CAROLEE DANIELLE BELEW
The Relationship Between Runoff and Soil Phosphorus Concentrations in a Benchmark Soil of the Southern Piedmont
(Under the direction of DAVID E. RADCLIFFE)

The relationship of P in runoff from simulated rainfall and soil test P (STP) was studied on Cecil and associated soils at six field sites. The strongest relationship ($R^2 = 0.692$) between STP and P in field runoff was obtained with BAP soil test on 5 cm soil samples and BAP in runoff. MIII STP and Total P in runoff was also highly correlated ($R^2 = 0.682$) at the 5 cm level. Laboratory rainfall simulations were conducted for comparison to field simulations. ANOVA was performed and no significant relationship was found with average field and laboratory P runoff values versus STP methods. To account for runoff variability, field and laboratory data were normalized by dividing by the depth of runoff. ANOVA was again performed and relationships between field and laboratory were significant ($P > 0.05$). Therefore, when runoff variability is accounted for, no significant difference existed between field and laboratory studies.

INDEX WORDS: STP, P in runoff, water quality, normalization

THE RELATIONSHIP BETWEEN RUNOFF AND SOIL PHOSPHORUS CONCENTRATIONS IN A BENCHMARK SOIL OF THE SOUTHERN PIEDMONT

by

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CHAPTER 1

INTRODUCTION

Since the passage of the Clean Water Act in 1973, a large amount of time and money has been devoted to controlling point source pollution, resulting in substantial reductions in the levels of many pollutants. Recently, lawsuits have been filed against the EPA and the state of Georgia citing their failure to carry out the responsibility of developing Total Maximum Daily Loads (TMDLs) as required by law under the CWA. As a result of court rulings against the EPA and Georgia, nationwide attention has shifted from point to non-point sources of pollution. The USEPA Clean Water Action Plan of 1998 states that polluted runoff, particularly from agricultural non-point sources, is now the most important source of water pollution that prevents the attainment of the water quality goals identified in the Clean Water Act (USEPA, 1998). Specifically, agricultural non-point source pollution is one of the main sources of nutrients to 50-60% of the eutrophied lakes and streams in the USA (USEPA, 1996). Phosphorus (P) is generally considered to be the limiting nutrient in eutrophication of freshwaters (Correll, 1998).

Phosphorus exists in the soil in a number of mineral and organic forms, but has been found to be mostly associated with iron and aluminum oxides in soils of the southeastern United States (U.S.) (Hsu, 1965). Iron and aluminum oxides have a large, but not unlimited, number of adsorption sites for P. When the adsorption capacity of these sites is exceeded, further additions of P in the form of chemical fertilizer or animal manure may lead to the loss of P to the surrounding environment.

It is unlikely, due to economic reasons, that a soil's fixation capacity for P will be exceeded through additions of chemical fertilizer. Recently, tremendous growth in the number of Confined Animal Feeding Operations (CAFOs) in the U.S. has led to increased production and land application of manure. Consequently, the potential for non-point source pollution from watersheds where CAFOs are found has increased. Most animal manures have roughly equal nitrogen (N) and P contents, but crops usually require more N than P. Manure application rates intended to supply a crop's need for N may result in the over-application of P.

The poultry (*Gallus gallus domesticus)* industry is a mainstay of the agricultural economy in many southeastern states, including Georgia. In 1999 alone, Georgia produced nearly 1.3 billion broilers (Georgia Agricultural Statistics Service, 2000). Yearly, this production generates about 1.4 million Mg of broiler litter (bedding plus manure). Broiler production in Georgia is concentrated in the northern counties with approximately 75% of all broilers raised in Georgia being produced in this area.

In addition to the broiler industry, beef cattle production is common throughout North and Central Georgia. Many farms in these areas combine cattle and broiler production. Due to its availability and relative inexpense, broiler litter is commonly applied to pastures and hayfields as fertilizer. In a review of the previous three years, the University of Georgia Soil Analysis Laboratory reported that over half of the Bermuda/Fescue pasture and hay samples submitted for testing contained "high" (46-83 kg ha^{-1}) or "very high" (>84 kg ha^{-1}) soil test phosphorus (STP) levels (D.E. Kissel, personal communication, 2001).

Numerous studies (Pote et al., 1996; Pote et al., 1999; Sharpley, 1995; Sharpley et al., 1996; and Sharpley, 1997) have shown that soils high in STP can contribute significant amounts of P to runoff in the form of dissolved reactive P (DRP) or particulate P (PP). The relationship between STP and P in the runoff is soil and site specific. Because of this, it is virtually impossible to assign a single acceptable STP value above which P loss will be unacceptable. Concentrations of 0.05 mg L^{-1} and 0.1 mg L^{-1} DRP have been identified as causing eutrophication in lakes and streams, respectively (USEPA, 1986). However, EPA has developed recommendations for limits on nurient levels in lakes and streams. The recommended limits vary by “ecoregion”. For Ecoregion IX, which includes most of Georgia, the proposed acceptable levels for total P (TP) are 0.02 mg L^{-1} and 0.04 mg L^{-1} for lakes and streams, respectively (USEPA, 2000a,b).

In the past, farmers viewed land applying poultry manure as a means of waste disposal rather than for its value as a fertilizer. Increased awareness to the benefits of poultry manure as a fertilizer has led to the over-application of P in many areas and farmers are now encouraged to develop and use a Nutrient Management Plan (NMP). A NMP is a convenient tool for farmers to assess nutrient inputs and outputs on their farms. NMPs were developed to insure that nutrients were not under-applied or over-applied to a given crop and have traditionally been based on a plant's need for N rather than P. The N:P ratio of most crops is 8:1 and because of the over-application of P, a shift from N-based to P-based NMPs seems likely and it will greatly impact the poultry's industry's ability to land apply broiler litter. The land area required for P-based NMP is three to four times larger than that required for current N-based plans. Environmentally sensitive or threshold soil P levels are those above which concern over the potential for P loss in runoff exceeds any crop production concerns (Sharpley, 1995). Consequently, regulations and economics demand that these "threshold" levels of STP that cause unfavorable environmental reactions be quickly and accurately determined.

The first objective of this research was to study the relationship between the concentration of DRP, bioavailable P (BAP), and total P (TP) in runoff from hayfields and pastures, and three different measures of soil P for a benchmark soil in the Piedmont of Georgia. The second objective of this research was to conduct indoor rainfall simulations for comparison with field rainfall simulations. The benchmark soil type chosen for this study was a fine, kaolinitic, thermic Typic Kanhapludults (Cecil, Madison, and Pacolet series).

CHAPTER 2

LITERATURE REVIEW

Forms of Phosphorus in Soils

Phosphorus (P) is a key component of cellular compounds, and is vital to both plant and animal life. P is essential to respiration and photosynthesis (ATP), genetic coding (DNA and RNA), and phospholipids, which play critical roles in cellular membranes (Brady and Weil, 1996). P does not occur as abundantly in soils as nitrogen (N) and potassium (K) (Tisdale et al., 1993). Sharpley (2000) reports that P concentrations in surface soils range from 100 to 3000 mg P kg^{-1}, while soil solution concentrations are < 0.01 mg P L^{-1}.

Soil P exists in both inorganic (P_i) and organic (P_o) forms. Inorganic P in soil is usually found in either calcium phosphate, or iron and aluminum phosphate minerals. Lindsay and Moreno (1960) concluded that the amount of P in solution was a factor of soil pH and the solubility of the P minerals present. At the low pH levels typically found in the weathered soils of the Southeastern U.S., solution P concentration will be governed by the solubility of variscite and strengite. However, Hsu (1965) found that surface-reactive amorphous Al hydroxides and Fe oxides were the real factors that govern the concentration of phosphate in solution, not variscite and strengite. The activity of variscite and strengite is limited by pH, being negligible at pH 5 or above, but no such limitations exist for the activities of Al and Fe oxides and hydroxides, which can be of any magnitude at any pH.

Hsu (1965) also observed that P added to soils undergoes two stages of reaction. The first stage is a rapid reaction where P is adsorbed to the surfaces of amorphous and crystalline Al hydroxides and Fe oxides in a matter of hours or even minutes. The availability of this adsorbed P to plants is a function of surface saturation. When the surface is nearly saturated, the adsorbed phosphate may be highly available to plants, whereas when the surface is unsaturated, desorption may be very difficult. The second stage in P fixation is a much slower reaction where the adsorbed P forms covalent bonds on Fe and Al oxide surfaces. Slow P fixation reactions also include the precipitation of a P compound, such as variscite or strengite, for which the solubility product has been exceeded. These second stage slow reactions comprise a shift from more loosely to a more tightly bound adsorbed P, which is less readily available to plants.

Organic P typically represents about 50% of the total P in soils but can vary between 15 and 80% (Tisdale et al., 1993). Most of the organic P compounds found in soils have not been characterized. Identified components of soil organic P include inositol phosphates (10 to 50%), phospholipids (1 to 5%), and nucleic acids (0.2 to 2.5%). The remaining 50% of organic P compounds are believed to contain very stable esters originating from microorganisms (Tisdale et al., 1993). Phytic acid is the most significant component of inositol phosphates which may account for 50% of the organic pool (Morgan, 1997). Only a small part of organic P is readily available for mineralization (Stewart and Tiessen, 1987). Phosphatase enzymes play a major role in the mineralization of organic phosphates in soil. Sharpley (1985a) found that as the phosphatase enzyme activity of surface soil increases, the potential for organic P mineralization increases as well. Rubaek et al. (1999) used ^{31}P Nuclear Magnetic

Resonance Spectroscopy to ascertain the identity of different categories of soil organic P. Six organic P categories were identified: monoester-P, teichoic acid-P, diester-P, phosphonates, pyrophosphates, and orthophosphates. Their results also suggest that the highly active and easily mineralized organic P was primarily associated with clay-sized particles.

Forms of Phosphorus in Runoff

Phosphorus in runoff occurs in both the dissolved (DP) and particulate (PP) forms. Dissolved phosphorus is comprised mostly of orthophosphate, which is immediately available for algal uptake (Walton and Lee, 1972). Particulate phosphorus refers to P associated with soil particles and organic matter eroded during runoff events and constitutes 60 to 90% of P transported in surface runoff from cultivated land (Sharpley et al., 1992). Due to low sediment losses from grass and forest land, DP is the dominant form found in runoff from these areas (Daniel et al., 1998). Dissolved phosphorus in runoff originates from the release of P from a thin zone of surface soil and vegetative material (Sharpley, 1985b). The effective depth of this interaction (EDI) is dependent upon soil aggregation, ground cover, slope, and rainfall intensity (Sharpley, 1985b). Studies conducted by Ahuja et al. (1981) and Sharpley (1985b) report a range of EDI's from 0.2 cm to more than 3.7 cm. EDI's in these studies were functions of the previously mentioned factors as well as the experimental methods employed. Clearly, the thickness of the soil layer that can supply P to runoff is thin, regardless of the experimental method used. In addition, the P in runoff may be characterized by its bioavailibility. Bioavailable P (BAP) represents the P potentially available for algal uptake and consists of DP and a variable portion of PP (Sharpley et al., 1992).

Phosphorus Runoff from Agricultural Land

Sources of P in agricultural runoff include commercial fertilizer, manure, and soil P. Recently, the number of soils with STP exceeding levels required for optimum crop yields has increased in areas of intensive agriculture and livestock production (Alley, 1991; Sims, 1992). Several factors that influence P losses from agricultural lands receiving poultry litter include rate, method, and time of litter application, STP level, and the interval between manure application and runoff-producing rainfall. Field research using simulated and natural rainfall has helped establish the relationship between P loss in runoff and the above mentioned factors.

Long-term applications of poultry litter tend to increase the concentration of P in the soil (Sharpley et al., 1993; Kingery et al., 1994). Impact assessments of long-term poultry litter application on soil and water resources in eastern Oklahoma indicate that P levels increase within the surface 5 cm of soil, making them more susceptible to P loss in runoff (Sharpley et al., 1991a; Sharpley et al., 1993). Several studies have investigated P surface runoff losses from pasture-applied broiler litter. Heathman et al. (1995) found total P concentrations to be 4.5 mg L^{-1} higher in runoff from bermudagrass plots with a litter application rate of 11 Mg ha^{-1} than from unfertilized plots. Researchers that used small runoff plots under simulated rainfall (McLeod and Hegg, 1984; Edwards and Daniel, 1993, 1994; Shreve et al., 1995) reported increases in the amounts of TP, DRP, and PP in runoff as a result of litter application. In addition, studies conducted on field-scale plots also found a positive correlation between the rates of litter applied and the amounts of TP, DRP and PP in runoff, although concentrations were usually lower than reported values from small plot studies (Mueller et al., 1984; Vervoort et al., 1998; Wood et al., 1999).

Most research has found that the highest concentration of P loss occurs after the first rainfall event from plots where poultry litter was applied (Edwards and Daniel, 1994; Heathman et al., 1995). Despite this, Heathman et al. (1995) reported that TP and SP concentrations were still greater than control plot values, 10 runoff events and 110 days after litter application. Likewise, Sharpley (1997) found that even after 10 rainfall events, P concentrations in runoff from treated soils were significantly greater than from untreated control plots. Additionally, Heathman et al. (1995) reported that less than 2% of P applied in litter was lost in runoff. Despite this, broadcast applications of poultry litter without incorporation still increased P loss in runoff up to 16 weeks after application.

Research has also documented contradictory results in field runoff studies. Sauer et al. (1999) found that soluble reactive P decreased from 13.5 mg L^{-1} to 1.2 mg L^{-1} after only two rainfall events. Additionally, Edwards and Daniel (1994) reported that levels of ortho-P and TP in runoff from litter-treated plots can approach background (control) levels after a fairly small number (2-5) of runoff events. These results can most likely be attributed to natural variability at the field level. Variations in fertilizer application rates, grazing effects, soil type, and hydrologic differences all contribute to the differences in reported levels of P leaving field plots.

A number of scientists (Westerman et al., 1983; Edwards and Daniel, 1993) have reported that litter application can elevate the concentration of nutrients and other materials in runoff from storms 1 to 3 days after application. Other scientists have found similar results associated with manure drying intervals. Westerman and Overcash (1980) investigated drying times of 1hr to 3 days. Their results indicate that concentrations of TP in runoff from grassed plots treated with liquid poultry manure was reduced approximately 90% over the course of a 3-day drying interval. Similarly, Sharpley (1997) found that by increasing the time between litter applications and rainfall from 1 to 35 days, DP was reduced from 0.74 to 0.45 mg L^{-1} and BAP from 0.99 to 0.65 mg L^{-1}. Both researchers agree that avoiding litter applications when rainfall events are likely reduces P runoff losses, and producers are encouraged to adopt this practice. However, these studies simulated different conditions than those normally found in Georgia pastures. Westerman and Overcash (1980) used liquid poultry manure while Sharpley (1997) incorporated poultry litter to a depth of 5cm. In Georgia, dry broiler litter is surface-applied to pastures and hayfields. Edwards et al. (1994) investigated dry poultry manure and the affects of extending the range of drying intervals to include 4, 7, and 14 days. They observed that the drying interval had no effect on either the concentration or mass of ortho-P or TP lost in runoff. When dry poultry litter is surface-applied, it is likely that a grass thatch layer will act to suspend much of the litter above the soil surface, thus conditions were not optimal for P fixation in this study. This result is contrary to the findings of Westerman and Overcash (1980) and Sharpley (1997) and is most likely attributable to the soil's ability to fix the manure P because of the direct contact between manure and soil. Additionally, if the soil P fixation process occurs rapidly, then drying interval should not influence runoff P concentration. As previously discussed, P added to soils undergoes a two stage reaction, with the first reaction of P adsorption to surfaces of amorphous Al hydroxides and Fe oxides occurring in a matter of hours or even minutes (Hsu, 1965). Therefore, in cases of liquid manure application and surface manure incorporation, soil P fixation processes may have a greater impact on the reduction of runoff P concentration than manure drying interval.

Agronomic Soil Testing for Environmental Purposes

Soil testing to determine the nutrient requirements for optimum plant growth began in the 19th century. Early testing efforts emphasized total soil analysis, until Daubeny (1845) developed the concept of active (*readily available*) and dormant (*unavailable or slowly available*) forms of plant nutrients in soils. Today, chemical extractants are commonly used to measure soil P as it relates to inorganic P minerals. Extractants are typically dilute concentrations of strong or weak acids, or buffered alkaline solutions that precipitate Al or Ca from solution (Sims, 1998). As the Al and Ca concentrations in solution decrease, native Al-P or Ca-P minerals dissolve to resupply Al or Ca to soil solution. This gives a measure of the plant available P present in the soil (Tisdale et al., 1993). Because these reactions can vary between physiographic regions, several different soil tests have been developed. The most common "routine" STP methods currently used in U.S. soil test labs include Bray and Kurtz (0.025 N HCl + 0.03 NH_4F), Mehlich I (0.25 N H_2SO_4 + 0.05 N HCl), Mehlich III (0.02 N CH3COOH + 0.025 N NH_4NO_3 + 0.015 N NH_4F + 0.013 N HNO_3 + 0.001 M EDTA), Morgan (0.72 N NaOAc + 0.52 N CH_3COOH, pH 4.8), Modified Morgan (0.62 N NaOAc + 1.25 N

CH_3COOH, pH 4.8), and Olsen-P (0.5 *N* $NaHCO_3$) (Gartley and Sims, 1994). In Georgia, the UGA Soil Testing Laboratory uses the Mehlich I extractant. These tests and subsequent interpretations have been developed from years of multi-site, multi-year field studies with a variety of crops. These "routine" tests have been very successful in predicting appropriate P applications, from an agronomic standpoint. However, there is less data regarding the use of "routine" soil tests and their interpretations for environmental assessments of nutrient loss potential.

