Annual Report

Water and Nutrient Research: In-field and Offsite Strategies

Matthew Helmers
Associate Professor

William Crumpton
Associate Professor

Carl Pederson
Research Associate

Greg Stenback
Research Associate

Bob Zhou
Research Associate

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Department of Agricultural and Biosystems Engineering
Department of Ecology, Evolution and Organismal Biology
Iowa State University, Ames

NUTRIENT AND WATER MANAGEMENT PROJECT 2010-2014

Much of Iowa is characterized by relatively flat, poorly-drained areas which with extensive subsurface drainage, have became some of the most valuable, productive land in the State. However, this drained land has also become a source of significant NO_3 loss because of the changes in land-use and hydrology brought about by tile drainage. While surface runoff is decreased with subsurface drainage (resulting in decreased losses of sediment, ammonium-nitrogen, phosphorus, pesticides and micro-organisms), subsurface flow and leaching losses of NO_3 are increased. This is due mostly to an increase in volume and the "short-circuiting" of subsurface flow, but also in part to the increased aeration of organic-rich soils with potentially increased mineralization and formation of NO_3 (and less denitrification) in the soil profile.

The problem of excess nutrient loads can probably be ameliorated by a combination of in field and off site practices, but the limitations and appropriateness of alternative practices must be understood and outcomes must be measurable. Promising in field practices include nutrient management, drainage management, and alternative cropping systems. Nitrate-removal wetlands are a proven edge-of-field practice for reducing nitrate loads to downstream water bodies and are a particularly promising approach in tile drained landscapes. Strategies are needed that can achieve measurable and predictable reductions in the export of nutrients from tile drained landscapes. The principal objectives of this project are (1) to evaluate the performance of nutrient management, drainage management, and alternative cropping systems with respect to profitability and export of water and nutrients (nitrate-nitrogen and total phosphorus) from tile drained systems and (2) to evaluate the performance of nitrate-removal wetlands in reducing nitrate export from tile drained systems.

This annual report describes activities related to objectives 1 and 2 along with outreach activities that were directly related to this project. Results for crop year 2010 are described.

Gilmore City Project Site

Treatments

The specific treatments investigated at the Gilmore City Research Facility are listed in Table 1. All treatments except the forage and kura treatments (Table 1) consist of 8 plots with 4 in soybeans and 4 in corn each year. The forage and kura treatments have 4 plots each.

The treatments included allow for varied comparisons. This includes the following comparisons:

- Timing of nitrogen application (treatments 1,2 vs. 5,6 vs. 15,16)
- Potential impacts of tillage (treatments 5,6 vs. 9,10)
- Source of nitrogen (treatments 3,4 vs. 5,6 vs. 13,14)
- Cropping practices through the use of a winter cover crop
    - Performance of winter rye cover crop when used in a conventional tillage system (treatments 5,6 vs. 7,8) or no-till system (treatments 9,10 vs. 11,12)
- Impacts of complete conversion to perennial cover crop (kura clover) and perennial vegetation (forage hay/pasture vegetation) (treatments 17 and 18 vs. other treatments)

Table 1. Treatments at the Gilmore City Research Facility for Crop Years 2010-2014.

Treatment Number*	Tillage	Cover Crop	Nitrogen Application Time	Nitrogen Application Rate (lb/acre)
1,2	Conventional tillage	–	Fall (Aqua-Ammonia)	150
3,4	Conventional tillage	–	Spring (Urea)	150
5,6	Conventional tillage	–	Spring (Aqua-Ammonia)	150
7,8	Conventional tillage	Rye planted after harvest of corn and beans	Spring (Aqua-Ammonia)	150
9,10	No-till	–	Spring (Aqua-Ammonia)	150
11,12	No-till	Rye planted after harvest of corn and beans	Spring (Aqua-Ammonia)	150
13,14	Conventional	–	Spring – Poly coated urea	150
15,16	Conventional	–	Late season side-dress	150
17	Kura clover - Corn		-	150
18	Orchardgrass + Red/Ladino clover		-	no fertilizer

* within the corn and soybean rotation treatments, odd numbers are soybean and receive no nitrogen.

Experimental studies over a period of five years will be used to evaluate the effects of reducing nitrogen application rate on water quality and crop yield. In addition the impacts of fall fertilizer application compared to spring application will be evaluated. Inclusion of the no-till as part of the in-field monitoring allows for evaluating impacts of tillage system on crop yield and water quality. Inclusion of cover crops and harvestable perennials allows for evaluating alternative cropping practices and rotations and their impacts on water quality exiting the subsurface drainage system. Evaluation of the performance of these practices is important through field monitoring for considering progressive methods for minimizing nutrient transport from tile-drained landscapes.

The concentration and loading of nutrients exiting the various treatments will be monitored and evaluated on an annual basis and for the five year study period, 2010-2014. In addition, crop yield will be documented each year to evaluate treatment effects on yield, specifically whether there are declines in annual yield at the lower nitrogen rate applications. The evaluation of the treatment effects will be for the study period but each year will be analyzed to evaluate treatment effects on a yearly basis and after the completion of this phase of the research study. It is understood that climatic variability plays a significant role in the leaching of nutrients in the tile drained landscape. Based on this, it is important to have numerous years of leaching data to evaluate the treatment effects both from a production (crop yield) perspective and a nutrient leaching perspective. The multiple years of data allows for evaluating how the treatments respond under varying climatic conditions and after subsequent years with similar cropping practices. Also, these multiple years of data allow for additional characterization of tile flow under varied precipitation conditions and allow for further understanding of the hydrology of the site.

Agronomic Activities

Agronomic field activities in 2010 were completed in a timely manner prior to and during the crop season. Rye for 2010 was seeded on November 20, 2009. Fall fertilization was completed on December 1, 2009. Chisel plowing was performed on April 16, 2010. Seedbed preparation for corn and soybean was completed on May 4. Corn was seeded on May 6 and soybean was seeded on May 18. Urea and ESN were applied on May 5. Aqua-ammonia was applied on June 3. Rye cover crop in corn plots was sprayed to eliminate rye on May 6. Soybean rye cover crop plots were sprayed to eliminate rye on May 14. Corn was harvested on October 14-15, 2010 and soybean was harvested on October 6-7, 2010.

Weed Control

Round Up ready crops were used at the site. Establish herbicide was used for pre-plant weed control and was broadcast on May 17. Application of Round Up was on June 22 for corn, and July 1 for soybean. Cultivation for weed control was not incorporated into the weed management system in 2010.

Precipitation

Precipitation was recorded at the site from April through November; freezing weather (Jan-March and December) precipitation was obtained from NOAA weather stations in Pocahontas and Humboldt. The total precipitation in 2010 was about 11” greater than normal (Table 2). June, July and September precipitation was well above normal (8.7”, 2.6” and 1.1” higher, respectively). August and October precipitation was 1.2” and 1.6” lower than normal, respectively. Precipitation in other months was close or slightly below normal.

Drainage

Treatment plot sampling pumps were installed during mid-March, 2010. Drainage started during this period and the first samples were collected on March 23rd. Samples were collected on at least a weekly basis, and for most plots, drainage was sufficient for sampling through the month of August. Nearly all drainage ceased after August 17th. Samples started to be collected again the last week of September and continued until November 29. Table 3 lists drainage volumes by treatment in 2010 with statistical differences at $p=0.05$. Twelve of the eighteen treatments had one of four replications removed due to erroneous (usually excessive) drainage volume values. All other replications were used in statistical analysis. Overall, no statistical differences among treatments were noted for drainage in 2010 (LSD=15.3 inches), except the spring nitrogen application with no-till treatment in the soybean year had significantly higher drainage than most of other treatments (Table 3). Average drainage for all treatments was 21.4 inches. With 35.73” of precipitation between April 1 and November 29 and using an overall drainage volume of

18.96”, approximately 53% of the precipitation became subsurface drainage (Table 4). June and November both had more drainage than precipitation, likely caused by drainage delay from the previous month’s precipitation (see Table 4). The site was winterized on November 29, 2010.

