## The Ozarks Environmental and Water Resources Institute (OEWRI)
## Missouri State University (MSU)
## City of Springfield, Missouri

**YEAR ONE ANNUAL REPORT FOR:**

# NUTRIENT TRANSPORT AND FATE FROM MUNICIPAL BIOSOLIDS LAND APPLICATION


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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 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 P to move off of 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 for the project (www.oewri.missouristate.edu). This report organizes and summarizes data collected for the first year of sampling from November 2008 through July 2009 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 0.5 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.

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

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 tons/acre application was roughly equivalent to the annual nitrogen recommendation for a 3 tons/acre yield goal of cool season grass (USEPA, 1994[2], UM, 2004). At a rate of 6 dry tons/acre 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 dry ton/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 dry tons/acre 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 calcidic limestone application was made by a commercial dealer on 9-9-2008 to adjust soil acidity to near neutral levels. The biosolids applications were made with a commercial Terra-Gator 3104 side discharge spreader on 10-23-2008 and the fertilizer applied by a commercial dealer on 10-28-2008. 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 2).

Site 1 would receive 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 ($N+P_2O_5+K_2O$) will be applied to mimic the slow release of N from the breakdown of biosolids over that time. Site 3 received 3 dryT/ac biosolid application, which is equivalent to the commercial fertilizer application. Finally, site 4 received 6 dryT/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 8-5-2009 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 dry tons/ac .

**Hydrology and Water Quality Sampling**

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 1). 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 1/100$^{th}$ inch increments over 5 minutes time periods. A pressure transducer level sensor with datalogger is 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 2 and Photos 1 and 2).

A strainer was positioned next to the pressure transducer upstream of each dam and connected to the auto-sampler with a 25 ft. suction line. Weirs at sites 3 and 4 had to be continually modified until samples began collecting. 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. Upon collection, bottles were removed from the sampler and composited and thoroughly homogenized in a one gallon container.

For logistical reasons, the auto-samplers were set to collect an event composite. They were fitted with 10 L Nalgene composite bottles and reprogrammed to both save time and limit error in the field as well as reduced prep time in the lab. Since June 2009, auto-samplers collect 500 ml samples every fifteen minutes when rainfall rate and level reach set point (0.10 in/30 min and 0.1 ft., respectively). After a sample has collected, composite bottles are removed, and the sample is split for further analysis. The composite sample was split among four 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, (3) total suspended solids (TSS), fecal coliforms, and pH – no preservative, and (4) specific conductivity – no preservative. 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 coliforms, and pH following Environmental Protection Agency Methods (EPA) and Standard Methods for the Examination of Water and Wastewater (SM4500) protocol (Table 4). Samples were analyzed at Ozarks Environmental and Water Resources Institute for specific conductivity by a Horiba U22 multi-probe meter. More details on the analyses can be found at http://www.epa.gov/waterscience/methods/.

## Surface Soil Monitoring

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 5 and Photo 3). 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. 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.

## Surface Soil 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).

## Soil Morphology Characterization

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.

**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, MO.

## YEAR 1 - PRELIMINARY RESULTS

**Sample Collection and Hydrology**

A total of 23 composite samples were collected at all four sites over a 9 month period between November 1, 2008 and August 1, 2009. Of the 23 composite samples collected, 6 were from site 1, 9 from site 2, 5 from site 3, and 3 from site 4 (Table 6). Samples were not collected over that period because:

1. Small catchments area
2. Equipment malfunctions (dead batteries, clogged lines, etc.)
3. Height of vegetation and dormancy
4. Pre-storm soil moisture conditions

5. Dam and weirs needed “seasoning” following installation

Runoff was generated either during relatively short, high intensity storm events, or relatively long, low intensity storm events. Rainfall totals generating runoff ranged from 0.56 inches on November 6, 2008 to 1.89 inches June 16, 2009 (Table 6). Individual storm rainfall intensities over the same period ranged from 0.06 in/hr (1.29 inches in 21.5 hrs) on April 19-20, 2009, to 1.18 in/hr (0.93 inches in 0.8 hrs) on May 13, 2009. Rainfall depth was converted to volume that ranged from 772 $ft^3$ at site 1 on November 6, 2008 to 18,731 $ft^3$ at site 3 on June 16, 2009. In general, > 1 inch of rain is needed to generate runoff if the event duration is greater than 1 hour. Runoff is generated even over long, slow rainfall events >1 inch when field capacity is reached and rainfall is greater than infiltration capacity. For rainfall durations < 1 hour, rainfall intensities of 1 in/hr are needed to generate runoff as rainfall exceeds infiltration rate. Again, these estimates vary by season.

Runoff discharge also varied among catchments over the sampling period due to variability in rainfall, drainage area, soils, vegetation, and slope. Some rainfall intensities 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, but no runoff data could be generated. For the storm events where runoff data was generated, peak instantaneous discharge measurements ranged from as low as 0.009 cfs on Feb. 10, 2009 for site 2 to as high as 0.58 cfs on June 16, 2009 at site 3 (Table 7). The maximum capacity of a 1 foot, 90 degree weir is 1 cfs.

Storms generating enough runoff to activate the stage recorder varied from as low as 1.5 $ft^3$ at site 1 on May 13, 2009 to as high as 4,358 $ft^3$ at site 3 on May 1, 2009. Runoff volume as a percentage of total rainfall volume also ranged from 0.1% runoff at site 1 on May 13, 2009 to 24.1% runoff at site 3 on May 1, 2009. These data suggest that under the current conditions of the site, nearly 25% of the total rainfall volume can leave the site as runoff at certain rainfall intensities. 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. The continued hydrological monitoring in the next year will help better understand the rainfall-runoff dynamics of this site.

Another observation worth mentioning is that the catchment draining site 4 has proven to behave differently than the other sites. Site 4 is located on the western slope of the ridge that runs south-to-north across the property, while the other 3 sites are located on the eastern side of the slope. Data collected over the study period indicates the western facing slope receives slightly more rainfall than the other sites, anywhere from 2%-17% higher rainfall amounts.

Most storms in this area come from the west, and whether the winds force more rain into the rain gage, or the sites on the eastern slope are a little more sheltered, there is a disparity in the total rainfall each side of the slope receives during some storms. Furthermore, runoff volumes at site 4 are also low compared to the same storms at the other sites. This most likely is due to the rockiness of site 4, where less water stays on the surface due to higher permeability soils on that side of the ridge.

**Water Quality**

Median TP concentrations for all samples vary from 0.06 mg/L at site 4 to 4.11 mg/L at site 2 (Figure 4). Sites 1 and 3 have similar median TP concentrations around 0.3 mg/L. Site 2, with commercial fertilizer, had the highest concentration of TP in the samples collected at over 34 mg/L during the November 6, 2008 storm event. This event was the first collected after commercial fertilizer was applied to site 2. Over the first year of this study it appears site 2 has produced the highest TP values among sites, with site 4 (6 dryT/ac) having the highest variability. Sites 1 and 3 seem to have similar TP concentrations so far in the study.

Median TKN concentrations ranged from 0.98 mg/L at site 4 to 3.62 mg/L at site 2 (Figure 5). Sites 1 and 3 had similar median TKN concentrations of 2.51 and 2.85 mg/L. Similar to TP concentrations, sites 2 and 4 have the highest variability among sites, and site 2 also has the highest concentration of TKN detected in this study at 66.7 mg/L in the November 6, 2008 storm event. Again sites 1 and 3 have similar variability over the sampling period.

Median total ammonia concentrations ranged from 0.14 mg/L at site 3 to 0.44 mg/L at site 4 (Figure 6). Sites 1 and 2 had similar median total ammonia concentrations of 0.26 and 0.19 mg/L. Again, site 2 has the highest overall total ammonia concentration of 37.4 mg/L during the November 6, 2008 storm. However, site 4 has the highest overall total ammonia concentration among sites. If the November 6, 2008 sample from site 2 is removed, site 4 has almost double the total ammonia concentration compared to the other three sites.

Median nitrate concentrations ranged from 0.12 mg/L at site 3 to 0.28 mg/L at site 4 (Figure 7). Sites 1 and 2 were slightly higher median nitrate concentrations than site 3 at 0.14 and 0.16 mg/L, respectively. Site 2 has the highest nitrate concentration among sites at 2.64 mg/L for the November 6, 2008 storm sample. Site 2 also has the highest variability in nitrate concentrations, but site 1, the control, has the second highest variability among sites. These data suggest that there is a natural variability of nitrate during storm events.

Median TSS concentrations ranged from 3 mg/L at site 3 to 34 mg/L at site 4. Sites 1 and 2 have similar TSS concentrations of 11 and 8 mg/L (Figure 8). Site 4, the 6 dryT/ac of biosolids, had the highest TSS concentration among sites at 180 mg/L. Sites 2 and 4 had the highest variability in TSS concentrations, but if the November 6, 2008 storm sample is removed site 4 clearly has the highest TSS concentrations among sites. Sites 2 and 3 had similar TSS concentrations with all samples containing < 20 mg/L TSS.

Median pH were very similar ranging from 7.1 to 7.3 for all 4 sites (Figure 9). Site 2, however, had the highest variability in pH readings ranging from 6.9 to 7.5.

Metals were detected in 4 of the 23 samples collected over the study period. At site 4, 6.3 ug/L Zn was detected in the water sample from the May 21, 2009 storm event (Table 8). Also at site 4, 69.1 ug/L Zn and 19.6 ug/L Cu were detected in the June 16, 2009 storm sample. At site 1, which is the control, 14.2 ug/L Cr and 10.8 ug/L Ni were detected in the May 21, 2009 storm sample. At site 2, 6.4 ug/L Zn was detected in the July 21, 2009 storm sample. All metals were non-detect for the remaining 19 samples collected.

Due to extremely high variability in Fecal Coliform concentrations, the geometric mean is used to describe variability among sites. The geometric means range from 30.2 coli/100 mL at site 3 to 68.3 coli/100 mL at site 2 (Table 9). All sites were below detect for the May 1, 2009 and May 14, 2009 storm samples, and these values were used to calculate the geometric mean using half the detection limit value. The highest Fecal Coliform concentration was 190,000 coli/100 mL at site 4 for the June 16, 2009 storm sample.

The field blanks and duplicates were high for nutrients during some events. These issues are being addressed with moving to the composites bottle sampling method.

**Surface Soils**

Soil pH and nutrients followed similar patterns with sites 1 and 2 sharing similar characteristics and sites 3 and 4 having similar characteristics (Figure 10). Median soil pH ranged from 5.8 to 5.9 at sites 1 and 2 while sites 3 and 4 had a soil pH range from 6.2 to 6.4. Minimum pH values were near 5.4 at sites 1 and 2. Soil P was nearly twice as high in sites 1 and 2 as in site 3 and 4 (Figure 11). Median soil P ranged from 11 ppm at site 3 and 4, to 23 ppm at site 1. Sites 1 and 4 had the highest within site variability of > 20 ppm. Soil N was just the opposite with sites 1 and 2 having no N measured, but sites 3 and 4 had median N values of 8 and 9 ppm (Figure 12).

With the exception of Zn and Pb, metals in the surface soils were fairly consistent among sites. Median soil Zn ranged from 0.9 ppm at site 4 to 2.1 ppm at site 2. The highest variability of Zn concentrations was at site 3 ranging from 0.9 to 3.4 ppm (Figure 13). Median total Pb in the soil ranged from 28 ppm at site 4 to 35 ppm at site 2 (Figure 14). The highest variability in soil Pb was at sites 1 and 2 with concentrations ranging 9 ppm from the minimum to maximum values. Median concentrations of Cu, Cd, and Ni did not vary among sites, and median Cr concentrations were 0.1 ppm for sites 1 and 2 and 0 at sites 3 and 4 (Figure 15-18).

Site and sample variability was high for some samples, but another year and further analysis is needed to verify.

**Soil Morphology**

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 14). 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. The presence of redoxamorphic features above the fragipan and within the prismatic seams through the fragipan are indicators of a seasonally high water table. The steeper sides slopes are coarser closer to the surface, with sporadic remnants of weathered sandstone present 50" to 60" below the surface. In the bottom of the colluvial valley there is nearly a 2 foot accumulation of alluvium over colluvium that contains high chert content.

**Forage Analysis**

Testing the forage harvested from each of the 4 sites showed improvement in the quantity of forage but not the quality of the forage at the sites where biosolids are applied compared to the control. Nitrogen content in the forage was higher at sites 3 and 4, with site 4 having the highest percentage (1.78%) (Figure 17). Phosphorus content was at least 30% higher in the fields that were treated with fertilizer or biosolids compared to the control. Copper content was relatively uniform among sites 2, 3, and 4, and lower at site 1. Zinc content was highest for forage collected at sites applied with biosolids (22.3 ppm at site 3 and 23 ppm at site 4) compared to sites 1 and 2 (17.67 ppm at each). Sites 3 and 4 had the highest forage yields with 2.1 and 2.7 dryT/ac being collected, with site 2 having 1.7 dryT/ac, and site 1 having 0.9 dryT/ac (Table 5). Overall forage quality was poor with Relative Feed Values (RFV) of <80 at all sites. Forage quality was ranked as poor for sites 1, 3, and 4, and site 2 had a reject forage grade. 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 report covers the activities over the first year of the Biosolids Runoff Monitoring Project from May 2008 through July 2009. There are 9 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. 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.
4. Over the 9 month sampling period (November 1$^{st}$, 2008 – July 31$^{st}$, 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.
5. 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 25% of the recorded rainfall measured as runoff for the larger storm events.
6. Concentrations of nutrients, metals and TSS were higher and more variable at site 2 and site 4 than at sites 3 and 1. Site 2 has treated with commercial fertilizer and site 4 was treated at the 6 dryT/ac biosolids application rate. No pattern could be seen in the total coliform concentrations over the sampling period.
7. Surface soil samples were collected and analyzed for nutrient and metals prior to application of fertilizer and biosolids to establish baseline soil geochemisrty. Three samples and one duplicate were collected at each of three landscape positions in each catchment for a total of 48 samples in year one.

