RESEARCH REPORT

ENVIRONMENT

Title: Evaluating Nutrient (nitrogen and ortho-phosphate) Export with Subsurface Drainage Water from Spring Applied Swine Manure to Soybean Planted Sub-watersheds - NPB #11-085

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Date Submitted: August 23, 2012

1. INDUSTRY SUMMARY

The objective of this project is to evaluate the impact of spring applied swine manure for soybean crop on sub-surface drainage water quality from non-replicated sub-watersheds. To evaluate this impact, sub-surface flow from tile outlets in two sub-watersheds is being monitored for nutrients (nitrogen and ortho-phosphate). Tile outlets from the two sub-watersheds have been instrumented with ISCO flow samplers and flow meters. This has been done to record flow volumes being discharged from the sub-watersheds. Water samples were collected to determine nitrate-nitrogen and ortho-phosphate mass and concentrations in tile flow. Manure was applied to one of the two sub-watersheds in spring of 2011 before it was planted to soybeans. Both sub-watersheds were monitored and data was recorded from May 15 to November 13, 2011. Analysis of data shows that the flow weighted nitrate-N (NO_3-N) concentrations were slightly higher for the sub-watershed where manure was applied in comparison to sub-watershed where no manure was applied. The flow weighted ortho phosphate-P (PO_4-P) concentrations were slightly higher for the sub-watershed where no manure was applied in comparison to sub-watershed where manure was applied. The project was carried out in collaboration with Iowa Select Farms. Funding, wholly or in part, was provided by The National Pork Board on behalf of the Iowa Pork Producers Association.

2. **KEYWORDS**: nitrates, soybeans, loss, tile, drainage, subsurface, water quality

3. **SCIENTIFIC ABSTRACT:** Manure application to soybeans has been put under focus in the recent years. Currently, in Iowa, there is a limit of 100 pounds per acre of available nitrogen that can be applied for soybean crop use. One-year study was conducted to compare nutrient movement with sub-surface tile water between a manure applied sub-watershed and a no manure applied sub-watershed, with both sub-watersheds planted to soybeans. Nutrients observed in this study were nitrate-N (NO_3-N) and ortho-phosphate (PO_4-P). Sub-watershed with no manure applied yielded more flow volume than the sub-watershed with manure application. Consequently, nitrate-N mass was higher for the sub-watershed with no manure applied in comparison with the

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sub-watershed with manure application. Ortho-phosphate mass showed the same trend. Flow weighted nitrate-N concentration was slightly higher for the sub-watershed with manure applied than the sub-watershed with no manure applied. Flow weighted ortho-phosphate concentration was slightly higher for the sub-watershed with no manure applied than the sub-watershed with manure applied. The use of data presented in this report should be evaluated very carefully as it is a non-replicated study with only one year data observed and reported.

4. INTRODUCTION:

Ninety percent of total freshwater input into the Gulf of Mexico originates in the Mississippi-Atchafalaya River Basin, which drains 41 percent of the continental United States. According to Goolsby, 1999 and Rabalais et al., 1999; this freshwater discharges an estimated 1.6 million metric tons of nitrogen annually. Sixty-one percent of this nitrogen discharge is in the form of nitrates (the mobile form of nitrogen). Similar data are available for phosphorus losses. Agricultural nitrogen losses are the major contributor to nitrogen loads in the Mississippi River. Of particular importance is the explicit focus on agricultural subsurface (tile) drainage, which has been identified as the major pathway for agricultural nitrate-nitrogen and soluble phosphorus (ortho-phosphate) losses in the upper Midwest. Agricultural subsurface tile drainage removes excess surface and sub-surface water from fields. This allows for development of a well-aerated soil profile allowing for optimal plant growth. A well - drained soil profile promotes good plant growth and allows for timely field operations. Agricultural subsurface tile drainage has also been shown to reduce the loss of phosphorus, organic nitrogen, and other pollutants, such as certain pesticides, with surface runoff to waterways (Skaggs et al., 1994). Transport of soluble nutrients (nitrate-nitrogen and soluble phosphorus) occurs at the subsurface level. Agricultural subsurface tile drainage can significantly hasten their movement to the edge of the field, and, thus, into an adjacent stream.