One concern with using agronomic soil P tests for environmental assessments centers on sampling depth. Traditional agronomic soil tests require samples be collected to a depth of about 20 cm. However, in areas where a history of repeated surface manure application without tillage exists, surface soil P may be greatly underestimated due to dilution of the surface P by low P subsoil materials. Sharpley et al. (1994) reported dramatic accumulations of P in the surface 5 cm of soil when manure is not incorporated. This can be especially significant in pastures and hayfields where incorporation is not practical.

Recent studies have shown, however, that there is a strong correlation between soluble P in agricultural runoff and soil test P, which may indicate that traditional soil tests may have environmental, as well as agronomic uses (Sharpley 1995; Pote et al., 1996). More recently, Pote et al. (1999) reported a significant relationship between surface soil P levels (0 -2 cm deep) and P in runoff from pasture plots. Additionally, Sharpley et al. (1996) reported that several field studies have shown that soil test P accounted for 58 to 98% of the variability of the DP concentration in runoff. However, Siebbesen and Sharpley (1997) conclude that variability in runoff volume and erosion as a result of climatic, topographic and agronomic factors plays a larger role than soil test P in determining the amount of P losses from agricultural land. Therefore, the use of soil test P as the sole criteria for determining potential P enrichment of runoff and subsequent fertilizer or manure recommendations may not be an environmentally sound option.

New testing methods that are more environmentally focused have been developed as alternatives to traditional soil P tests. One such method is to measure the amount of P extracted from soil by distilled water. Although distilled water dissolves less P than other extractants, it may be the most appropriate method for predicting runoff DRP because it more accurately simulates the potential release of P to runoff water than chemical extractants, since rainwater is chemically similar to distilled water.

Methods for Environmental P Assessments of Runoff

There are testing methods that have been developed to analyze runoff for P that may be more appropriate environmental P assessment tools than the traditional agronomic soil test. One method attempts to measure the amount of P that is potentially available for uptake by algae, termed bioavailable P (BAP). Two different methods have been presented in literature to analyze for BAP. One method uses a 0.1 *M* NaOH extractant to provide an estimate of particulate P bioavailibility of runoff (Sharpley et al., 1991b). When NaOH is added to the unfiltered runoff samples, a portion of the P that is bound to sediment is solubilized. In this method, BAP is determined by the P that is solubilized by the 0.1 *M* NaOH plus the DP originally in the runoff. A second method uses Fe oxide-impregnated paper strips to estimate BAP in unfiltered runoff samples (Sharpley, 1993). The strip is shaken for 16 hours at which time the strip is removed, any soil particles adhering to the filter strip are washed off with deionized water and the P sorbed by the Fe-oxide on the filter paper is extracted by dissolving the Fe-oxide with an acidic solution, and the desorbed P is then measured colorimetrically. The strips act as an "infinite sink" for P that can be desorbed from a soil and simulates P uptake by algae. The Fe oxide-impregnated paper strip method may also be used to estimate BAP in soil samples.

While these methods for testing P in runoff are more environmentally oriented than the more "traditional" soil P test, they are not a comprehensive means to assess the potential for P loss from agricultural fields to sensitive surface waters. By incorporating the advances in testing methods with management and hydrologic factors known to influence P loss from soil to water, a more holistic approach to the environmental management of P could be attained. One such approach is the Phosphorus Index. Lemunyon and Gilbert (1993) proposed a very simple and direct approach to the P index that integrates soil test P with estimates of soil erosion and runoff, and P fertilizer and/or organic P source application rate, method, and timing, in a simple, weighted matrix system that can rapidly rate the P loss potential of a field (Sims, 1998). The P Index assigns an interpretive "rating" for risk of P loss to each of the above mentioned characteristics with 1 indicating low risk while 8 denotes very high risk. The "rating" value for each characteristic is then multiplied by a "weighting" factor, which reflects its relative importance to P loss. The "weighted" values are then added together to arrive at the P index rating. A disadvantage to this approach involves the determination and assigning of the weighting factors. Currently, the weighting factors that are being used are based on the professional judgement of the scientists involved, and not derived from field research. There are however, field studies currently underway to identify appropriate weighting factors based on local soil properties, hydrologic conditions, and agricultural management practices.

The Natural Resource Conservation Service issued the Conservation Practice Standard for Nutrient Management (Code 590) in April 1999, requiring states to have in place a method to assess the risk of P loss from agricultural fields by September 2001. Code 590 outlines three options from which States must choose: P Index rating, soil phosphorus threshold values (environmental threshold), or the soil test (agronomic threshold). Georgia opted to develop and use a P Index designed specifically for the state. Georgia's P Index was innovative in its approach because the risk of P loss from a field has been divided into terms that include runoff, erosion, and leaching losses of P (Radcliffe, D.E., personal communication, 2000). By including source and transport factors, each factor is a separate indicator of the risk for P loss from a field. This approach may better represent whether P loss in runoff, erosion, or leaching is actually taking place in a field on a site-by-site basis. This is especially crucial in Georgia where there are particular regions of the state where P loss is dominated by only one or two of the pathways mentioned.

Indoor Rainfall Studies

Today, it is commonplace for P runoff studies to be conducted on a field scale, or even watershed basis. However, early studies of P runoff used indoor rainfall simulators in controlled laboratory settings. Studies have used a variety of indoor rainfall simulators as well as different designs for the "soil boxes". While experiments have been conducted on "packed" soil boxes, we are unaware of any reports of experiments using “intact” sod samples.

In an early study (Sharpley et al., 1981b), a simplified model to describe the kinetics of soil P release to water was developed. This model includes the factors of P content of the soil and the amount of water used for desorption and can be represented by the equation

$$P_d = KP_o t^{\alpha} ws^{\beta}$$

where P_d is the amount of P desorbed per g of soil, in time t (min), at a water/soil ratio ws (cm^3/g), with P_o the initial amount of desorbable P per g of soil, and K, α, β, constants for a given soil. The units of K are min$^{-\alpha}$ (cm^3/g)$^{-\beta}$ while α and β are dimensionless. This model was later used in the analysis of soil P release to runoff from soil boxes under a simulated rainfall (Sharpley et al., 1981a). Ahuja et al. (1982) furthered these earlier studies by investigating, under controlled laboratory conditions, the effect of slope length, percent slope, soil cover, and storm size on average solution P concentration of runoff, and to relate these effects to the equation listed above.

Experiments were conducted with two different soils (Ruston fine sandy loam and Houston Black clay) in packed soil boxes under simulated rainfall. Soil boxes were made of plywood covered with black polyethylene sheeting and had an open bottom made of a nylon screen. Soil boxes were 100 cm long, 30 cm wide, and 10 cm deep. One end wall was provided with a V-shaped funnel to catch runoff. Sidewalls were extended 20 cm above the top of the box to contain splash during the rainfall. The screen bottom was covered with a 2.5-cm layer of gravel, thereby leaving 7.5-cm depth for packing the soil. Soil boxes were placed on supporting stands at the desired slope of 4, 8, 12, or 16%.

Calcium phosphate was uniformly mixed with soil at a rate of 50 kg ha^{-1}. Soil boxes were slowly wetted to field capacity and allowed to equilibrate for 3 days before rainfall simulations. At the end of this period, two 30-minute rainfalls of 6.0 cm hr^{-1} were applied to the boxes by a capillary-tube rainfall simulator. Additionally, three levels of soil cover were studied separately by mounting three different-sized screens 10 cm above the soil level in the boxes during the rainfall. The fine, medium, and coarse screens were intended to simulate the effect of grass or other vegetative cover in decreasing kinetic energy of the raindrops under natural conditions.

Results presented by Ahuja et al. (1982) indicated that the concentration of P in solution is influenced by slope length, degree of slope, soil cover, and storm size. The degree of slope and soil cover primarily influence the effective soil mass that interacts with rainfall and runoff, while the slope length influences both the soil mass and water / soil ratio. The effect of storm size on average P concentration is a result of the kinetics of P desorption.

Westerman et al. (1983) conducted research to determine how various factors affect the surface erosion and runoff transport of solids and nutrients from soil which has received surface-applied manure, and to estimate the relative contributions of manure particles and soil particles to solids transport in runoff. A factorial design was used to examine five factors at two levels each. The five factors investigated included manure type, manure application rates, rainfall intensity and amount, soil type and delay period between application and rainfall. To control experimental conditions, small plots of disturbed soil and simulated rainfall were used.

No standard sizes of soil erosion bins or splash cups have been established in the literature from similar laboratory studies. Westerman et al. (1983) constructed their soil bins 1 m long by 0.64 m wide with a soil depth of 5 cm on top of 2 cm of crushed gravel. Soil and stone were supported by an expanded sheet metal floor and wire screen. Bins featured a lip on the downslope end so that a runoff collection device could be attached. Side walls of the bin extended 1.9 cm above the soil surface and a sidesplash collector with a V-shaped trough was attached to one wall. The sidesplash collector and the upslope wall extended 16 cm above the soil surface.

For each test, soil (Norfolk sandy loam and Cecil clay) was packed in the soil bin to the appropriate bulk density and placed in an environmental chamber that maintained temperature, relative humidity, and constant air flow conditions. Soil bins remained in the chamber during soil wetting, manure or litter application, and the drying period of 1 or 3 days. Additionally, lights were on for 12 hours and then off for 12 hours during the drying time. Soil bins that received litter applications were wetted to approximately 80% of field capacity for each soil type and allowed to equilibrate for 2 hours prior to receiving the litter. Upon completion of the appropriate drying time in the environmental chamber, soil bins were placed on a supporting table that allowed for leachate collection. All experiments were conducted on a 9% slope. Rainfall was applied to soil bins with a rotating-disk simulator for 30 minutes at an intensity of either 5 or 10 cm h^{-1}.

From these experiments, Westerman et al. (1983) found that additions of layer manure and broiler litter to clay and sand soils yielded increased transport of solids and nutrients in rainfall runoff. Loading rate strongly influenced volatile solids, manure solids and nutrient transport, but had little effect on total solids or runoff volume. Drying time and manure type were significant factors, with the greatest effect being that increased drying time reduced manure and soil transport. Estimated manure transport was similar on both soil types and had an erodibility factor (*K*) value between those for the sand and clay soils. In addition, the estimated erodibility of manure and litter increased with increased loading rate. Results from this study and previous similar studies on erosion and nutrient transport show that the effects of applying poultry manure and livestock manures depend on several factors such as manure characteristics, loading rates, whether it is incorporated, and time between application and first rainfall.

In a related study, Miller and Baharuddin (1987) investigated 15 highly weathered Alfisols and Ultisols from Georgia in runoff/erosion pan studies to delineate sediment characteristics of interrill-eroding soils and their relationship to soil particle size. Although their study does not account for P in runoff, experiments were conducted on packed soil runoff/erosion pans. Indoor rainfall simulations conducted recently were based on many of the parameters outlined in this study.

Runoff and erosion measurements were made on small pans that were 0.36 m long by 0.2 m wide. Pans were loosely packed with 12 cm of soil over 2.5 cm of washed medium sand and placed on a 9% slope. The soil surface was carefully leveled to reduce microtopographic effects, and the soil pan was saturated from the bottom by connecting a water head to the pan drain. Prior to rainfall simulation, the water inflow was removed, and the soils allowed to drain until drippage had ceased. Fifteen-centimeter tall splash guards were attached, and rainfall was applied by a rotating boom simulator at an intensity of 11.2 cm h^{-1} for a duration of 25 minutes. Runoff and sediment was collected via the flume built on the front of the pan.

Miller and Baharuddin (1987) found that runoff rates and sediment concentrations varied consistently over time for the soils used, with concentrations increasing until peaking at 10 to 15 minutes, then decreasing as crust formation resulted in surface consolidation and decreased detachability, despite continued high runoff rates for most of the soils. Particle sizes of interrill-eroded sediment became finer after the initial sampling period, and were dominated by silt-sized particles, with lesser amounts of primary clay and sand. Miller and Baharuddin (1987) also concluded that the high proportion of easily transportable sediment generated by interrill erosion on these weathered soils poses a serious environmental problem in areas of active soil erosion.

Using these early erosion/runoff studies as a guide, an indoor runoff P study was designed and conducted. Deviating from earlier studies, intact soil sod samples were taken and used for comparison with a larger, field-scale P runoff study. However, findings from earlier studies conducted on small bins of packed, disturbed soil may not be consistent with findings obtained from the "intact" sod sample research study.

CHAPTER 3

MATERIALS AND METHODS

Site Selection

Experiments were conducted on soils of felsic igneous and metamorphic parent materials from the Piedmont region of Georgia. The benchmark soil chosen for this study was fine, kaolinitic, thermic Typic Kanhapludults (Cecil, Madison, and Pacolet soil series). The well-drained Cecil soil comprises 14.7% of all soils mapped in the Piedmont (Soil Survey Staff, 1995). Madison and Pacolet soil series were included in this study because their surface horizons are very similar to that of Cecil soil and they are often mapped together.

Six sites in the Piedmont region of Northeastern Georgia were selected (Fig. 1). Three criteria were utilized in site selection: 1), Cecil and associated (Madison and Pacolet) soils should be present; 2), Mehlich I Soil Test P (STP) level covering a range from low (<10 ppm) to very high (>37.5 ppm); and 3), no manure application in the previous 12 months. Soil series was verified from borings prior to field experimentation. Sites with STP values of low (<10 ppm), medium (10.5 - 20 ppm), high (20.5 - 37.5 ppm), and very high (>37.5 ppm) ranges for fescue and clover pastures in the Piedmont (Soil Test Handbook for Georgia, 1989) were selected. Preliminary soil samples were taken to verify Mehlich I STP levels (Table 1). Manure application history was verified verbally by the owners and/or operators of the fields.

Field Simulations

Following site selection, plot areas were mowed to a uniform height across the plots one week prior to the initial rainfall simulation. Plots were pre-soaked 24 hours prior to the first simulated rainfall event via a drip-irrigation system with approximately 400 L of water to standardize antecedent soil moisture levels and reduce time to runoff (Fig. 2). Pre-soaking field plots also facilitated the installation of plot borders and flumes. Ground cover within each plot was estimated by counting the number of bare soil intersections on a 1 m^2 plexi-glass sheet with a 10-cm grid. Slope at each landscape position for the six sites was also measured and recorded. Site descriptions as well as soil profile descriptions can be found in Appendix A.

Paired 1 x 1-m plots (Fig. 3) were installed at three different landscape positions within each site (summit, backslope, and toeslope). Plot borders consisting of approximately 0.3-cm thick sheet metal 15-cm tall were pressed into the ground to a depth of at least 7 cm to isolate runoff. Due to drought conditions, plot border installation was facilitated by the use of a truck mounted hydraulic press (Fig. 4). Aluminum flumes were installed at the down-gradient edge of each plot to divert surface runoff to a collection point (Fig. 5). Special attention was placed on the installation of borders and flumes in an attempt to reduce leakage around plot edges. Clear silicone caulk was used at the intersections of metal borders to minimize the intrusion of runoff from outside the plots and to ensure that runoff did not escape from within the plots.

A total of 54 rainfall simulations (3 rainfall events, 3 paired plots, and 6 sites) were conducted in this study. The rainfall scheme consisted of three rainfall simulations at 48-hour intervals at each of the six sites. Cassel and Nielson (1986) reported that a

48-hour delay between rainfall events was sufficient time for soil to return to field capacity.

Simulated rainfall was applied to each pair of plots with a JOERNS INC. rainfall simulator (Fig. 6). Local well water was used as the water source for the simulator and rainfall was applied at a rate of 75 mm hr^{-1} to allow comparison of runoff between the six sites. Collection of runoff began after significant runoff commenced and continued for 30 minutes. Runoff was collected *in toto* and a 500-mL composite sample was taken and immediately placed on ice. Total runoff volume was recorded and a source water sample taken. In the lab, 125 mL of each runoff sample was filtered (0.45-μm pore diameter) to remove any particulate matter. The remaining unfiltered sample, filtrate, and source water sample were acidified with concentrated HCl (approximately 1 drop of acid per 10 mL of runoff sample to lower pH to around 2). All water samples were stored at -20°C until analyzed.

After the 3rd rainfall event, soil samples were collected from within each plot to 2-cm, 5-cm, and 10-cm depths by collecting 10 sub-samples at each depth with a soil probe. Soil samples were composited and placed on ice for transport and stored at -20°C until analyzed.

Laboratory Simulations

A sod sample pan runoff study, similar to small soil bin runoff-erosion studies (Ahuja et al., 1982, Westerman et al., 1983, and Miller and Baharuddin, 1987) was conducted utilizing an indoor rainfall simulator. The purpose of this study was to compare field rainfall simulations to laboratory rainfall simulations. Sod block samples were taken after the 3rd rainfall event from each field plot area to maintain as much uniformity in field conditions as possible. The 3rd outdoor rainfall event served as a "pre-soak" period and consequently the moist soil conditions made the sod removal process possible.

A total of six 20-by-40-by 4 cm sod blocks were taken from each site (two at each landscape position, one from each side of the paired plots) and placed in metal runoff pans of the same dimension. The metal runoff pans were similar to pans used by Miller and Baharuddin (1987). The pans were packed with 4 cm of sand and had small holes drilled in their bottoms to allow for pre-soaking of the sod blocks and drainage.

