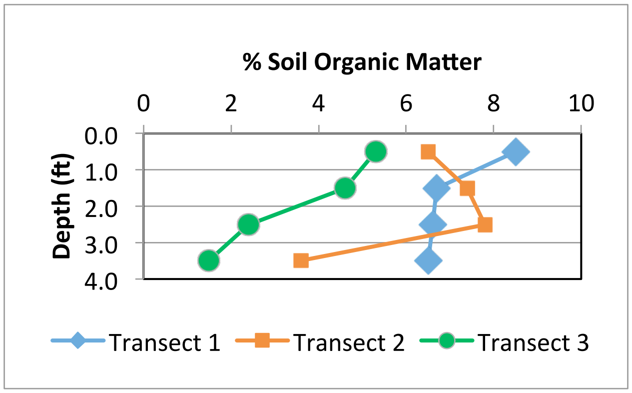
The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

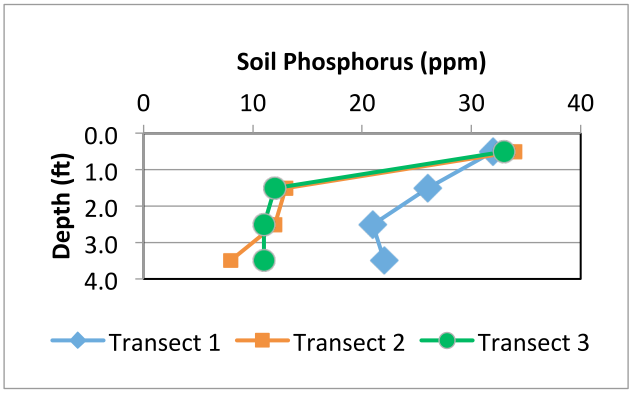
Soil Description (type, texture, etc.):
The soil map and soil series are given below. Soils in the buffer are mapped as Marshan clay loam. Soil cores showed the soil to be loam to silt clay loam down to 42 inches. The soil was a gleyed sand starting from 46 to 68 inches indicating continuous reducing (saturated) conditions

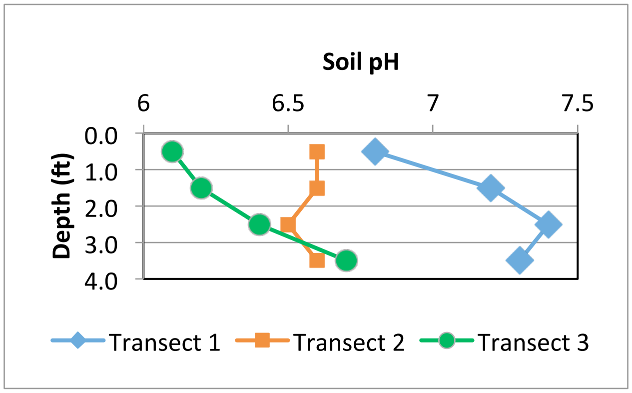
Map Symbol	**Unit Name**
M504A	Marshan Clay Loam, 0-2% slopes
M511A	Readlyn Silt Loam, 1-3% slopes
M514A	Lawler-Marshan Complex, 0-2% slopes
M515A	Tripoli Silty Clay Loam, 0-2% slopes
M525A	Dakota Silt Loam, 0-3% slopes

Soil Chemical Profiles

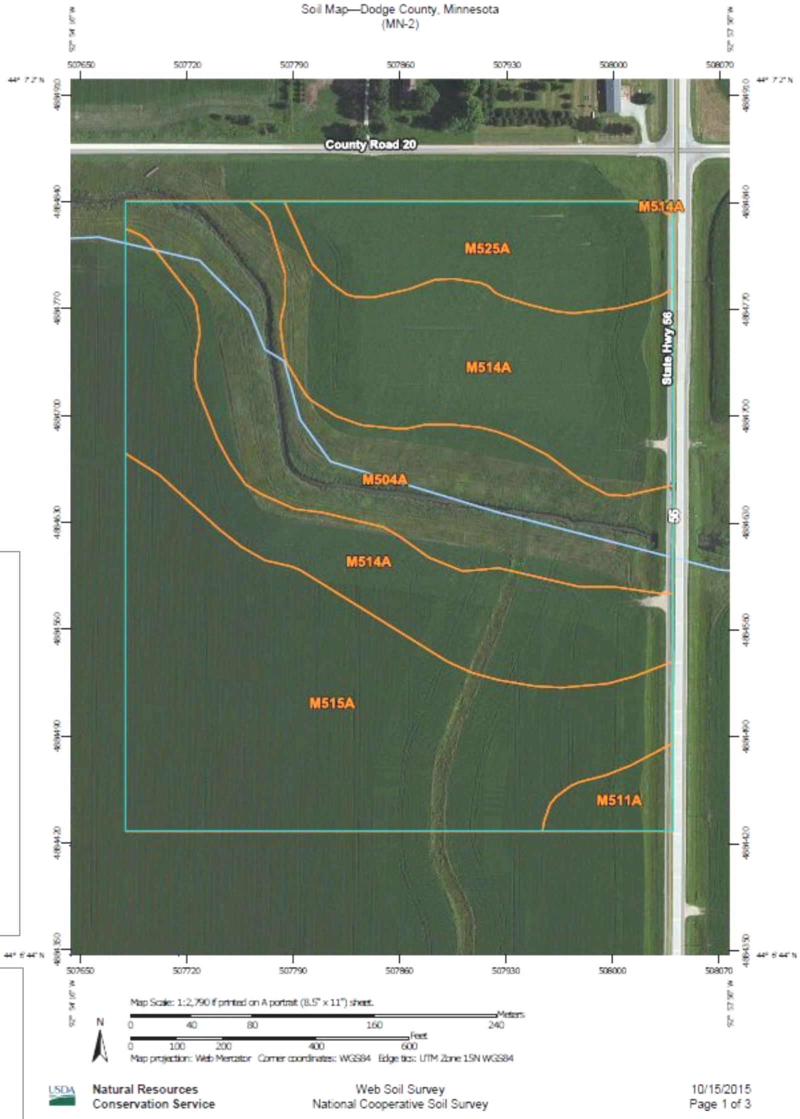
Soil organic matter was greater than 1.5% in the top 48 inches, but much greater than 5% in Transect 1. Bray-1 soil P decreased with depth and was slightly greater in Transect 1. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was slightly acidic at the surface increasing with depth. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.







Soil Map—Dodge County, Minnesota
(MN-2)



MN – 3 (FSA)

Location: Dodge Co. MN
S34 T108N R17W 5th Meridian (Concord Township)
44.113780°N 92.850176°W
Watershed HUC12 # 070400040304

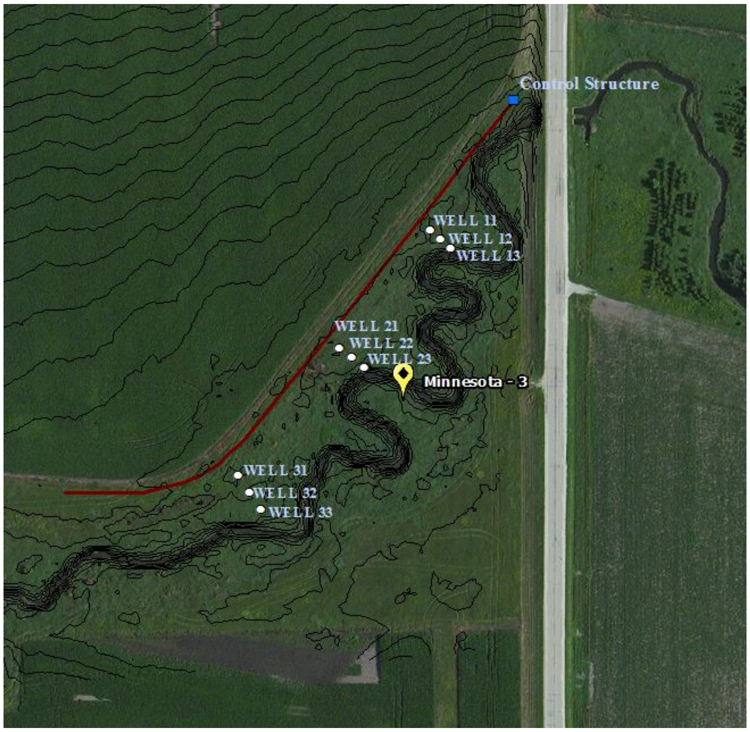
Drained Area and Tile System:
The saturated buffer was installed on an existing 6" outlet. The drainage area for this tile system is 28 ac. or 11.4 ha. The buffer is fairly flat with some wet depressions. The field slopes uniformly to the north. The field was in a corn-soybean rotation for the duration of the project.

Buffer Dimensions and Characteristics:
The existing CRP buffer is ~35 to 150 ft wide and is planted to hardy perennial grasses. There are also some occasional shrubs.

Installation Date: April, 2013

Installation Cost:
The overall cost for this project site was $3,670 with $1,400 attributed to the control structure.

Installation and Monitoring Information:
The saturated buffer was installed by a local contractor who used a backhoe and tile plow to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution line is ~1,000 ft long and runs westward from the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.



Ditch Characteristics:
The stream is less than six feet deep and meanders extensively through the buffer.

Other Important or Notable Site Features:
None.

Any Changes in Conditions During the Project?
None.

Well ID	Depth (ft.)
MN-3-11	5.83
MN-3-12	4.79
MN-3-13	5.67
MN-3-21	5.67
MN-3-22	5.67
MN-3-23	5.92
MN-3-31	6.13
MN-3-32	6.13
MN-3-33	5.29

Well Setup and Management:
A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the stream bank and the other two equally spaced between the stream and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the stream. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Structure Management:
The stop logs were not moved for the duration of the project.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	1214.8	1212.5
April 2013	30.19	17.57	1211.8	1210.7
2/25/2014	17.57	17.57	1210.7	1210.7
11/21/2014	30.19	17.58	1211.8	1210.7

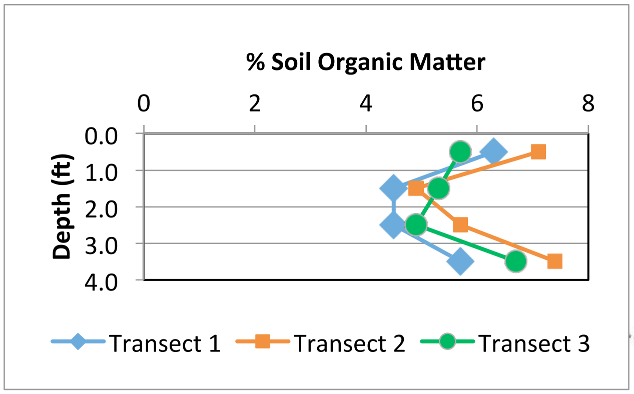
The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

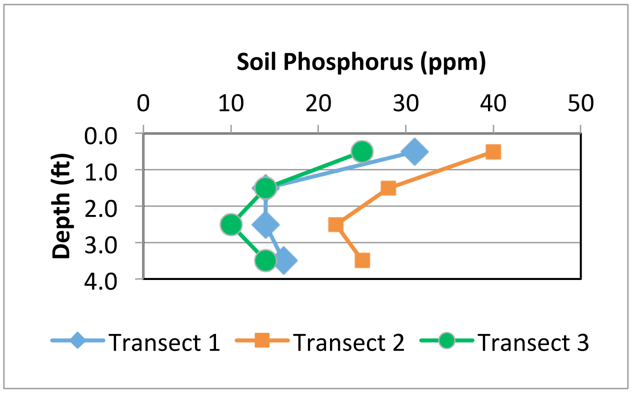
Soil Description (type, texture, etc.):
The soil map and soil series are below. Soils in the buffer are mapped as Coland-Spillville complex. Soil cores showed the soil to be loam to silt loam down to 42 inches. Starting at about 47 inches was a calcareous gleyed sandy material indicating reducing (saturated) conditions.

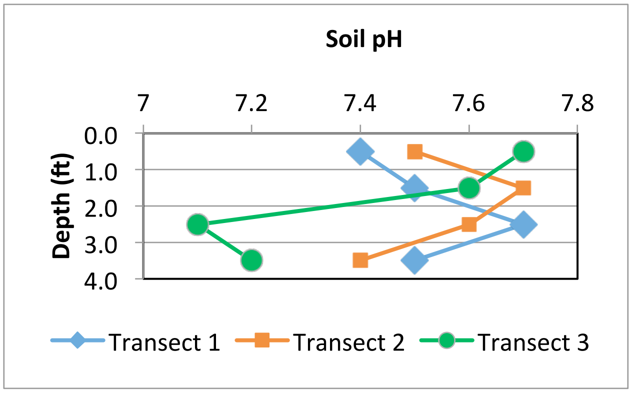
Map Symbol	**Unit Name**
1027A	Coland-Spillville Complex,0-2% slopes, flooded
M504A	Marshan Clay Loam, 0-2% slopes
M507B	Marquis Silt Loam, 2-6% slopes
M509A	Mantorville Loam, 0-2% slopes
M511A	Readlyn Silt Loam, 1-3% slopes
M518B	Clyde-Floyd complex, 1-4% slopes
M525A	Dakota Silt Loam, 0-3% slopes

Soil Chemical Profiles

Soil organic matter was very high at this site exceeding 4.5% everywhere in the top 48 inches. Bray-1 soil P decreased with depth and was slightly greater in Transect 2. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was neutral throughout the top 3½ feet although the soil was calcareous at 65 inches depth. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.







Map Scale: 1:1,660 if printed on A portrait (8.5" x 11") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 15N WGS84

USDA Natural Resources Conservation Service

Web Soil Survey
National Cooperative Soil Survey

10/15/2015
Page 1 of 3

MN – 4 (FSA)

Location: Dodge Co. MN
S6 T106N R16W 5th Meridian (Canisteo Township)
44.014358°N 92.793908°W
Watershed HUC12 # 070400040204

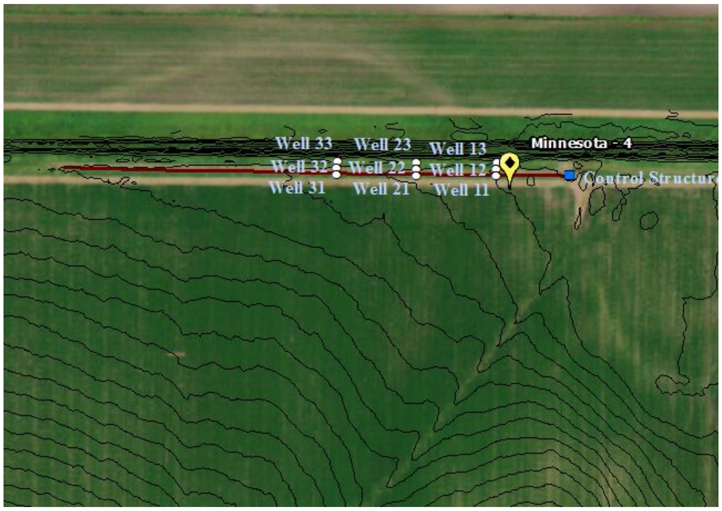
Drained Area and Tile System:
The saturated buffer was installed on an existing 6" outlet. The drainage area for this tile system is 40 ac. or 16.2 ha. The field has a fair amount of slope to it. However, the northeast corner (near the control structure) is relatively flat and at a similar elevation as the buffer. This field was in a corn-soybean rotation for the duration of the project.

Buffer Dimensions and Characteristics:
The existing CRP buffer is ~ 80 feet wide and is hardy perennial grasses.

Installation Date: June, 2013

Installation Cost:
The overall cost for this project site was $2,453 with $1,117 being attributed to the control structure

Installation Information:
The saturated buffer was installed by a local contractor who used a backhoe and tile plow to do the work in less than one day. The work included replacing a section of the main with non-perforated pipe and installation of the control structure and distribution line. The distribution line is ~850 ft and runs due west from the control structure. Flow depth was measured using water level sensors. Water samples were collected approximately twice a month when the tile was flowing.



Ditch Characteristics:
The stream is less than six feet deep and is well-vegetated with relatively stable banks.

Other Important or Notable Site Features:
None.

Any Changes in Conditions During the Project?
None.

Well Setup and Management:

A series of three groundwater monitoring well transects were installed at this site. Each transect contained three wells (one near the ditch bank and the other two equally spaced between the ditch and the distribution line) for sampling the groundwater in the buffer as it moved from the distribution line to the ditch. The depth of each monitoring well is given in the table to the right. The Well ID's correspond to the locations indicated on the previous page.

Well ID	Depth (ft.)
MN-4-11	4.79
MN-4-12	6.29
MN-4-13	6.71
MN-4-21	6.54
MN-4-22	6.21
MN-4-23	5.00
MN-4-31	5.21
MN-4-32	6.38
MN-4-33	6.75

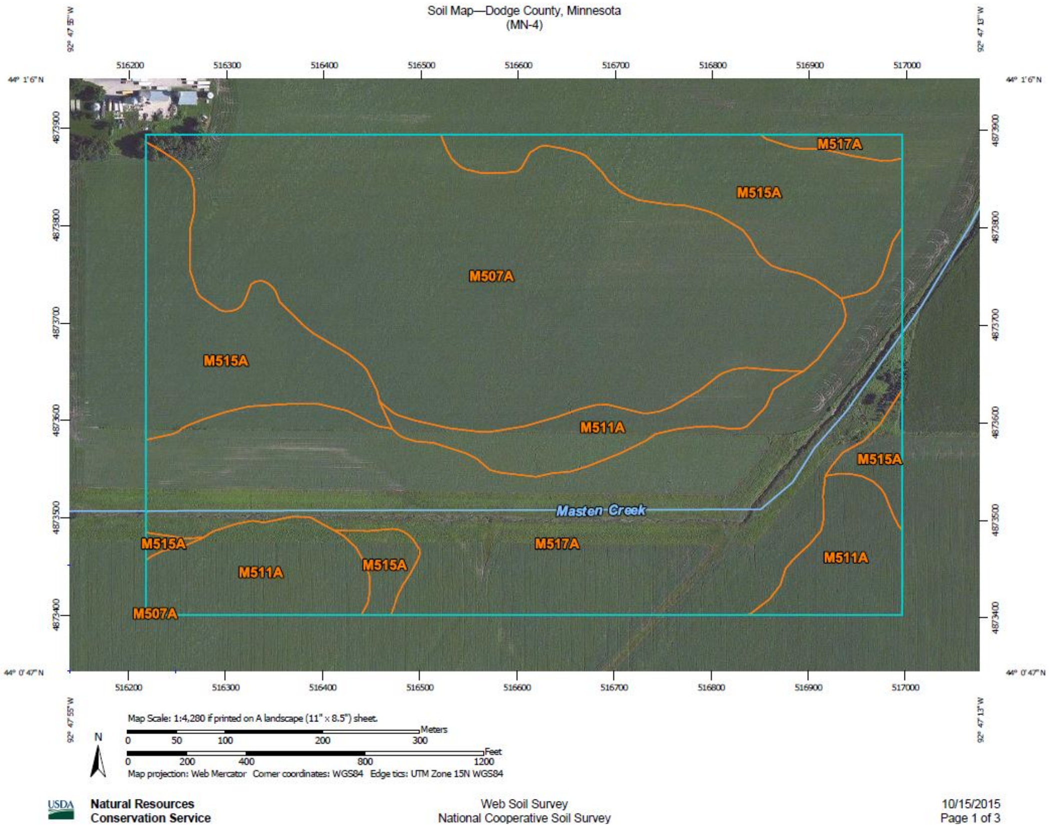
Structure Management:
Because the buffer and cropped area are at similar elevations the stop logs needed to be managed to ensure adequate drainage needs for crop production were satisfied.

Date	Board Height (in)		Elevation (ft)	
	Field	Buffer	Field	Buffer
Ground	NA	NA	1265.0	1263.5
June 2013	32.44	27.44	1261.9	1261.5
7/24/2014	27.50	22.50	1261.5	1261.1
5/26/2015	32.50	27.42	1261.9	1261.5

The "Board Height" refers to the height of stop logs within the structure and the corresponding "Elevation" of the top stop log.

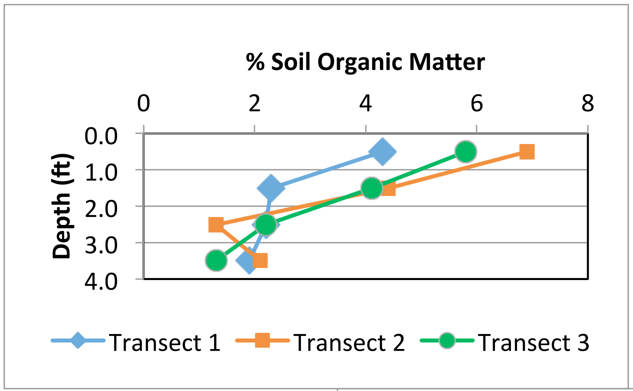
Soil Description (type, texture, etc.):
The soil map and soil series are below. Soils in the buffer are mapped as Clyde silty clay loam. Soil cores showed the soil to be loam or clay loam transitioning to sandy loam at 3½ feet. A narrow layer from about 26 to 41 was gleyed with high chroma redoximorphic concentrations indicating reducing (saturated) conditions. Under this layer was a sandy calcareous layer containing pebbles.

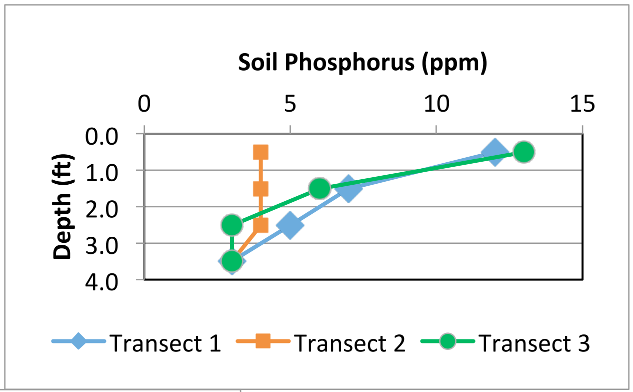
Map Symbol	**Unit Name**
M507A	Marquis Silt Loam, 1-3% slopes
M511A	Readlyn Silt Loam, 1-3% slopes
M515A	Tripoli Silty Clay Loam, 0-2% slopes
M517A	Clyde Silty Clay Loam, 0-3% slopes

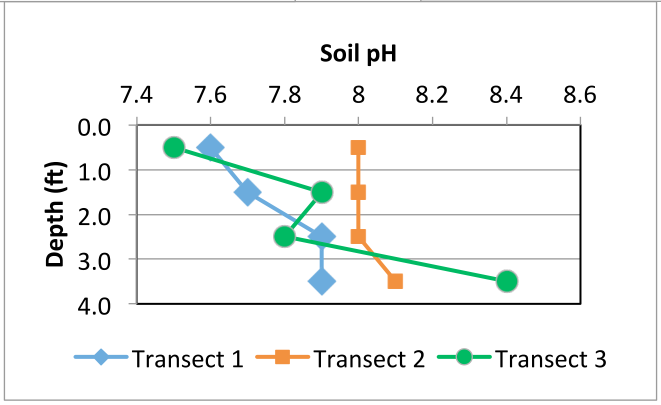


Soil Chemical Profiles

Soil organic matter was very high at the surface and exceeded 1.3% in the top 42 inches. Bray-1 soil P decreased with depth except at Transect 2 and was ≤ 7ppm at 1½ feet and deeper. Bray-1 P concentrations below about 10 ppm are considered low for corn production. Soil pH was neutral at the surface trending alkaline at depth reflecting the presence of calcareous soil at 35 – 45 inches. Denitrification is maximum at a pH between 7 and 8.5 and decreases sharply for pH ≤ 5.







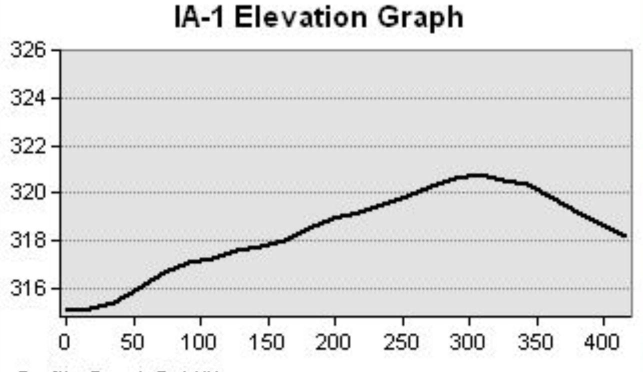
Landscape Characteristics

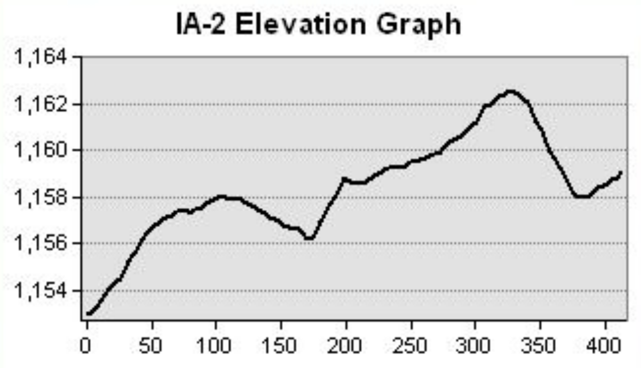
Because the water table is raised within the buffer for the saturated buffer practice, it is important to locate the practice either where there is some elevation relief between the buffer and the cropped field or to manage the flashboards so the water table does not interfere with farming. This would entail removing the boards in spring before planting and in the fall before harvest to lower the watertable to assure good trafficability in the field. The boards may also have to be managed during the growing season so that the watertable within the row crop field does not interfere with either farm operations or crop growth. This later condition would be similar to the controlled drainage practice where the watertable is actively managed during the year. While feasible it does require more management from the farmer in periodically adjusting the gates. Also the buffer would not be receiving water when the gates were lowered, reducing the potential effectiveness of the saturated buffer in removing nitrate.

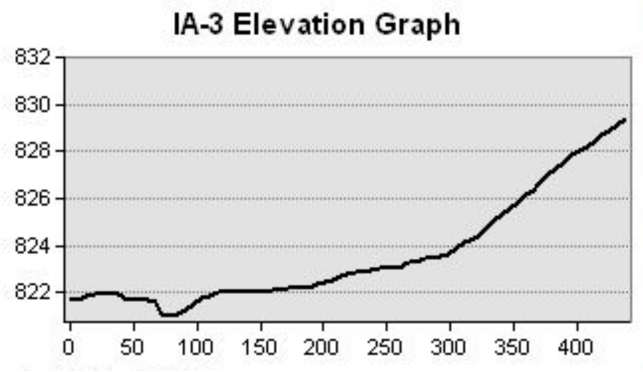
We plotted the elevation profile perpendicular to the buffers for the first 400 ft at each site where LiDAR elevation data was available to see how amenable the landscape was for the saturated buffer practice. The y-axis of each plot is set to a 10 ft range so that the sites can be easily compared. In the figures the x-axis origin is the edge of the stream and as the distance increases we are moving towards the field perpendicular to the stream.

Iowa

For IA-1, and IA-2 there is a steady rise in the landscape away from the buffer. Thus, there is little chance that the operation of the saturated buffer would adversely impact the row crop portion of the field. Field slope was much gentler at IA-3, so there may be an issue with raising the watertable too aggressively within the buffer at this site.

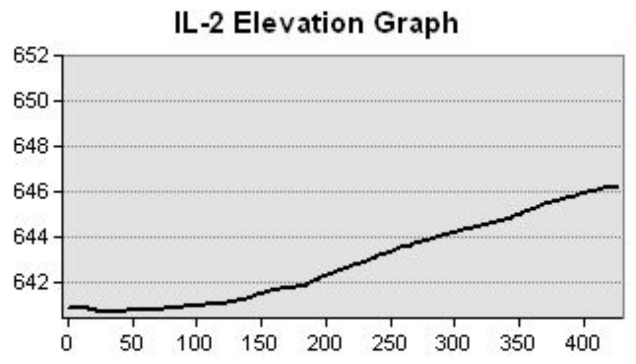


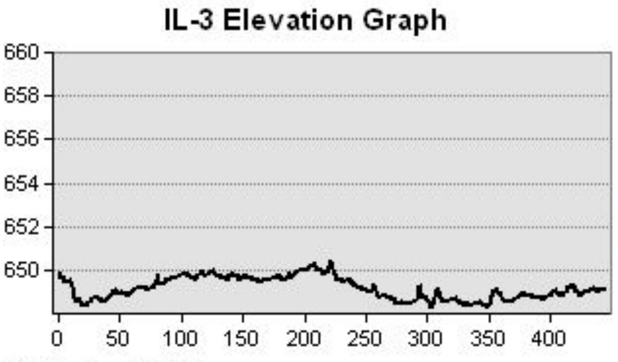


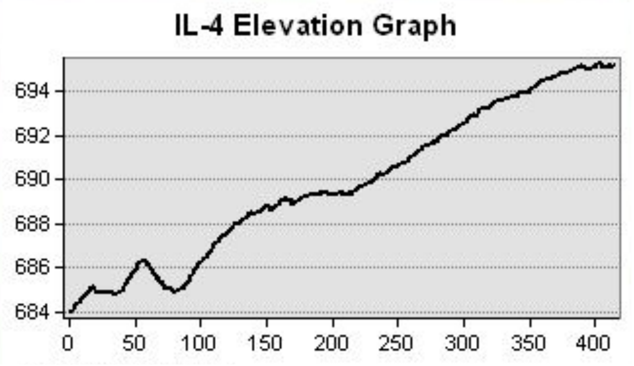


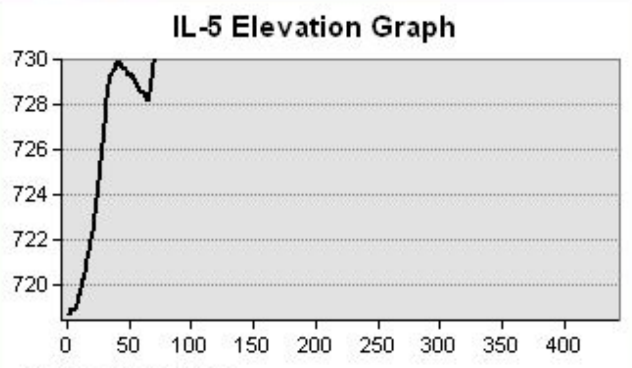
Illinois

We did not obtain quality elevation data for IL-1 so could not examine the landscape profile for that site. Except for IL-2, and IL-3, there is a steady increase in elevation away from the stream or ditch. Thus, we would expect no interference from raising the water table within the buffer on the row cropped field. Conversely, the landscape at IL-2 and IL-3 was very level near the stream which required active management of the flashboards within the control box of the saturated buffer so as not to interfere with row crop field operation.


IL-2 Elevation Graph

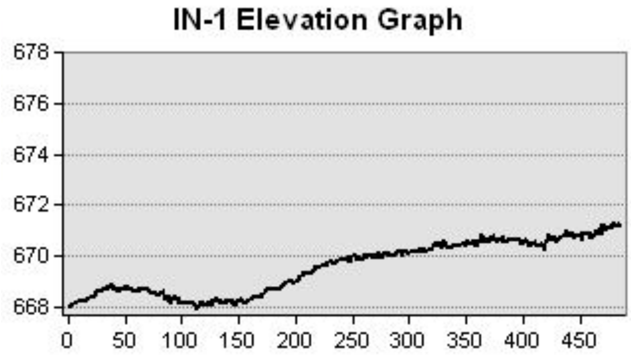

IL-3 Elevation Graph

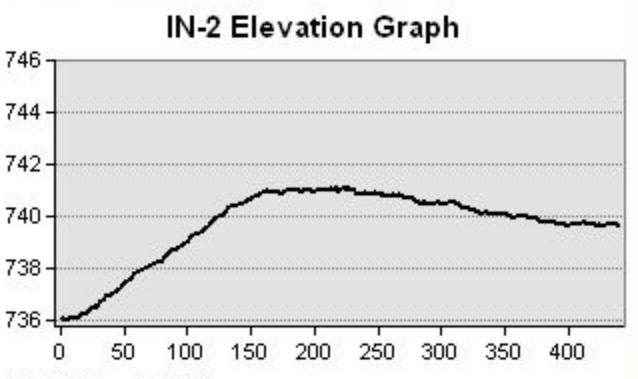

IL-4 Elevation Graph

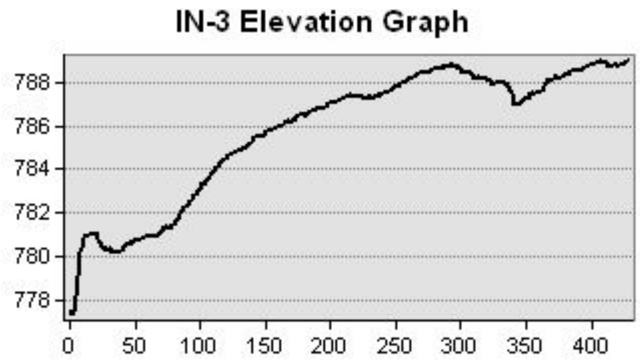

IL-5 Elevation Graph

Indiana

The elevation profile at IN-1 was fairly flat requiring active management of the flashboards of a saturated buffer. At IN-2 there was a 4 ft rise in elevation within the first 150ft, thus active management of the flashboards would probably not be required. IN-3 also had a marked increase in elevation away from the stream and should not require active management of the flashboards in a saturated buffer.

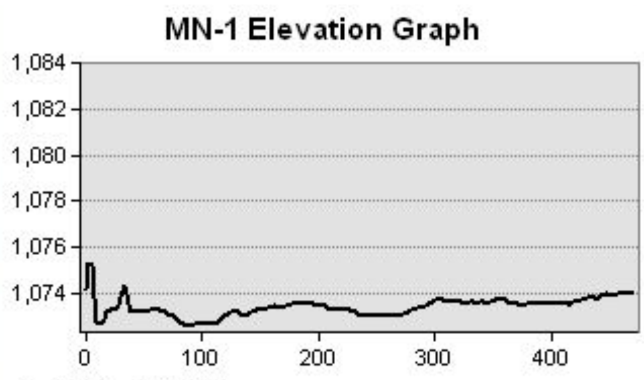


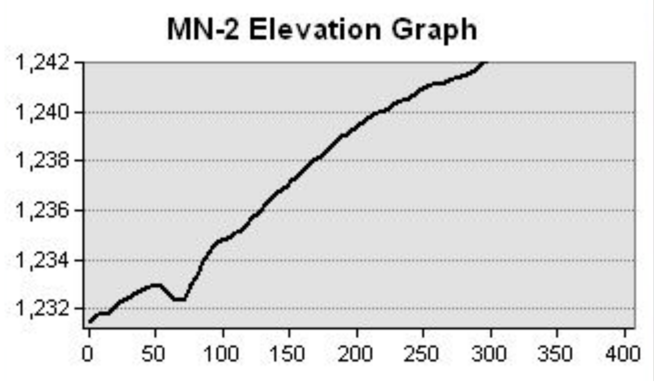


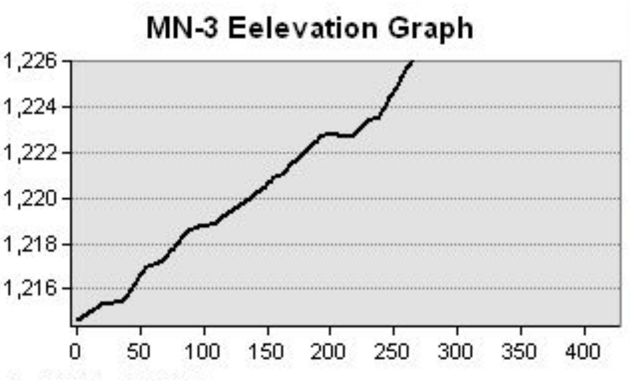


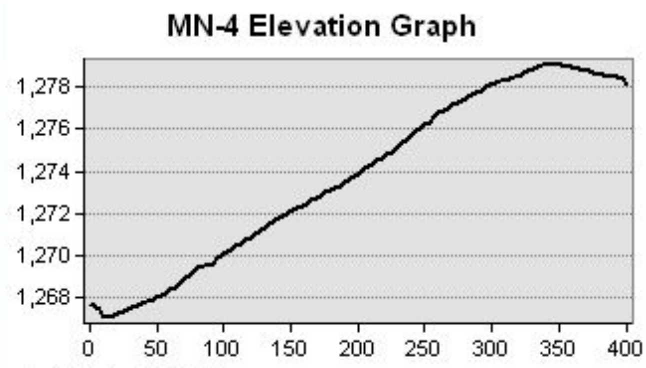
Minnesota

MN-1 was on a very flat terrain and would required active management of the flashboards within a saturated buffer in order to prevent the water table from interfering with field operations. MN-2 – 4 sloped nicely up from the buffer and should not required active management of the saturated buffer flashboards to be successful.