8. 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.
9. Forage was cut, collected and analyzed to measure differences in metal uptake and forage quality and quaintly among treated catchment areas. Metal content was similar for forage collected among sites with Zn being slightly higher in forage from the biosolids applied plots. Generally, forage quality is poor off of all plots, with the commercial fertilizer catchment having the lowest quality forage. Forage collected from site 4 produced the highest yield (2.7 T/ac), then site three (2.1 T/ac), site 2 (1.7 T/ac) and site 1 (0.9 T/ac).

Over the next year, a second round of soil testing and another year of water sampling will provide a larger dataset to which comparisons may be drawn.

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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<br>Nixa very gravelly silt loam, 3-8% slopes | Gravelly Upland<br>Gravelly Pan |
| 2 | Commercial Fertilizer | Nixa very gravelly silt loam, 3-8% slopes<br>Viraton silt loam, 2-5% slopes | Gravelly Pan<br>Loamy Pan |
| 3 | Biosolids at Commercial Fertilizer Equivalent | Nixa-Clarksville complex, 3-20% slopes<br>Viraton silt loam, 2-5% slopes | Gravelly Upland<br>Loamy Pan |
| 4 | Biosolids at Double Commercial Fertilizer Equivalent | Viraton silt loam, 2-5% slopes<br>Nixa very gravelly silt loam, 3-8% slopes | Loamy Pan<br>Gravelly Pan |

**Table 2. 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 3. 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 4. 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 5. 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 6. Rainfall Totals, Duration, and Sites Collected for Storm Events**

| Date | Total Rainfall (in) | Rainfall Duration (hrs) | Sites Collected |
|---|---|---|---|
| 11/6/09 | 0.56 | 0.63 | 1 & 2 |
| 2/11/09 | 1.72 | 15.1 | 1 & 2 |
| 4/12/09 | 1.2 | 12.4 | 1, 2, & 3 |
| 4/20/09 | 1.27 | 21.5 | 2 & 3 |
| 5/1/09 | 1.68 | 12 | 1, 2, 3, & 4 |
| 5/13/09 | 0.93 | 0.80 | 1, 2, 3, & 4 |
| 6/16/09 | 1.72 | 8.50 | 1, 2, 3, & 4 |
| 6/30/09 | 1.1 | 6.6 | 2 |
| 7/20/09 | 1.83 | 23.4 | 2 |

**Table 7. Rainfall and Discharge Data**

| Date | Site | Total Rainfall | Duration | Peak Rainfall Intensity | Avg. Rainfall Intensity | Total Rainfall Volume | Peak Q | Total Runoff Vol. | Est. Runoff | Est. Infiltration |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (in) | (hr) | (in/5min) | (in/hr) | (ft3) | (cfs) | (ft3) | % | % |
| 11/6/2008 | 1 | 0.56 | 0.63 | 0.13 | 0.88 | 772 | 0.01 | 3 | 0.3 | 99.7 |
| 2/11/2009 | 1 | 1.72 | 15.1 | 0.18 | 0.11 | 2,373 | 0.009 | 66 | 2.8 | 97.2 |
| 4/12/2009 | 1 | 1.29 | 12.4 | 0.05 | 0.1 | 1,779 | 0.02 | 145 | 8.2 | 91.8 |
| 5/1/2009 | 1 | 1.59 | 11.5 | 0.25 | 0.14 | 2,193 | 0.11 | 466 | 21.2 | 78.8 |
| 5/13/2009 | 1 | 0.93 | 0.8 | 0.22 | 1.16 | 1,283 | 0.003 | 1.5 | 0.1 | 99.9 |
| 6/16/2009 | 1 | 1.74 | 8.4 | 0.27 | 0.21 | 2,400 | 0.18 | 318 | 13.3 | 86.8 |
| | | | | | | | | | | |
| 11/6/2009 | 2 | 0.56 | 0.63 | 0.13 | 0.88 | 1,321 | nd | nd | nd | nd |
| 2/10/2009 | 2 | 1.76 | 15.3 | 0.3 | 0.12 | 4,153 | 0 | 0 | 0 | 100 |
| 4/12/2009 | 2 | 1.2 | 15.3 | 0.05 | 0.08 | 2,831 | 0 | 0 | 0 | 100 |
| 4/20/2009 | 2 | 1.29 | 21.5 | 0.1 | 0.06 | 3,044 | 0 | 0 | 0 | 100 |
| 5/1/2009 | 2 | 1.67 | 11.8 | 0.26 | 0.14 | 3,940 | 0.06 | 396 | 10.1 | 89.9 |
| 5/13/2009 | 2 | 0.94 | 0.8 | 0.22 | 1.18 | 2,218 | 0.019 | 17 | 0.8 | 99.2 |
| 6/16/2009 | 2 | 1.72 | 8.5 | 0.1 | 0.20 | 4,058 | 0.29 | 757 | 18.7 | 81.3 |
| 6/30/2009 | 2 | 1.1 | 6.6 | 0.03 | 0.17 | 2,595 | 0.08 | 39 | 1.5 | 98.5 |
| 7/20/2009 | 2 | 1.83 | 23.4 | 0.18 | 0.08 | 4,318 | 0 | 0 | 0 | 100 |
| | | | | | | | | | | |
| 4/12/2009 | 3 | 1.27 | 15.5 | 0.05 | 0.08 | 13,830 | 0.09 | 984 | 7.1 | 92.9 |
| 4/20/2009 | 3 | 1.24 | 21.5 | 0.07 | 0.06 | 13,504 | 0.04 | 406 | 3 | 97 |
| 5/1/2009 | 3 | 1.66 | 12.1 | 0.25 | 0.14 | 18,077 | 0.41 | 4,358 | 24.1 | 75.9 |
| 5/13/2009 | 3 | 0.93 | 0.8 | 0.2 | 1.16 | 10,128 | 0.02 | 90 | 0.9 | 99.1 |
| 6/16/2009 | 3 | 1.72 | 8.5 | 0.1 | 0.20 | 18,731 | 0.58 | 3,112 | 16.6 | 83.4 |
| | | | | | | | | | | |
| 5/1/2009 | 4 | 1.78 | 12.2 | 0.23 | 0.15 | 8,271 | 0.02 | 128.5 | 1.6 | 98.4 |
| 5/13/2009 | 4 | 0.95 | 0.75 | 0.17 | 1.27 | 4,414 | 0 | 0 | 0 | 100 |
| 6/16/2009 | 4 | 1.89 | 10.4 | 0.16 | 0.18 | 8,782 | 0.02 | 86.5 | 1 | 99 |

**Table 8. Metals Detected in Water Samples**

| Site | Date | Metal Detected (ppb) | | | |
|---|---|---|---|---|---|
| | | Cr | Ni | Zn | Cu |
| 1 | 6/16/2009 | 14.2 | 10.8 | - | - |
| 2 | 7/21/2009 | - | - | 6.4 | - |
| 4 | 5/21/2009 | - | - | 6.3 | - |
| 4 | 6/16/2009 | - | - | 69.1 | 19.6 |

**Table 9. Fecal Coliform in Water Samples**

| Site | Minimum (coli/100mL) | Geometric Mean (coli/100mL) | Maximum (coli/100mL) |
|---|---|---|---|
| 1 | <MDL | 288 | 29,000 |
| 2 | <MDL | 278 | 8,000 |
| 3 | <MDL | 464 | 9,000 |
| 4 | <MDL | 190,000 | 190,000 |

**Table 10. 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)<br>Fragipan (32”- 45”)<br>Redox features |
| 2 | Interfluve | Colluvium/Residuum | 1,199 | 2% | 10-60 | Weak fragipan (20”-35”)<br>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 11. Forage Analysis Data**

