The Ozarks Environmental and Water Resources Institute (OEWRI)
Missouri State University (MSU)

YEAR TWO ANNUAL REPORT FOR:

NUTRIENT TRANSPORT AND FATE FROM MUNICIPAL BIOSOLIDS LAND APPLICATION

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Completed for: The City of Springfield

December 16, 2010

OEWRI EDR-10-006

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SCOPE AND OBJECTIVES

Biosolids is the residual by-product of the municipal treatment of wastewater used to fertilize agricultural fields in southwestern Missouri. Human health risks for land application of biosolids are considered low when the material is properly handled and treated per environmental regulations (USEPA, 1994[1]). Regardless, the public perception is that land applied biosolids release nutrients and trace metals during runoff events and contribute to water quality problems in nearby streams and lakes. Land application rates of biosolids are site specific and are based on soil fertility, crop needs, and production goals to avoid over-fertilization where valuable nutrients can move off of fields and into receiving waters (MDNR, 1985).

Like all organic fertilizers (e.g. manure, chicken litter), biosolids are high in phosphorus (P) per unit nitrogen (N) and over-application of P can occur when applied at a rate based on N needs of the crop (Shober and Sims, 2003). Over-application can cause excess P to wash off the landscape into receiving waters during runoff events and is a leading factor in eutrophication of aquatic ecosystems (Correll, 1999; Dodds, 2006). Trace metal concentrations in runoff from biosolids applied fields are influenced by site specific conditions, such as soil type, moisture conditions, and conservation practices (Al-Wabel et. al., 2002; Richards et al, 2004; and Galdos et al, 2009). However, little is known about metals in runoff from other fertilizer sources since concentrations of many trace metals in biosolids are near or below concentrations of metals in poultry litter and inorganic fertilizers (Spicer, 2002).

In the Ozarks, questions still remain on the release of nutrients and metals from biosolids applications during runoff events and the contamination of downstream receiving water bodies under local soil, slope, and crop conditions. Working with the Missouri Department of Natural Resources, NRCS, and MSU, the City of Springfield is conducting a 3-year study to compare the runoff rates of nutrients and metals from fields treated with biosolids to fields treated with traditional inorganic fertilizer. The purpose of this study is to determine the effect of biosolids application on runoff quality under field conditions. The specific objectives of the study are:

1. Implement an experimental field plot monitoring program using runoff auto-samplers to measure the concentrations and loads of nutrients and metals released from fields treated with biosolids;

2. Compare the levels of nutrients and metals in runoff, surface soils, and forage measured in biosolids applied fields to fields treated as control (no application) and with traditional fertilizer;

3. Use this information to support the continued approval of biosolids applications by government regulators and provide information to the general public on the safety of using biosolids as a component in an overall nutrient management plan.

The Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University is responsible for providing technical support and implementation of water quality monitoring activities and surface soil sampling and testing activities, and reporting for the project (www.oewri.missouristate.edu). The Darr School of Agriculture at Missouri State University is responsible for the soil morphological classification, forage collection and analysis, and weed control of the site. The Natural Resources Conservation Service Southwest Missouri Water Quality Office provided the nutrient management plan. Specific contributions in data collection, reporting and editing for this report came from the following:

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This report organizes and summarizes data collected for the first two years of sampling from November 2008 through July 2010 and provides detailed methods and results for water quality monitoring, soil testing, and forage analysis. Maps, figures, tables, and photos corresponding to these sections are at the end of the narrative. Appendices of all data collected can also be found at the end of this report.

STUDY AREA

The Biosolids Demonstration site is located in Lawrence County in the Sac River Watershed (hydrologic unit code 10290106). The site is located on a 40 acre tract in the SE ¼ of the SE ¼ of the northern half of Section 3, Township 29N, Range 27W in northern Lawrence County (Figure 1). This tract is bisected by a small tributary valley flowing north into Limestone Creek, a tributary to Turnback Creek and the Sac River Basin. The surface geology of the area is typical of the Springfield Plateau of the Ozarks which is dominated by cherty Mississippian age limestone along with remnants of Pennsylvanian age sandstones. Generally, upland soils are derived from residuum topped by a thin layer of loess material (Hughes, 1982). On hillslopes, residual soils are capped by a layer of silty and cherty colluvium, which increases in thickness going downslope. Mapped soils for this property are the Viraton silt loam on the top of the uplands, Nixa cherty silt loam on the sideslopes, and the Clarksville cherty silt loam in the steeper areas below where the Nixa series is located (Figure 2). The Viraton and Nixa series typically contain a fragipan and are classified as moderately well drained while the Clarksville is somewhat excessively drained. Site specific soil descriptions and deviations from the typical profiles will be discussed later on in this report. Previous management included a combination of haying cool season grass fescue each spring followed by grazing of beef cattle for the duration of the season. Land was leased prior to the initiation of the study, cattle were removed off-site and excluded from returning by constructing a fence.

METHODS

Site Selection

This property was chosen based on the uniformity in land cover, landscape position, slope, and soil type as best as could be done under natural conditions. A site assessment was conducted during the initiation phase of planning to determine the feasibility of the experiment and to determine the site suitability for the application of biosolids. Existing conditions were inventoried, populated into the Missouri Phosphorus Index, and determined that application of organic material at nitrogen based rates was permissible.

Four separate catchments were selected in a single field on a Wilderness-Viraton Soil Association (Table 1). Catchments designated for the study plots are located off the east and west facing slopes along a ridge running generally south-to-north with slopes ranging from 3.5% to almost 14%. Sites were located near the top of the watershed to eliminate run-on influences. All sites drained to an identifiable pour point at the base of the slope in a small draw where concentrated flow could be captured. The entire site was surveyed and a topographic map created to identify the drainage area of each catchment ranging from 0.38 acres to 3 acres (Figure 3).

Because of the topography of the site, each watershed generally overlaid two of the four soil map units present on the site (Table 1). Goss soils are classified as a Clayey-skeletal, mixed, active, mesic Typic Paleudalfs and are typically found on side slopes of ridges. Viraton soils are generally located on more level summit landscape positions and are classified as a Fine loamy, siliceous, active, mesic Oxyaquic Fragiudalfs. The Nixa soils are more generally on ridge tops and are classified as a Loamy-skeletal, siliceous, active, mesic Glossic Fragiudults. Clarksville soils are on the steeper slopes of hillsides ranging from 3-20% and are classified as Loamy-skeletal, siliceous, semiactive, mesic Typic Paleudults. Forage suitability classifications for each soil were described as a gravelly upland, gravelly pan, or loamy pan suitability group with an estimated yield goal of 2-3 tons of grass per acre. All soils do not meet hydric criteria and each contain properties consistent with the karst geology of the Missouri Ozarks region.

Soil morphological classification was performed to assess the variability in soil properties across the site and to compare soil pit field descriptions to the mapping units in the soil survey. Test pit locations on the landscape were determined by using aerial photo maps of the area and comparing them with observations using clinometers to locate proper slopes on the landform for summit, shoulder, back slope and foot slope positions. Pits were dug to a depth of 60 in. to 80 in. (where permitted) to observe horizons of the soil pedons and recorded using field notes as described in USDA (2002). Taxonomy classifications were determined according to USDA (2006). Locations of soil pits can be found in Figure 2.

The dominant parent materials for this site are colluvium over residuum. On the flat uplands, the upper horizon consists of a thin layer of loess up to 8" deep (Table 2, Photo 1). Along the broad head slope, a well formed fragipan is present between 32"and 45" deep, while a shallower, weak fragipan exists on the narrow interfluve at the crest of the narrow ridge (Photo 2). The presence of redoxamorphic features above the fragipan and within the prismatic seams through the fragipan are indicators of a seasonally high water table (Photo 3). The steeper side slopes are coarser closer to the surface, with sporadic remnants of weathered sandstone present 50" to 60" below the surface (Photos 4 and 5). In the bottom of the colluvial valley there is nearly a 2 foot accumulation of alluvium over colluvium that contains high chert content (Photo 6). Soil morphology descriptions are available at the Missouri Cooperative Soil Survey website at soils.missouri.edu.

The experimental design called for four individual nutrient treatments, each applied to a separate catchment. Details of each catchment are described below:

Site 1 catchment size = 0.38 acres - this site drains the east side of the ridge on the north end of the property. This site drains primarily the backslope and footslope landscape positions. This site was designated as the control.

Site 2 catchment size = 0.65 acres - this site also drains the east side of the ridge and received a commercial fertilizer application. Only a small portion of this catchment drains the summit landscape position, mostly draining the backslope and footslope.

Site 3 catchment size = 3 acres - this site drains from the southern end of the property on the east side of the ridge. The majority of this catchment drains the summit landscape position. This site is designated to receive biosolids application.

Site 4 catchment size = 1.28 acres - this site drains the west side of the ridge running through the property. This site drains the summit and backslope landscape positions. This site will also receive a biosolids application at a rate higher than site 3.

Nutrient Management

In 2008, soil samples were collected at three different landscape positions (summit, back slope, and foot slope) along established transects in each watershed. At each landscape position, in each watershed, individual soil cores were collected at 6-8 inches in depth and bulked to comprise a single sample. Samples were used to establish the general fertility of the site and to determine the lime requirement at 400 Effective Neutralizing Material. Global positioning technology was utilized to assist in subsequent re-sampling each summer. Samples were air dried and sent to the University of Missouri Soil Testing Laboratory for soil analysis (Appendix A).

The City of Springfield, Missouri provided biosolids from its Southwest Wastewater Treatment Plant for the study. Initial analysis of biosolids conducted by the Southwest Wastewater Treatment Plant Laboratory was used to estimate Plant Available Nitrogen (PAN). PAN is estimated using the following equation:

$$PAN = f_o(\text{organic N (ppm)}) + f_a(NH_3\text{-N (ppm)}) + NO_3\text{-N (ppm)}$$

f_o (Availability factor (organic)) = 0.2
f_a (Availability factor (ammonia)) = 0.7

Using established mineralization rates for anaerobically digested sewage sludge, it was estimated the plant available nitrogen from a single 3 dry t/ac application was roughly equivalent to the annual nitrogen recommendation for a 3 t/ac yield goal of cool season grass (USEPA, 1994[2]; UM, 2004). At a rate of 6 dry t/ac of biosolids, nearly three growing seasons of nitrogen would be delivered. Because the Southwest Wastewater Treatment Plant is located in a nutrient sensitive watershed, limited phosphorus is allowed in the discharged wastewater. Consequently, large quantities of phosphorus are retained in the biosolids and applied to land with the nitrogen (nearly 600 lbs/ac P_2O_5 at the 6 t/ac rate).

Experimental design was also influenced by the desire to match experimental protocol to local farming practices. Typically, farmers participating in a cooperative program with the City of Springfield receive a single application of biosolids to suitable fields under specified conditions, including appropriate setback distances from surface features (MDNR, 1985). Repeat applications are infrequent within a three year time frame. Thus, biosolid applications were made only in the first year of the experiment. For the commercial fertilizer treatment, equivalent amounts of nutrients were included in the blend to balance the nutrients delivered from the 3 t/ac biosolid application rate. Similar to the biosolids application, all of the added phosphate and potash from the commercial fertilizer were applied in the first year. However, unlike the biosolid application, the total amount of nitrogen was divided into three annual applications to closer represent local practices. This strategy front loads nitrogen application for the biosolids treatments, but represents reality in the field.

A calcic limestone application was made by a commercial dealer on September 9, 2008 to adjust soil acidity to near neutral levels. The biosolids applications were made with a commercial Terra-Gator 3104 side discharge spreader on October 23, 2008 and the fertilizer applied by a commercial dealer on October 28, 2008. Biosolids samples were collected on the day of application and analyzed by the laboratory to determine actual nutrient concentrations of the processed material from the treatment plant. This analysis, coupled with actual field application measurements, was utilized to determine the actual nutrient application to each catchment area (Table 3).

Site 1 received no treatment and is designated as the control. Site 2 received a commercial fertilizer application based on a 3 t/ac yield goal of 54+299+13 ($N+P_2O_5+K_2O$) in year 1. In year 2 and 3, a fertilizer application rate of 54+0+0 ($N+P_2O_5+K_2O$) were applied to mimic the slow release of N from the breakdown of biosolids over that time. These subsequent applications occurred August 5, 2009 and August 30, 2010. Site 3 received 3 t/ac biosolid application, which is equivalent to the commercial fertilizer application. Finally, site 4 received 6 t/ac biosolids application rate, which is the maximum rate allowed.

The biosolid analysis revealed the material spread contained more (37 %) plant available nitrogen, nearly the same (+/- 3.5%) phosphorus and less (76%) potash than the analysis used for planning purposes. Adjustments to the commercial fertilizer rates applied in the second year on August 5, 2009 were made to compensate for variability of the application rate and biosolid concentration applied in the first year. Concerning the comparative treatments, the total nutrient quantities applied over the 3 growing seasons are estimated to be within 1 lbs/ac for nitrogen and phosphorus, but the watershed treated with commercial fertilizer received 10 lbs/ac more K_2O than the watershed treated with biosolids at 3 t/ac.

Hydrology and Water Quality Monitoring

Weir Design and Runoff Measurements

Runoff discharge was measured by weir-calibrated transducer measurements. At each site, a PVC board dam with a one foot tall 90° v-notch weir was constructed to intercept run-off in the individual catchments (Photo 7). The dam and weir allows water to be captured and released at a predictable rate based on standard weir-discharge relationships (French, 1985). Portable auto-samplers (Model # 6712, Teledyne ISCO) equipped with a rain gage and stage recorders were placed at each site to collect rainfall and run-off data. Rain gages measure and record total rainfall in 1/100th inch increments over 5 minutes time periods. A pressure transducer level sensor with datalogger was positioned upstream of the v-notch weir that measures and records water levels every 5 minutes at each site. Stage versus discharge relationships were created for each site based on the position of the pressure transducer to the bottom of the v-notch weir (Table 4 and Photos 7 and 8). Some storm events were able to generate enough runoff to collect behind the dams constructed below each site, but did not fill to a level where it flowed through the weir. In this case, samples were collected and analyzed, and half of the capacity above the weir at the level of the notch was used for the runoff volume estimated by field measurements.

Water Quality Sampling

A strainer was positioned next to the pressure transducer upstream of each dam and was connected to the auto-sampler with a 25 ft. suction line. Initially, each auto-sampler contained twenty-four 1 liter bottles and was programmed to collect 1 liter of water every 10 minutes when the stage recorder detected water behind the weir. However, since June 2009, auto-samplers were fitted with a single 10 L Nalgene composite bottle and reprogrammed to collect single event composite samples. During a storm event, the sampler collected 500 ml samples every fifteen minutes when rainfall rate and level reach set point (0.10 in/30 min and 0.1 ft., respectively). The new configuration saved time and limited error in the field as well as reduced prep time in the lab.

After a sample was collected, composite bottles are removed, and the sample is split for further analysis. Sample were split among three bottles to be analyzed for: (1) metals, preserved with HNO_3 to a pH < 2; (2) nutrients, preserved with H_2SO_4 to a pH < 2; and (3) total suspended solids (TSS), fecal coliform, and pH, no preservative added. In addition, a field duplicate and a field blank were collected for each sampling event to ensure proper sample collection procedure.

Water Quality Analysis

Samples were analyzed at the City of Springfield's Southwest Wastewater Treatment Plant for metals, nutrients, TSS, fecal coliform, and pH following Environmental Protection Agency Methods (EPA) and Standard Methods for the Examination of Water and Wastewater (SM4500) protocol (Table 5). Samples were analyzed at Ozarks Environmental and Water Resources Institute for specific conductivity by a Horiba U22 multi-probe meter. Average field blank concentrations were less than detection limits for metals, ammonia and fecal coliform. Average field blank concentrations for other parameters were 1.1 mg/l TSS, 0.25 mg/l TKN, 0.066 mg/l nitrate, and 0.062 mg/l TP. Median relative percent difference of the duplicate ranged from 4-29% for all parameters. More details on the analyses can be found at http://www.epa.gov/waterscience/methods/.

Surface Soil Monitoring

Sampling

Surface soils within each watershed were monitored to measure changes in metals and nutrients over the study period. Surface soils were sampled approximately 1 month after lime was applied, but prior to fertilizer and biosolids applications. Soil samples were collected at each of the 4 sites at the footslope, backslope, and summit landscape positions to determine site variability (Figure 3, Table 6 and Photo 9). To compare variability within each landscape position, four soil samples were collected along a transect at each landscape position; three on a 14 ft. cross-section. These the difference in concentrations in these three samples is used to assess the variability of soil parameters at each site. One randomly selected duplicate was collected to measure sampling variability. A total of twelve samples were collected at each site. Surface soil samples were collected with a trowel by removing vegetation and excavating soil in an area approximately 6 in. long, 6 in. wide, and 2 to 3 in. deep, and placed in a quart Ziploc bag. A total of 48 samples were collected in year one. Data on site and sample variability can be found in Appendix G.

Analysis

Samples were processed at Missouri State University by drying in a 60° C oven for 24 hr. Dried samples were sieved to 2 mm to remove debris, and one cup of sample was placed in a new Ziploc bag and labeled. Soil analysis was conducted by the University of Massachusetts Soil and Plant Tissue Testing Laboratory to determine pH, buffer pH, and concentrations of extractable nutrients, heavy metals, and aluminum (Appendix B).

Forage Analysis

Agronomic response to each of the four treatments was monitored by measuring yield along transects established on different landscape positions in each watershed. Plant and soil nutrient levels were also monitored by collecting annual forage and soil samples. Yield was measured by harvesting a known area of land, taking fresh forage weights, and drying subsamples to determine moisture content. Samples were also collected and sent to a laboratory for analysis of other forage characteristics. Forage sampling sites were selected along a line parallel to the soil sampling transects previously established in each watershed. The beginning and end of each transect were marked with a steel rod, flagged and geo-referenced for subsequent surveys. Forage sampling plots were established at three locations within treated areas of each watershed (1) “Low”, 25 to 65 feet from the steel rod (distances varied in order to assure the sample was collected well within the treated area), (2) “Summit”, 10 to 20 feet downslope from the highest landscape position along the transect (again, distance varied to assure that the samples were collected well within the treated area, and (3) “Mid”, near the midpoint between the low and summit positions. Each plot was 7 ft X 20 ft with the long axis perpendicular to the slope. Plots were mowed using a walk-behind sicklebar mower set to a cut height of 4 inches. The sample (excluding tree coppices and plant material and residues from below the cut height) was carefully raked, bagged and fresh biomass was determined using a precision spring scale. Where the crop had lodged (due to wind or rain), two or three iterations of cutting and raking were required to mow the forage to the desired height. Forage quality analysis was conducted by Custom Laboratory in Golden City, Missouri.

PRELIMINARY RESULTS

Hydrology and Sample Collection

<u>Rainfall Events</u>
Runoff was generated either during relatively short, high intensity storm events, or relatively long, low intensity storm events. Year 1 rainfall totals generating runoff ranged from 0.56 inches on November 6, 2008 to 1.89 inches June 16, 2009 (Table 7). Year 2 rainfall totals ranged from 0.63 inches on January 25, 2010 to 5.1 inches October 9, 2010. Individual storm rainfall totals for year 2 are substantially higher than year 1 with four events having greater totals than the highest event in Year 1.

<u>Runoff Events</u>
Runoff discharge also varied among catchments over the sampling period due to variability in rainfall, drainage area, soils, vegetation, and slope. For the storm events where runoff data was

generated, peak instantaneous discharge measurements ranged from as low as 0.009 ft^3/s on Feb. 10, 2009 for site 2 to as high as 0.91 ft^3/s on September 22, 2010 at site 3 (Table 8). The maximum capacity of a 1 foot, 90 degree weir is 1 ft^3/s.

Storm runoff volumes varied from as low as 1.5 ft^3 at site 1 on May 13, 2009 to as high as 33,645 ft^3 October 9, 2009 at site 3. Runoff volume as a percentage of total rainfall volume also ranged from <1% during several events up to 81% at site 2. These data show the high variability in runoff volume in these small catchments. Year 1 runoff volume results did not exceed 25% of the total rainfall volume and rainfall did not exceed 2 inches in the events sampled. However, year 2 results had several events where rainfall amounts exceeded 2 inches and runoff volumes reached as high as 80% for site 2. These hydrological characteristics become important in water quality studies because ultimately runoff volume determines the impact of a contaminant leaving a site during a storm event.

Sample Events

A total of 62 composite samples were collected at all four sites over a 21 month period between November 1, 2008 and July 31, 2010. During year 1, from November 1, 2008 to July 31, 2009, 23 composite samples were collected. Of these, 6 were from site 1, 9 from site 2, 5 from site 3, and 3 from site 4 (Table 7). In year 2, between August 1, 2009 to July 31, 2010, a total of 39 composite samples were collected. Of the year 2 samples, 10 were from site 1, 11 from site 2, 9 from site 3, and 9 from site 4. Samples were not collected over that period because:

1. Small catchment area generates low discharge volume
2. Equipment malfunctions (dead batteries, clogged lines, etc.)
3. Height of vegetation and dormancy impact interception and water uptake
4. Soil moisture conditions
5. Dam and weirs needed “seasoning” following installation in year 1

Water Quality

The following section will describe water quality data collected for each site over the November 1, 2008 to August 31, 2010 sampling period. Water quality trends are reported in three ways: (1) comparing site average over the entire sample period to look at overall trends and variability; (2) comparing annual median values for each site to assess yearly changes in water quality parameters; and (3) analysis of time-series plots from each site showing individual sample concentrations from the initial biosolids application date of October 23, 2010 to July 31, 2010, used to compare runoff water quality over the entire sample period.

Average nutrient concentrations were around 2-4 times higher in runoff from the fertilized site 2 compared to the biosolids applied sites and the control for the entire sampling period (Table 9). When comparing the biosolids applied sites, average concentrations of TKN, Nitrate, and TP are higher from the 6 t/ac site 4 compared to the 3 t/ac site 3. However, average ammonia was >5 times in the 6 t/ac site 4 compared to the 3 t/ac site 3. Average ammonia and TKN concentrations in the 3 t/ac site 3 were less than the average concentrations found at the control site 1. Nitrate and TP concentrations at the control site 1 were the lowest among sites. Average TSS concentrations ranged from 14 mg/l at site 1 to 80 mg/l at site 2 over the sample period. Sample pH remained consistent at all sites over the sample period.

Total Phosphorus (TP)

Median TP concentrations dropped significantly at site 2 in year 2 and increased in sites 3 and 4 (Figure 4). Site 2 median TP concentrations decreased 75% from year 1 to year 2. Median TP concentrations in the biosolids applied watersheds increased from year 1 to year 2. This increase is probably due to a combination of factors. One, the breakdown of organic phosphorus in the biosolids is more mobile in year 2 and two, significant rain events that occurred in year 2 physically transported biosolids material down slope. Regardless, median TP concentrations for sites 3 and 4 are less-than half of that from the fertilized site 2. Median TP concentrations at site 1 were similar in years 1 and 2.