A "sod cutter" was designed with the same dimensions as runoff pans and used in the acquisition of a 4-cm thick sod sample. The sample area was selected (Fig. 7A), the sod cutter was driven into the ground (Fig. 7B) and removed by first digging around the cutter itself, and then using a metal wire to slice off the underside (Fig. 7C). Sod samples were removed as carefully as possible in order to achieve a tight fit with the runoff pans (Fig. 7D). Runoff pans were transported to the indoor rainfall facility and pre-soaked in plastic containers for at least 48 hours prior to the initial rainfall simulation. Samples were allowed to drain freely until drippage ceased before the first rainfall simulation. Between rainfall simulations, pans were allowed to drain to field capacity and stored in plastic containers.

Two rainfall simulations were conducted on each of the six sod pan samples from each study site. Rainfall was produced by an indoor rainfall simulator based on a design by Miller (1987) (Fig. 8). All laboratory rainfall simulations were conducted on a slope of 9% with rainfall intensity approximately equal to that of field simulations. Rainfall intensity varied between 75 to 80 mm hr^{-1} for all simulations.

Runoff from the sod blocks drained via a flume built onto the front of the pans into collection beakers. A splash guard (Miller and Baharuddin, 1987) (Fig. 9) was attached to the top of pans to avoid collection of direct rainfall into the runoff flume. Runoff was collected *in toto* for 30 minutes after a steady stream of runoff had been achieved. Total runoff volume was recorded and a composite water sample was taken. Commonly, due to low runoff amounts, the entire runoff sample was retained. A sub-sample of each runoff sample was filtered (0.45-μm pore diameter) to remove any particulate matter. The amount filtered varied depending on runoff amount. Both filtered and unfiltered runoff samples were acidified with concentrated HCl (approximately 1 drop of acid per 10 mL of runoff sample to lower pH to around 2). All runoff samples were stored at -20°C until analyzed.

Laboratory Analyses

Laboratory analyses were conducted on both soil and water samples from field and laboratory rainfall simulations. Gravimetric water content was determined on a subsample of the soil obtained from each runoff plot by weighing the soil before and after drying for 24 hours at 60°C. Soil samples were air dried, ground, and sieved to 2 mm to remove large rock fragments and most of the grass thatch material, then oven-dried for 48 hours at 35°C (A.N. Sharpley, 2000, personal communication). Soil pH was determined in a 1:2 soil/water mixture using a glass electrode. Particle size distribution (Kilmer and Alexander, 1949) was determined for soil characterization samples (Appendix A).

Extractable P in each plot soil sample was determined using three different methods: Mehlich III (Mehlich, 1984), Fe oxide-coated paper circles (Myers et al., 1997), and distilled water (Pote et al., 1996). Runoff plot soil sample analyses can be found in Appendix B.

Water analyses were conducted on runoff and source water samples. Total P for all unfiltered runoff samples was determined by Kjeldahl digestion and measured colorimetrically (Murphy and Riley, 1962) with a Series 500 Perstorp Analytical autoanalyzer. Dissolved Reactive P (DRP) for all filtered runoff samples was determined colorimetrically with the autoanalyzer. Bioavailable P (BAP) was determined for the unfiltered field runoff samples by the Fe oxide-coated paper circle method (Myers et al., 1997) and measured colorimetrically with the autoanalyzer. The Fe oxide-coated paper circle method is a slight modification of the filter strip paper method documented by Sharpley (1993). Filter paper circles were found to be easier to control in extraction procedures than the paper filter strips. Due to the large volume of sample required to determine BAP, this procedure was not performed on the indoor runoff samples. Field runoff analyses can be found in Appendix C and indoor runoff analyses can be found in Appendix D.

Statistical Methods

For each soil test method, the mean, range, and coefficient of variation (CV) was calculated by site and depth for all samples and analyzed. For each P runoff analysis method, the mean, range, and CV was also calculated by site and analyzed. Overall flow-weighted total P, DRP, and BAP concentrations (3 landscape positions x 6 sites = 18) were calculated by multiplying the concentration of P in runoff from each plot by the runoff plot volume, adding these values together for the three simulated rainfall events, and dividing by the total runoff volume collected for the three events. Total P and DRP concentrations from the indoor runoff study were calculated by the same method.

All STP methods were statistically compared by correlating STP results to the overall flow weighted total P, DRP, and BAP losses from each field and indoor sites through regression analysis. Linear regressions were developed and coefficients of determination were calculated for each. Additionally, field (Appendix C) and indoor runoff data (Appendix D) were normalized by dividing by the depth of runoff from each site.

Statistical analyses were performed using the Statistical Analysis System (SAS Institute, 1987). The principle of conditional error, put forth by Bose (1949) was used to evaluate regression equations between average and normalized values for both pan and field runoff TP and DRP versus STP method at 2-cm, 5-cm, and 10-cm depths. The principle of conditional error is a technique for obtaining the sum of squares due to deviations from a hypothesis for linear models. Milliken and Johnson (1984) utilized computers to test this principle and similar procedures were used in this analysis. The null hypothesis first tested was that one equation could be used to describe both field and laboratory data. This procedure provided an estimate of the residual sum of squares for the null hypothesis. Secondly, the alternative hypothesis that a separate equation was needed for both field and laboratory simulations was tested. The addition of the residual sum of squares for each separate equation (field and lab) provided an estimate of the residual sum of squares for the alternative hypothesis. The difference between the residual sum of squares of the null and alternative hypotheses provided an estimate of the residual sum of squares due to deviations from the null hypothesis. This residual sum of squares was then used in an *F* test against the residual sum of squares of the alternative hypothesis to determine if field and lab simulations were significantly different.

CHAPTER 4

RESULTS AND DISCUSSION

Soil Phosphorus

The mean, range, and CV of STP concentrations obtained from all plots for each STP method used are shown in Table 2. Water extractable P resulted in the largest degree of variability with a CV range of 13 to 169% over all sites and depths. Mehlich III and BAP had similar ranges of variability with CVs of 10 to 36 and 9 to 45%, respectively. On average, the 0-2 cm sampling depth produced the least variable STP, regardless of method, over all sites with a CV range of 10 to 69%. The STP range of variability for all sites and STP methods for the 0-5 cm sampling depth (CV 11 to 50%) was slightly higher than the 0-2 cm CV. The 0-10 cm sampling depth produced the greatest variability over all sites and all STP methods with a CV range of 9 to 169%. This is most likely attributed to the variability of the A horizon thickness and that some 0-10 cm samples included sub-soil materials. Because this sub-soil material is typically lower in extractable P, it may have diluted the extractable P in some of the 0-10 cm samples, thereby resulting in increased variability. Sharpley et al. (1994) reported dramatic accumulations of P in the surface 5 cm of soil when manure is not incorporated. Although the field sites chosen for this study had not received additions of poultry manure for at least 12 months, higher concentrations were expected at the soil surface due to past manure applications. Generally, most STP values decreased with increasing depths, as expected (Table 2).

Field Simulations

The total surface runoff from each field plot ranged from a low of 0.09 mm to a high of 37.5 mm, with a mean of 16.1 mm. There was appreciable runoff variability from the plots (CV = 55.1%). The runoff variability was most likely related to differences in permeability and antecedent moisture conditions. Likewise, a portion of the variability in runoff volume was likely due to leakage around the plot borders and runoff collection flumes. Runoff volume by site and plot is listed in Appendix C.

Source water was analyzed for TP and ranged from a low of 0.012 mg L^{-1} to a high of 0.094 mg L^{-1}, with a mean of 0.04 mg L^{-1}. To eliminate this variability from data analyses, initial source water P concentrations were subtracted from TP, DRP, and BAP runoff concentrations from field and laboratory simulations.

The mean, range, and CV for Total P, DRP, and BAP runoff concentrations (mg L^{-1}) from each site from field simulations are presented in Table 3. Total P ranged from 0.42 mg L^{-1} to 1.25 mg L^{-1}, DRP ranged from 0.15 mg L^{-1} to 0.80 mg L^{-1}, and BAP ranged from 0.13 mg L^{-1} to 0.78 mg L^{-1}. BAP and DRP levels were similar at each site but DRP values showed greater variability with the CV of DRP ranging from 33 to 114%, whereas the CV of BAP ranged only from 17 to 57%. The high degree of variability in the DRP may most likely be attributed to the variability of runoff volume from the field plots.

The coefficient of determination, value, slope, and *y* intercept for each STP correlation to overall flow weighted total P, DRP, and BAP in runoff from field simulations was determined and summarized in Tables 5, 7, and 9, respectively. Strong relationships were found between all forms of P in runoff and all soil P test methods. The strongest relationship ($R^2 = 0.692$) between STP and P in runoff was obtained with BAP soil test on 5-cm samples and BAP in runoff (Fig 10). Because BAP was extracted by the Fe oxide-coated paper method in both the runoff and soil, a higher correlation between soil BAP and runoff BAP might be expected due to similar extraction method. The BAP soil test at 0-5 cm was also highly correlated with total P ($R^2 = 0.687$) (Fig. 11) and DRP ($R^2 = 0.610$) (Fig. 12) in runoff. The highest correlation between STP method and DRP in runoff occurred with water extractable P and the 0-5 cm sampling depth ($R^2 = 0.659$) (Fig. 13). Since water is the solvent for P in the runoff, a highly correlated relationship was expected with the distilled water STP extractant and DRP in runoff. Similar to Pote et al. (1996, 1999), we also found that the strongest correlations to DRP and BAP in runoff were obtained with STP extractants of distilled water or the Fe-oxide paper method. It's important to note, however, that the correlation between Mehlich III STP and DRP at one 0-5 cm depth was only slightly ($R^2 = 0.644$) correlated.

In this study it was found that regardless of the STP method or runoff P form, the strongest correlation between the two was observed for samples collected to 5 cm. These results are somewhat contradictory to those of Pote et al. (1996) who reported a highly significant relationship between P in runoff and several STP methods when soil samples were collected to a depth of only 2 cm. There are two likely reasons why we did not observe the same level of correlation as reported by Pote et al. (1996, 1999) and others. The first lies in the much lower STP levels present at the field sites chosen for this study and the high degree of variability present. Plots used in studies by Pote et al. were constructed in 1993 on well-established fescue pastures and STP levels had been controlled and manipulated by the additions of various fertilizer amendments over several years. Limiting our sites to fields where poultry litter had not been applied in the preceding 12 months made it difficult to find sites with very high STP (>400 mg P kg^{-1}). As a result, we did not span the range of low to high STP as adequately as similar studies.

Laboratory Simulations

The total surface runoff from each pan ranged from 0.30 mm to 22.46 mm, with a mean of 4.39 mm. There was significant runoff variability from the pans (CV = 112.5%). The runoff variability was most likely related to the goodness of fit between the sod sample and the runoff pan. Sod block samples were extremely difficult to collect to the exact dimensions (20 x 40 x 4 cm) of the runoff pans due to problems associated with the sod removal process. As a result, leakage occurred along sides of the pans.

The mean, range and CV for Total P and DRP runoff concentrations (mg L^{-1}) from each site from indoor rainfall simulations are presented in Table 4. Total P ranged from 0.14 mg L^{-1} to 0.66 mg L^{-1} and DRP ranged from 0.00 mg L^{-1} to 0.30 mg L^{-1}. Like field runoff losses, DRP values showed greater variability with the CV of DRP ranging from 0 to 172%, whereas the CV for Total P ranged only from 42 to 90%. The high degree of variability in DRP may most likely be attributed to the variability of runoff volume from the pans. This is reasonable due to high CV percentage for pan runoff variability.

Regression analysis to relate STP to overall flow weighted total P and DRP in runoff from indoor simulations was conducted and summarized in Tables 11 and 13. The relationships between forms of P in pan runoff and soil P test methods were not as strong as the relationships found in the field study. However, the overall strongest relationship

($R^2 = 0.3239$) between STP and P in pan runoff was obtained with BAP soil test on 5 cm samples and DRP in runoff (Fig. 14). The strongest relationship ($R^2 = 0.2638$) between STP and TP in pan runoff was obtained with water extractable soil P on 2 cm samples (Fig. 15). Like the field plots, regardless of STP method, 5 cm samples generally resulted in the best correlations, even though values were low.

If laboratory rainfall simulations were to be conducted again, several changes in the procedure to reduce the highly variable nature of the experiment would be suggested. First, collection of a larger sod block sample would help in soil and water interaction and perhaps aid in runoff variability. Second, rainfall simulation time should be longer than the 30 minute period simulated in the field. Because runoff pans were considerably smaller in size than field plots, 30 minutes of rainfall did not produce enough runoff to conduct the desired water analyses. Additionally, sealing the pan – soil interface would most likely reduce leakage around edged and would decrease runoff variability. Although no alternatives can be presented at this time, a better sod sample collection process would be helpful. The technique employed in this study made it difficult to obtain a precise 4 cm thick sod sample, which in turn affected the runoff volume.

Effects of Runoff Volume

Because site hydrology of each soil is likely to impact the relationships between soil P and runoff P (Gburek and Sharpley, 1998), we attempted to account for this by evaluating the effect of runoff volume on P runoff concentrations from both pan and field plots. Following research by Pote et al. (1999), TP and DRP concentrations from indoor simulations and TP, DRP, and BAP concentrations from field simulations were normalized by dividing by the depth of runoff from each site.

Regression analysis to relate STP to normalized overall flow weighted TP and DRP in runoff from indoor rainfall simulations was conducted (Tables 12 and 14). There was a strong relationship between DRP in runoff and all soil P test methods. The strongest relationship (R^2 = 0.9064) between STP and P in pan runoff was obtained with BAP soil test on 5 cm samples and DRP in pan runoff (Fig. 16). This relationship is reasonable due to the fact that BAP represents P potentially available for algal uptake and consists of a portion of DRP and particulate P. The best correlation (R^2 = 0.4028) between STP and TP in pan runoff was obtained with Mehlich III STP on 2 cm samples (Fig. 17). Correlations between overall flow weighted TP and DRP in runoff and STP method are not substantially different from one another. However, by normalizing runoff DRP data, the relationship between forms of P in the soil and DRP in runoff is significantly improved. In general, normalizing pan total P runoff data also improved the relationship between P method and TP in runoff. Furthermore, with normalized data, there were better correlations with STP methods over all sample depths.

TP, DRP, and BAP concentrations in runoff from field simulations were also normalized by runoff (Table 6, 8, and 10). The strongest relationship (R^2 = 0.7225) between STP and P in runoff was obtained with Mehlich III STP on 10 cm samples and DRP in runoff (Fig. 18). DRP in runoff was also highly correlated to water extractable STP (R^2 = 0.6933) at 10 cm (Fig, 19) and bioavailable soil P (R^2 = 0.6057) at 2 cm (Fig. 20). Because normalization accounts for runoff variability, this process did not significantly improve the relationships between forms of P in runoff and STP methods for the field rainfall simulations. This can be explained by the fact that there was less runoff variability from field simulations (CV = 55.1%) as compared to indoor simulations (CV = 112.5%).

Laboratory vs. Field Simulations

The second objective of this research was to conduct laboratory rainfall simulations and compare them to field rainfall simulations and evaluate any relationships that may be developed. Ideally, we would like to prove that one equation could describe the relationship between the pan and field data, and therefore conclude no difference between indoor pan and field simulations exists. To answer this question, analysis of variance was used to evaluate regression equations between average pan and field TP, average pan and field DRP, normalized pan and field TP, and normalized pan and field DRP.

For all average flow weighted values, whether for TP or DRP, pan or field, one equation could not describe the relationship for the laboratory and field simulations at ($P < 0.05$) (Table 15). However, when normalized values were examined, one equation was sufficient ($P < 0.05$) to describe the relationship between TP and DRP concentrations in pan and field runoff and differing STP methods (Table 16). Figures 21, 22, and 23 show the relationship between normalized pan and field DRP and water extractable soil P at each 2, 5, and 10 cm sample, respectively, with one equation. Figures 24, 25, and 26 show the relationship between normalized pan and field TP and water extractable soil P at 2, 5, and 10 cm sample, respectively, with one equation. Regression analysis results for one equation fitted through normalized total P and DRP data is summarized in Tables 19 and 20.

Normalizing by runoff does not improve the relationship between TP in runoff and STP. This is most likely attributed to a data point that is a possible outlier. In data analyses performed thud far, no TP data points have been removed. In future analyses of data, this point will be examined more closely and likely removed, thereby improving the relationship between TP and STP. However, it seems DRP acts differently and when there is more runoff, there is an increased concentration of DRP in the runoff. Like Pote et al. (1999), I expected higher volumes of runoff to ordinarily produce lower DRP concentrations due to dilution. Pote et al. (1999) attempts to explain this trend by hypothesizing that rapid movement of DRP into soil profiles of soils with low runoff volumes and high infiltration rates may take DRP away from the top few surface cm of soil, thus reducing the chances for transfer to surface runoff. Soils that have lower infiltration rates may have much more of the DRP remaining at the soil surface long enough to be lost in runoff water.

Because one equation could not describe the relationship between field and pan simulations plotted with average flow weighted values, we sought to determine whether it was due to the slope or intercepts differing from one another. To do this, the principal of conditional error was also applied and similar analyses conducted. The results of this test were not what we expected. Results did not clearly determine whether slopes or intercepts were the cause for the rejection of the null hypothesis. What could be determined was that a single equation with the same slope (Table 17) and intercept (Table 18) could not adequately describe this relationship. However, if an equation that has the same slope and different intercept, or vice-versa was used, a single model could be used to describe the relationship between average pan and field simulations.