Appendix B- Flow data processing notes

Flow values removed					**Does not account for data missing due to logger malfunction**
Site	**Sensor**	**Removed - Start**	**Removed - End**	**# days**	**Reason**
IA-2	Field/Buffer	6/24/2013	6/25/2013	2	flooding
IA-2	Buffer	7/9/2013	7/14/2013	6	buffer level sensor did not have usable data, field flow data also removed
IA-2	Buffer	5/27/2014	7/25/2014	60	buffer level sensor did not have usable data, field flow data also removed
IA-2	Field/Buffer	6/22/2015	6/23/2015	2	flooded
IA-2	Field/Buffer	8/28/2015	8/31/2015	4	flooded
IA-3	Field/Buffer	6/24/2013	6/29/2013	6	flooding
IA-3	Buffer	11/18/2013	11/29/2013	12	buffer sensor not reporting usable data, field flow data were already at zero
IA-3	Field/Buffer	12/12/2013	4/6/2014	116	level data from at least one of the sensors not usable
IA-3	Field/Buffer	5/31/2014	6/26/2014	27	flooding
IA-3	Field	9/8/2014	9/28/2014	21	field sensor not reporting usable data, buffer flow data were removed accordingly
IA-3	Field/Buffer	5/26/2015	5/28/2015	3	potential flooding, flow difference between sensors to large to be reasonable
IA-3	Field/Buffer	6/7/2015	6/7/2015	1	potential flooding, flow difference between sensors to large to be reasonable
IA-3	Field/Buffer	6/12/2015	7/1/2015	20	potential flooding, flow difference between sensors to large to be reasonable
IA-3	Field	7/28/2015	7/29/2015	2	unrealistically high flow values from field, do not match with buffer flow values
IL-1	Field/Buffer	5/31/2013	5/31/2013	1	flooding
IL-1	Field/Buffer	late Feb 2013	early July 2013	0	some of the flows look high and potentially suspect because of the large differences between L1 and L2, however, it could be real so I did not remove it
IL-2	L2	7/26/2013	12/22/2013	150	unrealistic level values (no flow from field during this time)
IL-2	L1	7/29/2013	4/14/2014	260	unrealistic flow values for the buffer, buffer flow values also removed
IL-2	L2	6/11/2014	6/11/2014	1	unrealistic level values (no flow from field during this time)
IL-2	L2	9/9/2014	9/15/2014	7	unrealistic level values (no flow from field during this time)
IL-2	L2	10/2/2014	10/13/2014	12	Flooding, also removed L1 flow
IL-2	L1	10/2/2014	12/7/2014	67	Level 1 reading is suspect, also removed Level 2 flow data
IL-2	L2	11/26/2014	12/16/2014	21	unrealistic level values (no flow from field during this time)
IL-2	L2	5/11/2015	5/12/2015	2	Flooding, also removed L1 flow
IL-2	L2	5/30/2015	5/31/2015	2	Flooding, also removed L1 flow
IL-2	L2	6/19/2015	6/19/2015	1	Flooding, also removed L1 flow

Appendix B-Cont. Flow data processing Notes

Site	Sensor	Removed-Start	Removed-End	# Days	Reason
IL-2	L2	6/25/2015	6/27/2015	3	Flooding, also removed L1 flow
IL-2	L2	7/7/2015	7/12/2015	6	Flooding, also removed L1 flow
IL-3	Buffer	12/23/2013	1/19/2014	28	buffer level suspect - it is higher than field boards and field level, field had no flow during this time period
IL-3	Buffer	4/7/2014	6/17/2014	72	Level data from the buffer sensor appears suspect - resulting flow values did not match the field flow values - field flow values also removed
IL-3	Field/Buffer	6/10/2014	6/17/2014	8	flooding
IL-3	Field/Buffer	9/30/2014	10/6/2014	7	values from both level sensors appear suspect
IL-3	Buffer	10/8/2014	11/25/2014	49	values from buffer sensor are highly suspect, field flow data also removed
IL-3	Field/Buffer	11/26/2014	12/16/2014	21	level values are incorrect due to issue with data logger firmware
IL-3	Field/Buffer	6/19/2015	6/20/2015	2	flooding
IL-3	Field/Buffer	6/25/2015	6/27/2015	3	flooding
IL-4	Buffer	11/26/2014	11/26/2014	1	flooding, field flow is zero
IL-4	Buffer	1/16/2015	4/15/2015	90	the buffer transducer appears to have a blown diaphragm, field flow data also removed
IL-5	Buffer	4/4/2013	11/30/2014	606	buffer sensor not reporting usable data, field flow data were removed accordingly
IL-5	Field	4/4/2013	6/21/2013	79	field sensor not reporting usable data, buffer flow data already removed due to bad data
IL-5	Buffer	12/12/2014	12/12/2014	1	buffer sensor not reporting usable data, field flow data were removed accordingly
IL-5	Field	12/13/2014	12/13/2014	1	field sensor not reporting usable data, buffer flow data were removed accordingly
IN-1	Field/Buffer	5/27/2013	6/2/2013	7	flooding
IN-1	Field/Buffer	2/20/2014	2/23/2014	4	flooding
IN-1	Buffer	3/10/2014	3/10/2014	1	flooding
IN-1	Buffer	10/3/2014	10/3/2014	1	flooding
IN-1	Buffer	11/24/2014	11/24/2014	1	flooding
IN-1	Buffer	3/9/2015	3/9/2015	1	flooding
IN-1	Field/Buffer	6/7/2015	6/9/2015	3	flooding
IN-1	Field/Buffer	6/13/2015	6/16/2015	4	flooding
IN-1	Field/Buffer	6/23/2015	6/24/2015	2	flooding

Appendix B- Cont. Flow data processing Notes

Site	Sensor	Removed-Start	Removed-End	# Days	Reason
IN-1	Field/Buffer	7/8/2015	7/11/2015	4	flooding
IN-2	Buffer	2/8/2015	2/10/2015	3	submerged outlet
IN-2	Buffer	2/21/2015	2/21/2015	1	submerged outlet
IN-2	Field/Buffer	3/8/2015	3/11/2015	4	submerged outlet
IN-2	Field/Buffer	6/18/2015	7/20/2015	33	submerged outlet
IN-3	Field	11/8/2013	5/6/2014	180	Field sensor did not report usable data, no flow from buffer
IN-3	Field/Buffer	12/6/2014	12/18/2014	13	flooding
IN-3	Field/Buffer	3/8/2015	3/17/2015	10	flooding
IN-3	Field/Buffer	3/25/2015	3/30/2015	6	flooding
IN-3	Field/Buffer	4/8/2015	4/22/2015	15	flooding
IN-3	Field/Buffer	4/25/2015	4/29/2015	5	flooding
MN-1	Field/Buffer	6/9/2013	7/7/2013	29	flooding
MN-1	Buffer	8/14/2014	10/23/2014	71	false sensor reading, field sensor working fine and indicated no flow
MN-2	Field/Buffer	6/16/2014	6/23/2014	8	flooding
MN-3	Field/Buffer	6/16/2014	6/23/2014	8	flooding
MN-3	Field/Buffer	6/7/2015	6/14/2015	8	unrealistic flow values for the buffer, field flow values also removed
MN-3	Field/Buffer	6/28/2015	6/30/2015	3	unrealistic flow values for the buffer, field flow values also removed
MN-4	Buffer	9/26/2013	12/23/2013	89	unrealistic level values (no flow from field during this time)
MN-4	Buffer	6/16/2014	6/22/2014	7	unrealistic level values (no flow from field during this time)
MN-4	Buffer	10/25/2014	12/14/2014	51	unrealistic level values (no flow from field during this time)
MN-4	Buffer	2/27/2015	2/28/2015	2	unrealistic level values (no flow from field during this time)
MN-4	Buffer	3/5/2015	3/5/2015	1	unrealistic level values (no flow from field during this time)
MN-4	Buffer	5/26/2015	5/26/2015	1	unrealistic level values (no flow from field during this time)
MN-4	Field/Buffer	5/30/2015	5/30/2015	1	flooding
MN-4	Field/Buffer	6/12/2015	6/12/2015	1	flooding

Appendix B- Flow data collected

Site	Start Date	End Date	Potential Days	Actual Days	Missing Days	% Data
IA-2	6/15/2013	9/15/2015	822	402	420	49%
IA-3	5/10/2013	9/15/2015	858	521	337	61%
IL-1	1/24/2013	9/15/2015	964	830	134	86%
IL-2	1/24/2013	9/15/2015	964	405	559	42%
IL-3	1/24/2013	9/15/2015	964	434	530	45%
IL-4	6/11/2013	9/15/2015	826	408	418	49%
IL-5	6/22/2013	9/15/2015	815	273	542	33%
IN-1	1/22/2013	9/15/2015	966	742	224	77%
IN-2	1/22/2013	9/15/2015	966	384	582	40%
IN-3	7/13/2013	9/15/2015	794	403	391	51%
MN-1	6/1/2013	9/15/2015	836	335	501	40%
MN-2	9/26/2013	9/15/2015	719	328	391	46%
MN-3	9/25/2013	9/15/2015	720	318	402	44%
MN-4	9/26/2013	9/15/2015	719	410	309	57%

Appendix C - Modeling Results on Drain Outflows at IL-2

Summary of Results

Drainage reduction is highly variable in Drainage Water Management (DWM) systems on a year to year basis due to random annual distributions and quantities of rainfall. 25 years of simulations were run to observe trends on the given soil types. In the DRAINMOD runs on the Virden soil type, 68% of years saw a reduction in drain flow due to DWM with an average reduction of 3%. The Ipava-Sable soil type simulations yielded 72% of years with drainage reductions with an average reduction of 7%. However, on a year to year basis, the greatest drainage reduction observed was 60% reduction, occurring during a year with 81 cm of precipitation, 14 cm less than the 25 year average.

Methods and Assumptions

- Historical site rainfall data was downloaded from NOAA referencing the nearest climate station (http://www.ncdc.noaa.gov/). Collected on site data for 2014 was used as well.
- Temperature data was received from the NOAA, referencing the nearest climate station (http://www.ncdc.noaa.gov/)

The hydrology model, DRAINMOD (Skaggs, 1980), was run for 25 years of simulation, from 1990 to 2014, using historical precipitation and temperature data from a nearby weather station (Springfield, IL, approximately 15 miles). The project was set to run in "Hydrology" mode, in which a water balance is simulated to solve for the amount of water entering and leaving the system. A drainage spacing of 60 feet was measured based on ArcGIS maps, however an optimal drain depth was assumed to by 3.3 feet. An effective drain radius of 1.1 cm, typical of 4 in laterals (assumed), was used, as well as a 1 cm (3/8 in.) drainage coefficient (assumed based on typical design in Illinois).

To receive the most accurate of outputs, the Freeze/Thaw algorithm was turned on (this algorithm was calibrated in the Midwest by Luo et al. (2000)), as well as Crop yield, to 1) Take into account the Midwest's snowfalls and ground freezing and 2) Allow the program to simulate crops on the surface to account for all forms of water use. Further, "Controlled Drainage" and "Conventional Drainage" modes were run for comparison, based on 2 different soil types.

The soils involved in the simulations were Virden and Ipava-Sable. Virden is considered a very deep, poorly drained, silty clay loam soil with low permeability, found on relatively flat (0-2%) lands (National Cooperative Soil Survey, NCSS). The Ipava-Sable soil type, composed mostly of Ipava, is considered a somewhat poorly drained, silt loam (NCSS). Both soil types are highly suited for DWM due to their deep impermeable layers (over 200 cm), low slopes, and low permeability (Web Soil Survey). Both soils were created in DRAINMOD using the Soil Creation utility with the assistance of the SPAW model (Washington State University and ARS). The SPAW model uses the soil texture triangle to estimate soil moisture curves and vertical saturated conductivities. DRAINMOD requires the relationship between the soil water content and the pressure head (graphed by SPAW), lateral saturated conductivity (typically ¼ - ½ of the vertical saturated conductivity (DRAINMOD Help Manual)), and the depth of each layer of the soil (for which each is solved within SPAW).

Creation of the weather files required use of the Weather Creation Utility within DRAINMOD. Daily maximum and minimum temperatures are required to receive accurate evapotranspiration values due to DRAINMOD's estimation of ET using the Thorthwaite method. For the most accurate water balance solutions, DRAINMOD uses hourly precipitation, so that ET and rainfall do not occur simultaneously, however, only daily rainfall was available for these simulations. Therefore, the rainfall was distributed for 4 hours in the evening of each day, beginning at 5 pm, approximately when the sun is beginning the set and ET is beginning the decline.

Within the Planting tab of DRAINMOD, the growing season was estimated to run for 151 growing days, starting on April 25. These values were obtained from the USDA's suggested planting/harvesting dates for Illinois. Since crop yield was not observed, the planting date reduction parameters were unchanged with the given file.

While free drainage simulations require no further inputs, DWM simulations take into weir settings within the field. Based upon recommendations by NC State University Extension, weir depths were set to 1 foot below the surface for all non-cropping periods (January to March and October to December), 2 feet during the growing season (May through mid-September), and the stop logs of the structure were completely removed for a 2 week period during planting and harvesting (to accommodate planting delay due to field saturation).

In addition to the full 25 years of simulation, actual site data (precipitation) was converted to DRAINMOD format and run for 2014 (run for comparison purposes).

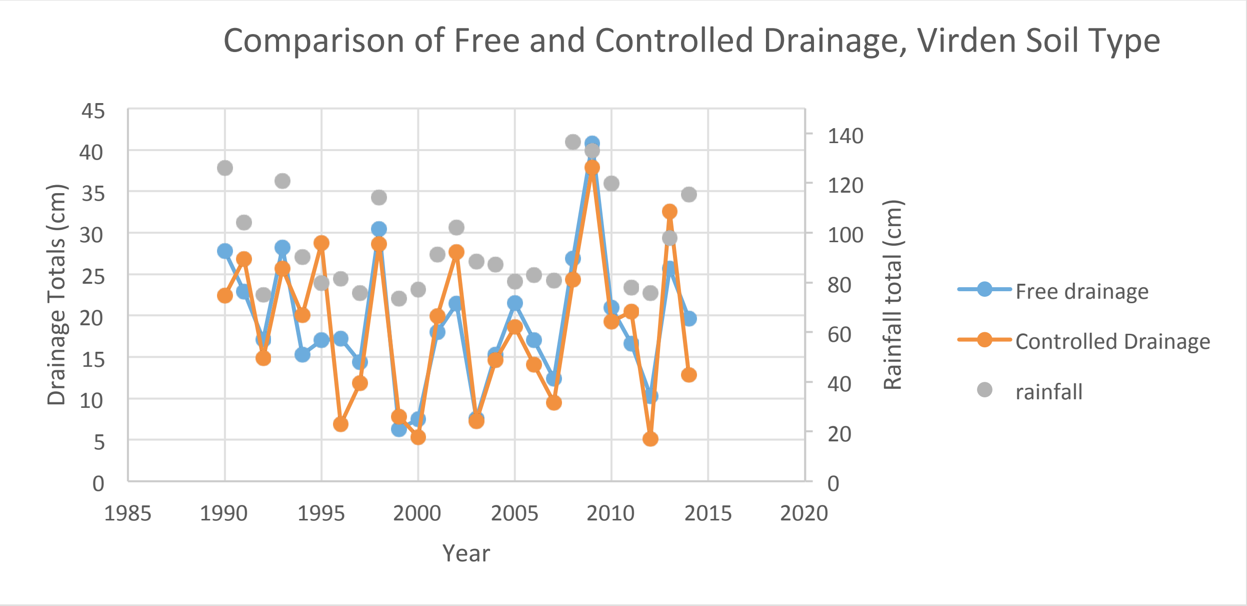
Results and Discussion

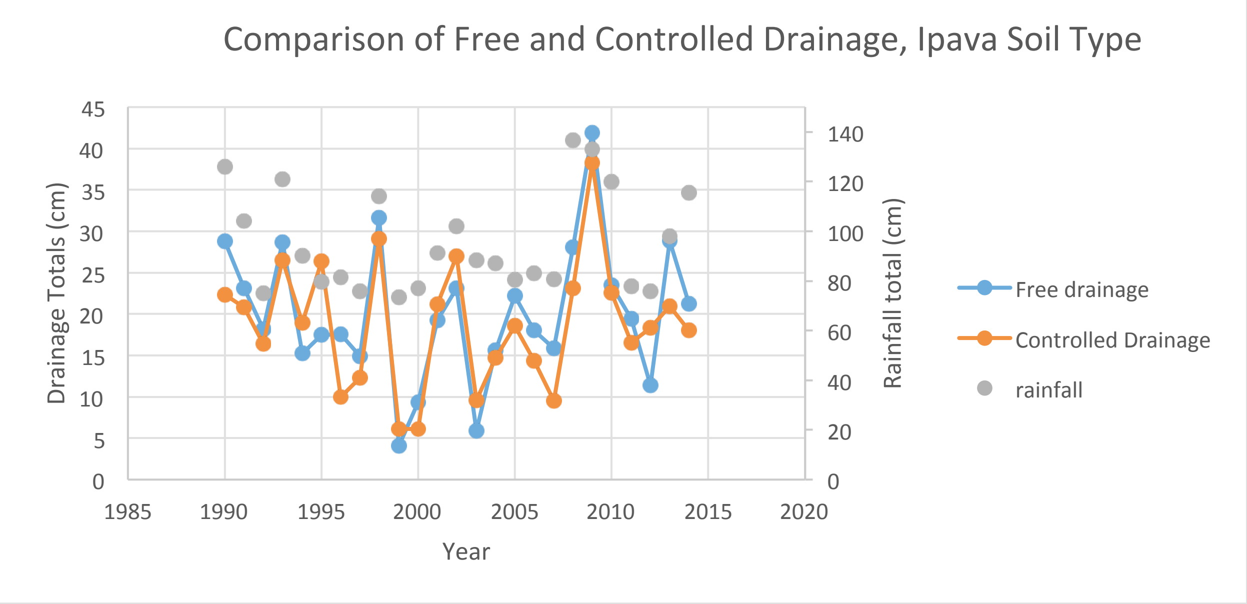
It was observed that the Virden and Ipava-Sable soil types saw reduction in drainage in 68% and 72% of years, respectively. The greatest reduction observed was 60% during 1996 on the Virden soil type. On average, DWM reduced drainage amounts by 3% and 7% in the Virden and Ipava-Sable soil types, respectively.

The onsite 2014 precipitation data gave only half the amount of the precipitation detected at the weather station, however, 25% reduction was observed for Virden and 40% reduction was observed for Ipava-Sable.

Typically, DRAINMOD requires calibration with comparisons of simulated and actual water table depths, as well as onsite flow data. Sensors on the weir appear to be malfunctioning, therefore no comparisons were able to be made. Daily water table outputs of DRAINMOD gave extremely deep values prior to years where DWM drainage surpassed free drainage outflows. It is unclear at this time if the DRAINMOD is accurate in this few cases, however, it seems that on average, DWM is serving its purpose of drainage reduction on this site.

Graphed Results





Modeling and analysis performed by:
Forrest Brooks, EIT
Hydrologic Engineering Technician
Ecosystem Services Exchange

Appendix D – Water Quality Assurance Manual

NLAE
National
Laboratory
for Agriculture
and the Environment

Effective:
01 February 2011

National Laboratory for Agriculture and the
Environment's Analytical Support Laboratory

LOCATION

2110 University Boulevard
Ames, Iowa 50011-3120
(515) 294-6536
(515)-294-8125

Governing:

National Laboratory for Agriculture and the Environment (NLAE) is a trans-disciplinary laboratory focused on integrating the fundamental principles in soil, water, and air into animal, cropping and watershed systems that leads to improved environmental quality, sustainability, and enhanced agricultural system efficiency. The purpose of the NLAE is to develop innovative solutions to enhance the efficiency of agricultural systems and reduce their environmental impact. Our mission is to integrate soil, water, and air processes into animal, cropping, and watershed systems to enhance agriculture and protect the environment. This integrated mission requires a blending of diverse expertise across a number of scientific disciplines in order to generate these solutions.

NLAE consists of two research units: Soil, Water, and Air Processes and Agroecosystems Management. The Analytical Support Laboratory provides routine analysis for these research units.

Soil, Water, and Air Processes

Research projects focus on the basic soil and air components of agricultural and environment systems; Biogeochemical processes affecting soil organic matter, structure, and environmental quality and Management of agricultural and natural resource systems for reduced atmospheric emissions and resilience to climate change.

Agroecosystem Management Research Unit

Projects within this unit are: Enhancing animal production systems to increase natural resource utilization and reduce environmental impact; Cropping systems to enhance sustainability and environmental quality in the Upper Midwest; and Field and watershed management to enhance environmental quality.

The 22 scientists within NLAE encompass a range of disciplines from biogeochemistry, soil physics, mathematics, chemistry, crop physiology, micrometeorology, animal nutrition, animal physiology, microbiology, watershed hydrology, agricultural engineering, agronomy, soil management, soil chemistry, and ecology. This diversity of scientific expertise within a single laboratory provides the foundation for the trans-disciplinary approach that allows this range of projects to be studied and the results to be generated.

Analytical Laboratory

Analytical procedures that are commonly required for the successful completion of the above projects are developed and implemented. Environmental research requires frequent spatial and temporal sampling regimes which result in large sample loads. This laboratory specializes in analyzing thousands of samples on a limited number of methods.

Good Laboratory Practices

Balances

Balances are checked weekly using NIST standard weights and the auto-calibration procedures on the balances. Weights are recorded in Sample Master. Balances falling outside of acceptable limits are taken out of service until repairs can be made.

Pipettes

Automated and manual pipettes are checked weekly using an analytical balance and de-ionized water to verify accuracy. Weights are recorded in Sample Master. Pipettes outside of manufacturer specified ranges are sent in for re-calibration. Pipette calibration and cleaning is performed by a certified laboratory every 12 months or when weekly checks indicate the need for calibration.

Oven

Drying ovens are checked weekly for temperature accuracy. Ovens falling outside of specified ranges are removed from operation until repairs are made. Cleaning ovens are monitored through the successful completion of the self-cleaning cycle. Ovens will error code if temperature set-points are not met. The broiler filament is on until 400^{O} C is obtained, then the bake and broil filaments alternate for additional heating up to $480\,^{O}$ C. Temperatures exceeding $500\,^{O}$ C will result in an oven failure.

Freezers and Refrigerators

Temperatures are verified weekly and documented in Sample Master using certified thermometers. Large refrigerator units have a gauge on the outside that are routinely checked when samples are removed. Temperatures outside acceptable ranges are reported and the unit is removed from use until repairs are made.

Key Instrumentation

Each analyst is responsible for specific instrumentation. They maintain a log of routine and non-routine maintenance. Repairs requiring outside service must be performed by certified, manufacturer trained service engineers.

Flow Injection Analysis

A. Water nitrate-nitrogen

Nitrate/nitrite is determined colorimetrically by flow injection analysis which forms a water soluble dye. The color intensity is directly proportional to the concentration of nitrate/nitrite present in the sample. Lachat QuikChem method 10-107-04-1-D is utilized. The instrument is calibrated prior to each analytical sequence. Seven calibration standards are used to generate the second order; 1/x weighing; calibration curve. Calibration is accepted with an $r^2 \geq 0.999$. Standards are made from a certified NIST traceable stock.

1. Instrument Configuration of Lachat 8500
   Manifold: 10-107-04-1-D
   Filter: 520 nm
   Flow cell: 10 mm path length
   Sample loop: micro-loop
   Proportioning pump
   Auto-dilutor

2 Reagents
   15 M sodium hydroxide
   Ammonium chloride buffer, pH 8.5
   Sulfanilamide color reagent
   1000 ppm NO_3-N certified stock standard solution

3. Calibration Standards
   50, 20, 15, 10, 5, 1, 0.5, 0.3, 0

4. Reporting Limit: 0.3 mg N/L

A check sample (CS) is ran immediately after calibration and every 15 samples throughout the run and must be within ± 5% of the known value for the sequence to continue.

Laboratory spikes (LS) are ran at different concentrations and must agree within ± 5% of the known value for the run to continue.

Quality control samples include a matrix spike (MS), duplicate (DS), laboratory blank (LB) and proficiency testing sample (PT). A MS and DS are analyzed at a 3.5% frequency. Acceptable MS data has a recovery between 90-110% and duplicates are accepted if the relative percent difference is within ± 10%. The LB is accepted if the area counts are ≤ ½ the area of the lowest standard. PT sample must fall within vender specified acceptance range.

Samples are preserved to pH 2 with 15% sulfuric acid upon submission to the lab or prior to storage if extended storage is expected prior to submission. Samples are kept at 4^o C.

B. Water Total Phosphorus as P

Acid persulfate digestion of a water sample converts the polyphosphates and organic phosphorus into orthophosphate ions. Orthophosphate is determined colorimetrically by flow injection analysis which forms a water soluble dye. The color intensity is directly proportional to the concentration of orthophosphate present in the sample. Lachat QuikChem method 10-115-01-1-F is utilized with the following modifications: sample loop is 75.5 cm, increasing the calibration range to 0.02-2.0 mg P/L; the ascorbic acid solution uses 1.75 g/L dodecyl sulfate; carrier is digested along with the samples and contains concentrations of persulfate and acid equivalent to those of the digested sample.

1. Instrument Configuration of Lachat 8000

Manifold:	10-115-01-1-F
Filter:	880 nm
Flow cell:	10 mm path length
Sample loop:	75.5 cm
Heater:	37° C
Heater coil:	175 cm

Proportioning pump
Auto-dilutor

2 Reagents
Molybdate Color Reagent
Ascorbic Acid Reducing Solution, 0.33 M
Carrier: sulfuric acid and persulfate equivalent to sample concentrations
1000 mg P/L certified stock standard solution

3. Calibration Standards
2.0, 1.0, 0.5, 0.25, 0.10, 0.03, 0.02, 0.01, 0 mg P/L

4. Reporting Limit: 0.02 mg P/L

Samples are digested according to EPA method 365.1 using a reduced volume variation with autoclave digestion. Samples are not adjusted for volume or pH and ran after cooled.

The instrument is calibrated prior to each analytical sequence. Ten digested calibration standards are used to generate the third order calibration curve. Calibration is accepted with an $r^2 \geq 0.999$. Standards are made from a certified NIST traceable stock standard solution.

A check sample (CS) is ran immediately after calibration and every 15 samples throughout the run and agree within ± 5% of the known value for the sequence to continue.

Laboratory spikes (LS) are ran at different concentrations and must agree within ± 5% of the known value for the run to continue. LS include digested samples and undigested samples that are both organic and inorganic forms of P. Undigested LS samples require a correction of 6% to account for the dilution of the digested samples and calibration standards.

Quality control samples include a matrix spike (MS), duplicate (DS), laboratory blank (LB) and proficiency testing sample (PT). One MS and DS are included for every 48 samples. Acceptable

MS data has a recovery between 90-110% and duplicates are accepted if the relative percent difference is within ± 10%. The LB is accepted if the area counts are ≤ ½ the area of the lowest standard. PT sample must fall within vender specified acceptance range.

Samples are kept at 4^o C.

C. Water orthophosphate as P

Orthophosphate is determined colorimetrically by flow injection analysis which forms a water soluble dye. The color intensity is directly proportional to the concentration of orthophosphate present in the sample. Lachat QuikChem method 10-115-01-1-A is utilized. The instrument is calibrated prior to each analytical sequence. Eight calibration standards are used to generate the first order calibration curve. Calibration is accepted with an $r^2 \geq 0.999$. Standards are made from a certified NIST traceable stock standard solution.

1. Instrument Configuration of Lachat 8000

Manifold:	10-115-01-1-A
Filter:	880 nm
Flow cell:	10 mm path length
Sample loop:	75.5 cm
Heater:	37^o C
Heater coil:	175 cm

Proportioning pump
Auto-dilutor

2 Reagents
Molybdate Color Reagent
Ascorbic Acid Reducing Solution, 0.33 M
Carrier: Milli-Q water
1000 mg P/L certified stock standard solution

3. Calibration Standards
2, 1, 0.5, 0.25, 0.10, 0.05, 0.01, 0 mg P/L

4. Reporting Limit: 0.01 mg P/L

A check sample (CS) is ran immediately after calibration and every 15 samples throughout the run and must be within ± 5% of the known value for the sequence to continue.

Laboratory spikes (LS) are ran at different concentrations and must agree within ± 5% of the known value for the run to continue.

Quality control samples include a matrix spike (MS), duplicate sample (DS) and laboratory blank (LB). One MS and DS are included for each case. Acceptable MS data has a recovery between 90-110% and duplicates are accepted if the relative percent difference is within ± 10%. The LB is accepted if the area counts are ≤ ½ the area of the lowest standard.

Samples are filtered in the field with 0.45 um filters and stored at 4° C for no more than 48 hours prior to analysis.

D. Water Ammonia-nitrogen

Ammonia is determined colorimetrically by flow injection analysis which forms a water soluble dye. The color intensity is directly proportional to the concentration of ammonia present in the sample. Lachat QuikChem method 10-107-06-2-A is utilized. The instrument is calibrated prior to each analytical sequence. Five calibration standards are used to generate the first order calibration curve. Calibration is accepted with an $r^2 \geq 0.999$. Standards are made from a certified NIST traceable stock standard solution.

1. Instrument Configuration of Lachat 8000
   Manifold: 10-107-06-2-A
   Filter: 660 nm
   Flow cell: 10 mm path length
   Sample loop: 20 cm
   Heater: 60° C
   Heater coil: 650 cm
   Proportioning pump
   Auto-dilutor

2 Reagents
   Buffer
   Salicylate – Nitroprusside Color Reagent
   Hypochlorite
   1000 mg N/L as NH_3 certified stock standard solution

3. Calibration Standards
   5, 3, 1, 0.3, 0 mg N/L

4. Reporting Limit: 0.3 mg N/L

A check sample (CS) is ran immediately after calibration and every 15 samples throughout the run and must be within ± 5% of the known value for the sequence to continue.

Laboratory spikes (LS) are ran at different concentrations and must agree within ± 5% of the known value for the run to continue.

Quality control samples include a matrix spike (MS), duplicate sample (DS) and laboratory blank (LB). One MS and DS are included for each case. Acceptable MS data has a recovery between 90-110% and duplicates are accepted if the relative percent difference is within ± 10%. The LB is accepted if the area counts are ≤ ½ the area of the lowest standard.

Samples are preserved to pH 2 with 15% sulfuric acid upon submission to the lab or prior to storage if extended storage is expected prior to submission. Samples are kept at 4° C.

E. Soil Nitrate-nitrogen

Nitrate is extracted from field moist soil using a 2M potassium chloride solution. Nitrate is determined colorimetrically by flow injection analysis which forms a water soluble dye. The color intensity is directly proportional to the concentration of nitrate present in the sample. Lachat QuikChem method 12-107-04-1-B is utilized. The instrument is calibrated prior to each analytical sequence. Eight calibration standards are used to generate the second order calibration curve. Calibration is accepted with an $r^2 \geq 0.999$. Standards are made from a certified NIST traceable stock standard solution.

1. Instrument Configuration of Lachat 8500 series 2
   Manifold: 12-107-04-1-B
   Filter: 520 nm
   Flow cell: 10 mm path length
   Sample loop: micro-loop
   Proportioning pump
   Auto-dilutor

2 Reagents
   15 M sodium hydroxide
   Ammonium chloride buffer, pH 8.5
   Sulfanilamide color reagent
   2 M potassium chloride
   1000 ppm NO_3-N certified stock standard solution

3. Calibration Standards
   15, 10, 5, 1, 0.5, 0.2, 0.1, 0 mg N/L

4. Reporting Limit: 0.5 mg N/Kg dried soil

Soils are extracted using a 1:5 ratio of field moist soil to 2 M KCl, shaken for 1 hour and filtered through glass fiber filter paper. Final results are reported on a dry weight basis.

A check sample (CS) is ran immediately after calibration and every 15 samples throughout the run and must be within ± 5% of the known value for the sequence to continue.

Laboratory spikes (LS) are ran at different concentrations and must agree within ± 5% of the known value for the run to continue.

Quality control samples include duplicate samples (DS), laboratory blanks (LB), laboratory controls (LC), and quarterly PT samples. One DS is included for every 100 samples. One LC and LB are processed for every 36 samples. Acceptable LC data has a recovery within ± 3 SD of the average analyte concentration. The LB is accepted if the area counts are ≤ ½ the area of the lowest standard. PT results must fall within vender specified acceptance criteria.

Soils and extracts are preserved by freezing.

F. Soil Ammonia-nitrogen

Ammonia is extracted from field moist soil with a 2M potassium chloride solution. Ammonia is determined colorimetrically by flow injection analysis which forms a water soluble dye. The color intensity is directly proportional to the concentration of ammonia present in the sample. Lachat QuikChem method 12-107-06-2-A is utilized. The instrument is calibrated prior to each analytical sequence. Eight calibration standards are used to generate the second order calibration curve. Calibration is accepted with an $r^2 \geq 0.999$. Standards are made from a certified NIST traceable stock solution.

1. Instrument Configuration of Lachat 8000
   Manifold: 12-107-06-2-A
   Filter: 660 nm
   Flow cell: 10 mm path length
   Sample loop: 70 cm
   Heater: 60° C
   Heater coil: 650 cm
   Proportioning pump
   Auto-dilutor

2 Reagents
   Buffer
   Salicylate – Nitroprusside Color Reagent
   Hypochlorite
   1000 mg N/L as NH_3 certified stock standard solution

3. Calibration Standards
   5, 3, 1, 0.3, 0 mg N/L

4. Reporting Limit: 0.5 mg N/Kg dried soil

Soils are extracted using a 1:5 ratio of field moist soil to 2M KCl, shaken for 1 hour and filtered with glass fiber filter paper. Final results are reported on a dry weight basis.

A check sample (CS) is ran immediately after calibration and every 15 samples throughout the run and must be within ± 5% of the known value for the sequence to continue.

Laboratory spikes (LS) are ran at different concentrations and must agree within ± 5% of the known value for the run to continue.

Quality control samples include duplicate samples (DS), laboratory blanks (LB), laboratory controls (LC) and PT samples. One DS is included for every 100 samples. One LC and LB is processed for every 36 samples. Acceptable LC data has a recovery within ± 3 SD of the average analyte concentration. The LB is accepted if the area counts are ≤ ½ the area of the lowest standard. PT results must fall within vender specified acceptance criteria.

Soils and extracts are preserved by freezing.

Sample Handling

The objectives are to describe the protocols, sampling procedures, and equipment used to ensure that the data collected from the sites are of the highest accuracy and precision. These procedures are used to determine the impacts of farming systems on surface and ground water quality. The plan describes the recommended procedures of sample collection and sample processing. The sampling procedures are recommendations for consistent and accurate sampling of the projects. The field manager is responsible for ensuring that standard operating procedures are followed for sample collection.

Sample Collection Devices-Water

A. Well Type and Installation

The wells and piezometers used will be a 5.0 cm i.d., schedule 40 Tri-loc PVC pipe with a 0.5 mm width slot in the well screen. Each well will be plugged with a sealed plug and each section sealed with an O-ring and threaded. After installation of the wells and piezometers, caps and locking covers will be added.

The piezometers are relatively shallow (less than 5 m) and will be used to characterize the depth of the water table in the saturated zone. They will be installed with a hydraulic coring rig without any seal around the well screens. A deflection plate will be installed just below the surface to prevent any direct movement of surface water along the edges of the pipe.

The wells will range in depth from 6-10 m and will be installed with a drilling rig provided by USGS in accordance with their procedures for well installation. These wells will be located throughout the watershed and surrounding the plots to provide a measure of nutrients and farm chemicals at various levels within the unsaturated zone.

B. Surface Runoff and Flow Monitoring

Surface runoff will be measured with H-flumes instrumented with OTT CBS stage (level) recorders and Campbell Scientific CR1000 dataloggers. The data- logger controls pacing of sample collection by the ISCO 6700/6712 automatic water samplers (350 mL glass bottles, 24 bottles/rack). The datalogger provides detailed record of sample times and corresponding flow and stage values.

C. Tile Flow Monitoring

Tile stage, velocity, and flow will be measured with Marsh-McBirnery Flo-Stations and Flo-Tote 3 sensors installed in each individual tile. Campbell Scientific CR1000 dataloggers will record tile flow parameters and control sampling by ISCO 3700/6700/6712 samplers configured for 350 mL glass bottles and 24 position racks.

D. Precipitation Samplers

Aerochem Metrics samplers with two 3 gallon plastic buckets can be used for alternate collection of precipitation or atmospheric dust. Precipitation samples are currently collected from these devices. Samples are collected after rainfall events.

Sample Collection Procedures-Water

Containers for sample collection are cleaned in a Miele Labwasher equipped with individual washing jet racks. Each cycle is programmed as follows: two pre-rinses, an 85^{o} C wash, rinse with citric acid neutralization, two di-water rinses, and a final 70^{o} C di-water rinse. Glassware for the collection of herbicides is pre-combusted at $350\ ^{o}$ C. Labware for the collection of ortho-phosphorus or ammonium is acid rinsed in 10% hydrochloric acid:milli-Q water bath, followed by a triple milli-Q water rinse.

A. Wells

Several days prior to sampling, wells are pumped out with a peristaltic pump allowing the well to recharge (Neal Smith watershed). At sampling, well water depths are measured with a Keck electronic well tape. Sample is pulled using a peristaltic pump that has been rinsed with de-ionized water. The sample is filtered through a 0.45 um filter and collected in an acid rinsed 125 mL Nalgene bottle and placed on ice for transport.

Wells within fine-grained sediment (South Fork watershed) have an abbreviated purging scheme due to slow recharge rates. At sampling, well depth is measured with a Keck electronic well tape. A de-ionized water rinsed peristaltic pump is used to pump out one gallon of well water before the sample is collected. The sample is filtered through a 0.45 um filter and collected in an acid rinsed 125 mL Nalgene bottle and placed on ice for transport.

B. Tile

Tile samples will be collected in 350 mL glass bottles based on stage changes using ISCO 3700/6700/6712 water samplers with a 24 bottles/rack configuration. Samples will be placed in insulated coolers for transport back to the lab.

C. Surface

Surface runoff sampling will be flow-based, with samples collected in 350 mL glass bottles using ISCO 3700/6700/6712 water samplers with a 24 bottles/rack configuration. Samples will be placed in insulated coolers for transport back to the lab.

A. Stream water

Stream water samples will be collected in 350 mL glass bottles (1000 mL plastic bottles are used at Neal Smith watershed) using ISCO 3700/6700/6712 water samplers with 24 bottles/rack. Sampling is based on either precipitation driven stream stage changes or flow. Samples will be placed in insulated coolers for transport back to the lab.

Sample Collection Procedures-Soil

A number of liners for zero-contamination field penetration devices for both hand and machine soil coring tubes are available with caps of different colors to differentiate depth. The liners are made of cellulose acetate polymers and range from 2.5-5.0 cm. in diameter, and from 20-200 cm. in length. Using waterproof, permanent markers, these liners are marked with the plot sample code immediately after removal from the soil coring tube.

A. Coring

In sample collection, the tube is inserted to its full length at once to avoid contamination from soil falling into the hole. This poses some difficulties with the longer tubes in hard soils; and, in that case, a shorter tube length is used with care taken to avoid contamination. Each field and farming system presents different problems, and precautions will be taken to obtain a sample which is not compressed by excess force.

B. Transport

After removing the core, the extra volume in the upper end of the tube will be packed with sterile cotton. This will keep the surface of the soil sample undisturbed. The marked and capped tube will be immediately placed horizontally into a container of dry ice or ice depending on site protocol for transport back to the laboratory.

C. Cleaning

A wire brush is used to remove any soil near the cutting edge of the soil probe. The tip of the probe is washed with methanol after each sample to remove any soil residue. If a hydraulic coring machine is used, a power wire brush is used to clean the soil tubes.

Sample Processing-Soil

A. Sectioning

Samples for nitrate and ammonia are sectioned in a pesticide-free environment into depth increments and subsampled, if necessary, before they are submitted to the analytical lab. The sample size ranges from 100-150 g.

B. Containers

Each processed sample is wrapped in aluminum foil and stored in an airtight moisture-proof container. Each container will record a complete sample description.

Sample Preservation

Sample preservation for water occurs at the time samples are submitted to the analytical laboratory with the exception of orthophosphate which is preserved in the field by filtration at the time of collection. The following tables contain the preservation method as well as sample size, container, and hold times.

Standard Operating Procedures

Standard operating procedures (SOP) are used at the NSTL's analytical lab to describe processes ranging from basic laboratory practices to detailed instrumental procedures. Procedures used by the analytical lab are based on peer reviewed methods, standard methods, or EPA methods. SOP's are divided into housekeeping, general and procedure/instrument specific categories. The following table details the SOPs used at the NSTL.