To limit the movement of nutrients to water bodies in Iowa, a simple strategy to utilize optimal amounts of nutrients has gained popularity and is being followed in production agriculture. Recently, manure nutrient application to soybean crop has come under focus. Soybean plant is a leguminous plant and is expected to fix atmospheric nitrogen for its own needs. As such, any nutrient application is being viewed as excess nutrient application on the agricultural landscape. In November 2008, Iowa Department of Natural Resources (IDNR) implemented a limit on liquid manure or open lot effluent that can be land applied to fields that will be planted to soybeans. This limit is specified as 100 pounds of available nitrogen, or N, per acre and applies to liquid manure or runoff containing manure from both open feedlots and animal confinements. This limit will turn into a complete ban of any manure application in the year 2013 unless scientific evidence justifies an alternate action.

5. OBJECTIVES:

Iowa State University has worked with Iowa Select Farms as co-collaborators on a one-year project for 2011. The objective of this project has been to evaluate impact of manure application for soybean crop on sub-surface drainage water quality. To evaluate this impact, sub-surface flow from tile outlets in two sub-watersheds has been monitored for nutrients (nitrate-nitrogen and ortho-phosphate). The intended outcome of the project is to evaluate how sub-surface drainage water quality (in terms of nitrate-nitrogen and ortho-phosphate) for manure applied sub-watershed compares with non-manure applied sub-watershed in this non-replicated study.

6. MATERIALS AND METHODS:

Site Preparation: Swine finishing manure, at the rate of 1,680 gallons per acre, was applied to sub-watershed D (Figure 1) using a 7300 gallon houle wagon with Dietrich-knife injection. Manure application was turned off in the passes over Sub-watershed C to achieve similar tillage between both sub-watersheds; and also to avoid any additional equipment passes over the field. The manure application took place on May 18, 2011. Soybeans were planted to both sub-watersheds on May 19, 2011 with a planting density of 140,000 plants per acre. No manure was applied to sub-watershed C which served as control for this non-replicated sub-watershed study.

Instrumentation: Tile outlets for both watersheds were secured for instrumentation by placing rodent guards at outlet. An ISCO low profile area velocity sensor was placed at the base of the tile outlet such that it would be submerged as the flow exited the tile. An ISCO portable sampler intake was also placed along with the velocity sensor for collecting tile water samples. The ISCO portable sampler (Figure 2) was linked with the low profile area velocity sensor using an ISCO link module. ISCO portable sampler was programmed to record the depth and velocity of flow every two-minutes and collect water samples every twelve hours. Two, twelve-hour tile water samples were composited into one sampler bottle to obtain a daily representative sample. ISCO samplers were placed in job-boxes to protect them from environmental conditions and to ensure interruption free automatic sampling. ISCO samplers and area velocity sensor were powered with 12-volt deep-cycle batteries which were kept charged using solar panels.

Sample Collection: Four manure samples were taken during application. One additional manure sample was taken two days prior to application on May 16, 2011. Four feet deep soil samples were taken from both sub-watersheds prior to manure application to get background nutrient data. Flow sampling and rate measurement equipment for both sub-watersheds was purchased from the funding provided in the project. Daily flow sampling for both sub-watersheds became functional on May 18th whereas the continuous flow rate measurements began June 14th. Prior to automatic flow sampling and continuous flow rate measurements on both sub-watersheds, instantaneous flow rate measurements and grab sampling for flow was performed daily starting from May 18th.

Sample Analysis: Manure samples were analyzed by Minnesota Valley Testing Labs. Pre-plant and post-harvest soil samples were also analyzed by Minnesota Valley Testing Labs. Tile water samples were analyzed for nitrate-nitrogen and ortho-phosphates at the Iowa State University Agricultural and Biosystems Engineering Water Quality Laboratory.

7. RESULTS:

Historical data was used to determine manure application rate to provide 100 pounds of available nitrogen to the Sub-Watershed D (J-North). Data on manure samples (Table 3) shows that the total nitrogen and phosphorus (P_2O_5) concentration, on average, was 69.1 and 27.9 pounds per 1,000 gallons. Using an application rate of 1,680 gallons per acre, total nitrogen was applied at a rate of 116.1 pounds per acre. The corresponding application rate for phosphorus (P_2O_5) was 46.9 pounds per acre.