CHAPTER 5

CONCLUSIONS

The results of this study reinforce previous evidence of a linear relationship between P levels in surface soil (0-5 cm deep) and DRP and BAP concentrations in runoff from the soil surface (Pote et al., 1996, 1999). For field simulations, there was significant correlation between all forms of P in runoff and all soil P test methods used. However, STP correlated best with field runoff P when extracted with Fe oxide-coated paper or distilled water. The strongest relationship ($R^2 = 0.692$) between STP and P in field runoff was obtained with BAP soil test on 5 cm samples and BAP in runoff. Because STP extractants gave results that were similarly correlated, the field simulation study did not clearly identify any particular STP method for maintaining the highest correlation to DRP and BAP concentrations in runoff from the six field plots. For indoor simulations, there was little correlation found between forms of P in runoff and soil P test method. The strongest relationship ($R^2 = 0.3239$) between STP and P in pan runoff was obtained with BAP soil test on 5 cm samples and DRP in runoff. Correlations between STP and P in pan runoff were significantly lower than those found by the field study. Like the field study, one particular STP method for maintaining the highest correlation to DRP and BAP concentrations in runoff could not be identified.

This research showed that differing STP levels on P concentrations in runoff are not always consistent across a soil series. When data for P concentrations in runoff were normalized (divide each concentration by the depth of runoff from each site), resulting correlations improved for the indoor pan study. The best correlation ($R^2 = 0.9064$) between STP and P in pan runoff was obtained with BAP soil test on 5 cm samples and DRP in pan runoff. Normalizing laboratory runoff data improved correlations with all STP methods over all sample depths. Field runoff data was normalized but did not significantly improve the relationship between runoff P and STP due to lower runoff variability from field simulations. However, DRP in runoff was highly correlated with all STP methods ($R^2 > 0.6$).

No significant difference was found between normalized TP and DRP values for laboratory and field runoff and forms of P in the soil. One equation was found to be sufficient ($P < 0.05$) to describe the relationship between TP and DRP concentrations in laboratory and field simulations. However, normalized laboratory and field runoff TP was not as highly correlated to P in the soil. In contrast, by accounting for runoff variability, the value of using STP data for predicting DRP concentrations in runoff is improved and may be effectively used for this purpose.

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Table 1. Preliminary STP results for area fields.

Field Identification		Mehlich I STP (mg kg^{-1})
UGA Dairy 1	(UGD1)	5.83
UGA Dairy 2	(UGD2)	11.06
McKinney Farm	(MCK)	22.71
Spruill Farm	(SPR)	47.67
Risse Farm	(RIS)	69.20
Davis Farm	(DAV)	182.55

Table 2. P extracted (mg kg^{-1}) from field soil samples by Mehlich III, distilled water, and iron oxide sink methods.

Mehlich III P

Site	0-2cm	CV*	Range	0-5cm	CV*	Range	0-10cm	CV*	Range
UGD2	40.4	21	(29.5-49.7)	32.2	19	(24.6-41.6)	34.5	30	(27.9-55.3)
UGD1	48.1	10	(43.5-56.7)	45.8	20	(32.2-59.7)	43.2	12	(35.9-49.9)
MCK	83.1	16	(62.7-101)	80.2	24	(48.9-103.3)	56.6	30	(35-73.7)
SPR	120.4	25	(76.3-147.2)	106	36	(49.3-139.7)	102.2	32	(56-129.6)
RIS	158.4	18	(126.6-198)	147.3	23	(107.3-172)	109.8	22	(82.4-153)
DAV	351.2	15	(296-431)	307.7	13	(253-373)	285.5	15	(215-327)

H_2O Extractable P

Site	0-2cm	CV*	Range	0-5cm	CV*	Range	0-10cm	CV*	Range
UGD2	5.0	34	(3.5-8.0)	1.4	36	(0.98-2.4)	0.5	169	(0-1.98)
UGD1	1.8	69	(0-3.6)	1.2	49	(0.1-1.7)	2.0	79	(0.7-2.4)
MCK	10.5	35	(5.3-15)	7.4	50	(2.2-11.7)	3.6	65	(0.6-6.2)
SPR	7.0	38	(3.2-9.9)	6.4	42	(2.2-8.6)	4.9	54	(1.3-7.3)
RIS	24.7	32	(16.1-34.5)	13.9	51	(5.6-26.1)	6.7	50	(2.2-11.1)
DAV	22.5	13	(18.8-25.8)	17.8	25	(9.5-21.9)	13.5	39	(4.6-20.4)

Bioavailable P

Site	0-2cm	CV*	Range	0-5cm	CV*	Range	0-10cm	CV*	Range
UGD2	14.3	26	(9.6-19.4)	7.4	13	(6.3-8.9)	5.3	29	(3.7-7.9)
UGD1	14.0	18	(11.8-18.3)	9.0	29	(6.4-14)	6.4	9	(5.8-7.2)
MCK	22.7	14	(17.9-27.4)	17.8	29	(11.2-25.8)	11.2	25	(6.8-14.1)
SPR	26.3	30	(15.5-34.7)	21.9	32	(12.9-31.5)	18.9	45	(9.7-29.5)
RIS	39.0	18	(34.0-52.1)	28.9	11	(24.1-33.6)	18.2	17	(14.4-22.9)
DAV	73.0	10	(65.1-85.7)	53.0	13	(43.3-62.1)	44.3	26	(32.9-60.8)

* Coefficient of variation (CV) as a percentage.

Table 3. Mean total, DRP, and BAP runoff concentrations (mg L^{-1}) from each site from field simulations.

	(mg L^{-1})								
Site	Total P	CV*	Range	DRP	CV*	Range	BAP	CV*	Range
UGD2	0.57	22	(0.37-0.93)	0.34	69	(0.08-0.81)	0.28	33	(0.18-0.59)
UGD1	0.42	24	(0.19-0.57)	0.15	114	(0-0.66)	0.13	57	(0.0-0.26)
MCK	0.75	29	(0.42-1.14)	0.36	74	(0.04-0.86)	0.39	53	(0.13-0.76)
SPR	0.59	18	(0.42-0.78)	0.28	50	(0.11-0.55)	0.27	25	(0.17-0.41)
RIS	0.92	22	(0.67-1.38)	0.54	33	(0.24-0.99	0.55	17	(0.41-0.74)
DAV	1.25	44	(0.69-2.77)	0.80	47	(0.27-1.44)	0.78	37	(0.40-1.44)

*Coefficient of variation (CV) as a percentage.

Table 4. Mean total and DRP runoff concentrations (mg L^{-1}) from each site from indoor rainfall simulations.

	(mg L^{-1})					
Site	Total P	CV*	Range	DRP	CV*	Range
UGD1	0.14	59	(0.02-0.28)	0	0	(0-0)
UGD2	0.16	89	(0-0.38)	0.01	172	(0-0.07)
MCK	0.37	42	(0.16-0.49)	0.13	74	(0.05-0.35)
SPR	0.38	90	(0.12-1.37)	0.04	156	(0-0.14)
DAV	0.40	79	(0-1.21)	0.26	98	(0-0.76)
RIS	0.66	67	(0.23-1.76)	0.30	100	(0.08-1.13)

*Coefficient of variation (CV) as a percentage.

Table 5. Relationship between STP method and average total P in runoff from field simulations.

	Relationship with Average Field Total P (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	0.44677	0.00216	0.5632	0.21597	0.0003	18
0-5 cm	0.41397	0.00268	0.6820	0.18429	<0.0001	18
0-10cm	0.45699	0.00264	0.5637	0.21585	0.0003	18
DI $H_2$0						
0-2 cm	0.46430	0.02278	0.4746	0.23687	0.0016	18
0-5 cm	0.44202	0.03660	0.6401	0.19604	<0.0001	18
0-10cm	0.50033	0.04534	0.4986	0.23140	0.0011	18
BAP						
0-2 cm	0.38119	0.01123	0.5754	0.21293	0.0003	18
0-5 cm	0.36289	0.01618	0.6872	0.18276	<0.0001	18
0-10cm	0.46558	0.01554	0.4768	0.23637	0.0015	18

Table 6. Relationship between STP method and normalized total P in runoff from field simulations.

	Relationship with Normalized Field Total P (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	0.20795	0.00117	0.0452	0.61096	0.3973	18
0-5 cm	0.22707	0.00115	0.0340	0.61453	0.4641	18
0-10cm	0.19326	0.00162	0.0581	0.60679	0.3352	18
DI $H_2$0						
0-2 cm	0.37343	-0.00008	0.0001	0.62519	0.9621	18
0-5 cm	0.32810	0.00452	0.0027	0.62440	0.8388	18
0-10cm	0.18664	0.03426	0.0778	0.23140	0.2624	18
BAP						
0-2 cm	0.20847	0.00494	0.0304	0.61565	0.4887	18
0-5 cm	0.21139	0.00664	0.0316	0.61527	0.4801	18
0-10cm	0.21727	0.00847	0.0387	0.61302	0.4341	18

Table 7. Relationship between STP method and average DRP in runoff from field simulations.

	Relationship with Average Field DRP (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	0.16293	0.00176	0.5481	0.18105	0.0004	18
0-5 cm	0.14023	0.00215	0.6437	0.16076	<0.0001	18
0-10cm	0.16702	0.00219	0.5692	0.17676	0.0003	18
DI H_20						
0-2 cm	0.16714	0.01937	0.5049	0.18950	0.0010	18
0-5 cm	0.15229	0.03060	0.6589	0.15730	<0.0001	18
0-10cm	0.19333	0.03939	0.5542	0.17982	0.0004	18
BAP						
0-2 cm	0.11378	0.00900	0.5439	0.18188	0.0005	18
0-5 cm	0.10842	0.01256	0.6097	0.16825	0.0001	18
0-10cm	0.18449	0.01227	0.4379	0.20192	0.0028	18

Table 8. Relationship between STP method and normalized DRP in runoff from field simulations.

	Relationship with Normalized Field DRP (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	-0.05734	0.00151	0.6944	0.11384	<0.0001	18
0-5 cm	-0.04785	0.00161	0.6158	0.12764	0.0001	18
0-10cm	-0.05392	0.00189	0.7219	0.10859	<0.0001	18
DI H_20						
0-2 cm	0.01076	0.01125	0.2914	0.17335	0.0207	18
0-5 cm	-0.00250	0.01835	0.4055	0.15879	0.0045	18
0-10cm	-0.18664	0.03368	0.6927	0.11416	<0.0001	18
BAP						
0-2 cm	-0.08426	0.00726	0.6051	0.12942	0.0001	18
0-5 cm	-0.05125	0.00851	0.4785	0.14871	0.0015	18
0-10cm	-0.04218	0.01076	0.5756	0.13417	0.0003	18

Table 9. Relationship between STP method and average BAP in runoff from field simulations.

	Relationship with Average Field BAP (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	0.16463	0.00172	0.5867	0.16352	0.0002	18
0-5 cm	0.14328	0.00209	0.6844	0.14288	<0.0001	18
0-10cm	0.17462	0.00208	0.5773	0.16536	0.0003	18
DI $H_2$0						
0-2 cm	0.16749	0.01903	0.5465	0.17129	0.0005	18
0-5 cm	0.15848	0.02937	0.6805	0.14376	<0.0001	18
0-10cm	0.20593	0.03636	0.5294	0.17449	0.0006	18
BAP						
0-2 cm	0.11263	0.00892	0.5990	0.16106	0.0002	18
0-5 cm	0.10300	0.01263	0.6919	0.14118	<0.0001	18
0-10cm	0.18092	0.01226	0.4905	0.18155	0.0012	18

Table 10. Relationship between STP method and normalized BAP in runoff from field simulations.

	Relationship with Normalized Field BAP (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	-0.01817	0.00130	0.5552	0.13173	0.0004	18
0-5 cm	-0.00089	0.00137	0.4853	0.14170	0.0013	18
0-10cm	-0.01529	0.00162	0.5775	0.12839	0.0003	18
DI $H_2$0						
0-2 cm	0.05300	0.00857	0.1840	0.17841	0.0757	18
0-5 cm	0.03971	0.01439	0.2708	0.16867	0.0268	18
0-10cm	0.00547	0.02884	0.5524	0.13214	0.0004	18
BAP						
0-2 cm	-0.04094	0.00621	0.4822	0.14213	0.0014	18
0-5 cm	-0.01834	0.00753	0.4075	0.15203	0.0044	18
0-10cm	-0.00782	0.00938	0.4754	0.14305	0.0015	18

Table 11. Relationship between STP method and average total P in runoff from laboratory simulations.

	Relationship with Average Pan Total P (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	0.28423	0.00105	0.0880	0.38205	0.2319	18
0-5 cm	0.24889	0.00146	0.1349	0.37210	0.1338	18
0-10cm	0.31391	0.00105	0.0587	0.38814	0.3326	18
DI H_20						
0-2 cm	0.17634	0.02080	0.2641	0.34320	0.0292	18
0-5 cm	0.24275	0.02260	0.1629	0.36604	0.0967	18
0-10cm	0.30286	0.02335	0.0882	0.38201	0.2313	18
BAP						
0-2 cm	0.28270	0.00448	0.0610	0.38766	0.3230	18
0-5 cm	0.24252	0.00788	0.1087	0.37769	0.1814	18
0-10cm	0.32780	0.00553	0.0404	0.39190	0.4240	18

Table 12. Relationship between STP method and normalized total P in runoff from laboratory simulations.

	Relationship with Normalized Pan TP (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	0.34756	0.00183	0.4028	0.25268	0.0047	18
0-5 cm	0.35997	0.00194	0.3550	0.26261	0.0091	18
0-10cm	0.36230	0.00218	0.3826	0.25692	0.0062	18
DI H_20						
0-2 cm	0.40073	0.01606	0.2355	0.28589	0.0412	18
0-5 cm	0.42153	0.02124	0.2154	0.28963	0.0523	18
0-10cm	0.40750	0.03555	0.3062	0.27237	0.0172	18
BAP						
0-2 cm	0.31841	0.00867	0.3424	0.26515	0.0107	18
0-5 cm	0.36551	0.00983	0.2534	0.28254	0.0332	18
0-10cm	0.36984	0.01278	0.3223	0.26918	0.0140	18

Table 13. Relationship between STP method and average DRP in runoff from laboratory simulations.

	Relationship with Average Pan DRP (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	0.05391	0.00084	0.2112	0.19546	0.0733	16
0-5 cm	0.04344	0.01501	0.2625	0.18899	0.0424	16
0-10cm	0.09205	0.01439	0.1219	0.20623	0.1851	16
DI $H_2$0						
0-2 cm	0.03029	0.01096	0.2617	0.18909	0.0428	16
0-5 cm	0.04344	0.01501	0.2625	0.18899	0.0424	16
0-10cm	0.09205	0.01439	0.1219	0.20623	0.1851	16
BAP						
0-2 cm	0.02204	0.00449	0.2244	0.19381	0.0638	16
0-5 cm	0.00228	0.00706	0.3237	0.18098	0.0214	16
0-10cm	0.06583	0.00577	0.1633	0.20130	0.1205	16

Table 14. Relationship between STP method and normalized DRP in runoff from laboratory simulations.

	Relationship with Normalized Pan DRP (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	-0.05419	0.00196	08219	0.10992	<0.0001	16
0-5 cm	0.00069	0.02555	0.5428	0.17614	0.0011	16
0-10cm	0.02225	0.03599	0.5437	0.17597	0.0011	16
DI $H_2$0						
0-2 cm	0.00766	0.01633	0.4148	0.19928	0.0071	16
0-5 cm	0.00069	0.02555	0.5428	0.17614	0.0011	16
0-10cm	0.02225	0.03599	0.5437	0.17597	0.0011	16
BAP						
0-2 cm	-0.12650	0.01042	0.8629	0.09647	<0.0001	16
0-5 cm	-0.11576	0.01399	0.9065	0.07964	<0.0001	16
0-10cm	-0.06400	0.01559	0.8507	0.10066	<0.0001	16

Table 15. Test of null hypothesis[†] for average flow-weighted values.

Regression type	SSres (H_o)	df	SSres (H_a)[‡]	df	F
		H_o			
TP vs. MIII-2cm	4.08	34	3.08	32	5.20*
TP vs. MIII-5cm	3.75	34	2.76	32	5.75*
TP vs. MIII-10cm	4.20	34	3.16	32	5.32*
DRP vs. MIII-2cm	1.59	30	1.11	28	6.15*
DRP vs. MIII-5cm	1.45	30	0.90	28	8.40*
DRP vs. MIII-10cm	1.61	30	1.05	28	7.40*
TP vs. DI H_2O-2cm	3.66	34	2.78	32	5.04*
TP vs. DI H_2O-5cm	3.71	34	2.76	32	5.53*
TP vs. DI H_2O-10cm	4.16	34	3.19	32	4.88*
DRP vs. DI H_2O-2cm	1.58	30	1.07	28	6.65*
DRP vs. DI H_2O-5cm	1.45	30	0.89	28	8.62*
DRP vs. DI H_2O-10cm	1.69	30	1.11	28	7.36*
TP vs. BAP-2cm	4.18	34	3.13	32	5.37*
TP vs. BAP-5cm	3.84	34	2.82	32	5.84*
TP vs. BAP-10cm	4.39	34	3.35	32	4.98*
DRP vs. BAP-2cm	1.58	30	1.05	28	7.03*
DRP vs. BAP-5cm	1.43	30	0.91	28	7.97*
DRP vs. BAP-10cm	1.74	30	1.22	28	5.99*

*Indicates significance at the 0.05 level of probability.