NSTL SOP	Last Revision	Title
House Keeping #1	2001	Deionized Water Preparation
House Keeping #2	10/2007	Automatic Dishwasing
House Keeping #3	2001	Glassware Purification
House Keeping #4	5/2008	Acid Rinsing of Labware
House Keeping #5	2001	Acetone Rinsing of Labware
House Keeping #6	2001	Loading and Operation of Ovens
General #1	2001	Receipt of Samples
General #2	2001	Log-in Procedure

NSTL SOP	Last Revision	Title
General #3	1/2008	Starting WinWedge Software and Scale Communication
General #4	2006	Calibrating the Pinnacle pH meter
General #5	2001	Data Entry
General #6	5/2008	Raw Data Storage
Manual Extraction #1	2001	Soil Nitrate-Nitrogen Extraction
Manual Extraction #2	2001	Soil Ammonia-Nitrogen Extraction
Manual Extraction #3	2001	Basal Stalk Nitrate-Nitrogen Extraction
Manual Extraction #4	8/2007	Soil pH Measurement
Manual Extraction #5	1/2008	Total Phosphorous Digestion Procedure
Manual Extraction #6	2007	Inorganic Carbon by Pressure Calcimeter
Manual Extraction #7	2001	Preparation of Water Samples
Manual Extraction #8	2001	Water Autotrace Extraction Procedure
Manual Extraction #9	2001	Manual Water Extraction Procedure for DIA and DE
Manual Extraction #10	2001	Manual Water Extraction Procedure
Elemental Analysis #1	2002	SOP for Total Nitrogen and Carbon
Elemental Analysis #2	2002	SOP for ^{15}N Micro Diffusion
Elemental Analysis #3	2002	SOP for Isotopic Carbon $^{13}C/^{12}C$
Elemental Analysis #4	2002	SOP for Isotopic Nitrogen $^{15}N/^{14}N$
Water Herbicides #1	2006	Analysis of Herbicides by GC-MS (Agilent)
Water Herbicides #2	2006	Analysis of Herbicides by GC-MS (Shimadzu)
FIA #1	2000	Lachat Startup and Operation
FIA #2	2000	Determination of Orthophosphate in Waters by Flow Injection Analysis Colorimetry
FIA #2a	4/2008	Matrix Spike Ortho P (DRP)

NSTL SOP	Last Revision	Title
FIA #3	11/2001	Determination of Total Phosphorus by Flow Injection Analysis Colorimetry (Acid Persulfate digestion Method)
FIA #3a	2007	Analysis of Total Phosphorus
FIA #4	8/1992	Ammonia in Surface Water, Wastewater
FIA #4a	2006	Water Ammonia Matrix Spike
FIA #5	8/2003	Determination of Nitrate/Nitrite by Flow Injection Analysis
FIA #5a	2006	Water Nitrate Matrix Spike
FIA #6	8/1986	Ammonia (Salicylate) in 2 M KCl Soil Extracts
FIA #7	11/1992	Nitrate in 2M KCl Soil Extracts
FIA #8	1/2008	Matrix Spikes Soil Nitrate and Ammonia
FIA #9	4/2008	SOP for the Acceptance of Water and Soil Lachat Data
FIA #10	5/2007	Soil Nitrate and Ammonium Waste Neutralization
FIA #11	5/2008	Waste Neutralization Procedure for Water
ICP #1	2007	Quality Control procedures for the ICP-AES
ICP #2	1/1998	Mehlich 3 Test for Phosphorus
ICP #3	1/1998	Micronutrients: Zinc, Iron, Manganese and Copper

Method Reference

Assay	Matrix	Reference
Nitrate-nitrogen	Water	Lachat Instruments (10-107-04-1-D) U.S. EPA method 353.2
Total phosphorus	Water	Lachat Instruments (15-115-01-1-F) U.S. EPA methods 365.1 & 365.3
Ammonia-nitrogen	Water	Lachat Instruments

		(10-107-06-2A) U.S. EPA method 351.2
Orthophosphate	Water	Lachat Instruments (10-115-01-1-A) U.S. EPA 365.1
Herbicides	Water	Thurman, E.M.; Meyer, M.; Pomes, M.; Perry, C.A.; Schwab, A.P. Anal. Chem. 1990, 62, 2043-2048
^{15}N Isotopes	Water	Soil Sci. Soc. Am. J. 62:406-412 (1998)
Nitrate-nitrogen	Soil	Lachat Instruments (12-107-04-1-B) U.S. EPA 353.2 Soil Sci. Soc. Am. Proc. 30:577-582
Nitrate-ammonia	Soil	Lachat Instruments (12-107-06-2-A) U.S. EPA 351.2 Soil Sci. Soc. Am. Proc. 30:577-582

Appendix E – Saturated Buffer Water Sampling Protocol

Water samples should be collected twice each month, when there is water in the structure and wells. The samples will need to be filtered within a few hours after collection. They need to be chilled immediately and then shipped over-night to the lab using an insulated shipping container. These samples will be analyzed for both Nitrate-N and Total Dissolved Phosphorus.

Sampling Equipment

The following items will be needed to collect the water samples:

- Sampling syringe
- Transfer jars
- Cooler with freezer packs
- Rubber bands
- Record sheet
- Pen/pencil

Filtration Equipment

The following items will be needed to filter the water samples:

- Funnel racks
- Funnel set
- Filter paper
- Sterile gloves
- Filter jars
- Syringe set
- Filter cartridges
- Sample jars
- Rinse bottle with distilled water

Step 1: Sample Collection

The following procedure should be followed when collecting the water samples:

1-A: Remove cap from sampling well (or lid from the control structure)

1-B: Screw the syringe onto the sampling tube

1-C: Slowly pull the plunger all the way up and draw water into the syringe

   a. Because some sediment may settle to the bottom of the well, pull up on the tube a few inches before you draw up the water into the syringe. This will help keep sediment out of the water make it easier to filter

1-D: Disconnect the syringe from the sampling tube

1-E: Place finger over the tip of the syringe and shake, rinsing the inside of the syringe with the water

1-F: Point the tip of the syringe downward and squirt all the water out

1-G: Reconnect the syringe to the sampling tube
1-H: Slowly pull the plunger all the way up and draw water into the syringe
1-I: Disconnect syringe from sampling tube
1-J: Point the tip of the syringe downward and empty into the corresponding transfer jar
1-K: Repeat steps 1-H through 1-J until there is approx. 50mL of water in the transfer jar
1-L: Place transfer jar in the cooler with ice packs for transport back to the office/lab/home
1-M: Repeat this procedure for each of the wells and the control structure.

Collecting from the ditch:

The sample should be collected upstream from the outlet.

1-N: Fasten the transfer jar to the end of the pole using rubber bands

1-O: Fill and empty the jar a few times to rinse
1-P: Take final sample, replace lid and place in cooler with freezer packs

Step 2: Sample Filtration

There are two parts in the filtration process. The first is used to remove any noticeable sediment from the sample. The water is then pushed through a second filter with very small pores. Always go through both parts of the filtration process, even if the sample looks pretty clear to start with. It is very important that the water samples are filtered within a few hours after they are collected.

2-A: Set up funnel racks

2-B: Wearing gloves, fold the filter paper

a. Fold in half, then half again
b. It is best to hold the paper in the air when folding as the countertop is a potential source of contamination
c. Only use the filter paper that has been supplied by the ADMC

2-C: Place the filter paper in the funnel

   a. Set the paper so that water will not be able to bypass the filter paper

2-D: Place a filter jar under the corresponding funnel

2-E: Empty contents of transfer jar into corresponding funnel

   a. Keep the water level below the top of the filter to prevent water bypassing the filter

2-F: Filtering will take approx. 30 to 45 minutes

2-G: Using the corresponding syringe, pull the water out of the filter jar

2-H: Connect the filter cartridge to the syringe

2-I: Push the water through the filter and into the final sample jar
  a. Only 50mL of water need to be filtered into the sample jar

2-J: Repeat this process for each sample
  a. Use a different filter cartridge for each sample

2-K: After samples have been filtered, replace lids on the sample jars

2-L: Keep in mind that the samples may be frozen at the lab, so do not overfill

2-M: Samples will need to be refrigerated until they are shipped

2-N: Rinse all transfer jars, funnels, syringes, and filter jars with distilled water

2-O: Allow all jars, funnels, and syringes to fully dry before putting away

- a. Air dry only!

Step 3: Shipping

3-A: Place all sample jars in the provided insulated shipping container with the freezer pack

- a. The freezer pack should have been frozen previously

3-B: Include the record sheet when shipping

3-C: The sample should be shipped overnight to the following address:

National Laboratory for Agriculture and the Environment
Attn: Kent Heikens
USDA-ARS
2110 University blvd
Ames, IA 50011-3120

Appendix F – Soil Sampling Results

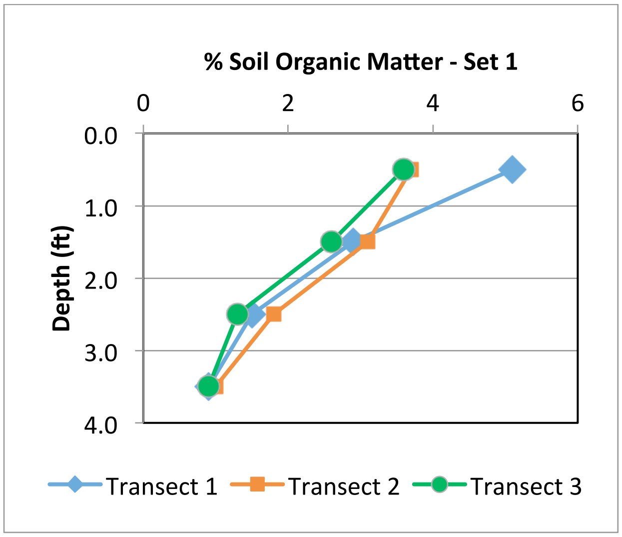
Soil sample collection dates

The following table lists the dates that the soil samples were collected. The samples were analyzed at the University of Wisconsin Soil and Plant Testing Lab (Verona, WI). The Set 1 samples were delivered to the lab in two separate batches. Batch 1, which consisted of samples for IL-4 only, was submitted on 6/25/2014. Batch 2, which comprised all other samples, was submitted on 7/9/2014. The samples for Set 2 were all submitted to the lab on 10/10/2015. The soil data shown in this section were collected by ESE staff. Data for the IA-1 site were collected by USDA-ARS staff and are not included in this section.

Sample collection dates

Site ID	Set 1	Set 2
IA-2	9/6/2013	6/4/2015
IA-3	6/26/2014	10/1/2015
IL-1	5/2/2014	9/30/2015
IL-2	5/2/2014	9/30/2015
IL-3	5/2/2014	7/24/2015
IL-4	6/21/2014	9/30/2015
IL-5	6/28/2014	10/1/2015
IN-1	5/1/2014	7/22/2015
IN-2	5/1/2014	7/22/2015
IN-3	5/2/2014	7/23/2015
MN-1	5/29/2014	6/5/2015
MN-2	5/28/2014	6/4/2015
MN-3	5/28/2014	6/4/2015
MN-4	7/2/2014	6/4/2015

IA – 2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6
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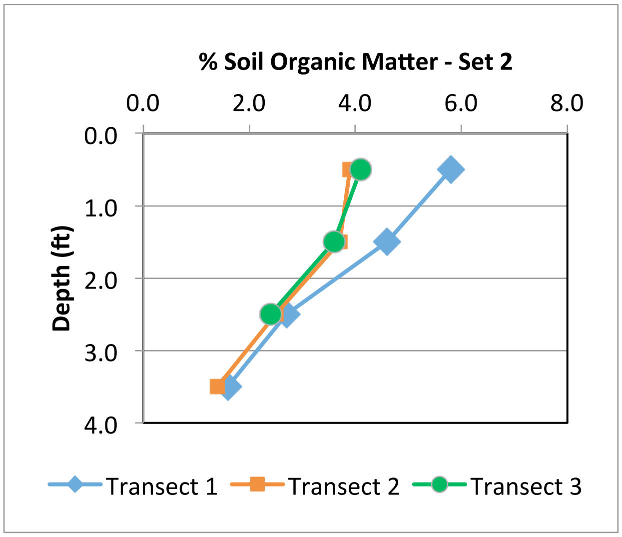
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3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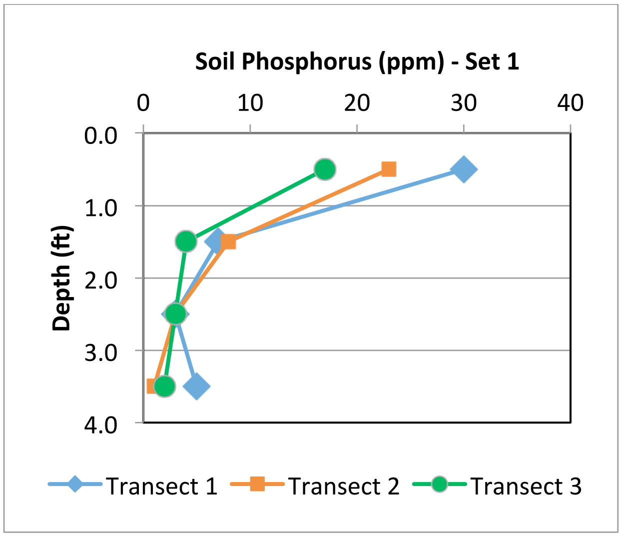
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3


Soil Phosphorus (ppm) - Set 1
0
10
20
30
40
0.0
1.0
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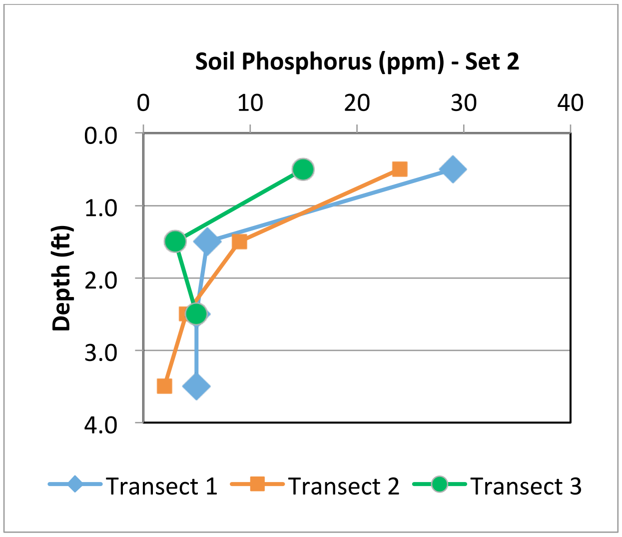
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3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30
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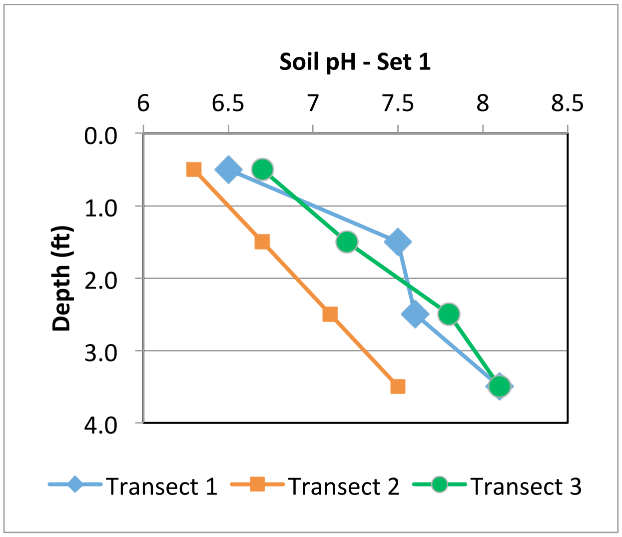
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3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7
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4.0
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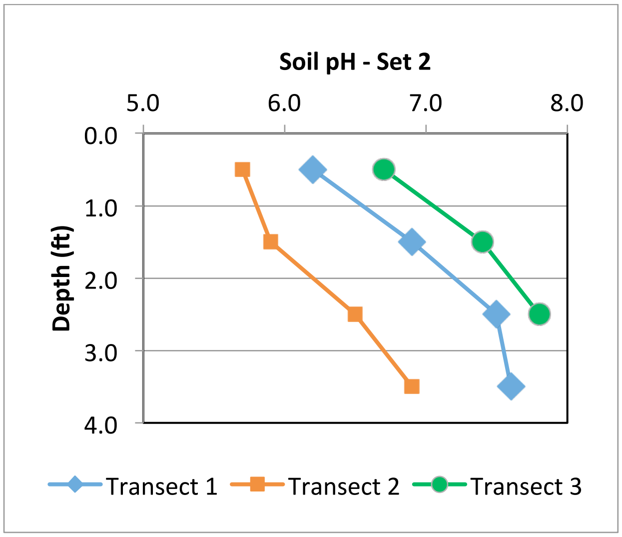
Transect 2
Transect 3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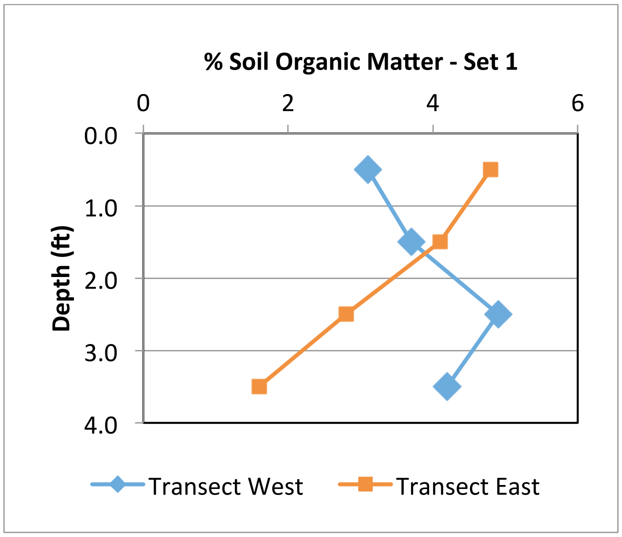
Transect 2
Transect 3

IA – 3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Depth (ft)
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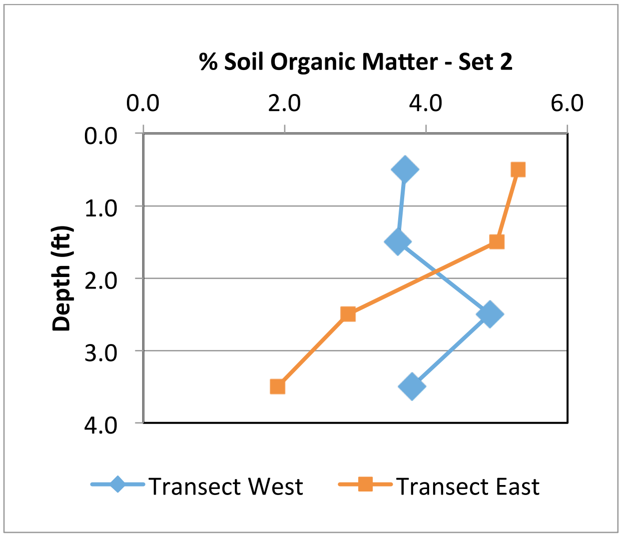
Transect East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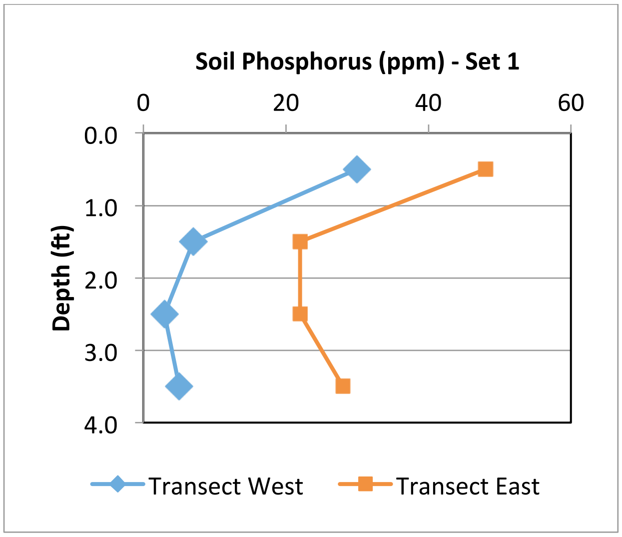
Transect West
Transect East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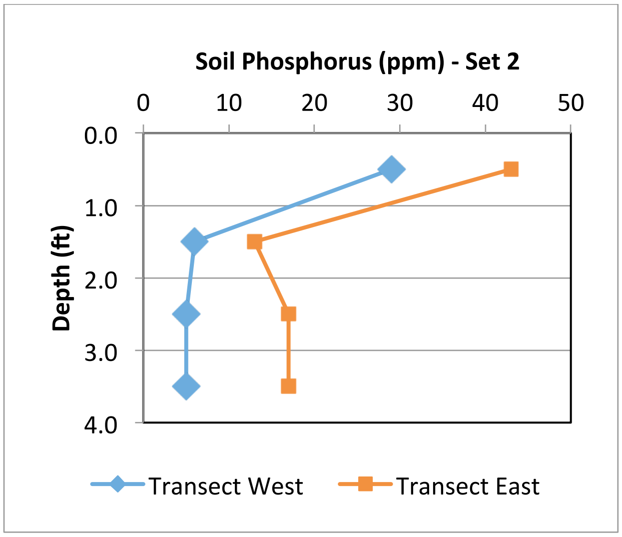
3.0
4.0
Depth (ft)
Transect West
Transect East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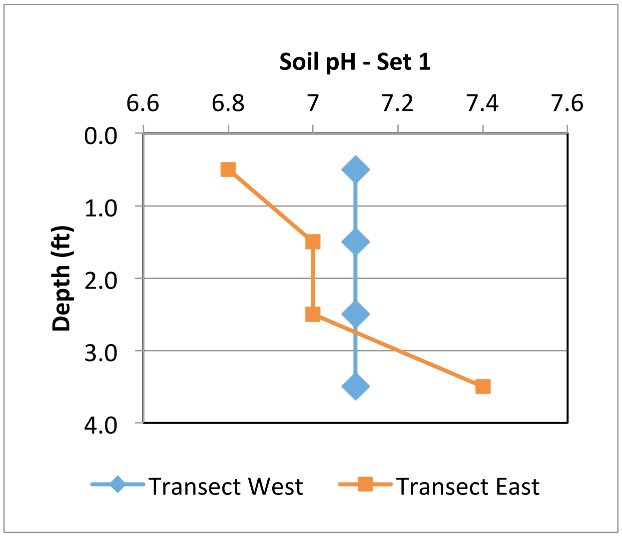
Depth (ft)
Transect West
Transect East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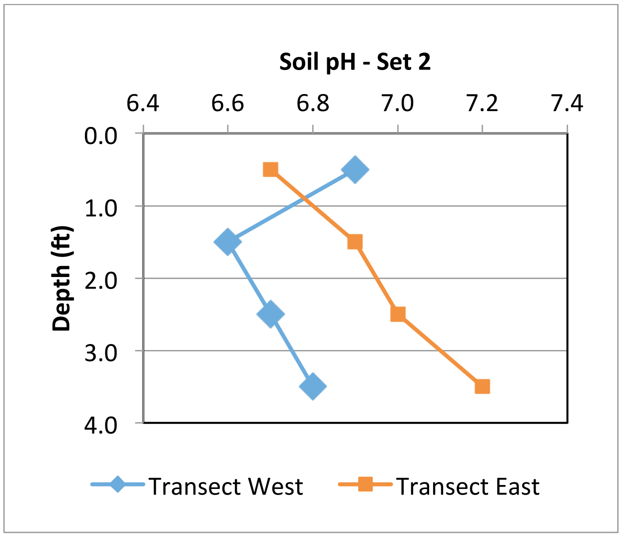
Depth (ft)
Transect West
Transect East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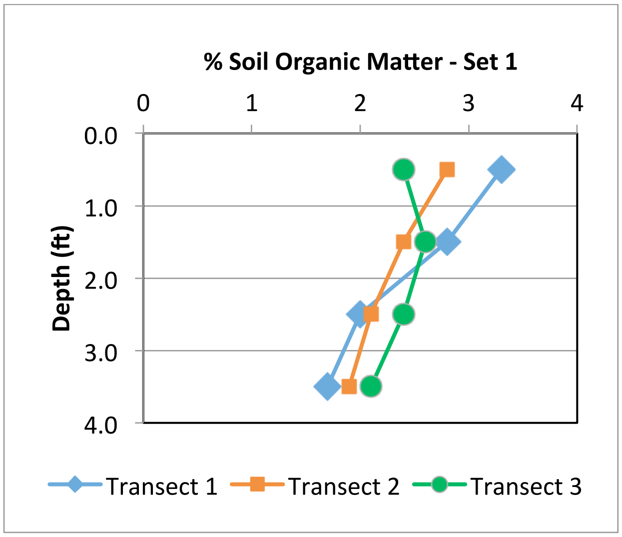
Depth (ft)
Transect West
Transect East

IL – 1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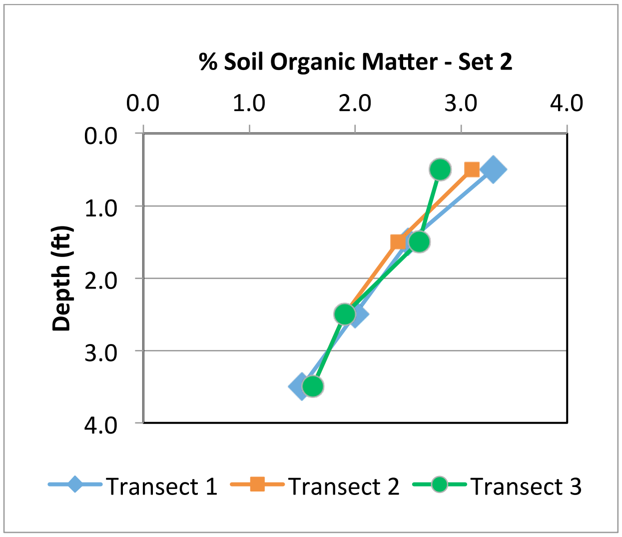
Depth (ft)
Transect 1
Transect 2
Transect 3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Depth (ft)
Transect 1
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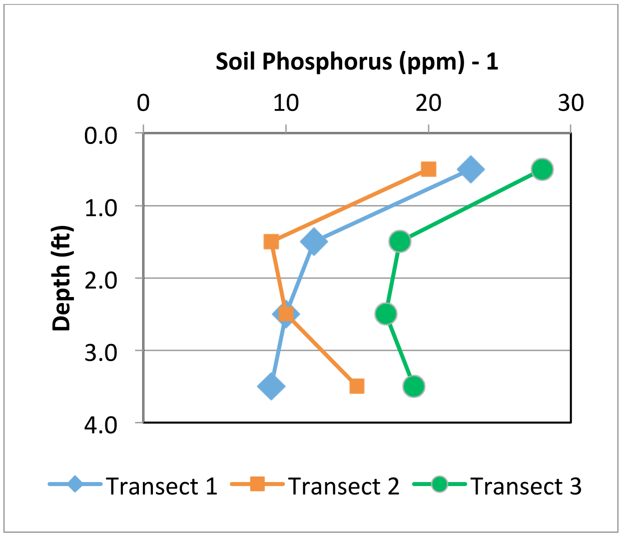
Transect 3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Depth (ft)
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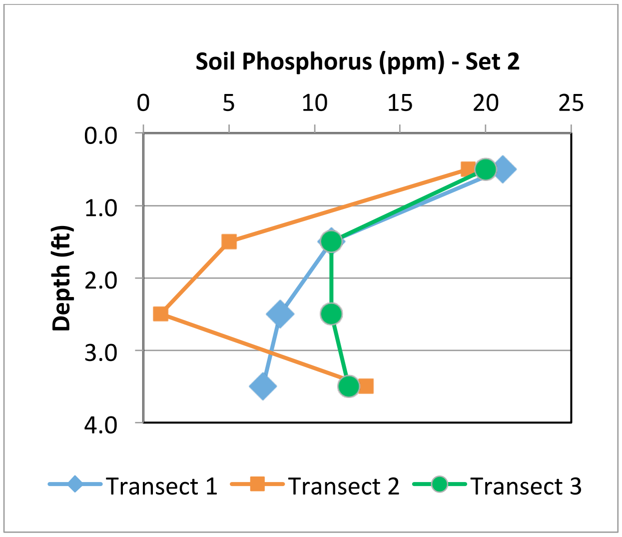
Transect 3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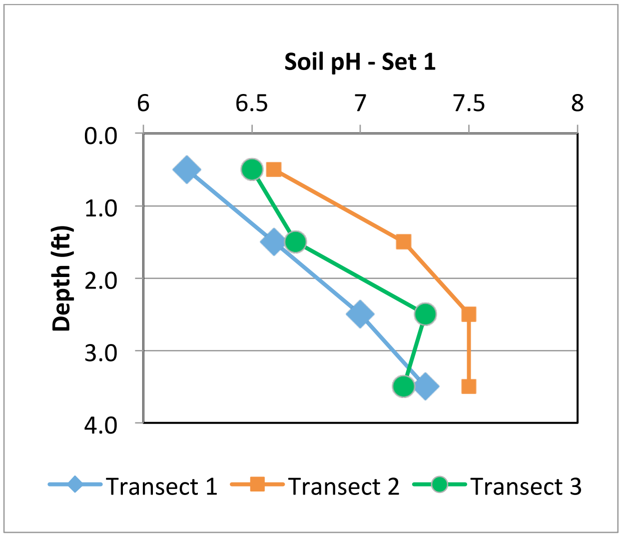
Transect 3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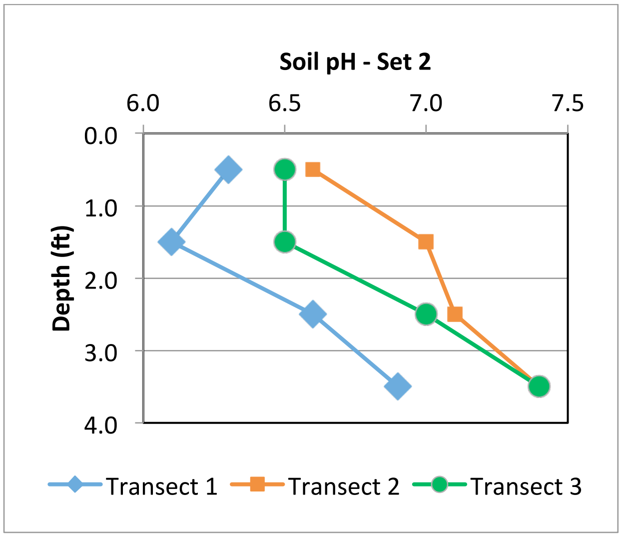
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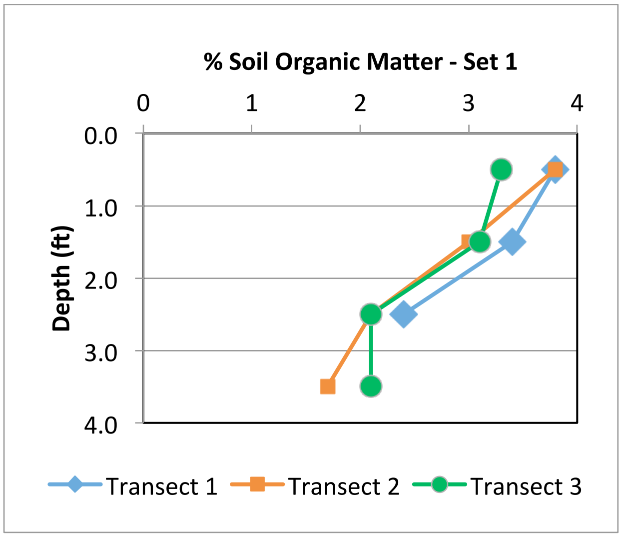
Transect 1
Transect 2
Transect 3

IL – 2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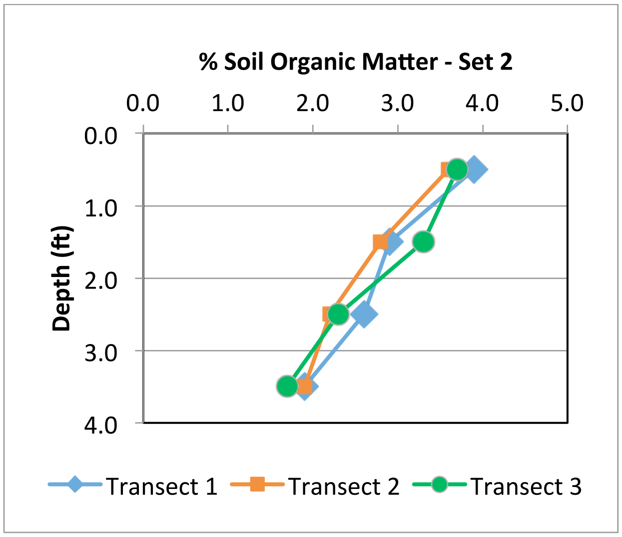
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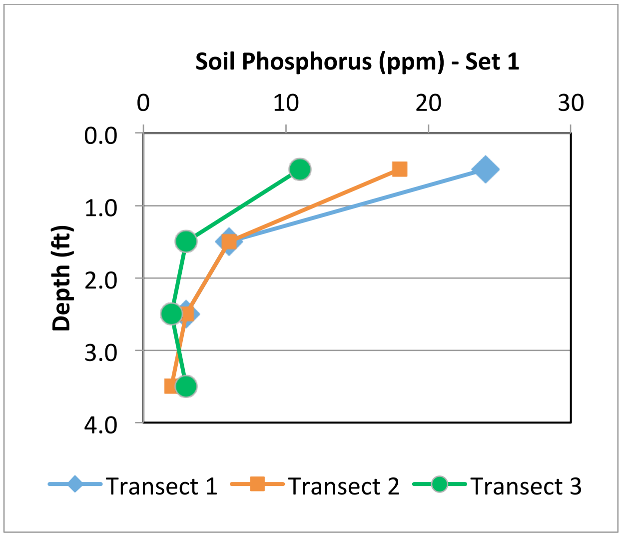
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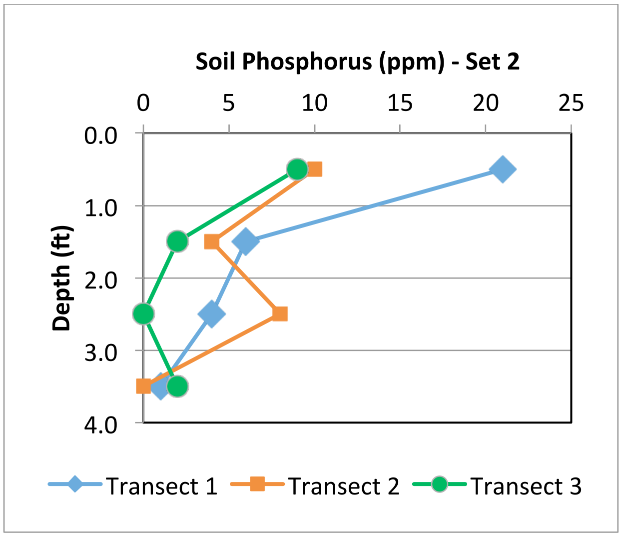
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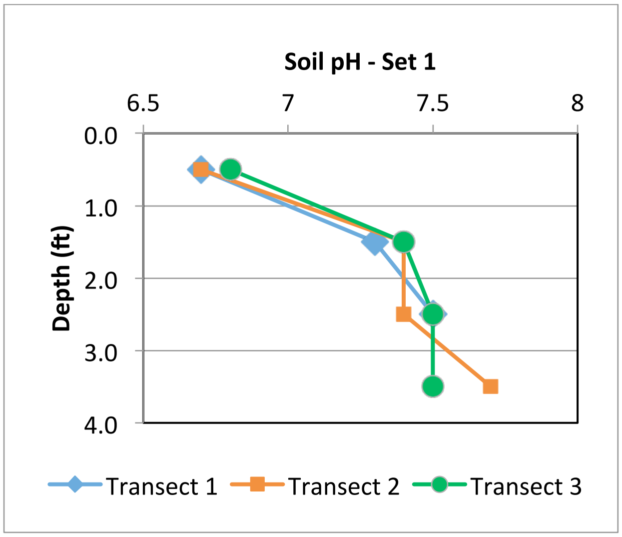
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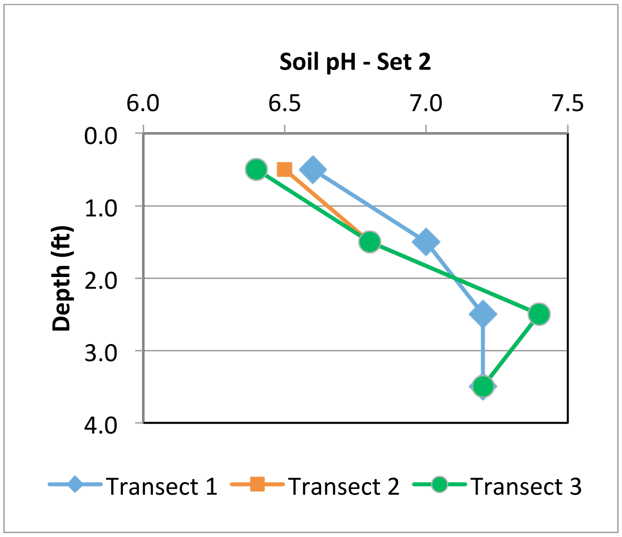
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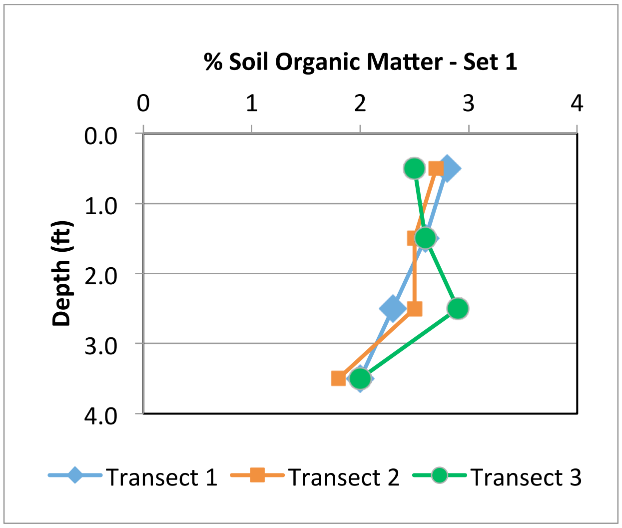
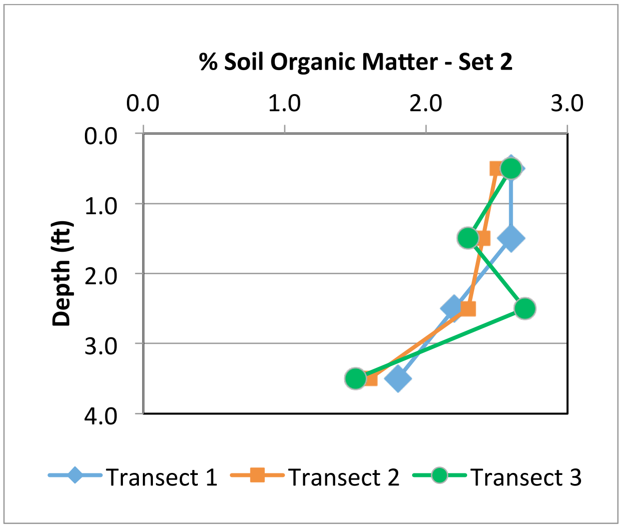
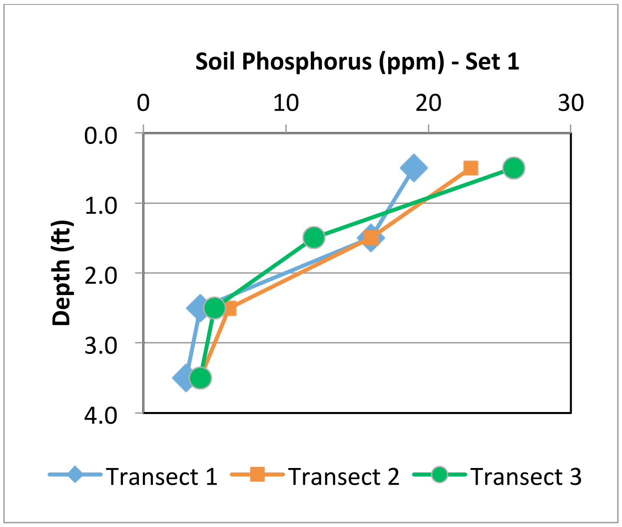
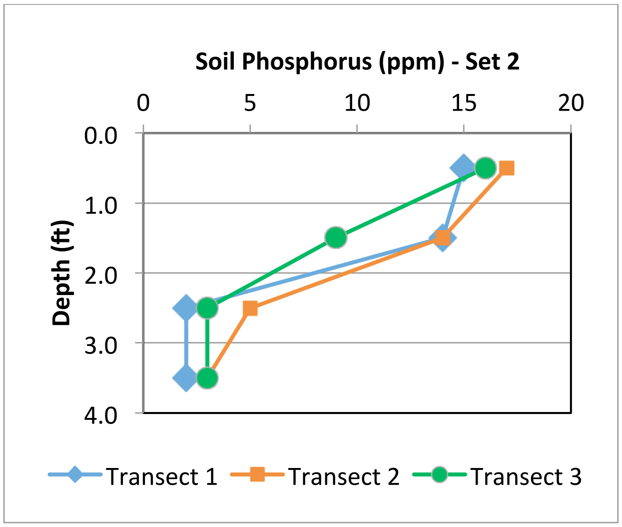
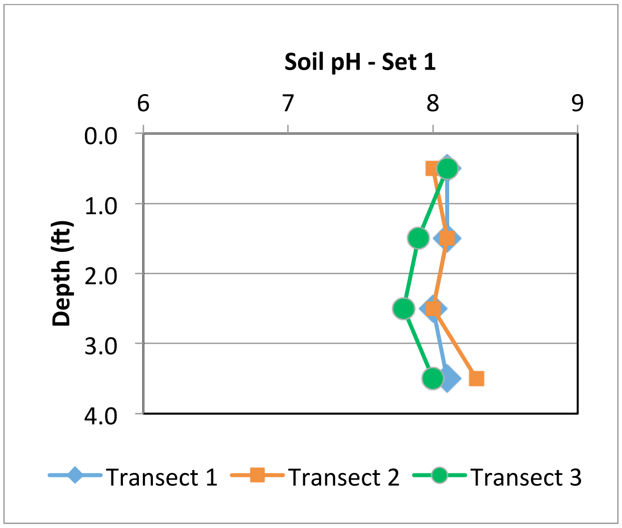
IL – 3