Table 2. Precipitation in 2010 at the research site and comparisons to norms and amounts at local NOAA weather stations.

Precipitation at the ADW site in 2010				NOAA weather stations in 2010		
			Normal*	Pocahontas	Humboldt	average
	mm	inches	inches		inches	
Jan	-	-	0.91	0.90	1.04	0.97
Feb	-	-	0.70	1.15	0.92	1.04
Mar	-	-	2.20	1.80	1.68	1.74
Apr	70	2.76	3.09	2.44	2.43	2.44
May	81	3.19	3.94	2.05	2.10	2.08
Jun	331	13.03	4.37	15.82	12.16	13.99
Jul	176	6.94	4.37	10.63	7.83	9.23
Aug	85	3.36	4.60	5.83	4.51	5.17
Sep	108	4.27	3.16	5.04	3.90	4.47
Oct	14	0.55	2.17	0.66	0.55	0.61
Nov	41	1.63	1.86	1.33	1.78	1.56
Dec	-	-	1.37	0.36	0.47	0.42
Total			32.74	48.01	39.37	43.69

* From: Climatological Data for Iowa, National Climate Data Center for Pocahontas Iowa 1971-00.

Nitrate Concentrations and Losses

Previous history of current plot treatments quite likely has influenced the nitrate-nitrogen concentrations observed during 2010. The highest nitrate concentrations in 2010 were recorded for the spring nitrogen application treatment in the soybean year and lowest were found in the perennial systems, specifically the orchardgrass/clover treatment; all other values were between these treatments values. Annual flow-weighted concentrations ranged from 1.9 to 22.7 mg L^{-1}. Individual plot/replication, flow weighted averages ranged from 0.4 to 28.7 mg L^{-1} and were recorded within the aforementioned treatments. No significant differences were noted when comparing the spring and fall application as well as the late season side-dress. Conventional tillage had significantly higher concentrations than no-till within the soybean year but showed no significant difference within the corn year. The nitrogen sources (aqua-ammonia, urea, and poly coated urea) did not exhibit any significantly different effects on NO_3-N concentrations. Treatments of rye cover crop had significantly lower nitrate concentrations in both crops under conventional tillage than the comparable treatments without cover crop (treatments 5, 6), but showed no significant difference under no-till. Table 5 lists the statistical differences among all treatments at the $p=0.05$ level.

Table 6 lists NO_3-N losses by treatment in 2010. Losses were calculated by multiplying subsurface drainage effluent concentration by drainage volume. Due to the inherent variability between experimental plots and among treatments, loss calculations for one year may not be the best indicator of treatment effect. Losses in 2010 ranged from 5.2 to 106.4 lbs NO_3-N for the orchardgrass/clover treatment and no-till treatment in the soybean year of the rotation, respectively (N applied on May 5-June 3, 2010 in the corn year). All statistical comparisons are listed in Table 6.

Table 3. Subsurface drainage volumes with statistical differences at p=0.05, by treatment in 2010.

Treatment	Description	Drainage (inches)
1	CP-FA-150-S	16.6b
2	CP-FA-150-C	20.0b
3	CP-SPUREA-150-S	26.0ab
4	CP-SPUREA-150-C	17.6b
5	CP-SP-150-S	16.5b
6	CP-SP-150-C	23.4b
7	CP-rye-150-S	16.7b
8	CP-rye-150-C	24.4b
9	NT-SP-150-S	40.3a
10	NT-SP-150-C	29.2ab
11	NT-rye-150-S	19.5b
12	NT-rye-150-C	22.2b
13	CP-SPPOLY-150-S	16.2b
14	CP-SPPOLY-150-C	16.7b
15	CP-SIDEDRESS-150-S	18.7b
16	CP-SIDEDRESS-150-C	23.8b
17	Kura clover	24.5b
18	Orchardgrass + Red/Ladino clover	17.2b
LSD		15.3
Average drainage		21.4
Standard deviation		10.0
Average for corn treatments		21.5
Average for soybean treatments		21.3

Table 4. Average drainage for each month over all treatments with totals and percentage as drainage for April- November 2010.

month	precipitation	drainage	percentage
	------inches------		
April	2.76	0.24	9
May	3.19	0.76	24
June	13.03	13.13	101
July	6.94	1.33	19
August	3.36	1.17	35
September	4.27	0.23	5
October	0.55	0.10	18
November	1.63	2.00	123
Total	35.73	18.96	53

Table 5. Nitrate concentrations by treatment in 2010 with statistical significance at p=0.05.

Treatment	Description	nitrate N (mg/L)
1	CP-FA-150-S	10.3ef
2	CP-FA-150-C	13.0bcde
3	CP-SPUREA-150-S	11.4def
4	CP-SPUREA-150-C	13.1bcde
5	CP-SP-150-S	22.7a
6	CP-SP-150-C	14.8b
7	CP-rye-150-S	11.8cdef
8	CP-rye-150-C	11.1ef
9	NT-SP-150-S	10.8ef
10	NT-SP-150-C	13.4bcde
11	NT-rye-150-S	11.0ef
12	NT-rye-150-C	11.0ef
13	CP-SPPOLY-150-S	15.4bc
14	CP-SPPOLY-150-C	11.9bcde
15	CP-SIDEDRESS-150-S	14.1bcd
16	CP-SIDEDRESS-150-C	11.9bcde
17	Kura clover	9.0f
18	Orchardgrass + Red/Ladino clover	1.9g
	LSD	4.0

Table 6. Nitrate losses by treatment in 2010 with statistical significance at p=0.05.

Treatment	Description	nitrate-N (lbs/acre)
1	CP-FA-150-S	38.6cd
2	CP-FA-150-C	60.1abc
3	CP-SPUREA-150-S	69.4abc
4	CP-SPUREA-150-C	49.7bcd
5	CP-SP-150-S	90.9ab
6	CP-SP-150-C	75.3abc
7	CP-rye-150-S	44.8bcd
8	CP-rye-150-C	47.4bcd
9	NT-SP-150-S	106.4a
10	NT-SP-150-C	88.7ab
11	NT-rye-150-S	48.9abc
12	NT-rye-150-C	61.6abc
13	CP-SPPOLY-150-S	66.2abc
14	CP-SPPOLY-150-C	46.4bcd
15	CP-SIDEDRESS-150-S	60.6abc
16	CP-SIDEDRESS-150-C	61.0abc
17	Kura clover	49.4bcd
18	Orchardgrass + Red/Ladino clover	5.2d
	LSD	49.5

Reactive Phosphorus Concentrations and Losses
Analyses of 2010 water samples for total reactive phosphorus concentrations are still in process and will be reported when available.

Stalk Nitrate Test
Corn stalk nitrate test sampling protocols were followed to determine nitrate-N concentrations in corn stalk tissue from each plot. Results are listed in Table 7. Stalks were sampled on October 12. Stalk nitrate values can be divided into four categories: low (less than 250 mg/L-N) marginal (250-700) optimal (700 and 2000 mg/L-N). Only the Kura clover and no-till with rye cover crop treatments were in the optimal range, all other treatments were in the marginal to low range.

Table 7. Stalk nitrate test concentrations in 2010. Optimal range is between 700 and 2000 mg/L-N.

Treatment	Description	nitrate-N* (mg/L)
2	CP-FA-150-C	83
4	CP-SPUREA-150-C	228
6	CP-SP-150-C	574
8	CP-rye-150-C	141
10	NT-SP-150-C	344
12	NT-rye-150-C	731
14	CP-SPPOLY-150-C	121
16	CP-SIDEDRESS-150-C	538
17	Kura	704

* low (less than 250 mg/L-N) marginal (250-700) optimal (700-2000 mg/L-N).