[†] H_o: One equation can be used to describe the relationship between average values for field and laboratory simulations.

[‡] H_a: Separate equations needed to describe the relationship between average values for field and laboratory simulations.

Table 16. Test of null hypothesis[†] for normalized flow-weighted values.

Regression type	SSres (H_o)	df	SSres (H_a)[‡]	df	F
		H_o			
TP vs. MIII-2cm	7.51	34	7.00	32	1.17
TP vs. MIII-5cm	7.66	34	7.15	32	1.16
TP vs. MIII-10cm	7.44	34	6.95	32	1.12
DRP vs. MIII-2cm	0.42	30	0.37	28	1.86
DRP vs. MIII-5cm	0.51	30	0.45	28	1.66
DRP vs. MIII-10cm	0.43	30	0.39	28	1.45
TP vs. DI H_2O-2cm	8.25	34	7.56	32	1.45
TP vs. DI H_2O-5cm	8.16	34	7.58	32	1.22
TP vs. DI H_2O-10cm	7.42	34	6.96	32	1.07
DRP vs. DI H_2O-2cm	1.08	30	1.04	28	0.64
DRP vs. DI H_2O-5cm	0.88	30	0.83	28	0.82
DRP vs. DI H_2O-10cm	0.65	30	0.63	28	0.63
TP vs. BAP-2cm	7.71	34	7.19	32	1.16
TP vs. BAP-5cm	7.82	34	7.34	32	1.07
TP vs. BAP-10cm	7.67	34	7.26	32	0.90
DRP vs. BAP-2cm	0.46	30	0.40	28	2.32
DRP vs. BAP-5cm	0.53	30	0.44	28	3.04
DRP vs. BAP-10cm	0.49	30	0.42	28	2.23

[†] H_o: One equation can be used to describe the relationship between normalized values for field and laboratory simulations.

[‡] H_a: Separate equations needed to describe the relationship between normalized values for field and laboratory simulations.

Table 17. Test of null hypothesis[†] for slopes of average flow-weighted values.

Regression type	SSres (H_o)	df	SSres (H_a)[‡]	df	F
		H_o			
TP vs. MIII-2cm	3.21	33	3.08	32	1.35
TP vs. MIII-5cm	3.08	33	2.76	32	3.70
TP vs. MIII-10cm	3.26	33	3.16	32	1.02
DRP vs. MIII-2cm	1.14	29	1.11	28	0.86
DRP vs. MIII-5cm	0.99	29	0.90	28	2.76
DRP vs. MIII-10cm	1.23	29	1.05	28	4.82*
TP vs. DI H_2O-2cm	2.79	33	2.78	32	0.12
TP vs. DI H_2O-5cm	2.84	33	2.76	32	0.98
TP vs. DI H_2O-10cm	3.29	33	3.19	32	1.03
DRP vs. DI H_2O-2cm	1.13	29	1.07	28	1.47
DRP vs. DI H_2O-5cm	0.99	29	0.89	28	3.07
DRP vs. DI H_2O-10cm	1.23	29	1.11	28	3.23
TP vs. BAP-2cm	3.31	33	3.13	32	1.84
TP vs. BAP-5cm	2.97	33	2.82	32	1.77
TP vs. BAP-10cm	3.52	33	3.35	32	1.63
DRP vs. BAP-2cm	1.13	29	1.05	28	2.06
DRP vs. BAP-5cm	0.98	29	0.91	28	2.03
DRP vs. BAP-10cm	1.29	29	1.22	28	1.57

*Indicates significance at the 0.05 level of probability.

[†] H_o: One equation with common slopes and different intercepts can be used to describe the relationship between average values for field and laboratory simulations.

[‡] H_a: Separate equations needed to describe the relationship between average values for field and laboratory simulations.

Table 18. Test of null hypothesis[†] for intercepts of average flow-weighted values.

Regression type	SSres (H_o)	df	SSres (H_a)[‡]	df	F
		H_o			
TP vs. MIII-2cm	3.17	33	3.08	32	0.95
TP vs. MIII-5cm	2.79	33	2.76	32	0.38
TP vs. MIII-10cm	3.17	33	3.16	32	0.14
DRP vs. MIII-2cm	1.10	29	1.11	28	-0.21
DRP vs. MIII-5cm	0.93	29	0.90	28	0.87
DRP vs. MIII-10cm	1.14	29	1.05	28	2.43
TP vs. DI H_2O-2cm	3.07	33	2.78	32	3.33
TP vs. DI H_2O-5cm	2.91	33	2.76	32	1.73
TP vs. DI H_2O-10cm	3.35	33	3.19	32	1.61
DRP vs. DI H_2O-2cm	1.12	29	1.07	28	1.25
DRP vs. DI H_2O-5cm	0.93	29	0.89	28	1.17
DRP vs. DI H_2O-10cm	1.14	29	1.11	28	1.04
TP vs. BAP-2cm	3.16	33	3.13	32	0.26
TP vs. BAP-5cm	2.89	33	2.82	32	0.45
TP vs. BAP-10cm	3.41	33	3.35	32	0.60
DRP vs. BAP-2cm	1.07	29	1.05	28	0.53
DRP vs. BAP-5cm	0.94	29	0.91	28	0.97
DRP vs. BAP-10cm	1.27	29	1.22	28	1.11

[†] H_o: One equation with different slopes and common intercepts can be used to describe the relationship between average values for field and laboratory simulations.

[‡] H_a: Separate equations needed to describe the relationship between average values for field and laboratory simulations.

Table 19. Relationship between normalized total P in runoff from laboratory and field simulations versus STP method using 1 equation.

	Relationship with Normalized total P (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	0.27773	0.00150	0.1100	0.46986	0.0482	36
0-5 cm	0.29339	0.00154	0.0912	0.47478	0.0734	36
0-10cm	0.27775	0.00190	0.1183	0.46767	0.0400	36
DI H_20						
0-2 cm	0.38704	0.00765	0.0217	0.49261	0.3913	36
0-5 cm	0.37479	0.01289	0.0322	0.48997	0.2953	36
0-10cm	0.29703	0.03492	0.1198	0.46725	0.0386	36
BAP						
0-2 cm	0.26341	0.00681	0.0856	0.47624	0.0833	36
0-5 cm	0.28844	0.00824	0.0722	0.47974	0.1131	36
0-10cm	0.29353	0.01063	0.0904	0.47500	0.0748	36

Table 20. Relationship between normalized DRP in runoff from laboratory and field simulations versus STP method using 1 equation.

	Relationship with Normalized DRP (mg P L^{-1})					
STP method	Intercept	Slope	R^2	RMSE	Prob > F	n
Mehlich III						
0-2 cm	-0.05261	0.00173	0.7444	0.11823	<0.0001	32
0-5 cm	-0.04930	0.00190	0.6921	0.12977	<0.0001	32
0-10cm	-0.04168	0.00211	0.7357	0.12023	<0.0001	32
DI H_20						
0-2 cm	0.01104	0.01373	0.3396	0.19004	0.0005	32
0-5 cm	0.00153	0.02192	0.4627	0.17114	<0.0001	32
0-10cm	-0.00277	0.03516	0.6010	0.14772	<0.0001	32
BAP						
0-2 cm	-0.10424	0.00884	0.7188	0.12401	<0.0001	32
0-5 cm	-0.08016	0.04086	0.6764	0.13302	<0.0001	32
0-10cm	-0.04983	0.01315	0.7002	0.12804	<0.0001	32

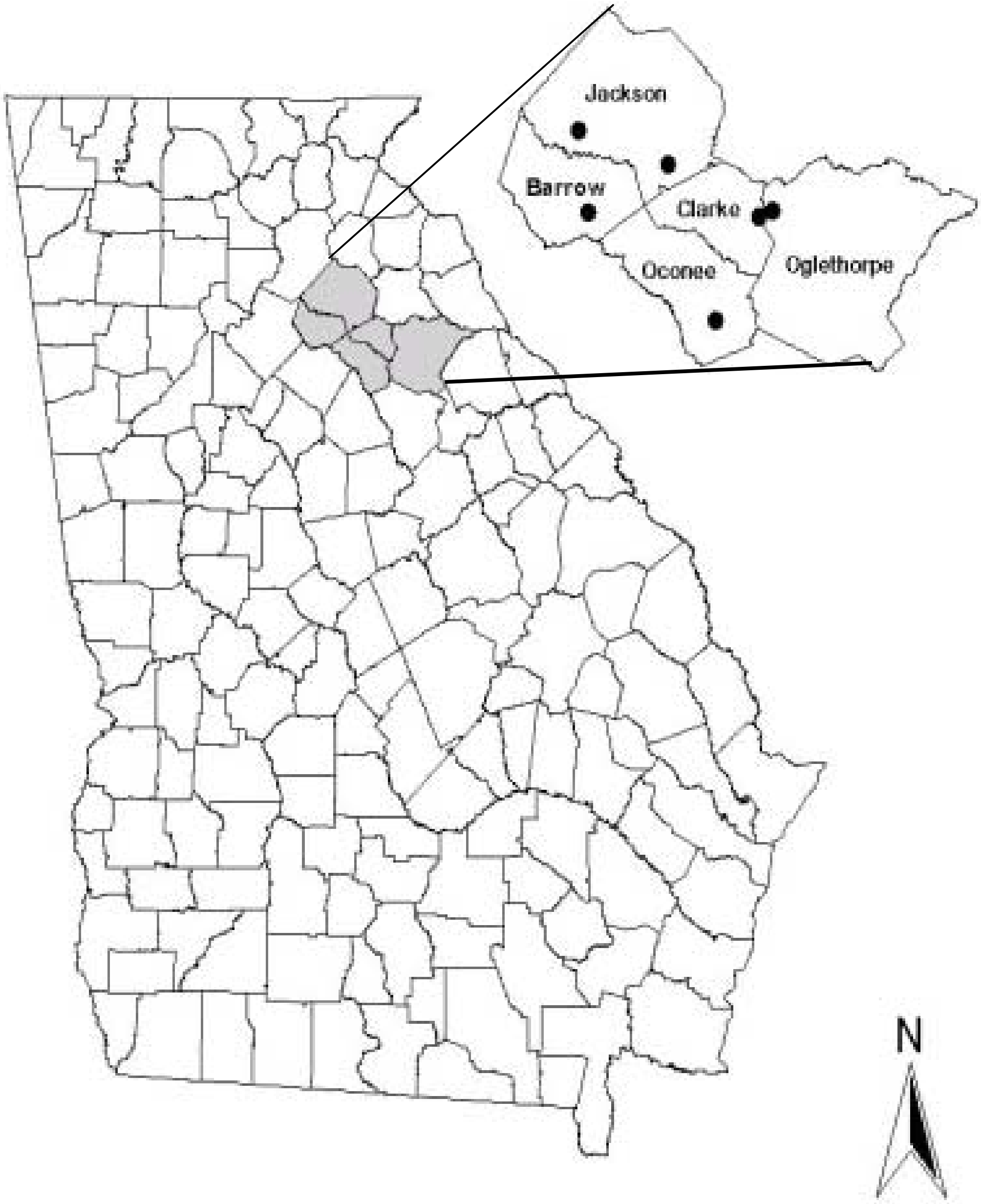

Figure 1. Phosphorus runoff study locations.

Figure 2. Drip-irrigation system used to pre-soak field plots.

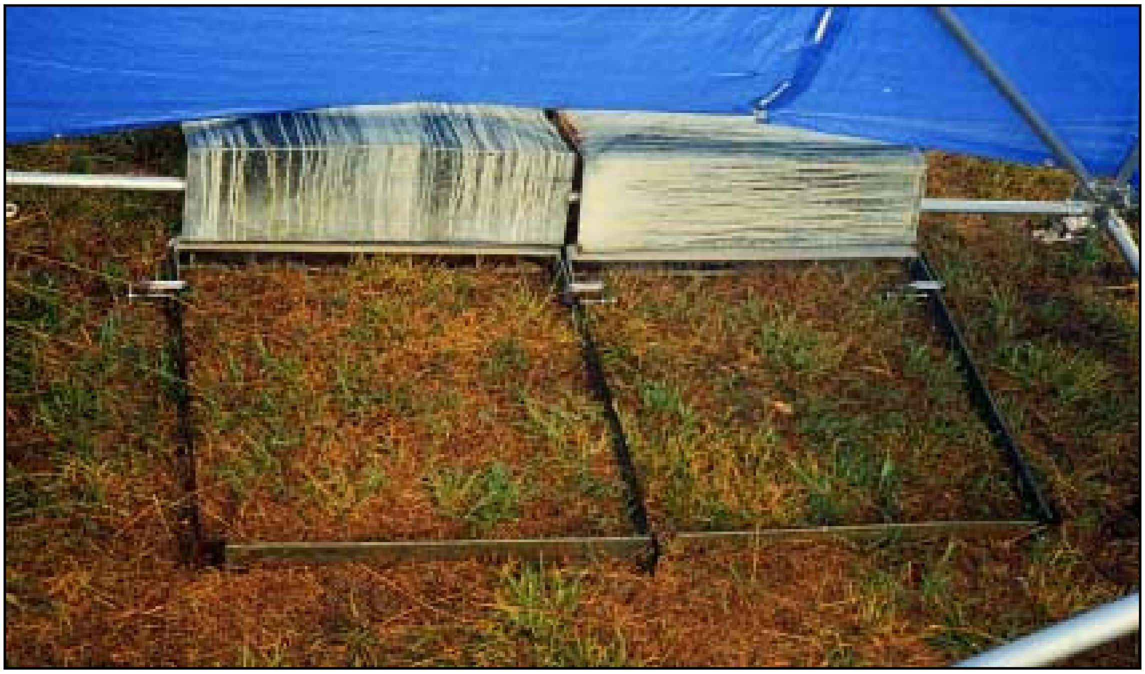

Figure 3. Paired plots that were installed at the summit, backslope, and toeslope landscape positions within each site.

Figure 4. Plot border installation using a hydraulic press.

Figure 5. Flumes were installed at the down-gradient edge of each plot to divert surface runoff to a collection point.

Figure 6. JOERNS INC. rainfall simulator fitted with tarps to provide a windscreen.

A)

B)

C)

D)

Figure 7. Sod sample collection.

Figure 8. Indoor rainfall simulator.

Figure 9. Runoff pans with intact sod samples and splash guards.

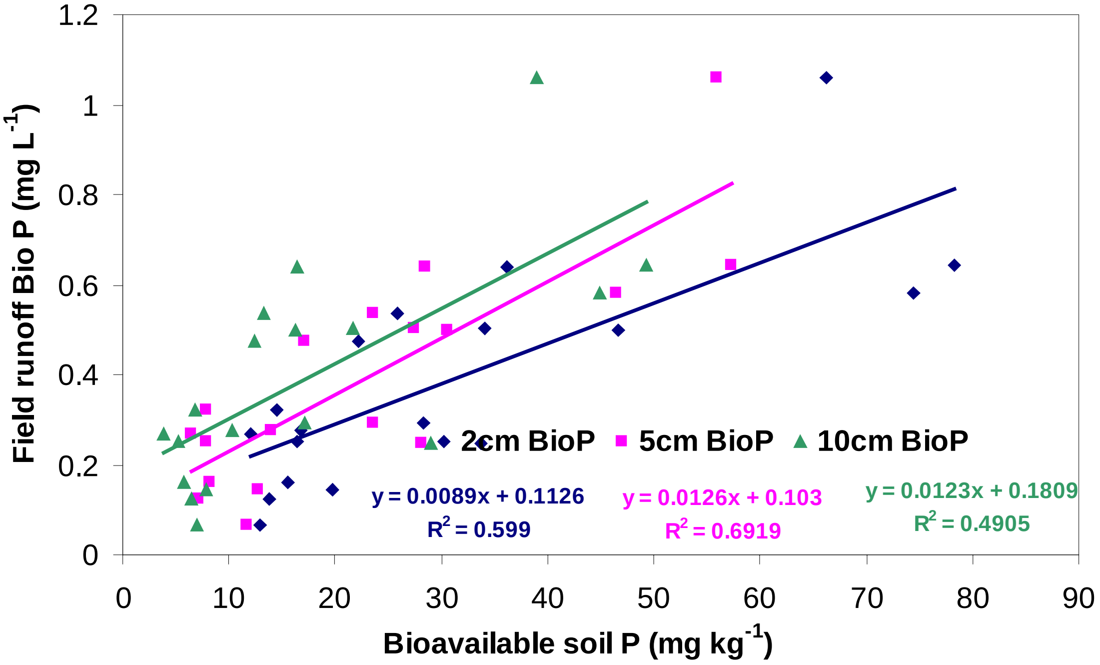

Figure 10. Relationship between bioavailable P in field runoff and bioavailable soil P.