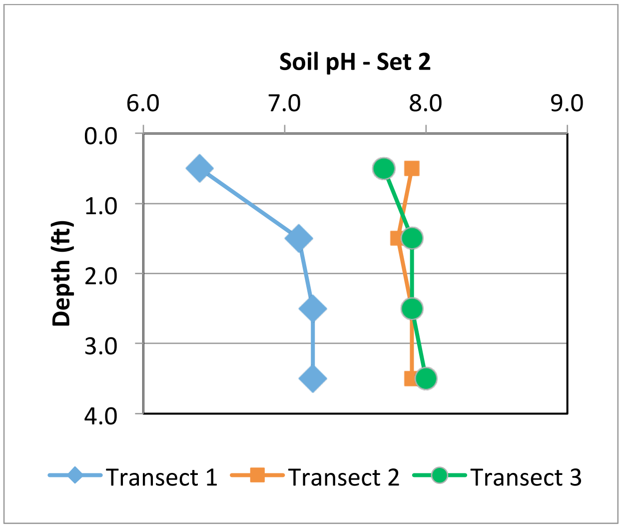

% Soil Organic Matter - Set 1
0
1
2
3
4
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3


% Soil Organic Matter - Set 2
0.0
1.0
2.0
3.0
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

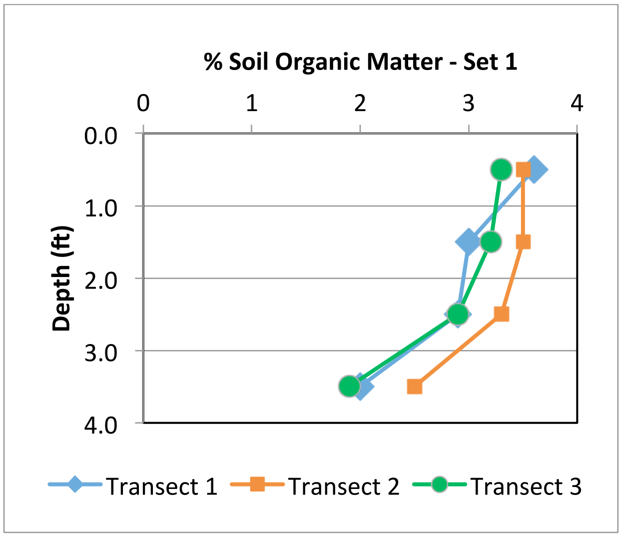

Soil Phosphorus (ppm) - Set 1
0
10
20
30
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

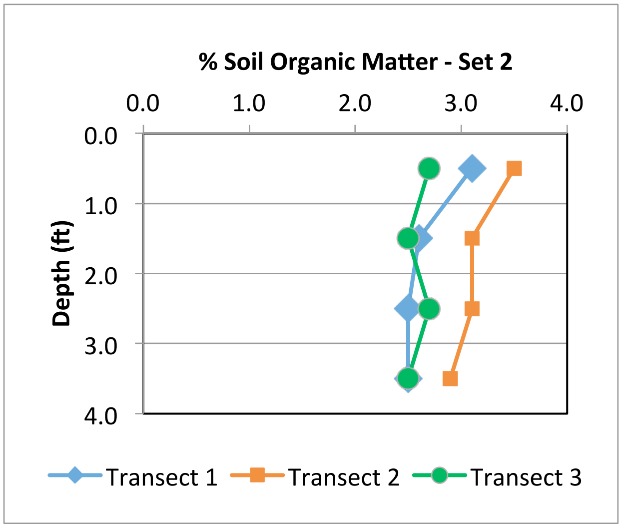

Soil Phosphorus (ppm) - Set 2
0
5
10
15
20
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

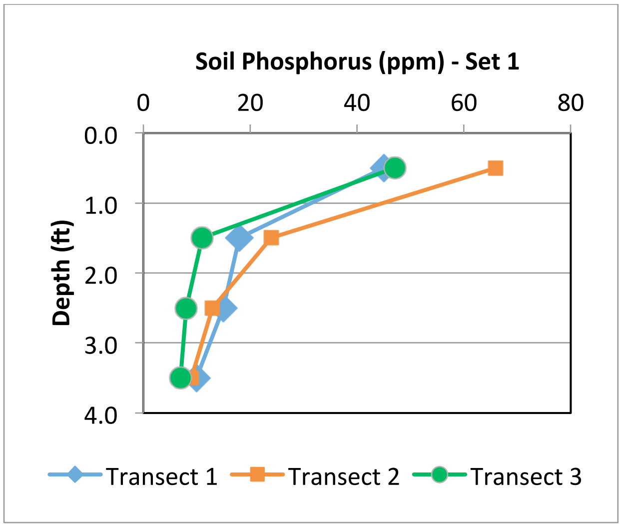

Soil pH - Set 1
6
7
8
9
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

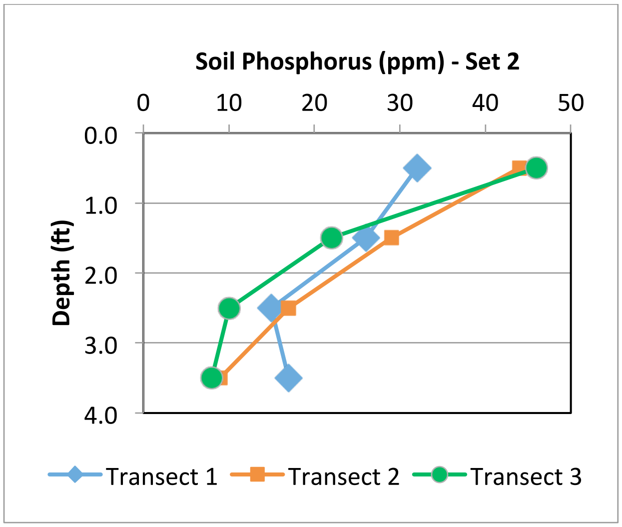

Soil pH - Set 2
6.0
7.0
8.0
9.0
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

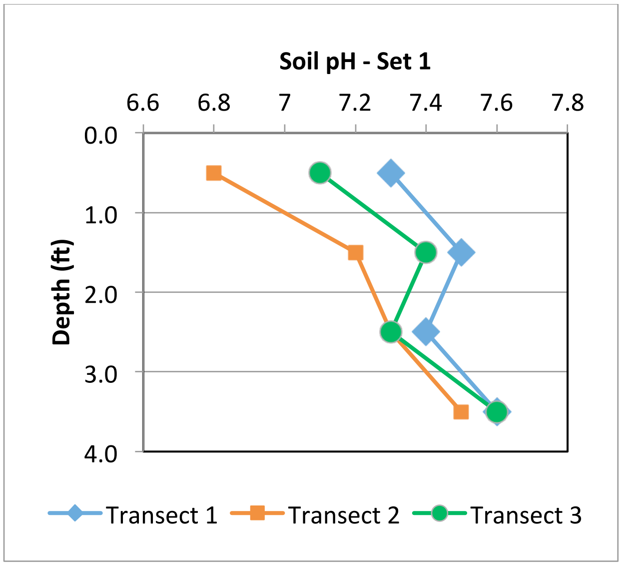
IL – 4

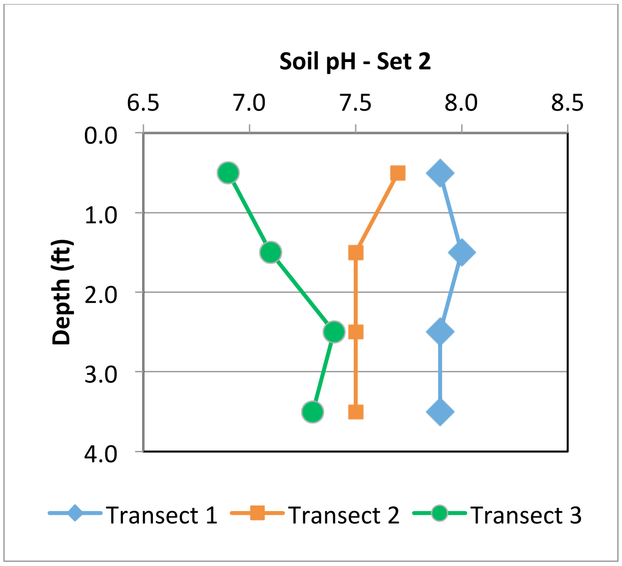

% Soil Organic Matter - Set 1
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3


% Soil Organic Matter - Set 2
0.0
1.0
2.0
3.0
4.0
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

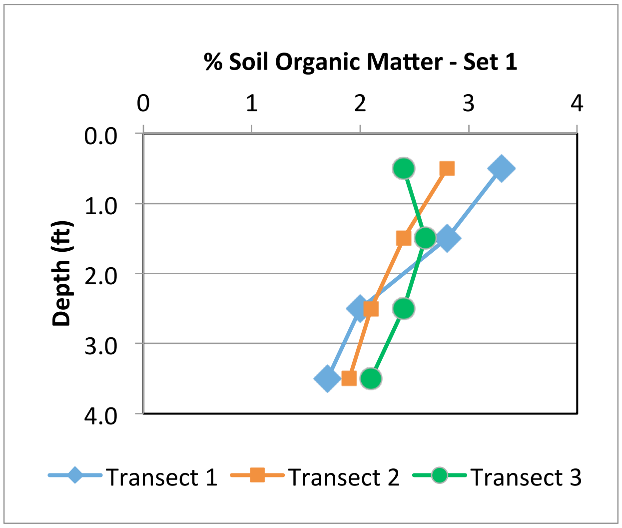

Soil Phosphorus (ppm) - Set 1
0
20
40
60
80
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

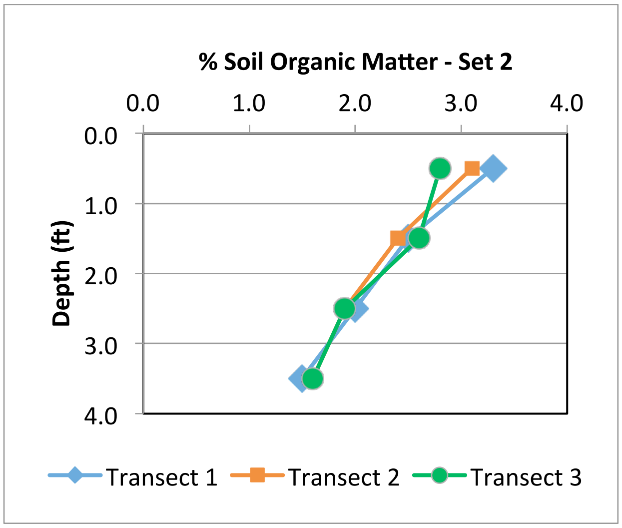

Soil Phosphorus (ppm) - Set 2
0
10
20
30
40
50
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

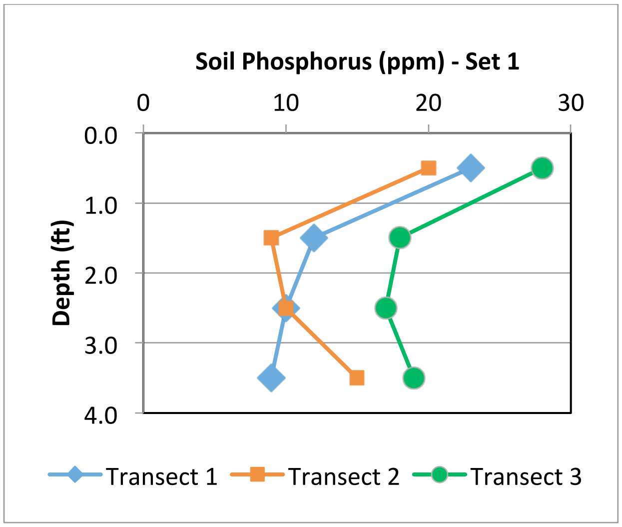

Soil pH - Set 1
6.6
6.8
7
7.2
7.4
7.6
7.8
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

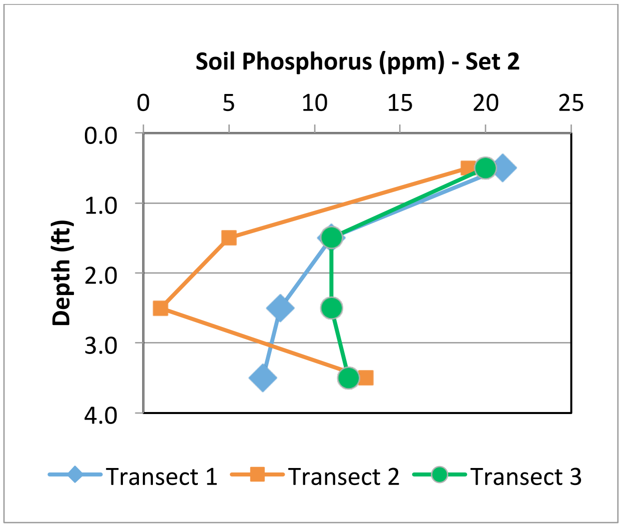

Soil pH - Set 2
6.5
7.0
7.5
8.0
8.5
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

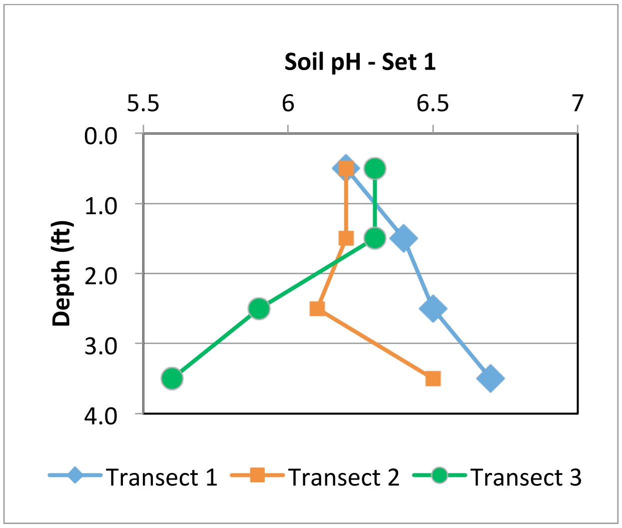
IL – 5

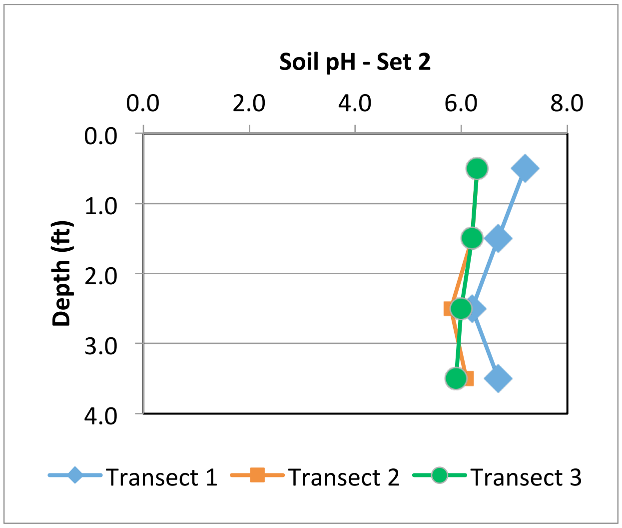

% Soil Organic Matter - Set 1
0
1
2
3
4
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3


% Soil Organic Matter - Set 2
0.0
1.0
2.0
3.0
4.0
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

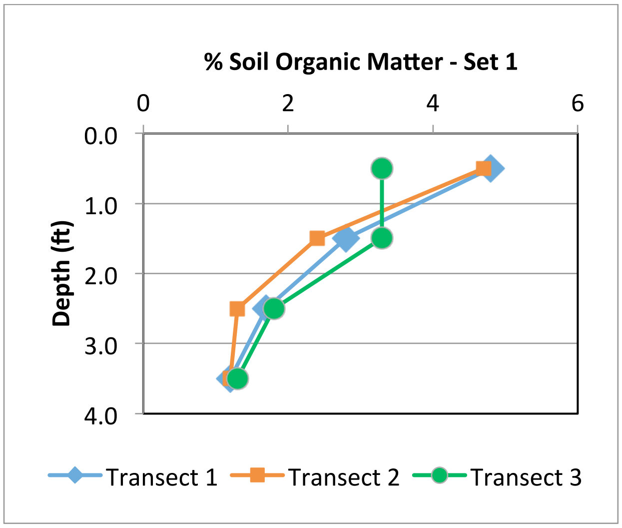

Soil Phosphorus (ppm) - Set 1
0
10
20
30
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

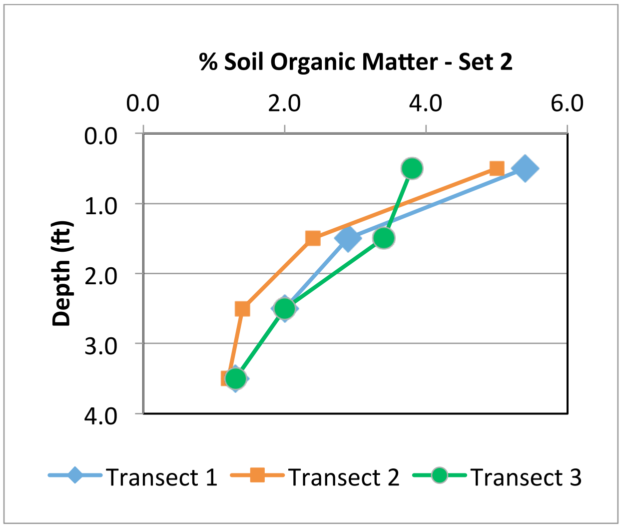

Soil Phosphorus (ppm) - Set 2
0
5
10
15
20
25
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

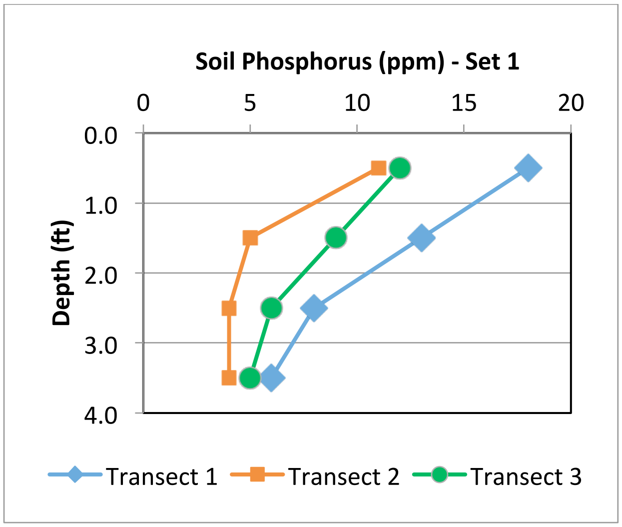

Soil pH - Set 1
5.5
6
6.5
7
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

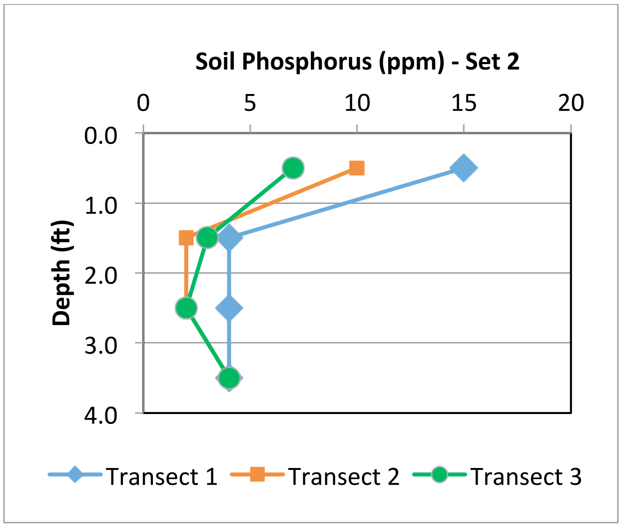

Soil pH - Set 2
0.0
2.0
4.0
6.0
8.0
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

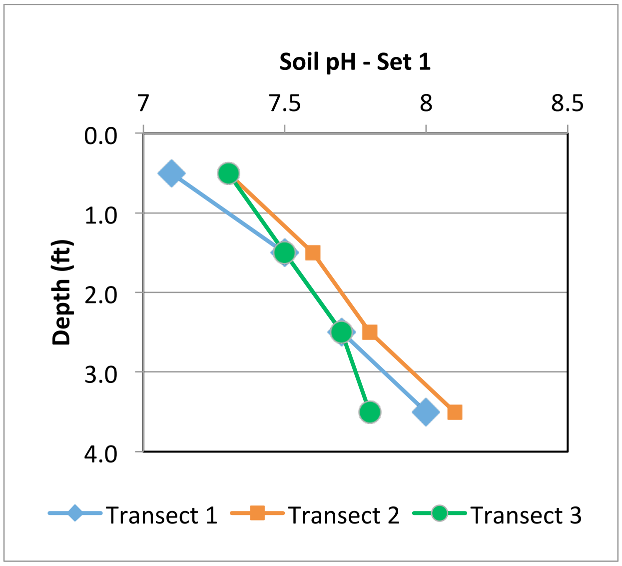
IN – 1

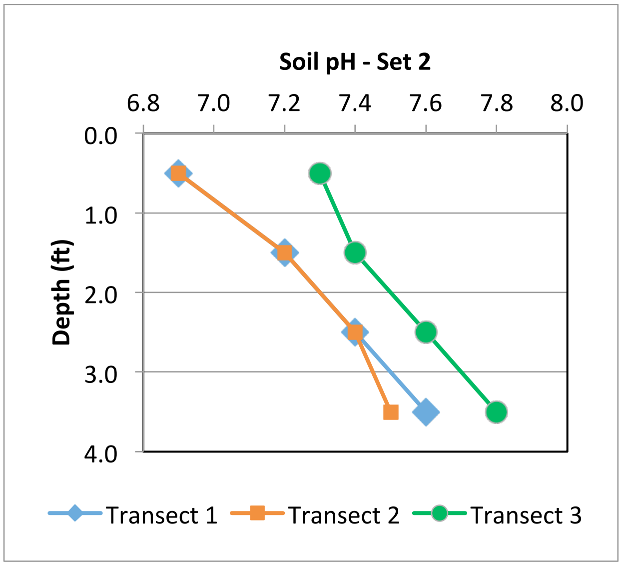

% Soil Organic Matter - Set 1
0
2
4
6
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3


% Soil Organic Matter - Set 2
0.0
2.0
4.0
6.0
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

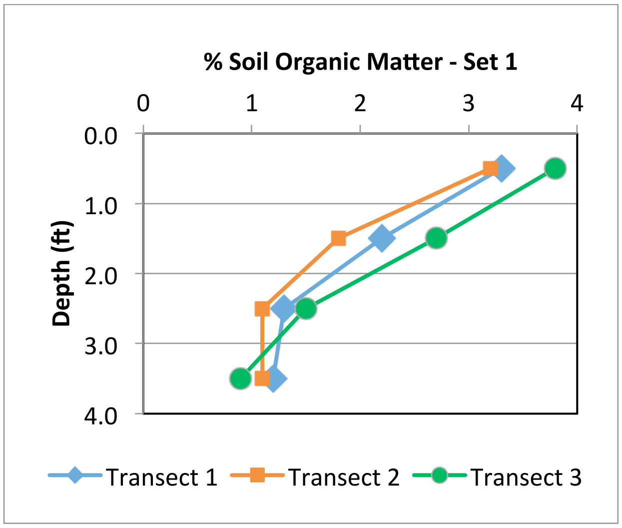

Soil Phosphorus (ppm) - Set 1
0
5
10
15
20
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

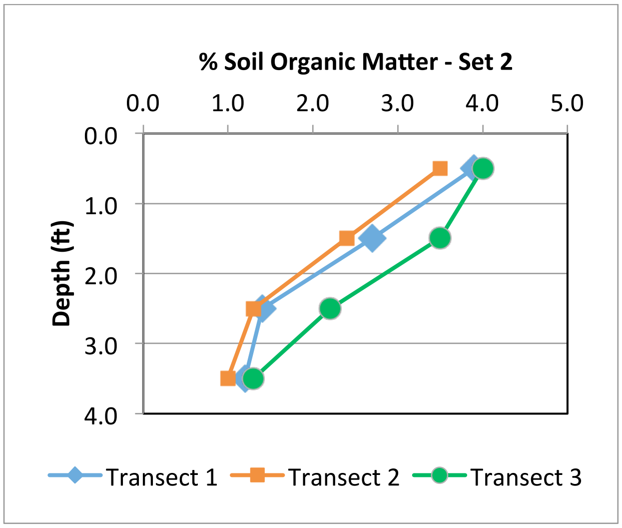

Soil Phosphorus (ppm) - Set 2
0
5
10
15
20
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

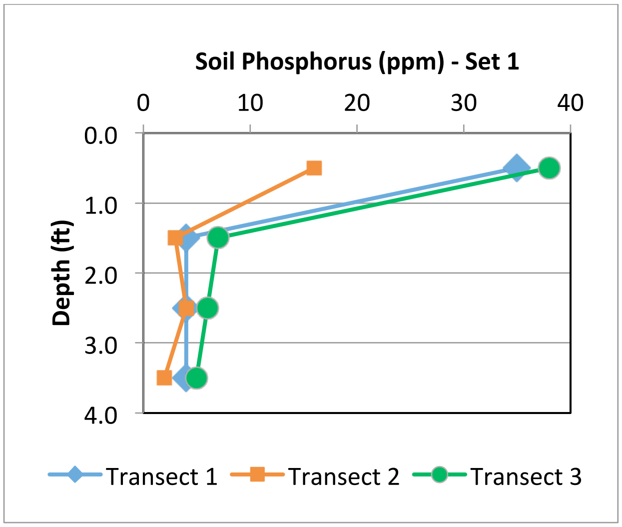

Soil pH - Set 1
7
7.5
8
8.5
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

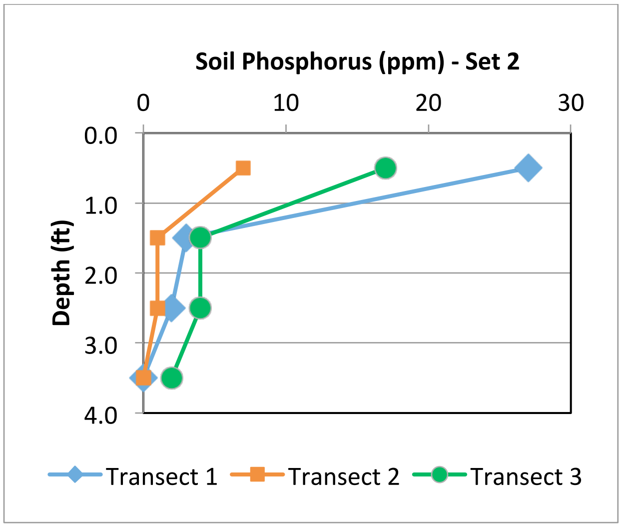

Soil pH - Set 2
6.8
7.0
7.2
7.4
7.6
7.8
8.0
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

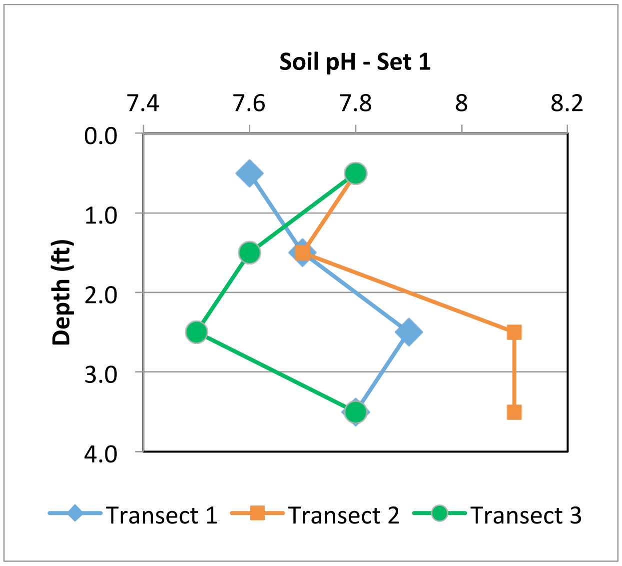
IN – 2

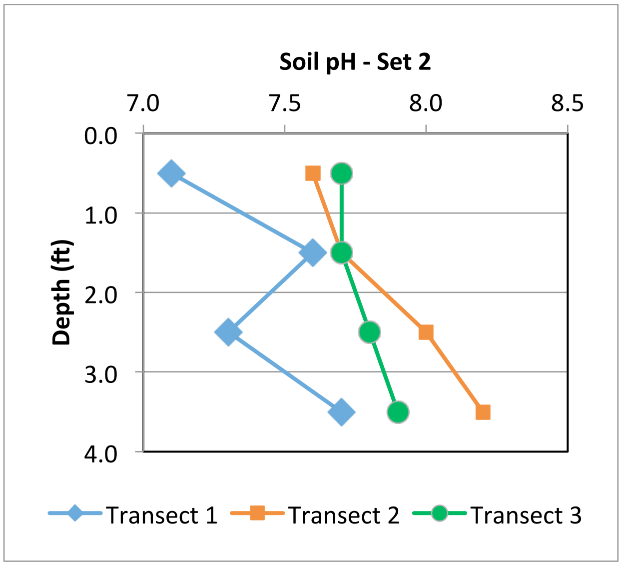

% Soil Organic Matter - Set 1
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3


% Soil Organic Matter - Set 2
0.0
1.0
2.0
3.0
4.0
5.0
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

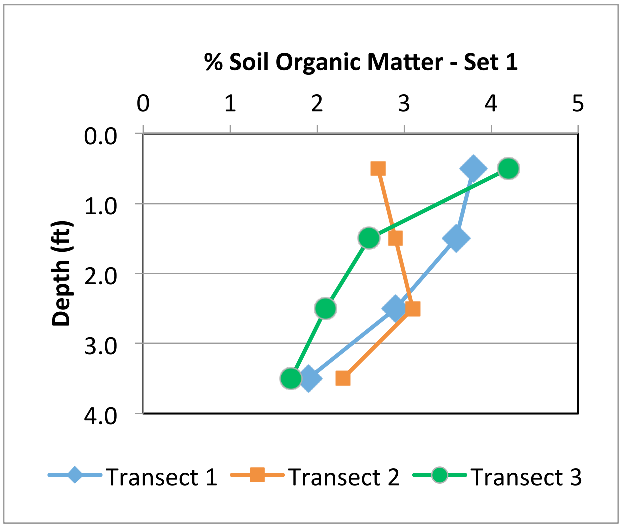

Soil Phosphorus (ppm) - Set 1
0
10
20
30
40
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3


Soil Phosphorus (ppm) - Set 2
0
10
20
30
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

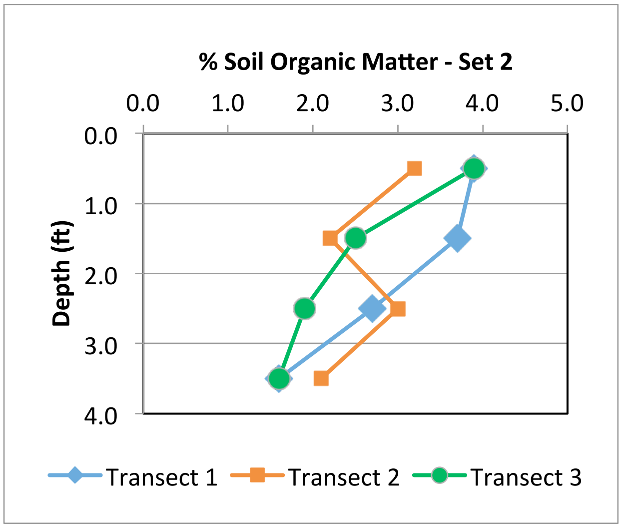

Soil pH - Set 1
7.4
7.6
7.8
8
8.2
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3


Soil pH - Set 2
7.0
7.5
8.0
8.5
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

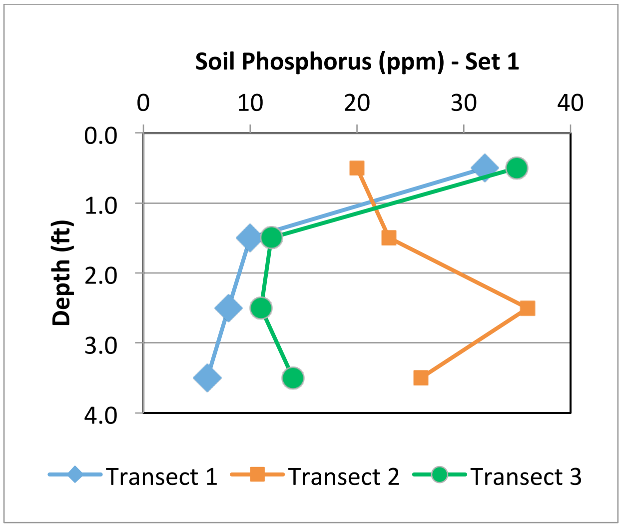
IN – 3



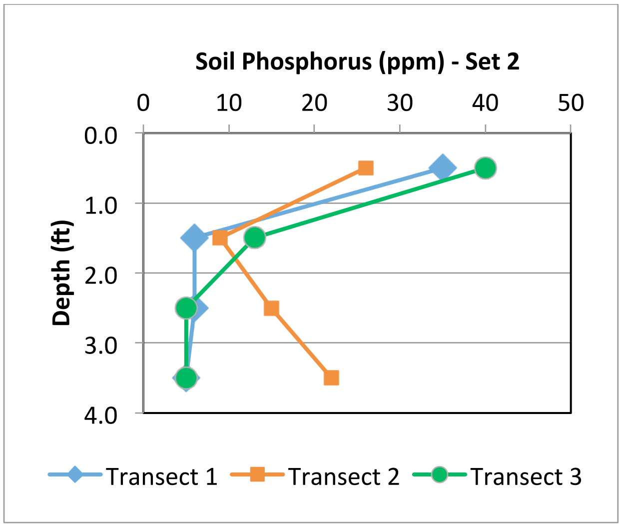
% Soil Organic Matter - Set 1
0
1
2
3
4
5
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3



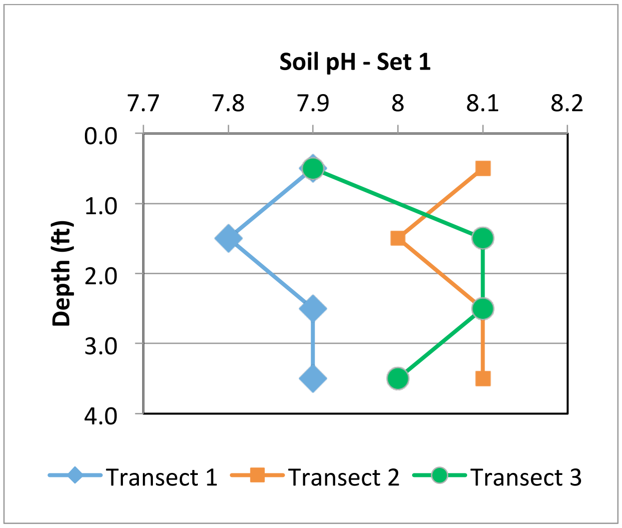
% Soil Organic Matter - Set 2
0.0
1.0
2.0
3.0
4.0
5.0
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3



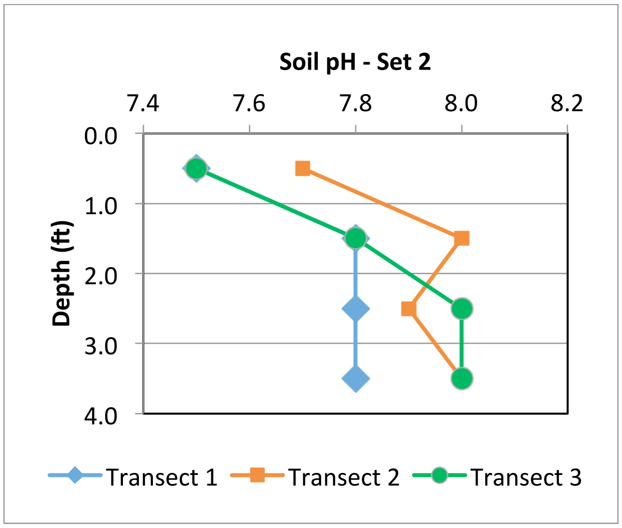
Soil Phosphorus (ppm) - Set 1
0
10
20
30
40
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3



Soil Phosphorus (ppm) - Set 2
0
10
20
30
40
50
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