Surface areas for both sub-watersheds were determined by using RTK-GPS enabled device. Sub-watershed C was determined to be 4.3 acres (Figure 1) whereas sub-watershed D was 5.8 acres in surface area. Surface area of a watershed does not represent the contributing area for sub-surface flow. Area for sub-surface flow can be different from the surface area due to changes in hydraulic conductivity within the soil profile.

Flow volume data was compiled for both watersheds from May 16, 2011 to November 14, 2011. Data in Figure 3 shows that no tile flow occurred from the start of September 2011 for both sub-watersheds due to lack of adequate rainfall. As shown in Table 1, a total of 1,272,602 gallons of tile flow volume with a daily average flow of 12,337 gallons was recorded for Sub-watershed D (J-South, manure applied). The corresponding numbers for sub-watershed C (J-North, no manure) were 1,694,627 gallons with a daily average flow of 14,797 gallons.

Two hand grab samples were collected for both watersheds prior to manure application. Average nitrate-N concentration was 10.78 mg/L for sub-watershed C and 11.41 mg/L for sub-watershed D. Average nitrate-N concentrations after manure application (from May 18 to November 14) were 9.96 and 11.59 mg/L, respectively for the two sub-watersheds.

Nitrate-N mass calculations were performed based on instantaneous flow data collected. Nitrate-N mass in drainage water totaled as 152 and 132 pounds respectively for the two sub-watersheds C and D following manure application (From May 18 to November 14). For the sub-watershed C, the monthly nitrate-N mass in sub-surface drainage water ranged between 0.3 to 70.6 pounds. Month of May only has one-half month of data collected as the project started at that time. This range for sub-watershed D (manure applied) was 6.7 to 54.8 pounds based on data collected. In the month of September, sub-surface drainage water was flowing for only first five days of the month before it stopped flowing due to lack of rain.

Ortho-phosphate mass calculations were performed based on instantaneous flow data collected. Ortho-phosphate mass in drainage water totaled as 1.4 and 2.1 pounds respectively for the two sub-watersheds following manure application (From May 18 to November 14). For the sub-watershed C, the monthly ortho-phosphate mass ranged between 0.0 to 2.0 pounds. This range for sub-watershed D (manure applied) was 0.0 to 0.9 pounds based on data collected.

8. DISCUSSION:

Daily nitrate-N concentrations for sub-surface drainage water in sub-watershed C and D are presented in Figure 4. Daily nitrate-N concentrations in tile water for sub-watershed D (manure applied) were relatively higher than the nitrate-N concentrations for sub-watershed C (no manure applied). Linear regression performed on this data shows that the concentrations for both watersheds decreased as the season progressed although the R^2 values for regression fits for both sub-watersheds were very low. Nitrate-N concentrations in sub-surface drainage water represent what leaches out of the soil profile. These concentrations are a function of how different pools of nitrogen interact with the amount of water moving through the soil profile under different conditions of temperatures and soil types.   As such, concentrations need to be evaluated together with the flow volume to estimate the mass of nitrate-N in drainage water.

The site experienced extremely dry weather from start of September to the end of season. Very little rainfall was measured at the site from start of September till November 14. Amount of sub-surface drainage flow volume resulting from rainfall was measured for both watersheds and is presented in Figure 3. Sub-watershed D has relatively larger surface area than sub-watershed C; however, greater flow volumes were recorded for sub-watershed C than for sub-watershed D. A total of 1,272,602 gallons of flow volume was recorded for Sub-watershed D (J-South, manure applied) whereas the corresponding numbers for sub-watershed C (J-North, no manure) was 1,627,694 gallons. The total nitrate-N mass for sub-watershed C was 152 pounds and sub-watershed D (manure applied) was 132 pounds. Taking the surface area of the sub-watersheds into account, the nitrate-N mass per acre in sub-surface drainage was 36 pounds per acre for sub-watershed C (no manure). The corresponding number for sub-watershed D (manure applied) was 23 pounds per acre. As the sub-surface area contributing to tile flow can be different from the surface area of a watershed, comparing nitrate-N mass in subsurface drainage on a per acre of surface area does not appropriately represent the nutrient movement in such sub-watersheds. A flow-weighted average nitrate-N concentration is a better comparison as it takes into account the flow volume yield in subsurface drainage water irrespective of the watershed size on ground surface. Flow weighted average nitrate-N concentration for sub-watershed C was 11.20 mg/L whereas the corresponding number for sub-watershed D was 12.39 mg/L. When monthly flow weighted concentrations were compared between the two sub-watersheds, sub-watershed C had slightly lower nitrate-N concentrations than the sub-watershed D concentrations.