| 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 | |

## FIGURES

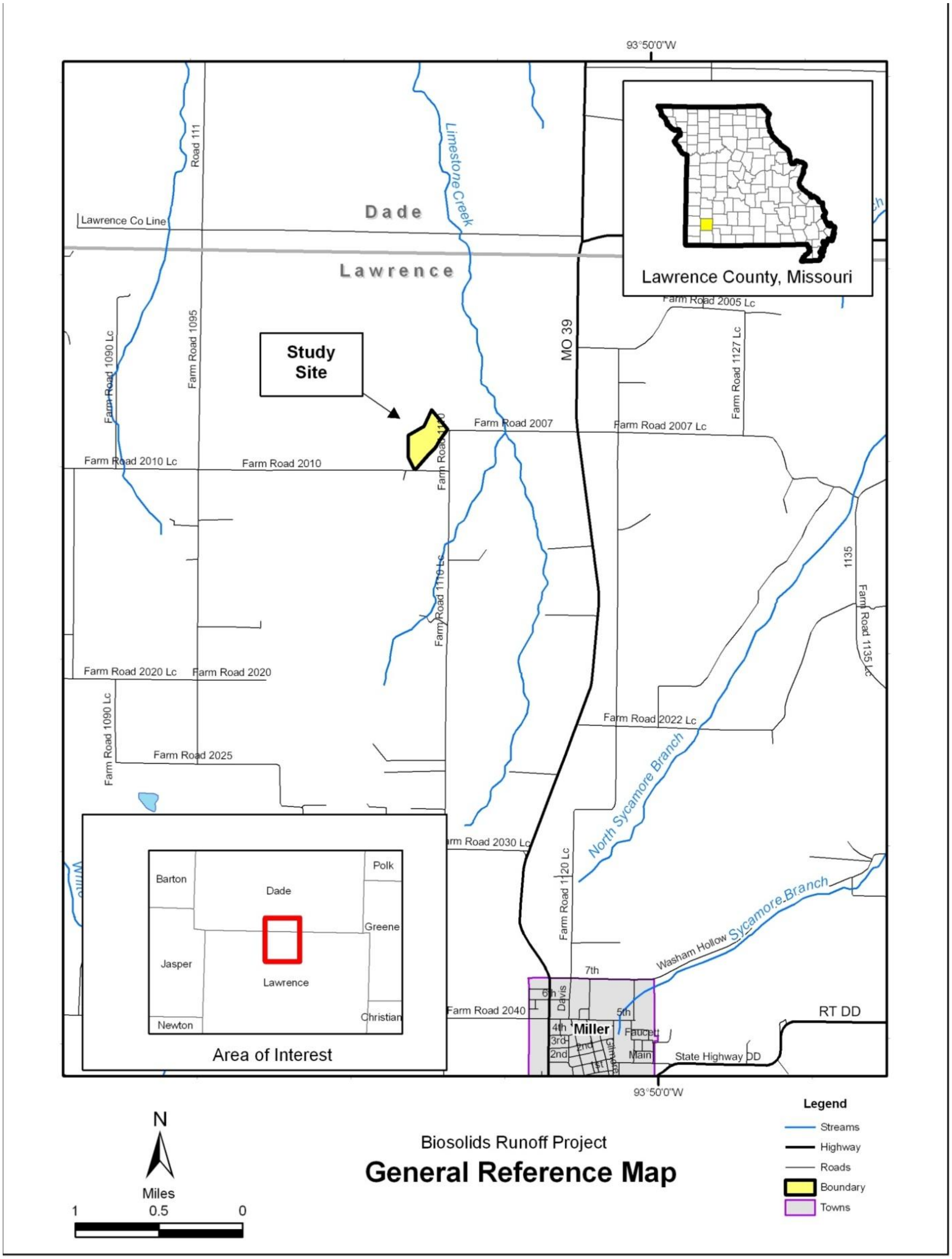



**Figure 1. Study site location**

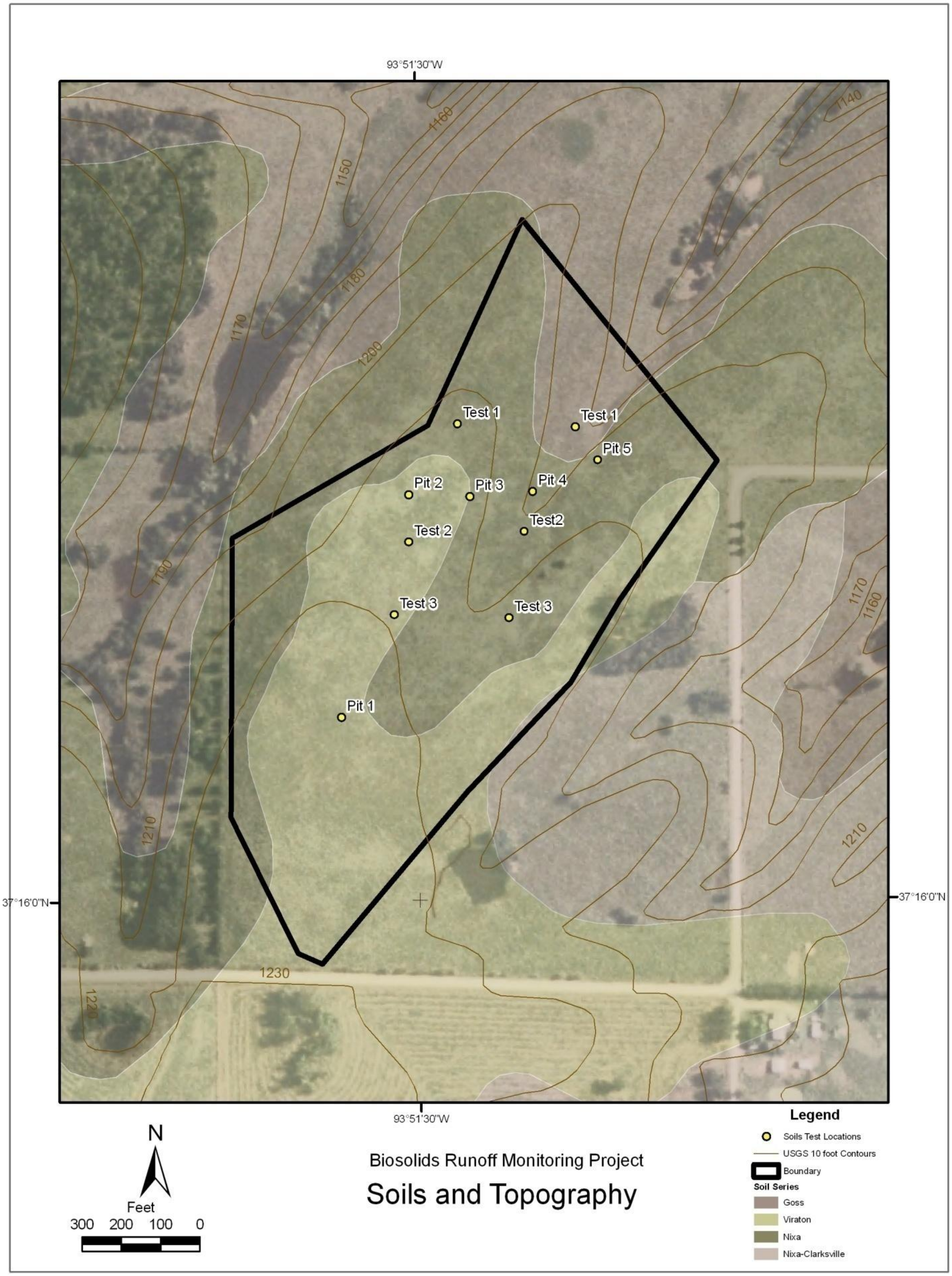



**Figure 2. Mapped soils with soil test and soil morphology soil pit locations**

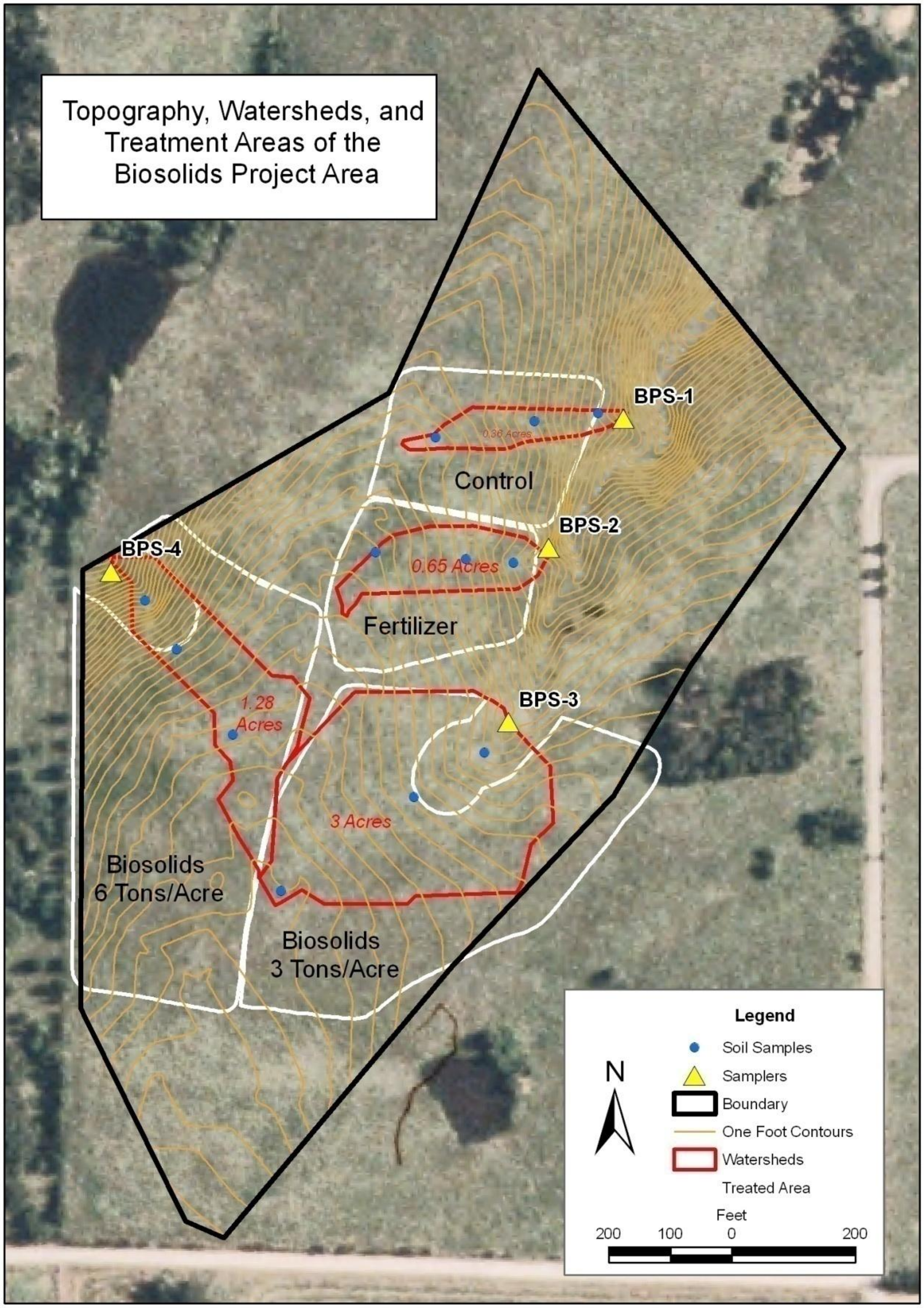



**Figure 3. Site topography, watershed areas, surface soil sample locations, and treatment zones**

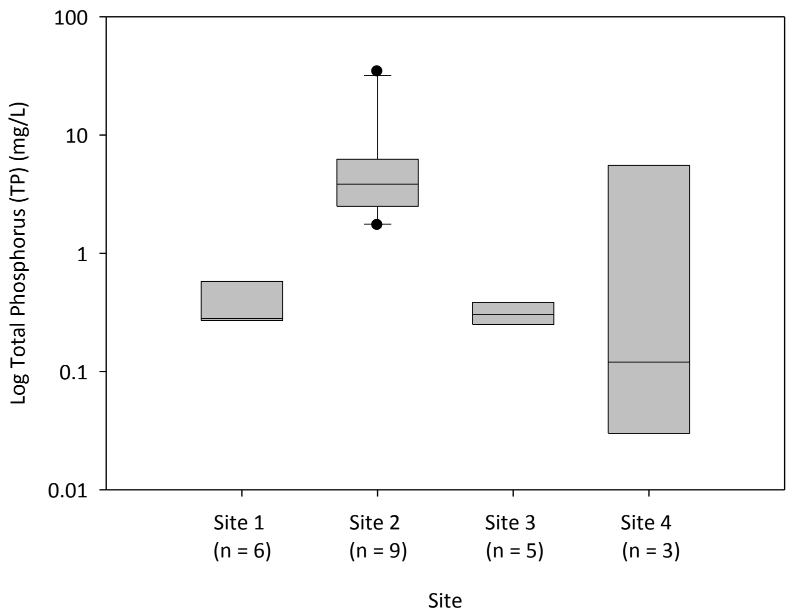



**Figure 4. Total Phosphorus**

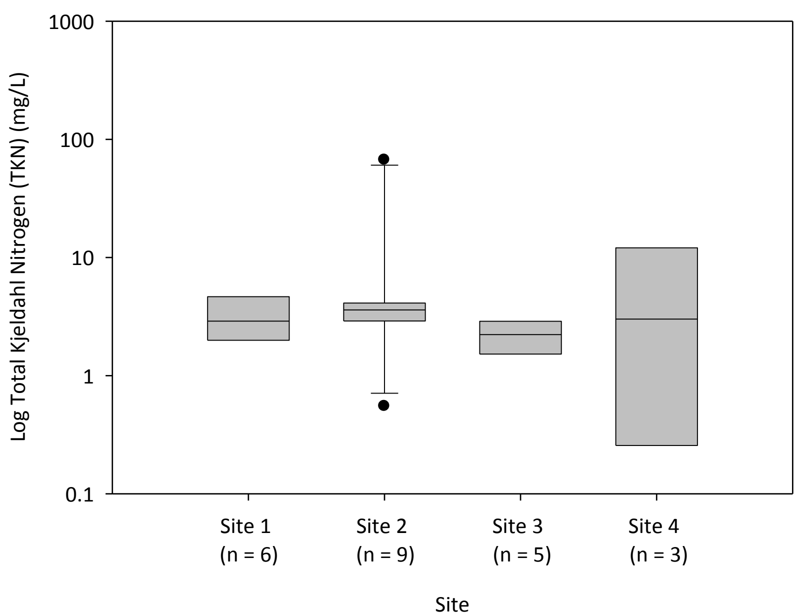



**Figure 5. Total Kjeldahl Nitrogen**

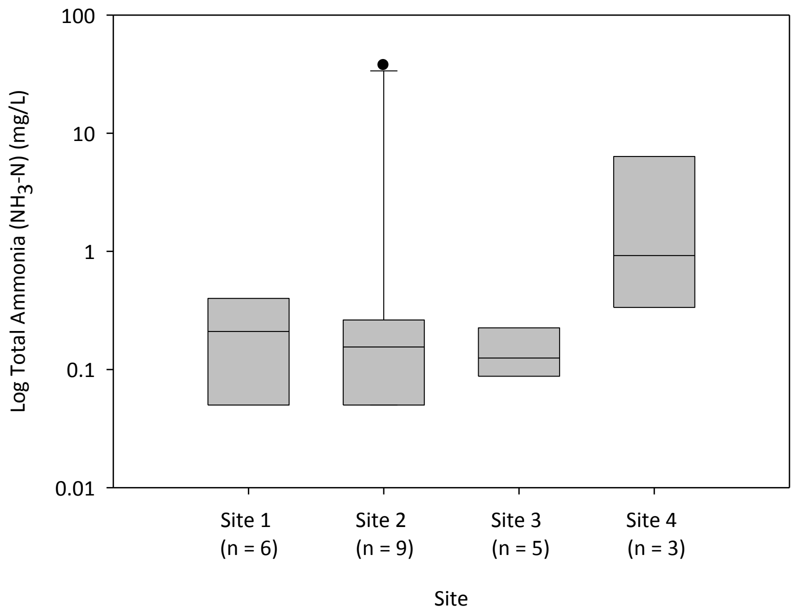



**Figure 6. Total Ammonia**

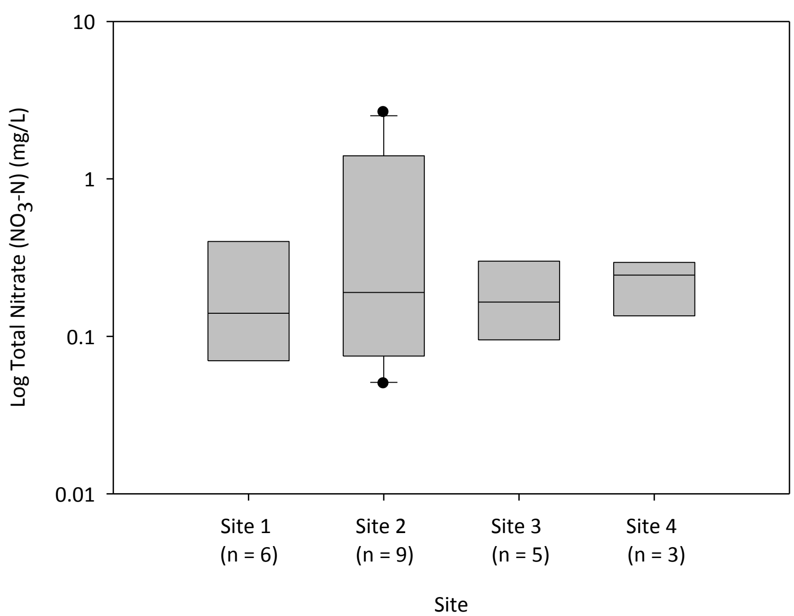



**Figure 7. Total Nitrate**

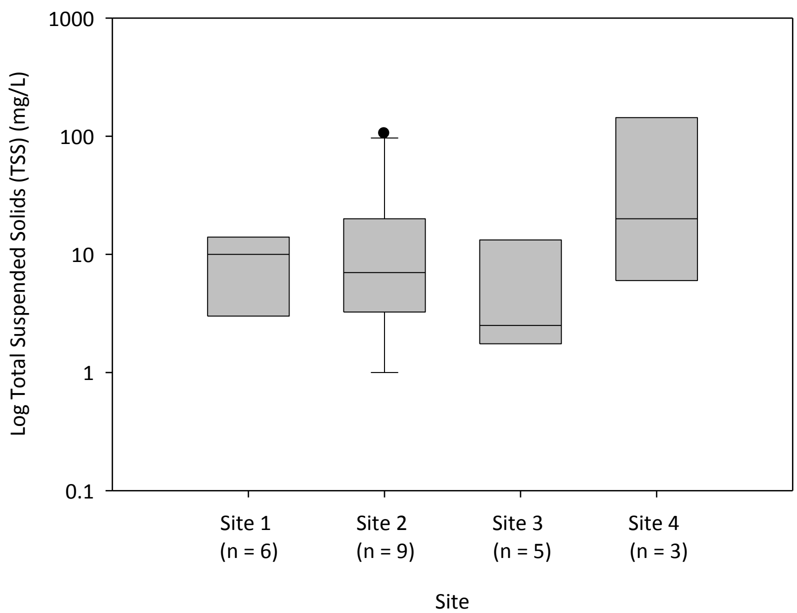



**Figure 8. Total Suspended Solids**

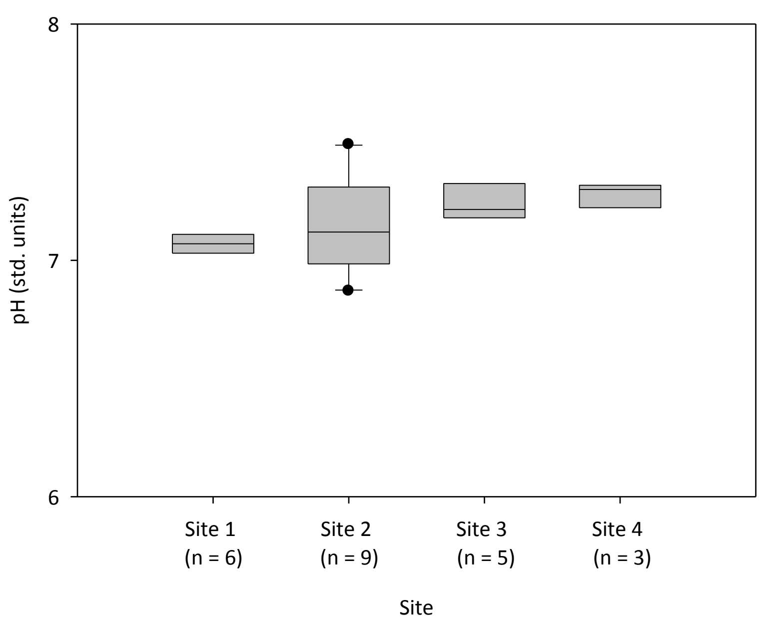



**Figure 9. Water Sample pH**

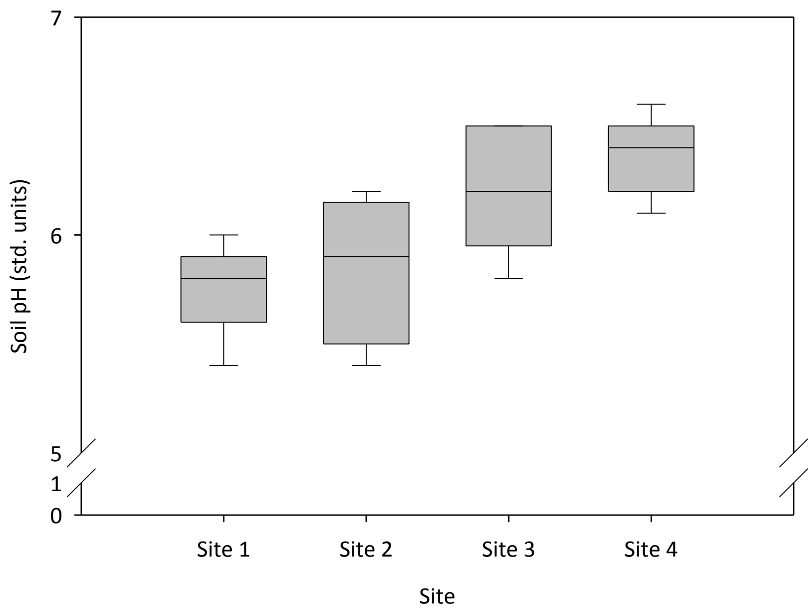



**Figure 10. Soil pH (n=9 each site)**

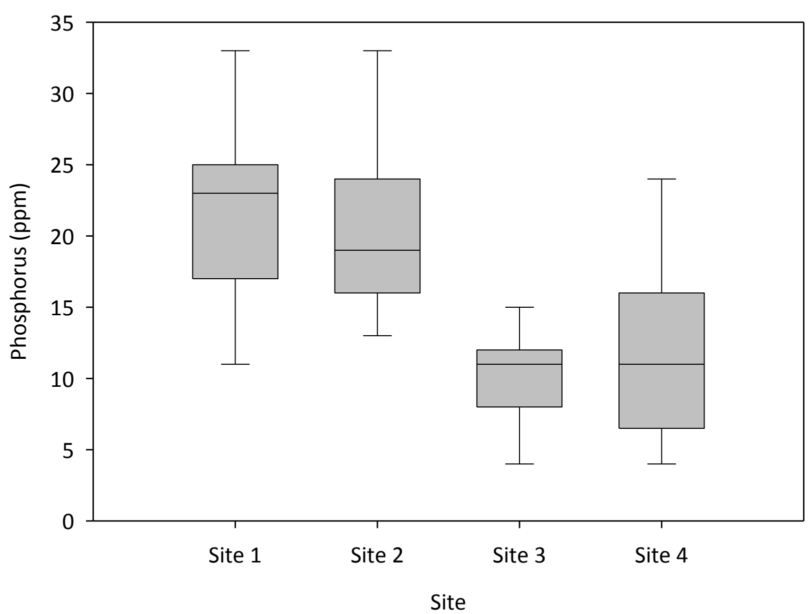



**Figure 11.  Soil Phosphorus (n=9 each site)**

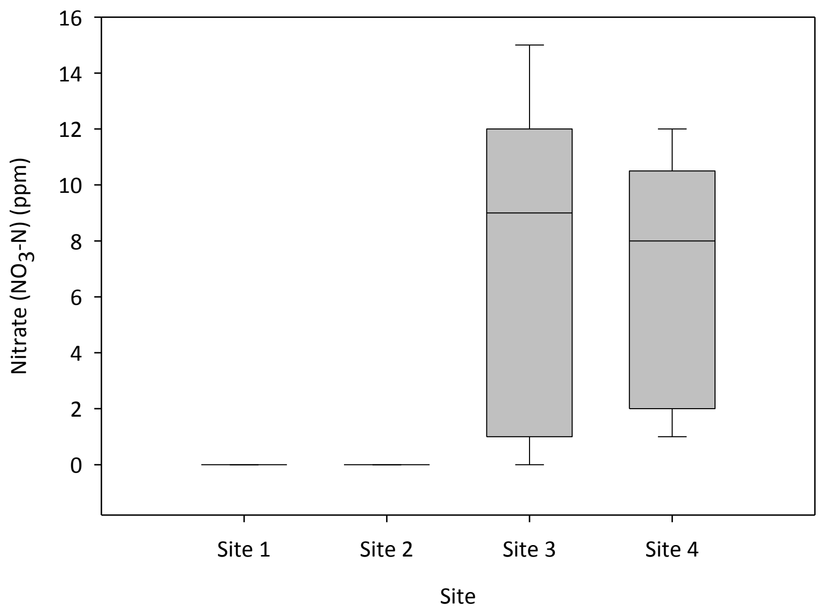



**Figure 12. Nitrate in Soil (n=9 each site)**

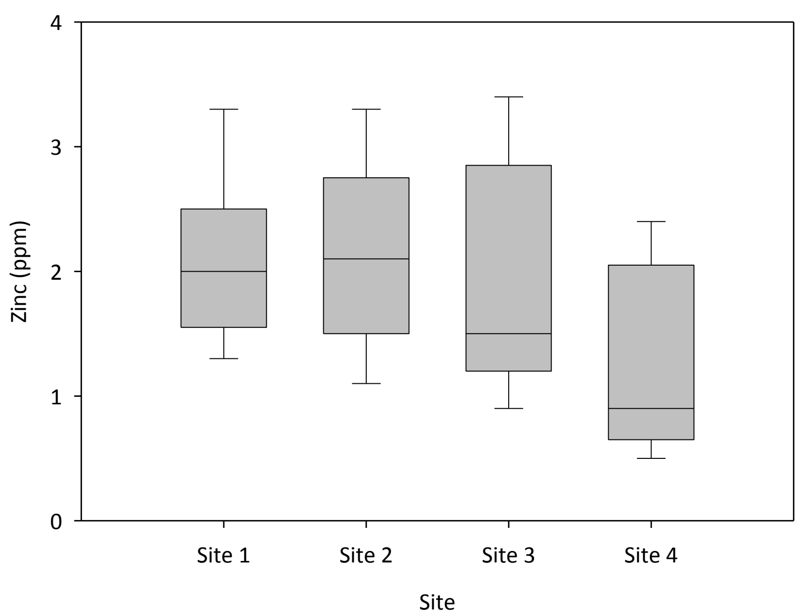



**Figure 13.  Soil Zinc (n=9 each site)**

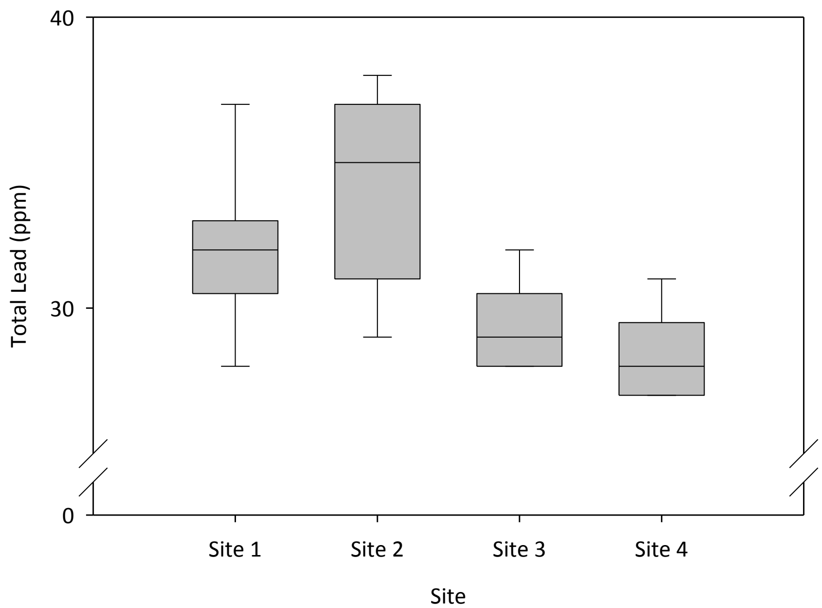