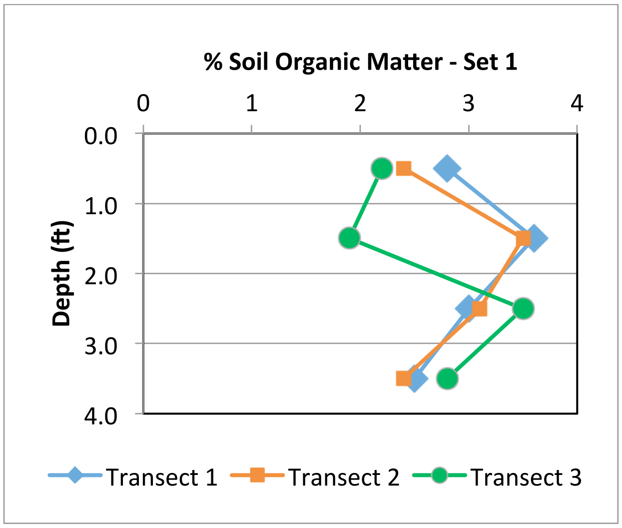


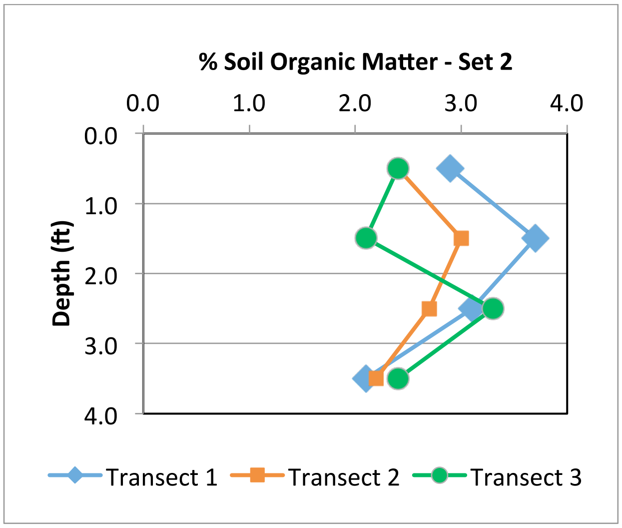
Soil pH - Set 1
7.7
7.8
7.9
8
8.1
8.2
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

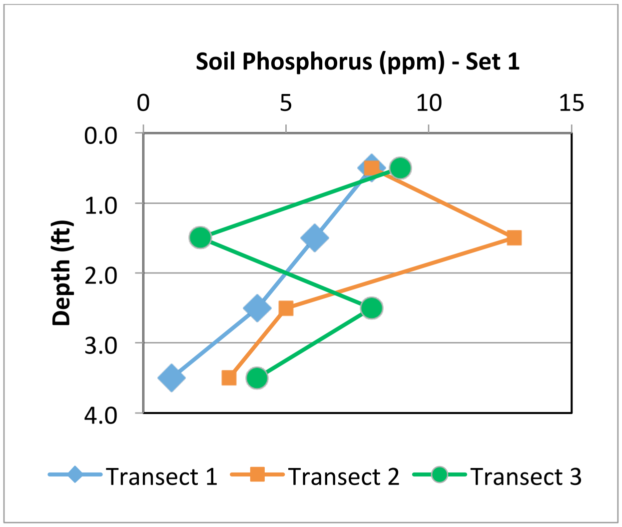


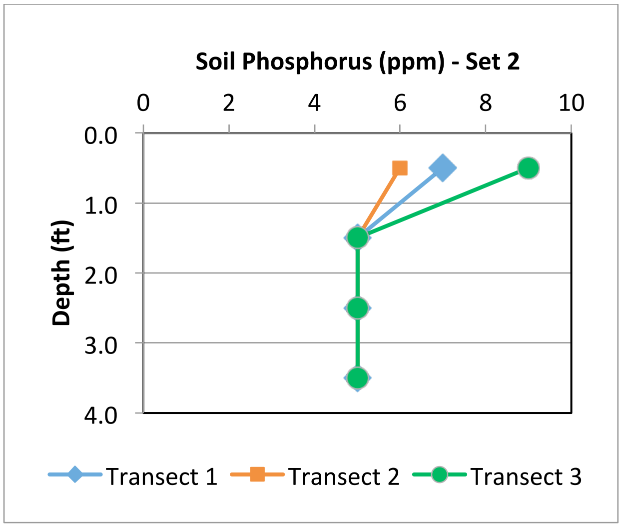
Soil pH - Set 2
7.4
7.6
7.8
8.0
8.2
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

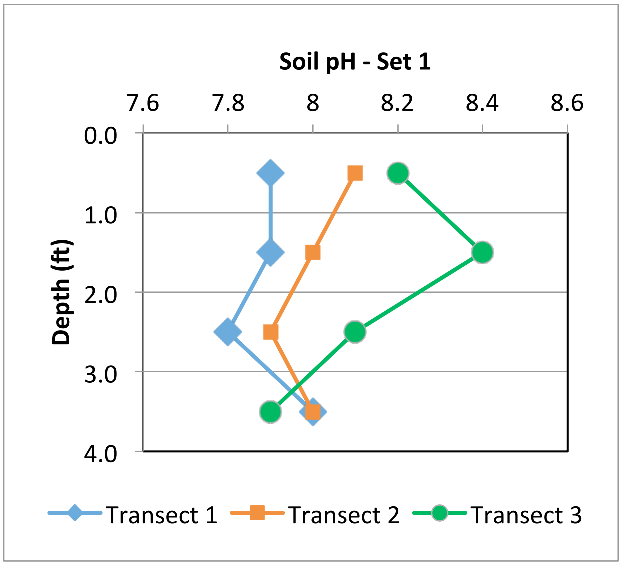
MN – 1

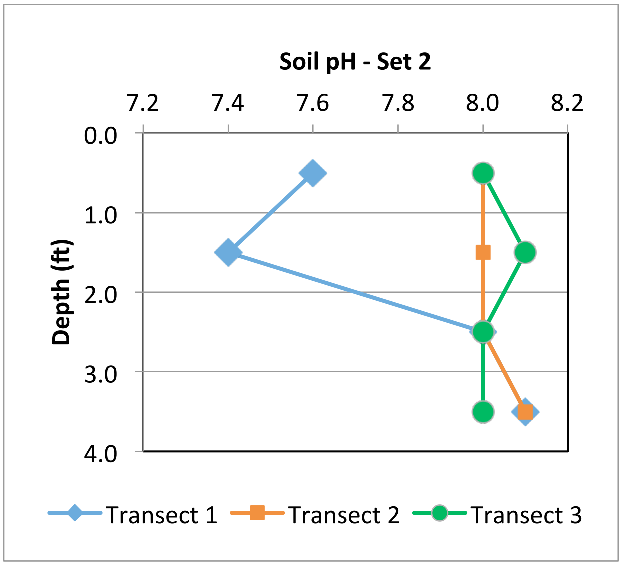

% Soil Organic Matter - Set 1


% Soil Organic Matter - Set 2

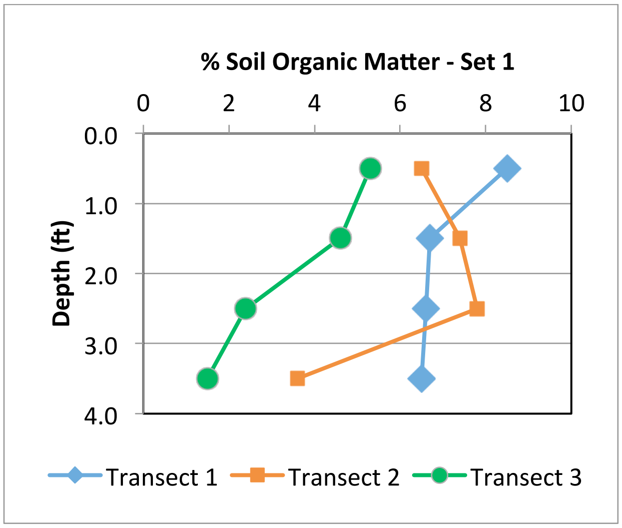

Soil Phosphorus (ppm) - Set 1

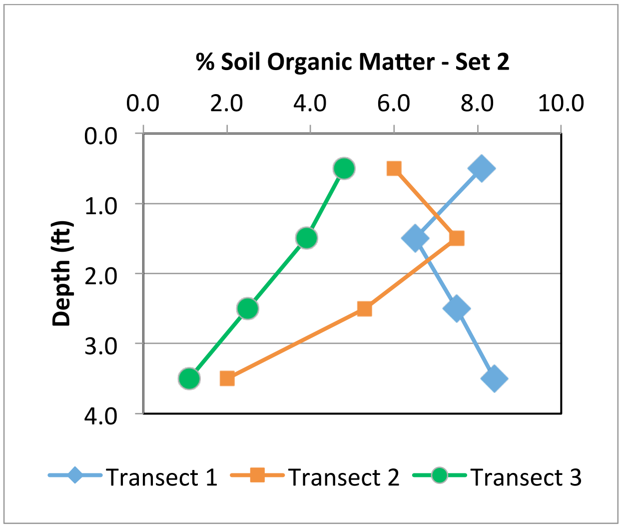

Soil Phosphorus (ppm) - Set 2

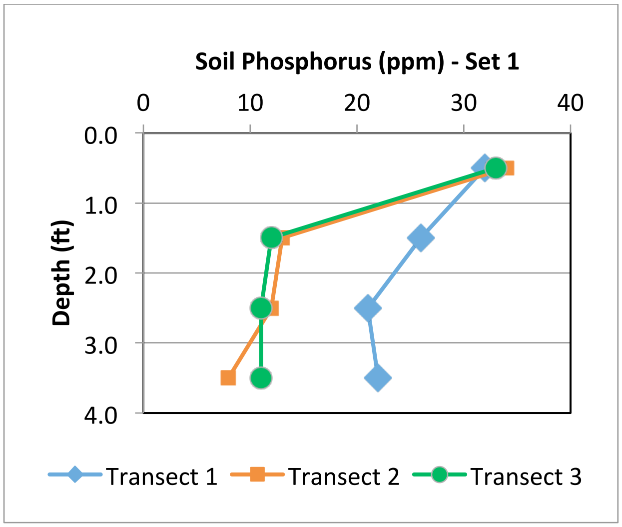

Soil pH - Set 1

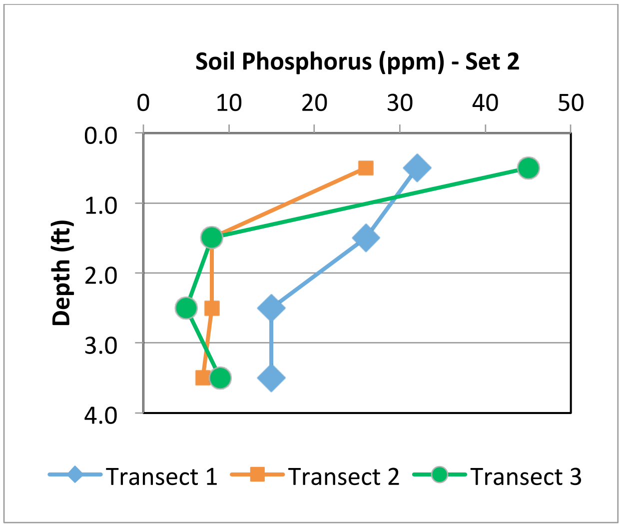

Soil pH - Set 2

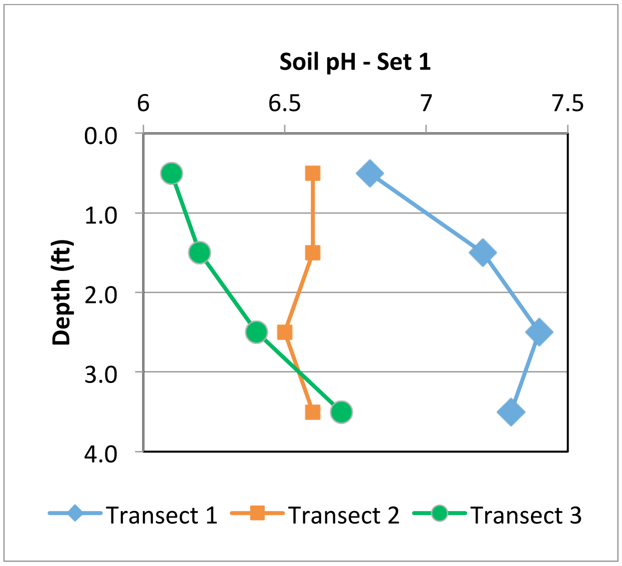
MN – 2

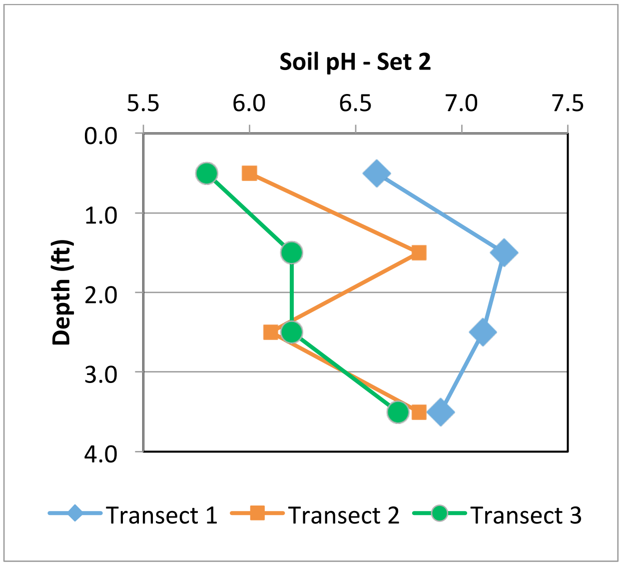

% Soil Organic Matter - Set 1
0
2
4
6
8
10
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3


% Soil Organic Matter - Set 2
0.0
2.0
4.0
6.0
8.0
10.0
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

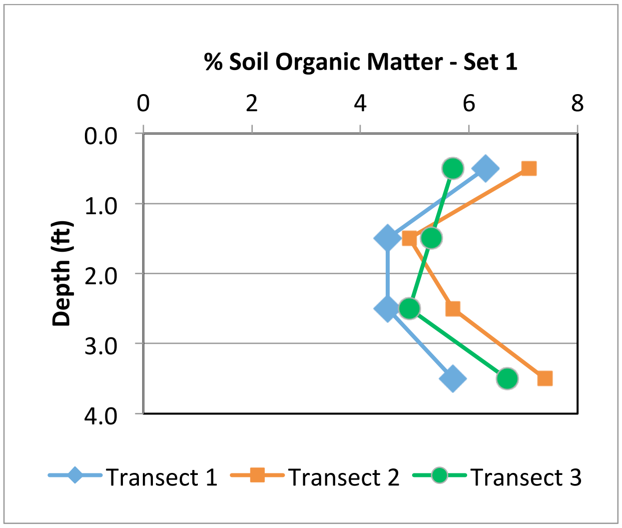

Soil Phosphorus (ppm) - Set 1
0
10
20
30
40
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

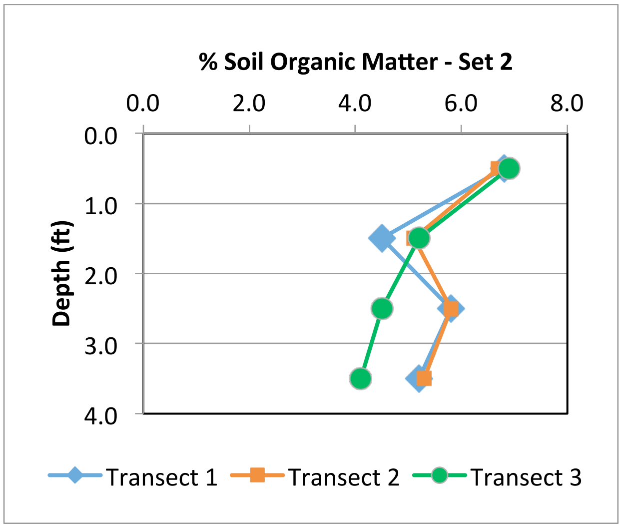

Soil Phosphorus (ppm) - Set 2
0
10
20
30
40
50
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

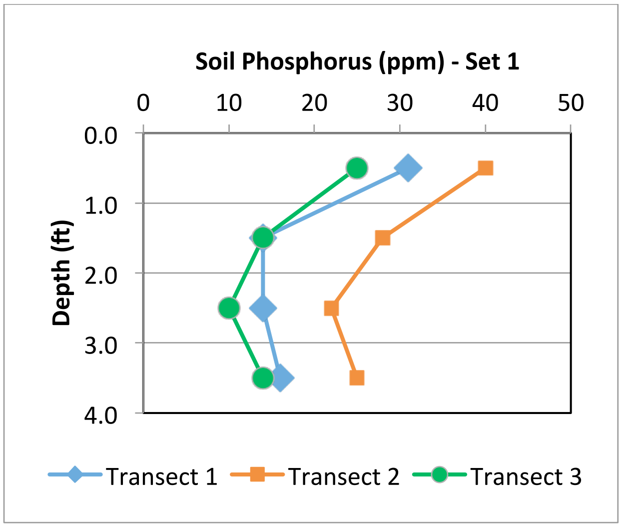

Soil pH - Set 1
6
6.5
7
7.5
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

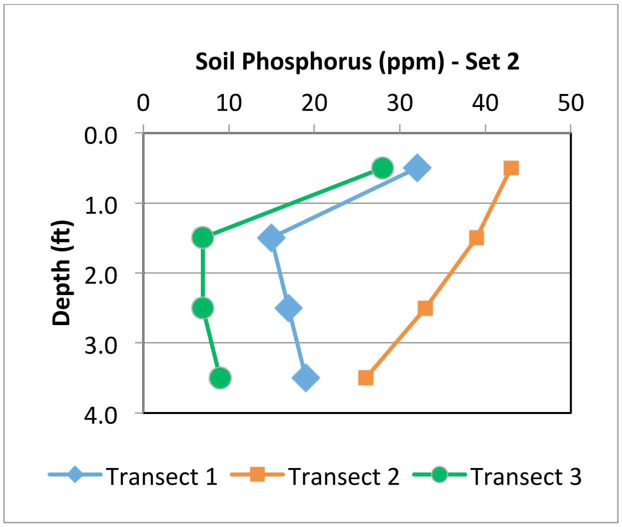

Soil pH - Set 2
5.5
6.0
6.5
7.0
7.5
Depth (ft)
0.0
1.0
2.0
3.0
4.0
Transect 1
Transect 2
Transect 3

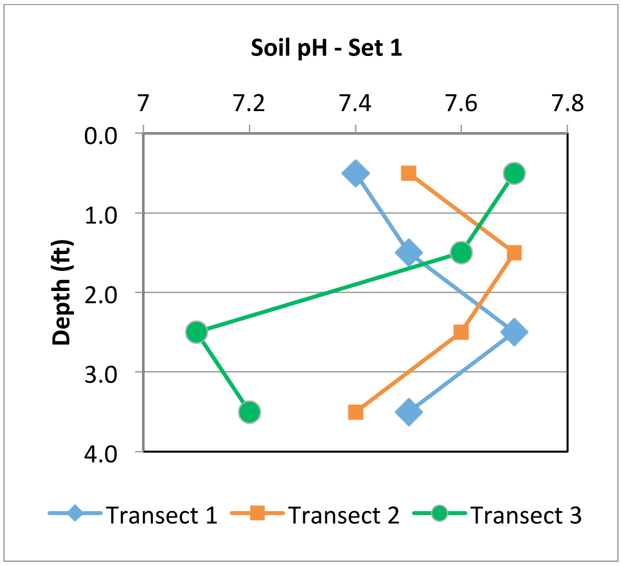
MN – 3

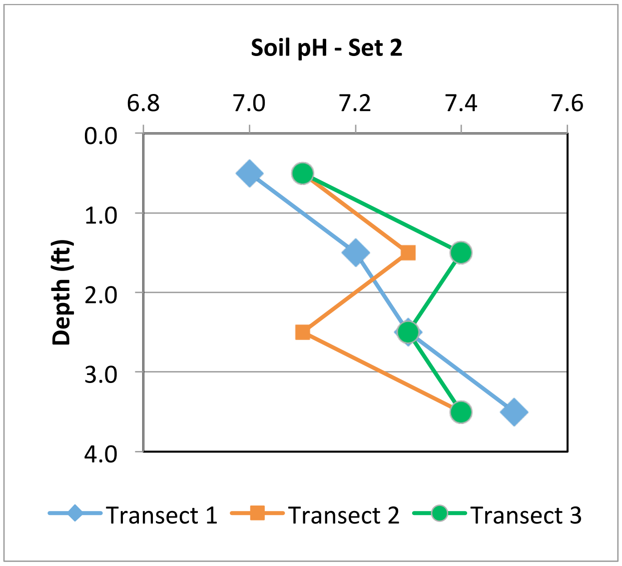

% Soil Organic Matter - Set 1
0
2
4
6
8
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3


% Soil Organic Matter - Set 2
0.0
2.0
4.0
6.0
8.0
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

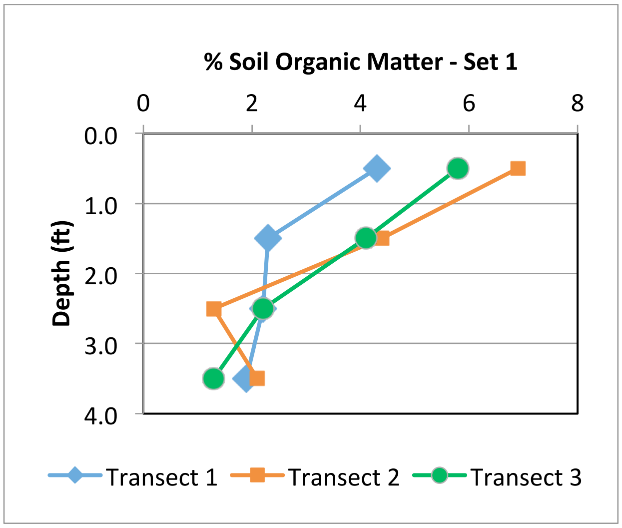

Soil Phosphorus (ppm) - Set 1
0
10
20
30
40
50
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

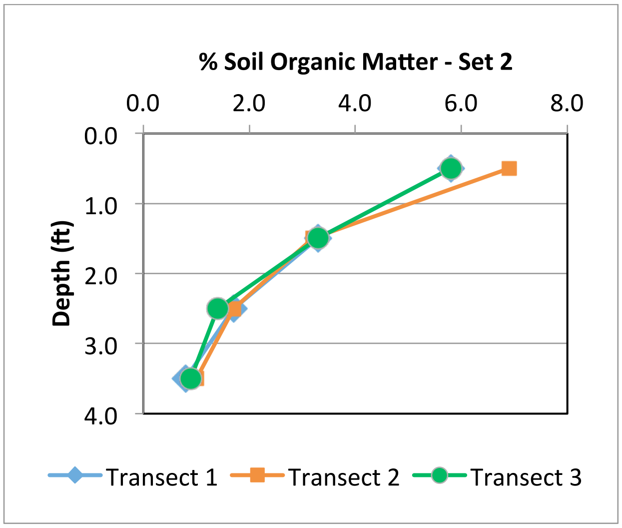

Soil Phosphorus (ppm) - Set 2
0
10
20
30
40
50
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

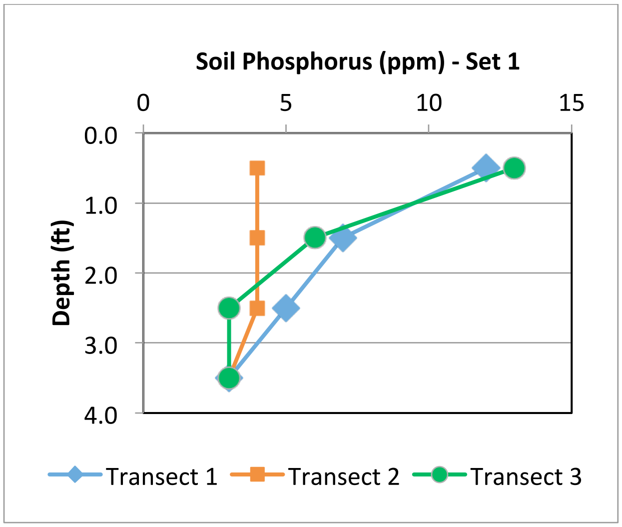

Soil pH - Set 1
7
7.2
7.4
7.6
7.8
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

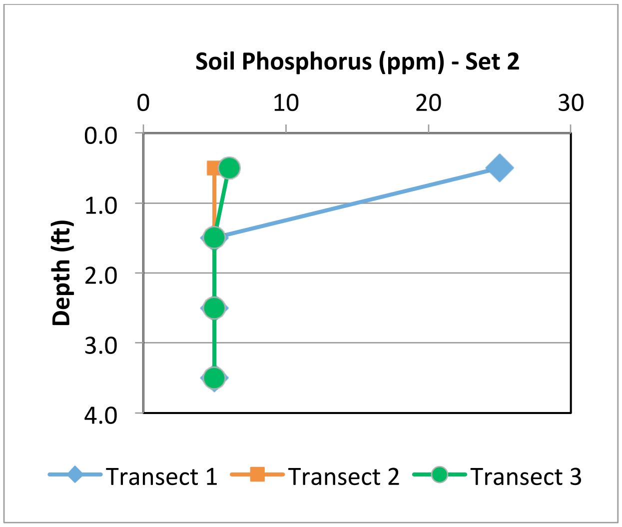

Soil pH - Set 2
6.8
7.0
7.2
7.4
7.6
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

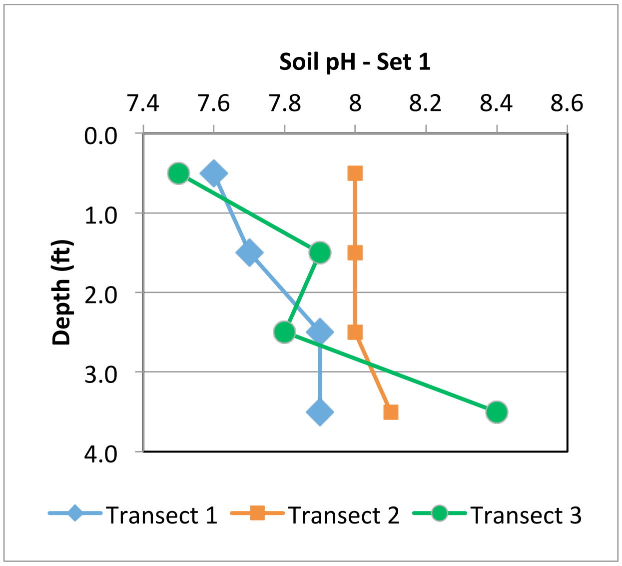
MN – 4

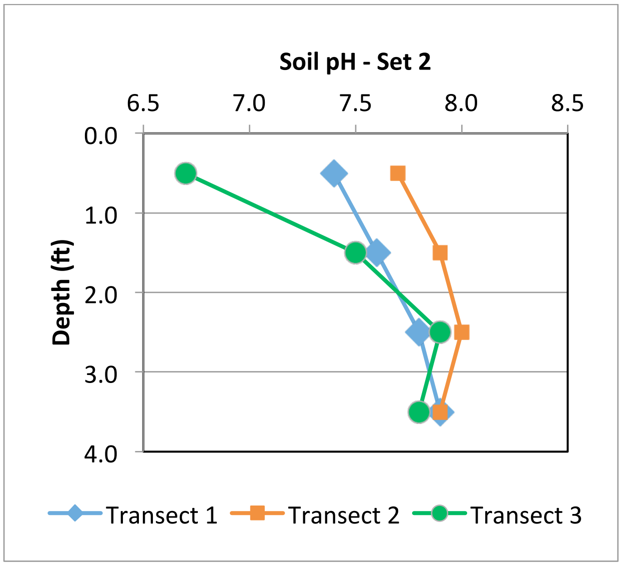

% Soil Organic Matter - Set 1
0
2
4
6
8
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3


% Soil Organic Matter - Set 2
0.0
2.0
4.0
6.0
8.0
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3


Soil Phosphorus (ppm) - Set 1
0
5
10
15
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3


Soil Phosphorus (ppm) - Set 2
0
10
20
30
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3


Soil pH - Set 1
7.4
7.6
7.8
8
8.2
8.4
8.6
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

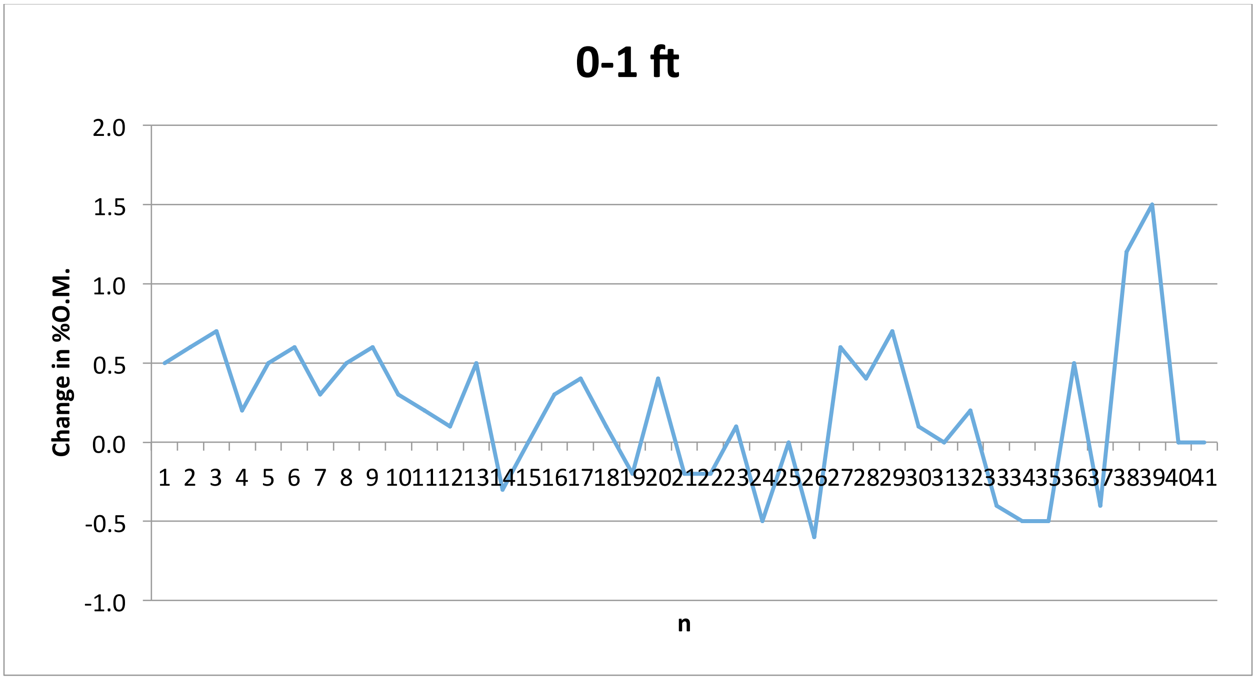

Soil pH - Set 2
6.5
7.0
7.5
8.0
8.5
0.0
1.0
2.0
3.0
4.0
Depth (ft)
Transect 1
Transect 2
Transect 3

Soil Organic Matter Results

The statistical analysis were performed in Excel using alpha = 0.10

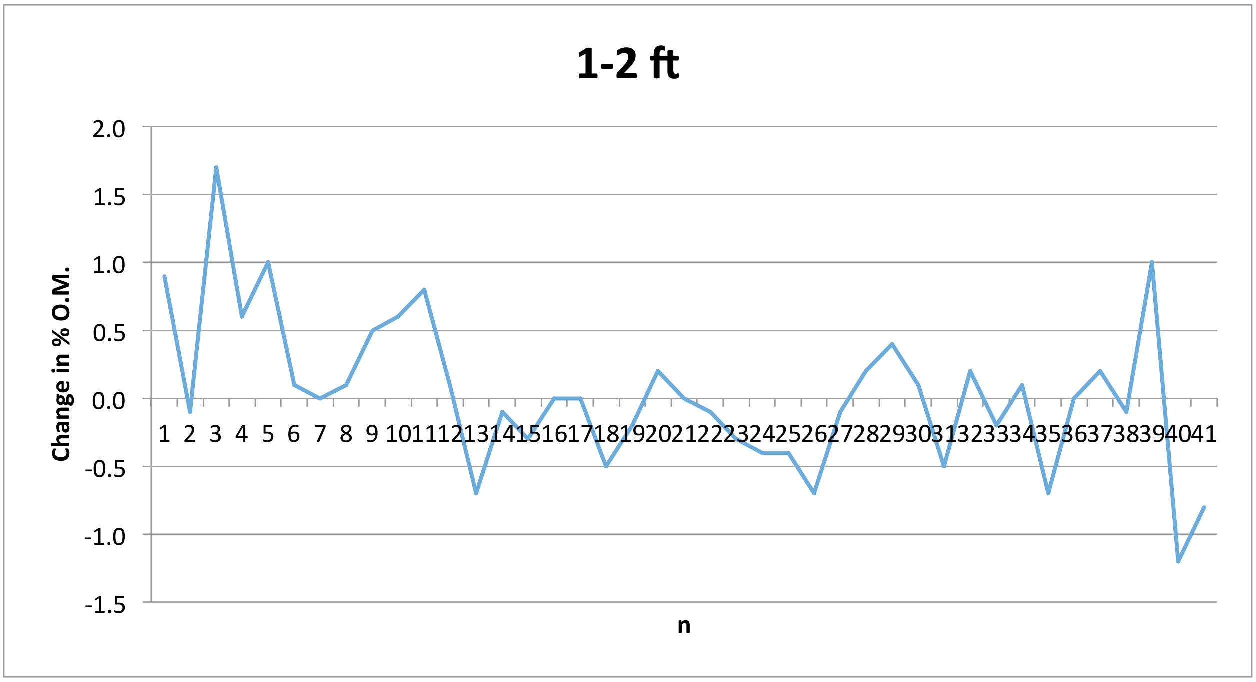
0 – 1 ft depth

	Set 1 (%O.M.)	*Set 2 (%O.M.)*
Mean	4.007317073	4.209756098
Variance	2.193695122	2.158902439
Observations	41	41
Pearson Correlation	0.952761217	
Hypothesized Mean Difference	0	
df	40	
t Stat	-2.857739762	
P(T<=t) one-tail	0.003370624	
t Critical one-tail	1.303077053	
P(T<=t) two-tail	0.006741248	
t Critical two-tail	1.683851013	



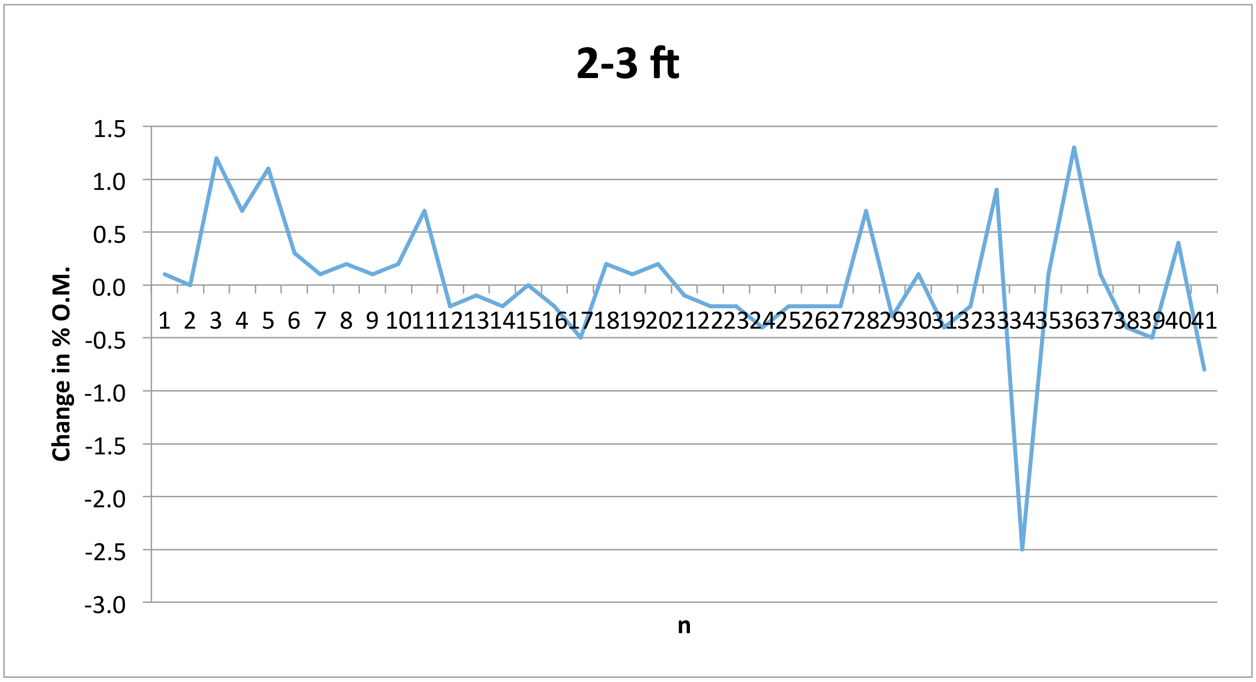
1 – 2 ft depth

	Set 1 (%O.M.)	*Set 2 (%O.M.)*
Mean	3.33902439	3.373170732
Variance	1.370939024	1.340012195
Observations	41	41
Pearson Correlation	0.886516407	
Hypothesized Mean Difference	0	
df	40	
t Stat	-0.394092671	
P(T<=t) one-tail	0.347802912	
t Critical one-tail	1.303077053	
P(T<=t) two-tail	0.695605824	
t Critical two-tail	1.683851013	



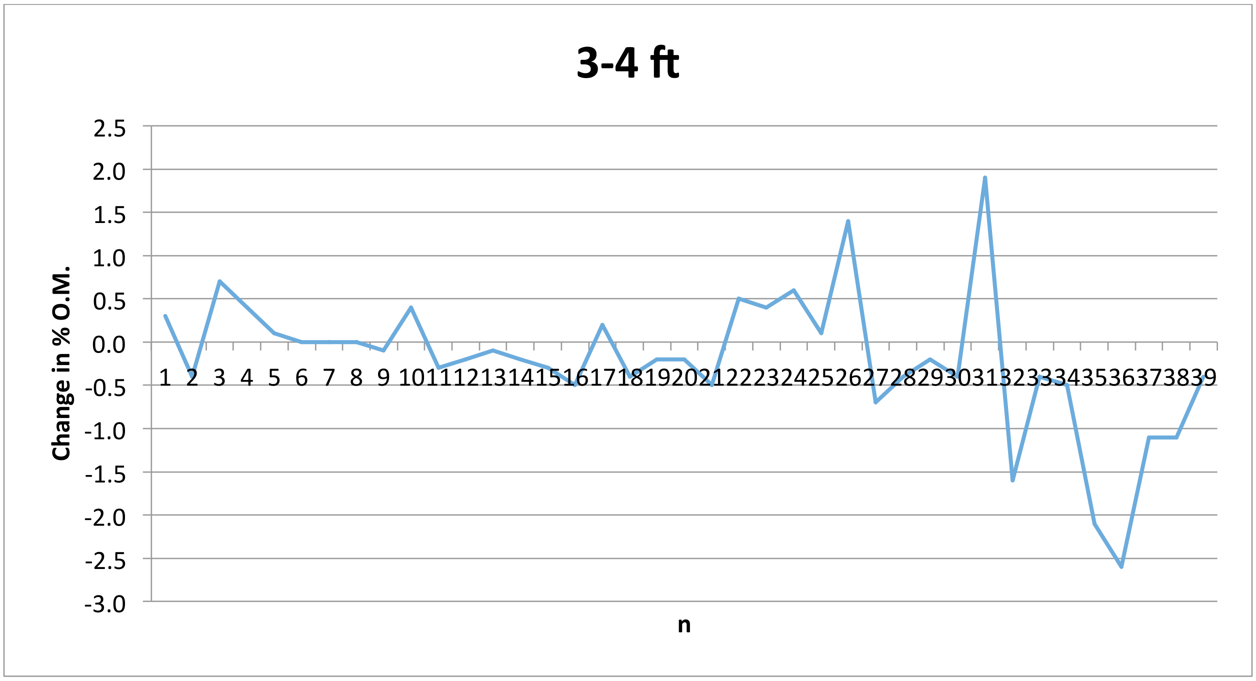
2 – 3 ft

	Set 1 (%O.M.)	*Set 2 (%O.M.)*
Mean	2.824390244	2.848780488
Variance	2.103390244	1.822060976
Observations	41	41
Pearson Correlation	0.904147667	
Hypothesized Mean Difference	0	
df	40	
t Stat	-0.251569342	
P(T<=t) one-tail	0.401330986	
t Critical one-tail	1.303077053	
P(T<=t) two-tail	0.802661972	
t Critical two-tail	1.683851013	