A similar comparison for the flow-weighted average ortho-phosphate concentrations in tile water, taking into account the flow volume yield in subsurface drainage water, was also

done. Flow weighted average ortho-phosphate concentration for sub-watershed C was 0.15 mg/L whereas the corresponding number for sub-watershed D was 0.13 mg/L. When monthly flow weighted concentrations were compared between the two sub-watersheds, sub-watershed C had slightly higher ortho-phosphate concentrations than the sub-watershed D concentrations.

Average nitrate-N concentrations in soil for different depths for both sub-watersheds are presented in Table 2. For both spring and fall measurements, nitrate-N concentrations in sub-watershed D (J-South) where manure was applied were the relatively higher for almost all of the measured five depths.

9. CONCLUSIONS:

1. Year 2011 represents a weather pattern where it was wet in the earlier part of the growing season (May through August) after which it became extremely dry with almost no recordable rainfall. Thus, the use of data should be evaluated very carefully.

2. Majority of manure application in Iowa takes place in fall. As manure in this study was applied in May 2011 before planting, comparison of data presented in this report to fall- applied manure conditions is not recommended.

3. Delays in project start-up due to delayed manure application, set-up, and equipment irregularities experienced, the measurements were not made for about 30 days from April 1 to May 15. Thus, the data

contained in this report does not represent the entire growing season (April 15 through November 15) or the entire calendar year.

4. Total flow volume yield from sub-watershed C was higher in comparison with the sub-watershed D. Consequently, nitrate-N mass in sub-surface drainage water from sub-watershed C where no manure was applied was higher than the Nitrate-N mass from manure applied sub-watershed D over similar data recording time period. As both sites received similar rainfall, the sub-watersheds need to be further evaluated to ascertain any co-variance between these two watersheds.

5. Ortho-phosphate mass in sub-surface drainage water from sub-watershed C was higher than the mass from sub-watershed D. Soil phosphorus concentrations in sub-watershed D both in Spring and Fall were higher for the 0-6 inch depth when compared with sub-watershed C.

6. One year data cannot provide conclusive and repeatable results as a minimum of three to five years water quality data would be needed for such large size plots. This one year study shows that the flow-weighted nitrate-N concentrations in tile water were comparable between the two watersheds. The sub-watershed D, where manure was applied, did show slightly higher flow weighted nitrate-N concentrations (higher by about 1 mg/L) when compared with the sub-watershed where no manure was applied.

7. In case of ortho-phosphate (PO_4), after manure applications to soybean plots, flow weighted average ortho-phosphate (PO_4) concentrations in tile water were comparable between the two sub-watersheds. For sub-watershed C, where no manure was applied, the concentrations were 0.15 mg/L which is slightly higher than the flow weighted concentrations for manure applied sub-watershed D (0.13 mg/L). For both watersheds, such average concentrations of ortho-phosphate in sub-surface drainage water exceed the proposed water quality standards by several times.

10. CREDIT:

The project was carried out in collaboration with Iowa Select Farms. Funding, wholly or in part, was provided by The National Pork Board on behalf of the Iowa Pork Producers Association.