**Figure 14. Total Lead in Soil (n=9 each site)**

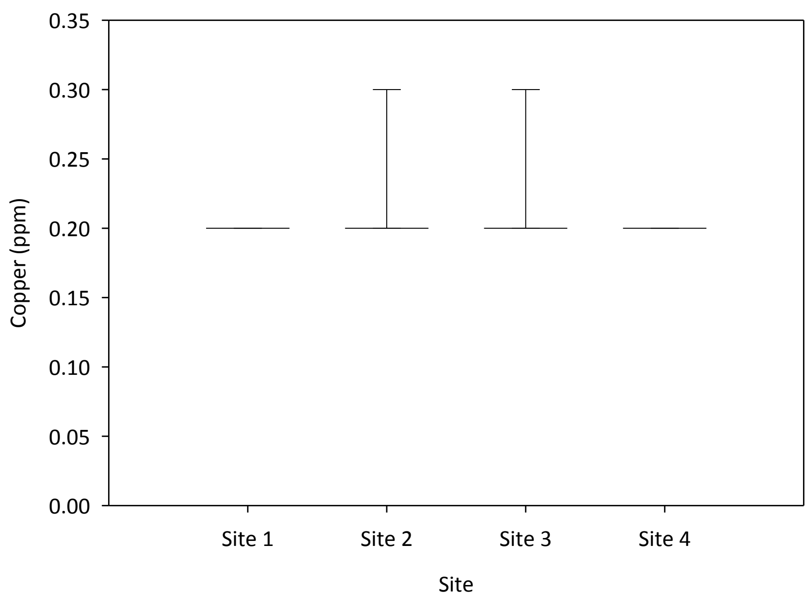



**Figure 15. Soil Copper (n=9 each site)**

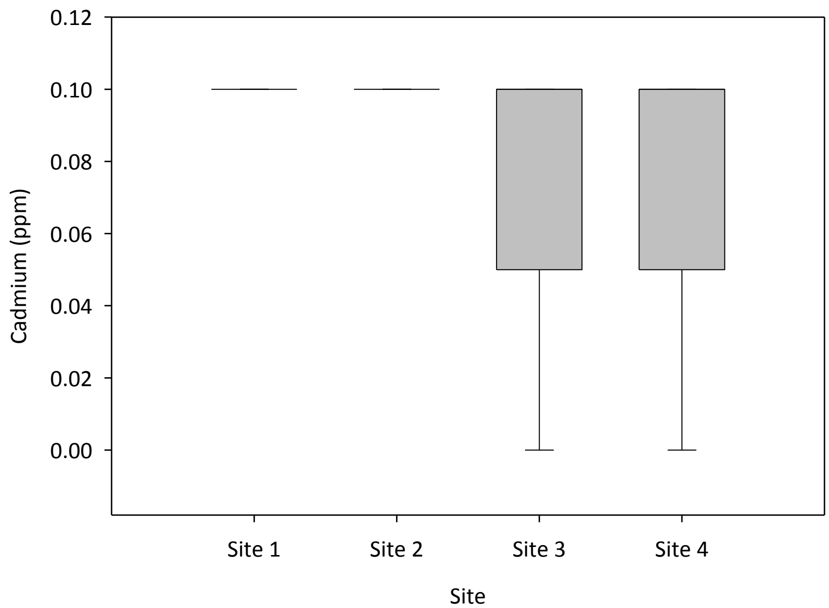



**Figure 16. Cadmium in Soil (n=9 each site)**

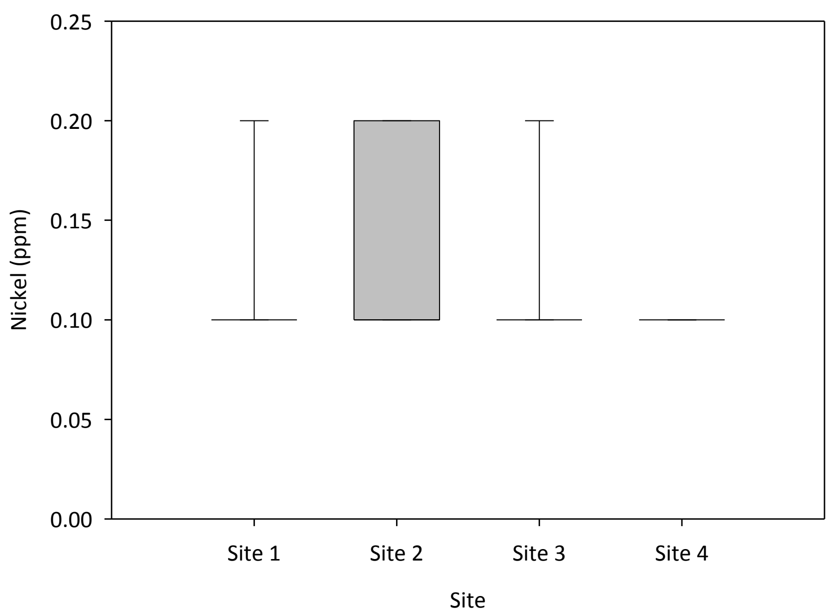



**Figure 17. Nickel in Soil (n=9 each site)**

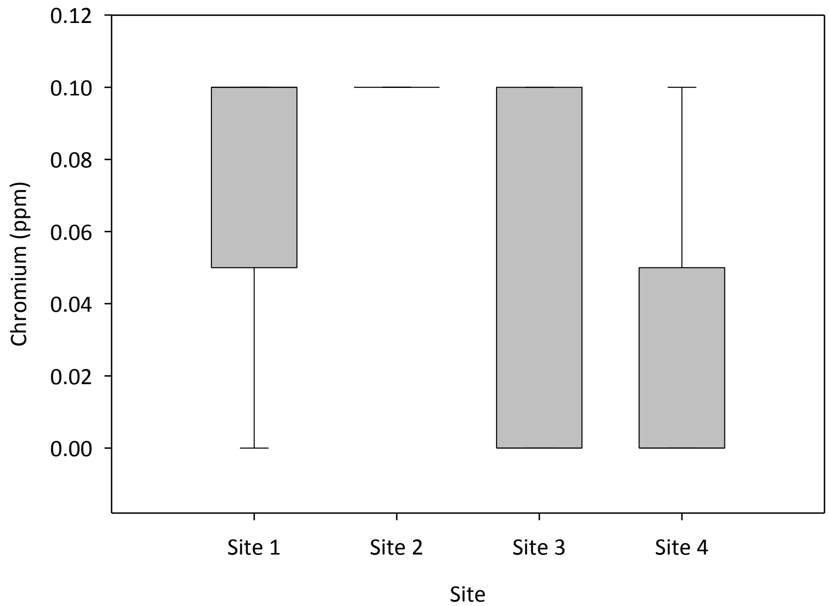



**Figure 18. Chromium in Soil (n=9 each site)**

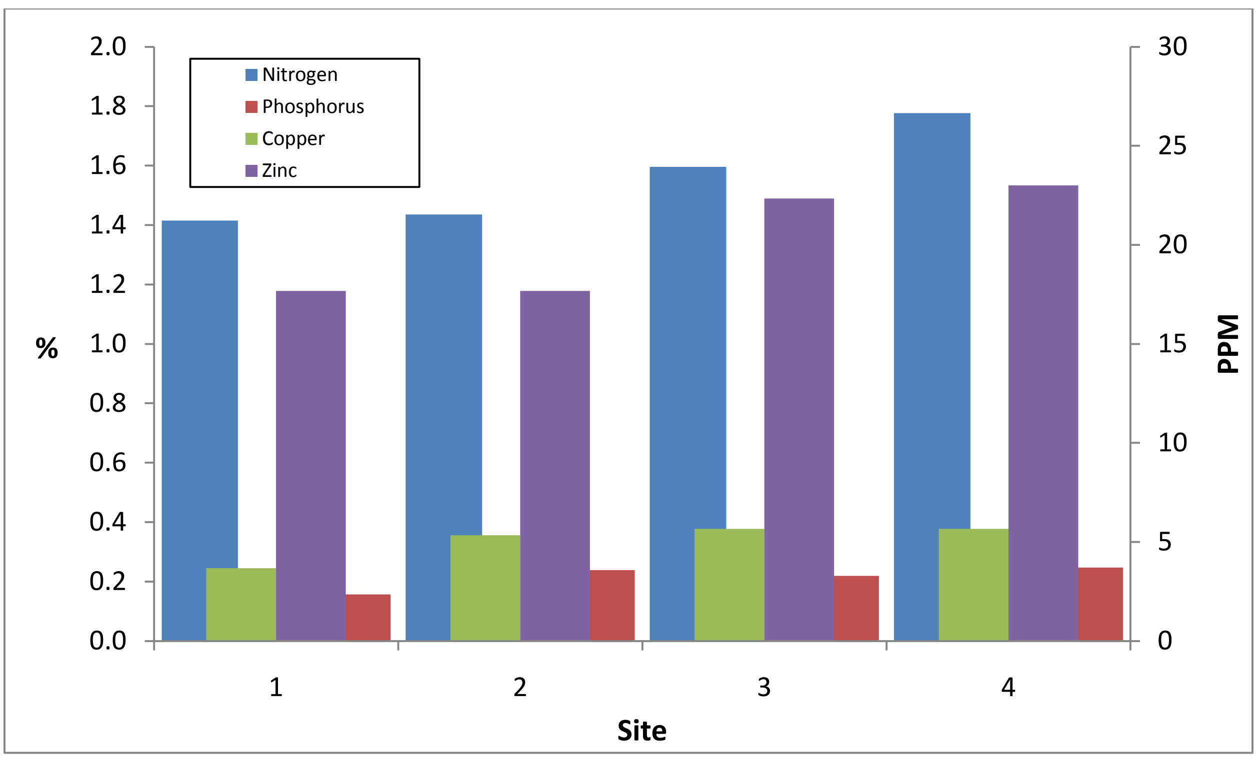



**Figure 19. % Nitrogen, % Phosphorus, Copper (ppm) and Zinc (ppm) in Forage**

## PHOTOS

**Photo 1. V-Notch Weir, Pressure Transducer, and Strainer Location**

**Photo 2. Presssure Transducer and Strainer Location**

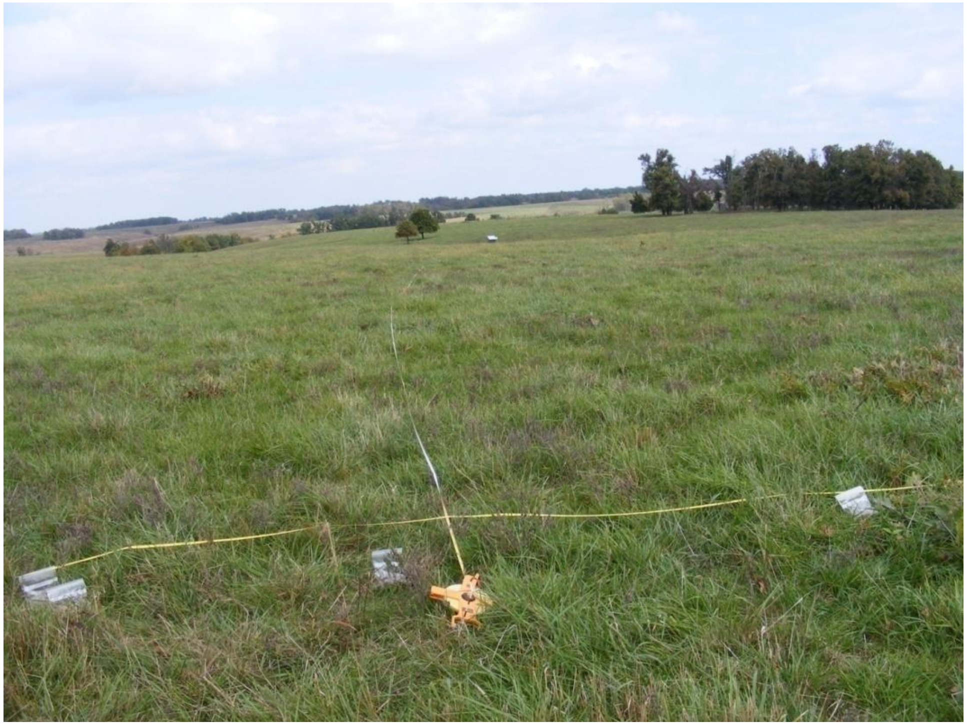


**Photo 3. Surface Soil Sample Transect**

**Photo 4. Sampler housing along main draw on the project site (October 2008)**


**Photo 5. Auto-sampler and Rain Gage Installation (October 2008)**


**Photo 6. Tom Dewitt Soil Coring Along the Ridge with Class (October 2008)**

**Photo 7. Example of a Soil Profile at the Project Site (Loess over Colluvium over Residuum) (October 2008)**

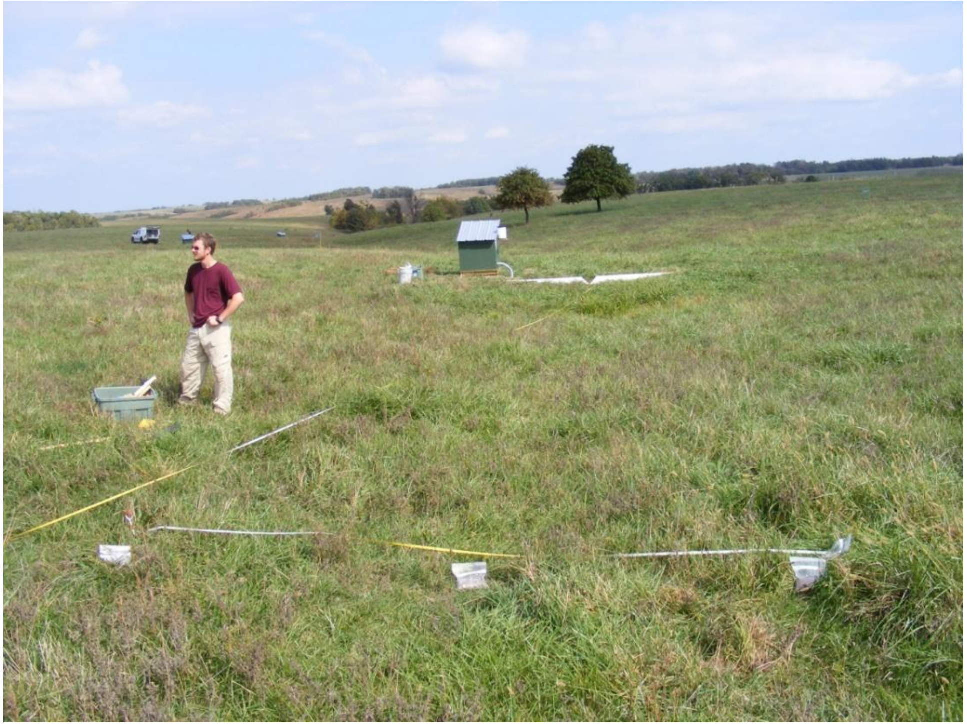