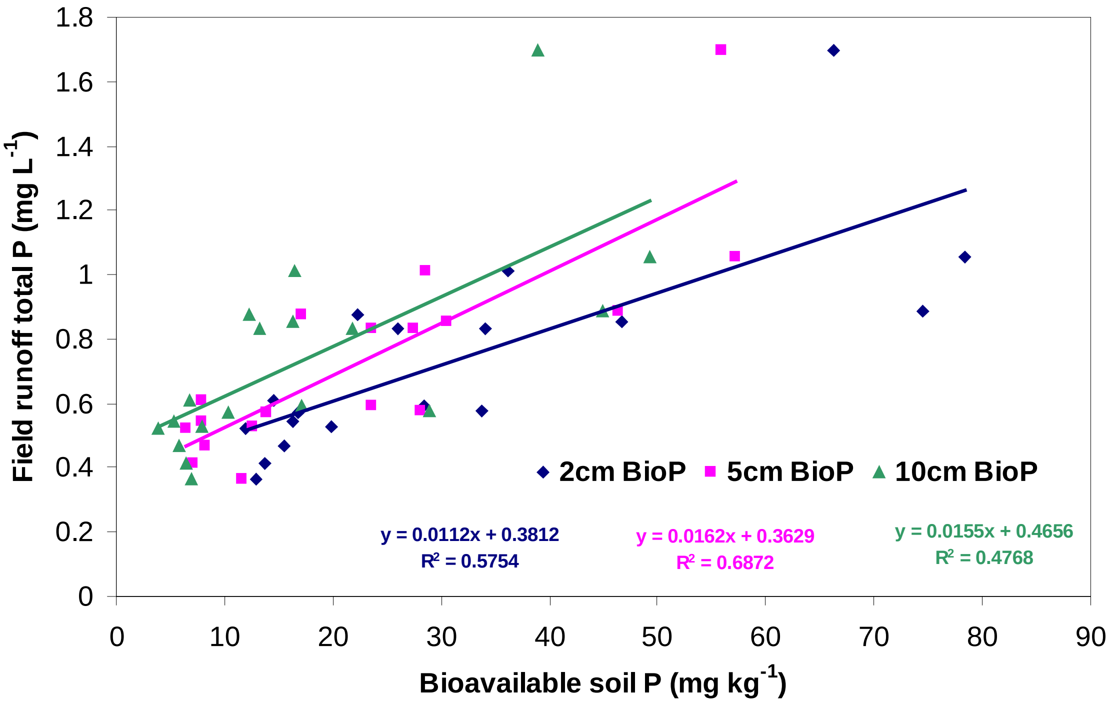

Figure 11. Relationship between total P in field runoff and bioavailable soil P.

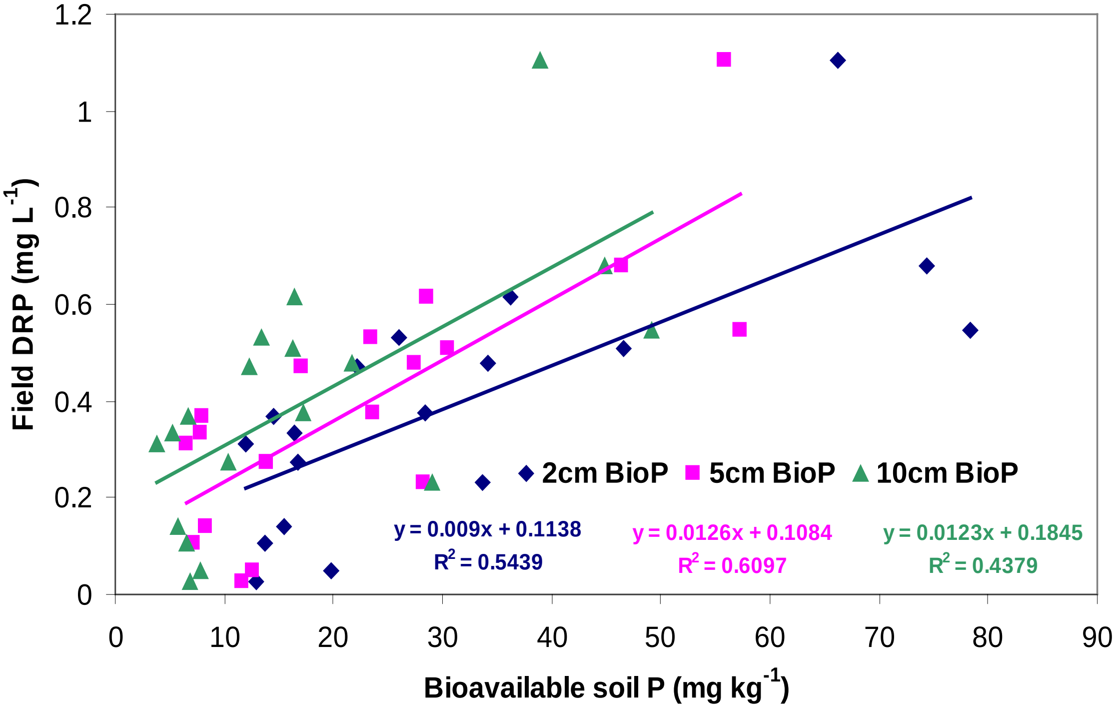

Figure 12. Relationship between dissolved reactive P in field runoff and bioavailable soil P.

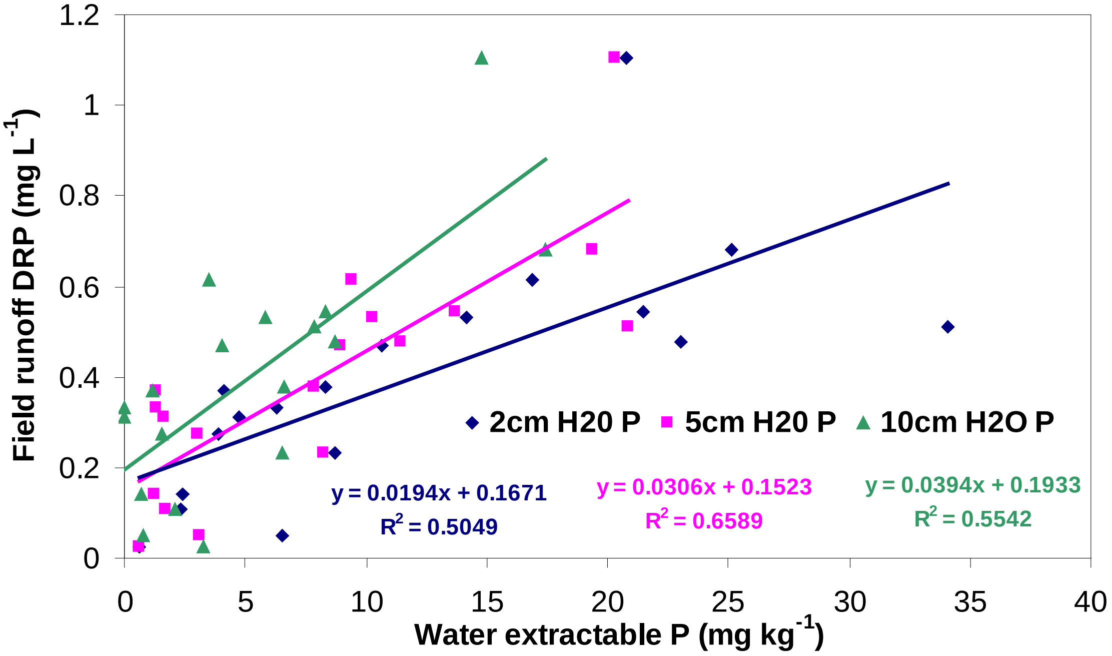

Figure 13. Relationship between dissolved reactive P in field runoff and water extractable soil P.

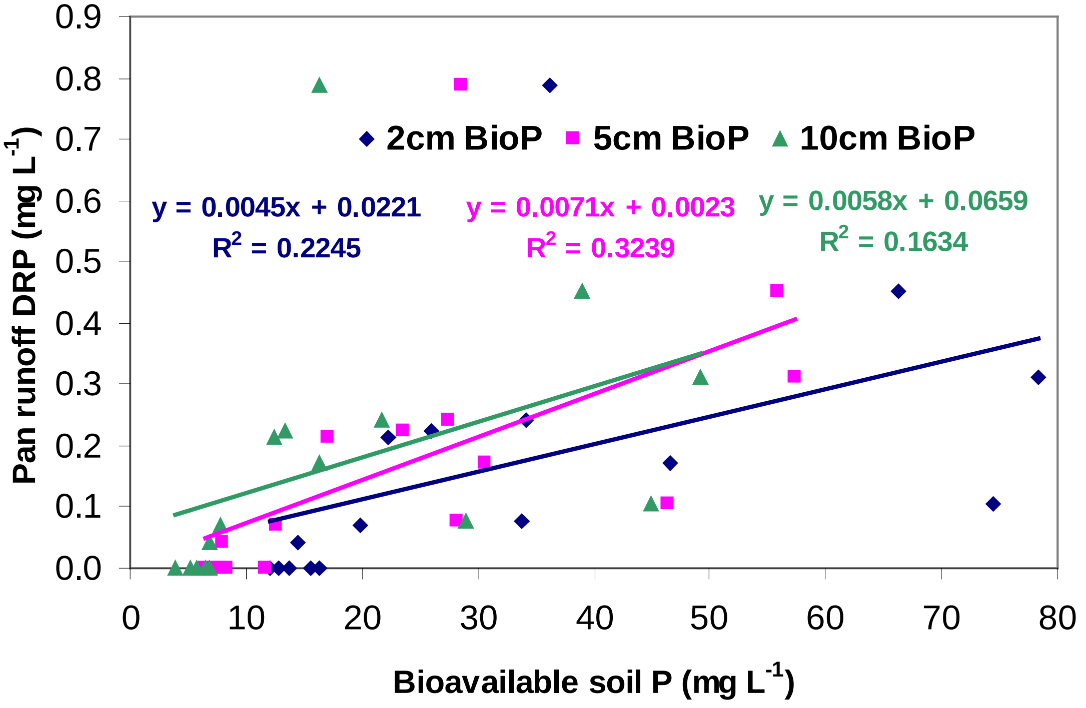

Figure 14. Relationship between dissolved reactive P in pan runoff and bioavailable soil P.

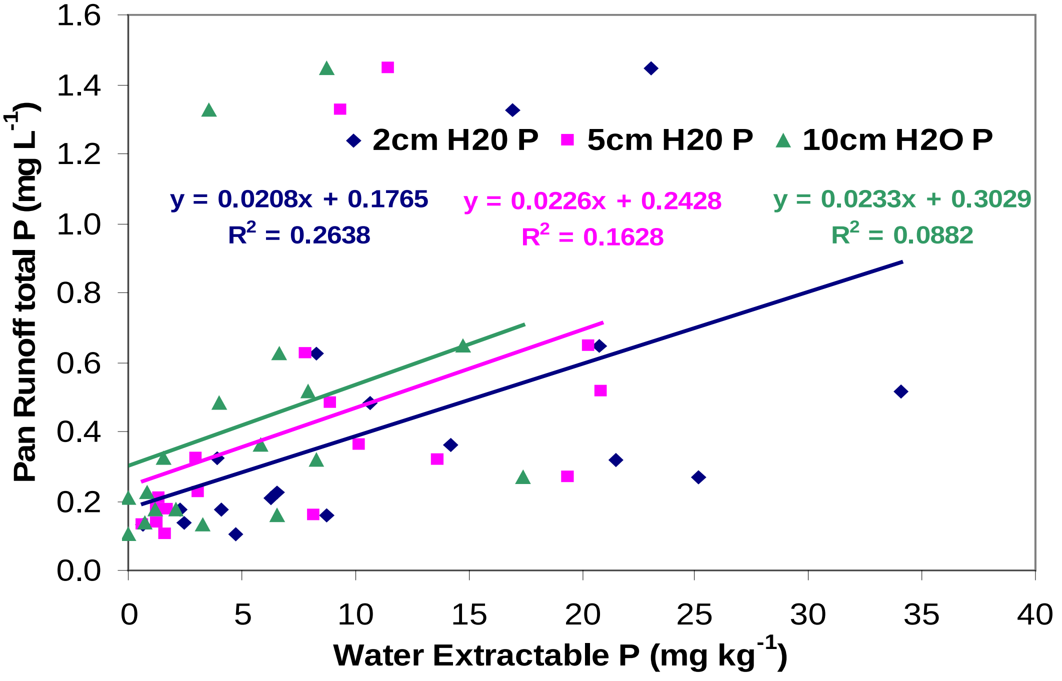

Figure 15. Relationship between total P in pan runoff and water extractable soil P.

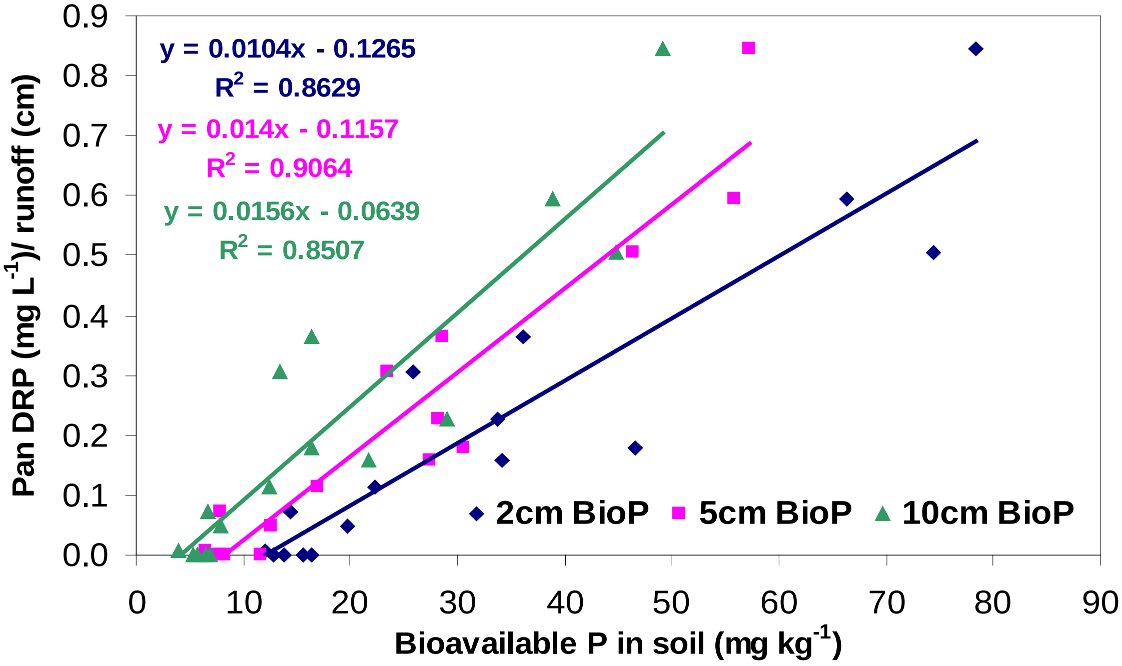

Figure 16. Relationship between normalized dissolved reactive P in pan runoff and bioavailable soil P.

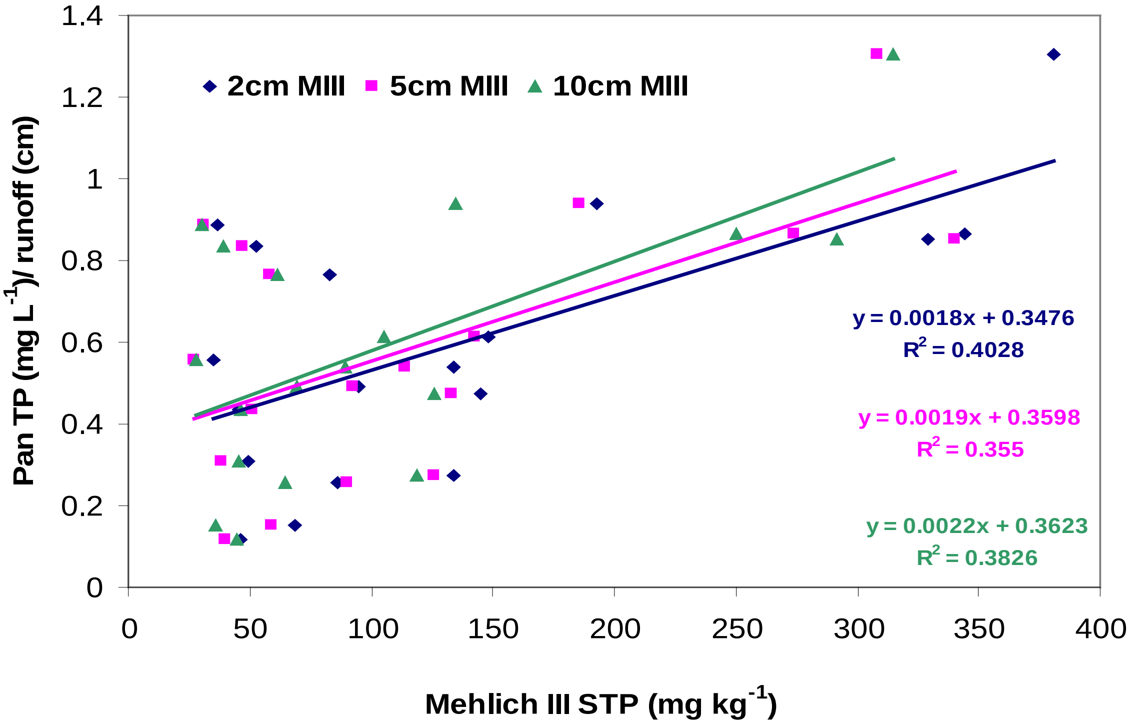

Figure 17. Relationship between normalized total P in pan runoff and Mehlich III STP.