Time-series analysis of TP concentrations shows generally decreasing concentrations over time (Figure 5). High concentrations immediately after application of fertilizer at site 2 were extremely high for the first sample collected and then concentrations decrease steadily. Concentrations of TP are more variable for the biosolids applied sites over time again suggesting physical transport by storm event is likely causing higher concentrations over time. All TP concentrations past day 400 are <2 mg/L, which is near the highest TP concentration sampled at control site 1. This suggests that TP concentrations are back to pre-treatment levels.

Total Kjeldahl Nitrogen (TKN)

Concentrations of TKN have proven to be highly variable for this project. Median TKN concentrations decrease at 3 of the 4 sites from year 1 to year 2, while increasing at site 4 (Figure 6). High variability at site 1 suggests high natural variability cannot be distinguished from changes in management. Time-series analysis show TKN concentrations may be event driven. High TKN concentrations at site 2 immediately after application dropped sharply and stayed fairly consistent for the rest of the sampling period (Figure 7). Perhaps particulate fertilizer was sampled in the first event giving such high concentrations. Sites 1, 3 and 4 are more variable over time that shows storm events may be transporting particulate nitrogen down slope. However, the single high concentration at site 1 suggests this may be natural variability. Given year 1 and year 2 results, TKN variability cannot be attributed to fertilizer or biosolids application.

Ammonia

Median ammonia concentrations remained relatively consistent at sites 1, 2 and 3 between year 1 and 2, while concentrations dropped significantly in year 2 at site 4 (Figure 8). With the acceptation of year 1 sampling at site 4, median ammonia concentrations are higher at the control site 1 compared to the other sites during the sampling period. Time-series analysis again shows extremely high ammonia concentrations for the 1st sample collected after fertilizer application at site 2 (Figure 9). Ammonia concentrations at site 2 then decrease to near the levels at the other sites and stays fairly consistent for the remainder of the sampling period. Ammonia concentrations at site 4 are also elevated in the first sampling after application of 6 dryT/ac biosolids. However, similarly to site 2, ammonia concentrations decrease after that near levels at the other sites.

Nitrate

Median nitrate concentrations varied slightly between year 1 and 2 for sites 1, 3 and 4 and increased significantly in year 2 at site 2 (Figure 10). Changes in nitrate concentrations at sites 3 and 4 are near that of the control site 1, suggesting natural variability is as high as in the biosolids applied sites. However, nitrate concentrations at site 2 nearly double in year 2. Time-series analysis shows nitrate concentrations at site 2 are highly variable throughout the sample period (Figure 11). Nitrate concentrations at other sites are consistently low and have less variability. These data suggest excess nitrate moves off fertilizer sites at greater rates than biosolids applied fields.

Total Suspended Solids (TSS)

Median TSS concentrations varied considerably between years at each site (Figure 12). This variability is due to differences between site characteristics and storm events. Concentrations of TSS increased in year 2 at site 1, 2 and 3 and decreased at site 4. Time-series analysis indicates high median concentrations are influenced by single high events samples and the majority of samples are <100 mg/L for most events (Figure 13).

pH

Median pH reading were similar for all sites between years 1 and 2 (Figure 14). Time series analysis shows site 2 has the most variability among sites over the sampling period (Figure 15).

However, pH varies <1 standard unit over the sampling period. These data indicate variability in runoff pH does not influence water quality differences among sites.

Trace Metals

Trace metals concentrations above the method detection limit were found in only a portion of the 60 samples collected over the sample period. Concentrations of Arsenic, Cadmium, Lead, Mercury, Molybdenum and Silver were all below detection limits for all samples. Nickel and Selenium were found in only 1 of the 60 samples and Chromium was found in only 2 of the samples. Copper (Cu) and Zinc (Zn) were found in multiple samples throughout the period.

Sites where biosolids was applied tend to have higher concentrations of Cu and Zn than sites without. For the control site 1, no Cu was detected over the sample period (Table 10). Of the samples collected at site 2 and site 3, 90% of the samples were below detection limits. However, the highest concentration at site 3 (3 dryT/ac) was 8.2 ppb Cu slightly higher than 5.5 ppb Cu at site 2 (fertilizer). Cu was detected in a quarter of the samples from site 4 (6 dryT/ac). The maximum Cu concentration for the study (19.6 ppb) is from site 4 with 10% of the samples having Cu concentrations that exceed 10 ppb.

Zinc was detected in <10% of the samples collected at site 1 with the maximum concentration of 6.4 ppb (Table 11). At site 2 (fertilizer), Zn was detected in 10% of the samples with a maximum concentration of 17.4 ppb. At site 3 (3 dryT/ac), Zn was detected in <10% of the samples, but the maximum concentration was 50% higher than site 2 at 26.1 ppb. At Site 4 (6 dryT/ac) Zn was detected in 50% of the samples collected and maximum concentration was nearly 4 times higher than the fertilizer site 2 and nearly 10 times graeter than the maximum concentration at the control site 1.

Fecal Coliform

Biosolids applied sites tend to have higher fecal coliform concentrations more often than the control and fertilizer sites (Table 12). However, high concentrations were found at all sites. While the control site 1 tended to have lower concentrations during most of the sampling period, the 90^{th} percentile and maximum concentrations were higher than the fertilizer site 2 and 3 T/ac biosolids site. Furthermore, the 90^{th} percentile concentration for the control site is similar to the high 6 T/ac biosolids applied site 4. These data show high fecal coliform concentrations can occur on non-biosolids applied fields. However, there appears to be a tendency for biosolids to yield higher fecal counts than the control and fertilizer sites.

Surface Soils

Site and Sample Variability

Variability in soil parameters was assessed at two different scales, variability within a landscape position and variability. While soil pH has fairly low variability at a site, concentrations of soil Zn and P can have high variability across the landscape. The coefficient of variation percentage (cv%) is the percent difference of the standard deviation compared to the average for the three samples collected at each landscape position. The cv% for pH was <10% at all landscape position reflecting the consistency of pH across the landscape (Table 13). The highest variability within a landscape position is in soil P, having cv% higher than 30% at sites 1, 2, and 3. Interestingly, P concentrations were less variable at site 4, where cv% were <30% among samples. Concentrations of Zn were less variable at a landscape position. The majority of the cv% were < or near 30%. However, one sample at site 2 had extremely high variability with a cv% >200%.

Sample variability was also assessed by collecting a random duplicate at the same location as one of the three samples collected for site variability. The difference is reported as relative percent difference (RPD). Again, pH varied little between samples (Table 14). Most of the duplicate samples of P and Zn had cv% <30%. The higher cv% ranged from 40-84% suggesting sample variability can also be high for P and Zn. These data suggest differences in P and Zn in the soil could be due to high variability of these parameters within the landscape.

Soil pH

Mean soil pH ranged from 5.6 to 7 for all site over the entire sampling period (Figure 16). At each site, soil pH increased every year with the largest increase occurring at site 2. The annual increase in soil pH is due to the breakdown of agriculture lime designed to raise the pH in the soil prior to application of fertilizers and biosolids. Soil pH trends are similar for each landscape position for all sites (Figure 17). These data suggest variations in soil pH are not contributing to soil geochemical trends.

Soil Phosphorus (P)

Mean soil P concentrations increased every year at sites 2, 3 and 4 and decreased at site 1 after the first year (Figure 18). A year 2 increase in P at these sites is due to fertilizer and biosolids application. While site 2 has an overall increase from year to year, it appears this only occurs on the flat, summit landscape position (Figure 19). However, on the steeper backslope and footslope, P concentrations increase in year 2 but drop in year 3. Site 3 also has an increase at the summit and a year 3 loss from the backslope. Site 4 show increase in soil P at the summit and backslope landscape positions. However, the footslope appears to be losing P each year.

Soil Zinc (Zn)
Average soil Zn concentrations are low at all sites, ranging from 1-2.5 ppm (Figure 20). Concentrations of Zn decrease at sites 1 and 2 in each of three consecutive years. Soil Zn increases in year 2 at the two biosolids applied sites 3 and 4 indicting slight enrichment from biosolids application. At these sites, soil Zn decreases in year 3 indicting leaching could be occurring during rain events. Again, concentrations are only slightly higher than the control and fertilizer sites. Annual Zn concentrations decrease in all landscape positions at sites 1 and 2, suggesting possible Zn presence in the pre-application lime is breaking down over time (Figure 21). Concentrations of soil Zn increase in year 2 at the summit and backslope landscape positions at site3 and the summit of site 4 due to biosolids application. Year 3 Zn increase at the summit of site 3 and decrease at the summit of site 4 and backslope of site 3 indicate Zn maybe mobile in this setting.

Forage Analysis

The amount of nutrients present in forage crops from the fertilized site 2 and biosolids applied sites 3 and 4 are higher in the fall cutting compared to the control site 1 (Figure 22). Nutrients tend to be higher in sites 2, 3 and 4 in the fall cutting compared to the spring cutting. Rainfall, the timing of harvest, and grass species may all factor into the variability in forage nutrient uptake. However, increased nutrient content in post application are evident. The amount of copper and zinc in the forage was variable between sites and between cuttings. These data suggest no significant changes in copper and zinc content in forage harvested from biosolids applied sites compared to the fertilized and control sites.

Forage crop yields from biosolids applied sites were greater in year 1 compared to the fertilized site, but yields dropped in year 2 yet were still higher than the control. Year 1 average forage yield for the fertilized site 2 was 50% greater than the control site 1 (Figure 23). Average year 1 forage yield was 2-2.5 times greater in the biosolids applied sites than in the fertilized site 2. Year 2 yields dropped at all sites, with the biosolids applied sites having similar yields as the fertilized site. However, the fertilized and biosolids applied sites had 50% higher yields than the control in year 2.

Relative feed values (RFV) at site 1 remained fairly consistent over the first three cuttings before dropping in fall 2010 (Table 15). The fertilized and biosolids applied fields did not see benefits in RFV until the fall 2009 cutting where the highest RFV in the entire study came from site 2. The RFV in the spring 2010 cutting was less than the previous cutting in the fall of 2009. However, RFV increased in the biosolids applied sites in fall 2010 and not in the fertilized site 2.

The plots lacked true replication, the results were averaged across landscape positions within each treatment. The results should therefore be considered descriptive statistics rather than results of a properly constructed hypothesis test.

CONCLUSIONS

This section covers the activities over the two years of the Biosolids Runoff Monitoring Project from May 2008 through July 2010. There are 16 main conclusions of this report:

1. Samples sites were chosen based on uniformity of landscape position and land cover typical of agricultural practices in southwest Missouri. The site was surveyed and four small catchments were delineated, ranging from 0.38 to 3 acres.

2. Soil samples were collected and analyzed for fertilizer and liming recommendations. A nutrient management plan was created that outlined specifications for fertilizer based on soil test reports for biosolids and equivalent commercial fertilizer applications. A fertilizer and equivalent biosolids application rate (3 dryT/ac) was applied for a 3 T/ac forage yield goal site 2 and 3. On site 4, the maximum allowable biosolids application rate of 6 dryT/ac was applied. Site 1 was not treated and left as the control.

3. Five individual soil pits were characterized for soil morphology over the study area to access the variability in soil type over multiple landscape positions that may not be represented in published soil surveys. Pedogenic differences in soil parent material, structure, and thickness can impact infiltration rate and infiltration capacity, as well as soil fertility and growth rates.

4. Weirs were constructed in areas of concentrated flow near the bottom of each catchment to capture runoff and estimate discharge. Automatic samplers were deployed and fitted with rain gages and stage recorders programmed to sample when runoff occurred. A 500 mL sample was collected at the first flush and then a subsequent 500 mL sample was collected every 15 minutes over the duration of the storm.

5. Over the year 1, 9 month sampling period (November 1st, 2008 – July 31st, 2009) covered by this report, 23 individual composite samples were collected and analyzed. Rainfall intensities capable of producing runoff ranged from quick, high intensity rain events lasting < 1 hour to long, slow rain events that last several hours.

6. Over the year 2, 12 month sampling period (August 1, 2009 – July 31, 2010) covered by this report, 39 individual composite samples were collected and analyzed. Rainfall intensities capable of producing runoff ranged from quick, high intensity rain events lasting < 1 hour to long, slow rain events that last >24 hours.

7. The amount of runoff volume generated from different storm events varied with rainfall intensity and duration. Maximum runoff volume measured over the sampling period was as high as 80% of the recorded rainfall measured as runoff for the larger storm events during the year 2 sampling period. Higher rainfall amounts were recorded in the year 2 sample period compared to year 1.

8. Sites treated with fertilizer and biosolids had higher concentrations of nutrients in runoff than the control. Concentrations of nutrients in runoff from the fertilized site 2 were greater than the biosolids applied sites 3 and 4.

9. While concentrations of TKN, nitrate and TP were similar in runoff from sites 3 and 4, ammonia was >5 times higher in the 6 t/ac applied site 4.

10. Annual median nutrient concentrations in runoff decrease over time.

11. Concentrations of Cu and Zn tend to be detectable more often in the 6 t/ac biosolids applied site 4 and at higher concentrations compared to the other 3 sites.

12. The highest fecal coliform concentration over the sampling period came from the biosolids applied site 4, but fecal concentrations were high at all sites over the entire sample period.

13. Surface soil samples can be highly variable for P and Zn at a site suggesting differences that are <50% cannot be attributed to management.

14. Surface soil data shows an increase in soil P after fertilizer and biosolids application and no significant soil Zn was measured after application. Soil pH is very consistent over the three sampling periods.

15. Forage crop quality and yields tended to be higher in the biosolids applied sites compare to the fertilizer applied site. Nutrient uptake by the plants tended to be higher in the fall cutting compared to the spring in forage harvested from the fertilized and biosolids applied sites. No distinction could be made between concentrations of Cu and Zn in

forage harvested from the biosolids applied sites compared to forage harvested from the fertilized or control sites.

16. Forage plots lacked true replication, the results were averaged across landscape positions within each treatment. The results should therefore be considered descriptive statistics rather than results of a properly constructed hypothesis test.

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TABLES

Table 1. Watershed and Nutrient Management Treatment Details at the Study Site

Site	Nutrient Treatment	Soil Map Units Present (Hughes, 1982)	Forage Suitability Group
1	Control	Goss very cobbly silt loam, 15-35% slopes Nixa very gravelly silt loam, 3-8% slopes	Gravelly Upland Gravelly Pan
2	Commercial Fertilizer	Nixa very gravelly silt loam, 3-8% slopes Viraton silt loam, 2-5% slopes	Gravelly Pan Loamy Pan
3	Biosolids at Commercial Fertilizer Equivalent	Nixa-Clarksville complex, 3-20% slopes Viraton silt loam, 2-5% slopes	Gravelly Upland Loamy Pan
4	Biosolids at Double Commercial Fertilizer Equivalent	Viraton silt loam, 2-5% slopes Nixa very gravelly silt loam, 3-8% slopes	Loamy Pan Gravelly Pan

Table 2. Summary of Soil Morphology Analysis

Pit #	Landscape Position	Parent Material	Elevation (feet)	Slope	% Coarse Rock Frag.	Notes
1	Head Slope	Loess/Colluvium/Residuum	1,215	1%	0-25	8” Loess (10 YR4/3) Fragipan (32”- 45”) Redox features
2	Interfluve	Colluvium/Residuum	1,199	2%	10-60	Weak fragipan (20”-35”) Redox features
3	Side Slope	Colluvium/Residuum	1,195	4%	5-50	Weathered sandstone present (50”-60”)
4	Side Slope	Colluvium/Residuum	1,176	12%	5-60	
5	Colluvial Valley	Alluvium/Colluvium	1,166	6%	40-50	Alluvium (0”-23”)

Table 3. Watershed and Nutrient Management Details at the Study Site

Site	Treatment Name	Experimental Year	Planned Nutrient Application (lbs/a) $N + P_2O_5 + K_2O$	Actual Nutrient Application (lbs/a) $N + P_2O_5 + K_2O$
1	Control	1	0 + 0 + 0	0 + 0 + 0
		2	0 + 0 + 0	0 + 0 + 0
		3	0 + 0 + 0	0 + 0 + 0
2	Commercial Fertilizer	1	54 + 299 + 13	54 + 299 + 13
		2	54 + 0 + 0	82 + 20 + 0
		3	54 + 0 + 0	82 + 0 + 0 *
3	Commercial Fertilizer Equivalent Biosolids @ 3 dry tons/a	1	111 + 299 + 13	160 + 319 + 3
		2	34 + 0 + 0	38 + 0 + 0
		3	17 + 0 + 0	19 + 0 + 0
4	Double Commercial Fertilizer Equivalent Biosolids @ 6 dry tons/a	1	222 + 598 + 26	303 + 558 + 6
		2	68 + 0 + 0	64 + 0 + 0
		3	34 + 0 + 0	32 + 0 + 0

Table 4. Drainage Area, Weir Geometry, and Discharge Equations

Site	Ad (acres)	Weir			Rating Curve Equation
		Top Width (ft)	Height (ft)	Height of Notch ab. Ground Level (ft)	
1	0.38	1.23	0.61	0.22	$Q = 1.9069(d_w)^3 - 0.4207(d_w)^2 - 0.0981(d_w) + 0.0206$
2	0.65	1.18	0.6	0.22	$Q = 1.4413(d_w)^3 + 0.3164(d_w)^2 - 0.4538(d_w) + 0.0733$
3	3	1.18	0.6	0.26	$Q = 1.626(d_w)^3 - 0.5969(d_w)^2 - 0.2461(d_w) + 0.091$
4	1.28	1.19	0.64	0.23	$Q = 1.3331(d_w)^3 + 0.4238(d_w)^2 - 0.5228(d_w) + 0.0855$

Ad = drainage area

Q = Discharge in cubic feet per second (cfs)

d_w = depth of water (feet)

Table 5. Test Parameters, Methods, Method Detection Limits, Method Accuracy and Precision, and Project Accuracy and Precision

Nutrient	Method	Method Detection Limit (mg/L)	Method Accuracy (mg/L)	Method Precision (mg/L)	Project Accuracy (mg/L)	Project Precision (mg/L)
Total Kjheldal Nitrogen	EPA 351.2	0.03	±10	±10	±15	±10
Total Phosphorus	EPA 365.4	0.01	±10	±5	±15	±7
Nitrate	EPA 300.0	0.01	±10	±5	±15	±10
Ammonia	SM4500-NH3-D	0.1	±20	±10	±20	±10
Metal		**Method Detection Limit (µg/L)**	**Method Accuracy (µg/L)**	**Method Precision (µg/L)**	**Project Accuracy (µg/L)**	**Project Precision (µg/L)**
Arsenic	EPA 200.7	15	±10	±5	±10	±5
Cadmium	EPA 200.7	5	±10	±5	±10	±5
Chromium	EPA 200.7	10	±10	±5	±10	±5
Copper	EPA 200.7	5	±10	±5	±10	±5
Lead	EPA 200.7	15	±10	±5	±10	±5
Nickel	EPA 200.7	10	±10	±5	±10	±5
Molybdenum	EPA 200.7	20	±10	±5	±10	±5
Potassium	EPA 200.7	50	±10	±5	±10	±5
Selenium	EPA 200.7	20	±10	±5	±10	±5
Silver	EPA 200.7	5	±10	±5	±10	±5
Zinc	EPA 200.7	5	±10	±5	±10	±5
Mercury	EPA 245.1	0.2	±10	±5	±10	±5
Other		**Method Detection Limit**	**Method Accuracy**	**Method Precision**	**Project Accuracy**	**Project Precision**
Total Suspended Solids	SM2540 D	1 mg/L	±10 mg/L	±5 mg/L	±10 mg/L	±4 mg/L
pH	SM4500-H+B	0.1 std units	±20 std units	±20 std units	±10 std units	±5 std units
Fecal Coliform/100mL	SM 9222 D	1 coli/100mL	±10 coli/100mL	±10 coli/100mL	±20 coli/100mL	±14 coli/100mL

Table 6. Landscape Position and Surface Soil Sample Locations Upstream of Weir

Site	Landscape Position	Distance of Slope Break Upstream of Weir (ft)	Distance Upstream of Weir (ft)
Site 1	Footslope	0 – 98	26
	Backslope	98 - 180	131
	Summit	> 180	295
Site 2	Footslope	0 – 131	53
	Backslope	131 - 213	131
	Summit	> 213	279
Site 3	Footslope	0 – 131	66
	Backslope	131 - 253	197
	Summit	> 253	459
Site 4	Footslope	0 – 98	69
	Backslope	98 - 246	164
	Summit	> 246	328

Table 7. Rainfall Totals, Duration, and Sites Collected for Storm Events

Date	Total Rainfall (in)	Rainfall Duration (hrs)	Peak Intensity (in/5 min)	Avg. Intensity (in/hr)	Sites Collected
			Year 1		
11/6/09	0.56	0.63	0.13	0.88	1 & 2
2/11/09	1.74	15.2	0.24	0.11	1 & 2
4/12/09	1.25	14.4	0.05	0.09	1, 2, & 3
4/20/09	1.27	21.5	0.09	0.06	2 & 3
5/1/09	1.68	11.9	0.25	0.14	1, 2, 3, & 4
5/13/09	0.94	0.79	0.20	1.19	1, 2, 3, & 4
6/16/09	1.77	9.0	0.16	0.20	1, 2, 3, & 4
6/30/09	1.10	6.6	0.03	0.17	2
7/20/09	1.83	23.4	0.18	0.08	2
			Year 2		
8/11/2009	1.38	6.0	0.16	0.23	4
8/19/2009	1.44	14.6	0.17	0.10	4
9/10/2009	1.21	13.3	0.11	0.09	4
9/20/2009	1.27	17.1	0.03	0.07	4
9/22/2009	2.80	16.4	0.22	0.18	1, 2, 3, & 4
10/9/2009	5.07	26.5	0.12	0.20	1, 2, 3, & 4
10/30/2009	0.98	14.9	0.09	0.07	1, 2, 3, & 4
1/22/2009	0.54	22.4	0.04	0.02	2
1/25/2010	0.63	20.3	0.06	0.03	1, 2, & 3
2/22/2010	0.83	23.4	0.04	0.04	1, 2, & 3
3/22/2010	0.82	44.9	0.15	0.02	1 & 2
3/25/2010	1.37	19.8	0.06	0.07	1, 2, 3, & 4
5/14/2010	1.95	12.3	0.11	0.16	1, 2, 3, & 4
7/12/2010	2.24	7.5	0.22	0.33	1, 2, & 3