**Photo 8. Surface Soil Sampling (October 2008)**

## 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 | | |
| | | | | | | |
| | | | | | | |

| 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
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. S41722-5** | **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 |
|---|---|---|---|---|---|---|
| 18 COOL SEASON GRASS HAY | 3 T/A | 120 | 70 | 120 | | |
| 18 COOL SEASON GRASS HAY | 5 T/A | 200 | 90 | 190 | | |
| | | | | | | |
| | | | | | | |

(N, $P_2O_5$, $K_2O$, Zn, S in pounds per acre)

**LIMESTONE SUGGESTIONS**

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

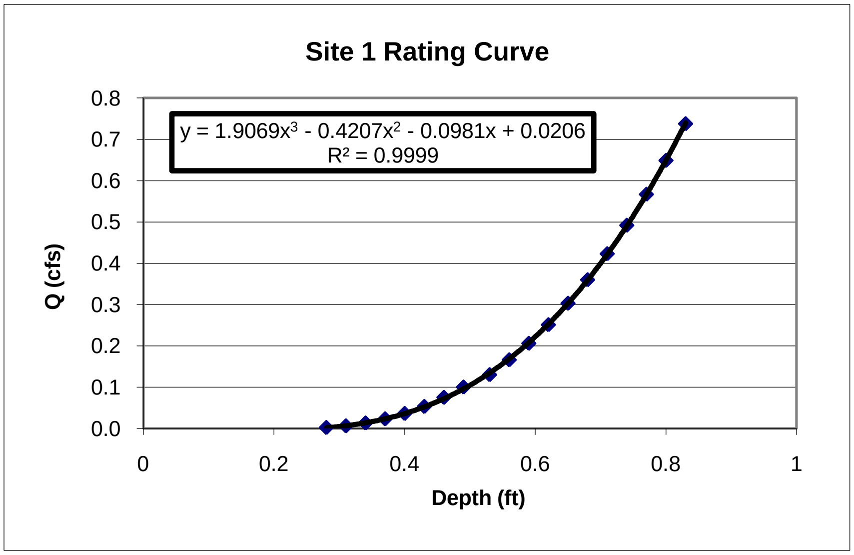
Comments
---For hay production apply nitrogen just before spring growth begins (typically March). Consider splitting nitrogen applications if the rate exceeds 90 lbs N/acre, applying 60% in March and the balance in mid August.
---Some herbicide labels list restrictions based on soil pH in water. This 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.

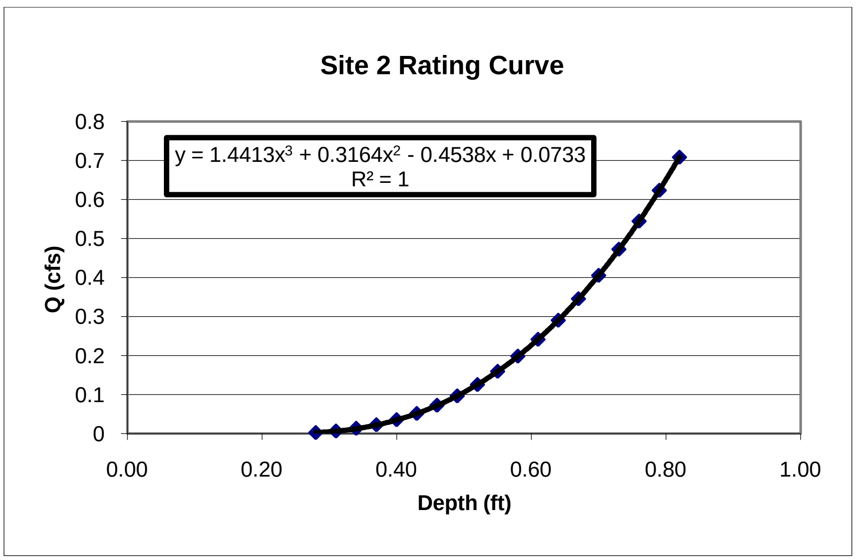
Regional Agronomy Specialist Tim Schnakenberg Phone 417-357-6812 *Tim Schnakenberg*
Signature

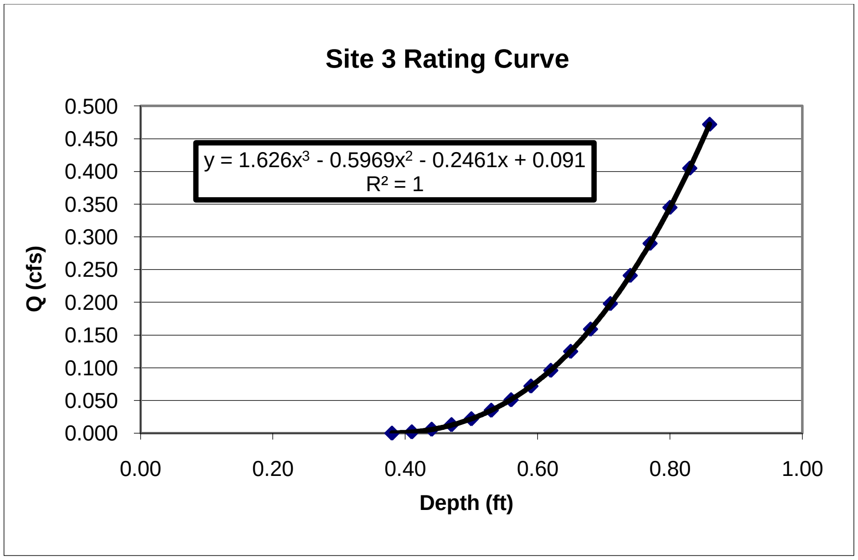
White-Farmer, Yellow-FSA, Blue-Firm, Pink-Extension MP 189 Revised 1/96