Yields
Corn and soybean yields, by treatment, are listed in Tables 8 and 9. High corn and soybean yields were harvested due to early planting and above normal precipitation in June and July. Excluding the kura clover treatment, corn yields of each treatment in 2010 ranged from 169 to 185 bu/acre (Table 8). The highest corn yield was for the spring nitrogen application with conventional tillage treatment while the lowest corn yield was for the fall nitrogen application with conventional tillage treatment. Soybean yields were similar for all the treatments, ranging from 57-60 bu/acre (Table 9).

Table 8. Corn yield by treatment in 2010 with statistical significance at p=0.05.

Treatment	Description	yield (bu/acre)
2	CP-FA-150-C	169a
4	CP-SPUREA-150-C	178a
6	CP-SP-150-C	186a
8	CP-rye-150-C	180a
10	NT-SP-150-C	177a
12	NT-rye-150-C	177a
14	CP-SPPOLY-150-C	175a
16	CP-SIDEDRESS-150-C	185a
17	Kura	69b

Table 9. Soybean yield by treatment in 2010 with statistical significance at p=0.05.

Treatment	Description	yield (bu/acre)
1	CP-FA-150-S	59a
3	CP-SPUREA-150-S	59a
5	CP-SP-150-S	59a
7	CP-rye-150-S	57a
9	NT-SP-150-S	57a
11	NT-rye-150-S	60a
13	CP-SPPOLY-150-S	60a
15	CP-SIDEDRESS-150-S	59a

Summary

Crop year 2010 could be considered a transition year for the new treatments imposed at the research site. So, it is difficult to draw broad conclusions from crop year 2010.

The total precipitation in 2010 was about 11” greater than the historical average. June, July and September precipitation was well above normal. August and October precipitation was below normal. Precipitation in other months was close or slightly below normal.

Overall, no statistical differences among treatments were noted for drainage in 2010, except the spring nitrogen application with no-till treatments in the soybean year had significantly higher drainage than most of other treatments. Average drainage for all treatments was 18.96”. Approximately 53% of the precipitation became subsurface drainage between April 1 and November 29.

The highest nitrate concentrations in 2010 were recorded for the spring nitrogen application treatment which had soybean in 2010 and lowest were found in the perennial systems, specifically the orchardgrass/clover treatment treatment; all other values were between these treatments values. Annual flow-weighted concentrations ranged from 1.9 to 22.7 mg L-1. Individual plot/replication, flow weighted averages ranged from 0.4 to 28.7 mg L-1 and were recorded within the aforementioned treatments. No significant differences were noted when comparing the spring and fall application as well as the late season side-dress. Conventional tillage had significantly higher concentrations than no-till within the soybean year but showed no significant difference within the corn year. The nitrogen sources (aqua-ammonia, urea, and poly coated urea) did not exhibited any significantly different effects on NO3-N concentrations. Treatments of rye cover crop had significantly lower nitrate concentrations in both crops under conventional tillage than the comparable treatments without cover crop, but showed no significant difference under no-till.

Losses in 2010 ranged from 5.2 to 106.4 lbs NO_3-N for the orchardgrass/clover treatment and no-till treatment in the soybean year of the rotation, respectively. The annual nitrate losses were relatively high compared to previous years due to the greater precipitation and drainage in 2010.

During 2010 the corn and soybean yields were much higher than previous years because of early planting and above normal precipitation in June and July. Excluding the kura clover treatment, there was no statistical difference of corn yield among treatments in 2010. The corn yields of each treatment ranged from 169 to 185 bu/acre (Table 8). The highest corn yield was for the spring nitrogen application with conventional tillage treatment while the lowest corn yield was for the fall nitrogen application with conventional tillage treatment. Soybean yields were similar for all the treatments, ranging from 57-60 bu/acre.

Pekin Project Site

Drainage management practices are being evaluated at the Pekin school drainage facility. There are a total of nine plots at this facility. Three different management practices are being be utilized and evaluated. The treatments include the following:

- 3 – plots with conventional drainage (**FF**).
- 3 – plots with controlled drainage with free flow in the spring (April –May) and fall (September-October) (**CDV**). The outlet control will be set at 2 ft below the ground surface except during free flow.
- 3 – plots with controlled drainage with no free flow (**CDF**). This treatment would be used to represent a system similar to shallow drainage. The outlet control will be set at 2 ft below the ground surface.

These three treatments are being evaluated to investigate the impacts of drainage management practices on drainage volume, nutrient concentrations in the subsurface drainage, and grain yield. Again, these factors will be evaluated over the five year term of this project. Since significant climate variability exists and the response of variable weather conditions on drainage management systems is needed it is important to evaluate the treatment response over the entire duration of the project phase. In addition to drainage management practices, flow from two plots flows through a passive biofilter. One of the plots is a FF plot and one is a CDF plot. The concentration of nutrients entering and exiting the biofilter is being monitored to document any reductions as a result of the passive biofilter.

Precipitation and Drainage

The total precipitation in 2010 was 52.5 inches which is well above the historical average of 35.9 inches (Figure 1). The recorded precipitation was 20 inches in June-July. Overall, 48% of precipitation became conventional subsurface drainage. The controlled drainage system drainage volume yielded substantially less with 9% of precipitation. The shallow drainage system was reduced to 13% of precipitation. Respectively, drainage volumes were 25.2, 4.6, and 6.8 inches for each of the three systems (Figure 2). The outlet on control drainage plots were lowered to 48” below the ground surface from March 19 through May 27 and September 2 through December 2.

Corn and Soybean Yields

Historically, corn yields have been relatively low at the Pekin research fields, when compared to state and county averages. Corn yields were 105, 112, and 121 bu/acre for the controlled, conventional, and shallow drainage fields, respectively (Figure 3).

Soybean yields in 2010 were comparable to previous years with 44, 39 and 46 bu/ac for the controlled, conventional, and shallow drainage fields, respectively (Figure 4).

Nitrate-Nitrogen Concentrations

Water samples were collected from early April to mid-November in 2010. Listed in Table 10 are flow-weighted NO_3-N concentrations for all treatments for all monitoring years. NO_3-N concentrations between treatments were very similar, ranging from 3.20 to 3.77 mg/L, which are lower than the values in previous years. The use of a wood-based boireactor constructed at the time of subsurface drain installation and consisting of wood chips surrounding the drain line decreased the concentrations being released from the standard installation, conventional drainage treatment (Figure 5). Results from the bioreactor collecting drainage from the shallow management scheme are presented in Figures 6. Due to minimal drainage volumes, only one sample was taken for effluent drainage for the shallow management scheme in 2010.

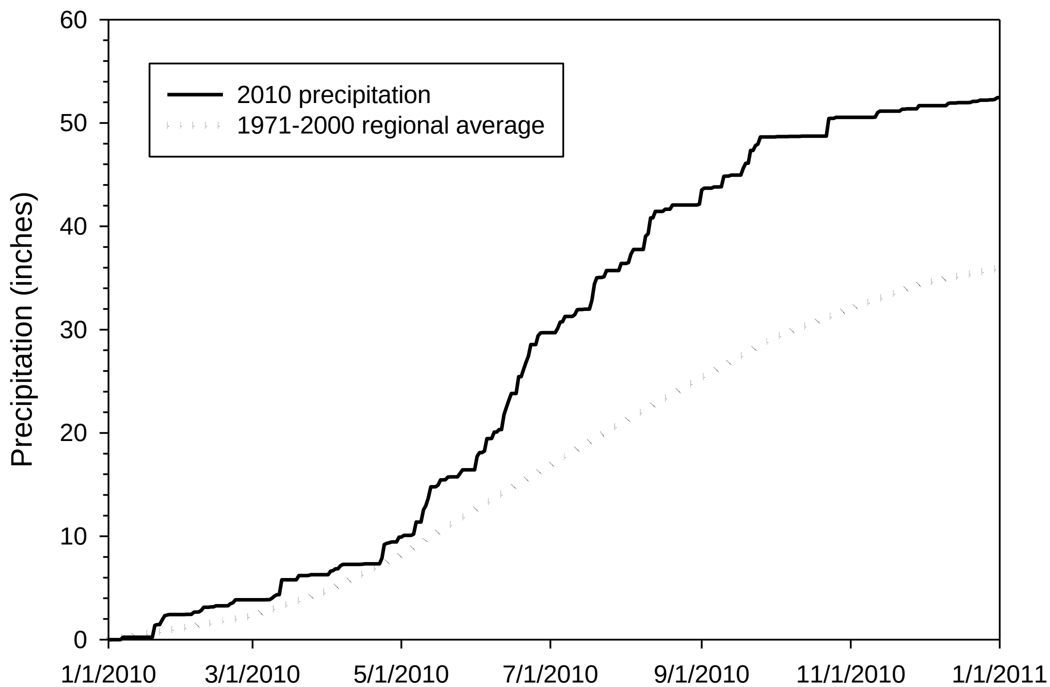

Figure 1. Precipitation in 2010 compared to the 30-year regional average.