3 – 4 ft depth

	Set 1 (%O.M.)	*Set 2 (%O.M.)*
Mean	2.469230769	2.266666667
Variance	2.650607287	2.250175439
Observations	39	39
Pearson Correlation	0.871626358	
Hypothesized Mean Difference	0	
df	38	
t Stat	1.577064412	
P(T<=t) one-tail	0.061535177	
t Critical one-tail	1.304230204	
P(T<=t) two-tail	0.123070354	
t Critical two-tail	1.68595446	

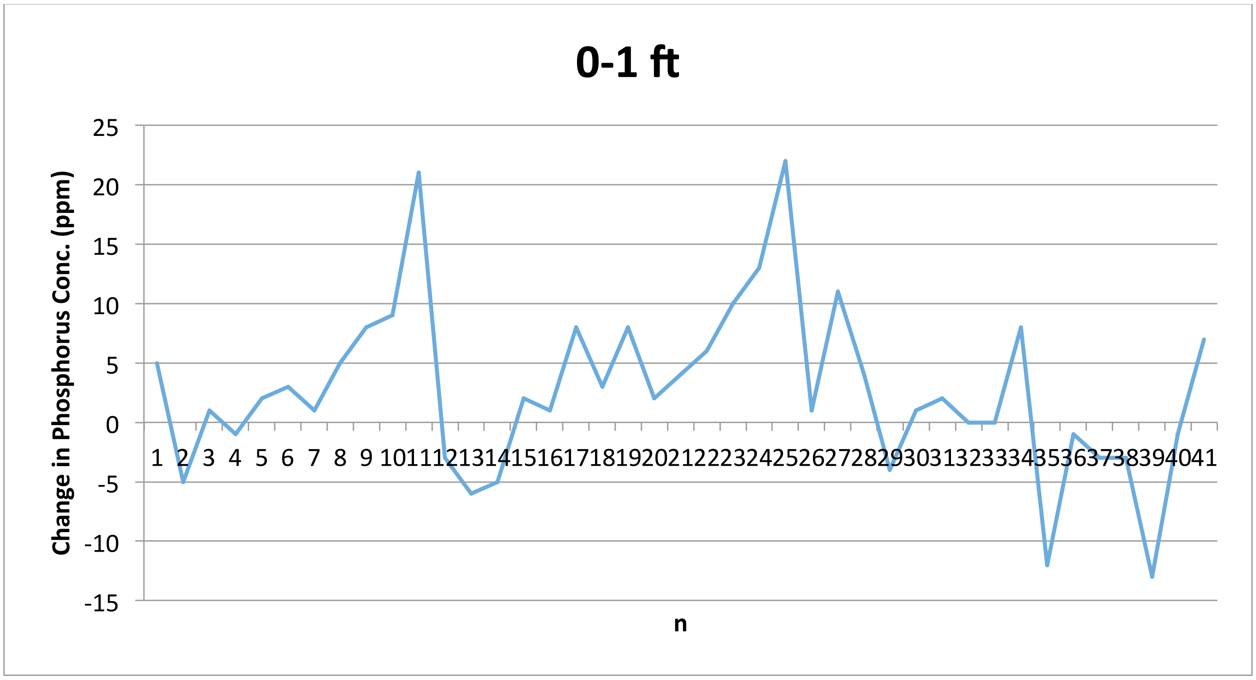


Soil Phosphorus Concentrations

The statistical analysis were performed in Excel using alpha = 0.10

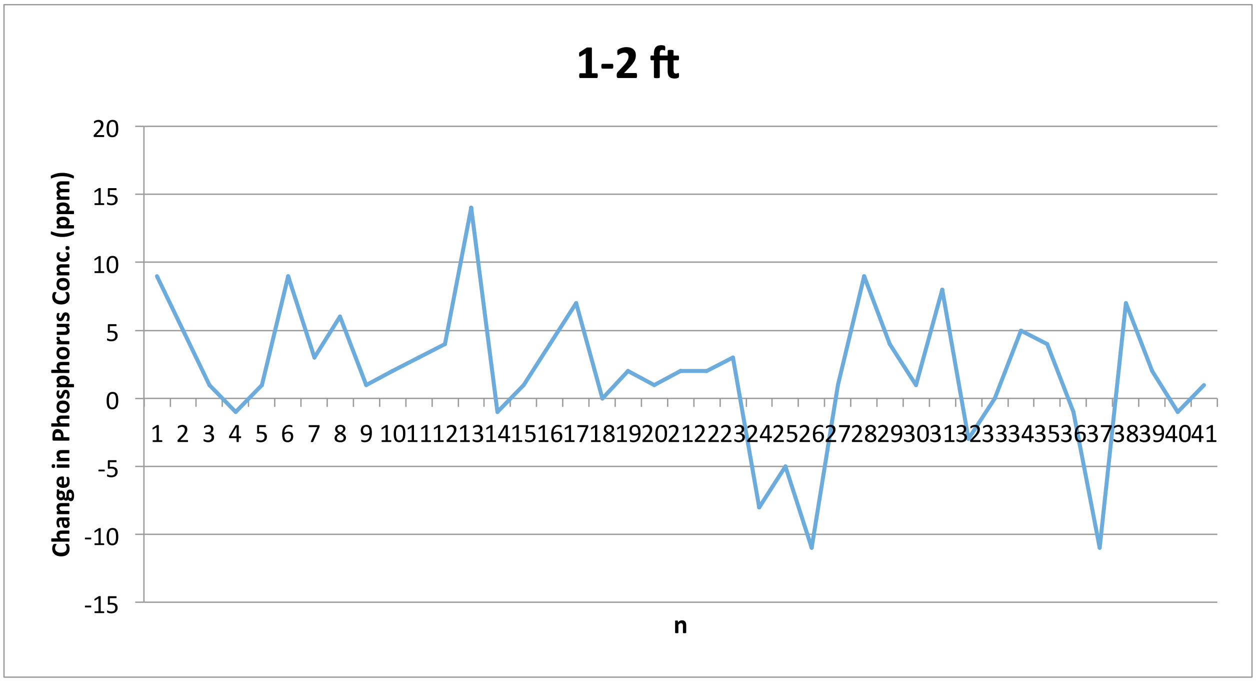
0 – 1 ft depth

	Set 1 (ppm)	*Set 2 (ppm)*
Mean	25.73170732	23.02439024
Variance	186.0012195	174.2743902
Observations	41	41
Pearson Correlation	0.86150122	
Hypothesized Mean Difference	0	
df	40	
t Stat	2.450056537	
P(T<=t) one-tail	0.009377387	
t Critical one-tail	1.303077053	
P(T<=t) two-tail	0.018754774	
t Critical two-tail	1.683851013	



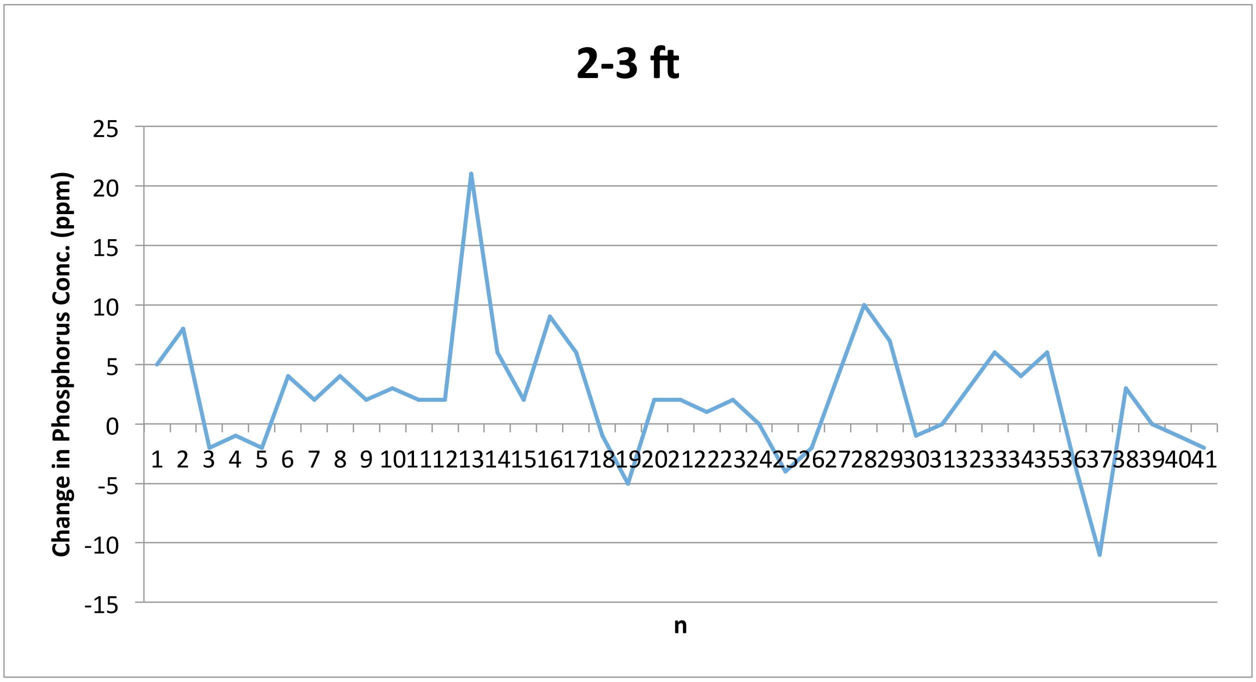
1 – 2 ft depth

	Set 1 (ppm)	*Set 2 (ppm)*
Mean	12.2195122	10.26829268
Variance	51.12560976	71.85121951
Observations	41	41
Pearson Correlation	0.809528686	
Hypothesized Mean Difference	0	
df	40	
t Stat	2.50643344	
P(T<=t) one-tail	0.008181059	
t Critical one-tail	1.303077053	
P(T<=t) two-tail	0.016362118	
t Critical two-tail	1.683851013	



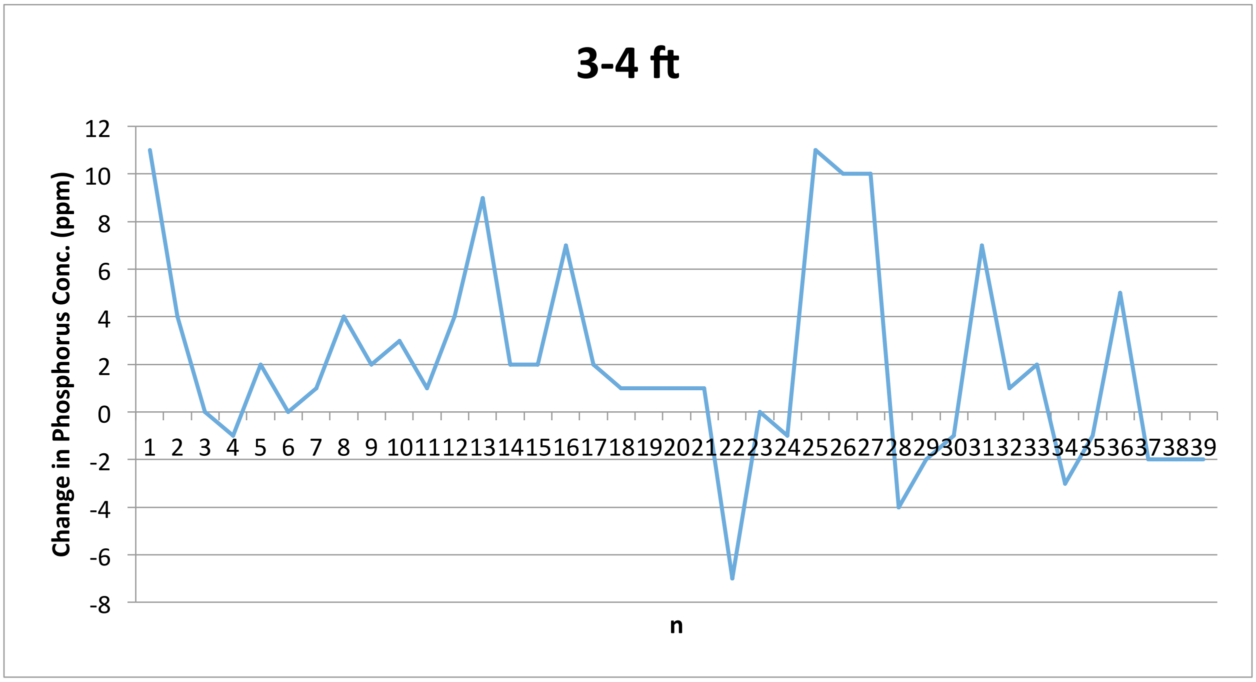
2 – 3 ft depth

	Set 1 (ppm)	*Set 2 (ppm)*
Mean	10.43902439	8.219512195
Variance	69.10243902	49.02560976
Observations	41	41
Pearson Correlation	0.796348149	
Hypothesized Mean Difference	0	
df	40	
t Stat	2.81847233	
P(T<=t) one-tail	0.003732862	
t Critical one-tail	1.303077053	
P(T<=t) two-tail	0.007465723	
t Critical two-tail	1.683851013	



3 – 4 ft depth

	Set 1 (ppm)	*Set 2 (ppm)*
Mean	10.66666667	8.666666667
Variance	93.33333333	56.96491228
Observations	39	39
Pearson Correlation	0.909363229	
Hypothesized Mean Difference	0	
df	38	
t Stat	2.970088984	
P(T<=t) one-tail	0.002568147	
t Critical one-tail	1.304230204	
P(T<=t) two-tail	0.005136293	
t Critical two-tail	1.68595446	



Lab Analysis Results

Field ID	Depth	pH		Phosphorus (ppm)		%OM		% Sand	% Silt	%Clay	Texture
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2				
IA2-T1	0-1	6.5	6.2	30	29	5.1	5.8	21	46	33	Clay Loam
IA2-T1	1-2	7.5	6.9	7	6	2.9	4.6	32	35	33	Clay Loam
IA2-T1	2-3	7.6	7.5	3	5	1.5	2.7	36	33	31	Clay Loam
IA2-T1	3-4	8.1	7.6	5	5	0.9	1.6	50	19	31	Sandy Clay Loam
IA2-T2	0-1	6.3	5.7	23	24	3.7	3.9	38	34	28	Clay Loam
IA2-T2	1-2	6.7	5.9	8	9	3.1	3.7	36	38	26	Loam
IA2-T2	2-3	7.1	6.5	3	4	1.8	2.5	32	39	29	Clay Loam
IA2-T2	3-4	7.5	6.9	1	2	1	1.4	29	41	30	Clay Loam
IA2-T3	0-1	6.7	6.7	17	15	3.6	4.1	34	36	30	Clay Loam
IA2-T3	1-2	7.2	7.4	4	3	2.6	3.6	34	36	30	Clay Loam
IA2-T3	2-3	7.8	7.8	3	5	1.3	2.4	38	33	29	Clay Loam
IA2-T3	3-4	8.1	-	2	-	0.9	-	35	36	29	Clay Loam
IA3-TE	0-1	6.8	6.7	48	43	4.8	5.3	20	54	26	Silt Loam
IA3-TE	1-2	7	6.9	22	13	4.1	5.0	20	48	32	Silty Clay Loam
IA3-TE	2-3	7	7.0	22	17	2.8	2.9	29	39	32	Clay Loam
IA3-TE	3-4	7.4	7.2	28	17	1.6	1.9	26	41	33	Clay Loam
IA3-TW	0-1	7.1	6.9	51	56	3.1	3.7	33	46	21	Loam
IA3-TW	1-2	7.1	6.6	27	22	3.7	3.6	32	47	21	Loam
IA3-TW	2-3	7.1	6.7	28	20	4.9	4.9	25	50	25	Loam
IA3-TW	3-4	7.1	6.8	28	24	4.2	3.8	17	51	32	Silty Clay Loam
IL1-T1	0-1	6.2	6.3	23	21	3.3	3.3	11	63	26	Silt Loam
IL1-T1	1-2	6.6	6.1	12	11	2.8	2.5	12	56	32	Silty Clay Loam
IL1-T1	2-3	7	6.6	10	8	2	2.0	11	54	35	Silty Clay Loam
IL1-T1	3-4	7.3	6.9	9	7	1.7	1.5	11	55	34	Silty Clay Loam
IL1-T2	0-1	6.6	6.6	20	19	2.8	3.1	13	63	24	Silt Loam
IL1-T2	1-2	7.2	7.0	9	5	2.4	2.4	19	54	27	Silty Clay Loam
IL1-T2	2-3	7.5	7.1	10	1	2.1	1.9	19	49	32	Silty Clay Loam

Field ID	Depth	pH		Phosphorus (ppm)		%OM		% Sand	% Silt	% Clay	Texture
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2				
IL1-T2	3-4	7.5	7.4	15	13	1.9	1.6	17	49	34	Silty Clay Loam
IL1-T3	0-1	6.5	6.5	28	20	2.4	2.8	18	57	25	Silt Loam
IL1-T3	1-2	6.7	6.5	18	11	2.6	2.6	17	56	27	Silt Loam
IL1-T3	2-3	7.3	7.0	17	11	2.4	1.9	21	49	30	Clay Loam
IL1-T3	3-4	7.2	7.4	19	12	2.1	1.6	17	52	31	Silty Clay Loam
IL2-T1	0-1	6.7	6.6	24	21	3.8	3.9	5	64	31	Silty Clay Loam
IL2-T1	1-2	7.3	7.0	6	6	3.4	2.9	3	58	39	Silty Clay Loam
IL2-T1	2-3	7.5	7.2	3	4	2.4	2.6	3	57	40	Silty Clay Loam
IL2-T1	3-4	-	7.2	-	1	-	1.9	-	-	-	-
IL2-T2	0-1	6.7	6.5	18	10	3.8	3.6	5	64	31	Silty Clay Loam
IL2-T2	1-2	7.4	6.8	6	4	3	2.8	7	54	39	Silty Clay Loam
IL2-T2	2-3	7.4	7.4	3	8	2.1	2.2	7	53	40	Silty Clay Loam
IL2-T2	3-4	7.7	7.2	2	0	1.7	1.9	4	59	37	Silty Clay Loam
IL2-T3	0-1	6.8	6.4	11	9	3.3	3.7	5	64	31	Silty Clay Loam
IL2-T3	1-2	7.4	6.8	3	2	3.1	3.3	4	57	39	Silty Clay Loam
IL2-T3	2-3	7.5	7.4	2	0	2.1	2.3	3	59	38	Silty Clay Loam
IL2-T3	3-4	7.5	7.2	3	2	2.1	1.7	8	72	20	Silt Loam
IL3-T1	0-1	8.1	6.4	19	15	2.8	2.6	29	43	28	Clay Loam
IL3-T1	1-2	8.1	7.1	16	14	2.6	2.6	19	46	35	Silty Clay Loam
IL3-T1	2-3	8	7.2	4	2	2.3	2.2	19	44	37	Silty Clay Loam
IL3-T1	3-4	8.1	7.2	3	2	2	1.8	15	46	39	Silty Clay Loam
IL3-T2	0-1	8	7.9	23	17	2.7	2.5	33	44	23	Loam
IL3-T2	1-2	8.1	7.8	16	14	2.5	2.4	27	44	29	Clay Loam
IL3-T2	2-3	8	7.9	6	5	2.5	2.3	27	43	30	Clay Loam
IL3-T2	3-4	8.3	7.9	4	3	1.8	1.6	27	42	31	Clay Loam
IL3-T3	0-1	8.1	7.7	26	16	2.5	2.6	30	43	27	Clay Loam
IL3-T3	1-2	7.9	7.9	12	9	2.6	2.3	23	45	32	Clay Loam
IL3-T3	2-3	7.8	7.9	5	3	2.9	2.7	14	49	37	Silty Clay Loam

Field ID	**Depth**	**pH**		**Phosphorus (ppm)**		**%OM**		**% Sand**	**% Silt**	**% Clay**	**Texture**
		Set 1	**Set 2**	**Set 1**	**Set 2**	**Set1**	**Set 2**				
IL3-T3	3-4	8	8.0	4	3	2	1.5	13	49	38	Silty Clay Loam
IL4-T1	0-1	7.3	7.9	45	32	3.6	3.1	26	53	21	Silt Loam
IL4-T1	1-2	7.5	8.0	18	26	3	2.6	27	48	25	Loam
IL4-T1	2-3	7.4	7.9	15	15	2.9	2.5	27	45	28	Clay Loam
IL4-T1	3-4	7.6	7.9	10	17	2	2.5	30	41	29	Clay Loam
IL4-T2	0-1	6.8	7.7	66	44	3.5	3.5	25	54	21	Silt Loam
IL4-T2	1-2	7.2	7.5	24	29	3.5	3.1	21	54	25	Silt Loam
IL4-T2	2-3	7.3	7.5	13	17	3.3	3.1	30	43	27	Clay Loam
IL4-T2	3-4	7.5	7.5	9	9	2.5	2.9	31	40	29	Clay Loam
IL4-T3	0-1	7.1	6.9	47	46	3.3	2.7	27	52	21	Silt Loam
IL4-T3	1-2	7.4	7.1	11	22	3.2	2.5	22	53	25	Silt Loam
IL4-T3	2-3	7.3	7.4	8	10	2.9	2.7	25	46	29	Clay Loam
IL4-T3	3-4	7.6	7.3	7	8	1.9	2.5	41	34	25	Loam
IL5-T1	0-1	6.2	7.2	37	26	3.1	3.7	7	70	23	Silt Loam
IL5-T1	1-2	6.4	6.7	20	19	3	2.9	5	71	24	Silt Loam
IL5-T1	2-3	6.5	6.2	28	24	3.7	3.5	7	66	27	Silty Clay Loam
IL5-T1	3-4	6.7	6.7	41	30	3.6	3.7	11	56	33	Silty Clay Loam
IL5-T2	0-1	6.2	6.3	18	14	2.9	3.3	17	64	19	Silt Loam
IL5-T2	1-2	6.2	6.2	20	11	3.1	3.3	13	68	19	Silt Loam
IL5-T2	2-3	6.1	5.8	24	14	3.2	3.9	13	66	21	Silt Loam
IL5-T2	3-4	6.5	6.1	20	10	1.9	3.3	15	56	29	Silty Clay Loam
IL5-T3	0-1	6.3	6.3	15	19	2.6	3.3	13	66	21	Silt Loam
IL5-T3	1-2	6.3	6.2	11	7	2.2	2.6	22	57	21	Silt Loam
IL5-T3	2-3	5.9	6.0	15	8	2.7	2.4	22	56	22	Silt Loam
IL5-T3	3-4	5.6	5.9	23	13	4.2	3.5	15	58	27	Silty Clay Loam
IN1-T1	0-1	7.1	6.9	18	15	4.8	5.4	54	34	12	Sandy Loam
IN1-T1	1-2	7.5	7.2	13	4	2.8	2.9	55	29	16	Sandy Loam
IN1-T1	2-3	7.7	7.4	8	4	1.7	2.0	53	30	17	Sandy Loam

Field ID	Depth	pH		Phosphorus (ppm)		%OM		% Sand	% Silt	% Clay	Texture
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2				
IN1-T1	3-4	8	7.6	6	4	1.2	1.3	53	31	16	Sandy Loam
IN1-T2	0-1	7.3	6.9	11	10	4.7	5.0	55	34	11	Sandy Loam
IN1-T2	1-2	7.6	7.2	5	2	2.4	2.4	59	25	16	Sandy Loam
IN1-T2	2-3	7.8	7.4	4	2	1.3	1.4	67	16	17	Sandy Loam
IN1-T2	3-4	8.1	7.5	4	4	1.2	1.2	48	33	19	Loam
IN1-T3	0-1	7.3	7.3	12	7	3.3	3.8	55	33	12	Sandy Loam
IN1-T3	1-2	7.5	7.4	9	3	3.3	3.4	57	31	12	Sandy Loam
IN1-T3	2-3	7.7	7.6	6	2	1.8	2.0	57	25	18	Sandy Loam
IN1-T3	3-4	7.8	7.8	5	4	1.3	1.3	53	27	20	Sandy Loam
IN2-T1	0-1	7.6	7.1	35	27	3.3	3.9	35	41	24	Loam
IN2-T1	1-2	7.7	7.6	4	3	2.2	2.7	37	36	27	Loam
IN2-T1	2-3	7.9	7.3	4	2	1.3	1.4	39	33	28	Clay Loam
IN2-T1	3-4	7.8	7.7	4	0	1.2	1.2	29	39	32	Clay Loam
IN2-T2	0-1	7.8	7.6	16	7	3.2	3.5	32	42	26	Loam
IN2-T2	1-2	7.7	7.7	3	1	1.8	2.4	25	43	32	Clay Loam
IN2-T2	2-3	8.1	8.0	4	1	1.1	1.3	43	35	22	Loam
IN2-T2	3-4	8.1	8.2	2	0	1.1	1.0	35	43	22	Loam
IN2-T3	0-1	7.8	7.7	38	17	3.8	4.0	32	45	23	Loam
IN2-T3	1-2	7.6	7.7	7	4	2.7	3.5	44	32	24	Loam
IN2-T3	2-3	7.5	7.8	6	4	1.5	2.2	51	27	22	Sandy Clay Loam
IN2-T3	3-4	7.8	7.9	5	2	0.9	1.3	51	28	21	Sandy Clay Loam
IN3-T1	0-1	7.9	7.5	32	35	3.8	3.9	26	54	20	Silt Loam
IN3-T1	1-2	7.8	7.8	10	6	3.6	3.7	25	54	21	Silt Loam
IN3-T1	2-3	7.9	7.8	8	6	2.9	2.7	25	52	23	Silt Loam
IN3-T1	3-4	7.9	7.8	6	5	1.9	1.6	25	49	26	Loam
IN3-T2	0-1	8.1	7.7	20	26	2.7	3.2	34	45	21	Loam
IN3-T2	1-2	8	8.0	23	9	2.9	2.2	30	49	21	Loam
IN3-T2	2-3	8.1	7.9	36	15	3.1	3.0	39	42	19	Loam

Field ID	Depth	pH		Phosphorus (ppm)		%OM		% Sand	% Silt	% Clay	Texture
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2				
IN3-T2	3-4	8.1	8.0	26	22	2.3	2.1	42	39	19	Loam
IN3-T3	0-1	7.9	7.5	35	40	4.2	3.9	15	62	23	Silt Loam
IN3-T3	1-2	8.1	7.8	12	13	2.6	2.5	34	47	19	Loam
IN3-T3	2-3	8.1	8.0	11	5	2.1	1.9	41	40	19	Loam
IN3-T3	3-4	8	8.0	14	5	1.7	1.6	43	37	20	Loam
MN1-T1	0-1	7.9	7.6	8	7	2.8	2.9	22	53	25	Silt Loam
MN1-T1	1-2	7.9	7.4	6	5	3.6	3.7	20	53	27	Silty Clay Loam
MN1-T1	2-3	7.8	8.0	4	5	3	3.1	18	49	33	Silty Clay Loam
MN1-T1	3-4	8	8.1	1	5	2.5	2.1	10	49	41	Silty Clay
MN1-T2	0-1	8.1	8.0	8	6	2.4	2.4	33	44	23	Loam
MN1-T2	1-2	8	8.0	13	5	3.5	3.0	25	47	28	Clay Loam
MN1-T2	2-3	7.9	8.0	5	5	3.1	2.7	18	45	37	Silty Clay Loam
MN1-T2	3-4	8	8.1	3	5	2.4	2.2	12	45	43	Silty Clay
MN1-T3	0-1	8.2	8.0	9	9	2.2	2.4	37	44	19	Loam
MN1-T3	1-2	8.4	8.1	2	5	1.9	2.1	39	42	19	Loam
MN1-T3	2-3	8.1	8.0	8	5	3.5	3.3	28	47	25	Loam
MN1-T3	3-4	7.9	8.0	4	5	2.8	2.4	18	49	33	Silty Clay Loam
MN2-T1	0-1	6.8	6.6	32	32	8.5	8.1	20	55	25	Silt Loam
MN2-T1	1-2	7.2	7.2	26	26	6.7	6.5	31	48	21	Loam
MN2-T1	2-3	7.4	7.1	21	15	6.6	7.5	32	49	19	Loam
MN2-T1	3-4	7.3	6.9	22	15	6.5	8.4	28	51	21	Silt Loam
MN2-T2	0-1	6.6	6.0	34	26	6.5	6.0	36	49	15	Loam
MN2-T2	1-2	6.6	6.8	13	8	7.4	7.5	30	56	14	Silt Loam
MN2-T2	2-3	6.5	6.1	12	8	7.8	5.3	36	50	14	Loam
MN2-T2	3-4	6.6	6.8	8	7	3.6	2.0	44	33	23	Loam
MN2-T3	0-1	6.1	5.8	33	45	5.3	4.8	40	47	13	Loam
MN2-T3	1-2	6.2	6.2	12	8	4.6	3.9	34	50	16	Loam
MN2-T3	2-3	6.4	6.2	11	5	2.4	2.5	32	43	25	Loam

Field ID	**Depth**	**pH**		**Phosphorus (ppm)**		**%OM**		**% Sand**	**% Silt**	**% Clay**	**Texture**
		Set 1	**Set 2**	**Set 1**	**Set 2**	**Set 1**	**Set 2**				
MN2-T3	3-4	6.7	6.7	11	9	1.5	1.1	34	39	27	Clay Loam
MN3-T1	0-1	7.4	7.0	31	32	6.3	6.8	25	54	21	Silt Loam
MN3-T1	1-2	7.5	7.2	14	15	4.5	4.5	22	52	26	Silt Loam
MN3-T1	2-3	7.7	7.3	14	17	4.5	5.8	21	53	26	Silt Loam
MN3-T1	3-4	7.5	7.5	16	19	5.7	5.2	20	53	27	Silty Clay Loam
MN3-T1	0-1	7.5	7.1	40	43	7.1	6.7	20	59	21	Silt Loam
MN3-T1	1-2	7.7	7.3	28	39	4.9	5.1	28	48	24	Loam
MN3-T1	2-3	7.6	7.1	22	33	5.7	5.8	26	51	23	Silt Loam
MN3-T1	3-4	7.4	7.4	25	26	7.4	5.3	42	37	21	Loam
MN3-T3	0-1	7.7	7.1	25	28	5.7	6.9	26	54	20	Silt Loam
MN3-T3	1-2	7.6	7.4	14	7	5.3	5.2	33	48	19	Loam
MN3-T3	2-3	7.1	7.3	10	7	4.9	4.5	34	43	23	Loam
MN3-T3	3-4	7.2	7.4	14	9	6.7	4.1	13	46	41	Silty Clay
MN4-T1	0-1	7.6	7.4	12	25	4.3	5.8	37	42	21	Loam
MN4-T1	1-2	7.7	7.6	7	5	2.3	3.3	16	55	29	Silty Clay Loam
MN4-T1	2-3	7.9	7.8	5	5	2.2	1.7	21	48	31	Clay Loam
MN4-T1	3-4	7.9	7.9	3	5	1.9	0.8	23	49	28	Clay Loam
MN4-T2	0-1	8	7.7	4	5	6.9	6.9	51	32	17	Loam
MN4-T2	1-2	8	7.9	4	5	4.4	3.2	16	51	33	Silty Clay Loam
MN4-T2	2-3	8	8.0	4	5	1.3	1.7	21	55	24	Silt Loam
MN4-T2	3-4	8.1	7.9	3	5	2.1	1.0	41	36	23	Loam
MN4-T3	0-1	7.5	6.7	13	6	5.8	5.8	37	40	23	Loam
MN4-T3	1-2	7.9	7.5	6	5	4.1	3.3	21	47	32	Clay Loam
MN4-T3	2-3	7.8	7.9	3	5	2.2	1.4	24	49	27	Clay Loam
MN4-T3	3-4	8.4	7.8	3	5	1.3	0.9	57	23	20	Sandy Loam

Appendix G – Streambank Stability Measurements

This section contains maps of sites IL-3 and IN-2 showing locations where the stream bank stability studies were performed. Graphical representations of the “before” and “after” surveys of the stream bank profiles for each transect are also given.