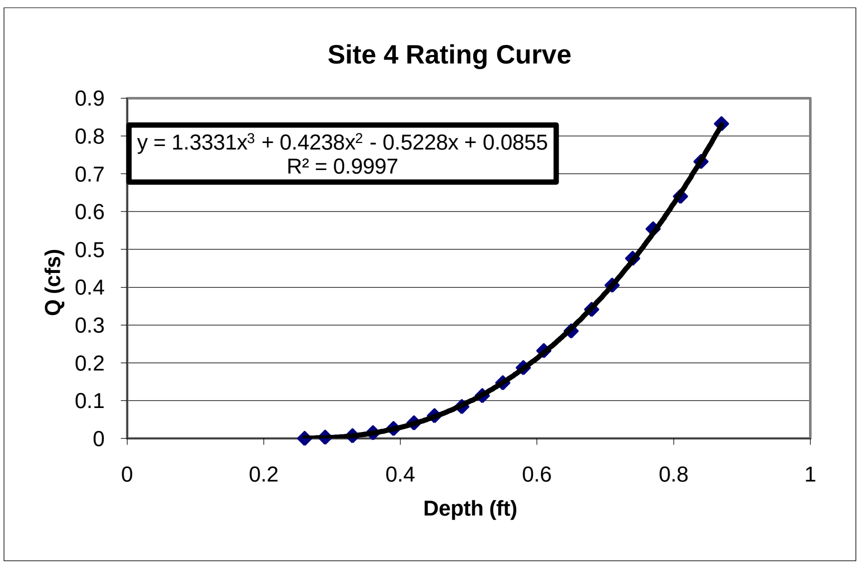
University of Missouri, Lincoln University, U.S. Department of Agriculture & Local University Extension Councils Cooperating Columbia
Equal opportunity institutions

## 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) | | | | | | | Metals (µg/L) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TKN | NH3-N | NO3-N | TP | % Total Solids | Fecal coliform (coli/100 mL) | pH (std units) | 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

| 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 | 2290 | 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 | 2474 | 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 | 1467 | 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 | 2465 | 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 | 3935 | 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 | 3548 | 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 | 3003 | 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 | 3712 | 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 | 3127 | 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 | 3161 | 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 | 5024 | 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 | 2671 | 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 | 2867 | 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 | 2054 | 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 | 2903 | 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 | 2127 | 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 | 4104 | 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 | 4478 | 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 | 4427 | 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 | 3233 | 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 | 3737 | 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 | 4264 | 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 | 3419 | 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 | 5339 | 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 | 3901 | 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 | 2435 | 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 | 2939 | 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 | 2048 | 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 | 2443 | 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 | 2695 | 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 | 1988 | 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 | 2798 | 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 | 2462 | 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 | 1685 | 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 | 4578 | 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 | 2172 | 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 | 3280 | 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 | 2680 | 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 | 2477 | 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 | 2714 | 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 | 4513 | 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 | 3319 | 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 | 2624 | 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 | 4907 | 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 | 1814 | 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 | 2332 | 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 | 1913 | 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 | 1821 | 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

## APPENDIX E: Water Quality Analysis Results

| | | Nutrients (mg/L) | | | | | | | Metals (µg/L) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Date | TKN | $NH_3$-N | $NO_3$-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 | 6.73 | 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 | 7.03 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 6250 | <20 | <5 | <5 |
| | 4/13/2009 | 2.89 | 0.4 | 0.13 | 0.28 | 1 | 10 | 7.16 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 1600 | <20 | <5 | <5 |
| | 4/13/2009* | 1.86 | 0.14 | 0.11 | 0.19 | 2 | 30 | 7.17 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 1540 | <20 | <5 | <5 |
| | 5/1/2009 | <0.03 | <0.1 | 0.14 | 0.27 | 11 | NR | 7.03 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 2690 | <20 | <5 | <5 |
| | 5/14/2009 | 2.80 | 0.2 | 0.07 | 0.29 | 10 | NR | 7.11 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 1850 | <20 | <5 | <5 |
| | 6/16/2009 | 4.65 | 0.3 | 0.40 | 0.58 | 16 | 29000 | 7.10 | <15 | <5 | 14.2 | <5 | <15 | <0.2 | <20 | 10.8 | 8700 | <20 | <5 | <5 |
| | 6/16/2009* | 5.72 | 0.3 | 0.46 | 0.57 | 14 | 29000 | 7.08 | <15 | <5 | 15 | <5 | <15 | <0.2 | <20 | 10.9 | 8860 | <20 | <5 | <5 |
| Site 2 | 11/6/2008 | 66.70 | 37.4 | 1.41 | 34.20 | 105 | 250 | 7.46 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| | 2/11/2009 | 3.50 | <0.1 | 0.77 | 10.10 | 20 | 30 | 7.49 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 12600 | <20 | <5 | <5 |
| | 4/13/2009 | 3.15 | 0.2 | 0.13 | 4.11 | 1 | 70 | 7.22 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 2580 | <20 | <5 | <5 |
| | 4/20/2009 | 2.15 | <0.1 | 0.08 | 3.57 | <2 | 20 | 7.26 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 2120 | <20 | <5 | <5 |
| | 4/20/2009* | 2.02 | <0.1 | 0.08 | 3.73 | 2 | <1 | 7.32 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 1970 | <20 | <5 | <5 |
| | 5/1/2009 | 3.57 | 0.1 | 0.16 | 4.95 | 13 | NR | 7.04 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 3280 | <20 | <5 | <5 |
| | 5/14/2009 | 3.62 | 0.2 | 0.06 | 2.94 | 4 | NR | 6.91 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 2740 | <20 | <5 | <5 |
| | 6/16/2009 | 4.58 | 0.5 | 1.40 | 4.94 | 8 | 8000 | 7.01 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 12200 | <20 | <5 | <5 |
| | 6/30/2009 | 3.96 | <0.1 | 2.64 | 2.60 | 20 | 1545 | 7.09 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 10600 | <20 | <5 | <5 |
| | 7/21/2009 | 3.95 | 0.2 | <0.01 | 1.72 | 6 | 1000 | 7.15 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 10700 | <20 | <5 | 6.4 |
| Site 3 | 4/13/2009 | 1.49 | 0.1 | 0.12 | 0.25 | 3 | 370 | 7.31 | <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 | 7.19 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 1050 | <20 | <5 | <5 |
| | 5/1/2009 | 2.51 | 0.1 | 0.21 | 0.25 | 13 | NR | 7.37 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 1890 | <20 | <5 | <5 |
| | 5/1/2009* | 5.23 | <0.1 | 0.2 | 0.18 | 12 | NR | 7.35 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 1840 | <20 | <5 | <5 |
| | 5/14/2009 | 2.69 | 0.2 | 0.05 | 0.31 | 14 | NR | 7.23 | <15 | <5 | <10 | 8.2 | <15 | <0.2 | <20 | <10 | 2440 | <20 | <5 | <5 |
| | 6/16/2009 | 3.48 | 0.4 | 0.45 | 0.61 | 2 | 9000 | 7.20 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 10100 | <20 | <5 | <5 |
| Site 4 | 5/1/2009 | <0.03 | 0.3 | 0.28 | 0.06 | 34 | NR | 7.32 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | 1330 | <20 | <5 | 6.3 |

| 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 |
| | 5/14/2009 | 0.98 | 0.4 | 0.11 | 0.02 | 6 | NR | 7.31 | <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 | 7.36 | <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 | 190000 | 7.29 | <15 | <5 | <10 | 19.6 | <15 | <0.2 | <20 | 13.7 | 190000 | <20 | <5 | 69.1 |
| Field Blank | 11/6/2008 | 0.14 | <0.1 | <0.05 | <0.01 | <1 | <1 | 6.51 | 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 | 6.55 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | <50 | <20 | <5 | <5 |
| | 4/13/2009 | 0.45 | <0.1 | 0.12 | 0.15 | <1 | <1 | 6.50 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | <50 | <20 | <5 | <5 |
| | 4/20/2009 | <0.03 | <0.1 | 0.07 | 0.22 | <2 | <1 | 6.24 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | <50 | <20 | <5 | <5 |
| | 5/1/2009 | 0.17 | <0.1 | 0.14 | 0.02 | <1 | NR | 6.28 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | <50 | <20 | <5 | <5 |
| | 5/14/2009 | 0.19 | <0.1 | <0.01 | <0.01 | <1 | NR | 6.75 | <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 | 6.79 | <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 | 6.79 | <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 | 6.71 | <15 | <5 | <10 | <5 | <15 | <0.2 | <20 | <10 | <50 | <20 | <5 | <5 |

Notes: *field duplicate

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

| Location | Date | TKN RPD | NH3-N RPD | NO3-N RPD | TP RPD | TSS RPD | Fecal RPD |
|---|---|---|---|---|---|---|---|
| Site 1 | 4/13/2009 | 43.37 | 96.30 | 16.67 | 38.30 | -66.67 | 100.0 |
| | 6/16/2009 | -20.64 | 0.00 | -13.95 | 1.74 | 13.33 | 0.0 |
| Site 2 | 4/20/2009 | 6.24 | 0.00 | 0.00 | -4.38 | -66.67 | 190.24 |
| Site 3 | 5/1/2009 | -70.28 | 75.0 | 4.88 | 32.56 | 8.0 | Below Detect |
| | 6/10/2009 | 196.12 | 0.00 | -11.32 | 3.28 | 120.0 | 0.0 |
| Site 4 | 5/14/2009 | -9.71 | -2.25 | -152.69 | -120 | 40.0 | Below Detect |

| Location | Date | TKN RPD | $NH_3$-N RPD | $NO_3$-N RPD | TP RPD | TSS RPD | Fecal RPD |
|---|---|---|---|---|---|---|---|
| Field Blank | 11/16/2008 | 3 | FBD | FBD | FBD | FBD | FBD |
| | 2/11/2009 | 18 | FBD | 100 | 4 | FBD | FBD |
| | 4/13/2009 | 30 | FBD | 100 | 75 | FBD | FBD |
| | 4/20/2009 | FBD | FBD | 88 | 73 | FBD | FBD |
| | 5/1/2009 | 850 | FBD | 100 | 33 | FBD | FBD |
| | 5/14/2009 | 19 | FBD | FBD | FBD | FBD | FBD |
| | 6/16/2009 | 18 | FBD | 127 | 14 | FBD | FBD |
| | 6/30/2009 | 9 | FBD | FBD | 4 | FBD | FBD |
| | 7/21/2009 | 10 | FBD | FBD | FBD | FBD | FBD |

FBD = Field blank below detection limit

## APPENDIX G: Surface Soil Sampling Site and Sampling Variability Data

| Site | Soil pH | P | $NO_3$-N | Zn | Total Pb |
|---|---|---|---|---|---|
| Site 1 | | | | | |
| Footslope | 2.1 | 48.8 | 0.0 | 11.0 | 7.8 |
| Backslope | 2.6 | 11.1 | 0.0 | 12.7 | 1.8 |
| Summit | 1.7 | 28.4 | 0.0 | 46.1 | 5.1 |
| | | | | | |
| Site 2 | | | | | |
| Footslope | 1.1 | 28.0 | 0.0 | 13.8 | 1.5 |
| Backslope | 3.5 | 16.5 | 0.0 | 21.9 | 9.4 |
| Summit | 1.6 | 22.9 | 0.0 | 22.9 | 7.1 |
| | | | | | |
| Site 3 | | | | | |
| Footslope | 2.6 | 30.1 | 0.0 | 13.3 | 3.2 |
| Backslope | 2.7 | 17.3 | 15.4 | 25.4 | 2.0 |
| Summit | 4.0 | 48.0 | 86.6 | 22.9 | 4.0 |
| | | | | | |
| Site 4 | | | | | |
| Footslope | 2.4 | 25.3 | 9.1 | 11.6 | 0.0 |
| Backslope | 0.9 | 17.3 | 84.5 | 16.7 | 3.4 |
| Summit | 1.6 | 27.0 | 90.1 | 31.1 | 5.2 |