Table 8. Rainfall Volume and Discharge Data

Date	Total Rainfall Volume	Peak Q	Total Runoff Vol.	Est. Runoff	Est. Infiltration
	(ft3)	(cfs)	(ft3)	%	%
			Site 1		
Year 1					
11/6/2008	772	0.01	3	0.3	99.7
2/11/2009	2,373	0.009	66	2.8	97.2
4/12/2009	1,779	0.02	145	8.2	91.8
5/1/2009	2,193	0.11	466	21.2	78.8
5/13/2009	1,283	0.003	1.5	0.1	99.9
6/16/2009	2,400	0.18	318	13.3	86.8
Year 2					
9/22/2009	2,621	0.36	748	28.5	71.5
10/9/2009	7,173	0.11	1,996	27.8	72.2
10/30/2009	1,283	0.03	78	6	94
1/25/2010	883	0	0.37	<1	>99
2/22/2010	1,021	0	0.37	<1	>99
3/22/2010	924	0	0.37	<1	>99
3/25/2010	1,917	0.007	30	1.6	98.4
5/14/2010	2,566	0.07	368	14.3	85.7
7/12/2010	2,897	0.06	41.7	1.4	98.6
			Site 2		
Year 1					
11/6/2009	1,321	0	0.66	<1	>99
2/10/2009	4,153	0	0.66	<1	>99
4/12/2009	2,831	0	0.66	<1	>99
4/20/2009	3,044	0	0.66	<1	>99
5/1/2009	3,940	0.06	396	10.1	89.9
5/13/2009	2,218	0.019	17	0.8	99.2
6/16/2009	4,058	0.29	757	18.7	81.3
6/30/2009	2,595	0.08	39	1.5	98.5
7/20/2009	4,318	0	0	<1	>99
Year 2					
9/22/2009	6,866	0.62	263	38.2	61.8
10/9/2009	12,954	0.42	10,544	81.4	18.6
10/30/2009	2,501	0.13	275	11	89
1/22/2010	1,274	0	0.66	<1	>99
1/25/2010	1,581	0.015	25	1.6	98.4
2/22/2010	2,242	0	0.66	<1	>99
3/22/2010	2,265	0.065	957	42.3	57.7
3/25/2010	3,468	0.096	1,841	53.1	46.9
5/14/2010	4,790	0.020	100	2.1	97.9
7/12/2010	5,450	0.130	126	2.3	97.7

			Site 3		
Year 1					
4/12/2009	13,830	0.09	984	7.1	92.9
4/20/2009	13,504	0.04	406	3	97
5/1/2009	18,077	0.41	4,358	24.1	75.9
5/13/2009	10,128	0.02	90	0.9	99.1
6/16/2009	18,731	0.58	3,112	16.6	83.4
Year 2					
9/22/2009	29,839	0.91	17,300	58	42
10/9/2009	52,381	0.78	33,645	64.2	35.8
10/30/2009	9,801	0.29	5,539	56.5	43.5
1/25/2010	6,207	0.17	1,591	25.6	74.4
2/22/2010	8,821	0.13	1,101	12.5	87.5
3/25/2010	14,048	0.60	7,632	54.3	45.7
5/14/2010	20,691	0.20	573	2.8	97.2
7/12/2010	25,156	0.17	51	0.2	99.8
			Site 4		
Year 1					
5/1/2009	8,271	0.02	128.5	1.6	98.4
5/13/2009	4,414	0	0.27	<1	>99
6/16/2009	8,782	0.02	86.5	1	99
Year 2					
8/11/2009	6,412	0	0.27	<1	>99
8/19/2010	6,691	0	0.27	<1	>99
9/10/2009	5,622	0	0.27	<1	>99
9/20/2009	5,901	0	0.27	<1	>99
9/22/2009	12,824	0.17	1,295	10.1	89.9
10/9/2009	22,163	0.25	4,732	21.3	78.7
10/30/2009	4,693	0	0.27	<1	>99
3/25/2010	6,226	0.08	875	14.1	85.9
5/14/2010	9,246	0.003	14.8	0.2	99.8

Table 9. Water Quality Summary Statistics

		TSS (mg/l)	TKN (mg/l)	NH3-N (mg/l)	NO3-N (mg/l)	TP (mg/l)	pH (Std Units)
Site 1 (control)	n	16	16	16	16	16	16
	mean	14	2.71	0.281	0.166	0.364	7.1
	sd	*13*	*2.34*	*0.243*	*0.177*	*0.355*	*0.1*
Site 2 (fertilizer)	n	20	20	20	20	20	20
	mean	80	6.40	2.05	0.788	4.06	7.2
	sd	*136*	*14.2*	*8.32*	*0.916*	*7.46*	*0.2*
Site 3 (3T Bio)	n	14	14	14	14	14	14
	mean	59	2.56	0.169	0.170	0.631	7.2
	sd	*161*	*1.76*	*0.098*	*0.117*	*0.645*	*0.1*
Site 4 (6T Bio)	n	12	12	11	12	12	12
	mean	31	3.43	0.952	0.216	0.878	7.2
	sd	*49*	*3.96*	*2.34*	*0.105*	*2.03*	*0.1*

Table 10. Frequency Distribution for Cu Samples

Cu (ppb)	min	10%	25%	50%	75%	90%	max
Site 1 (n=15)	<DL	<DL	<DL	<DL	<DL	<DL	<DL
Site 2 (n=19)	<DL	<DL	<DL	<DL	<DL	<DL	5.5
Site 3 (n=14)	<DL	<DL	<DL	<DL	<DL	<DL	8.2
Site 4 (n=12)	<DL	<DL	<DL	<DL	3.7	11.3	19.6

Table 11. Frequency Distribution for Zn Samples

Zn (ppb)	min	10%	25%	50%	75%	90%	max
Site 1 (n=15)	<DL	<DL	<DL	<DL	<DL	<DL	6.4
Site 2 (n=19)	<DL	<DL	<DL	<DL	<DL	7.7	17.4
Site 3 (n=14)	<DL	<DL	<DL	<DL	<DL	<DL	26.1
Site 4 (n=12)	<DL	<DL	<DL	4.4	7.3	15.3	69.1

Table 12. Frequency Distribution for Fecal Coliform

Fecal (col/100 ml)	min	10%	25%	50%	75%	90%	max
Site 1 (n=16)	<DL	5.3	28	141	834	5,650	29,000
Site 2 (n=20)	<DL	4.6	28	182	1,014	1,591	8,000
Site 3 (n=14)	<DL	9.3	105	641	1,070	5,260	9,000
Site 4 (n=12)	<DL	1.5	18	670	3,070	5,800	190,000

Table 13. Annual soil sample variability in pH, P, and Zn from each landscape position by site. Coefficient of variation percentage (cv%) of three samples collected from each position each year.

		pH (cv%)			P (cv%)			Zn (cv%)		
Site	Year	Summit	Backslope	Footslope	Summit	Backslope	Footslope	Summit	Backslope	Footslope
	1	2.1	2.6	1.7	49	11	28	11	13	46
1	2	7.1	2.7	4.5	46	8.3	41	26	5.6	27
	3	8.3	7.1	1.4	69	17	18	29	7.5	27
	1	1.1	3.5	1.6	28	17	23	14	22	23
2	2	3.7	2.5	4.6	68	35	25	2.8	221	22
	3	0.9	2.6	3.6	3	20	28	8.7	20	6.7
	1	2.6	2.7	4.0	30	17	48	13	25	23
3	2	1.7	0.9	2.7	21	37	31	28	24	45
	3	0.8	1.8	1.5	31	5.3	33	11	11	31
	1	2.4	0.9	1.6	25	17	27	12	17	31
4	2	3.3	6.1	1.8	6.9	23	6.0	23	34	19
	3	1.5	5.8	2.3	16	37	27	16	9.1	30

Table 14. Annual average relative percent difference (RPD) from randomly selected duplicates to assess soil sample variability.

Site	Year	n	pH (RPD)	P (RPD)	Zn (RPD)
	1	3	2.3	23	18
1	2	3	3.0	25	13
	3	3	1.0	19	19
	1	3	1.2	27	22
2	2	3	2.7	40	1.6
	3	3	2.5	19	13
	1	3	1.6	27	12
3	2	3	4.2	25	5.1
	3	3	1.0	21	13
	1	3	1.5	16	19
4	2	3	3.6	16	4.9
	3	3	5.6	66	84

Table 15. Forage Relative Feed Value (RFV)

Cutting	Site 1 (Control)	Site 2 (Fert)	Site 3 (3T Bio)	Site 4 (6T Bio)
Spring 2009	79	73	76	78
Fall 2009	82	97	90	90
Spring 2010	79	77	78	80
Fall 2010	66	76	89	96

FIGURES

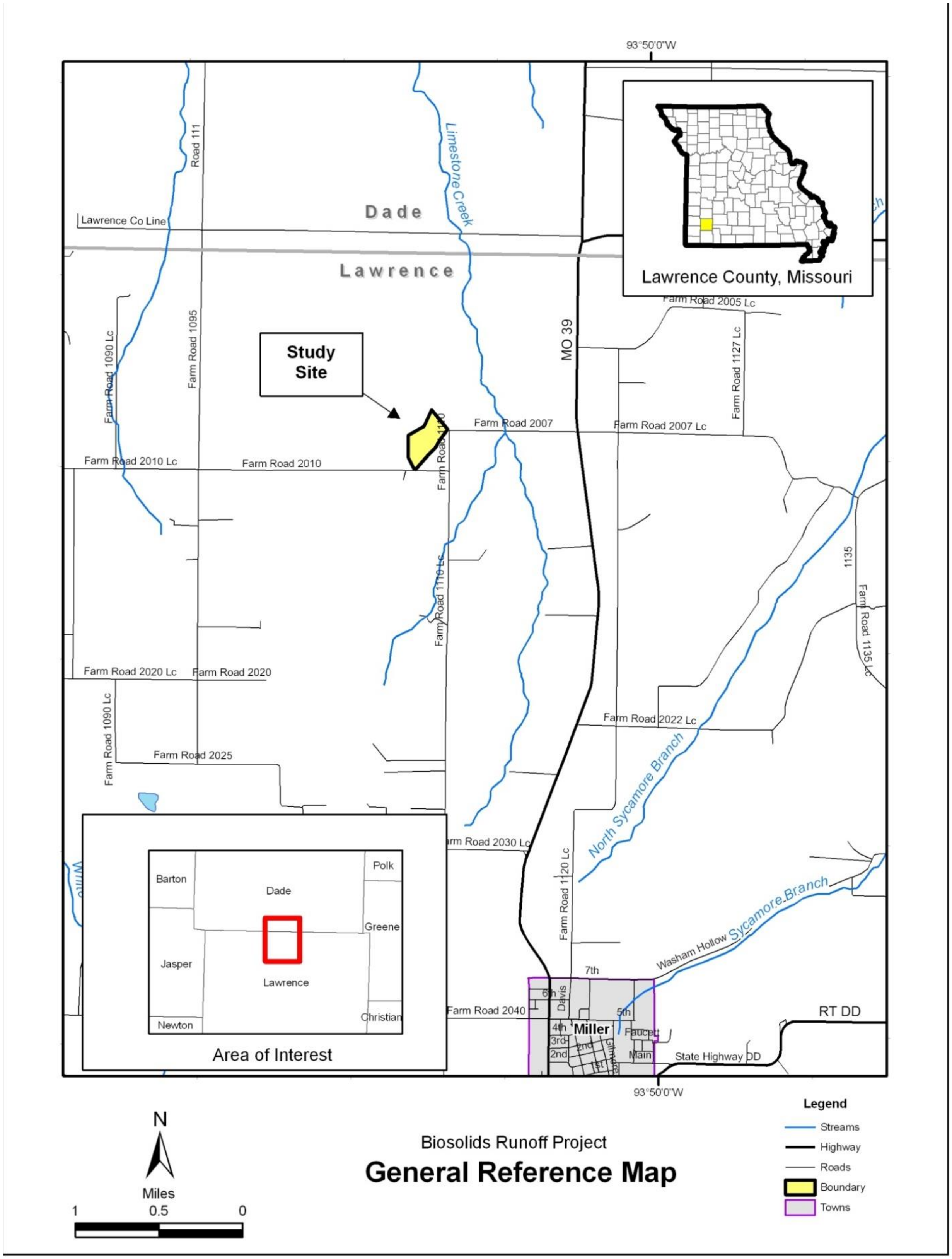

Figure 1. Study site location

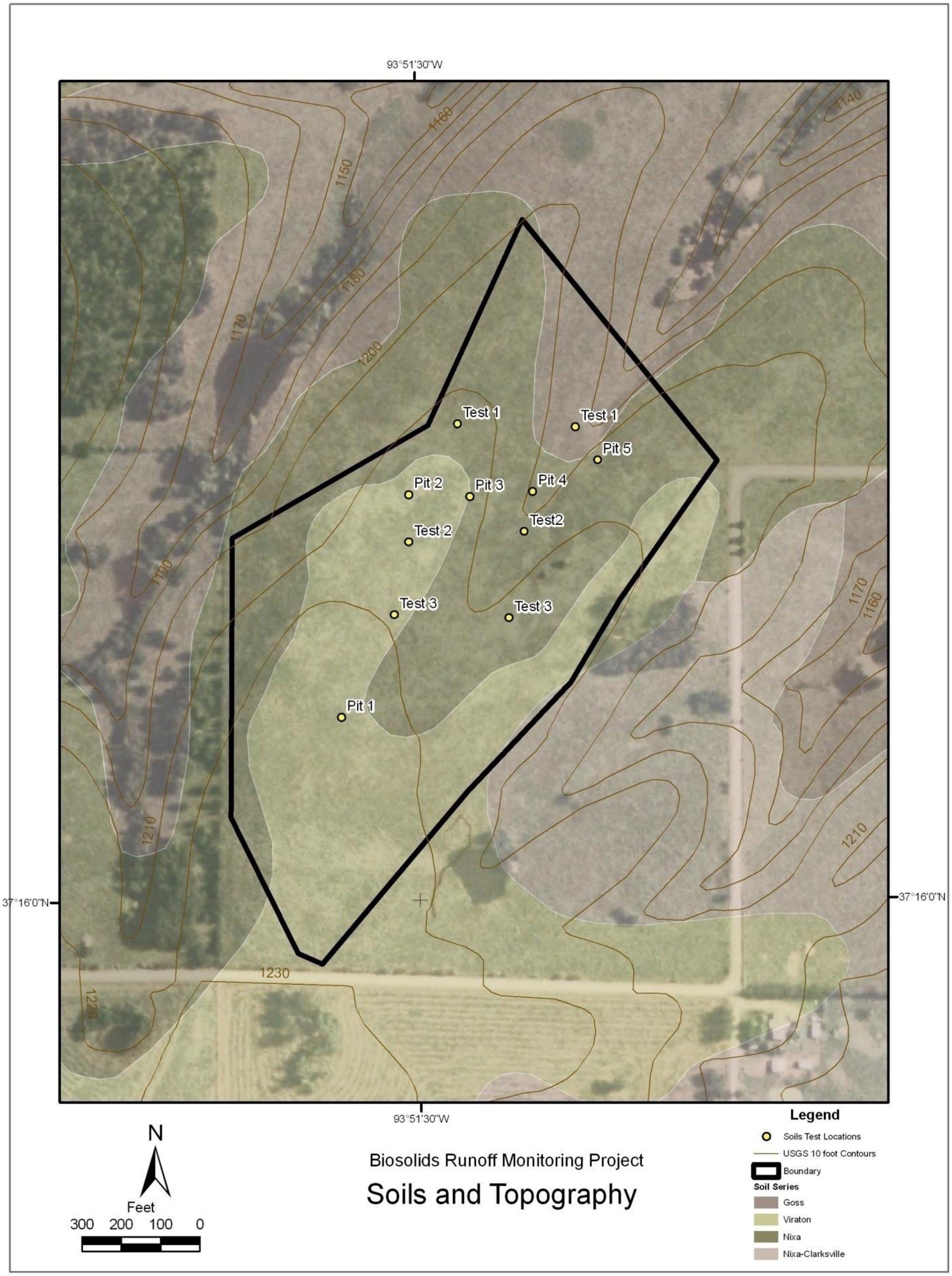

Figure 2. Mapped soils with soil test and soil morphology soil pit locations

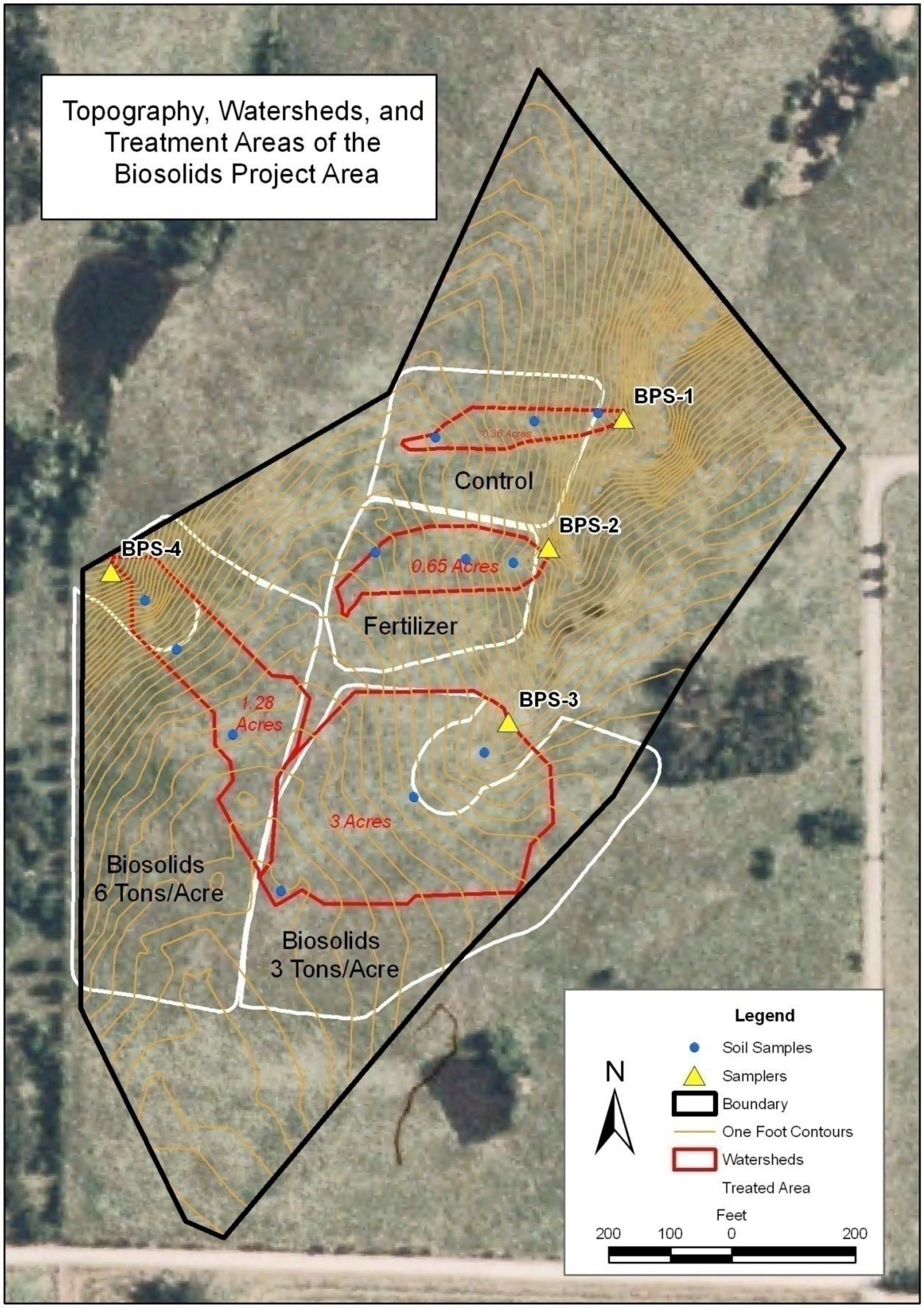

Figure 3. Site topography, watershed areas, surface soil sample locations, and treatment zones