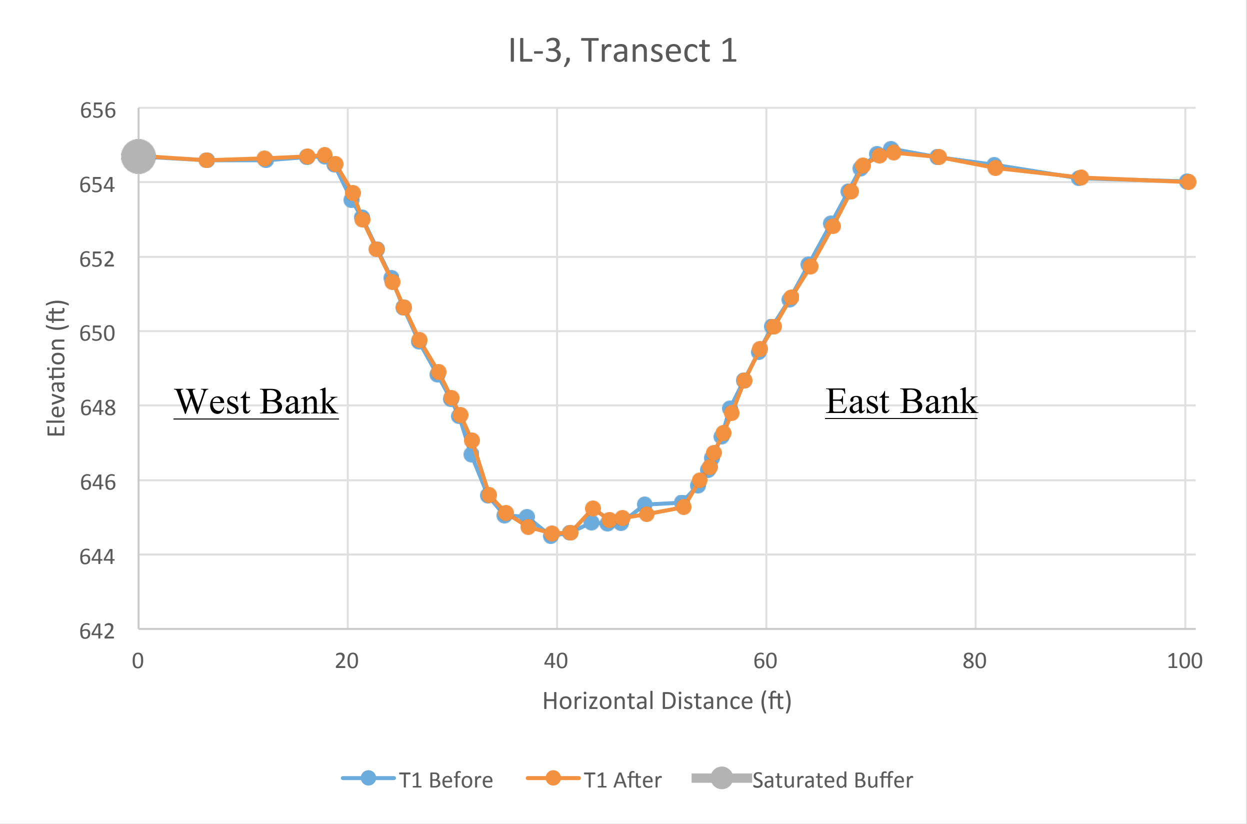
IL-3: Streambank Stability Measurements

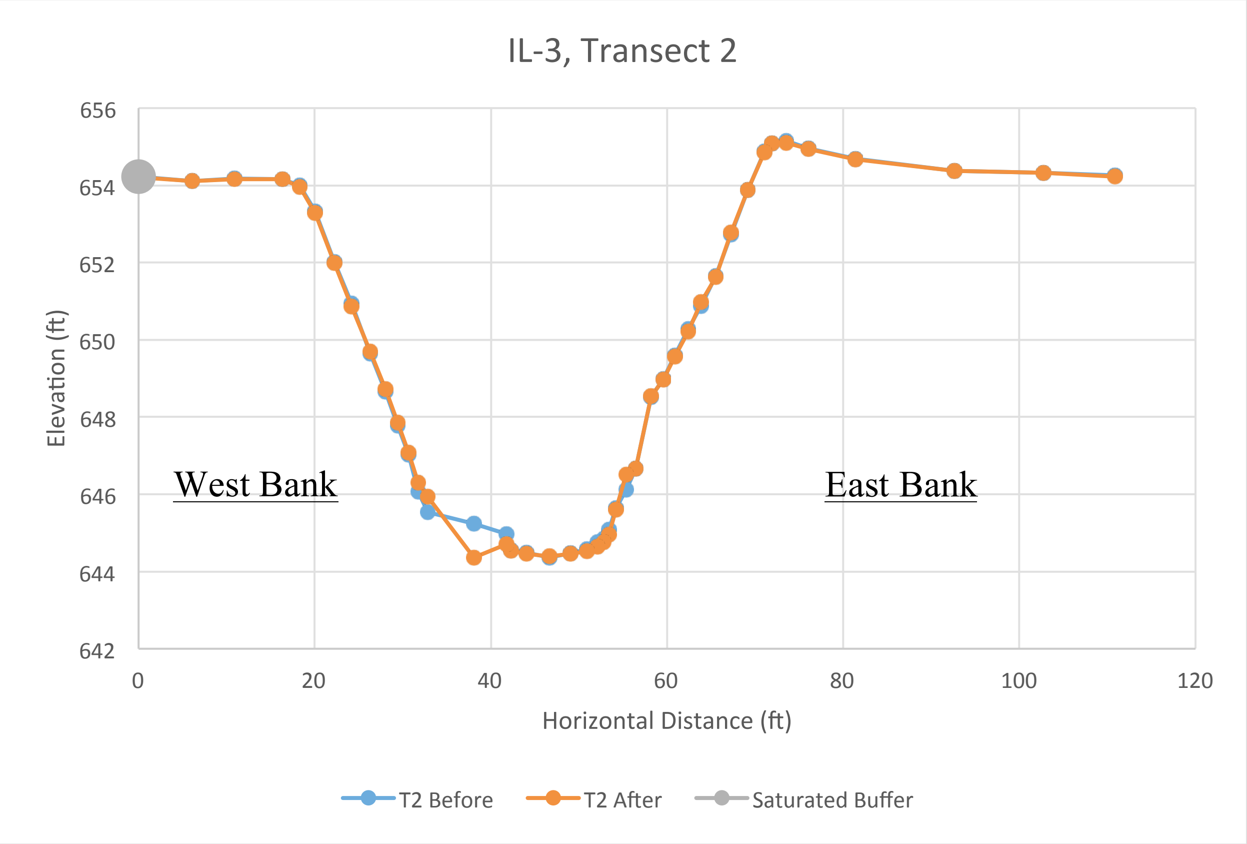
Lat/Long: 39.789 N, 87.852 W

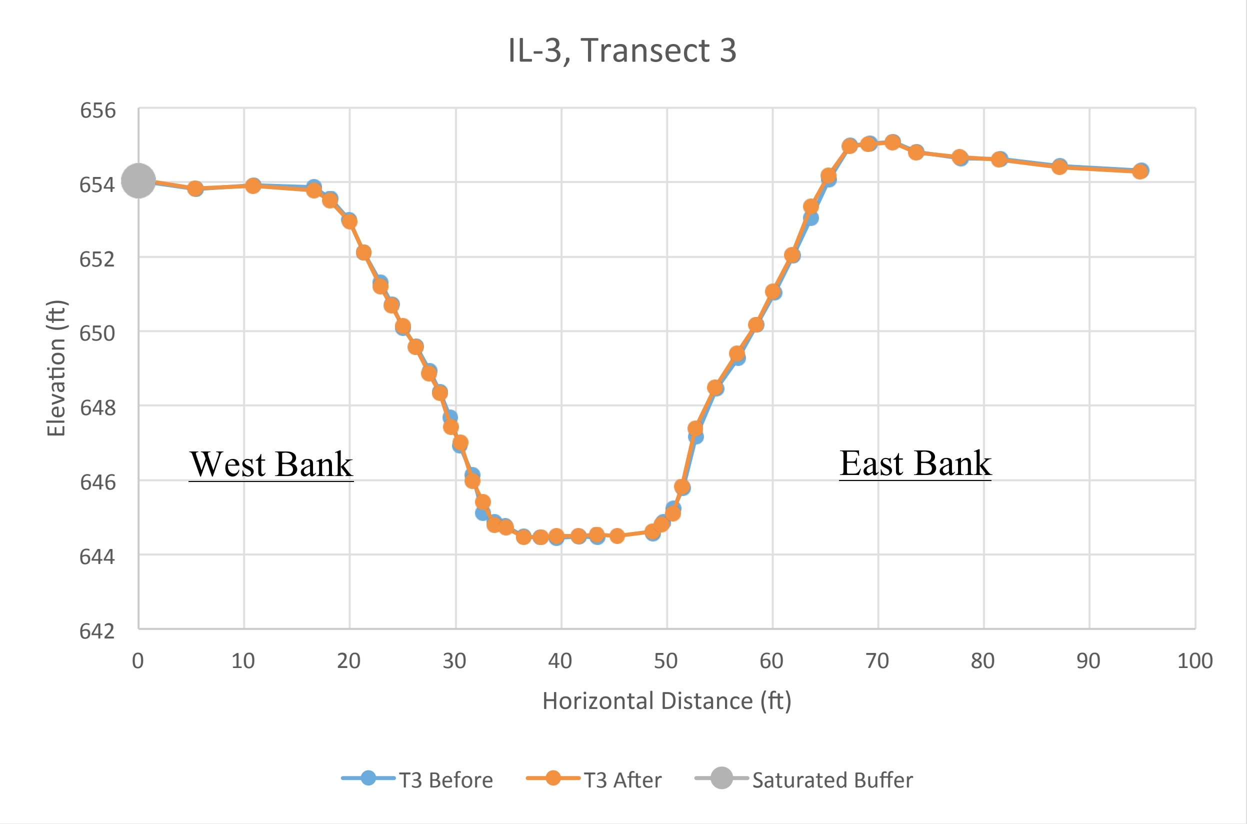
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

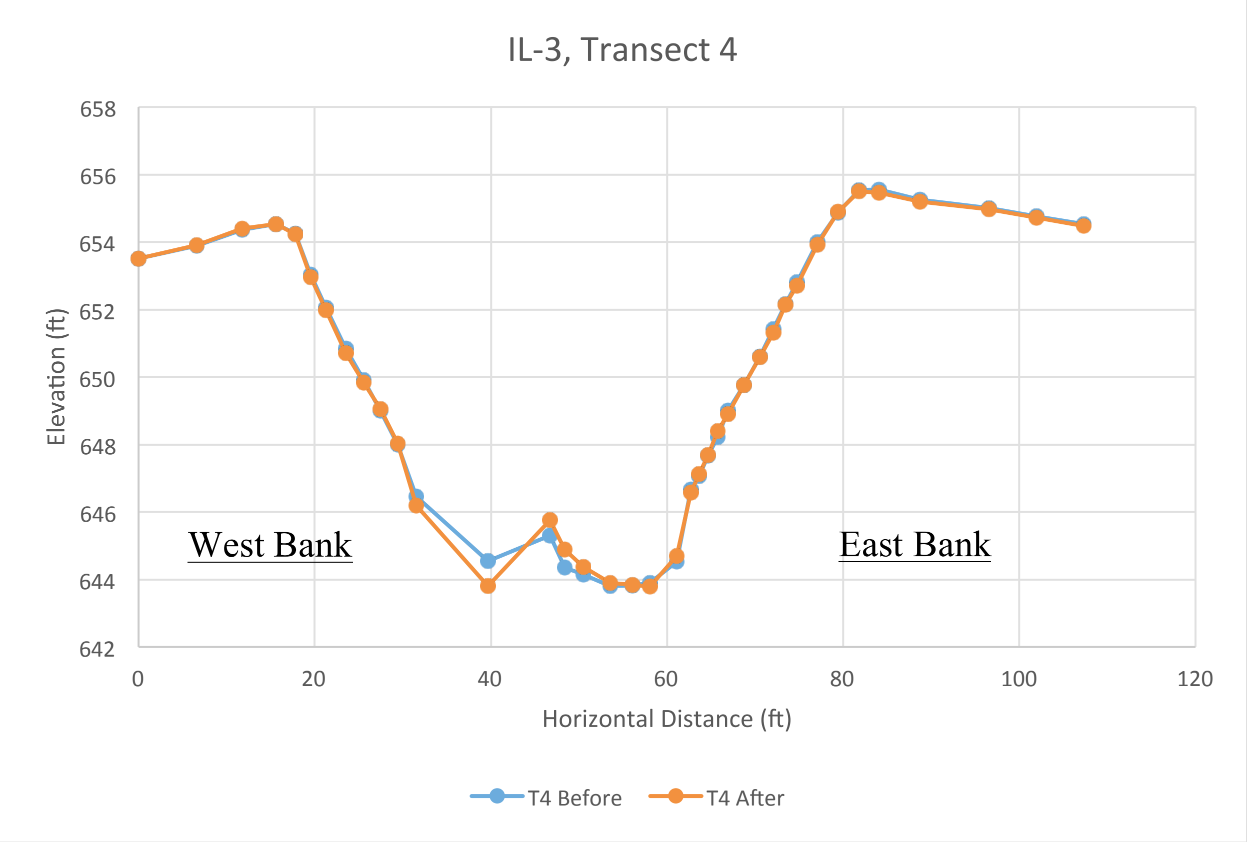
ESE
Ecosystem Services Exchange

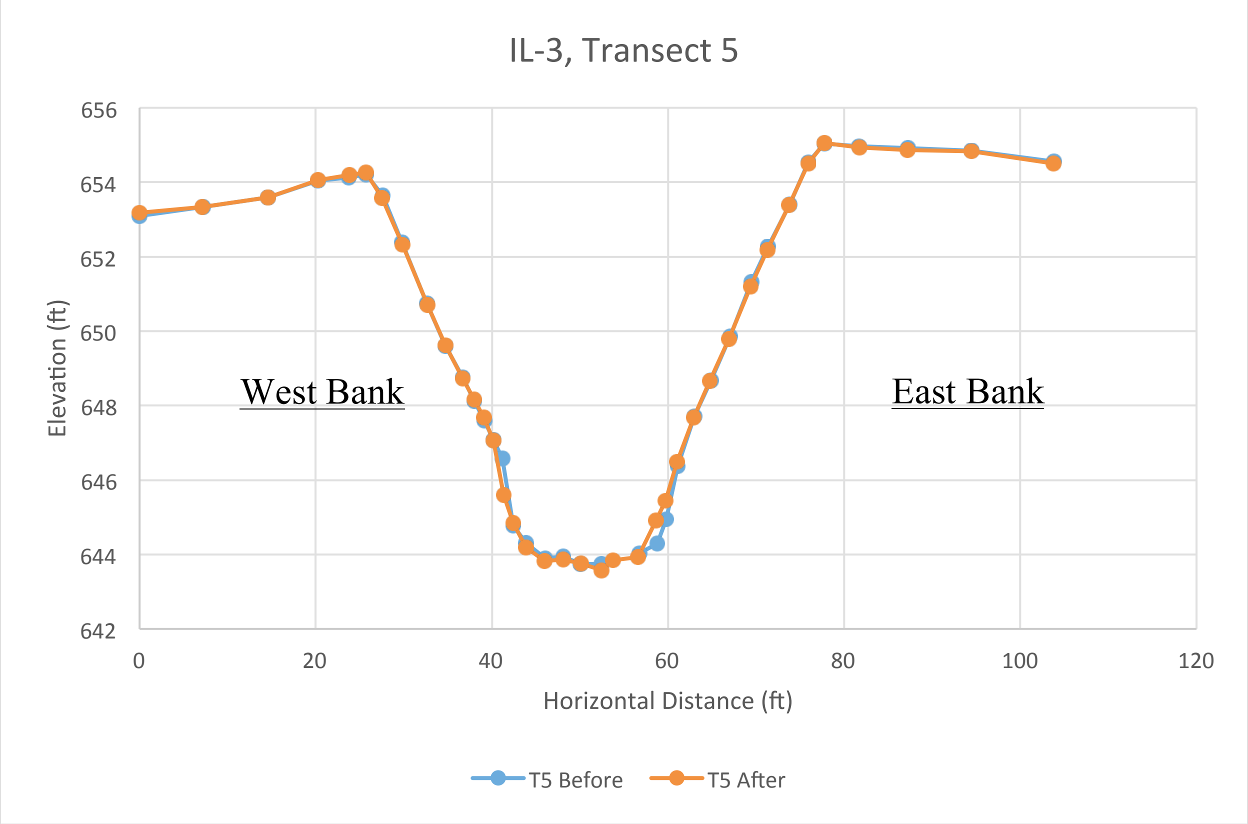
Map created by Nathan Utt 12/10/2015
nathan@EcoExch.com

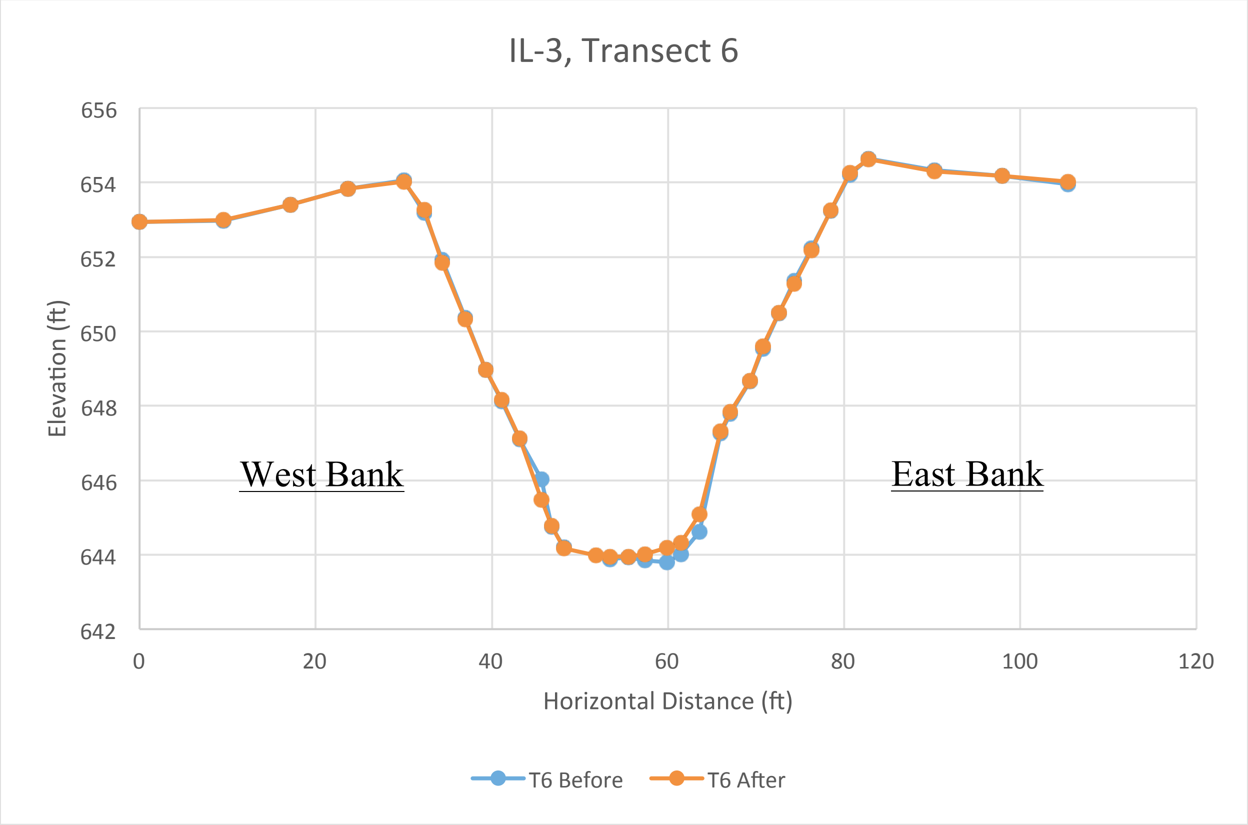

IL-3, Transect 1
656
654
652
650
648
646
644
642
Elevation (ft)
West Bank
East Bank
0
20
40
60
80
100
Horizontal Distance (ft)
T1 Before
T1 After
Saturated Buffer


IL-3, Transect 2
656
654
652
650
648
646
644
642
Elevation (ft)
West Bank
East Bank
0
20
40
60
80
100
120
Horizontal Distance (ft)
T2 Before
T2 After
Saturated Buffer


IL-3, Transect 3
Elevation (ft)
656
654
652
650
648
646
644
642
0
10
20
30
40
50
60
70
80
90
100
Horizontal Distance (ft)
West Bank
East Bank
T3 Before
T3 After
Saturated Buffer

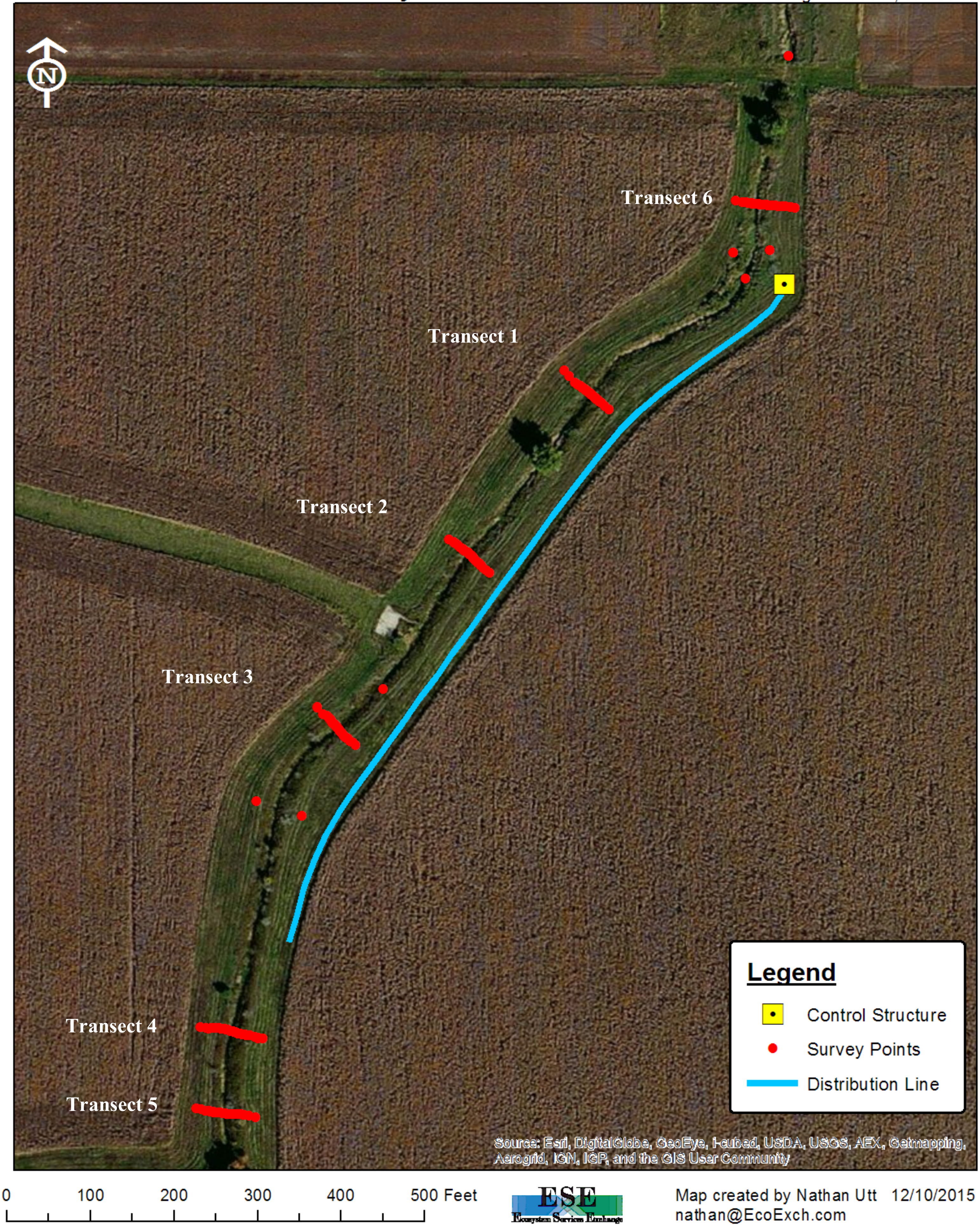

IL-3, Transect 4
Elevation (ft)
658
656
654
652
650
648
646
644
642
0
20
40
60
80
100
120
Horizontal Distance (ft)
West Bank
East Bank
T4 Before
T4 After


IL-3, Transect 5
656
654
652
650
648
646
644
642
Elevation (ft)
0
20
40
60
80
100
120
Horizontal Distance (ft)
West Bank
East Bank
T5 Before
T5 After


IL-3, Transect 6
656
654
652
650
648
646
644
642
Elevation (ft)
0
20
40
60
80
100
120
Horizontal Distance (ft)
West Bank
East Bank
T6 Before
T6 After

IN-2: Streambank Stability Measurements

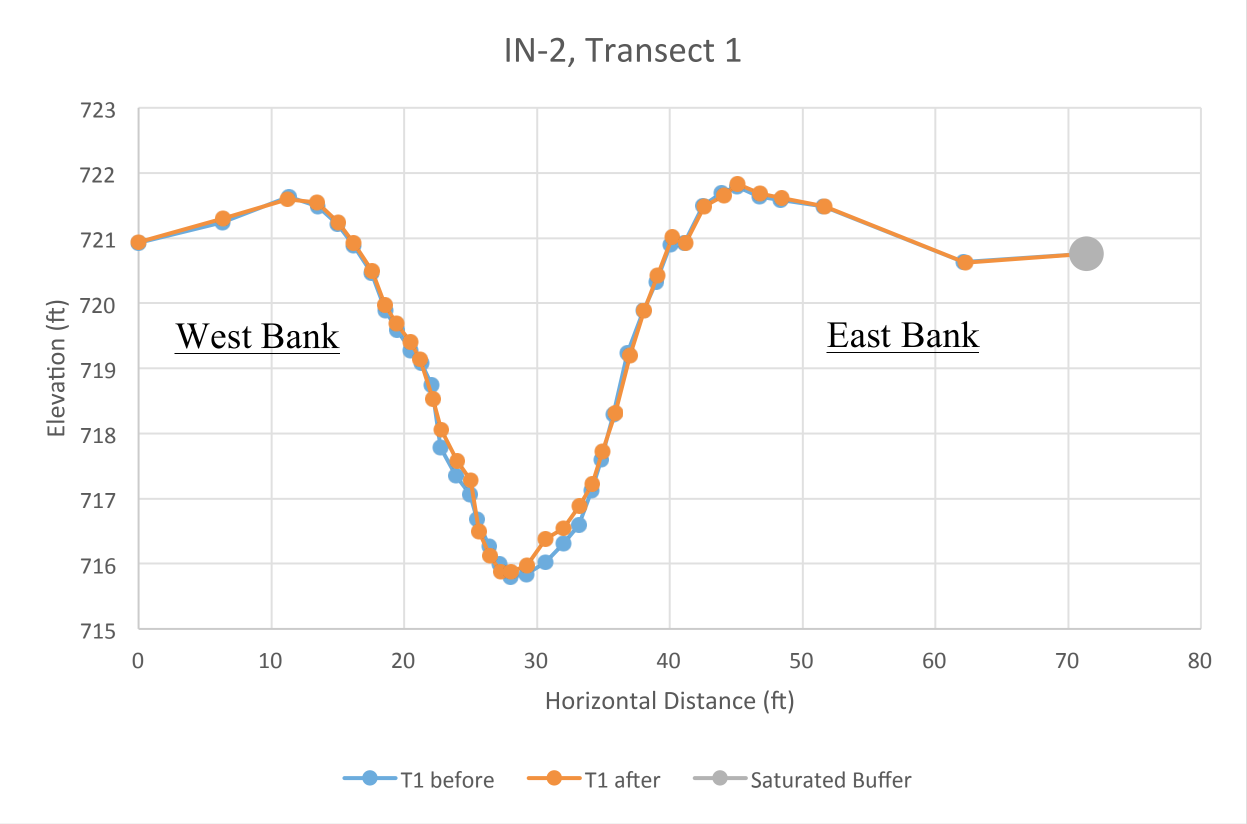
Lat/Long: 40.758 N, 87.186 W

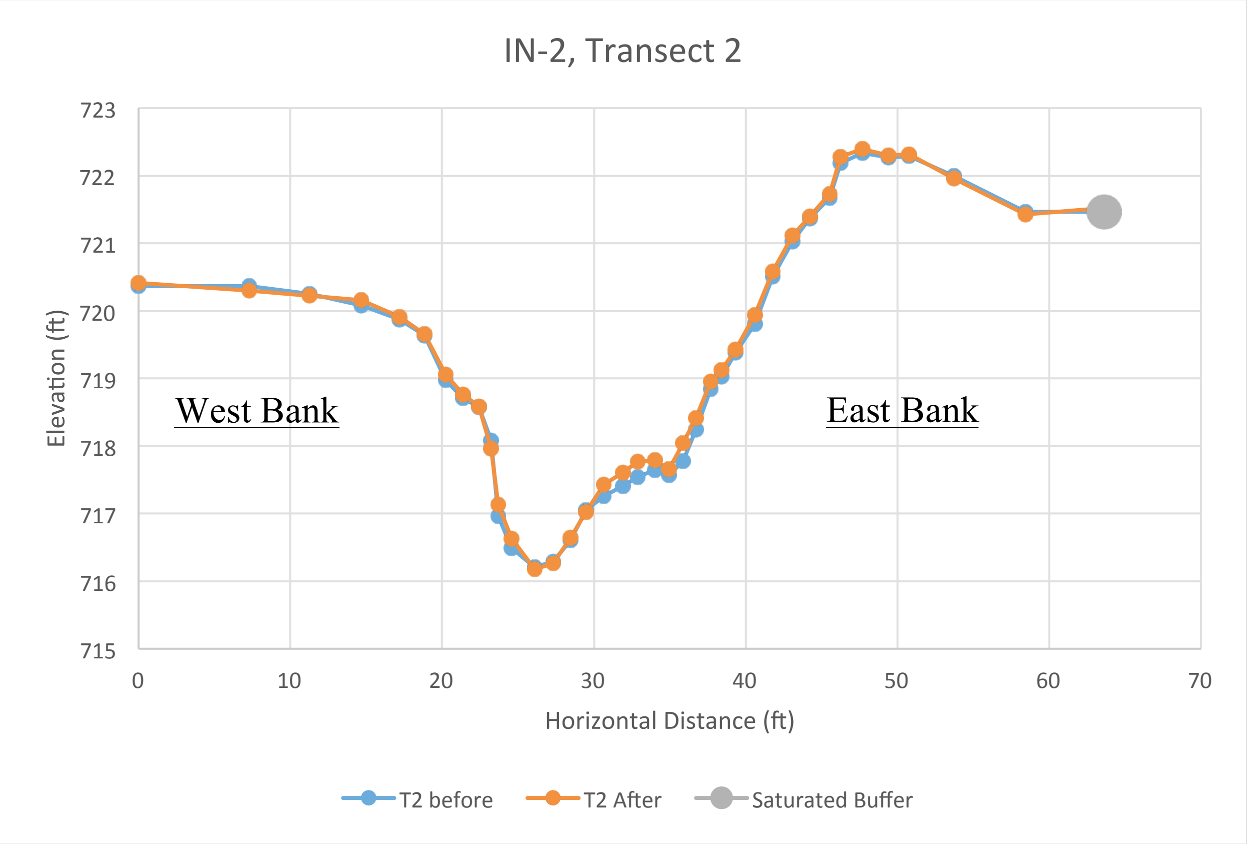


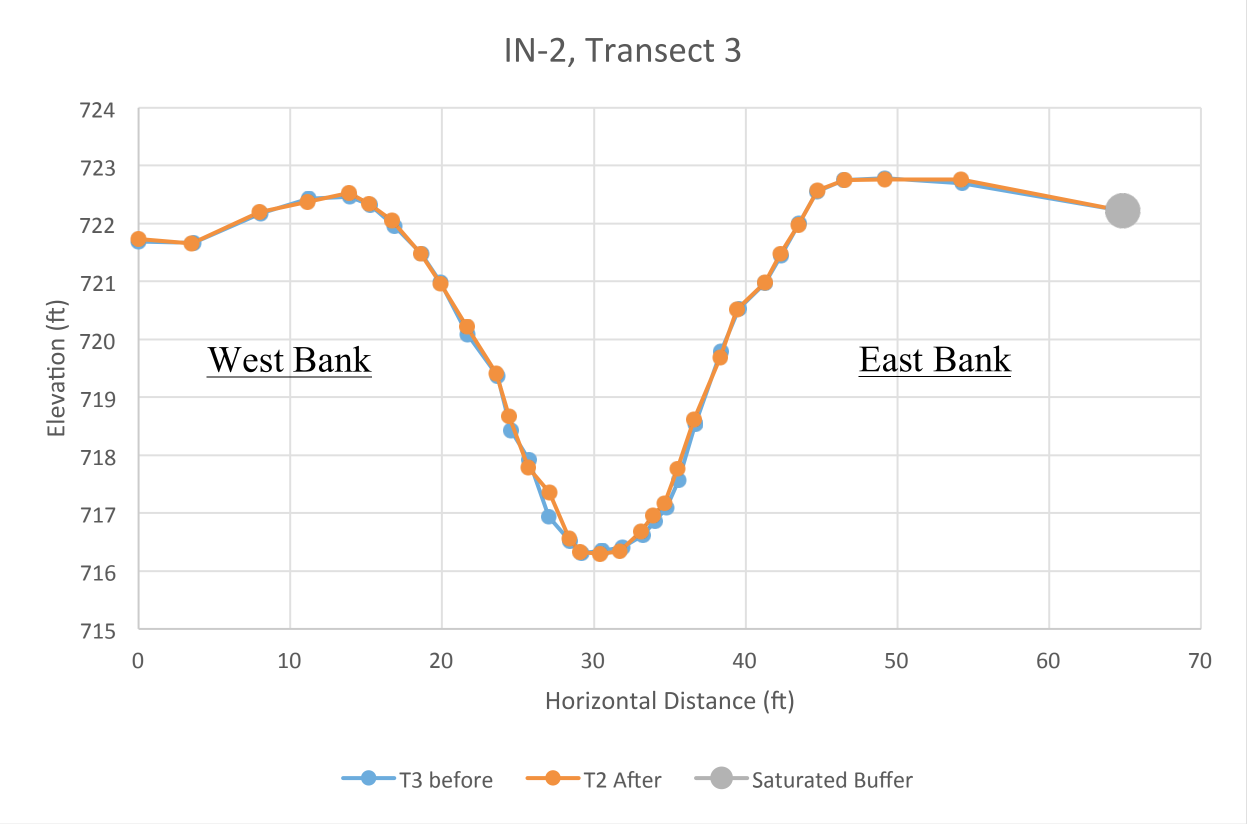
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

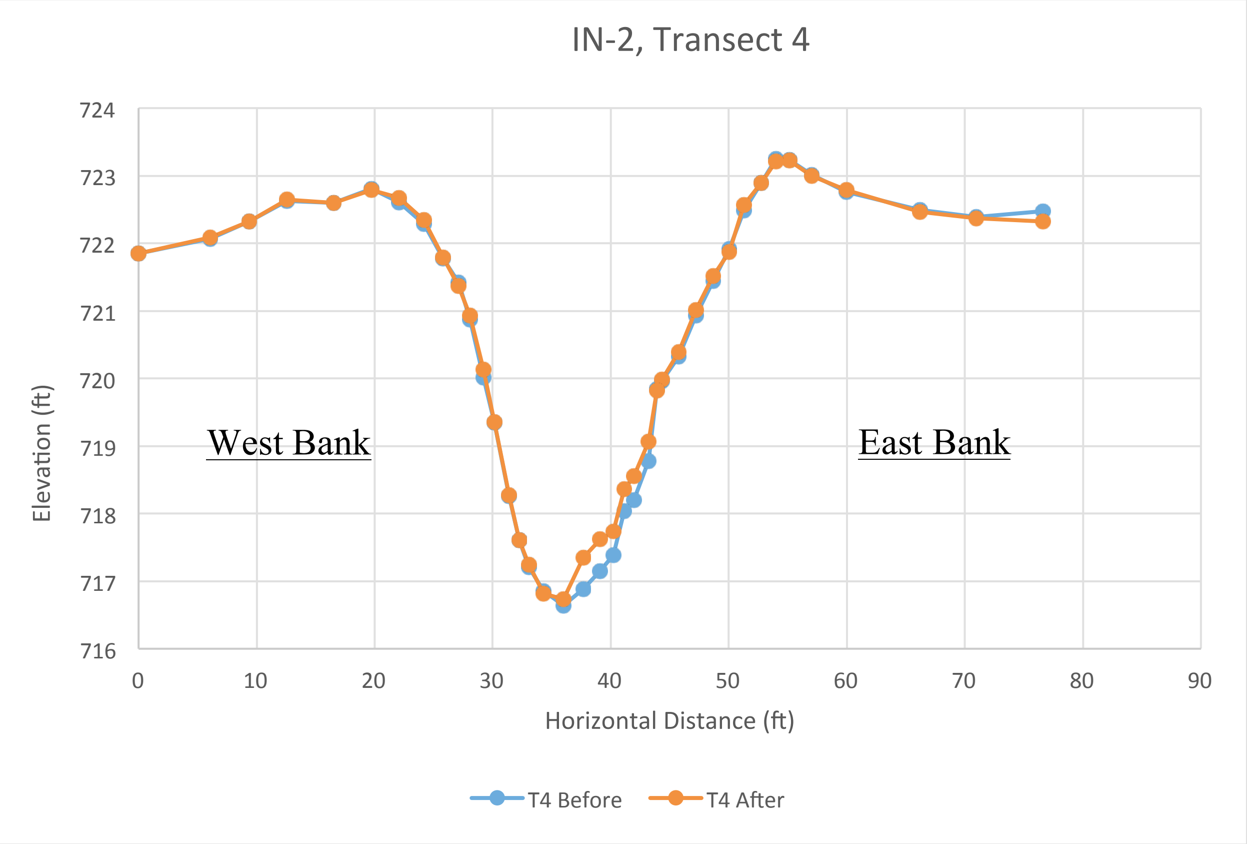
ESE Ecosystem Services Exchange

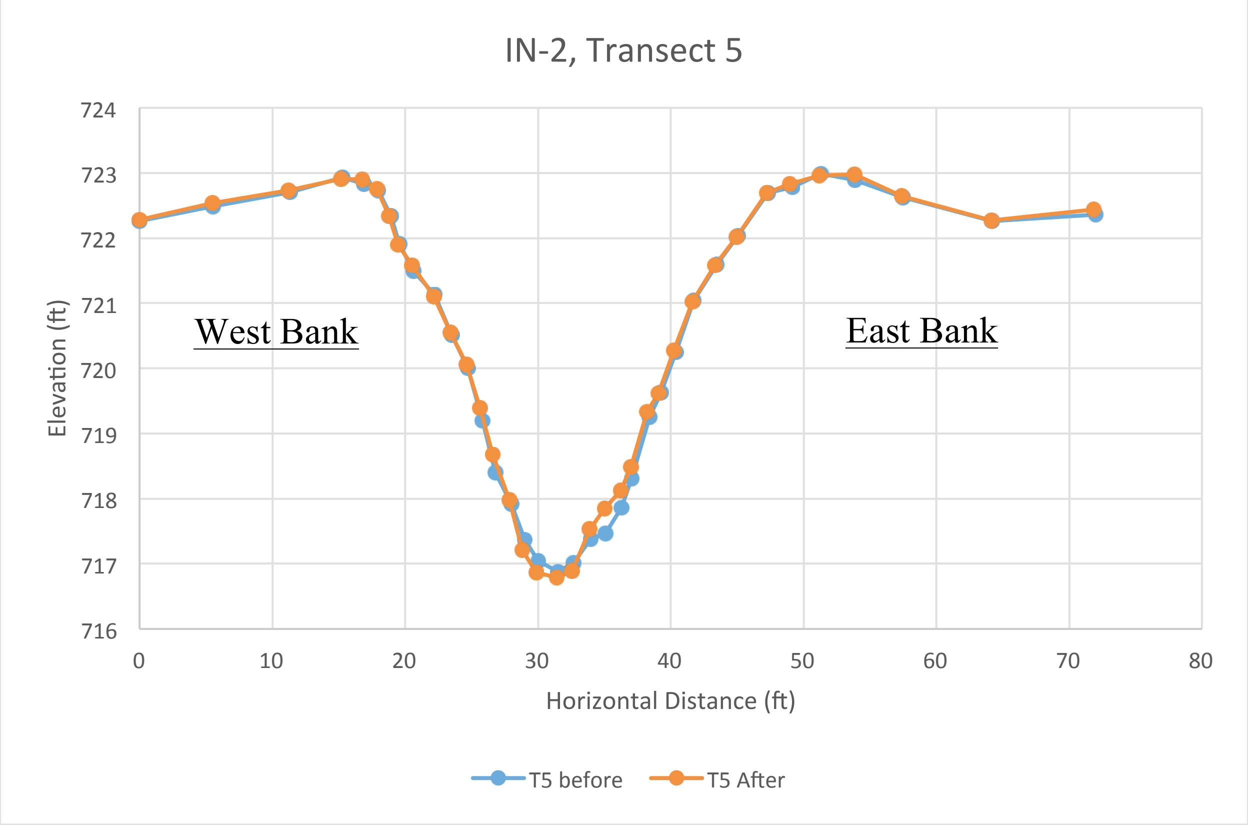
Map created by Nathan Utt 12/10/2015
nathan@EcoExch.com

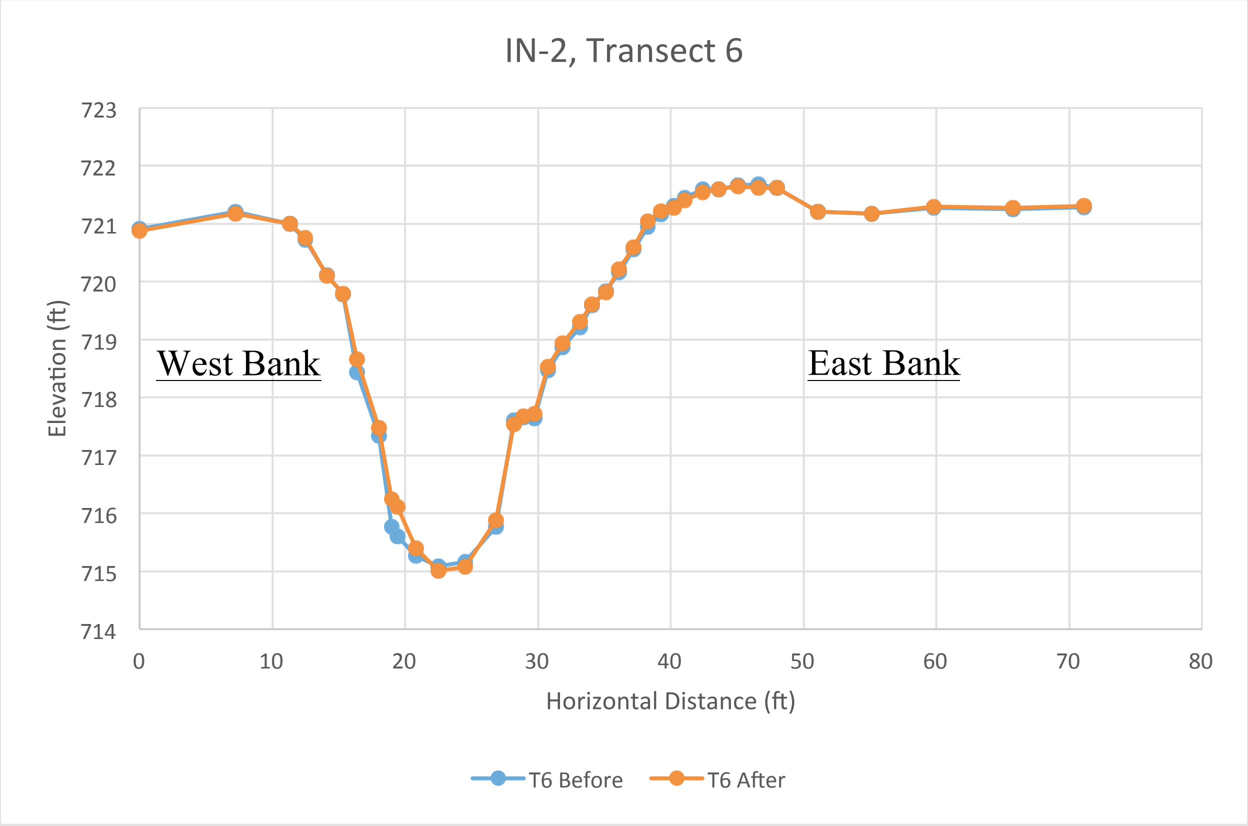

IN-2, Transect 1
723
722
721
720
719
718
717
716
715
Elevation (ft)
0
10
20
30
40
50
60
70
80
Horizontal Distance (ft)
West Bank
East Bank
T1 before
T1 after
Saturated Buffer


IN-2, Transect 2
723
722
721
720
719
718
717
716
715
Elevation (ft)
0
10
20
30
40
50
60
70
Horizontal Distance (ft)
West Bank
East Bank
T2 before
T2 After
Saturated Buffer


IN-2, Transect 3
Elevation (ft)
724
723
722
721
720
719
718
717
716
715
0
10
20
30
40
50
60
70
Horizontal Distance (ft)
West Bank
East Bank
T3 before
T2 After
Saturated Buffer


IN-2, Transect 4
Elevation (ft)
724
723
722
721
720
719
718
717
716
0
10
20
30
40
50
60
70
80
90
Horizontal Distance (ft)
West Bank
East Bank
T4 Before
T4 After


IN-2, Transect 5
Elevation (ft)
724
723
722
721
720
719
718
717
716
0
10
20
30
40
50
60
70
80
Horizontal Distance (ft)
West Bank
East Bank
T5 before
T5 After


IN-2, Transect 6
Elevation (ft)
723
722
721
720
719
718
717
716
715
714
0
10
20
30
40
50
60
70
80
Horizontal Distance (ft)
West Bank
East Bank
T6 Before
T6 After

Appendix H- Calculating Flow in Agri Drain Control Structures

The following equations are used for calculating flow rates through the control structures. The units of the variables are

$$H = inches$$
$$W = inches$$
$$Q = gpm$$

where H is the height of water above the stop log, W is the width of the weir (this varies with the control structure), and Q is the flow rate of water over the weir.