| Site | Position | Soil pH | P | $NO_3$-N | Zn | Cu | Total Pb | Cd | Ni | Cr |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Footslope | 5.6 | 24.0 | 0.0 | 2.2 | 0.2 | 37.0 | 0.1 | 0.1 | 0.0 |
| 1-D | Footslope | 5.7 | 24.0 | 0.0 | 2.0 | 0.2 | 33.0 | 0.1 | 0.1 | 0.1 |
| Difference | | 0.1 | 0.0 | 0.0 | 0.2 | 0.0 | 4.0 | 0.0 | 0.0 | 0.1 |
| RPD | | | 0.0 | 0.0 | 9.5 | 0.0 | 11.4 | 0.0 | 0.0 | 200.0 |
| 1 | Backslope | 5.6 | 20.0 | 0.0 | 1.7 | 0.2 | 33.0 | 0.1 | 0.1 | 0.1 |
| 1-D | Backslope | 5.7 | 17.0 | 0.0 | 1.5 | 0.2 | 33.0 | 0.1 | 0.1 | 0.1 |
| Difference | | 0.1 | 3.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RPD | | | 16.2 | 0.0 | 12.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Summit | 5.8 | 14.0 | 0.0 | 1.3 | 0.2 | 31.0 | 0.1 | 0.1 | 0.1 |
| 1-D | Summit | 6.0 | 24.0 | 0.0 | 1.8 | 0.2 | 30.0 | 0.1 | 0.1 | 0.1 |
| Difference | | 0.2 | 10.0 | 0.0 | 0.5 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 |
| RPD | | | 52.6 | 0.0 | 32.3 | 0.0 | 3.3 | 0.0 | 0.0 | 0.0 |
| 2 | Footslope | 5.5 | 24.0 | 0.0 | 3.0 | 0.2 | 38.0 | 0.1 | 0.1 | 0.1 |
| 2-D | Footslope | 5.3 | 18.0 | 0.0 | 2.4 | 0.2 | 41.0 | 0.1 | 0.2 | 0.1 |
| Difference | | 0.2 | 6.0 | 0.0 | 0.6 | 0.0 | 3.0 | 0.0 | 0.1 | 0.0 |
| RPD | | | 28.6 | 0.0 | 22.2 | 0.0 | 7.6 | 0.0 | 66.7 | 0.0 |
| 2 | Backslope | 5.9 | 18.0 | 0.0 | 1.7 | 0.2 | 32.0 | 0.1 | 0.1 | 0.1 |
| 2-D | Backslope | 5.9 | 17.0 | 0.0 | 1.9 | 0.2 | 33.0 | 0.1 | 0.1 | 0.1 |
| Difference | | 0.0 | 1.0 | 0.0 | 0.2 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 |
| RPD | | | 5.7 | 0.0 | 11.1 | 0.0 | 3.1 | 0.0 | 0.0 | 0.0 |
| 2 | Summit | 6.0 | 21.0 | 0.0 | 2.1 | 0.2 | 31.0 | 0.1 | 0.1 | 0.1 |
| 2-D | Summit | 6.0 | 13.0 | 0.0 | 1.5 | 0.2 | 32.0 | 0.1 | 0.1 | 0.1 |
| Difference | | 0.0 | 8.0 | 0.0 | 0.6 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| RPD | | | 47.1 | 0.0 | 33.3 | 0.0 | 3.2 | 0.0 | 0.0 | 0.0 |
| 3 | Footslope | 5.9 | 12.0 | 9.0 | 3.1 | 0.2 | 31.0 | 0.1 | 0.2 | 0.1 |
| 3-D | Footslope | 5.8 | 8.0 | 8.0 | 2.8 | 0.2 | 31.0 | 0.1 | 0.1 | 0.0 |
| Difference | | 0.1 | 4.0 | 1.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| RPD | | | 40.0 | 11.8 | 10.2 | 0.0 | 0.0 | 0.0 | 66.7 | 200.0 |
| 3 | Backslope | 6.5 | 11.0 | 15.0 | 1.5 | 0.2 | 29.0 | 0.1 | 0.1 | 0.0 |
| 3-D | Backslope | 6.4 | 9.0 | 10.0 | 1.4 | 0.2 | 28.0 | 0.0 | 0.1 | 0.0 |
| Difference | | 0.1 | 2.0 | 5.0 | 0.1 | 0.0 | 1.0 | 0.1 | 0.0 | 0.0 |
| RPD | | | 20.0 | 40.0 | 6.9 | 0.0 | 3.5 | 0.0 | 0.0 | 0.0 |
| 3 | Summit | 6.0 | 10.0 | 0.0 | 1.4 | 0.2 | 30.0 | 0.1 | 0.1 | 0.0 |
| 3-D | Summit | 5.9 | 8.0 | 0.0 | 1.7 | 0.2 | 32.0 | 0.1 | 0.1 | 0.0 |
| Difference | | 0.1 | 2.0 | 0.0 | 0.3 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 |
| RPD | | | 22.2 | 0.0 | 19.4 | 0.0 | 6.5 | 0.0 | 0.0 | 0.0 |
| 4 | Footslope | 6.2 | 17.0 | 10.0 | 2.4 | 0.2 | 27.0 | 0.1 | 0.1 | 0.0 |
| 4-D | Footslope | 6.2 | 17.0 | 10.0 | 2.1 | 0.2 | 30.0 | 0.1 | 0.1 | 0.0 |
| Difference | | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 |
| RPD | | | 0.0 | 0.0 | 13.3 | 0.0 | 10.5 | 0.0 | 0.0 | 0.0 |
| 4 | Backslope | 6.5 | 11.0 | 5.0 | 0.7 | 0.2 | 28.0 | 0.1 | 0.1 | 0.0 |
| 4-D | Backslope | 6.7 | 18.0 | 7.0 | 0.9 | 0.2 | 28.0 | 0.1 | 0.1 | 0.1 |
| Difference | | 0.2 | 7.0 | 2.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| RPD | | | 48.3 | 33.3 | 25.0 | 0.0 | 0.0 | 0.0 | 0.0 | 200.0 |
| 4 | Summit | 6.3 | 7.0 | 8.0 | 0.9 | 0.2 | 28.0 | 0.0 | 0.1 | 0.0 |
| 4-D | Summit | 6.2 | 7.0 | 1.0 | 1.1 | 0.2 | 27.0 | 0.1 | 0.1 | 0.0 |
| Difference | | 0.1 | 0.0 | 7.0 | 0.2 | 0.0 | 1.0 | 0.1 | 0.0 | 0.0 |
| RPD | | | 0.0 | 155.6 | 20.0 | 0.0 | 3.6 | 0.0 | 0.0 | 0.0 |

## APPENDIX H: 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:<br>37° 16.073’ N: 93° 51.542’ W +/-12ft | Described By:<br>Recorded By:<br>Doug Gisselbeck Tom DeWitt | Excavation Depth:<br>60’ | Landscape Position:<br>Summit | Aspect:<br>Elevation:<br>N<br>1215’ | % Slope:<br>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)<br>AS | 10YR 4/3 | | SIL | 12 | 0 | 0 | VFR | 1 F GR<br>1 F SBK | M F/M<br>M F/M | 1% F/FMM |
| BE | 5 – 8” (20cm)<br>CS | 10YR 5/4 | | SIL | 14 | 0 | 0 | FR | 2 F SBK | MF<br>CF | 1% F/FMM |
| Bt1 | 8 – 18” (45cm)<br>CW | 7.5YR 5/4 | 5% 10YR 5/4 CLF/APF | SIL | 25 | 1 | 0 | FR | 2 M SBK | MF<br>CF | 2% F/FMM |
| Bt2 | 18 – 25” (64cm)<br>CW | 7.5YR 4/4 | 10YR 4/3 CLF/HPF | SICL | 36 | 2 | 0 | FI | 2 M PR →<br>2 M SBK | FF<br>FF | 5% F/FMM |
| Bt3 | 25 – 32” (89cm)<br>CW | 7.5YR 4/4 | 10YR 4/2 CLF/VPF | SICL | 30 | 5 | 0 | FI | 2 M PR →<br>2 M SBK | FF<br>FF | 5% D/FMM |
| 2Btx1 | 32 – 38” (97cm)<br>CW | 7.5YR 4/6 | 10YR 4/2 CLF/VPF | GR SICL | 32 | 20 | 0 | FI | 1 M PR →<br>3 M SBK | VFF<br>VFF | 10YR 5/2 FED<br>2% D/FMN Clay films on vertical prism faces. Vert. seams <3” apart |
| 2Btx2 | 38 – 45” (114cm)<br>CW | 5YR 4/6 | ↓ | GR SICL | 38 | 25 | 0 | VFI | 1 M PR →<br>3 M SBK | VFF<br>VFF | ↓ |
| 3Bt | 45 – 60” (152cm)<br>---- | 2.5YR 4/6 | ↓ | GR SICL | 36 | 20 | 0 | FI | 1 M PR →<br>2 F SBK | VFF<br>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: N / Elevation: 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)<br>CS | 10YR 3/3 | | SIL | 14 | 10 | | VFR | 2 M GR | M F/M<br>M VF/F | |
| BE or Ap2 | 4 – 7" (18cm)<br>CS | 10YR 5/3 | | SIL | 12 | 10 | | VFR | 2 F SBK → 1 F GR | M F/M<br>M VF/F | (SLF?) |
| Bt1 | 7 – 11" (28cm)<br>CW | 7.5YR 5/3 | | GR SIL | 18 | 20 | | FR | 2 M SBK | M VF/F<br>M VF/F | F/F CLF |
| Bt2 | 11 - 20" (51cm)<br>CW | 5YR 4/4 | | GRV SICL | 36 | 25 | 15 | FR | 2 M SBK | CF<br>CF | |
| 2Btx1 | 20 - 29" (74cm)<br>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<br>CF | Weak fragipan; 7.5YR 6/2 FED in gray seams. Gray seams 2 – 3" apart |
| 2Btx2 | 29 - 38" (97cm)<br>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<br>FF | ↓ |
| 3Bt | 38 - 60" (152cm)<br>---- | 10R 3/6 | 10YR 5/2 CLF/VPF | GRV C | 60 | 15 | 15 | EF | 2 M PR → 2 M SBK | FF<br>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<br>M F/M | |
| Ap2 | 3 – 7” (18cm) CS | 10YR 4/3 | | SIL | 12 | 10 | | VFR | 2 M SBK → 1 F GR | M F/M<br>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<br>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<br>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<br>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<br>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 | ----<br>---- | 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 | ----<br>---- | 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:<br>37° 16.173‘ N: 93° 51.443‘ W +/-12ft | Described By:<br>Recorded By:<br>Doug Gisselbeck Tom DeWitt | Excavation Depth:<br>80” | Landscape Position:<br>Back Slope |
| | | Aspect:<br>Elevation:<br>E<br>1176’ | % Slope:<br>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)<br>CS | 10YR 3/2 | | SIL | 12 | 5 | | VFR | 2 F GR | M F/M<br>M F/M | |
| Ap2 | 4 – 8” (20cm)<br>CS | 10YR 4/3 | | SIL | 12 | 10 | | VFR | 1 F SBK → 1 F GR | M F/M<br>M F/M | |
| Bt1 | 8 – 18” (46cm)<br>CS | 7.5YR 4/4 | 10YR 4/2 CLF/APF | SICL | 28 | 15 | | FR | 2 M SBK | CF<br>CF | |
| Bt2 | 18 - 25” (64cm)<br>CW | 7.5YR 5/3 15% 5YR 4/4 | (CRK or RPO?) ↨ | GR SICL | 38 | 20 | | FI | 2 M SBK | CF<br>CF | (SLF?) |
| Bt3 | 25 - 32” (81cm)<br>CW | 2.5YR 3/6 | ↓ | GR SIC | 42 | 30 | | VFI | 2 M PR → 3 M SBK | FF<br>FF | 10YR 5/2 FED<br>Roots in vertical seams |
| 2Bt4 | 32 – 62” (157cm)<br>CW | 2.5YR 3/6 | ↓ | GRV SIC | 48 | 45 | 15 | VFI | 2 M PR → 3 M SBK | FF<br>FF | ↓ |
| 2Bt5 | 62 – 80” (203cm)<br>---- | 2.5YR 3/6 | ↓ | GRV C | 55 | 20 | 20 | EF | 2 M PR → 3 M SBK | FF<br>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<br>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<br>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<br>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<br>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 I: Forage Data

| Parameter | Site 1 Toe | | Site 1 Mid | | Site 1 Summit | | Site 1 Average and SEM | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | WET | DRY | WET | DRY | WET | DRY | WET | | DRY | |
| Moist / Dry Matter % | 71.46488 | 28.53513 | 69.43573 | 30.56428 | 70.25546 | 29.74454 | 70.39 | 1.02 | 29.61 | 1.02 |
| Protein .......... % | 2.35056 | 8.237425 | 2.667428 | 8.727271 | 2.845663 | 9.56701 | 2.62 | 0.25 | 8.84 | 0.67 |
| Adj Cr Protein ... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Avail Protein .... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| A.D.F. - N ....... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Urea ............ % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| A D Fiber ........ % | 12.56972 | 44.05 | 13.46968 | 44.07 | 12.51948 | 42.09 | 12.85 | 0.53 | 43.40 | 1.14 |
| N D Fiber(a) ..... % | 18.66483 | 65.41001 | 19.98904 | 65.4 | 18.84317 | 63.35 | 19.17 | 0.72 | 64.72 | 1.19 |
| Crude Fiber ...... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Lignin ........... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| T D N ............ % | 14.72764 | 51.61232 | 15.76989 | 51.59581 | 15.83316 | 53.23049 | 15.44 | 0.62 | 52.15 | 0.94 |
| NE Lactation MCAL/LB | 0.1447073 | 0.50712 | 0.1549389 | 0.506928 | 0.1564372 | 0.525936 | 0.152 | 0.006 | 0.513 | 0.011 |
| NE Gain .... MCAL/LB | 6.12E-02 | 0.2145625 | 6.55E-02 | 0.2143193 | 0.0708596 | 0.2382273 | 0.066 | 0.005 | 0.222 | 0.014 |
| NE Maint ... MCAL/LB | 0.1325316 | 0.4644508 | 0.1418762 | 0.4641896 | 0.1457255 | 0.4899234 | 0.140 | 0.007 | 0.473 | 0.015 |
| Digst Energy MCAL/LB | 0.1325316 | 0.4644508 | 0.1418762 | 0.4641896 | 0.1457255 | 0.4899234 | 0.140 | 0.007 | 0.473 | 0.015 |
| Crude Fat (EE) ... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| pH ............... | 0 | | 0 | | 0 | | | | | |
| Ash .............. % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Salt ............. % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Nitrogen ......... % | 0.3760895 | 1.317988 | 0.4267884 | 1.396363 | 0.4553061 | 1.530722 | 0.419 | 0.040 | 1.415 | 0.108 |
| Calcium ......... % | 8.56E-02 | 0.3 | 9.17E-02 | 0.3 | 0.1249271 | 0.42 | 0.101 | 0.021 | 0.340 | 0.069 |
| Phosphorus ....... % | 0.0456562 | 0.16 | 5.20E-02 | 0.17 | 4.16E-02 | 0.14 | 0.046 | 0.005 | 0.157 | 0.015 |
| Magnesium ........ % | 3.71E-02 | 0.13 | 3.36E-02 | 0.11 | 0.0386679 | 0.13 | 0.036 | 0.003 | 0.123 | 0.012 |
| Potassium ........ % | 0.450855 | 1.58 | 0.507367 | 1.66 | 0.5056572 | 1.7 | 0.488 | 0.032 | 1.647 | 0.061 |
| Sodium ........... % | 1.43E-03 | 0.005 | 1.53E-03 | 0.005 | 2.38E-03 | 0.008 | 0.002 | 0.001 | 0.006 | 0.002 |
| Iron ........... PPM | 19.97459 | 70 | 21.395 | 70 | 29.74454 | 100 | 23.70 | 5.28 | 80.00 | 17.32 |
| Copper ......... PPM | 1.141405 | 4 | 1.222571 | 4 | 0.8923361 | 3 | 1.09 | 0.17 | 3.67 | 0.58 |
| Manganese ...... PPM | 12.84081 | 45 | 7.335427 | 24 | 15.16972 | 51 | 11.78 | 4.02 | 40.00 | 14.18 |
| Zinc ........... PPM | 5.992377 | 21 | 4.890285 | 16 | 4.759126 | 16 | 5.21 | 0.68 | 17.67 | 2.89 |
| RFV/Quality Standrd | 78 [4] | | 78 [4] | | 82 [4] | | 79 | [4] | | |
| Nitrate (NO3) .... | Negative | | Negative | | Negative | | Negative | | | |