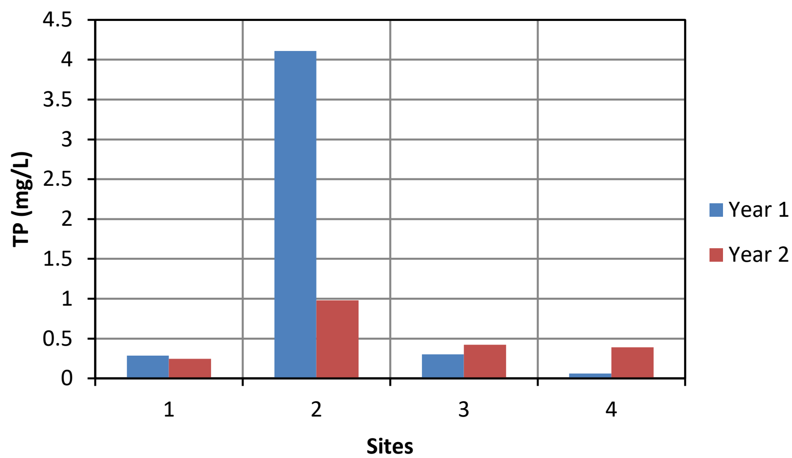

Figure 4. Annual median TP by site

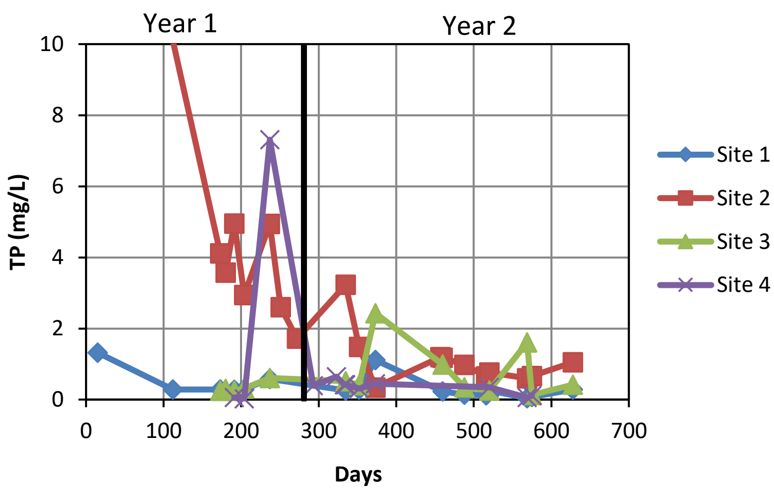

Figure 5. Time-series plot of TP over the sample period

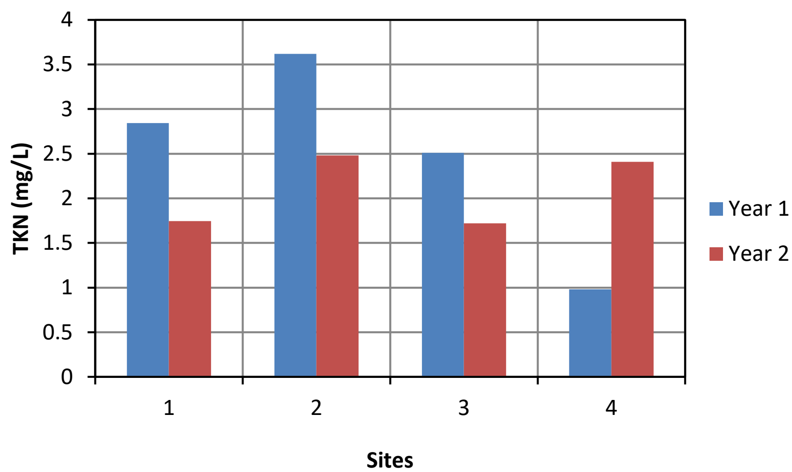

Figure 6. Annual median TKN by site

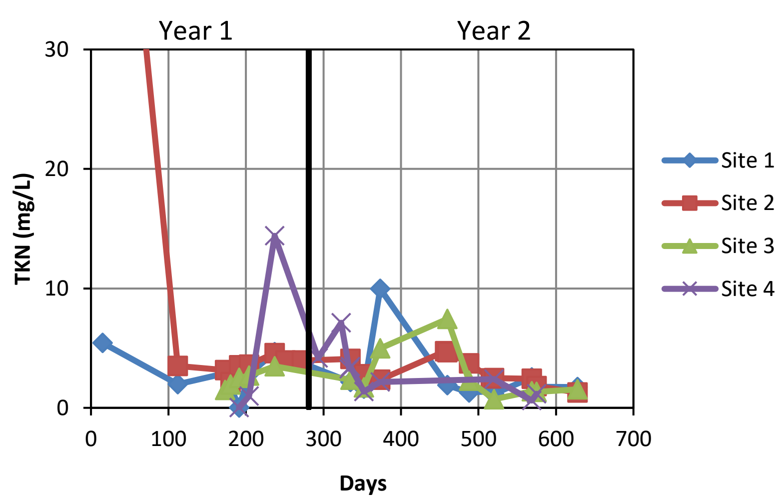

Figure 7. Time-series plot of TKN over the sample period

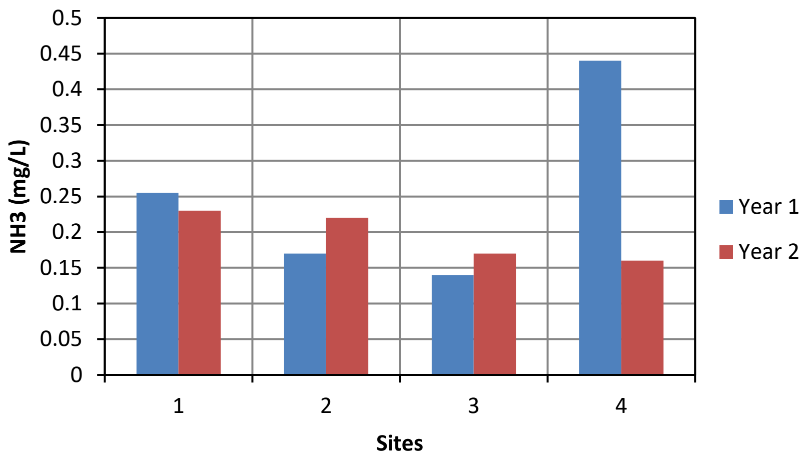

Figure 8. Annual median ammonia by site

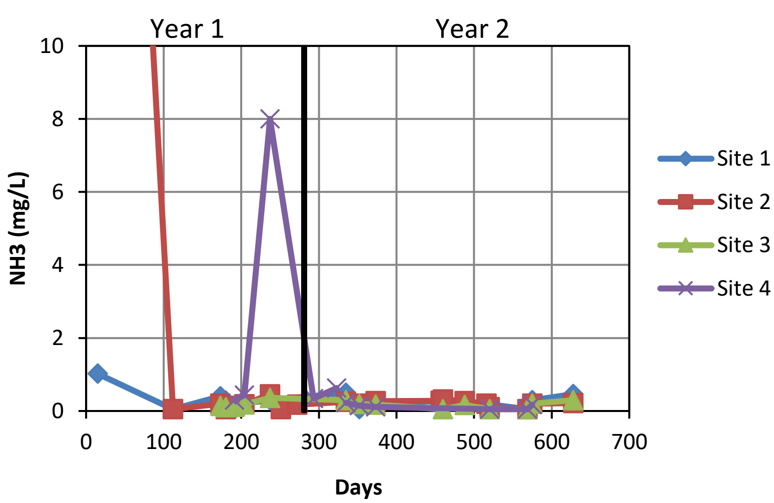

Figure 9. Time-series plot of ammonia over the sample period

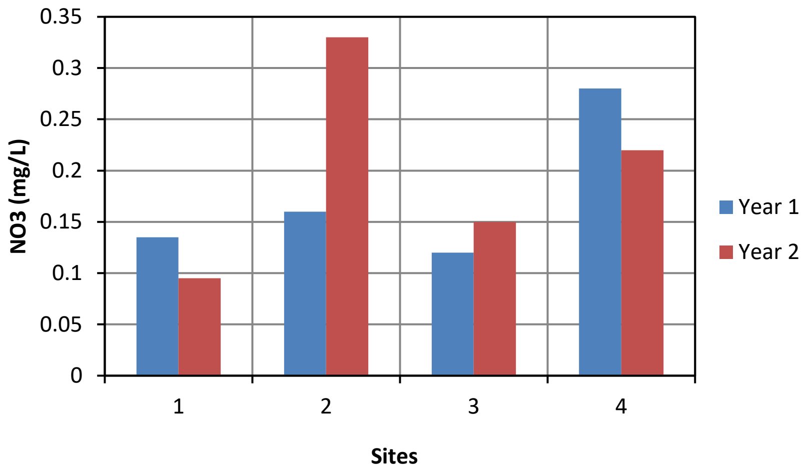

Figure 10. Annual median nitrate over time

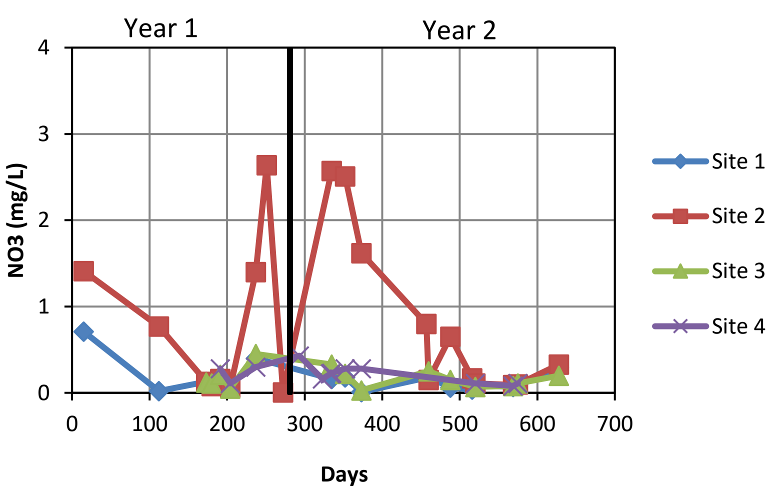

Figure 11. Time-series plot of nitrate over the sample period

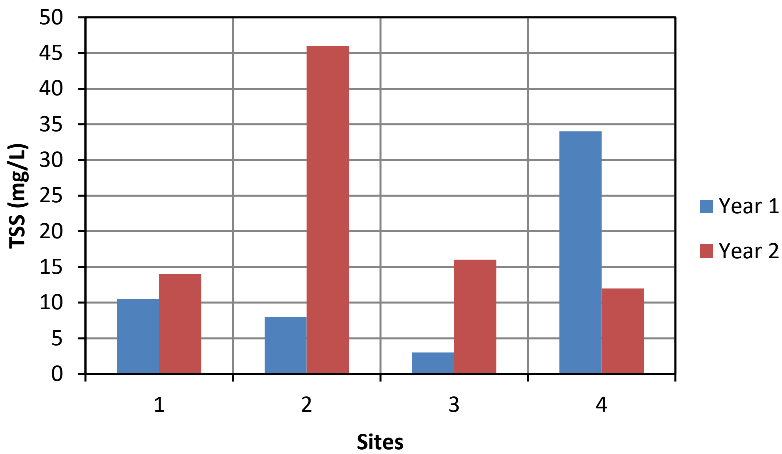

Figure 12. Annual median TSS by site

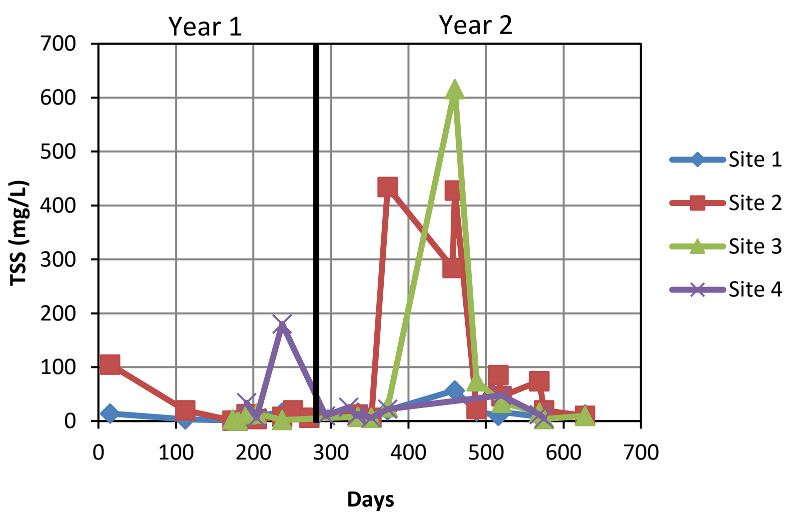

Figure 13. Time-series plot of TSS over the sample period

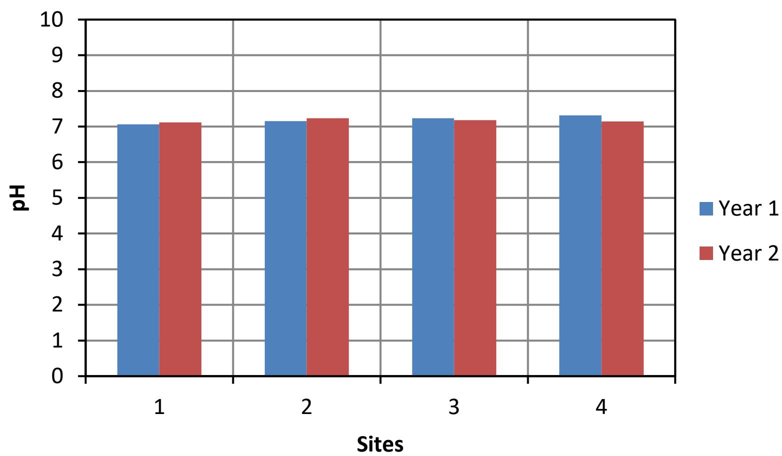

Figure 14. Annual median pH by site

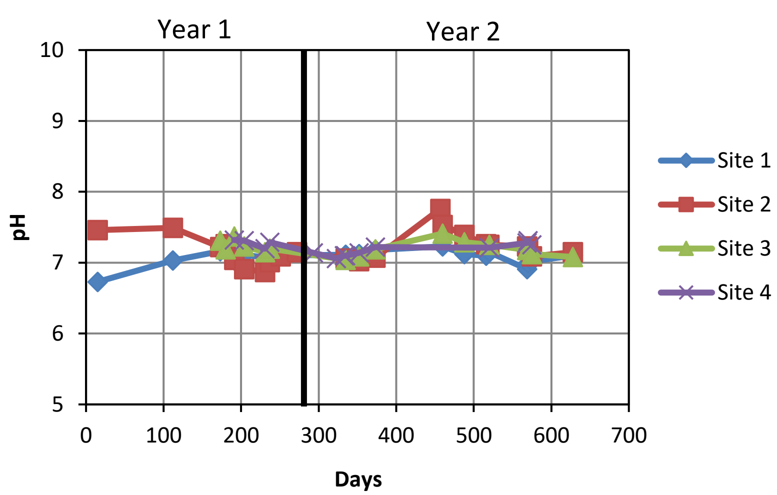

Figure 15. Time-series plot of pH over the sample period

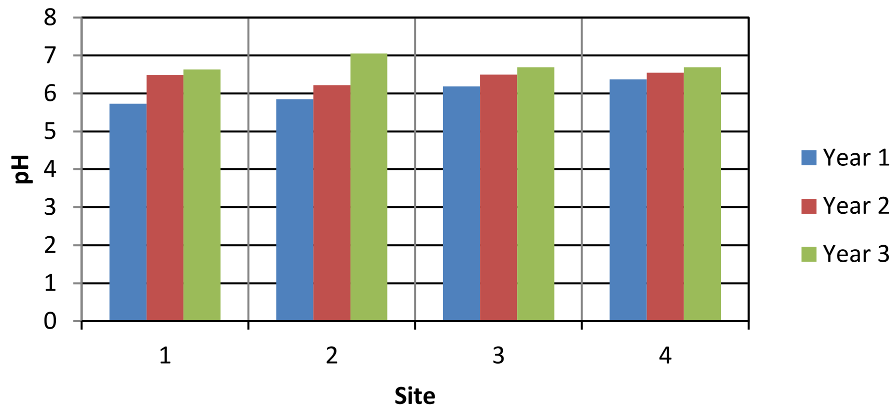

Figure 16. Annual mean soil pH by site

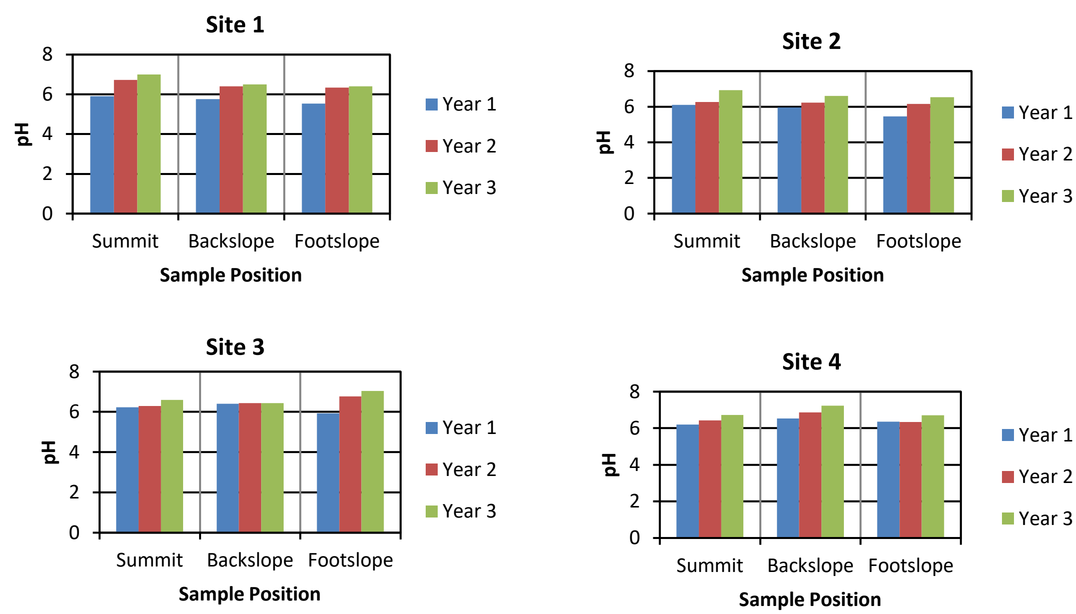

Figure 17. Annual mean soil pH by landscape position

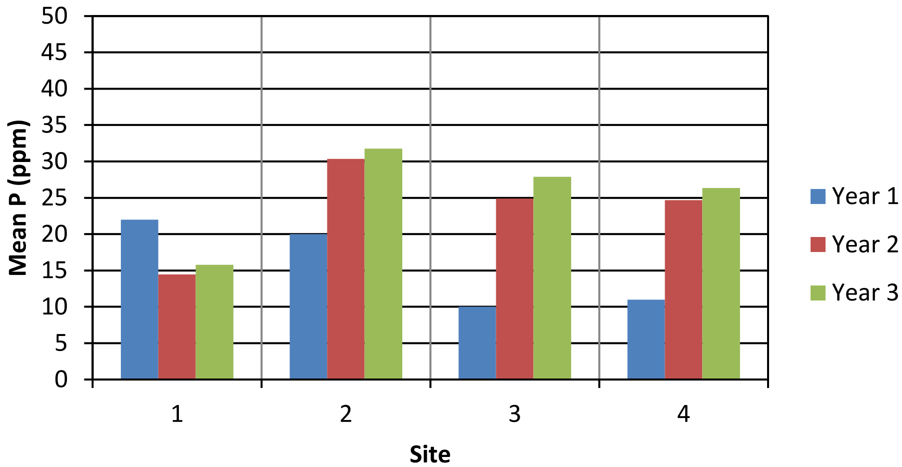

Figure 18. Annual mean soil P by site

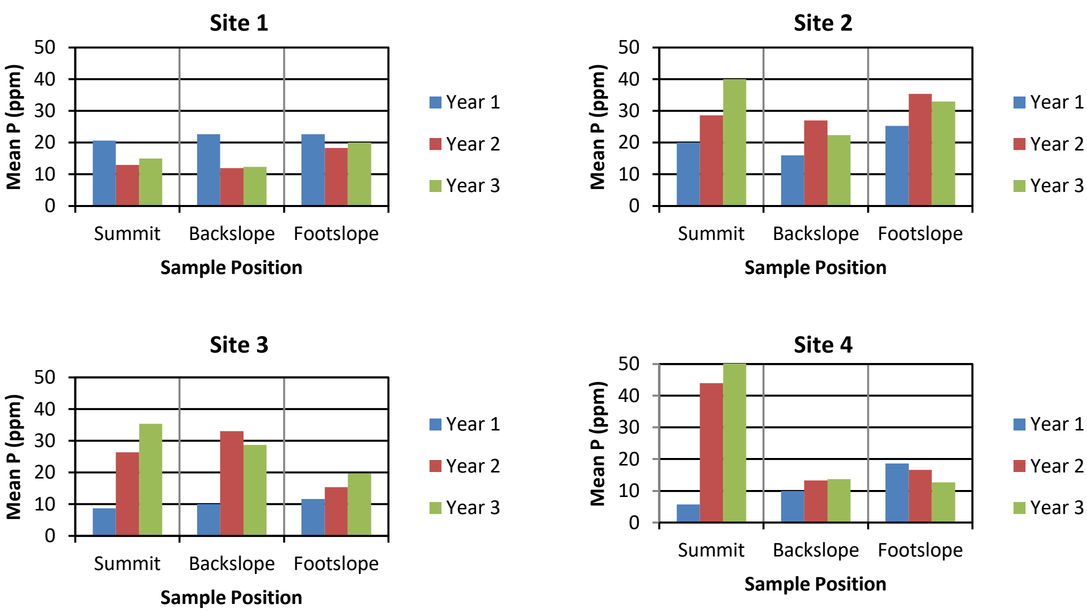

Figure 19. Annual mean soil P by landscape position

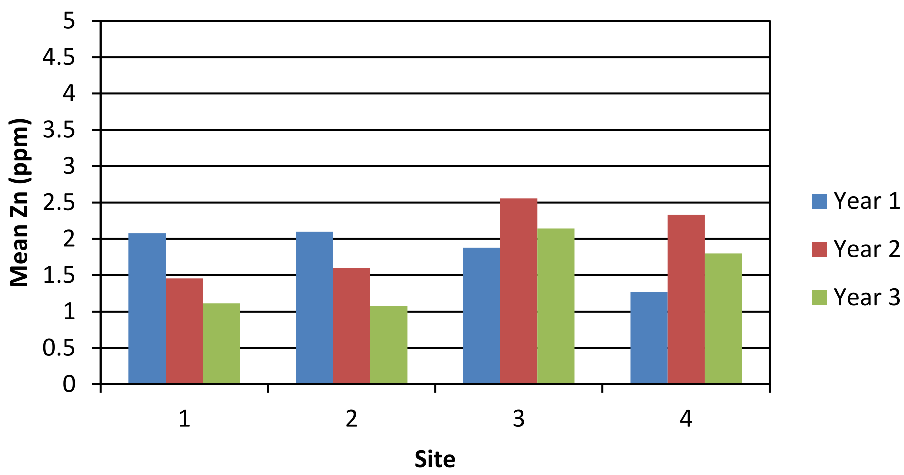

Figure 20. Annual mean soil Zn by site

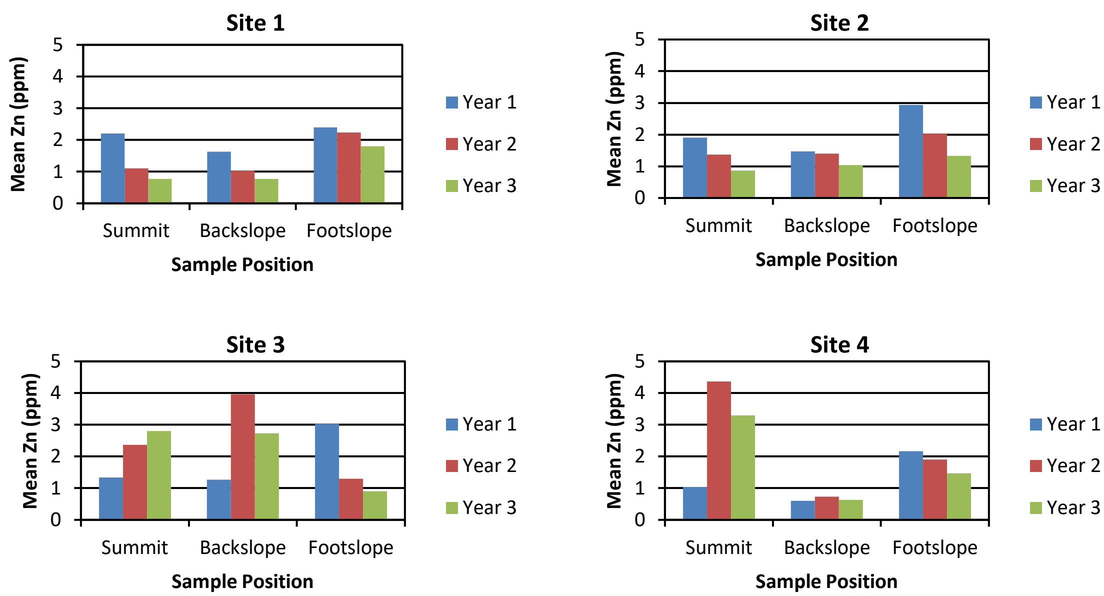

Figure 21. Annual mean soil Zn by landscape position

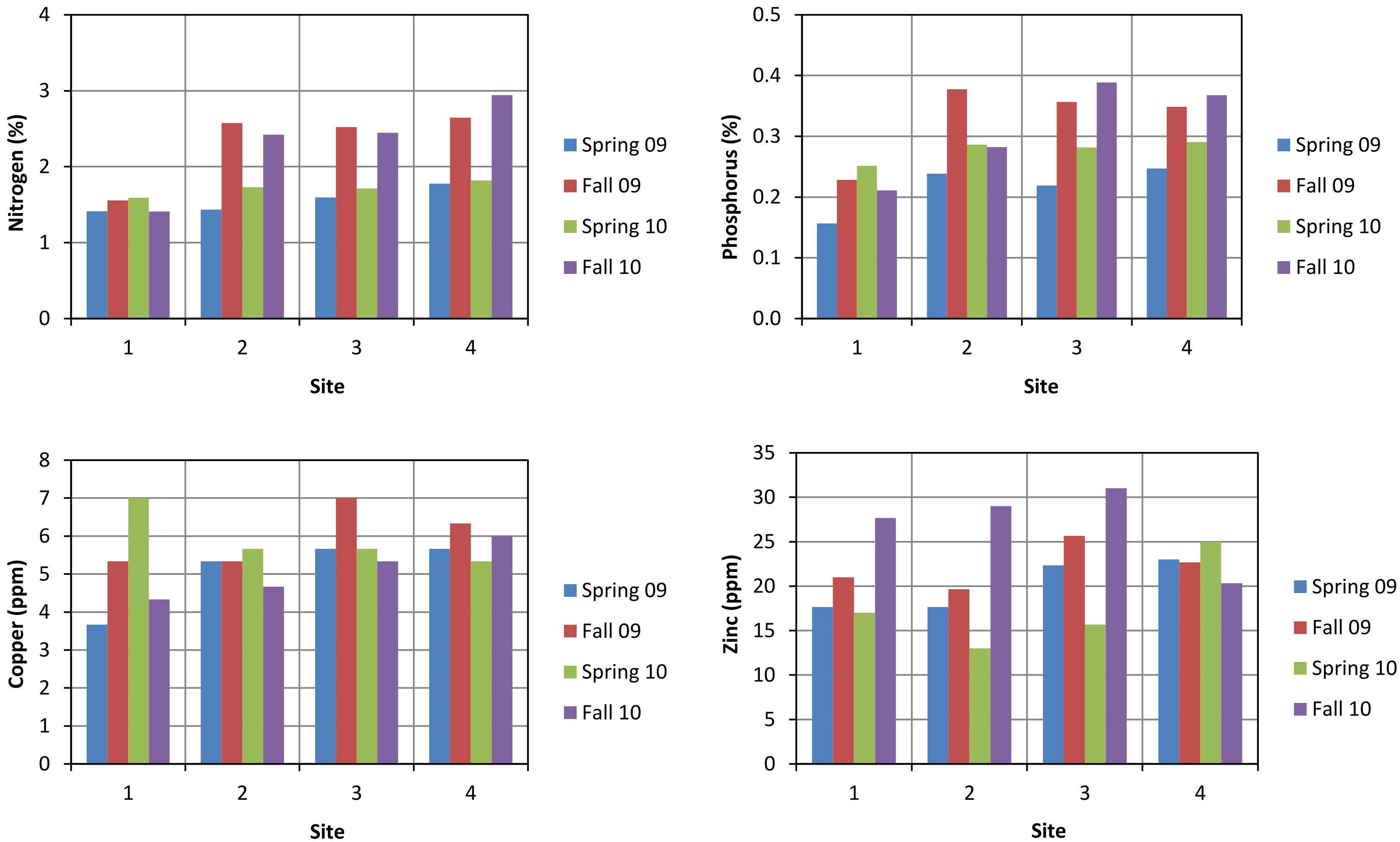

Figure 22. Annual Nitrogen, Phosphorus, Copper and Zn in forage harvest

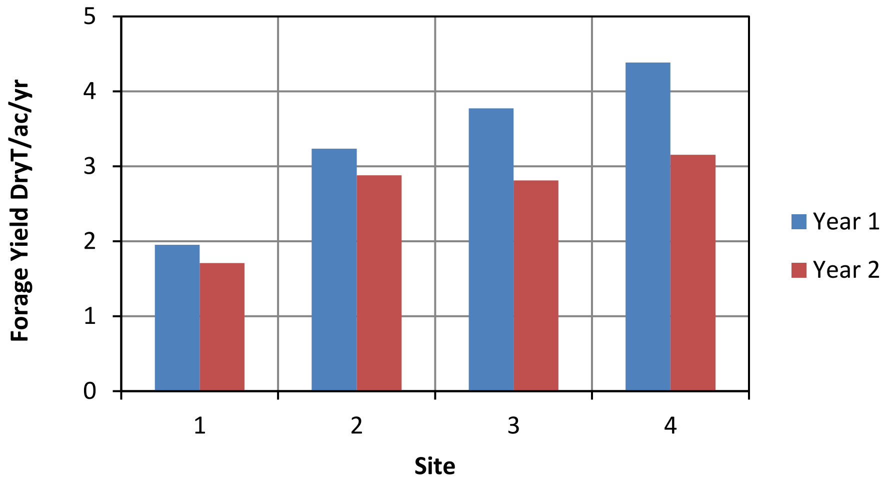

Figure 23. Annual average forage yield by site

PHOTOS

Photo 1. Soil pit #1 from the head slope landscape position showing silty texture from loess parent material over older reworked loess sitting on top of a fragipan.

Photo 2. Soil pit #2 from the narrow interfluve between sites 1 and 4 showing colluvial material over a weak fragipan over red residuum below.

Photo 3. Prismatic structure and gray seams indicative of fragipan pedology in SW Missouri.

Photo 4. Soil pit #3 from the slightly steeper shoulder side slope with rocky colluvium over cherty red clay residiuum.

Photo 5. Top 15 inches of pit #4 similar to pit #3 above.

Photo 6. Soil pit from the valley bottom landscape position with unconsolidated rocky colluvial parent material that may be result of past land clearing.

Photo 7. V-Notch Weir, Pressure Transducer, and Strainer Location

Photo 8. Pressure Transducer and Strainer Location

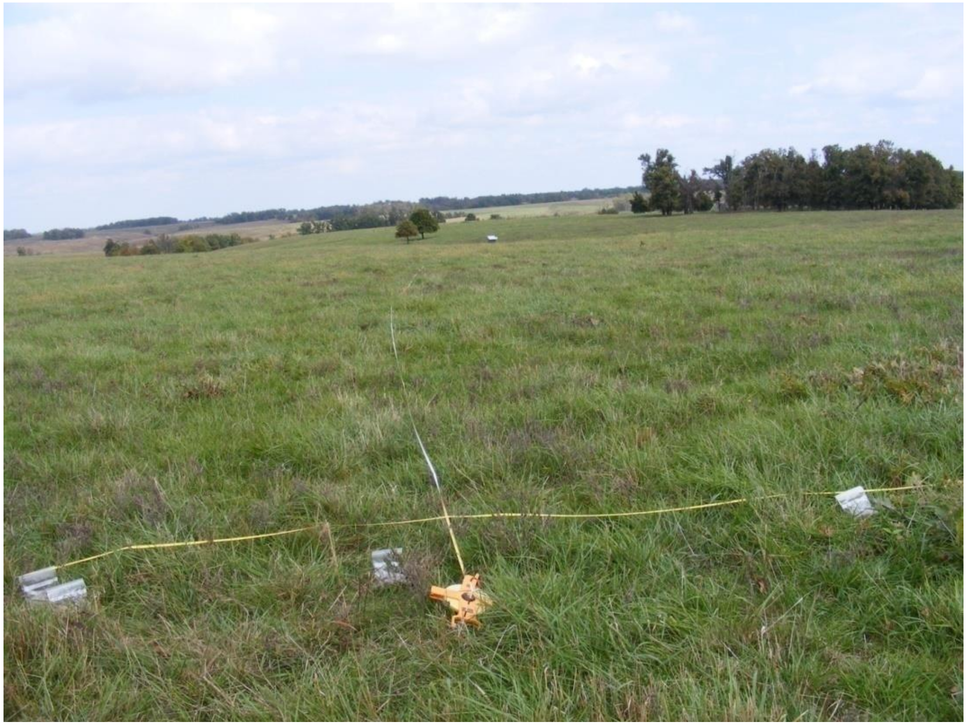

Photo 9. Surface Soil Sample Transect

Photo 10. Sampler housing along main draw on the project site (October 2008)

Photo 11. Auto-sampler and Rain Gage Installation (October 2008)

Photo 12. Tom Dewitt Soil Coring Along the Ridge with Class (October 2008)

Photo 13. Example of a Soil Profile at the Project Site (Loess over Colluvium over Residuum) (October 2008)

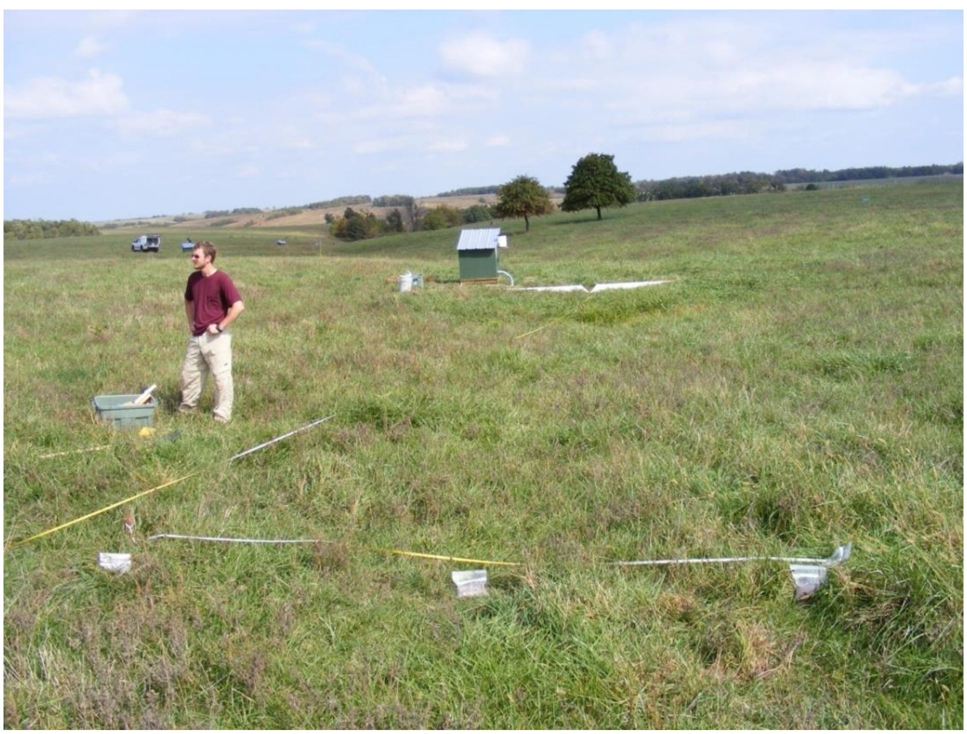

Photo 14. Surface Soil Sampling (October 2008)

Photo 15. Watershed divide between the 6 t/ac biosolids applied site 4 (right) and control site 1 (left).

APPENDIX A: Soil Test Results

University Extension
University of Missouri-Columbia

Soil Test Report

Soil Testing Laboratory
23 Mumford Hall, MU
Columbia, MO 65211
Phone: (573) 882-0623

or

Soil Testing Laboratory
P.O. Box 160
Portageville, MO 63873
Phone: (573)379-5431

http://www.soiltest.psu.missouri.edu/

Serial no. S41722-1	**Lab no. C0810745**
County Greene	Region 6
Submitted 8/1/2008	Processed 8/6/2008

Soil sample submitted by: Firm Number: Outlet:

FIELD INFORMATION		
Field ID BIO 1	Sample no 1	
Acres	Last Limed unknown	Irrigated No
Last crop 18 COOL SEASON GRASS HAY		FSA Copy N

This report is for:
MSU-GGP
901 NATIONAL
SPRINGFIELD MO 65802

SOIL TEST INFORMATION				RATING: Very Low / Low / Medium / High / Very High / Excess
pH_s	(salt pH)	5.7		* *
Phosphorus	(P)	29	lbs/A	* *
Potassium	(K)	173	lbs/A	* *
Calcium	(Ca)	1987	lbs/A	* *
Magnesium	(Mg)	131	lbs/A	* * * * * * * * * * * *
Sulfur	(SO_4-S)		ppm	
Zinc	(Zn)		ppm	
Manganese	(Mn)		ppm	
Iron	(Fe)		ppm	
Copper	(Cu)		ppm	

Organic matter 3.7 %	Neutralizable acidity 3.0 meq/100g	Cation Exch. Capacity 8.7 meq/100g
PH in water	Electrical Conductivity Mmho/cm	Sodium (Na) lbs/A
Nitrate (NO_3-N) Topsoil ppm	Subsoil ppm	Sampling Depth Top Inches Subsoil Inches

NUTRIENT REQUIREMENTS

Cropping options	Yield goal	N	P_2O_5	K_2O	Zn	S
18 COOL SEASON GRASS HAY	3 T/A	120	40	115		
18 COOL SEASON GRASS HAY	5 T/A	200	60	180		

(Pounds per acre)

LIMESTONE SUGGESTIONS

Effective Neutralizing Material (ENM)	0
Effective magnesium (EMg)	***

Comments
---For hay production apply nitrogen just before spring growth begins (typically March). Consider splitting nitrogen applications if the rate exceeds 90 lbs N/acre, applying 60% in March and the balance in mid August.
---Some herbicide labels list restrictions based on soil pH in water. This sample has an estimated pH in water of 6.2 . Use this estimated pH in water as a guide. If you wish to have soil pH in water analyzed, contact your dealer or Extension specialist listed below.
***Limestone is not currently recommended. For a future limestone application, suggest using dolomitic limestone if readily available, but yield response to magnesium is not likely.

I normally suggest no more than 120 lbs nitrogen per year on cool season grass hay fields. I suggest split applications of this amount with 60-80 lbs in the early spring and the balance in the early fall.