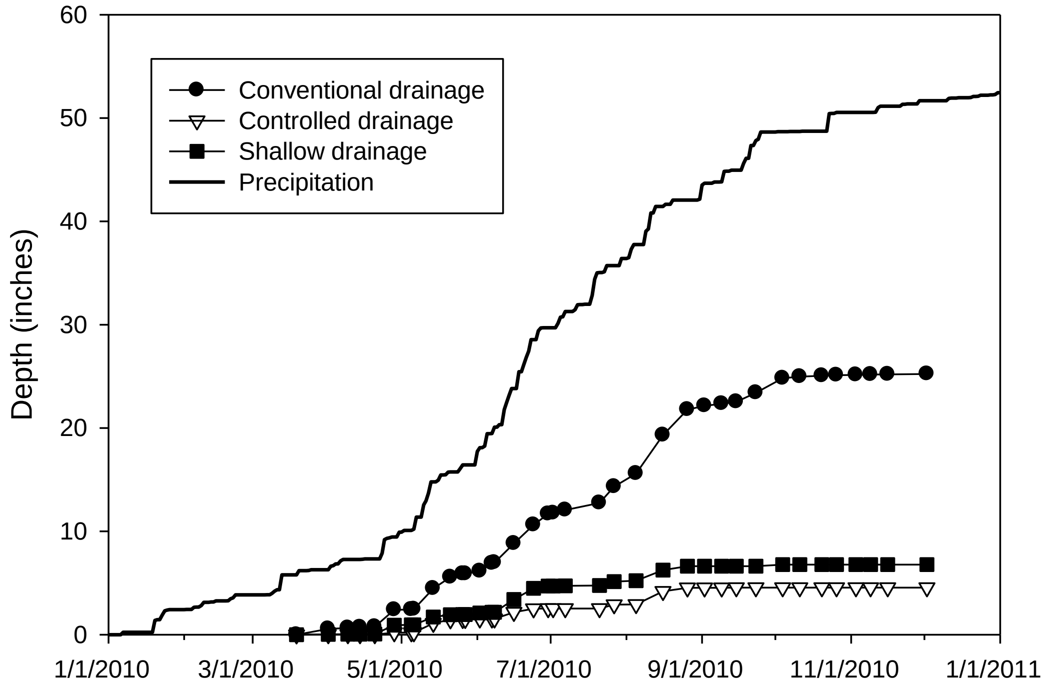

Figure 2. Precipitation and subsurface drainage at the Pekin site in 2010.

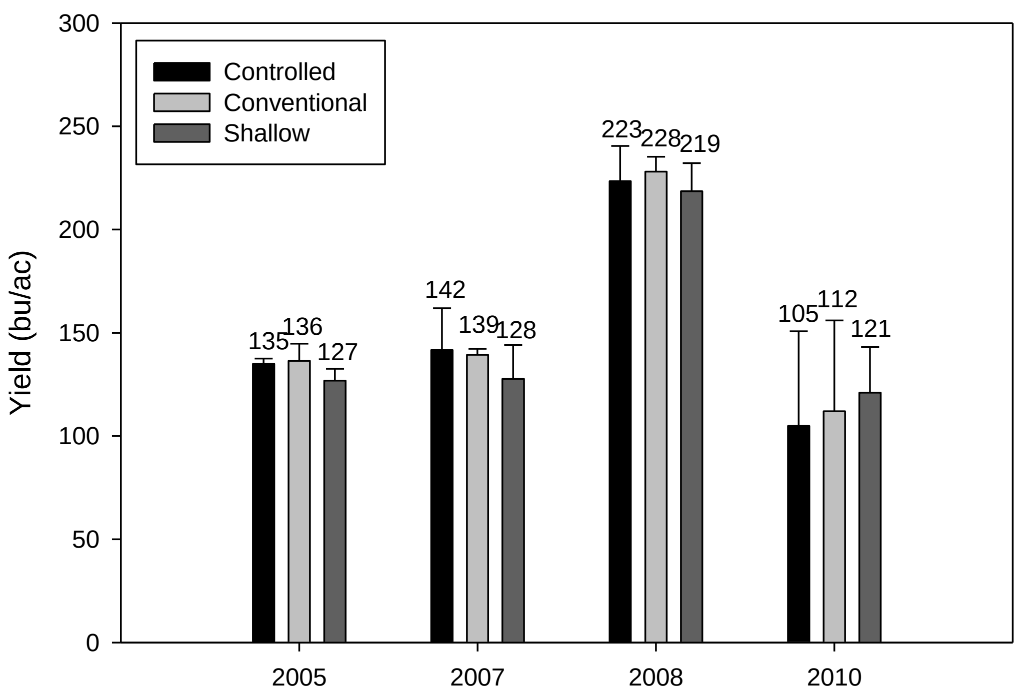

Figure 3. Corn yields at the Pekin site.

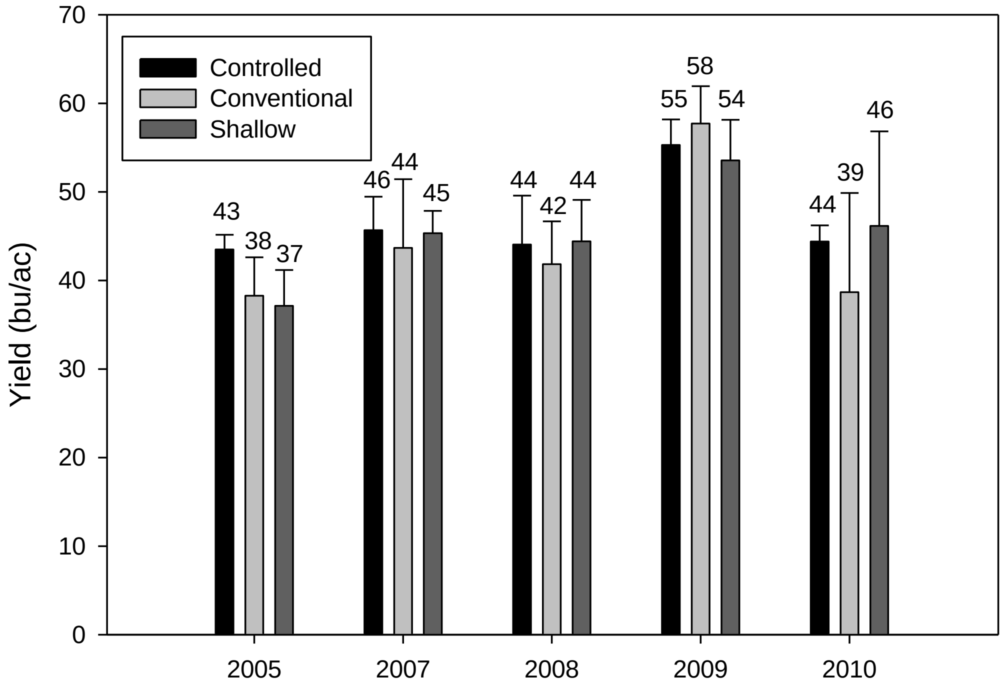

Figure 4. Soybean yields at the Pekin site.