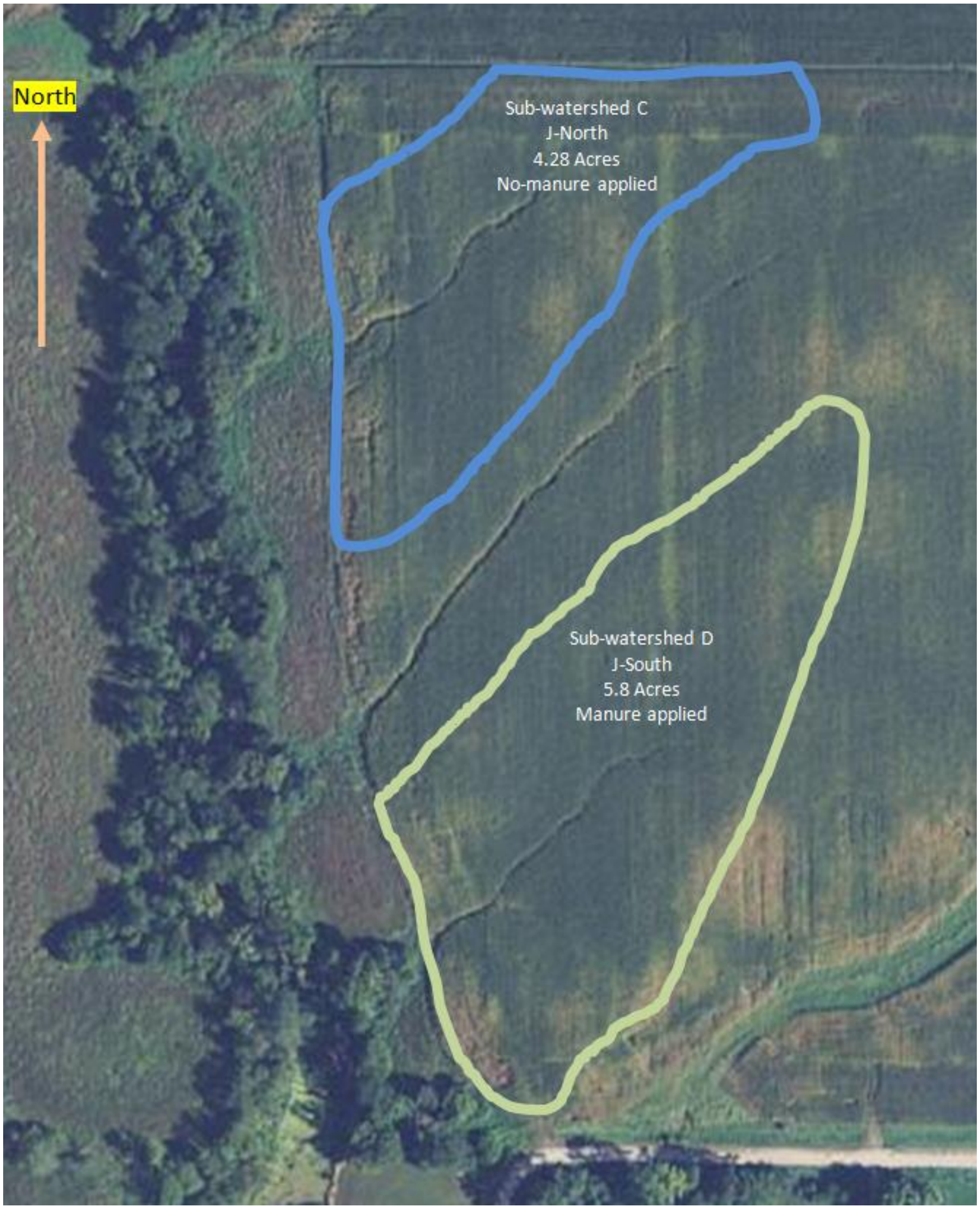

Figure 1: Project Site Map

Figure 2: ISCO Portable Sampler being placed in the job-box.