| Parameter | Site 2 Toe | | Site 2 Mid | | Site 2 Summit | | Site 2 Average and SEM | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | WET | DRY | WET | DRY | WET | DRY | WET | | DRY | |
| Moist / Dry Matter % | 72.70585 | 27.29416 | 71.52039 | 28.47962 | 72.96292 | 27.03708 | 27.89 | 0.84 | 72.40 | 0.77 |
| Protein .......... % | 2.556663 | 9.367071 | 2.394387 | 8.407371 | 2.470417 | 9.137144 | 8.89 | 0.68 | 2.47 | 0.08 |
| Adj Cr Protein ... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Avail Protein .... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| A.D.F. - N ....... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Urea ............. % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| A D Fiber ........ % | 12.34242 | 45.22 | 13.33985 | 46.84 | 12.36406 | 45.73 | 46.03 | 1.15 | 12.68 | 0.57 |
| N D Fiber(a) ..... % | 18.25979 | 66.9 | 19.77055 | 69.42 | 18.36088 | 67.91001 | 68.16 | 1.78 | 18.80 | 0.84 |
| Crude Fiber ...... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Lignin ........... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| T D N ............ % | 13.8235 | 50.64636 | 14.04298 | 49.30889 | 13.57946 | 50.22531 | 49.98 | 0.95 | 13.82 | 0.23 |
| NE Lactation MCAL/LB | 0.1353484 | 0.495888 | 0.1367978 | 0.480336 | 0.1327499 | 0.490992 | 0.488 | 0.011 | 0.135 | 0.002 |
| NE Gain .... MCAL/LB | 5.47E-02 | 0.20028 | 0.0513512 | 0.1803086 | 5.25E-02 | 0.1940173 | 0.190 | 0.014 | 0.053 | 0.002 |
| NE Maint ... MCAL/LB | 0.1225858 | 0.4491283 | 0.121826 | 0.4277656 | 0.1196179 | 0.4424216 | 0.438 | 0.015 | 0.121 | 0.002 |
| Digst Energy MCAL/LB | 0.1225858 | 0.4491283 | 0.121826 | 0.4277656 | 0.1196179 | 0.4424216 | 0.438 | 0.015 | 0.121 | 0.002 |
| Crude Fat (EE) ... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| pH ............... | 0 | | 0 | | 0 | | | | | |
| Ash .............. % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Salt ............. % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Nitrogen ......... % | 0.4090661 | 1.498731 | 0.3831019 | 1.34518 | 0.3952667 | 1.461943 | 1.422 | 0.109 | 0.396 | 0.013 |
| Calcium ......... % | 9.28E-02 | 0.34 | 7.69E-02 | 0.27 | 9.19E-02 | 0.34 | 0.305 | 0.049 | 0.087 | 0.009 |
| Phosphorus ....... % | 0.0682354 | 0.25 | 6.72E-02 | 0.236 | 6.22E-02 | 0.23 | 0.243 | 0.010 | 0.066 | 0.003 |
| Magnesium ........ % | 3.55E-02 | 0.13 | 3.42E-02 | 0.12 | 3.24E-02 | 0.12 | 0.125 | 0.007 | 0.034 | 0.002 |
| Potassium ........ % | 0.5431537 | 1.99 | 0.5980719 | 2.1 | 0.5001859 | 1.85 | 2.045 | 0.078 | 0.547 | 0.049 |
| Sodium ........... % | 1.36E-03 | 0.005 | 2.28E-03 | 0.008 | 2.70E-03 | 0.01 | 0.007 | 0.002 | 0.002 | 0.001 |
| Iron ........... PPM | 19.10591 | 70 | 19.93573 | 70 | 18.92596 | 70 | 70.00 | 0.00 | 19.32 | 0.54 |
| Copper ......... PPM | 1.910591 | 7 | 1.139185 | 4 | 1.351854 | 5 | 5.50 | 2.12 | 1.47 | 0.40 |
| Manganese ...... PPM | 19.37885 | 71 | 17.65736 | 62 | 15.68151 | 58 | 66.50 | 6.36 | 17.57 | 1.85 |
| Zinc ........... PPM | 5.458832 | 20 | 4.556739 | 16 | 4.596304 | 17 | 18.00 | 2.83 | 4.87 | 0.51 |
| RFV/Quality Standrd | 75 [5] | | 70 [5] | | 73 [5] | | 73 | [5] | | |
| Nitrate (NO3) .... | Negative | | Negative | | Negative | | Negative | | | |

| Parameter | Site 3 Toe | | Site 3 Mid | | Site 3 Summit | | Site 3 Average and SEM | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | WET | DRY | WET | DRY | WET | DRY | WET | | DRY | |
| Moist / Dry Matter % | 71.131 | 28.869 | 71.11187 | 28.88813 | 71.71913 | 28.28088 | 28.88 | 0.01 | 71.32 | 0.35 |
| Protein .......... % | 2.750356 | 9.527021 | 2.977435 | 10.30678 | 2.855476 | 10.09684 | 9.92 | 0.55 | 2.86 | 0.11 |
| Adj Cr Protein ... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Avail Protein .... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| A.D.F. - N ....... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Urea ............. % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| A D Fiber ........ % | 12.78897 | 44.3 | 12.95633 | 44.85 | 12.57085 | 44.45 | 44.58 | 0.39 | 12.77 | 0.19 |
| N D Fiber(a) ..... % | 19.25563 | 66.7 | 19.09505 | 66.1 | 18.75022 | 66.3 | 66.40 | 0.42 | 19.03 | 0.26 |
| Crude Fiber ...... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Lignin ........... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| T D N ............ % | 14.84038 | 51.40592 | 14.71903 | 50.95184 | 14.50302 | 51.28208 | 51.18 | 0.32 | 14.69 | 0.17 |
| NE Lactation MCAL/LB | 0.1457076 | 0.50472 | 0.1442789 | 0.49944 | 0.142332 | 0.50328 | 0.502 | 0.004 | 0.144 | 0.002 |
| NE Gain .... MCAL/LB | 6.11E-02 | 0.2115206 | 5.92E-02 | 0.2048094 | 5.93E-02 | 0.2096928 | 0.208 | 0.005 | 0.060 | 0.001 |
| NE Maint ... MCAL/LB | 0.1331393 | 0.4611842 | 0.1311473 | 0.4539834 | 0.1298721 | 0.4592223 | 0.458 | 0.005 | 0.131 | 0.002 |
| Digst Energy MCAL/LB | 0.1331393 | 0.4611842 | 0.1311473 | 0.4539834 | 0.1298721 | 0.4592223 | 0.458 | 0.005 | 0.131 | 0.002 |
| Crude Fat (EE) ... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| pH ............... | 0 | | 0 | | 0 | | | | | |
| Ash .............. % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Salt ............. % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Nitrogen ......... % | 0.440057 | 1.524324 | 0.4763897 | 1.649085 | 0.4568761 | 1.615495 | 1.587 | 0.088 | 0.458 | 0.018 |
| Calcium ......... % | 0.0692856 | 0.24 | 8.67E-02 | 0.3 | 8.48E-02 | 0.3 | 0.270 | 0.042 | 0.080 | 0.010 |
| Phosphorus ....... % | 6.21E-02 | 0.215 | 6.24E-02 | 0.216 | 6.39E-02 | 0.226 | 0.216 | 0.001 | 0.063 | 0.001 |
| Magnesium ........ % | 0.0375297 | 0.13 | 4.04E-02 | 0.14 | 0.0452494 | 0.16 | 0.135 | 0.007 | 0.041 | 0.004 |
| Potassium ........ % | 0.5340765 | 1.85 | 0.5055423 | 1.75 | 0.4977434 | 1.76 | 1.800 | 0.071 | 0.512 | 0.019 |
| Sodium ........... % | 1.44E-03 | 0.005 | 4.62E-03 | 0.016 | 1.70E-03 | 0.006 | 0.011 | 0.008 | 0.003 | 0.002 |
| Iron ........... PPM | 23.0952 | 80 | 20.22169 | 70 | 42.42131 | 150 | 75.00 | 7.07 | 28.58 | 12.07 |
| Copper ......... PPM | 1.44345 | 5 | 1.444407 | 5 | 1.979661 | 7 | 5.00 | 0.00 | 1.62 | 0.31 |
| Manganese ...... PPM | 10.97022 | 38 | 11.84413 | 41 | 15.27167 | 54 | 39.50 | 2.12 | 12.70 | 2.27 |
| Zinc ........... PPM | 6.062491 | 21 | 6.64427 | 23 | 6.504602 | 23 | 22.00 | 1.41 | 6.40 | 0.30 |
| RFV/Quality Standrd | 76 [4] | | 76 [4] | | 76 [4] | | 76 | [4] | | |
| Nitrate (NO3) .... | Negative | | Negative | | Negative | | Negative | | | |

| Parameter | Site 4 Toe | | Site 4 Mid | | Site 4 Summit | | Site 4 Average and SEM | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | WET | DRY | WET | DRY | WET | DRY | WET | | DRY | |
| Moist / Dry Matter % | 70.42554 | 29.57446 | 73.75879 | 26.24121 | 73.82553 | 26.17448 | 27.91 | 2.36 | 72.67 | 1.94 |
| Protein .......... % | 3.039305 | 10.27679 | 3.001056 | 11.43642 | 3.037907 | 11.60637 | 10.86 | 0.82 | 3.03 | 0.02 |
| Adj Cr Protein ... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Avail Protein .... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| A.D.F. - N ....... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Urea ............. % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| A D Fiber ........ % | 12.99502 | 43.94 | 11.81379 | 45.02 | 10.97758 | 41.94 | 44.48 | 0.76 | 11.93 | 1.01 |
| N D Fiber(a) ..... % | 19.66998 | 66.51 | 17.60785 | 67.1 | 16.55536 | 63.25 | 66.81 | 0.42 | 17.94 | 1.58 |
| Crude Fiber ...... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Lignin ........... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| T D N ............ % | 15.29092 | 51.70314 | 13.33355 | 50.81149 | 13.96522 | 53.35433 | 51.26 | 0.63 | 14.20 | 1.00 |
| NE Lactation MCAL/LB | 0.1502903 | 0.508176 | 0.1306308 | 0.497808 | 0.1380379 | 0.527376 | 0.503 | 0.007 | 0.140 | 0.010 |
| NE Gain .... MCAL/LB | 6.39E-02 | 0.2158992 | 5.32E-02 | 0.2027298 | 6.28E-02 | 0.240025 | 0.209 | 0.009 | 0.060 | 0.006 |
| NE Maint ... MCAL/LB | 0.1377835 | 0.4658868 | 0.1185457 | 0.4517538 | 0.1287425 | 0.4918629 | 0.459 | 0.010 | 0.128 | 0.010 |
| Digst Energy MCAL/LB | 0.1377835 | 0.4658868 | 0.1185457 | 0.4517538 | 0.1287425 | 0.4918629 | 0.459 | 0.010 | 0.128 | 0.010 |
| Crude Fat (EE) ... % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| pH ............... | 0 | | 0 | | 0 | | | | | |
| Ash .............. % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Salt ............. % | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Nitrogen ......... % | 0.4862888 | 1.644286 | 0.480169 | 1.829828 | 0.4860652 | 1.85702 | 1.737 | 0.131 | 0.484 | 0.003 |
| Calcium ......... % | 0.1064681 | 0.36 | 9.71E-02 | 0.37 | 6.81E-02 | 0.26 | 0.365 | 0.007 | 0.091 | 0.020 |
| Phosphorus ....... % | 6.80E-02 | 0.23 | 6.95E-02 | 0.265 | 6.44E-02 | 0.246 | 0.248 | 0.025 | 0.067 | 0.003 |
| Magnesium ........ % | 3.55E-02 | 0.12 | 3.94E-02 | 0.15 | 4.19E-02 | 0.16 | 0.135 | 0.021 | 0.039 | 0.003 |
| Potassium ........ % | 0.5175531 | 1.75 | 0.5300725 | 2.02 | 0.4318789 | 1.65 | 1.885 | 0.191 | 0.493 | 0.053 |
| Sodium ........... % | 4.44E-03 | 0.015 | 1.31E-03 | 0.005 | 6.28E-03 | 0.024 | 0.010 | 0.007 | 0.004 | 0.003 |
| Iron ........... PPM | 29.57446 | 100 | 28.86533 | 110 | 26.17448 | 100 | 105.00 | 7.07 | 28.20 | 1.79 |
| Copper ......... PPM | 1.478723 | 5 | 1.574473 | 6 | 1.570469 | 6 | 5.50 | 0.71 | 1.54 | 0.05 |
| Manganese ...... PPM | 11.82979 | 40 | 11.54613 | 44 | 14.13422 | 54 | 42.00 | 2.83 | 12.50 | 1.42 |
| Zinc ........... PPM | 5.914893 | 20 | 6.560303 | 25 | 6.281875 | 24 | 22.50 | 3.54 | 6.25 | 0.32 |
| RFV/Quality Standrd | 76 [4] | | 75 [5] | | 83 [4] | | 78 | [4] | | |
| Nitrate (NO3) .... | Negative | | Negative | | Negative | | Negative | | | |