Table 10. Flow-weighted nitrate concentration for all treatments (mg/L).

	Conventional		**Controlled**		**Shallow**	
	Average	Std. Dev.	**Average**	Std. Dev.	**Average**	Std. Dev.
2005	6.71	1.16	6.40	2.14	4.57	2.49
2006	6.92	0.59	7.20	1.44	6.72	1.86
2007	10.69	1.98	12.08	2.75	12.88	1.63
2008	6.23	2.97	5.17	3.32	5.95	2.05
2009	6.39	2.83	7.35	2.23	7.88	1.47
2010	3.20	2.13	3.24	1.86	3.77	0.67

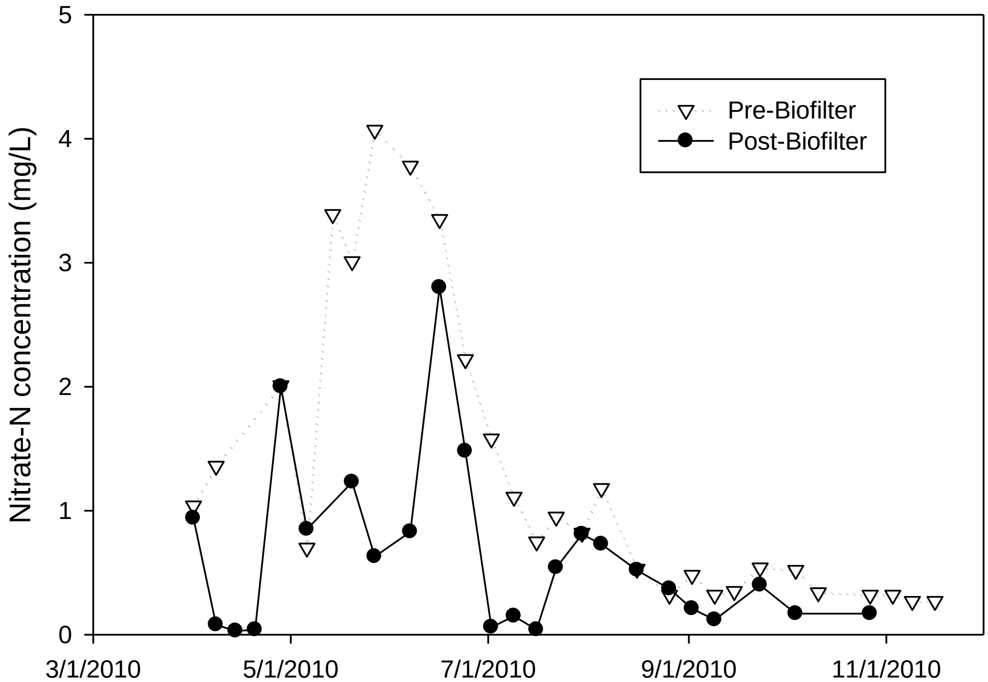

Figure 5. 2010 Conventional drainage bio-filter nitrate data.

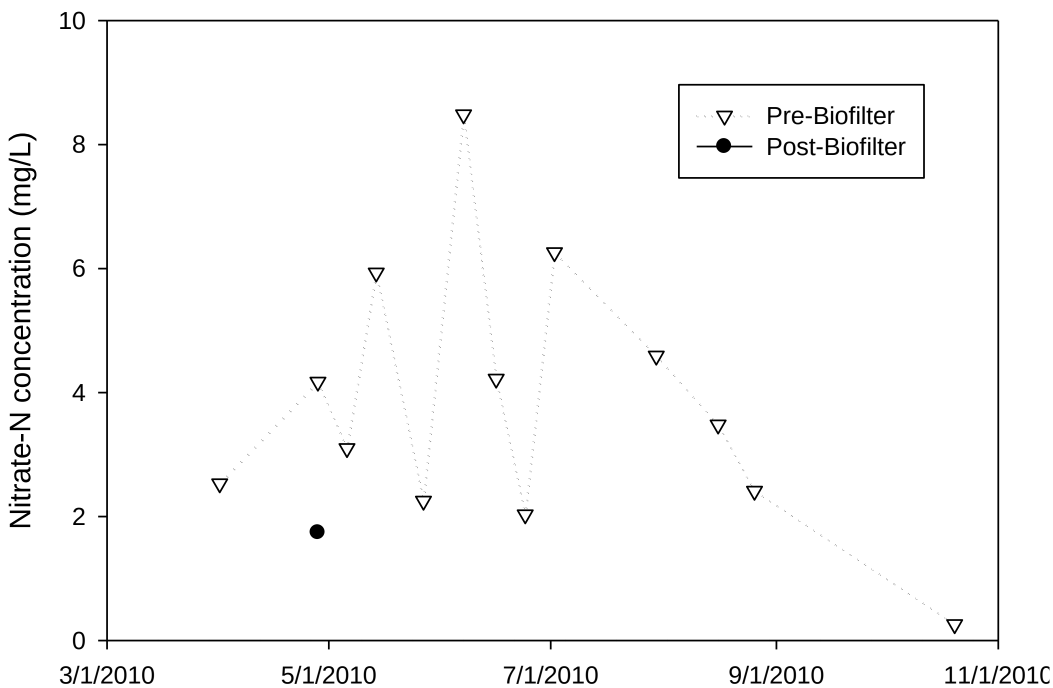

Figure 6. 2010 Shallow drainage bio-filter nitrate data.

Wetlands Monitoring and Evaluation

A unique aspect of the Iowa CREP is that nitrate reduction is not simply assumed based on wetland acres enrolled, but is calculated based on the measured performance of CREP wetlands. As an integral part of the Iowa CREP, a representative subset of wetlands is monitored and mass balance analyses performed to document nitrate reduction. In addition to documenting wetland performance, this will allow continued refinement of modeling and analytical tools used in site selection, design, and management of CREP wetlands.

During 2010, six wetlands were monitored for the Iowa CREP (Figure 7). These include AA, JM, HS north, LICA, AL, and KS wetlands. For close interval monitoring of nitrate-nitrogen concentrations, wetlands were instrumented with automated samplers that collected daily composite water samples at wetland inflows and outflows from mid-March (AL, HS, and KS only) through late November. Grab samples were collected throughout the year at an approximately weekly interval at inflow and outflow locations, and from within the wetland near the outflow location when there was no outflow. Sampling at the AA wetland was initiated in August, at the LICA in June where only grab samples were collected, and at the JM wetland starting in May.

Wetland inflow and/or outflow stream channel water velocity and depth measurements were taken at five minute intervals using submerged area velocity (SAV) meters and stage recorders. Stream cross section profiles were measured to develop cross-sectional area versus depth relationships at each discharge measurement location. Discharge, calculated as the velocity multiplied by the cross-sectional area, was calibrated against point discharge measurements taken at multiple water depths at each measurement site. Manual point discharge measurements were determined using the mid-section method whereby the stream depth was determined at 10 cm intervals across the stream and the water velocity was measured at the midpoint of each interval. Velocity was measured with a hand held Sontek Doppler water velocity probe using the 0.6 depth method where the velocity at 0.6 of the depth from the surface is taken as the mean velocity for the interval. The interval velocity multiplied by area summed over intervals gives the point discharge. These point discharge measurements were used to develop stream stage-discharge equations and to calibrate weir discharge equations and SAV based discharge measurements. Wetland pool surface elevation was monitored using stage recorders. Wetland pool water depth and wetland outflow structure dimensions were used to develop discharge equations for wetland outflow structures. Wetland pool water levels were monitored at five minute intervals using stage recorders in order to calculate pool volume and discharge at outflow structures. Wetland water temperatures were recorded at five minute intervals for numerical modeling of nitrate loss rates.