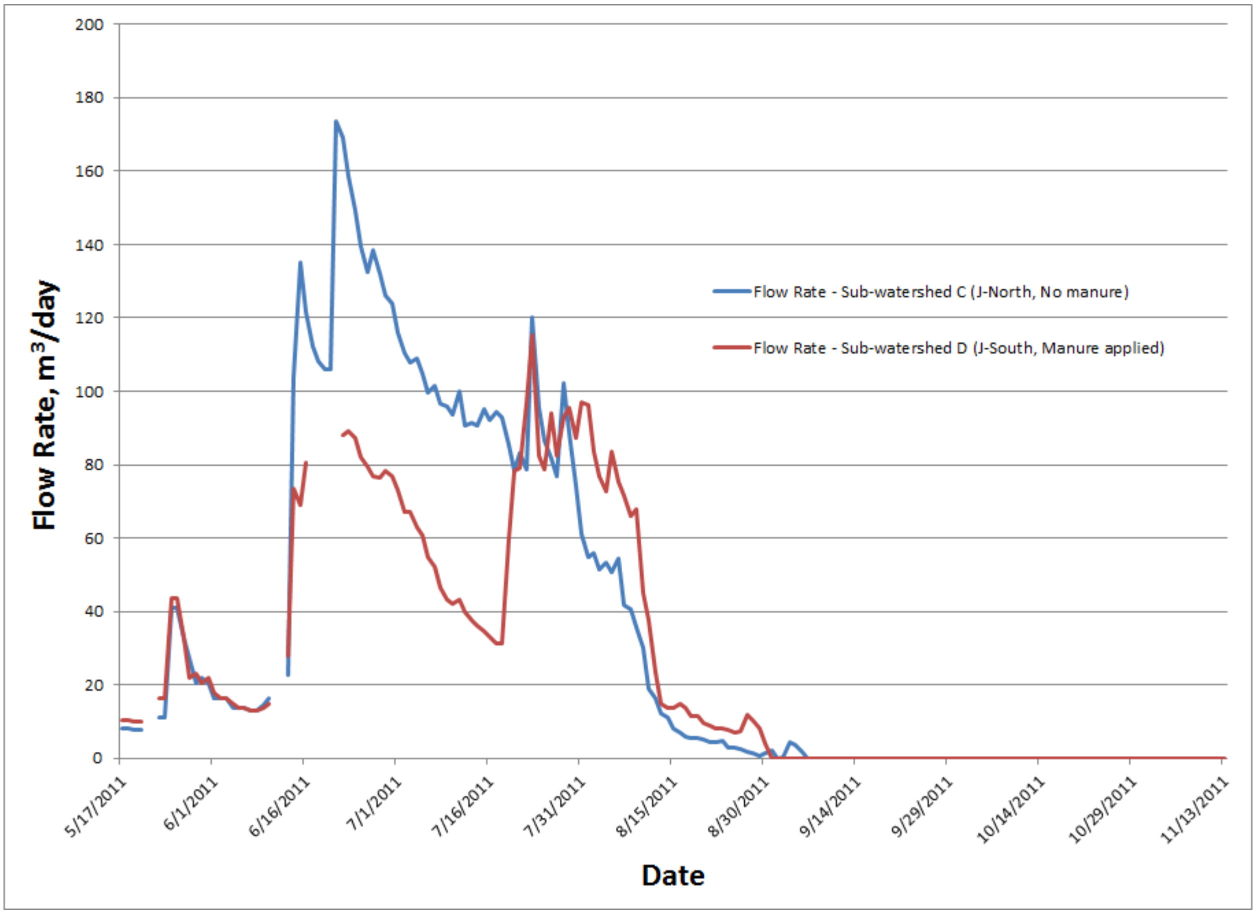

Figure 3: Drainage flow rate (m^3/day) for both sub-watersheds.