For a 6" control structure, flat weir:

$If \quad H \leq 0.44W, \qquad Q = 3.19924(W - 0.437H)H^{1.48}$

$If \quad H > 0.44W, \qquad Q = 3.3268WH^{1.20}$

For 8" – 24" control structures, flat weir:

$If \quad H \leq 0.27W, \qquad Q = 3.19924(W - 0.74H)H^{1.48}$

$If \quad H > 0.27W, \qquad Q = 3.0318WH^{1.37}$

Size	6 inch	8 inch	10 inch	12 inch	15 inch	18 inch	24 inch
Width(in) (W)	6.31	10.31	12.31	14.31	18.31	22.31	29.31

V – notch stop log

Stop logs with a V-notch cut into it can also be used for more accurately measuring low-flow conditions. The distance from the top of the stop log to the bottom of the V-notch is 6.56 inches, regardless of structure size. In this case, *H* is the height of water above the bottom of the V-notch. The V-notch is 45° and has a rounded bottom.

$If \quad H \leq 6.56, \quad Q = 2.5866H^{2.0464}$

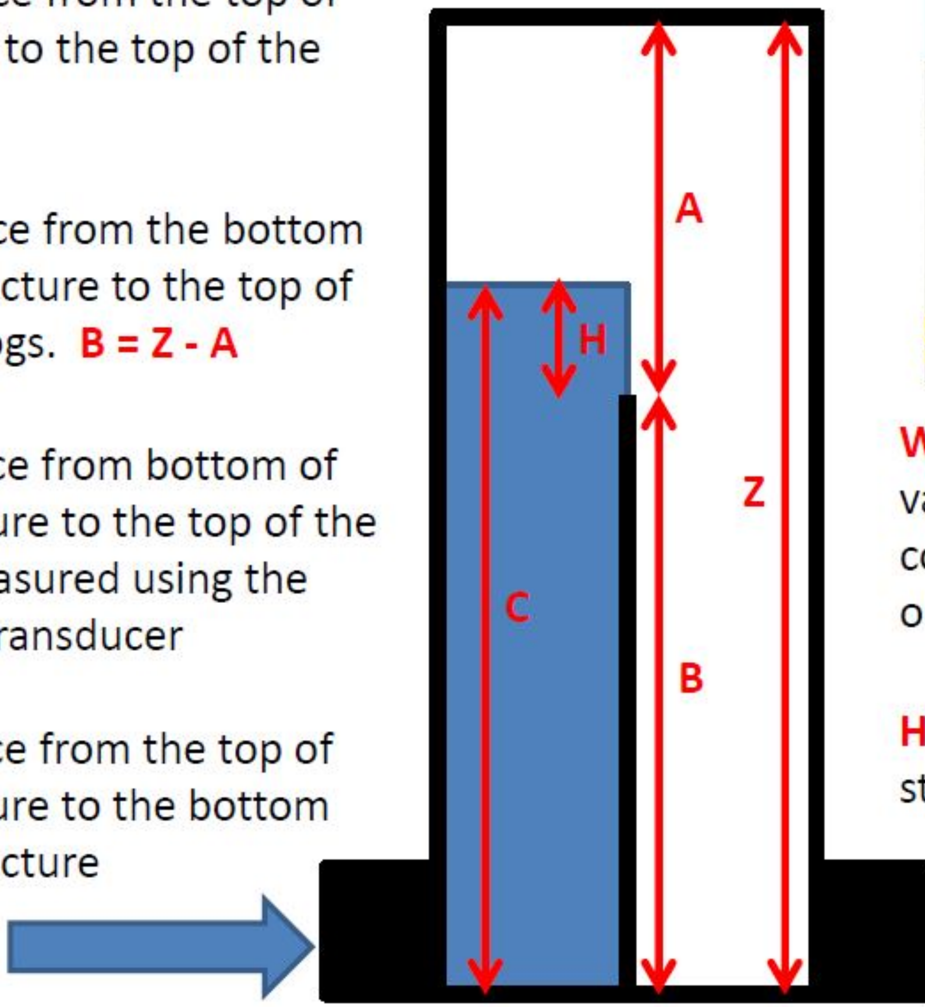
$If \quad H > 6.56, \quad Q = Q_{v-notch} + Q_{flat\ weir} \ = \ 2.5866(6.56)^{2.0464} + Q_{flat\ weir}$

A = distance from the top of structures to the top of the stop logs.

B = distance from the bottom of the structure to the top of the stop logs. **B = Z - A**

C = distance from bottom of the structure to the top of the water, measured using the pressure transducer

Z = distance from the top of the structure to the bottom of the structure



W = width of the weir. This value is manufactured to a consistent width, dependent on the size of the structure.

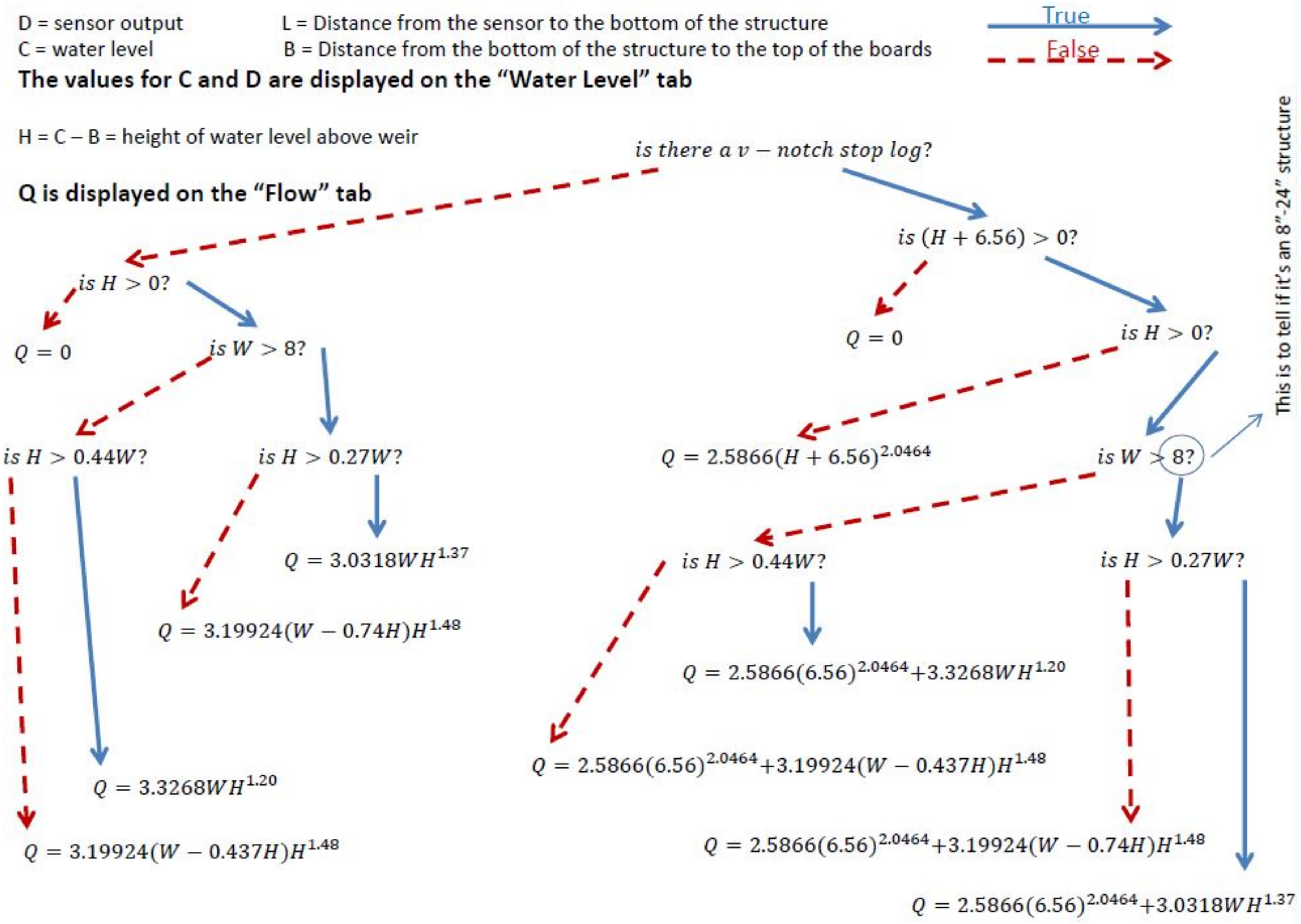
H = height of water above the stop logs **H = C – B**

D = sensor output
C = water level
L = Distance from the sensor to the bottom of the structure
B = Distance from the bottom of the structure to the top of the boards

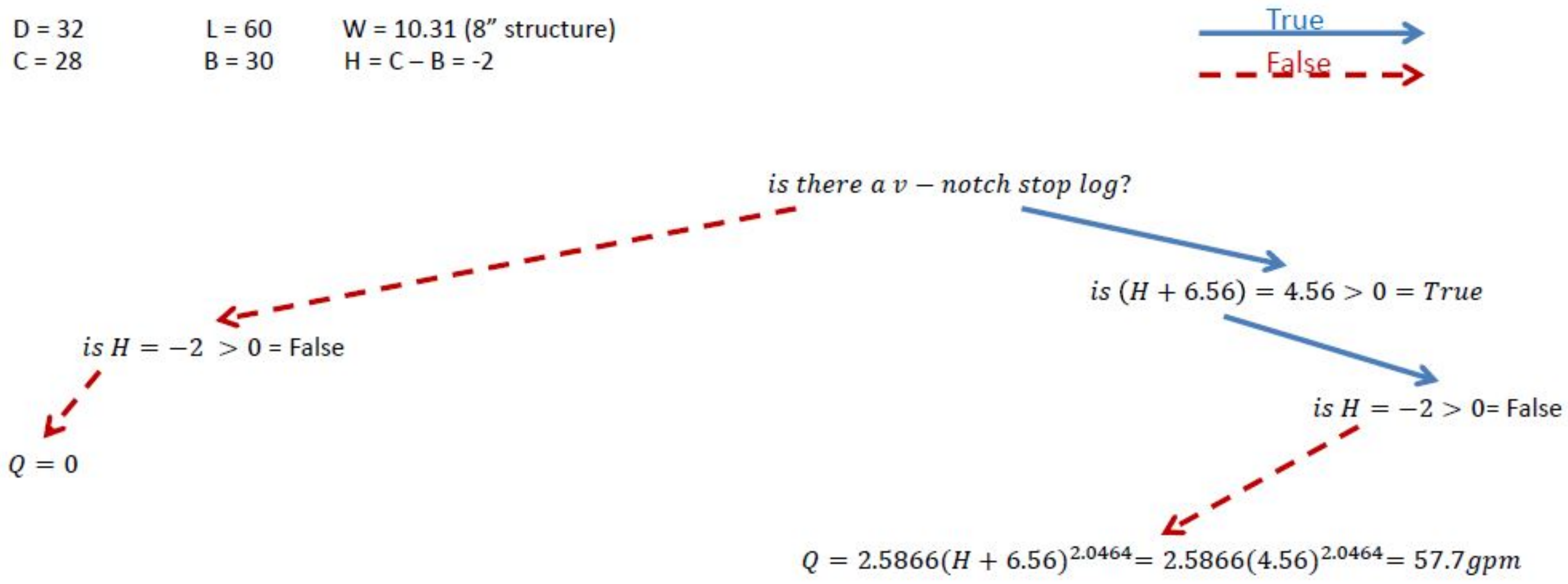
The values for C and D are displayed on the "Water Level" tab

H = C – B = height of water level above weir

Q is displayed on the "Flow" tab



D = 32 L = 60 W = 10.31 (8” structure)
C = 28 B = 30 H = C – B = -2



$is\ there\ a\ v - notch\ stop\ log?$

$is\ (H + 6.56) = 4.56 > 0 = True$

$is\ H = -2 > 0$ = False

$Q = 0$

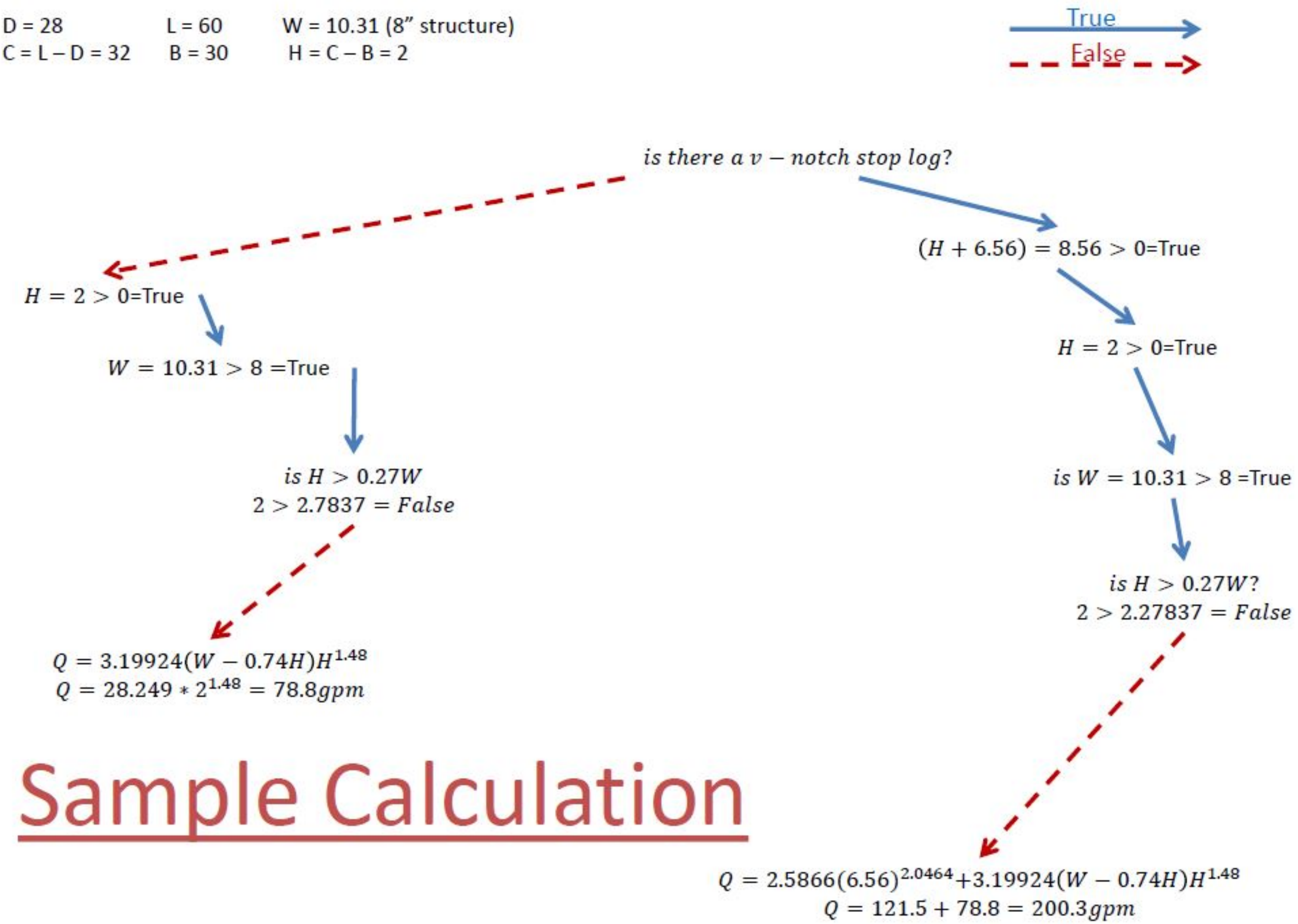
$is\ H = -2 > 0$= False

$Q = 2.5866(H + 6.56)^{2.0464} = 2.5866(4.56)^{2.0464} = 57.7gpm$

Sample Calculation

D = 28 L = 60 W = 10.31 (8” structure)

C = L – D = 32 B = 30 H = C – B = 2



$is\ there\ a\ v - notch\ stop\ log?$

$(H + 6.56) = 8.56 > 0$=True

$H = 2 > 0$=True

$is\ W = 10.31 > 8$ =True

$is\ H > 0.27W?$

$2 > 2.27837 = False$

$$Q = 2.5866(6.56)^{2.0464} + 3.19924(W - 0.74H)H^{1.48}$$

$$Q = 121.5 + 78.8 = 200.3gpm$$

$H = 2 > 0$=True

$W = 10.31 > 8$ =True

$is\ H > 0.27W$

$2 > 2.7837 = False$

$$Q = 3.19924(W - 0.74H)H^{1.48}$$

$$Q = 28.249 * 2^{1.48} = 78.8gpm$$

Sample Calculation

Appendix I - Soil OM Lab Method

Organic Matter

Weight Loss (LOI360°)

1. Application

This procedure is used for the routine estimation of soil organic matter by the loss of weight in a sample heated at a temperature high enough to burn organic matter but not so high as to decompose carbonates.

2. Summary of Methods

A sample of soil is dried at 105° C to remove moisture. The sample is weighed, heated at 360° C for 2 hours and weighed again after the temperature drops below 150° C.

3. Safety

Care should be exercised in handling hot samples. Be sure to cool the oven to 150° C before removing the samples from the oven. Use a good pair of tongs and grasp the sample firmly.

4. Interferences

Any material that losses moisture below 360° C is a potential source of error. Therefore, soil moisture must be removed before the base weight of the sample is taken. Also, ignited samples must not be allowed to re-absorb moisture from the air before they are weighed.

Gypsum loses water of hydration gradually. Soils containing gypsum should be heated initially at 150° C instead of 105° C. Some hydrated clays may also lose water below 360° C.

It is important that the results of this method be calibrated against organic carbon, preferably using a carbon analyzer, on soils from the area for which the test will be used.

5. Apparatus and Materials

5.1 Oven, or muffle furnace capable of being heated to 400° C and controlled to within ± 10° C.

5.2 Beakers, 20 ml

5.3 Crucible rack, stainless steel

5.4 Balance accurate to ± 0.001 g in a draft free, low humidity environment

5.5 Soil scoop calibrated to hold 5 g of light-colored silt loam soil

5.6 Drying oven, 105° C

6. Reagents

An advantage of this method is that no reagents are required.

7. Methods

7.1 Place a 5 g scoop of soil into a tared 20-ml beaker

7.2 Dry for 2 hours or longer at 105° C

7.3 Record weight to ± 0.001 g

7.4 Bring oven to 360° C. Samples must then remain at 360° C for two hours.

7.5 Cool to < 150° C

7.6 Weigh to ± 0.001 g, in a draft-free environment

8. Calculations

8.1 Calculate percent weight loss-on- ignition (LOI)

$$\text{LOI} = \frac{(\text{wt. at } 105°\text{C}) - (\text{wt. at } 360°\text{ C}) \times 100}{\text{Wt. at } 105°\text{ C}}$$

8.2 Estimate % organic matter. Organic matter is estimated from LOI using regression analysis. Select soils covering the range in organic matter expected in the area serviced by the lab. Determine % organic matter using a carbon analyzer or by the Walkley-Black procedure for organic carbon. Regress OM on LOI.

9. Quality Control

9.1 At least one standard soil of known LOI value should be run with each batch of samples. If the result is not within the known standard deviation, corrective action is required.

9.2 All beakers should be re-tared monthly. Two beakers from each batch of 50 should be re-tared weekly. If the results are not within ± 0.002 g of the previous tared weight; re-tare all beakers in the batch.

10. Reporting

Data are reported as % LOI or as estimated % O.M.

11. References

11.1 Combs, S.M., and Nathan, M.V. 1998. Soil organic matter. Pp. 57-58. *In* J.R. Brown (Ed.), Recommended Chemical Soil Test Procedure for the North Central Region. NCR Publ. N0. 221 (revised). Missouri Agr. Exp. Sta. SB 1001. Columbia, MO.

11.2 Schulte, E.E., and Hopkins, B.G. 1996. Estimation of soil organic matter by weight loss-on- ignition. Pp.21-31. *In* F.R. Magdoff, M.A. Tabatabai, and E.A. Hanlon, Jr. (eds.), Soil Organic Matter: Analysis and Interpretation. Soil Sci. Soc. Am., Madison, WI.

Appendix J- Available Phosphorus

1. Application

This procedure covers the extraction and analysis of plant available phosphorus (P) from soil.

2. Summary of Methods

Plant available phosphorus (P) is extracted from the soil with 0.03 N NH4F in 0.025 N HCl (Bray P1extract). This extractant primarily measures P adsorbed by Al compounds. The Al is complexed by F- ions, liberating P. Lesser amounts of Fe-, MN-, and Ca-P may be extracted, along with water-soluble P. Extracted P is reacted with ammonium molybdate to form a blue phosphomolybdate compound in the presence of a reducing agent.

The concentration of P is determined colorimetrically or by UV – Vis spectrophotometer.

Potassium is extracted simultaneously with P and analyzed separately.

3. Safety

Each chemical compound should be treated as a potential health hazard. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material handling data sheets should be made available to all personnel involved in the chemical analysis.

4. Interferences

Color development is complete in 15 minutes but will continue at a slower rate. For this reason, samples should be read within two hours. Arsenic forms a blue molybdate complex but is usually present in very low amounts unless an arsenical pesticide has been applied in the past.

Very high soil pH interferes with phosphorus by this extraction method.

The Bray test for P is less reliable in alkaline soil containing free CaCO3. The carbonate reacts with HCl in the Bray extract, forming CaCl2, and the Ca++ ions react with F-, precipitating CaF2. Where alkaline soils predominate, NaHCO3 (Olsen) is the preferred extractant.

5. Apparatus and Materials

5.1 Soil scoop calibrated to hold 1.5 g of light-colored silt loam soil.

5.2 Erlenmeyer flasks (50-ml)

5.3 Pipette banks (3-ml)

5.4 Time-controlled oscillating shaker (Eberbach) set at 160 excursions per minute.

5.5 Filter paper (9-cm Whatman no. 2 or equivalent)

5.6 Funnel tubes (15-ml)

5.7 Matched colorimetric tubes (10-ml)

5.8 UV-Vis spectrophotometer

5.9 Brewer Automatic Pipetting Machine (SEPCO Model #40A)

6. Reagents

6.1 Stock P-A solution (1.25 N HCl, 1.5 N NH4F): Add 54 ml of 48% HF to 700 ml of deionized water. Neutralize to pH 7.0 with NH4OH. Add 108 ml of concentrated HCl (11.6 N) and dilute to 1 liter

6.2 Dilute P-A solution (0.025 N HCl, 0.03 N NH4F): Dilute 20 ml of stock P-A solution to 1 liter with deionized water.

6.3 P-B solution (0.87 N HCl, 0.38% ammonium molybdate, 0.5%H3BO3): Dissolve 3.8 g ammonium molybdate, (NH4) 6Mo7O24·4H2O, in 300 ml of deionized water at about 60° C. Cool. Dissolve 5.0 g boric acid, H3BO3, in 500 ml of deionized water, and add 75 ml concentrated HCl (11.6 N). Then, add the molybdate solution and dilute to 1 liter with deionized water.

6.4 P-C powder: Thoroughly mix and grind to a fine powder 2.5 g of 1-amino-2- napthol-4 sulfonic acid, 5.0 g sodium sulfite (Na2SO3), and 146 g of sodium metabisulfite (Na2S2O5).

6.5 P-C solution: Dissolve 8 g of dry P-C powder in 50 ml of warm deionized water. Let stand overnight, if possible. A fresh reagent should be prepared every three weeks. (Upon standing, some material may crystallize out, but this is still satisfactory.)

6.6 Standard P solution (1000 ppm P, 500 ppm P)

6.7 Working standards (0, 1.0, 2.5, 5, 10, 20, 40 ppm P, prepares with same matrix as the samples.)

7. Methods

7.1 Place a 1.5 g scoop of soil into a 50-ml Erlenmeyer flask.

7.2 Add 15 ml of P-A solution with Automatic Brewer Pipette.

7.3 Shake the suspension on oscillating shaker for 5 minutes.

7.4 Filter through filter paper into a 15-ml funnel tube.

7.5 Pipette a 3.0-ml aliquot of filtrate with constant suction pipette apparatus and transfer to a 10-ml colorimeter tube.

7.6 Add 3.0 ml of P-B solution with the same pipette apparatus and mix well.

7.7 Add 3 drops of P-C solution, and mix immediately.

7.8 Read color after 15 min., but before two hr., with a photoelectric colorimeter or a UV-Vis spectrophotometer.

Note: UV – Vis spectrophotometer should be set at 645 nm.

7.10 Calibrate the instrument to read directly in ppm P in soil using working standards. These standard preparations are treated in the same manner as the soil extracts. (color development is complete in 15 minutes. and standards should be read within two hours.).

8. Calculations

In lieu of direct calibration of the colorimeter scale, calculate extractable P, ppm P in soil = ppm P in solution x 15 ml/1.5 g = ppm P in solution x 10.

9. Quality Control

9.1 Laboratory Reagent Blank (LRB) – At least one LRB is analyzed with each batch of samples to assess contamination from the laboratory environment. Contamination from the laboratory or reagents is suspected if LRB values exceed the detection limit of the method. Corrective action must be taken before proceeding.

9.2 Standard soil – One or more standard soils of known extractable P content is analyzed with each batch of samples to check instrument calibration and procedural accuracy.

10. Reporting

Results are reported as ppm P in soil. (Strictly speaking, the results should be reported as Mg P per dm3 of soil because a known volume, rather than a weight is used. This is not a familiar unit, however. Use of a volume of soil is reasonable because it represents a volume-fraction of an acre plow layer.)

11. References

11.1 Bray, R.H., and L.T. Kurtz. 1945. Determination of total, organic, and available forms of phosphorus in soil. Soil Sci. 59: 39-45

11.2 Munter, R.C. 1988. Laboratory factors affecting the extractability of nutrients. Pp. 8-10. *In* W.C Dahnke (ed.), Recommended Chemical Soil Test procedures for the North Central Region. NCR Publ. 221 (revised). ND Agr. Exp. Sta., Fargo, ND.

11.3 Frank, K., D, Beegle, and J. Denning. 1998. Phosphorus, pp. 21-26. *In* J.R. Brown (ed.) Recommended Chemical Soil Test Procedures for the North Central Region. NCR Publ. No. 221 (revised). Missouri Agr. Sta. SB 1001. Columbia, MO

Appendix K -Particle Size Analysis (Hydrometer Method)

1. Application

The percentage of sand, silt and clay in the inorganic fraction of soil is measured in this procedure. The method is based on Stoke's law governing the rate of sedimentation of particles suspended in water.

2. Summary of Methods

The sample is treated with sodium hexametaphosphate to complex Ca++, Al3+, Fe3+, and other cations that bind clay and silt particles into aggregates. Organic matter is suspended in this solution. The density of the soil suspension is determined with a hydrometer calibrated to read in grams of solids per liter after the sand settles out and again after the silt settles. Corrections are made for the density and temperature of the dispersing solution.

3. Safety

Each chemical compound should be treated as a potential health hazard. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material handling data sheets should be made available to all personnel involved in the chemical analysis.

4. Interferences

The principal source of error in this procedure is the incomplete dispersion of soil clays.

These clays are cemented by various chemical agents and organic matter into aggregates of larger size. Failure to effect complete dispersion results in low values for clay and high values for silt and sand. The rate of sedimentation also is affected by temperature and the density of the dispersing solution.

5. Apparatus and Materials

5.1 Glass cylinders, 1000-ml capacity

5.2 Thermometer, Fahrenheit

5.3 Hydrometer, Bouyoucos (Fisherbrand Model # 14-331-5c)

5.4 Electric mixer with dispersing cup

5.5 Plunger

5.6 Balance sensitive to ± 0.01g

6. Reagents

6.1 Dispersing solution, 5%: Dissolve 50 g of sodium hexametaphosphate, Na6(PO3)6 in deionized water and dilute to 1 liter.

7. Methods

7.1 Mix 100 ml of the 5% dispersing solution and 880 ml of deionized water in a 1000 ml cylinder. This mixture is the blank. (Note: 100 ml + 880 ml = 980 ml.

This blank is not diluted to 1000 ml; the other 20 ml is the volume occupied by 50 g of soil.).

7.2 Weigh 25-50 g of soil and transfer to a dispersing cup. Record weight to ± 0.01g.

7.3 Add 100-ml of 5% dispersing solution.

7.4 Attach dispersing cup to mixer and mix the sample for 30 – 60 sec.

7.5 Transfer the suspension quantitatively from the dispersing cup to a 1000 ml cylinder.

7.6 Fill to the 1000- ml mark with deionized water equilibrated to room temperature, or allow to stand overnight to equilibrate.

7.7 At the beginning of each set, record the temperature, and the hydrometer reading of the blank, using the procedure described below.

7.8 To determine the density insert plunger into suspension, and carefully mix for 30 sec. until a uniform suspension is obtained. Remove plunger (begin 40 second timer) and gently insert the hydrometer into the suspension.

7.9 Record the hydrometer reading at 40 sec. This is the amount of silt plus clay suspended. The sand has settled to the bottom of the cylinder by this time.

(Repeat 7.8 – 7.9 for each sample)

7.10 Record the hydrometer reading again after 6 hours, 52 minutes. This is the amount of clay in suspension. The silt has settled to the bottom of the cylinder by this time.

8. Calculations

8.1 Temperature and density corrections:

- add 0.2 unit to the readings of the samples for every 1° F above 67° F, and subtract 0.2 unit for every 1° F below 67° F.
- subtract the density of the blank at each reading, from the corresponding density readings for the samples.

8.2 Percent clay: % clay = corrected hydrometer reading at 6 hrs, 52 min. x 100/ wt. of sample

8.3 Percent silt: % silt = corrected hydrometer reading at 40 sec. x 100/ wt. of sample - % clay

8.4 Percent sand: % sand = 100% - % silt - % clay

9. Quality Control

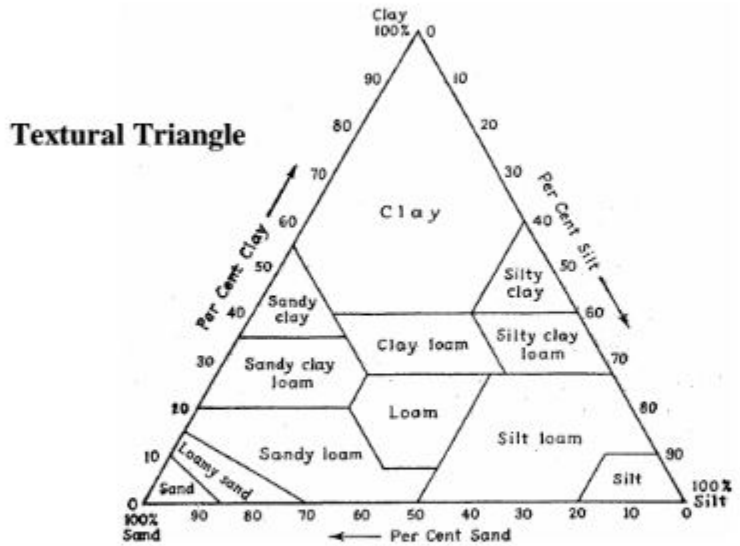
9.1 Standard soil - a standard soil of known particle size content is analyzed with each batch of samples to check for instrument calibration and procedural accuracy.

10. Reporting

Results are reported as percentages of the mineral fraction, % sand, % silt, and % clay.
Soil texture is based on the USDA textural triangle. (see chart below)

11. References

11.1 Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soils. Agron. J. 54:464-465.



Appendix L: Field Days, Presentations, and Articles

Field Days and Presentations

The following list details all recorded field days and presentations where an ADMC member spoke about the saturated buffer practice and discussed this project. Field days held at one of the 15 sites are also included.

- Presentations were given by ADMC members the Illinois LICS Convention, Christian City Farm Bureau, Chicago Farmers Investment Fair, and Midwest Cropping Seminar
- A tour of the IL-1/2 buffers was given to the IL Dept of Ag, The Nature Conservancy, City of Bloomington Water Dept, NRCS officials University of Illinois Professor of BioMass
- Tours of the IL-1/2 buffers were provided for the Assoc SWCD's and the Info Ag Conference (summer 2013)
- Presentation at the annual 2013 Drainage Research Forum, located in Sioux Falls, SD
- Presentation at the drainage district commissioners meeting hosted by the Champaign County Farm Bureau and SWCD, 8/28/2014, Champaign Illinois
- Mini Field Day at an FSA saturated buffer (IL-4). Attendees included NRCS staff, UIUC faculty, contractors, and others. 6/16/2014 near Cisco, IL
- Springfield Plastics hosted a field day for saturated buffers and drainage water management, approximately 75 producers and watershed parties attended. A summary of the press release is included at the end of this report. 7/16/2014 near Auburn, IL
- Field day sponsored by IA Soybean, Black Hawk County, IA (9/18/14)
- Field day for saturated buffer installation (different grant), Dysart, IA (10/2/14)
- Gave invited presentation "Saturated Buffers", at NE Iowa Project Coordinator Fall Meeting, Elkader, IA. 20 Coordinators, NRCS, IDALS, IA DNR personnel. (10/15/14)
- Toured David White,former NRCS Chief, Chris Adamo, Senate Ag Committee Majority Staff Director, Sean McMahon, Executive Director, Iowa Water Alliance and Jeff Moore, lobbyist for municipal wastewater treatment facilities to see saturated buffer, drainage water management, and bioreactor sites in Mid-Iowa. (10/27/14)
- Minnesota Board of Water and Soil Resources (BWSR) Academy; Breezy Point, MN – approx. 100 people attended the session (10/29/14)
- Illinois Land Improvement Contractors , Peoria, IL – 35 participants (1/15/15)
- Montgomery County SWCD Contractors & Landowners Meeting, Hillsboro, IL – 40 participants (1/29/15)
- Association of Illinois Drainage Districts, Champaign, IL – 40 participants (1/30/15)
- Knox County SWCD Contractors Seminar, Galesburg, IL – 20 participants (2/3/15)
- IA Soybean Research Conference; Ames, IA – approx. 150 people attended the session (2/19/15)
- Stark County Conservation Meeting, Bradford, IL – 20 participants (2/20/15)
- Mercer County SWCD Contractors Meeting, Aledo, IL – 25 participants (3/5/15)
- Henderson County SWCD Contractors Meeting, Lomax, IL – 15 participants (3/16/15)
- Gave invited presentation "Saturating Riparian Buffers in Tile Drained Landscapes for Nitrate Removal" at 2015 Waseca County Farmer Forum, Waseca, MN. 150 farmers and state agency personnel. (3/11/15)
- Saturated Buffer Field Day, Rensselaer, IN – Field day held at the IN-1 site, hosted by Fractco, Jasper County SWCD, ESE, and the landowner, approximately 30 attendees (6/16/15)
- Saturated Buffer Conservation Field Day, Kasson, MN – Field day held at the MN-4 site, hosted by Prinsco, Dodge County SWCD, ESE, and the landowner, 76 attendees (6/16/15)

- 2015 Conservation Technology Innovation Center (CTIC) Tour – One tour stop included a saturated buffer installation near Northfield, MN – approx. 250 attendees (8/12/15)
- Fall 2015 Iowa Watershed Coordinator's Meeting, Williamsburg, IA – approx. 70 attendees (9/16/15)
- Agriculture Conservation Field Day, Kenton, OH - Hosted by The Nature Conservancy, The Ohio State University, John Deere, Hardin County SWCD (9/18/15)

Published Articles

- A saturated buffer (MN-1) was highlighted in the cover story of the February 2014 issue of Corn/Soybean Digest
- Four State Study Tests Nitrate Reduction Technology, Springfield Journal Register daily newspaper , Springfield, IL (3/17/15)
- Four State Study Tests Nitrate Reduction Technology, Soil & Water Conservation Society, Internet News Story (3/9/15)
- Four State Study Tests Nitrate Reduction Technology, Missouri Land Improvement Contractor Association, April Bulletin
- Gave interview for article "Saturated buffer zone keeping pollutant out of Hamilton County stream" by Larry Kershner appearing in the 20 March 2015 issue of Farm News and in the 22 March 2015 Sunday edition of the Ft. Dodge Messenger.
- Interviewed by Donnelle Eller for article in the Des Moines Register on Saturated Buffers to appear in April 2015.

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References

Burkart, M.R., W.W. Simpkins, A.J. Morrow, and J.M. Gannon. Occurrence of total dissolved phosphorus in unconsolidated aquifers and aquitards in iowa1. JAWRA Journal of the American Water Resources Association 40:827-834 (2004).

Iowa Department of Agriculture and Land Stewardship, Iowa Department of Natural Resources, and Iowa State University College of Agriculture and Life Sciences. Iowa nutrient reduction strategy: A science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico. Iowa State Univ. http://www.nutrientstrategy.iastate.edu/sites/default/files/documents/NRSfull-141001.pdf (accessed 24 Nov. 2014).

Jaynes, D.B., and T.M. Isenhart, Reconnecting tile drainage to riparian buffer hydrology for enhanced nitrate removal. Journal of Environmental Quality 43:631-638 (2014)

Mayer, P.M., S. Reynolds, T. Canfield, and M. McCutchen, Riparian buffer width, vegetative cover, and nitrogen removal effectiveness: A review of current science and regulations. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-05/118, 2005.

Quality Assurance Manual 1-22-13 – pages: Tile, i, ii, 8-15, 26-29, 33-34

U.S. Environmental Protection Agency, 1986, Quality criteria for water 1986: Washington, D.C., U.S. Environmental Protection Agency, Office of Water, EPA 440/5-86-001.