By design, the CREP wetlands selected for monitoring span the 0.5% - 2.0% wetland/watershed area ratio range approved for Iowa CREP wetlands. The wetlands also span a 2-3 fold range in average nitrate concentration. The wetlands thus provide a broad spectrum of those factors most affecting wetland performance: hydraulic loading rate, residence time, nitrate concentration, and nitrate loading rate. Despite significant variation with respect to average nitrate concentrations and loading rates, the wetlands display similar seasonal patterns. Because nitrate load is the product of nitrate concentration and discharge and discharge varies over several orders of magnitude, temporal nitrate loading is strongly correlated with discharge. Nitrate mass loads are typically low during winter because discharge is usually low during winter. One exception to this occurred during late November and early December 2010 at the AL wetland where concentrations were high and discharge was moderately elevated. Samples collected during late winter or early spring high discharge events show low nitrate concentrations thought to be due to dilution from snow melt (see AL, HS north, and KS wetlands during March in Figure 8). This combination of increased flow from snow melt and associated low nitrate concentrations was also observed during February 2009. Nitrate concentrations generally increase to their highest levels during high flow periods in spring and early summer, may decline with declining flow in mid to late summer, and are usually elevated if there is increased flow during late summer or fall. These nitrate concentration and flow patterns are representative of the patterns that are expected for future wetlands restored as part of the Iowa CREP.

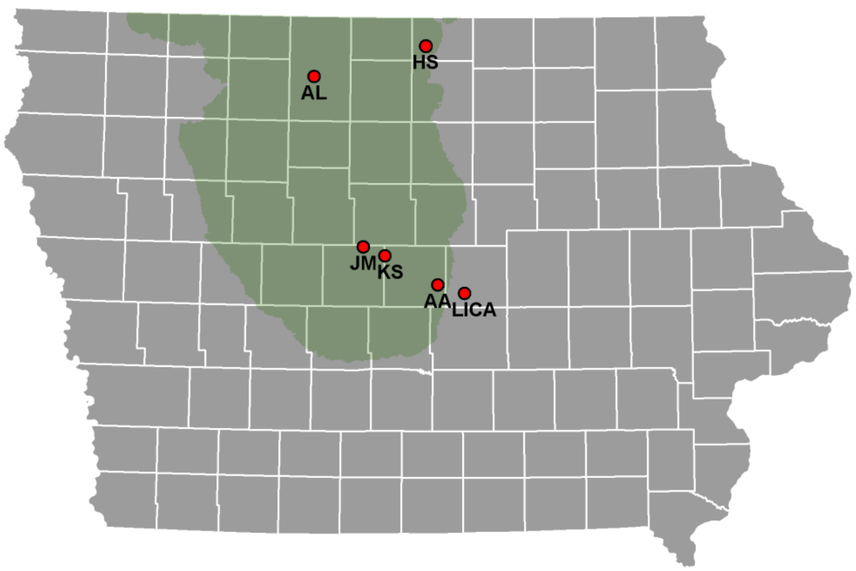

Figure 7. Wetlands monitored during 2010.

Nitrate Loss from Wetlands

Mass balance analysis and modeling were used to calculate observed and predicted nitrate removal for the monitored wetlands. Inflow and outflow nitrate concentrations and discharge measured in 2010 are illustrated in Figure 8. In addition, Figure 8 shows the range of outflow concentrations predicted for these wetlands by mass balance modeling with 2010 water budget, water temperature, and measured inflow nitrate concentration as model inputs.

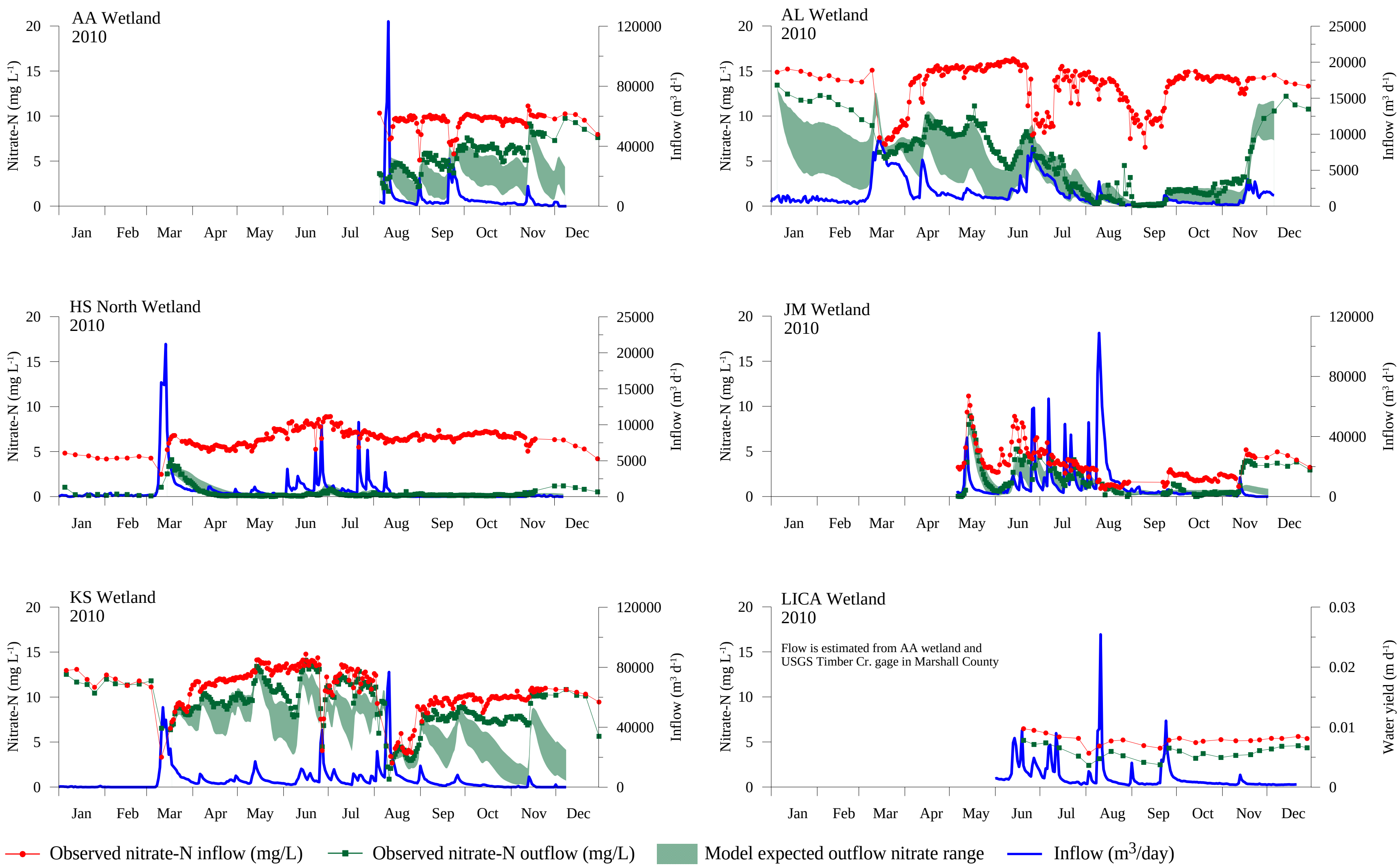

Figure 8. Measured and modeled nitrate concentrations and flows for wetlands monitored during 2010.

The monitored wetlands performed as expected with respect to nitrate removal efficiency (expressed as percent mass removal) and mass nitrate-N removal (expressed as Kg N ha^{-1} $year^{-1}$). Wetland performance is a function of hydraulic loading rate (HLR), hydraulic efficiency, nitrate concentration, temperature, and wetland condition. Of these, HLR and nitrate concentration are especially important for CREP wetlands. The range in hydraulic loading rates expected for CREP wetlands is significantly greater than would be expected based on just the four fold range in wetland/watershed area ratio approved for the Iowa CREP. In addition to spatial variation in precipitation (average precipitation declines from southeast to northwest across Iowa), there is substantial annual variation in precipitation. The combined effect of these factors means that loading rates to CREP wetlands can be expected to vary by more than an order of magnitude, and will to a large extent determine nitrate loss rates for individual wetlands.