Regional Agronomy Specialist Tim Schnakenberg Phone 417-357-6812 *Tim Schnakenberg*
Signature

White-Farmer, Yellow-FSA, Blue-Firm, Pink-Extension MP 189 Revised 1/96
University of Missouri, Lincoln University, U.S. Department of Agriculture & Local University Extension Councils Cooperating Columbia
Equal opportunity institutions

University Extension
University of Missouri-Columbia

Soil Test Report

Soil Testing Laboratory
23 Mumford Hall, MU
Columbia, MO 65211
Phone: (573) 882-0623

or

Soil Testing Laboratory
P.O. Box 160
Portageville, MO 63873
Phone: (573)379-5431

http://www.soiltest.psu.missouri.edu/

Serial no. S41722-3	**Lab no. C0810747**
County Greene	Region 6
Submitted 8/1/2008	Processed 8/6/2008

Soil sample submitted by: Firm Number: Outlet:

FIELD INFORMATION			
Field ID BIO 3		Sample no 3	
Acres	Last Limed unknown		Irrigated No
Last crop 18 COOL SEASON GRASS HAY			FSA Copy N

This report is for:
MSU-GGP
901 NATIONAL
SPRINGFIELD MO 65802

SOIL TEST INFORMATION				RATING (Very Low / Low / Medium / High / Very High / Excess)
pH_s	(salt pH)	5.5		**********************
Phosphorus	(P)	18	lbs/A	****************
Potassium	(K)	171	lbs/A	*************************
Calcium	(Ca)	2156	lbs/A	*********************************
Magnesium	(Mg)	106	lbs/A	********
Sulfur	(SO_4-S)		ppm	
Zinc	(Zn)		ppm	
Manganese	(Mn)		ppm	
Iron	(Fe)		ppm	
Copper	(Cu)		ppm	

Organic matter 5.1 %	Neutralizable acidity 4.0 meq/100g	Cation Exch. Capacity 10.1 meq/100g
PH in water	Electrical Conductivity Mmho/cm	Sodium (Na) lbs/A
Nitrate (NO_3-N) Topsoil ppm, Subsoil ppm	Sampling Depth Top Inches	Subsoil Inches

NUTRIENT REQUIREMENTS

Cropping options	Yield goal	N	P_2O_5	K_2O	Zn	S
18 COOL SEASON GRASS HAY	3 T/A	120	55	115		
18 COOL SEASON GRASS HAY	5 T/A	200	75	185		

(Pounds per acre)

LIMESTONE SUGGESTIONS

Effective Neutralizing Material (ENM)	650
Effective magnesium (EMg)	65

Comments
---For hay production apply nitrogen just before spring growth begins (typically March). Consider splitting nitrogen applications if the rate exceeds 90 lbs N/acre, applying 60% in March and the balance in mid August.
---Some herbicide labels list restrictions based on soil pH in water. This sample has an estimated pH in water of 6.0 . Use this estimated pH in water as a guide. If you wish to have soil pH in water analyzed, contact your dealer or Extension specialist listed below.
---To determine limestone needed in tons/acre, divide your ENM requirement by the guarantee of your limestone dealer.
***Suggest using dolomitic limestone to increase magnesium in your soil. If dolomitic limestone is not available, under high management use a soluble source of magnesium fertilizer at a rate of 30 to 40 pounds Mg per acre.

Our lime recommendations are for a one-time application and N-P-K are annual applications. Retest in 3-4 years.

Regional Agronomy Specialist Tim Schnakenberg Phone 417-357-6812 *Tim Schnakenberg*
Signature

White-Farmer, Yellow-FSA, Blue-Firm, Pink-Extension MP 189 Revised 1/96
University of Missouri, Lincoln University, U.S. Department of Agriculture & Local University Extension Councils Cooperating Columbia
Equal opportunity institutions

University Extension
University of Missouri-Columbia

Soil Test Report

Soil Testing Laboratory
23 Mumford Hall, MU
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or

Soil Testing Laboratory
P.O. Box 160
Portageville, MO 63873
Phone: (573)379-5431

http://www.soiltest.psu.missouri.edu/

Serial no. S41722-5	**Lab no. C0810749**
County Greene	Region 6
Submitted 8/1/2008	Processed 8/6/2008

Soil sample submitted by: Firm Number: Outlet:

FIELD INFORMATION			
Field ID BIO 5		Sample no 5	
Acres	Last Limed unknown	Irrigated No	
Last crop 18 COOL SEASON GRASS HAY			FSA Copy N

This report is for:
MSU-GGP
901 NATIONAL
SPRINGFIELD MO 65802

SOIL TEST INFORMATION				RATING
				Very Low / Low / Medium / High / Very High / Excess
pH_s	(salt pH)	5.4		**********************
Phosphorus	(P)	10	lbs/A	********
Potassium	(K)	155	lbs/A	**************************
Calcium	(Ca)	2080	lbs/A	************************************
Magnesium	(Mg)	125	lbs/A	************
Sulfur	(SO_4-S)		ppm	
Zinc	(Zn)		ppm	
Manganese	(Mn)		ppm	
Iron	(Fe)		ppm	
Copper	(Cu)		ppm	

Organic matter 2.7 %	Neutralizable acidity 3.5 meq/100g	Cation Exch. Capacity 9.4 meq/100g
PH in water	Electrical Conductivity Mmho/cm	Sodium (Na) lbs/A
Nitrate (NO_3-N) Topsoil ppm	Subsoil ppm	Sampling Depth Top Inches Subsoil Inches

NUTRIENT REQUIREMENTS

Cropping options	Yield goal	N	P_2O_5	K_2O	Zn	S
		Pounds per acre				
18 COOL SEASON GRASS HAY	3 T/A	120	70	120		
18 COOL SEASON GRASS HAY	5 T/A	200	90	190		

LIMESTONE SUGGESTIONS

Effective Neutralizing Material (ENM)	640
Effective magnesium (EMg)	***

Comments
---For hay production apply nitrogen just before spring growth begins (typically March). Consider splitting nitrogen applications if the rate exceeds 90 lbs N/acre, applying 60% in March and the balance in mid August.
---Some herbicide labels list restrictions based on soil pH in water. This sample has an estimated pH in water of 5.9 . Use this estimated pH in water as a guide. If you wish to have soil pH in water analyzed, contact your dealer or Extension specialist listed below.
---To determine limestone needed in tons/acre, divide your ENM requirement by the guarantee of your limestone dealer.
***Suggest using dolomitic limestone if readily available, but yield response to magnesium is not likely.