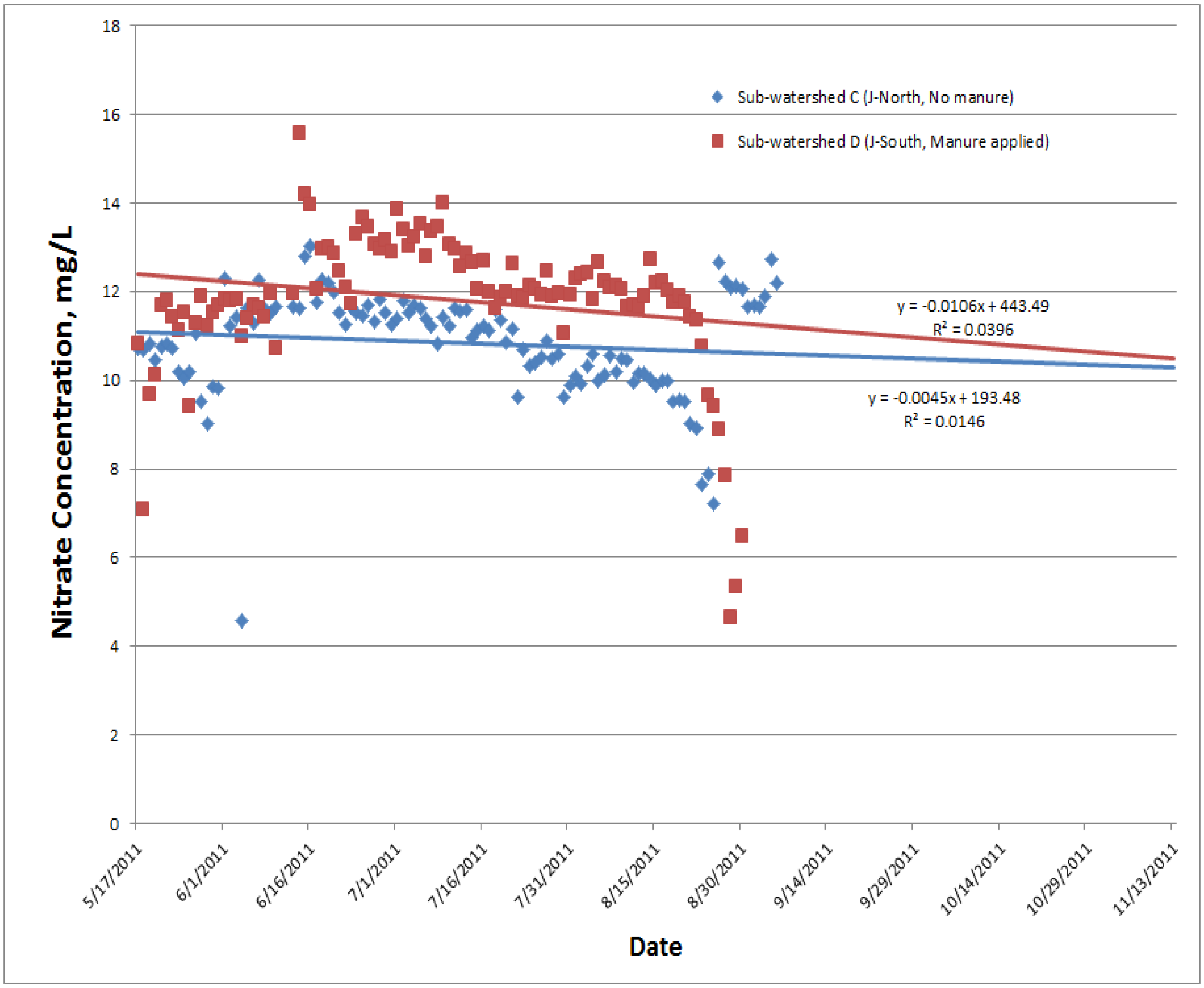

Figure 4: Nitrate-N concentrations in drainage water for both sub-watersheds.

Table 1: Monthly flow volumes, nitrate-N mass and concentrations, and ortho-phosphate mass and concentrations for both sub-watersheds.