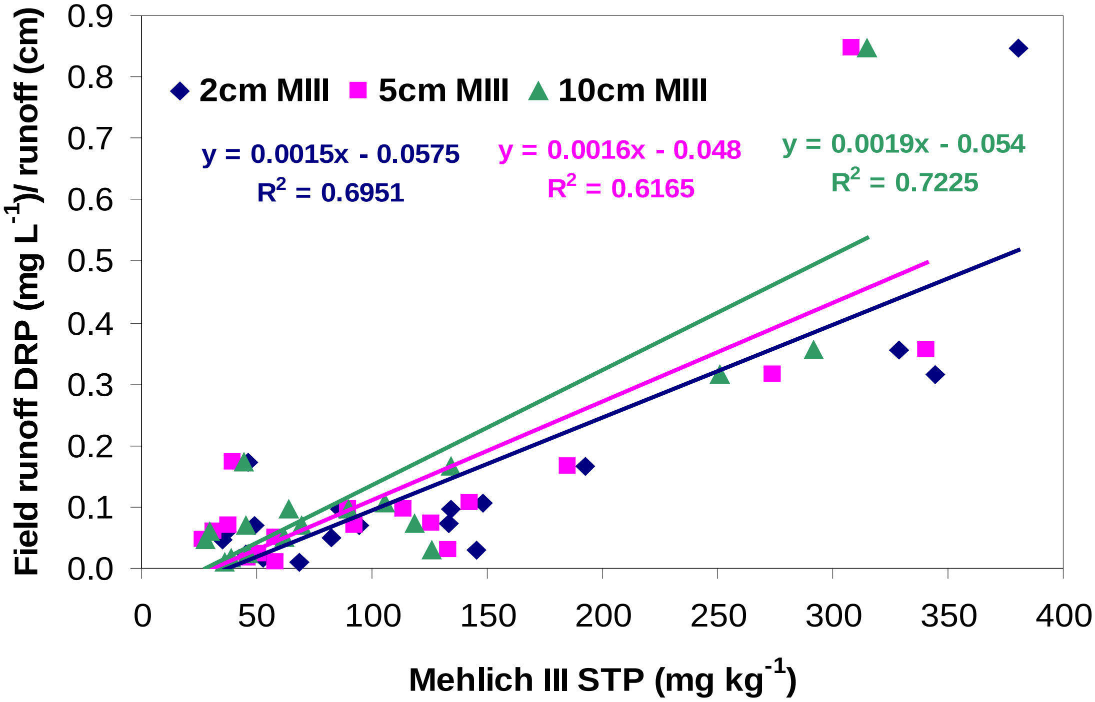

Figure 18. Relationship between normalized dissolved reactive P in field runoff and Mehlich III STP.

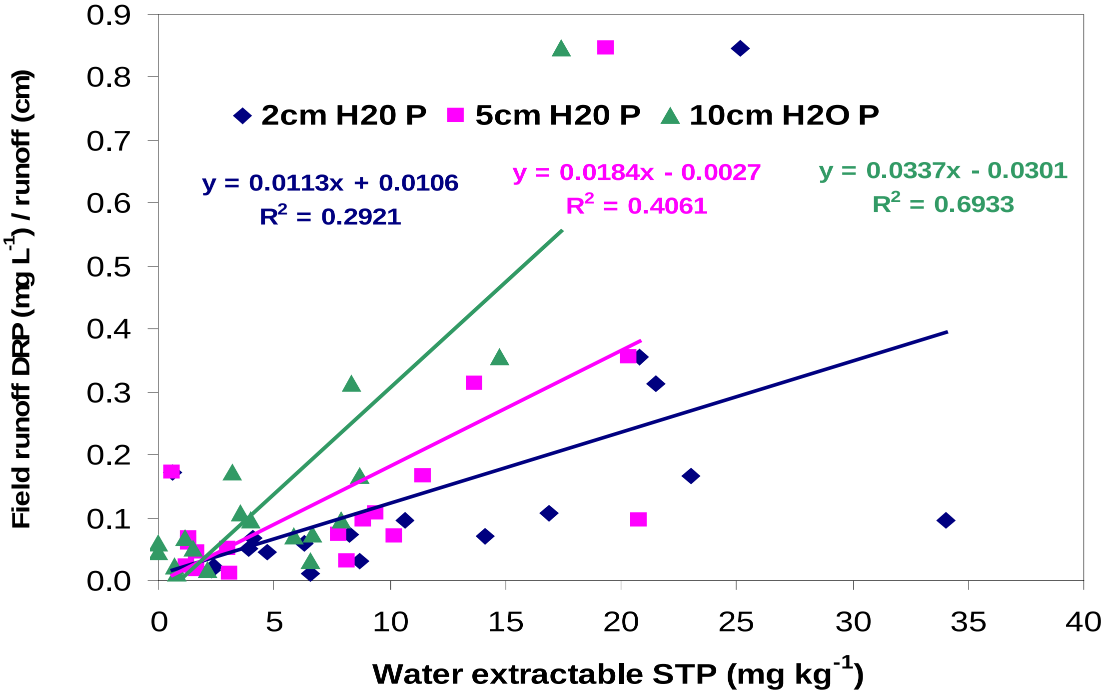

Figure 19. Relationship between normalized dissolved reactive P in field runoff and water extractable STP.

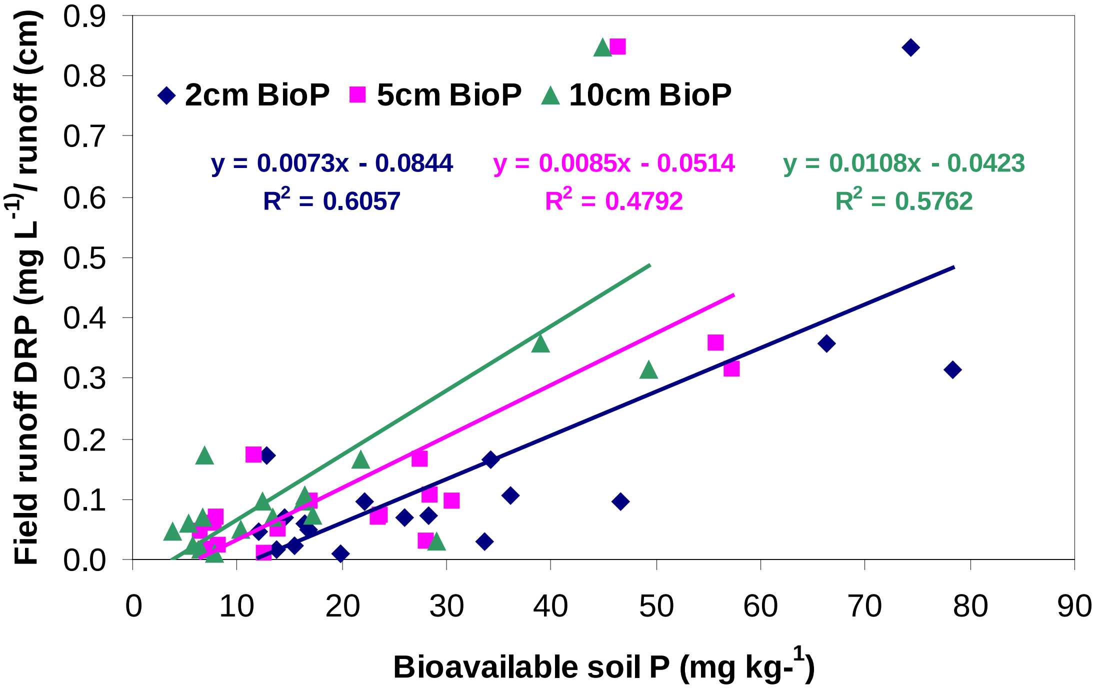

Figure 20. Relationship between normalized dissolved reactive P in field runoff and bioavailable soil P.

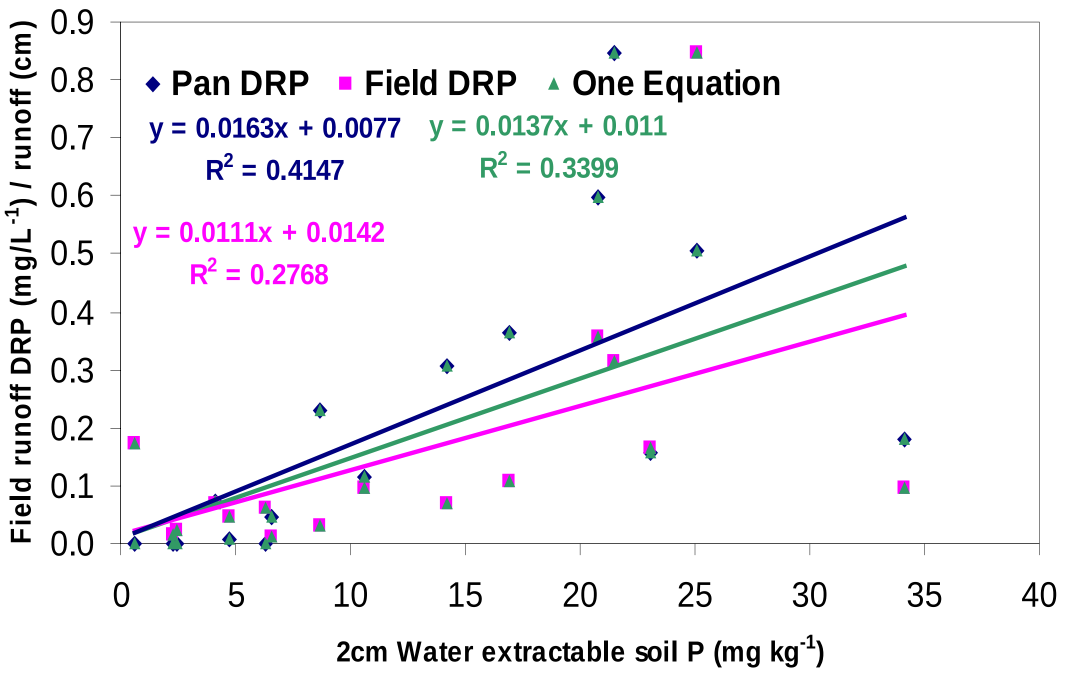

Figure 21. Relationship between normalized DRP values and 2cm water extractable soil P with one equation.

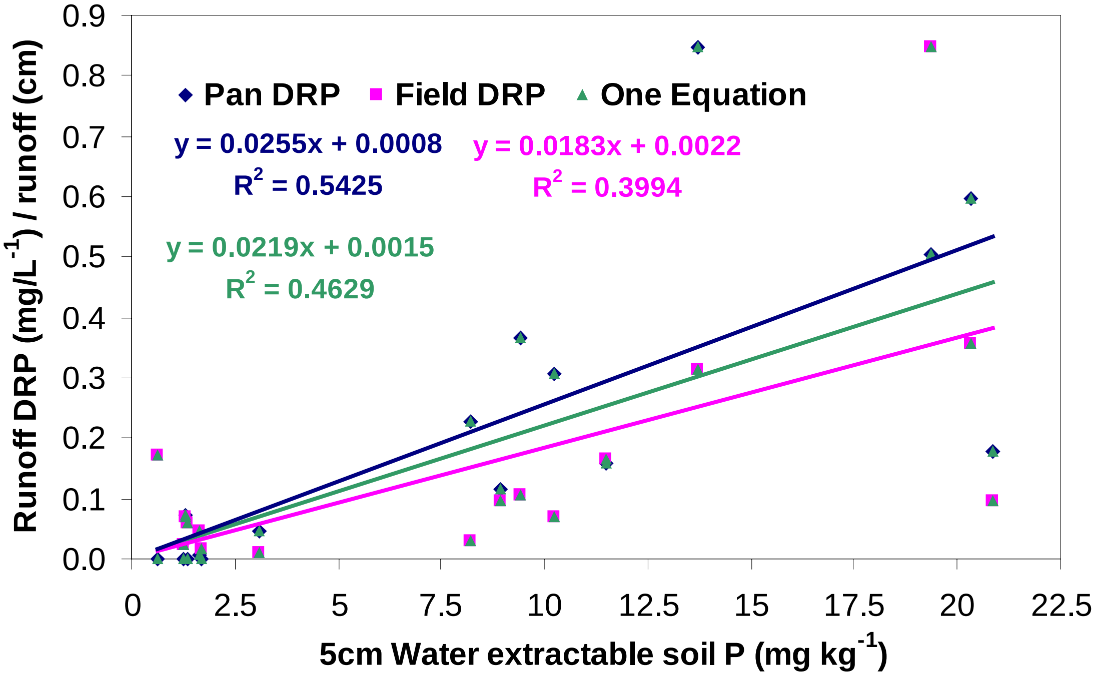

Figure 22. Relationship between normalized DRP values and 5cm water extractable soil P with one equation.

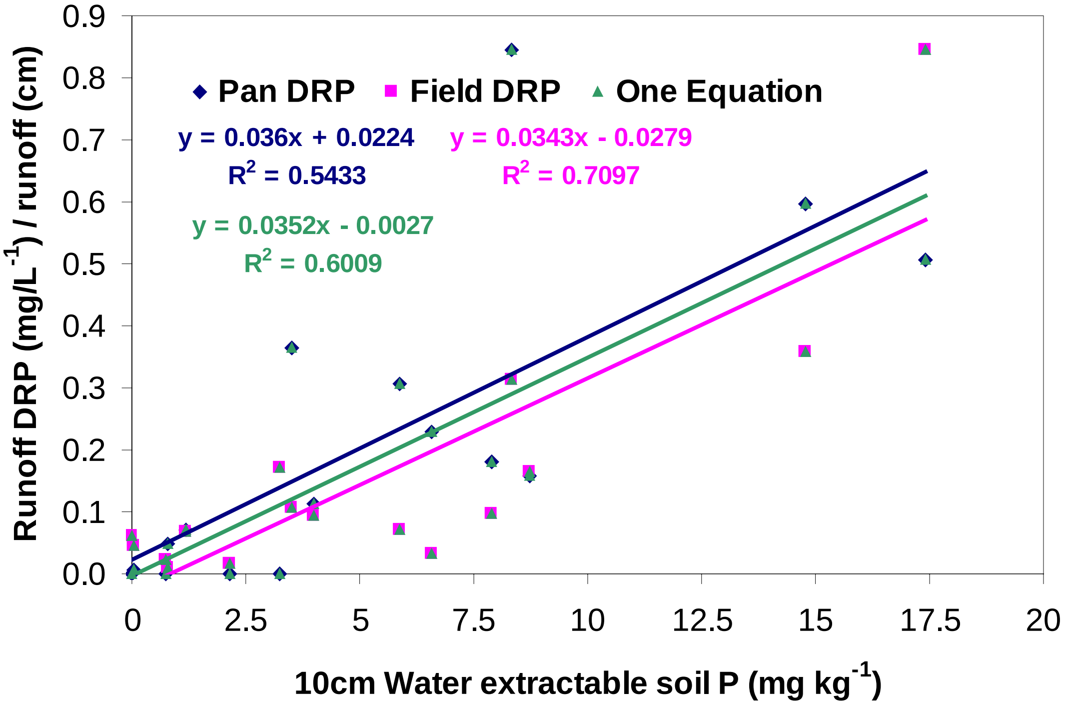

Figure 23. Relationship between normalized DRP values and 10cm water extractable soil P with one equation.

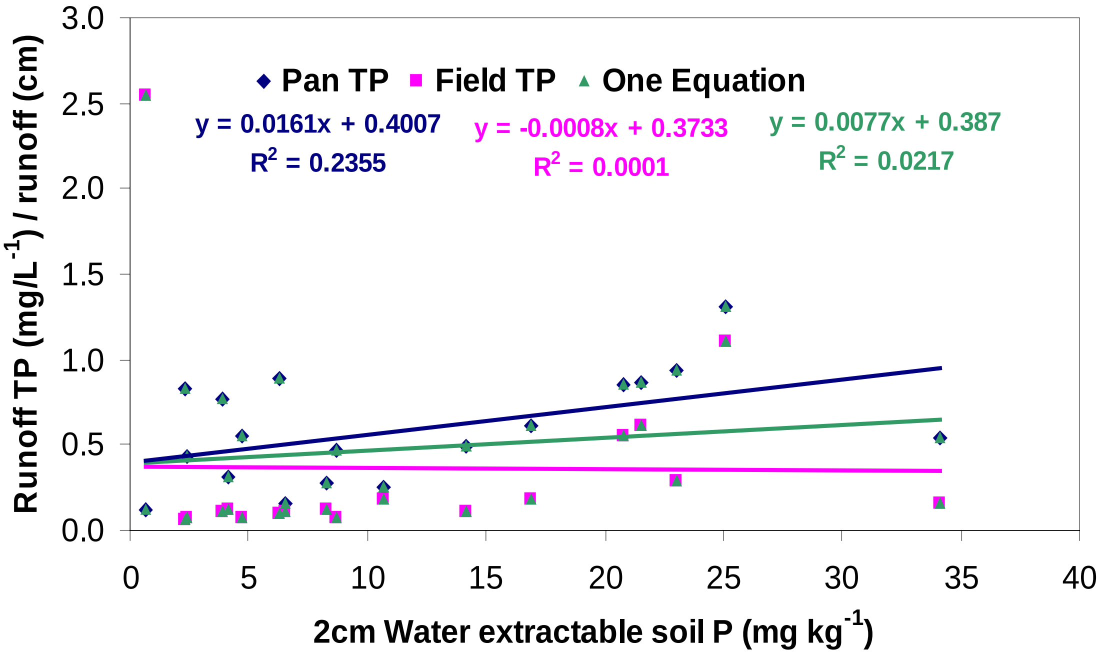

Figure 24. Relationship between normalized TP values and 2cm water extractable soil P with one equation.