Mass balance modeling was used to estimate the variability in performance of CREP wetlands that would be expected due to spatial and temporal variability in temperature and precipitation patterns. The percent nitrate removal expected for CREP wetlands was estimated based on hindcast modeling over the 25 year period from 1980 through 2005 (Figure 9). For comparison, percent nitrate removal measured for wetlands monitored during 2004 to 2010 are also presented and illustrate reasonably good correspondence between observed and modeled performance. An estimated mean value function (solid line), which explains 96% of the observed variation in measured percent nitrate loss, and the 95% prediction bands (dashed lines) for the percent loss range for individual wetlands are also shown in Figure 9. Percent nitrate removal is clearly a function of HLR (Figure 9).

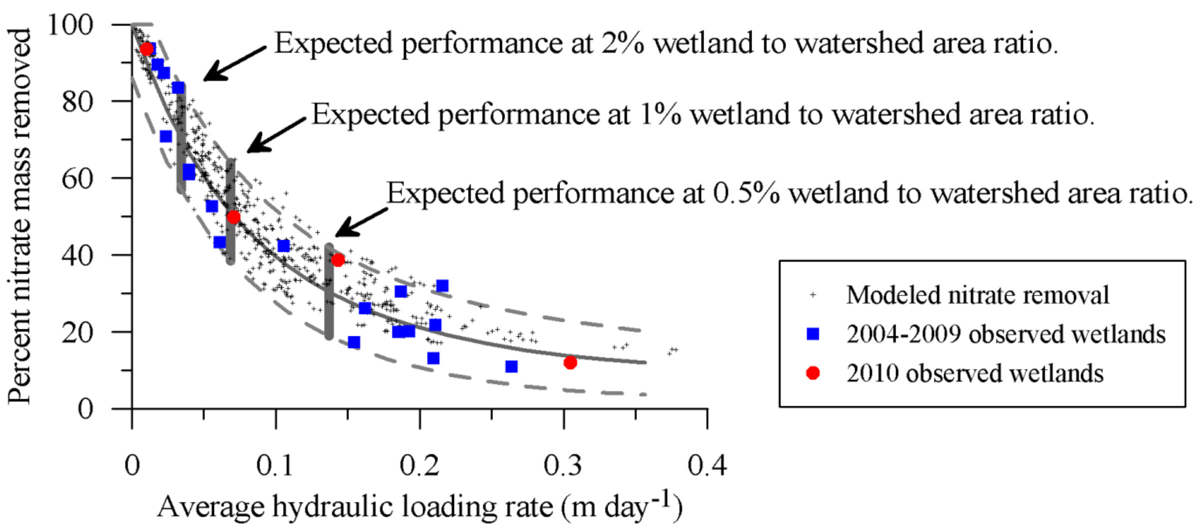

Figure 9. Modeled and observed nitrate removal efficiencies for CREP qualifying wetlands versus hydraulic loading rate. The lines show estimated average percent removal and 95% upper and lower prediction bounds estimated from the observed wetland data. The LICA wetland is not shown because only grab samples were collected at that site during 2010. The expected ranges for 0.5, 1, and 2% wetland to watershed area ratios assume a 25 cm/yr water yield.

The relationship in Figure 9 represents the annual percent nitrate removal as a function of the annual average hydraulic loading rate. However, since so much of the annual nitrate load comes during elevated springtime flows it is also important to compare nitrate removal efficiency during those periods. May and June tend to be the wettest months of the year and have the greatest nitrate concentrations. In most years, there is generally less flow in July, very little flow in August and September, and some increase in flow during October and November. We sometimes observe elevated runoff flow associated with snow melt in February or March, but, as previously mentioned, these events generally have low nitrate concentration resulting in low nitrate loading.

We compared annual nitrate removal efficiency with springtime nitrate removal efficiency based on the nitrate loss for the period April-May-June (AMJ) for wetlands monitored from 2004-2010. Although potential denitrification rates can be expected to increase with increasing summer temperatures, the percent nitrate mass loss in AMJ is very similar to the annual percent loss (Figure 10, R^2 = 0.98). This is in in large part because the bulk of the nitrate load is delivered during AMJ (Figure 11, about 60% on average) and during late October-November (about 20% on average). Considerably less of the load is delivered during July and August (about 12% on average) when temperatures are high but discharge is generally low.

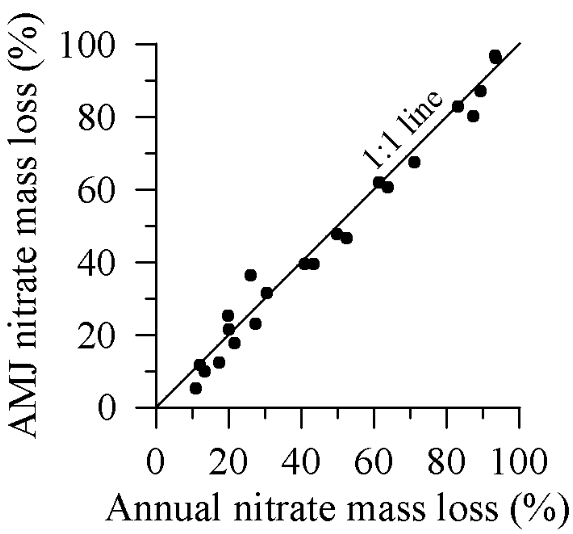

Figure 10. April-May-June (AMJ) versus annual percent nitrate loss for monitored wetlands (R^2 = 0.98).

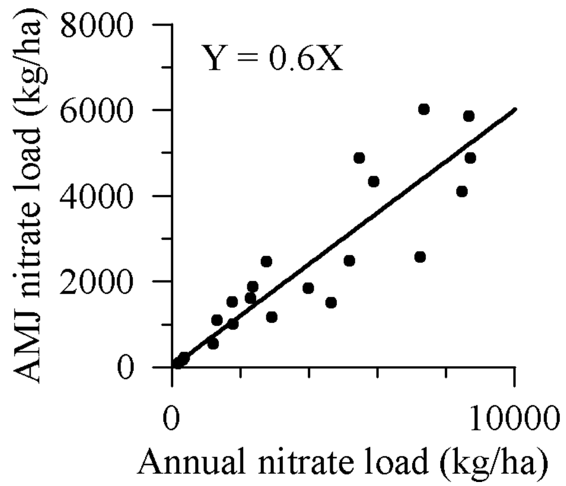

Figure 11. AMJ versus annual nitrate mass loading for monitored wetlands (R^2 = 0.81).

Total nitrogen (TN) concentrations assayed from 2007 through 2010 show that nitrate-N comprises about 93% to 97% of the total nitrogen load at the monitored Iowa wetlands. TN percent mass loss is generally slightly less than nitrate loss and, like nitrate, shows a decreasing relationship with increasing HLR (Figure 12).

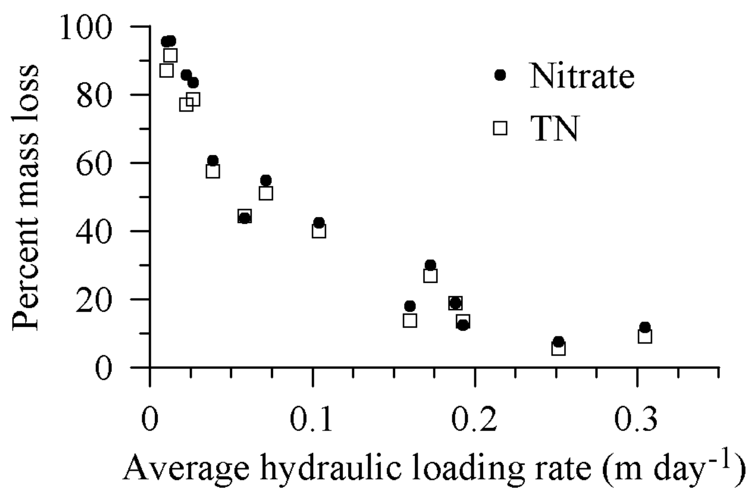

Figure 12. Total nitrogen (TN) and nitrate-N percent mass loss tend to decline with increasing hydraulic load rate.