Regional Agronomy Specialist Tim Schnakenberg Phone 417-357-6812 *Tim Schnakenberg*
Signature

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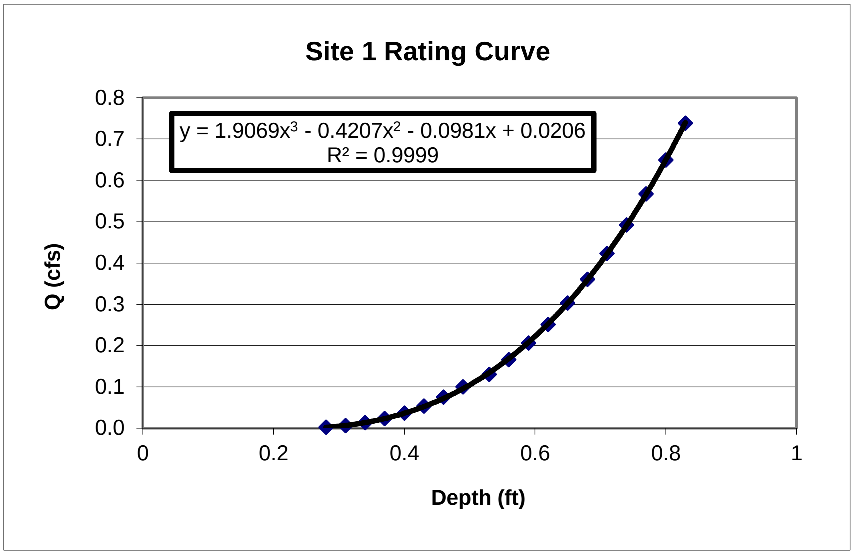
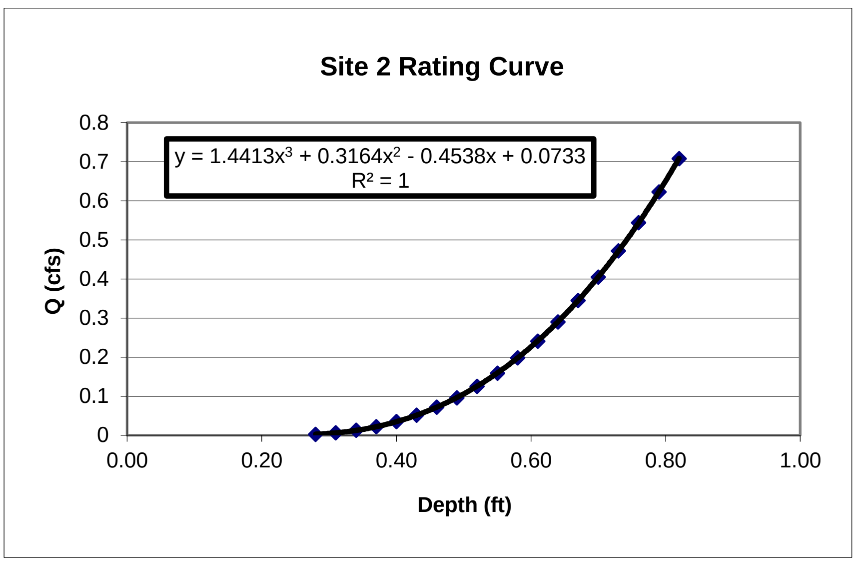
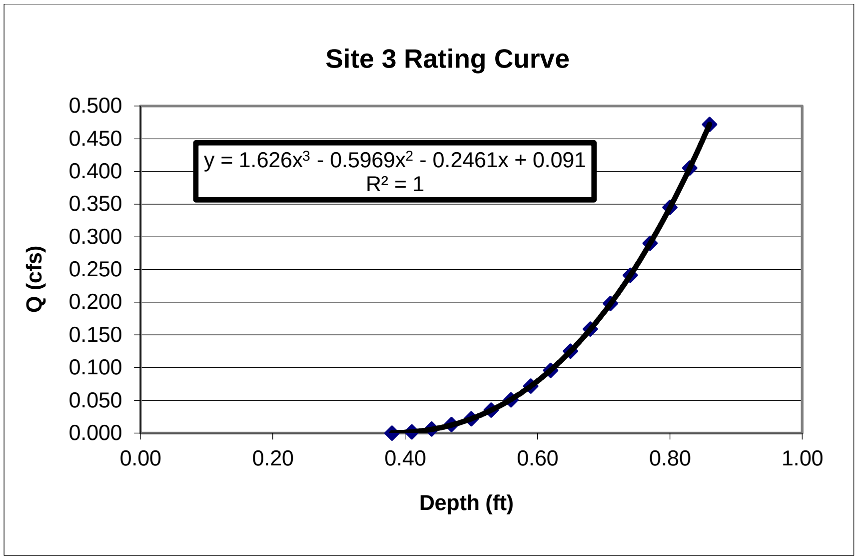
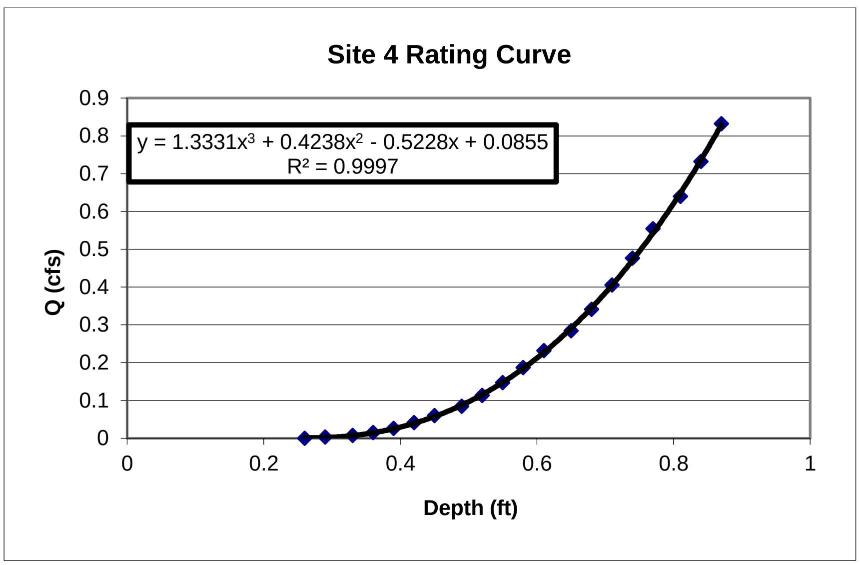
APPENDIX B: Discharge Rating Curves






Site 3 Rating Curve
y = 1.626x³ - 0.5969x² - 0.2461x + 0.091
R² = 1
Q (cfs)
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.00
0.20
0.40
0.60
0.80
1.00
Depth (ft)


Site 4 Rating Curve
y = 1.3331x³ + 0.4238x² - 0.5228x + 0.0855
R² = 0.9997
Q (cfs)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
Depth (ft)

APPENDIX C: Raw Fertilizer and Biosolids Nutrient and Metals Analysis

Location	Nutrients (mg/L)				% Total Solids	Fecal coliform (coli/100 mL)	pH (std units)	Metals (µg/L)											
	TKN	NH3-N	NO3-N	TP				As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	K	Se	Ag	Zn
Commercial Fertilizer	83,979	19,800	14,364	36,166	-	NS	NS	<15	5.8	125	8.2	<15	<0.2	<20	15.4	25,300	<20	<5	230
Biosolids - 3 Dry Tons	78,400	18,430	136	21,860	22.3	100,500	NS	<15	<5	10.7	61.5	<15	0.24	<20	<10	408	<20	<5	101
Biosolids - 6 Dry Tons	76,340	21,410	195	20,990	22.9	99,200	NS	<15	<5	10.6	59.7	<15	0.23	<20	<10	417	<20	<5	99

APPENDIX D: Surface Soil Sample Data

Year 1 Soil Data collected October 13, 2008

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3-N	Mg	B	Mn	Zn	Cu	Fe	S	Pb*	Total Pb**	Cd	Ni	Cr
BIO 1	1	26.2	0	4.35	5.6	6.7	12	24	125	2,290	0	169	0.3	110	2.2	0.2	3.5	49.3	1	37	0.1	0.1	0
BIO 2	1	26.2	0-D	4.19	5.7	6.7	11	24	125	2,474	0	151	0.4	127	2	0.2	3.6	54.2	0	33	0.1	0.1	0.1
BIO 3	1	26.2	6.6	4.95	5.4	6.7	19	11	66	1,467	0	104	0.3	123	2.3	0.2	6.3	39.4	1	33	0.1	0.1	0
BIO 4	1	26.2	13.1	4.18	5.6	6.7	12	33	187	2,465	0	166	0.4	190	2.7	0.2	3.1	59.7	0	32	0.1	0.1	0.1
BIO 5	1	131.2	0	4.26	5.8	6.8	11	25	129	3,935	0	207	0.3	114	1.8	0.2	3.3	70.9	0	32	0.1	0.1	0.1
BIO 6	1	131.2	6.6	4.22	5.9	6.9	14	23	152	3,548	0	165	0.4	174	1.4	0.2	4.1	68	1	33	0.1	0.1	0.1
BIO 7	1	131.2	13.1	4.69	5.6	6.8	19	20	141	3,003	0	147	0.3	96.6	1.7	0.2	7.6	63.6	1	33	0.1	0.1	0.1
BIO 8	1	131.2	13.1-D	4.39	5.7	6.8	20	17	383	3,712	0	122	0.3	123	1.5	0.2	7.5	73	1	33	0.1	0.1	0.1
BIO 9	1	295.3	0	4.8	5.8	6.9	13	14	79	3,127	0	110	0.3	128	1.3	0.2	8.3	58.4	0	31	0.1	0.1	0.1
BIO 10	1	295.3	0-D	4.49	6	7	13	24	75	3,161	0	131	0.4	172	1.8	0.2	5.8	63.1	0	30	0.1	0.1	0.1
BIO 11	1	295.3	6.6	4.36	6	6.8	14	23	198	5,024	0	131	0.4	308	3.3	0.2	6.3	90.2	0	30	0.1	0.2	0.1
BIO 12	1	295.3	13.1	4.54	5.9	6.9	13	25	87	2,671	0	117	0.5	378	2	0.2	4.8	59.6	0	28	0.1	0.1	0.1
BIO 13	2	52.5	0	4.46	5.5	6.6	19	24	169	2,867	0	131	0.3	131	3	0.2	8	63	1	38	0.1	0.1	0.1
BIO 14	2	52.5	0-D	4.56	5.3	6.7	25	18	138	2,054	0	108	0.3	170	2.4	0.2	8.4	53.3	1	41	0.1	0.2	0.1
BIO 15	2	52.5	6.6	4.54	5.5	6.7	21	19	109	2,903	0	112	0.3	183	2.5	0.3	10.5	65.2	1	37	0.1	0.2	0.1
BIO 16	2	52.5	13.1	4.03	5.4	6.6	14	33	317	2,127	0	188	0.3	153	3.3	0.2	5	55.5	1	37	0.1	0.1	0.1
BIO 17	2	131.2	0	4.73	6.2	7	8	17	213	4,104	0	123	0.4	97.9	1.1	0.2	4.5	70.1	0	29	0.1	0.1	0.1
BIO 18	2	131.2	6.6	4.52	5.9	6.8	10	18	106	4,478	0	144	0.3	78.4	1.7	0.2	4.1	73.2	0	32	0.1	0.1	0.1
BIO 19	2	131.2	6.6-D	4.59	5.9	6.9	14	17	97	4,427	0	148	0.3	96.9	1.9	0.2	5.1	73.9	0	33	0.1	0.1	0.1
BIO 20	2	131.2	13.1	4.66	5.8	6.7	27	13	214	3,233	0	133	0.3	83.3	1.6	0.2	8.5	60.2	1	35	0.1	0.2	0.1
BIO 21	2	278.9	0	4.4	6.1	6.9	13	24	137	3,737	0	197	0.4	102	2.2	0.2	3.7	65.5	0	31	0.1	0.1	0.1
BIO 22	2	278.9	6.6	4.41	6	6.8	13	21	160	4,264	0	153	0.4	134	2.1	0.2	4.9	73.6	0	31	0.1	0.1	0.1
BIO 23	2	278.9	6.6-D	4.45	6	6.9	14	13	156	3,419	0	138	0.3	116	1.5	0.2	4.4	58.9	0	32	0.1	0.1	0.1
BIO 24	2	278.9	13.1	4.58	6.2	6.9	19	15	120	5,339	0	136	0.3	75.4	1.4	0.2	4.8	82.6	1	35	0.1	0.2	0.1
BIO 25	3	65.6	0	4.55	6.1	6.7	10	15	208	3,901	9	205	0.3	53.2	3.4	0.2	1.5	57.6	0	30	0.1	0.1	0.1

BIO 26	3	65.6	6.6	4.69	5.8	6.6	19	8	74	2,435	9	78	0.2	53.9	2.6	0.2	2.6	39.3	0	32	0.1	0.1	0
BIO 27	3	65.6	13.1	4.2	5.9	6.7	15	12	180	2,939	9	139	0.3	65.2	3.1	0.2	3.5	49.1	0	31	0.1	0.2	0.1
BIO 28	3	65.6	13.1-D	4.51	5.8	6.6	17	8	141	2,048	8	111	0.2	57.1	2.8	0.2	3.3	36.1	0	31	0.1	0.1	0
BIO 29	3	196.9	0	4.1	6.5	7	6	11	193	2,443	15	178	0.3	22.3	1.5	0.2	0.9	39.6	0	29	0.1	0.1	0
BIO 30	3	196.9	0-D	4.69	6.4	7	7	9	128	2,695	10	148	0.3	24.3	1.4	0.2	1	40.8	0	28	0	0.1	0
BIO 31	3	196.9	6.6	4.54	6.2	6.9	10	8	350	1,988	13	144	0.3	33.2	1.4	0.3	1.8	34	0	29	0	0.1	0
BIO 32	3	196.9	13.1	4.37	6.5	7	6	11	153	2,798	11	161	0.3	34.8	0.9	0.2	1	42.8	0	28	0.1	0.1	0
BIO 33	3	459.3	0	4.63	6	6.8	12	10	88	2,462	0	141	0.2	40.5	1.4	0.2	3.1	40.7	0	30	0.1	0.1	0
BIO 34	3	459.3	0-D	4.57	5.9	6.8	15	8	117	1,685	0	123	0.2	42.3	1.7	0.2	4.3	31.2	0	32	0.1	0.1	0
BIO 35	3	459.3	6.6	4.24	6.5	7	8	12	196	4,578	1	193	0.3	49.9	1.6	0.2	2.7	69.2	0	28	0.1	0.1	0.1
BIO 36	3	459.3	13.1	5.11	6.2	7	16	4	88	2,172	1	103	0.2	38.6	1	0.3	6.8	33.4	0	28	0	0.1	0
BIO 37	4	68.9	0	4.16	6.5	7	5	15	110	3,280	12	86	0.4	78.6	1.9	0.2	0.7	49.7	0	27	0.1	0.1	0
BIO 38	4	68.9	6.6	4.3	6.2	6.8	8	17	108	2,680	10	108	0.3	103	2.4	0.2	0.9	44.2	0	27	0.1	0.1	0
BIO 39	4	68.9	6.6-D	4.17	6.2	6.8	8	17	108	2,477	10	117	0.3	93.1	2.1	0.2	0.9	42	0	30	0.1	0.1	0
BIO 40	4	68.9	13.1	4.31	6.4	6.9	5	24	103	2,714	11	136	0.4	77.1	2.2	0.2	0.7	44.2	0	27	0.1	0.1	0
BIO 41	4	164.0	0	4.21	6.5	7	11	11	137	4,513	1	114	0.3	56.7	0.5	0.2	1.3	64.4	0	30	0.1	0.1	0.1
BIO 42	4	164.0	6.6	4.42	6.6	7	7	8	91	3,319	10	86	0.3	56.5	0.6	0.2	1	49.4	0	29	0.1	0.1	0.1
BIO 43	4	164.0	13.1	4.28	6.5	7	9	11	145	2,624	5	133	0.3	65.9	0.7	0.2	1	43.8	0	28	0.1	0.1	0
BIO 44	4	164.0	13.1-D	4.26	6.7	7.1	6	18	217	4,907	7	161	0.4	63.7	0.9	0.2	1	70.1	0	28	0.1	0.1	0.1
BIO 45	4	328.1	0	4.33	6.3	7	12	7	186	1,814	8	135	0.3	38.2	0.9	0.2	1.6	33	0	28	0	0.1	0
BIO 46	4	328.1	0-D	4.45	6.2	6.9	14	7	118	2,332	1	130	0.3	53	1.1	0.2	2.1	36.5	0	27	0.1	0.1	0
BIO 47	4	328.1	6.6	4.78	6.1	6.9	19	4	84	1,913	1	73	0.2	47.5	0.8	0.2	1.9	32	0	29	0	0.1	0
BIO 48	4	328.1	13.1	4.57	6.2	6.8	11	6	81	1,821	3	88	0.2	33.3	1.4	0.2	1.7	31.4	0	31	0.1	0.1	0

Notes: D refers to duplicate sample.
All elements are in parts per million (ppm).
* Extracted Pb
**Estimated total Pb

Year 2 Soil Data Collected July 16, 2009

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3-N	Mg	B	Mn	Zn	Cu	Fe	Pb*	Total Pb**	Cd	Ni	Cr
BIO 49	1	26.2	0	3.34	6.8	7.1	9	28	262	3,758	29	197	0.2	40.8	1.8	0.3	1.2	1	33	0.1	0.1	0.1
BIO 50	1	26.2	0D	3.51	6.6	7.1	8	19	202	3,300	31	172	0.2	28.3	1.6	0.3	1	1	34	0.1	0.1	0.1
BIO 51	1	26.2	6.6	3.82	6.3	6.9	9	15	258	2,251	35	182	0.2	27.9	2	0.4	2.2	0	33	0.1	0.1	0.1
BIO 52	1	26.2	13.1	4.03	5.9	6.6	12	12	196	2,027	36	149	0.1	40.3	2.9	0.4	2.1	1	34	0.1	0.1	0.1
BIO 53	1	131.2	0	4.31	6.3	6.9	9	11	202	1,949	22	126	0.1	26.4	1	0.4	1.1	0	32	0.1	0.1	0
BIO 54	1	131.2	6.6	4.11	6.3	6.9	9	12	125	2,505	13	107	0.2	25.5	1.1	0.3	2	0	32	0.1	0.1	0
BIO 55	1	131.2	6.6D	4.23	6.4	7.0	9	11	126	2,158	14	96	0.1	20.4	0.9	0.3	1.6	0	32	0.1	0.1	0
BIO 56	1	131.2	13.1	4.19	6.6	6.9	9	13	154	3,355	30	162	0.2	28	1	0.2	1.7	1	35	0.1	0.1	0.1
BIO 57	1	295.2	0	4.49	6.4	6.9	9	7	103	1,975	11	104	0.1	29	1.1	0.2	1.8	0	32	0.1	0.1	0
BIO 58	1	295.2	6.6	4.38	7.0	7.1	8	15	118	4,082	27	124	0.2	37.2	0.8	0.2	1.2	0	31	0.1	0.1	0.1
BIO 59	1	295.2	13.1	4.08	6.8	7.0	8	17	279	3,101	43	164	0.2	37.3	1.4	0.2	1.7	0	31	0.1	0.1	0.1
BIO 60	1	295.2	13.1D	4.22	6.5	7.0	7	13	273	2,650	36	157	0.2	42.6	1.5	0.2	1.1	0	31	0.1	0.1	0
BIO 61	2	52.5	0	3.9	6.3	6.9	11	22	187	4,098	30	172	0.2	38.2	2	0.2	2.4	1	34	0.1	0.1	0.1
BIO 62	2	52.5	6.6	4.43	5.9	6.7	15	21	95	2,150	32	102	0.1	43.7	2	0.2	3.4	1	36	0.1	0.1	0.1
BIO 63	2	52.5	13.1	3.6	6.3	6.9	10	63	166	2,555	38	172	0.2	27.8	2.1	0.2	2.8	0	32	0.1	0.1	0.1
BIO 64	2	52.5	13.1D	3.96	6.0	6.8	11	46	126	2,178	22	151	0.2	28.1	2.2	0.2	2.9	0	33	0.1	0.1	0.1
BIO 65	2	131.2	0	4.06	6.4	6.9	11	38	156	3,094	21	172	0.2	25.4	1.4	0.2	2.2	0	32	0.1	0.1	0.1
BIO 66	2	131.2	6.6	4.21	6.2	6.9	13	21	155	2,417	8	115	0.1	32.1	1.1	0.2	2.5	1	35	0.1	0.1	0
BIO 67	2	131.2	6.6D	4.34	6.3	6.9	14	16	133	2,430	9	113	0.1	29.6	1.1	0.2	2.7	1	35	0.1	0.1	0.1
BIO 68	2	131.2	13.1	4.12	6.1	6.8	16	22	126	2,643	10	102	0.1	29	1.7	0.2	2.8	1	35	0.1	0.1	0.1
BIO 69	2	278.8	0	4.54	6.1	6.9	13	22	76	2,001	10	101	0.1	41.3	1.3	0.2	2.7	0	32	0.1	0.1	0
BIO 70	2	278.8	6.6	4.33	6.1	6.9	12	36	95	2,432	11	119	0.1	48.8	1.7	0.2	3.1	0	33	0.1	0.1	0.1
BIO 71	2	278.8	0D	4.65	6.2	6.9	12	42	93	2,472	13	107	0.1	47.7	1.3	0.2	3.2	0	31	0.1	0.1	0.1
BIO 72	2	278.8	13.1	4.49	6.6	7.0	10	28	246	2,766	12	116	0.1	59.1	1.1	0.2	2	0	30	0.1	0.1	0.1
BIO 73	3	65.6	0	4.18	6.7	7.0	10	13	127	3,064	11	112	0.1	40.6	1.4	0.2	1.3	0	33	0.1	0.1	0.1
BIO 74	3	65.6	6.6	3.98	6.7	7.0	8	19	165	2,254	12	135	0.2	48.8	1.6	0.2	1.2	0	31	0.1	0.1	0.1
BIO 75	3	65.6	6.6D	4.3	6.2	6.9	10	13	131	2,178	13	126	0.1	46.9	1.7	0.2	1.6	0	32	0.1	0.1	0.1
BIO 76	3	65.6	13.1	4.31	6.9	7.1	8	14	130	2,782	7	108	0.2	30.9	0.9	0.2	1.2	0	32	0.1	0.1	0
BIO 77	3	196.8	0	4.18	6.4	6.9	13	26	160	3,417	45	183	0.3	51.5	3.8	0.3	2	0	31	0.1	0.1	0.1
BIO 78	3	196.8	6.6	4.1	6.5	7.0	8	47	297	2,327	38	239	0.3	66.5	3.1	0.3	1.3	0	31	0.1	0.1	0.1
BIO 79	3	196.8	6.6D	4.39	6.3	6.9	9	32	278	2,009	56	198	0.2	80.3	3	0.2	1.3	0	30	0.1	0.1	0.1
BIO 80	3	196.8	13.1	4.25	6.4	7.0	9	26	176	2,104	38	199	0.2	42.9	5	0.3	1.4	0	30	0.1	0.1	0.1

BIO 81	3	459.2	0	4.17	6.2	6.9	10	35	128	2,581	45	178	0.3	47.5	3.6	0.3	2.2	0	31	0.1	0.1	0.1
BIO 82	3	459.2	6.6	4.31	6.2	6.9	10	19	104	2,221	36	141	0.2	31.5	1.7	0.2	1.6	0	31	0.1	0.1	0
BIO 83	3	459.2	6.6D	4.34	6.3	7.0	10	19	113	1,965	15	145	0.2	32.3	1.6	0.3	1.6	0	31	0.1	0.1	0
BIO 84	3	459.2	13.1	4.17	6.5	7.0	10	25	159	2,594	16	144	0.2	31	1.8	0.2	2.3	0	30	0.1	0.1	0.1
BIO 85	4	68.9	0	3.82	6.5	6.9	8	18	124	2,670	14	95	0.2	137	2.2	0.2	0.9	0	30	0.1	0.1	0.1
BIO 86	4	68.9	6.6	3.96	6.4	6.9	8	16	107	2,470	15	113	0.2	108	2.1	0.2	0.8	0	31	0.1	0.1	0.1
BIO 87	4	68.9	13.1	4.09	6.1	6.9	10	16	106	1,786	11	112	0.1	98.6	1.4	0.2	1.2	0	32	0.1	0.1	0.1
BIO 88	4	68.9	0D	3.81	6.7	7.0	9	18	141	2,802	14	111	0.2	169	1.9	0.2	0.9	0	30	0.1	0.1	0.1
BIO 89	4	164.0	0	4.03	7.2	7.1	9	16	180	4,023	16	94	0.2	35.7	0.5	0.2	0.9	0	31	0.1	0.1	0.1
BIO 90	4	164.0	6.6	4.17	7.0	7.1	11	14	214	3,430	6	106	0.2	78.7	0.7	0.2	0.9	0	31	0.1	0.1	0.1
BIO 91	4	164.0	13.1	4.28	6.4	6.9	12	10	147	2,472	10	107	0.1	97.4	1	0.2	1.3	0	32	0.1	0.1	0.1
BIO 92	4	164.0	0D	4.14	7.1	7.2	9	15	170	3,746	36	89	0.2	39.5	0.5	0.2	1	0	31	0.1	0.1	0.1
BIO 93	4	328.0	0	4.1	6.3	6.9	9	45	177	2,680	38	183	0.3	50.2	4.9	0.5	2.1	0	30	0.1	0.1	0.1
BIO 94	4	328.0	6.6	4.08	6.5	7.0	9	41	140	2,553	34	171	0.3	41.6	3.4	0.3	1.9	0	30	0.1	0.1	0.1
BIO 95	4	328.0	13.1	4.14	6.5	6.9	10	46	166	2,812	45	194	0.3	47.2	4.8	0.5	2.3	0	30	0.1	0.1	0.1
BIO 96	4	328.0	13.1D	4.44	6.1	6.8	12	30	131	2,427	36	161	0.2	59.6	4.8	0.4	2.8	0	31	0.1	0.1	0.1