Sub-watershed C (No Manure)		Flow Volume	Nitrate Mass	Ortho-Phosphate Mass	Flow Weighted Nitrate Conc.	Flow Weighted Ortho-Phosphate Conc.
Month	Days	Gallons	Pounds	Pounds	mg/L	mg/L
May	15	68,220	5.77	0.0052	10.14	0.0092
June	28	635,464	62.19	2.0261	11.73	0.3821
July	31	764,792	70.56	0.0630	11.06	0.0099
August	31	156,584	13.28	0.0015	10.16	0.0012
September	5	2,634	0.27	0.0000	12.24	0.0000
October	0	0	0.00	0.0000	-	-
November	0	0	0.00	0.0000	-	-
Total	110	1,627,694	152.08	2.0959	11.20	0.1543
Sub-watershed D (Manure Applied)		Flow Volume	Nitrate Mass	Ortho-Phosphate Mass	Flow Weighted Nitrate Conc.	Flow Weighted Ortho-Phosphate Conc.
Month	Days	Gallons	Pounds	Pounds	mg/L	mg/L
May	15	73,980	6.70	0.0032	10.86	0.0052
June	28	410,857	44.35	0.4492	12.94	0.1310
July	31	527,579	54.77	0.9170	12.44	0.2083
August	30	260,186	25.76	0.0239	11.86	0.0110
September	0	0	0.00	0.0000		
October	0	0	0.00	0.0000		
November	0	0	0.00	0.0000		
Total	104	1,272,602	131.59	1.3933	12.39	0.1312

Table 2: Soil analysis data for sub-watershed C (J-North, no manure) and sub-watershed D (J-South, manure applied) for Spring 2011 and Fall 2011. Data presented is an average of three soil samples each for both watersheds for both sampling time periods.

Soil Sample ID	Depth (inches)	Date Taken	Organic Matter (%)	pH	buffer pH	Mehlich-3 P ppm	Nitrate ppm	Mehlich-3 K ppm
J - North	0 – 6	May-2011	2.97	5.5	6.5	20	7.0	140
J - North	6 – 12	May-2011	2.80	6	6.7	5	3.8	72
J - North	12 – 24	May-2011	2.03	6.7	7.1	3	3.7	73
J - North	24 – 36	May-2011	1.27	7.4	7.3	2	2.4	85
J - North	36 – 48	May-2011	0.80	7.8	7.4	4	1.7	71
J - South	0 – 6	May-2011	3.17	5.5	6.4	32	8.7	212
J - South	6 – 12	May-2011	3.47	5.7	6.4	9	3.3	95
J - South	12 – 24	May-2011	2.83	6.2	6.8	5	2.9	77
J - South	24 – 36	May-2011	1.67	6.7	7.2	5	2.7	72
J - South	36 – 48	May-2011	1.03	7.6	7.4	4	1.1	61
J - North	0 – 6	November-2011	2.70	6.0	6.6	25	2.9	214
J - North	6 – 12	November-2011	2.53	6.0	6.7	7	3.1	74
J - North	12 – 24	November-2011	1.97	6.5	7.0	3	2.4	47
J - North	24 – 36	November-2011	1.10	7.0	7.3	4	1.2	56
J - North	36 – 48	November-2011	0.80	7.5	7.4	6	1.5	58
J - South	0 – 6	November-2011	3.07	5.8	6.5	66	3.5	278
J - South	6 – 12	November-2011	2.83	6.2	6.7	17	5.5	151
J - South	12 – 24	November-2011	2.53	6.5	6.9	13	5.2	83
J - South	24 – 36	November-2011	1.10	7.1	7.3	8	2.4	68
J - South	36 – 48	November-2011	0.57	7.8	7.4	5	2.1	50

Table 3: Analysis of finishing swine manure applied in May 2011 to sub-watershed D before planting. Samples were collected at the time of application.

Analyte	Units	Sample 1	Sample 2	Sample 3	Sample 4
Moisture	%	93.5	93.8	93.3	93.3
Total Nitrogen	%	0.82	0.82	0.83	0.83
Phosphorus (as P_2O_5)	%	0.36	0.36	0.39	0.22
Potassium (as K_2O)	%	0.47	0.50	0.50	0.30
Ammonia Nitrogen	%	0.60	0.60	0.61	0.57
Sulfur	%	0.05	0.08	0.07	0.07
Copper	mg/kg	25.6	28.5	27.3	33.0
Calcium	mg/kg	1070	1070	1140	1060
Iron	mg/kg	82.8	82.6	86.1	102
Magnesium	mg/kg	942	912	957	447
Manganese	mg/kg	13.2	13.1	13.6	15.4
Sodium	mg/kg	1190	1260	1260	568
Zinc	mg/kg	66.2	67.5	68.7	60.2