The expected long term average annual nitrate removal capacity for CREP wetlands constructed between 2004 and 2010 was estimated based on actual wetland acreage, watershed acreage, an assumed long term average water yield of 0.25 m/yr, and a wetland inflow flow-weighted average (FWA) concentration of 12 mg N/L, which is the observed FWA nitrate concentration of monitored CREP wetlands (Figure 13). The expected nitrate mass removal for these calculations is based on the removal function derived for monitored wetlands illustrated in Figure 9. Figure 13 illustrates the increase in nitrate removal capacity with the annual addition of new CREP wetlands. For the 44 CREP wetlands completed by Spring 2010, the estimated long term average annual nitrate removal rate is about 1600 kg N ha^{-1} yr^{-1} (1430 lb N $acre^{-1}$ yr^{-1}).

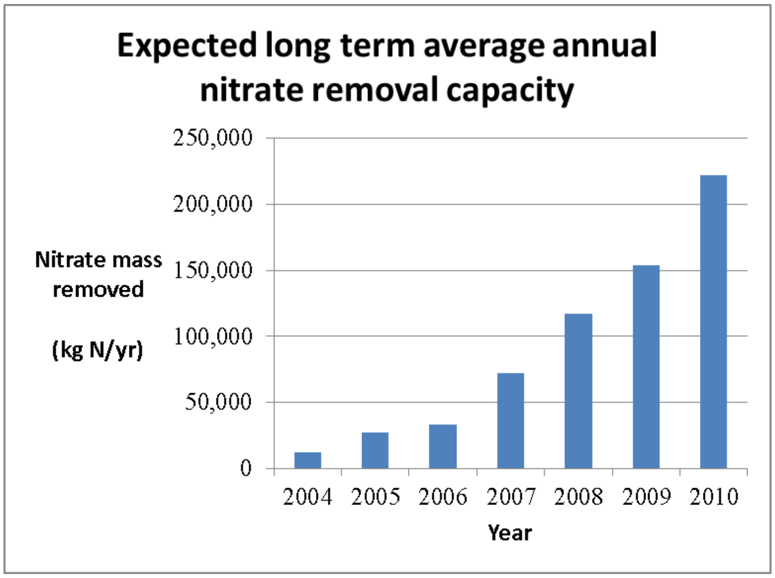

Figure 13. Estimated nitrate removal capacity of constructed CREP wetlands.

Outreach Activities
In addition to the evaluation that is taking place at the project sites in Gilmore City and Pekin we have an active outreach program associated with this project. This includes presentations at technical and Extension related meetings, field days, the Drainage Research Forum, and Extension and scientific publications. The activities and publications that are directly associated with the outreach component of this project are described below.

Events Organized

11th Annual IA-MN Drainage Research Forum

November 23, 2010 – Coordinated with Dr. Gary Sands from the University of Minnesota the forum in Ames, IA. There were 85 attendees consisting of producers, contractors, and agency representatives from Iowa and Minnesota.

Oral Presentations at Extension Related Meetings

Extension Presentations (Iowa):

December 10, 2010 – Presentation on "Tile drainage and water quality: Controlled drainage, bioreactors, and wetlands" at Drainage Workshop in Calmar, IA (30 attendees)

December 8, 2010 – Presentation on "Tile drainage and water quality: Controlled drainage, bioreactors, and wetlands" at Drainage Workshop in Jefferson, IA (55 attendees)

December 7, 2010 – Presentation on "Tile drainage and water quality: Controlled drainage, bioreactors, and wetlands" at Drainage Workshop in Pella, IA (30 attendees)

December 1, 2010 – Presentation on "Strategies for nitrate reduction: The Cedar River case study" at the Integrated Crop Management Conference in Ames, IA (300 attendees)

June 30, 2010 – Presentation on "An update on ag land drainage" at the Northwest Research Farm Field Day near Calumet, IA (250 people)

June 24, 2010 – Presentation on "Soil drainage research" at the Spring Field Day at the Southeast Research and Demonstration Farm near Crawfordsville, IA (160 attendees)

June 24, 2010 – Presentation on "Subsurface drainage design and management" at Certified Crop Advisors meeting at the Southeast Research and Demonstration Farm near Crawfordsville, IA (40 attendees)

March 30, 2010 – Presentation on "Drainage design and water quality impacts of drainage" at Pioneers Growers meeting in Reinbeck, IA (45 attendees)

March 17, 2010 – Presentation on "Water quality impacts of drainage" at Drainage Workshop in Dyersville, IA (15 attendees)

February 18, 2010 – Presentation on "Tile drainage and water quality in Iowa" at Northeast Iowa Project Coordinators meeting in Independence, IA (40 attendees)

February 4, 2010 – Presentation on "Nitrogen loss through tile lines" at Crop Advantage Series meeting in Fort Dodge, IA (30 attendees)

January 12, 2010 – Presentation on "Nitrogen loss through tile lines" at Crop Advantage Series Meeting in Ames, IA (75 attendees)

January 11, 2010 – Presentation on "Drainage design and water quality impacts of drainage" at the Iowa Land Improvement Contractors meeting in Des Moines, IA (75 attendees)

Extension Presentations (Regional):

November 17, 2010 – Presentation "Drainage management and nitrogen loss" at the North Central Extension-Industry Conference in Des Moines, IA (200 attendees)

April 6, 2010 – Presentation "Impacts of subsurface drainage" on Plant Management Network (available on-line)

Technical Papers (Peer-reviewed)

Qi, Z., M. J. Helmers, and A. Kaleita. 2011. Soil water dynamics under various land covers in Iowa. *Agricultural Water Management* 98(4): 665-674.

Qi, Z., M.J. Helmers, R.D. Christianson, and C.H. Pederson. Crop uptake of nitrogen and nitrate-nitrogen losses from various land covers in a subsurface drained field in Iowa. Submitted December 2010 to *Journal of Environmental Quality.*

Lawlor, P.A., M.J. Helmers, J.L. Baker, S.W. Melvin, and D.W. Lemke. Comparison of liquid swine manure and ammonia nitrogen application timing on subsurface drainage water quality in Iowa. Submitted December 2010 to *Trans. ASABE.*

Helmers, M.J., X. Zhou, J.L. Baker, S.W. Melvin, and D.W. Lemke. Nitrogen loss on tile-drained Mollisols as affected by nitrogen application rate under continuous corn and corn-soybean rotation systems. Submitted December 2010 to *Canadian Journal of Soil Science.*

Qi, Z., M. J. Helmers, R. Malone, and K. Thorp. Simulating long-term impacts of winter rye cover crop on hydrologic cycling and nitrogen dynamics for a corn-soybean crop system. Submitted July 2010 to *Trans. ASABE.*

Technical Papers, Conference Papers, and Extension Related Publications

Helmers, M.J., X. Zhou, and Z. Qi. 2010. Artificial drainage and associated nutrient loss on Mollisols in Iowa. International Symposium on Soil Quality and Management of World Mollisols. Harbin, China.

Helmers, M.J. 2010. Drainage Management and nitrogen loss. North Central Extension-Industry Conference Proceedings. Des Moines, IA

Helmers, M. J. 2010. Nitrogen loss through tile lines. p. 22. *In:* 2010 Proceedings Crop Advantage Series. AEP 0200. Iowa State Univ., Ames, IA. [Oral Presentation - Helmers]