Notes: D refers to duplicate sample.
All elements are in parts per million (ppm).
* Extracted Pb
**Estimated total Pb

Year 3 Soil Data Collected June 18, 2010

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3-N	Mg	B	Mn	Zn	Cu	Fe	Pb*	Total Pb**	Cd	Ni	Cr
BIO 97	1	26.2	0.0	4.01	6.0	6.7	7	11	130	1,812	2.0	134	0.2	56.3	2.4	0.10	1.6	1	41	0.1	0	0
BIO 98	1	26.2	6.6	3.51	6.2	6.8	5	13	133	1,818	2.0	125	0.2	52.7	1.6	0.10	2.4	1	40	0	0	0.1
BIO 99	1	26.2	13.1	3.49	7.0	7.1	3	36	201	4,026	2.0	178	0.5	59.8	1.4	0.10	1.3	1	42	0	0	0.1
BIO 100	1	26.2	6.6	3.85	6.3	6.8	5	13	142	2,087	2.0	135	0.2	50	1.6	0.00	2.2	1	36	0	0	0
BIO 101	1	131.2	0.0	3.67	6.0	6.9	6	10	146	1,497	0.0	94	0.2	46.7	0.8	0.00	1.7	1	35	0	0	0
BIO 102	1	131.2	6.6	3.73	6.9	7.1	3	13	136	2,716	0.0	113	0.3	39.9	0.8	0.10	1.2	1	35	0	0	0
BIO 103	1	131.2	13.1	3.78	6.6	7.1	4	14	138	2,591	0.0	101	0.2	33.7	0.7	0.00	1.6	1	35	0	0	0
BIO 104	1	131.2	6.6	3.78	7.0	7.1	3	21	194	3,442	0.0	128	0.3	50.2	1.2	0.00	1.2	1	37	0	0	0.1
BIO 105	1	295.2	0.0	3.75	7.1	7.2	3	17	182	3,306	0.0	135	0.3	10.3	0.6	0.00	2.7	0	33	0	0	0
BIO 106	1	295.2	6.6	3.76	6.9	7.1	3	16	137	3,675	0.0	124	0.3	30.8	1	0.10	2.9	1	35	0	0	0
BIO 107	1	295.2	13.1	3.67	7.0	7.2	2	12	292	3,274	0.0	104	0.3	39.5	0.7	0.00	104	1	35	0	0	0
BIO 108	1	295.2	13.1	3.82	7.0	7.2	2	11	350	2,973	0.0	95	0.3	45.3	0.6	0.10	1.2	1	34	0	0	0
BiIO 109	2	52.5	0.0	3.59	6.6	7.0	5	34	122	2,405	7.0	119	0.2	20.5	1.4	0.00	2.6	1	35	0	0	0
BIO 110	2	52.5	6.6	3.79	6.5	7.0	7	32	124	2,191	5.0	103	0.2	42.9	1.4	0.10	2	1	37	0.1	0	0.1
BIO 111	2	52.5	13.1	3.36	6.5	7.0	6	33	94	2,714	0.0	79	0.1	23.9	1.2	0.10	2.2	1	39	0	0	0
BIO 112	2	52.5	0.0	3.96	6.5	7.0	5	36	130	2,334	2.0	117	0.2	26.9	1.3	0.00	2.8	1	35	0	0	0
BIO 113	2	131.2	0.0	3.83	6.7	7.1	4	27	106	2,576	0.0	104	0.2	29.9	1.1	0.10	1.9	1	33	0	0	0
BIO 114	2	131.2	6.6	4.02	6.7	7.1	6	18	99	2,803	2.0	94	0.2	33.7	0.8	0.10	1.6	1	33	0	0	0
BIO 115	2	131.2	13.1	3.65	6.4	7.0	9	22	158	2,599	2.0	111	0.2	35.1	1.2	0.00	2.5	1	34	0	0	0
BIO 116	2	131.2	6.6	4.02	6.4	7.0	8	19	122	2,393	0.0	100	0.2	32.1	0.9	0.00	2.2	1	33	0	0	0
BIO 117	2	278.8	0.0	3.98	7.2	7.2	3	52	103	3,629	1.0	101	0.2	40.2	0.9	0.00	1.8	0	31	0	0	0
BIO 118	2	278.8	6.6	4.07	6.9	7.0	4	38	92	2,416	1.0	93	0.2	32.3	0.8	0.00	1.6	0	31	0	0	0
BIO 119	2	278.8	13.1	3.78	6.7	7.1	5	30	110	2,659	0.0	94	0.2	36.7	0.9	0.00	2.2	0	32	0	0	0
BIO 120	2	278.8	13.1	3.83	6.6	7.0	6	48	115	3,019	0.0	120	0.2	41.1	1.1	0.00	2	1	33	0	0	0
BIO 121	3	65.6	0.0	3.69	7.1	7.2	3	26	142	3,181	10.0	116	0.2	24.9	0.9	0.00	1.2	1	33	0	0	0
BIO 122	3	65.6	6.6	3.7	7.0	7.1	2	14	147	2,603	4.0	129	0.2	21.7	0.8	0.00	0.9	0	31	0	0	0
BIO 123	3	65.6	13.1	3.66	7.0	7.1	2	19	166	2,471	2.0	143	0.2	22.2	1	0.00	1.1	0	32	0	0	0
BIO 124	3	65.6	0.0	3.53	7.1	7.1	2	25	152	3,217	7.0	131	0.2	22.8	1.1	0.00	1.5	1	33	0	0	0
BIO 125	3	196.8	0.0	4.1	6.3	7.0	5	30	87	2,059	10.0	114	0.2	37.5	2.8	0.10	2	0	31	0	0	0
BIO 126	3	196.8	6.6	4.15	6.5	7.0	5	27	117	2,143	3.0	107	0.2	27.9	2.4	0.10	1.8	0	31	0	0	0
BIO 127	3	196.8	13.1	4.08	6.5	7.0	5	29	119	2,255	9.0	111	0.3	33.2	3	0.20	1.8	0	30	0	0	0

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3-N	Mg	B	Mn	Zn	Cu	Fe	Pb*	Total Pb**	Cd	Ni	Cr
BIO 128	3	196.8	6.6	4.22	6.3	6.9	8	20	157	1,999	0.0	98	0.2	38.9	2.4	0.10	2	0	31	0	0	0
BIO 129	3	459.2	0.0	3.77	6.5	7.0	6	46	110	2,447	13.0	122	0.3	60.3	3.6	0.20	1.6	0	30	0	0	0
BIO 130	3	459.2	6.6	3.76	6.7	7.0	5	37	94	2,256	12.0	109	0.3	54	2.9	0.10	1.3	0	30	0	0	0
BIO 131	3	459.2	13.1	4.45	6.6	7.0	8	23	67	1,729	2.0	35	0.2	35.6	1.9	0.10	1.4	0	29	0	0	0
BIO 132	3	459.2	13.1	4.17	6.6	7.0	7	31	75	2,228	13.0	82	0.2	45.2	2.3	0.20	1.6	0	30	0	0	0
BIO 133	4	68.9	0.0	4.17	6.7	7.0	3	12	89	2,272	0.0	93	0.2	148	1.2	0.00	0.4	1	37	0.1	0	0.1
BIO 134	4	68.9	6.6	3.8	6.8	7.1	2	15	91	2,771	12.0	69	0.3	84.1	1.6	0.00	0.6	1	35	0.1	0	0
BIO 135	4	68.9	13.1	4.39	6.6	6.9	3	11	111	2,587	3.0	88	0.3	83.3	1.6	0.00	0.5	0	32	0.1	0	0
BIO 136	4	68.9	13.1	4.03	6.7	6.9	3	13	110	2,569	3.0	85	0.3	111	1.8	0.00	33	0	33	0.1	0	0
BIO 137	4	164.0	0.0	3.88	7.7	7.1	4	19	165	4,211	1.0	101	0.3	66.4	0.6	0.00	0.9	1	35	0	0	0
BIO 138	4	164.0	6.6	4.19	6.9	7.0	6	9	144	3,141	12.0	102	0.3	55.8	0.7	0.00	0.6	1	35	0	0	0
BIO 139	4	164.0	13.1	4.06	7.1	7.1	4	13	153	4,029	11.0	73	0.3	53.4	0.6	0.00	0.9	1	35	0	0	0
BIO 140	4	164.0	0.0	3.94	6.8	7.1	4	41	119	3,527	17.0	119	0.3	47.5	2.7	0.10	1.3	1	33	0	0	0
BIO 141	4	328.0	0.0	3.21	6.9	7.1	4	62	229	3,799	18.0	133	0.4	29.3	3	0.20	1.8	1	34	0	0	0
BIO 142	4	328.0	6.6	4.46	6.7	7.0	5	36	126	2,536	17.0	128	0.3	28.5	2.5	0.10	1.3	0	31	0	0	0
BIO 143	4	328.0	13.1	4.36	6.6	7.0	5	60	172	3,324	17.0	143	0.4	36.4	4.4	0.30	1.7	0	32	0	0	0
BIO 144	4	328.0	6.6	4.14	6.9	7.0	6	11	143	3,394	7.0	108	0.3	68.7	0.7	0.00	0.5	1	33	0	0	0

Notes: D refers to duplicate sample.
All elements are in parts per million (ppm).
* Extracted Pb
**Estimated total Pb

APPENDIX E: Water Quality Analysis Results

		Nutrients (mg/L)							Metals (µg/L)											
Location	Date	TKN	NH3-N	NO3-N	TP	TSS (mg/L)	Fecal coliform (coli/100 mL)	pH (std units)	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	K	Se	Ag	Zn
Site 1																				
	11/6/2008	5.44	1.0	0.71	1.32	14	790	6.7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	2/11/2009	1.99	<0.1	0.02	0.28	3	30	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	6,250	<20	<5	<5
	4/13/2009	2.89	0.4	0.13	0.28	1	10	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1,600	<20	<5	<5
Site 1	4/13/2009*	1.86	0.14	0.11	0.19	2	30	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1,540	<20	<5	<5
Year 1	5/1/2009	<0.03	<0.1	0.14	0.27	11		7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	2,690	<20	<5	<5
	5/14/2009	2.80	0.2	0.07	0.29	10		7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	1,850	<20	<5	<5
	6/16/2009	4.65	0.3	0.40	0.58	16	29,000	7.1	<15	<5	14.2	<5	<15	<0.2	<20	10.8	8,700	<20	<5	<5
	6/16/2009*	5.72	0.3	0.46	0.57	14	29,000	7.1	<15	<5	15	<5	<15	<0.2	<20	10.9	8,860	<20	<5	<5
	9/22/2009	2.16	0.5	0.16	0.26	16	2,300	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	9,000	<20	<5	6.4
	10/9/2009	1.59	<0.1	0.18	0.28	10	520	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	5,180	<20	<5	<5
	10/30/2009	9.97	0.2	0.01	1.11	20	200	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	7,680	<20	<5	<5
Site 1	1/25/2010	1.91	0.3	0.18	0.23	57	50	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	3,400	<20	<5	<5
Year 2	2/22/2010	1.29	0.3	0.06	0.14	18	20	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	3,610	<20	<5	<5
	3/22/2010	1.38	0.2	0.04	0.12	10	30	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	1,460	20.2	<5	<5
	3/26/2010	1.18	0.2	0.09	0.26	17	82	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1,750	<20	<5	<5
	5/14/2010	2.54	<0.1	0.07	0.04	8	227	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	1,440	<20	<5	<5
	5/20/2010	1.75	0.3	0.10	0.08	5	964	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	810	<20	<5	<5
	7/12/2010	1.74	0.5	0.29	0.28	12	9,000	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	5,080	<20	<5	<5
Site 2																				
	11/6/2008	66.70	37.4	1.41	34.20	105	250	7.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Site 2	2/11/2009	3.50	<0.1	0.77	10.10	20	30	7.5	<15	<5	<10	<5	<15	<0.2	<20	<10	12,600	<20	<5	<5
Year 1	4/13/2009	3.15	0.2	0.13	4.11	1	70	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	2,580	<20	<5	<5
	4/20/2009	2.15	<0.1	0.08	3.57	<2	20	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	2,120	<20	<5	<5

		Nutrients (mg/L)												Metals (µg/L)						
Location	**Date**	**TKN**	**NH3-N**	**NO3-N**	**TP**	**TSS (mg/L)**	**Fecal coliform (coli/100 mL)**	**pH (std units)**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Hg**	**Mo**	**Ni**	**K**	**Se**	**Ag**	**Zn**
	4/20/2009*	2.02	<0.1	0.08	3.73	2	<1	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1,970	<20	<5	<5
	5/1/2009	3.57	0.1	0.16	4.95	13	NR	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	3,280	<20	<5	<5
Site 2	5/14/2009	3.62	0.2	0.06	2.94	4	NR	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	2,740	<20	<5	<5
Year 1	6/16/2009	4.58	0.5	1.40	4.94	8	8,000	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	12,200	<20	<5	<5
	6/30/2009	3.96	<0.1	2.64	2.60	20	1,545	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	10,600	<20	<5	<5
	7/21/2009	3.95	0.2	<0.01	1.72	6	1,000	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	10,700	<20	<5	6.4
	9/22/2009	4.09	0.3	2.57	3.23	12	2,000	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	12,600	<20	<5	<5
	10/9/2009	2.82	0.2	2.51	1.48	6	890	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	10,800	<20	<5	<5
	10/30/2009	2.34	0.3	1.62	0.34	434	190	7.1	<15	<5	<10	5.5	<15	<0.2	<20	<10	11,050	<20	<5	17.4
	1/22/2010	4.73	0.3	0.80	1.19	284	40	7.8	<15	<5	<10	<5	<15	<0.2	<20	<10	7,080	<20	<5	6.9
Site 2	1/25/2010	4.66	0.3	0.15	1.18	428	50	7.5	<15	<5	<10	<5	<15	<0.2	<20	<10	3,600	<20	<5	10.9
Year 2	2/22/2010	3.71	0.3	0.65	0.98	22	5	7.4	<15	<5	<10	<5	<15	<0.2	<20	<10	5,570	<20	<5	<5
	3/22/2010	2.46	0.2	0.17	0.65	85	5	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	2250	<20	<5	<5
	3/26/2010	2.48	0.1	0.11	0.76	46	173	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1,050	<20	<5	<5
	5/14/2010	2.44	0.1	0.09	0.60	74	1,129	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	2,240	<20	<5	<5
	5/20/2010	1.82	0.2	0.10	0.66	20	1,054	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	1,170	<20	<5	<5
	7/12/2010	1.28	0.2	0.33	1.05	10	624	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	5,600	<20	<5	<5
								Site 3												
	4/13/2009	1.49	0.1	0.12	0.25	3	370	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	839	<20	<5	<5
	4/20/2009	1.94	0.1	0.11	0.30	<2	30	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1,050	<20	<5	<5
Site 3	5/1/2009	2.51	0.1	0.21	0.25	13	NR	7.4	<15	<5	<10	<5	<15	<0.2	<20	<10	1,890	<20	<5	<5
Year 1	5/1/2009*	5.23	<0.1	0.2	0.18	12	NR	7.4	<15	<5	<10	<5	<15	<0.2	<20	<10	1,840	<20	<5	<5
	5/14/2009	2.69	0.2	0.05	0.31	14	NR	7.2	<15	<5	<10	8.2	<15	<0.2	<20	<10	2,440	<20	<5	<5
	6/16/2009	3.48	0.4	0.45	0.61	2	9,000	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	10,100	<20	<5	<5

Location	Date	Nutrients (mg/L)							Metals (µg/L)											
		TKN	NH3-N	NO3-N	TP	TSS (mg/L)	Fecal coliform (coli/100 mL)	pH (std units)	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	K	Se	Ag	Zn
	9/22/2009	2.34	0.3	0.33	0.52	8	4,700	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	7500	<20	<5	<5
	10/9/2009	1.72	0.2	0.22	0.41	6	760	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	5500	<20	<5	<5
	10/30/2009	4.97	0.2	0.03	2.43	26	609	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	6290	<20	<5	<5
Site 3 Year 2	1/25/2010	7.44	<0.1	0.25	0.99	616	50	7.4	<15	<5	<10	<5	<15	<0.2	<20	<10	5800	<20	<5	26.1
	2/22/2010	2.26	0.2	0.15	0.35	74	270	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	4410	<20	<5	<5
	3/26/2010	0.72	<0.1	0.07	0.26	34	1,173	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1200	<20	<5	<5
	5/14/2010	1.39	<0.1	0.08	1.61	16	730	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	3200	<20	<5	<5
	5/20/2010	1.34	0.2	0.11	0.13	4	5,500	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	902	<20	<5	<5
	7/12/2010	1.55	0.3	0.20	0.42	10	673	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	4170	<20	<5	<5
								Site 4												
	5/1/2009	<0.03	0.3	0.28	0.06	34	NR	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1,330	<20	<5	6.3
Site 4 Year 1	5/14/2009	0.98	0.4	0.11	0.02	6	NR	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	807	<20	<5	<5
	5/14/2009*	1.08	0.45	0.82	0.08	4	NR	7.4	<15	<5	<10	<5	<15	<0.2	<20	<10	638	<20	<5	<5
	6/16/2009	14.40	8.0	0.30	7.31	180	190,000	7.3	<15	<5	<10	19.6	<15	<0.2	<20	13.7	190000	<20	<5	69.1
	8/11/2009	4.18	0.3	0.43	0.390	10	2,000	7.1	<15	<5	<10	7.3	<15	<0.2	<20	<10	5410	<20	<5	9.4
	9/10/2009	7.12	0.6	0.16	0.640	26	20	7.1	<15	<5	12.7	11.7	<15	<0.2	<20	<10	12600	<20	<5	16
	9/20/2009	3.25		0.22	0.420	10	3,060	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	10000	<20	<5	6.6
Site 4 Year 2	9/22/2009	3.45	0.2	0.23	0.420	13	6,100	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	<500	<20	<5	6.2
	10/9/2009	1.36	0.2	0.28	0.310	6	940	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	4330	<20	<5	<5
	10/30/2009	2.17	0.1	0.28	0.450	22	3,100	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	7400	<20	<5	<5
	3/26/2010	2.41	<0.1	0.11	0.350	48	60	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1810	<20	<5	<5
	5/14/2010	0.61	<0.1	0.08	0.060	12	10	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1620	<20	<5	<5
	5/20/2010	1.18	0.2	0.11	0.110	5	400	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1070	<20	<5	<5
									Field Blanks											
	11/6/2008	0.14	<0.1	<0.05	<0.01	<1	<1	6.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	2/11/2009	0.36	<0.1	0.02	0.01	<1	<1	6.6	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5

		Nutrients (mg/L)							Metals (µg/L)											
Location	**Date**	**TKN**	**NH3-N**	**NO3-N**	**TP**	**TSS (mg/L)**	**Fecal coliform (coli/100 mL)**	**pH (std units)**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Hg**	**Mo**	**Ni**	**K**	**Se**	**Ag**	**Zn**
	4/13/2009	0.45	<0.1	0.12	0.15	<1	<1	6.5	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Field	4/20/2009	<0.03	<0.1	0.07	0.22	<2	<1	6.2	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Blanks	5/1/2009	0.17	<0.1	0.14	0.02	<1		6.3	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Year 1	5/14/2009	0.19	<0.1	<0.01	<0.01	<1		6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	6/16/2009	0.62	<0.1	0.38	0.08	<1	<1	6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	6/30/2009	0.36	<0.1	<0.01	0.11	<1	<1	6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	7/21/2009	0.40	<0.1	<0.01	<0.01	<1	<50	6.7	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	8/11/2009	<0.03	<0.1	0.14	0.14	<1	<1	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	9/10/2009	<0.03	<0.1	0.12	0.08	<1	<1	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	9/20/2009	0.08	ns	0.17	0.04	<1		6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	9/22/2009	0.09	<0.1	<0.05	0.03	<1	<1	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	10/9/2009	0.29	<0.1	<0.05	0.21	<1	<1	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Field	10/30/2009		<0.1	<0.01		<1	<1	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Blanks	1/22/2010	<0.03	<0.1	<0.01	0.12	<1	<2	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Year 2	1/25/2010	<0.03	<0.1	<0.01	0.10	<1	<1	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	2/22/2010	<0.03	<0.1	<0.01	<0.01	<1	<1	6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	3/22/2010	0.32	<0.1	<0.01	0.04	<1	<1	6.5	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	3/26/2010	0.36	<0.1	0.06	0.10	<1	<1	6.5	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	5/14/2010	<0.03	<0.1	0.07	<0.01	4	<1	6.6	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	5/15/2010	<0.03	<0.1	0.12	<0.01	<1	<1	6.6	<15	<5	<10	<5	<15	<0.2	<20	<10	88.6	<20	<5	<5
	5/20/2010	0.45	<0.1	0.10	<0.01	<1	<1	6.6	<15	<5	<10	<5	<15	<0.2	<20	<10	87.8	<20	<5	<5
	7/12/2010	0.41	<0.1	0.01	<0.01	<1	<1	6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5

APPENDIX F: Water Quality Sampling Field Duplicate and Field Blank Data

Date	TKN RPD	NH3-N RPD	NO3-N RPD	TP RPD	TSS RPD	Fecal RPD	pH RPD
			Year 1				
4/13/2009	43	96	17	38	67	100	0.1
6/16/2009	6.2	0.0	0.0	4.4	67	0.0	0.8
4/20/2009	70	75	4.9	33	8.0	190	0.3
5/1/2009	9.7	2.2	153	120	40		0.7
6/10/2009	196	0.0	11	3.3	120	0.0	0.4
5/14/2009	21	0.0	14	1.7	13		0.3
			Year 2				
8/11/2009	21	3.0	4.8	0.0	18	133	0.7
9/10/2009	5.5	4.7	55	1.6	18	0.0	0.9
9/22/2009	6.6	67	6.3	1.9	22	65	0.1
10/9/2009	3.4	17	0.0	2.4	0.0	9.7	0.1
10/30/2009		43	0.0		89	42	0.1
2/22/2010	0.0	36	18	0.0	77	0.0	0.3
3/22/2010	21	29	0.0	8.0	22	50	0.3
3/26/2010	99	32	12	21	124	0.0	0.4
5/14/2010	40	0.0	0.0	0.0	13	126	0.0
5/15/2010	11	115	8.7	156	67	111	2.7
5/15/2010	29	32	8.7	67	100	3.2	0.3
5/20/2010	58	67	120	13	22	17	0.3
7/12/2010	1.9	31	4.9	2.4	33	13	0.3

APPENDIX G: Soil Morphology Data

Owner: Biosolid Project		County: Lawrence, MO	Soil Drainage Class:		Date: 11/19/2008
Depth to Bedrock:		Pit #: 1	Up Slope: Convex, Across Slope: Convex		Geomorphic: Head Slope
GPS Location: 37° 16.073' N: 93° 51.542' W +/-12ft	Described By: Recorded By: Doug Gisselbeck Tom DeWitt	Excavation Depth: 60'	Landscape Position: Summit	Aspect: Elevation: N 1215'	% Slope: 1
Vegetation: Grass (Pasture- fescue)	Parent Material: Loess / Colluvium / Residuum			Geology: Mo	

Horizon		Munsell Color (moist)	P/V Surface Features (2)	Texture		% Coarse Fragment By Volume		Consistence (4)	Structure (5)	Roots/ Pores (6)	RMF /or Notes
Designation	Depth/ Boundary (1)			USDA (3)	% Clay	< 3"	> 3"				
Ap	0 – 5" (13cm) AS	10YR 4/3		SIL	12	0	0	VFR	1 F GR 1 F SBK	M F/M M F/M	1% F/FMM
BE	5 – 8" (20cm) CS	10YR 5/4		SIL	14	0	0	FR	2 F SBK	MF CF	1% F/FMM
Bt1	8 – 18" (45cm) CW	7.5YR 5/4	5% 10YR 5/4 CLF/APF	SIL	25	1	0	FR	2 M SBK	MF CF	2% F/FMM
Bt2	18 – 25" (64cm) CW	7.5YR 4/4	10YR 4/3 CLF/HPF	SICL	36	2	0	FI	2 M PR → 2 M SBK	FF FF	5% F/FMM
Bt3	25 – 32" (89cm) CW	7.5YR 4/4	10YR 4/2 CLF/VPF	SICL	30	5	0	FI	2 M PR → 2 M SBK	FF FF	5% D/FMM
2Btx1	32 – 38" (97cm) CW	7.5YR 4/6	10YR 4/2 CLF/VPF	GR SICL	32	20	0	FI	1 M PR → 3 M SBK	VFF VFF	10YR 5/2 FED 2% D/FMN Clay films on vertical prism faces. Vert. seams <3" apart
2Btx2	38 – 45" (114cm) CW	5YR 4/6	↓	GR SICL	38	25	0	VFI	1 M PR → 3 M SBK	VFF VFF	↓
3Bt	45 – 60" (152cm) ----	2.5YR 4/6	↓	GR SICL	36	20	0	FI	1 M PR → 2 F SBK	VFF VFF	↓

Owner: BioSolid Project	County: Lawrence, MO	Soil Drainage Class:	Date: 11/19/2008
Depth to Bedrock:	Pit #: 2	Up Slope: Convex Across Slope: Convex	Geomorphic: Interfluve
GPS Location: 37° 16.173′ N: 93° 51.507′ W +/-12ft	Described By: Recorded By: Doug Gisselbeck Tom DeWitt	Excavation Depth: 60″	Landscape Position: Summit; Aspect: Elevation: N 1199′; % Slope: 2
Vegetation: Grass (Pasture-fescue)	Parent Material: Colluvium / Residuum		Geology: Mo

Horizon		Munsell Color (moist)	P/V Surface Features (2)	Texture		% Coarse Fragment By Volume		Consistence (4)	Structure (5)	Roots/ Pores (6)	RMF /or Notes
Designation	Depth/ Boundary (1)			USDA (3)	% Clay	< 3″	> 3″				
Ap	0 – 4″ (10cm) CS	10YR 3/3		SIL	14	10		VFR	2 M GR	M F/M M VF/F	
BE or Ap2	4 – 7″ (18cm) CS	10YR 5/3		SIL	12	10		VFR	2 F SBK → 1 F GR	M F/M M VF/F	(SLF?)
Bt1	7 – 11″ (28cm) CW	7.5YR 5/3		GR SIL	18	20		FR	2 M SBK	M VF/F M VF/F	F/F CLF
Bt2	11 - 20″ (51cm) CW	5YR 4/4		GRV SICL	36	25	15	FR	2 M SBK	CF CF	
2Btx1	20 - 29″ (74cm) CW	2.5YR 4/6	10YR 5/2 CLF/VPF 10YR 5/3 SLF F/F	GRX SICL	32	40	20	BR	1 M PR → 2 M SBK	CF CF	Weak fragipan; 7.5YR 6/2 FED in gray seams. Gray seams 2 – 3″ apart
2Btx2	29 - 38″ (97cm) CW	2.5YR 4/6	10YR 5/2 CKF/VPF 2.5YR 3/6 CLF	GRX SICL	36	40	20	BR	1 M PR → 3 M SBK	FF FF	↓
3Bt	38 - 60″ (152cm) ----	10R 3/6	10YR 5/2 CLF/VPF	GRV C	60	15	15	EF	2 M PR → 2 M SBK	FF FF	↓

Owner: BioSolid Project	County: Lawrence, MO	Soil Drainage Class:			Date: 11/19/2008
Depth to Bedrock:	Pit #: 3	Up Slope: Convex Across Slope: Convex			Geomorphic: Side Slope
GPS Location: 37° 16.173‘ N: 93° 51.471‘ W +/-12ft	Described By: Recorded By: Doug Gisselbeck Tom DeWitt	Excavation Depth: 60”	Landscape Position: Shoulder	Aspect: Elevation: E 1195’	% Slope: 4
Vegetation: Grass (Pasture=fescue)	Parent Material: Colluvium / Residuum		Geology: Mo		

Horizon		Munsell Color (moist)	P/V Surface Features (2)	Texture		% Coarse Fragment By Volume		Consistence (4)	Structure (5)	Roots/ Pores (6)	RMF /or Notes
Designation	Depth/ Boundary (1)			USDA (3)	% Clay	< 3”	> 3”				
Ap	0 – 3” (8cm) CS	10YR 3/3		SIL	12	5		VFR	2 F GR	M F/M M F/M	
Ap2	3 – 7” (18cm) CS	10YR 4/3		SIL	12	10		VFR	2 M SBK → 1 F GR	M F/M M F/M	
Bt1	7 – 16” (41cm) CS	7.5YR 5/4	10YR 6/3 SLF 10YR 4/2 CLF/APF	SICL	28	15		FR	2 M SBK	CF CF	F/F FMM
Bt2	16 - 28” (71cm) CW	5YR 4/4	10YR 6/3 SLF 10YR 4/2 CLF/APF	GR SICL	36	25	5	FR	2 M SBK	CF FF	F/F FMM
2Bt3	28 - 36” (91cm) CW	2.5YR 4/4	10YR 6/3 SLF 10YR 4/2 CLF/APF	GR SICL	39	20/5 G/PG	5	FI	1 M PL → 2 M SBK	FF FF	Vertical Seams Para-rock frag. 1 M sandstone channers
2Bt4	36 - 43” (109cm) CW	2.5YR 4/6	40% 10YR 4/2 CLF/VPF	GR C	55	20/5 G/PG	5	EF	2 M PL → 2 M SBK	FF FF	20% 2.5Y 7/2 FED
3Bt5	43 - 50” (127cm) GW	2.5YR 4/6	30% 10YR 4/2 CLF/VPF 20% 10YR 6/2	GR SIC	45	15	10	VFI	1 M PR → 1M PL	---- ----	20% 2.5Y 7/2 FED
3Bt	50 – 60” (152cm) ----	2.5YR 4/6		CNV SICL	38	25 PGR	25 PCN	FI	1 M PL	---- ----	30% 2.5Y 7/2 FED Masses of Weathered sandstone

Owner: BioSolid Project	County: Lawrence, MO	Soil Drainage Class:	Date: 11/19/2008
Depth to Bedrock:	Pit #: 4	Up Slope: Convex Across Slope: Convex	Geomorphic: Side Slope
GPS Location: 37° 16.173‘ N: 93° 51.443‘ W +/-12ft	Described By: Recorded By: Doug Gisselbeck Tom DeWitt	Excavation Depth: 80”	Landscape Position: Back Slope
		Aspect: Elevation: E 1176’	% Slope: 12
Vegetation: Grass (Pasture-fescue)	Parent Material: Colluvium / Residuum	Geology: Mo	

Horizon		Munsell Color (moist)	P/V Surface Features (2)	Texture		% Coarse Fragment By Volume		Consistence (4)	Structure (5)	Roots/ Pores (6)	RMF /or Notes
Designation	Depth/ Boundary (1)			USDA (3)	% Clay	< 3”	> 3”				
Ap	0 – 4” (10cm) CS	10YR 3/2		SIL	12	5		VFR	2 F GR	M F/M M F/M	
Ap2	4 – 8” (20cm) CS	10YR 4/3		SIL	12	10		VFR	1 F SBK → 1 F GR	M F/M M F/M	
Bt1	8 – 18” (46cm) CS	7.5YR 4/4	10YR 4/2 CLF/APF	SICL	28	15		FR	2 M SBK	CF CF	
Bt2	18 - 25” (64cm) CW	7.5YR 5/3 15% 5YR 4/4	(CRK or RPO?) ↨	GR SICL	38	20		FI	2 M SBK	CF CF	(SLF?)
Bt3	25 - 32” (81cm) CW	2.5YR 3/6	↓	GR SIC	42	30		VFI	2 M PR → 3 M SBK	FF FF	10YR 5/2 FED Roots in vertical seams
2Bt4	32 – 62” (157cm) CW	2.5YR 3/6	↓	GRV SIC	48	45	15	VFI	2 M PR → 3 M SBK	FF FF	↓
2Bt5	62 – 80” (203cm) ----	2.5YR 3/6	↓	GRV C	55	20	20	EF	2 M PR → 3 M SBK	FF FF	↓

Owner: BioSolid Project	County: Lawrence, MO	Soil Drainage Class:	Date: 11/19/2008
Depth to Bedrock:	Pit #: 5	Up Slope: Concave Across Slope: Concave	Geomorphic: Head Slope
GPS Location: 37° 16.184' N: 93° 51.406' W +/-12ft	Described By: Recorded By: Doug Gisselbeck Tom DeWitt	Excavation Depth: 60"	Landscape Position: Footslope
		Aspect: Elevation: NE 1166'	% Slope: 6
Vegetation: Grass (Pasture-fescue)	Parent Material: Local Alluvium / Colluvium	Geology: Mo	

Horizon		Munsell Color (moist)	P/V Surface Features (2)	Texture		% Coarse Fragment By Volume		Consistence (4)	Structure (5)	Roots/ Pores (6)	RMF /or Notes
Designation	Depth/ Boundary (1)			USDA (3)	% Clay	< 3"	> 3"				
Ap	0 – 12" (30cm) CS	10YR 3/2		GRV SIL	14	35	5	VFR	3 F GR	M F/M M F/M	
Ap2	12 - 23" (58cm) CW	10YR 3/3		GRV SIL	16	40	20	VFR	1 F SBK → 2 F GR	M F/M M F/M	
2Bt1	23 – 47" (119cm) AW	5YR 4/4	10YR 4/3 CLF/VPF	GRV SICL	38	35	5	FI	2 M SBK	FF C F/M	5% FMM Vertical Gray Seams
2Bt2	47 – 60" (152cm) ----	2.5YR 3/6	10YR 4/2 CLF/VPF	GRV SIC	45	45	5	VFI	1 M PR → 2 M SBK	FF FF	8% FMM Irregular shaped 20% 10yr 5/2 FED

Comments: Alluvial / Colluvial mix, pit is in a narrow drainage way.

Taxonomy/Series: **Clayey-Skeletal Pachic Paleudolls**

Notations used to describe soil profile descriptions.

(1) Boundary: (A = abrupt, C = clear, G = gradual, D = diffuse) (S = smooth, W = wavy, I = irregular)

(2) NASIS Code: [(RMF and P & V Surface Features: (Amount class = %) (Distinctness class, F = faint, D = distinct, P = prominent) (Continuity class, D = discontinuous) (Kind, SAF = clean sand or silt over clay, CLF = clay films) (Location code, APF = on faces of peds, LPO = lining pores, RPO = on surfaces along root channels, SPO = on surfaces along pores)]

(3) Texture: (texture modifier, fragment content % by volume, GR = 15 to < 35 %, GRV = 35 to < 60 %, GRX = 60 to < 90 %) (SIL = silt loam, SICL = silty clay loam, C = clay, SIC = silty clay, L= loam, CL = clay loam)

(4) Consistence, moist conditions (VFR = very friable, FR = friable, FI = firm, VFI = very firm, EFI = extremely firm)

(5) Structure [(grade, 1 = weak, 2 = moderate, 3 =strong)(size, VF = very fine, F = fine, M = medium, C = coarse) (shape, GR = granular, SBK = subangular blocky, ABK = angular blocky, PR = prismatic, M = massive)

(6) Roots/Pores (abundance, F = few, C = common, M = many) (size, VF = very fine, F = fine, M = medium, C = coarse)

APPENDIX H: Forage Data

Spring 2009

Parameter	Site 1		Site 2		Site 3		Site 4	
	AVG	SEM	AVG	SEM	AVG	SEM	AVG	SEM
Dry Matter %	29.61	1.02	27.60	0.77	28.68	0.35	27.33	1.94
Protein .... %	8.84	0.67	8.97	0.50	9.98	0.40	11.11	0.72
A D Fiber .... %	43.40	1.14	45.93	0.83	44.53	0.28	43.63	1.56
N D Fiber(a) ..... %	64.72	1.19	68.08	1.27	66.37	0.31	65.62	2.07
Crude Fiber ...... %								
Lignin .... %								
T D N .... %	52.15	0.94	50.06	0.68	51.21	0.23	51.96	1.29
NE Lactation MCAL/LB	0.513	0.011	0.489	0.008	0.502	0.003	0.511	0.015
NE Gain .... MCAL/LB	0.222	0.014	0.192	0.010	0.209	0.003	0.220	0.019
NE Maint ... MCAL/LB	0.473	0.015	0.440	0.011	0.458	0.004	0.470	0.020
Digst Energy MCAL/LB	0.473	0.015	0.440	0.011	0.458	0.004	0.470	0.020
Nitrogen .... %	1.415	0.108	1.435	0.080	1.596	0.065	1.777	0.116
Calcium .... %	0.340	0.069	0.317	0.040	0.280	0.035	0.330	0.061
Phosphorus .... %	0.157	0.015	0.239	0.010	0.219	0.006	0.247	0.018
Ca:P 1.5 to 2.0	*2.2*		*1.3*		*1.3*		*1.3*	
Magnesium .... %	0.123	0.012	0.123	0.006	0.143	0.015	0.143	0.021
Potassium .... %	1.647	0.061	1.980	0.125	1.787	0.055	1.807	0.191
Sodium .... %	0.006	0.002	0.008	0.003	0.009	0.006	0.015	0.010
Iron .... PPM	80.00	17.32	70.00	0.00	100.00	43.59	103.33	5.77
Copper .... PPM	3.67	0.58	5.33	1.53	5.67	1.15	5.67	0.58
Manganese ...... PPM	40.00	14.18	63.67	6.66	44.33	8.50	46.00	7.21
Zinc .... PPM	17.67	2.89	17.67	2.08	22.33	1.15	23.00	2.65
RFV/Quality Standrd	79	[4]	73	[5]	76	[4]	78	[4]
Nitrate (NO3)	Negative		Negative		Negative		Negative	
Yield								
fresh lbs/plot (140sqft)	19.0		38.7		46.3		63.8	
dry lbs/plot	5.6		10.7		13.3		17.4	
dry tons/A (extrap)	0.9		1.7		2.1		2.7	

Fall 2009

Parameter	Site 1		Site 2		Site 3		Site 4	
	AVG	SEM	AVG	SEM	AVG	SEM	AVG	SEM
Moist / Dry Matter %	40.11	1.16	29.61	0.71	32.29	0.76	29.36	2.08
Protein .... %	9.73	0.98	16.08	0.88	15.76	1.06	16.54	1.79
A D Fiber .... %	42.63	0.93	37.72	0.35	40.12	0.63	40.29	2.03
N D Fiber(a) ..... %	63.17	0.54	57.15	0.65	59.11	0.45	58.50	2.37
Crude Fiber ...... %								
Lignin .... %								
T D N .... %	52.78	0.77	56.84	0.28	54.86	0.52	54.71	1.68
NE Lactation MCAL/LB	0.52	0.01	0.57	0.00	0.54	0.01	0.54	0.02
NE Gain .... MCAL/LB	0.23	0.01	0.29	0.00	0.26	0.01	0.26	0.02
NE Maint ... MCAL/LB	0.48	0.01	0.55	0.00	0.52	0.01	0.51	0.03
Digst Energy MCAL/LB	0.48	0.01	0.55	0.00	0.52	0.01	0.51	0.03
Nitrogen .... %	1.56	0.16	2.57	0.14	2.52	0.17	2.65	0.29
Calcium .... %	0.44	0.04	0.52	0.03	0.53	0.04	0.50	0.09
Phosphorus .... %	0.23	0.01	0.38	0.03	0.36	0.02	0.35	0.03
Magnesium .... %	0.14	0.03	0.23	0.02	0.27	0.03	0.24	0.02
Potassium .... %	1.91	0.11	3.10	0.16	2.88	0.19	3.22	0.33
Sodium .... %	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00
Iron .... PPM	80.00	17.32	90.00	17.32	236.67	228.11	106.67	5.77
Copper .... PPM	5.33	1.15	5.33	0.58	7.00	1.73	6.33	0.58
Manganese ...... PPM	36.67	13.61	62.00	8.00	47.33	3.21	43.67	7.51
Zinc .... PPM	21.00	4.00	19.67	4.16	25.67	2.52	22.67	3.06
RFV/Quality Standrd	82 [4]		97 [3]		90 [3]		90 [3]	
Nitrate (NO3)	Negative		Negative		Negative		Negative	
<u>Yield</u>								
fresh lbs/plot (140sqft)	17.3		34.2		34.0		36.5	
dry lbs/plot								
dry tons/A (extrap)	1.1		1.6		1.7		1.7	

Spring 2010

Parameter	Site 1		Site 2		Site 3		Site 4	
	AVG	SEM	AVG	SEM	AVG	SEM	AVG	SEM
Dry Matter %	27.14	1.01	26.53	1.73	27.20	0.15	26.33	0.96
Protein .... %	9.94	0.97	10.81	1.08	10.70	0.42	11.37	1.08
A D Fiber .... %	41.03	0.90	41.49	1.20	41.47	0.21	40.31	0.42
N D Fiber(a) ..... %	66.92	1.79	68.08	1.49	67.69	0.59	66.49	0.30
Crude Fiber ...... %								
Lignin .... %								
T D N .... %	54.10	0.74	53.73	0.99	53.74	0.18	54.70	0.34
NE Lactation MCAL/LB	0.536	0.009	0.532	0.012	0.532	0.002	0.543	0.004
NE Gain .... MCAL/LB	0.251	0.011	0.245	0.014	0.246	0.003	0.259	0.005
NE Maint ... MCAL/LB	0.504	0.012	0.498	0.016	0.498	0.003	0.513	0.005
Digst Energy MCAL/LB	0.504	0.012	0.498	0.016	0.498	0.003	0.513	0.005
Nitrogen .... %	1.590	0.155	1.729	0.174	1.713	0.067	1.820	0.172
Calcium .... %	0.423	0.023	0.360	0.036	0.373	0.031	0.357	0.015
Phosphorus .... %	0.251	0.008	0.286	0.031	0.282	0.006	0.291	0.012
Ca:P 1.5 to 2.0	*1.7*		*1.3*		*1.3*		*1.2*	
Magnesium .... %	0.157	0.006	0.153	0.015	0.163	0.015	0.150	0.010
Potassium .... %	1.573	0.152	1.640	0.207	1.540	0.052	1.707	0.137
Sodium .... %	0.005	0.000	0.005	0.000	0.012	0.013	0.005	0.000
Iron .... PPM	160.00	30.00	110.00	10.00	103.33	5.77	106.67	11.55
Copper .... PPM	7.00	2.65	5.67	0.58	5.67	0.58	5.33	0.58
Manganese ...... PPM	37.00	3.00	41.33	4.73	27.67	5.86	31.33	0.58
Zinc .... PPM	17.00	1.00	13.00	6.93	15.67	1.53	25.00	3.46
RFV/Quality Standrd	79 [4]		77 [4]		78 [4]		80 [4]	
Nitrate (NO3)	Negative		Negative		Negative		Negative	
Yield								
fresh lbs/plot (140sqft)	19.2		38.2		47.8		58.7	
dry lbs/plot	5.2		10.1		13.0		15.5	
dry tons/A (extrap)	0.8		1.6		2.0		2.4	

Fall 2010

Parameters	Site 1		Site 2		Site 3		Site 4	
	AVG	SEM	AVG	SEM	AVG	SEM	AVG	SEM
Dry Matter %	37.78	1.89	32.11	1.17	28.91	1.67	29.81	1.58
Protein .... %	8.81	0.37	15.15	3.13	15.30	1.30	18.38	1.98
A D Fiber .... %	46.57	1.36	42.70	2.31	38.28	0.96	35.98	1.48
N D Fiber(a) ..... %	73.88	2.26	68.22	3.32	61.74	0.21	59.43	1.82
Crude Fiber ...... %								
Lignin .... %								
T D N .... %	49.53	1.12	52.73	1.91	56.38	0.79	58.27	1.22
NE Lactation MCAL/LB	0.483	0.013	0.520	0.022	0.563	0.009	0.585	0.014
NE Gain .... MCAL/LB	0.184	0.017	0.231	0.028	0.283	0.011	0.310	0.017
NE Maint ... MCAL/LB	0.431	0.018	0.482	0.030	0.539	0.012	0.568	0.019
Digst Energy MCAL/LB	0.431	0.018	0.482	0.030	0.539	0.012	0.568	0.019
Nitrogen .... %	1.410	0.059	2.423	0.501	2.447	0.208	2.940	0.317
Calcium .... %	0.463	0.065	0.440	0.020	0.537	0.032	0.623	0.071
Phosphorus .... %	0.211	0.021	0.282	0.027	0.389	0.018	0.368	0.029
Ca:P 1.5 to 2.0	*2.2*		*1.6*		*1.4*		*1.7*	
Magnesium .... %	0.103	0.015	0.137	0.006	0.200	0.030	0.207	0.012
Potassium .... %	1.043	0.172	1.537	0.210	1.713	0.358	1.797	0.111
Sodium .... %	0.005	0.000	0.005	0.000	0.005	0.000	0.005	0.000
Iron .... PPM	113.33	23.09	93.33	11.55	100.00	0.00	46.67	40.41
Copper .... PPM	4.33	0.58	4.67	0.58	5.33	0.58	6.00	0.00
Manganese ...... PPM	38.00	14.73	45.00	20.07	52.33	10.26	40.00	11.79
Zinc .... PPM	27.67	4.04	29.00	11.36	31.00	6.56	20.33	0.58
RFV/Quality Standrd	66 [5]		76 [4]		89 [3]		96 [3]	
Nitrate (NO3)	Trace		Negative		Negative		0.90%	
Yield								
fresh lbs/plot (140sqft)	15.3		26.2		17.5		16.25	
dry lbs/plot	5.8		8.4		5.1		4.8	
dry tons/A (extrap)	0.9		1.3		0.8		0.8	