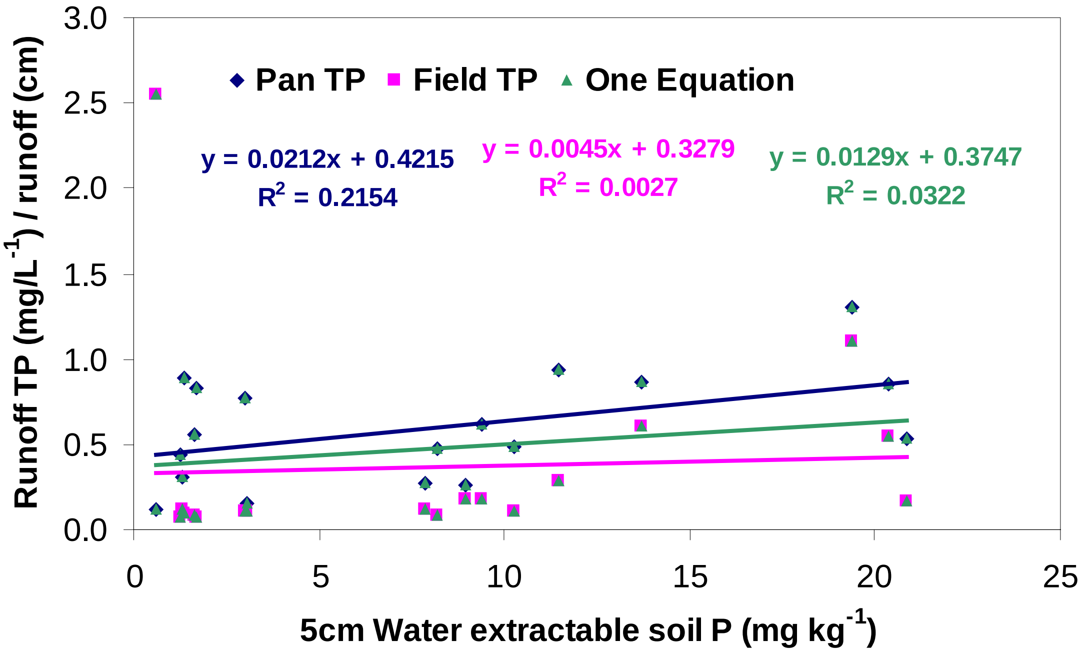

Figure 25. Relationship between normalized TP values and 5cm water extractable soil P with one equation.

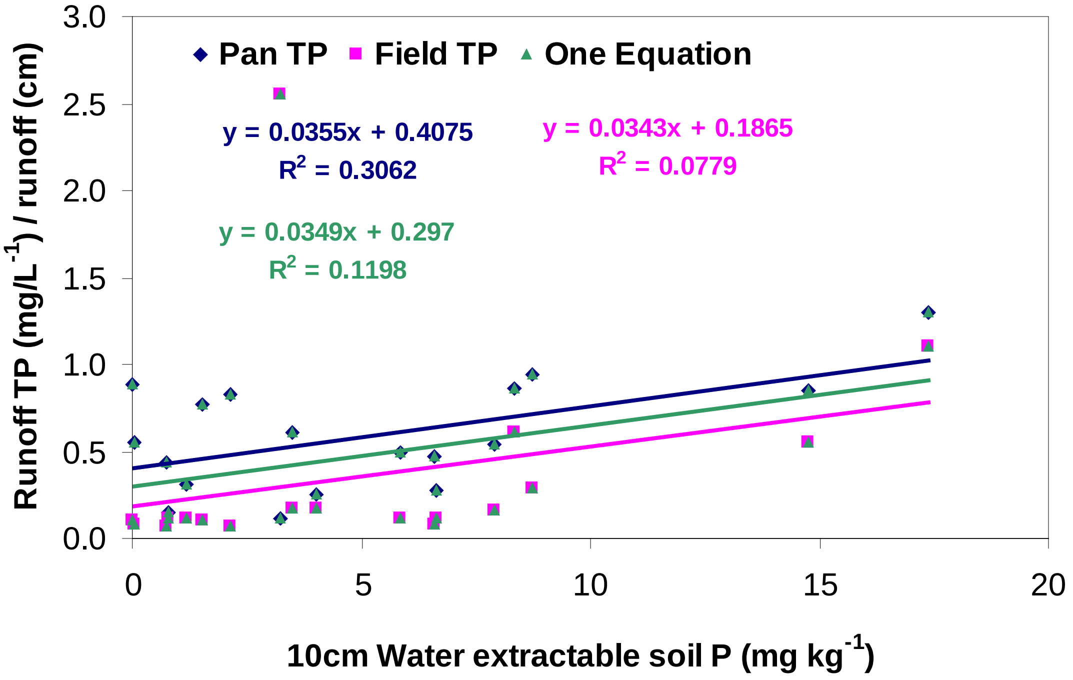

Figure 26. Relationship between normalized TP values and 10cm water extractable soil P with one equation.

APPENDIX A

SITE DESCRIPTIONS

Profile description for UGA Dairy 1-1, shoulder position, Clarke county Georgia.

Location: N 33˚ 55' 03" W 83˚ 14' 96"
Ground Cover: 100%

Horizon	Depth (cm)	Description
Ap	0 to 15	Yellowish Red (5YR 4/6) sandy loam; weak, granular structure; very friable consistence; many, fine roots; abrupt boundary
Bt1	15 to 53	Dark red (2.5YR 3/6) clay; moderate, medium subangular blocky structure; friable consistence; common, fine roots; clear boundary
Bt2	53 to 97	Dark red (2.5YR 3/6) clay loam; strong, medium, angular blocky structure; firm consistence; few, fine roots; few, thin, clay films on ped faces (2.5YR 3/6); clear boundary
Bt3	114+	Dark red (2.5YR 3/6) clay loam; few, fine depletions (7.5YR 7/6); moderate, medium subangular blocky structure; friable consistence

Profile description for UGA Dairy 1-2, sideslope position, Clarke county Georgia.

Location: N 33˚ 55' 03" W 83˚ 14' 96"
Ground Cover: 100%

Horizon	Depth (cm)	Description
Ap	0 to 15	Dark reddish brown (5YR 3/4) sandy loam; weak subangular blocky structure; very friable consistence; many, fine roots; abrupt boundary
Bt1	15 to 41	Dark red (2.5YR 3/6) clay; moderate, medium subangular blocky structure; friable consistence; few, fine roots; clear boundary
Bt2	41 to 61	Dark red (2.5YR 3/6) clay; moderate, medium subangular blocky structure; friable consistence; few, fine roots; clear boundary
Bt3	61 to 94	Dark red (2.5YR 3/6) clay loam; moderate, medium subangular blocky structure; friable consistence; few, fine roots; common, thin, clay films on ped faces (2.5YR 3/6); clear boundary
Bt4	102+	Dark red (2.5YR 3/6) clay loam; common, medium depletions (7.5YR 6/8); moderate, medium subangular blocky structure; friable consistence; few, fine roots

Profile description for UGA Dairy 1-3, footslope position, Clarke county Georgia.

Location: N 33˚ 55' 03" W 83˚ 14' 96"
Ground Cover: 100%

Horizon	Depth (cm)	Description
Ap	0 to 8	Reddish brown (5YR 4/4) fine sandy loam; very friable consistence; abrupt boundary
BA	8 to 15	Dark red (2.5YR 3/6) sandy clay loam; weak, medium subangular blocky structure; very friable consistence; many, fine roots; clear boundary
Bt1	15 to 30	Dark red (2.5YR 3/6) clay; moderate, medium subangular blocky structure; friable consistence; few, fine roots; few, thin, clay films on ped faces (2.5YR 3/6); clear boundary
Bt2	30 to 53	Dark red (2.5YR 3/6) clay; moderate, medium subangular blocky structure; friable consistence, few, fine roots; few, thin, clay films on ped faces (2.5YR 3/6); clear boundary
Bt3	89+	Yellowish red (5YR 5/8) clay loam; common, medium depletions (10YR 7/8) and few, fine depletions (10YR 8/3); moderate, medium subangular blocky structure; friable consistence; common, thin, clay films on ped faces (2.5YR 4/6)

Profile description for McKinney Farm 1-1, shoulder position, Jackson County Georgia.

Location: N 34˚ 02' 05" W 83˚ 30' 76"
Ground Cover: 90%
Slope: 5%

Horizon	Depth (cm)	Description
Ap	0 to 15	Dark reddish brown (5YR 3/4) sandy loam; weak, granular structure; very friable consistence; few, medium and common, fine roots; abrupt boundary
Bt1	15 to 41	Red (2.5YR 4/8) clay; moderate, fine subangular blocky structure; friable consistence; common, fine roots; clear boundary
Bt2	41 to 64	Red (2.5YR 4/8) sandy clay loam; weak, prismatic structure parting to moderate, medium subangular blocky structure; firm consistence; few, fine roots; many mica flakes; clear boundary
Bt3	64 to 79	Red (2.5YR 4/8) sandy clay loam; moderate, medium subangular blocky structure; few, thin, clay films on ped faces (2.5YR 4/8); many mica flakes; clear boundary
BC	79 to 97	Red (2.5YR 4/8) sandy clay loam; weak, subangular blocky structure; very friable consistence, few, fine roots, many mica flakes, clear boundary
C	109+	Sandy loam; moderate structure; few, fine roots; mica

Profile description for McKinney Farm 1-2, sideslope position, Jackson County Georgia.

Location: N 34˚ 02' 05" W 83˚ 30' 76"
Ground Cover: 95%
Slope: 10%

Horizon	Depth (cm)	Description
Ap	0 to 15	Yellowish red (5YR 4/6) sandy loam; weak, granular structure; very friable consistence; few, medium and many, fine roots; 5% quartz rock fragments; abrupt boundary
Bt1	15 to 38	Red (2.5YR 4/8) clay; moderate, medium subangular blocky structure; friable consistence; few, fine roots; clear boundary
Bt2	38 to 76	Red (2.5YR 4/8) clay; friable consistence; few, fine roots; clear boundary
Bt3	76 to 109	Red (2.5YR 4/8) clay loam; weak, subangular blocky tructure; friable consistence; clear boundary
CB	114+	Red (2.5YR 4/8) sandy clay loam; weak, coarse subangular blocky structure

Profile description for McKinney Farm 1-3, footslope position, Jackson County Georgia.

Location: N 34˚ 02' 05" W 83˚ 30' 76"
Ground Cover: 90%
Slope: 12%

Horizon	Depth (cm)	Description
Ap	0 to 15	Dark reddish brown (5YR 3/4) sandy loam; very friable consistence; many, fine roots; clear boundary
Bt1	15 to 48	Red (2.5YR 4/6) sandy clay loam; moderate, medium subangular blocky structure; friable consistence; few, fine roots; clear boundary
Bt2	48 to 66	Red (2.5YR 4/6) clay; moderate, medium subangular blocky structure; firm consistence; clear boundary
Bt3	66 to 89	Red (2.5YR 4/6) clay; moderate, medium subangular blocky structure; firm consistence; few mica flakes; clear boundary
BC	94+	Yellowish red (5YR 4/6) clay loam; weak, subangular blocky structure; friable consistence; few mica flakes; 5% quartz rock fragments

Profile description for Spruill Farm 1-1, summit position, Jackson County Georgia.

Location: N 34˚ 05' 96" W 83˚ 43' 97"
Ground Cover: 99%
Slope: 6%

Horizon	Depth (cm)	Description
Ap	0 to 13	Strong brown (7.5YR 4/6) loam; weak, medium subangular blocky structure; friable consistence; many, fine roots; clear boundary
Bt1	13 to 3	Yellowish red (5YR 5/8) clay loam; common, fine depletions (10YR 6/8) and few fine depletions (10YR 7/6); moderate, medium platy structure parting to moderate, medium subangular blocky structure; thin, clay films on ped faces (5YR 5/6); clear boundary
Bt2	33 to 72	Yellowish red (5YR 5/8) clay loam; few, fine depletions (10YR 6/8) and few, fine depletions (10YR 7/6); weak, medium platy structure parting to moderate, medium subangular blocky structure; clay films; gradual boundary
Bt3	72 to 102	Yellowish red (5YR 5/8) clay loam; common, fine depletions (10YR 6/8) and few, fine depletions (10YR 7/6); weak, platy structure parting to moderate, medium subangular blocky structure; gradual boundary
CB	122+	Yellowish red (5YR 5/6) sandy clay loam; weak, medium subangular blocky structure

Profile description for the Spruill Farm 1-2, sideslope position, Jackson County Georgia.

Location: N 34˚ 05' 96" W 83˚ 43' 97"
Ground Cover: 100%
Slope: 12%

Horizon	Depth (cm)	Description
Ap	0 to 13	Strong brown (7.5 YR 4/6) sandy loam; weak medium subangular blocky structure; many fine roots; 5% quartz; clear boundary
BA	13 to 25	Yellowish red (5YR 4/6) sandy clay loam; weak, medium subangular blocky structure; friable consistence; common, fine roots; clear boundary
Bt1	25 to 64	Yellowish red (5YR 4/6) clay; few, fine depletions (10YR 5/8); moderate, medium subangular blocky structure; friable consistence; few, fine roots; common, thin, film coatings (7.5YR 4/6) on ped faces; few, fine MN stainings on ped faces; clear boundary
Bt2	64 to 91	Strong brown (7.5YR 5/8) clay ; common fine depletions (10YR 7/8) and few fine depletions (10YR 8/3); moderate medium subangular blocky structure; many thin clay films on ped faces (5YR 4/6); few fine Mn stainings on ped faces; clear boundary
Bt3	91 to 147	Yellowish red (5YR 5/8) clay; common, coarse depletions (10YR 7/8) and few, fine depletions (10YR 8/3); moderate, medium subangular blocky structure; few, thin, clay films on ped faces (5YR 5/6); clear boundary
Bt4	147 to 168	Reddish yellow (5YR 6/8) clay loam; few, coarse depletions (10YR 8/3) and many, medium depletions (10YR 7/8); few, thin, clay films on ped faces (5YR 5/8); abrupt boundary
C	183+	

Profile description for Spruill Farm 1-3, toeslope position, Jackson County Georgia.

Location: N 34˚ 05' 96" W 83˚ 43' 97"
Ground Cover: 100%
Slope: 11%

Horizon	Depth (cm)	Description
Ap	0 to 13	Strong brown (7.5YR 4/6) sandy loam; weak, subangular blocky structure; very firm consistence; many, fine roots; clear boundary
BA	13 to 25	Yellowish red (5YR 4/6) clay loam; weak, medium subangular blocky structure; friable consistence; common, fine roots; few, thin clay films (5YR 4/6) and few, fine Mn stainings on ped faces; clear boundary
Bt1	25 to 46	Red (2.5YR 4/6) clay; moderate, medium subangular blocky structure; friable consistence; few, fine roots, common, fine, clay films (5YR 4/6) and common, fine Mn stainings on ped faces; clear boundary
Bt2	46 to 69	Yellowish red (5YR 5/6) clay ; few, fine depletions (10YR 7/8); moderate, medium subangular blocky structures; few, fine roots; few, thin, clay films (5YR 5/6) and common, medium Mn stainings on ped faces; abrupt boundary
BC	69 to 86	Yellowish red (5YR 5/8) sandy clay loam; common, medium depletions (10YR 6/8) and few, medium depletions (10YR 8/2); weak, subangular blocky structure; common, medium Mn stainings on ped faces; clear boundary
CB	117+	Yellowish red (5YR 5/8) loam; common, coarse Mn concentrations; common, medium depletions (10YR 7/8) and few, fine depletions (10YR 7/3); and weak, moderate subangular blocky structure; many coarse Mn concretions

Profile description for the UGA Dairy 2-1, shoulder position, Oglethorpe county Georgia.

Location: N 33˚ 54' 35" W 83˚ 15' 20"
Ground Cover: 99%
Slope: 6.25%

Horizon	Depth (cm)	Description
Ap	0 to 8	Dark reddish brown (5YR 3/4) sandy loam; weak, granular structure; very friable consistence; many, fine roots; abrupt boundary
Bt1	8 to 36	Red (2.5YR 4/8)clay; strong, medium subangular blocky structure; friable consistence; common, fine roots; clear boundary
Bt2	36 to 61	Red (2.5YR 5/8) clay loam; strong, medium subangular blocky structure; friable consistence, few, fine roots; common, thin, clay films on ped faces (2.5YR 5/8); few mica flakes; clear boundary
CB	122+	Yellowish red (5YR 5/8) clay loam; moderate, medium subangular blocky structure; very friable consistence; common, thin, clay films on ped faces (2.5YR 4/8); common mica flakes

Profile description for UGA Dairy 2-2, sideslope position, Oglethorpe county Georgia.

Location: N 33˚ 54' 35" W 83˚ 15' 20"
Ground Cover: 99%
Slope: 8.33%

Horizon	Depth (cm)	Description
Ap	0 to 8	Dark reddish brown (5YR 3/4) clay loam; weak, granular structure; very friable consistence; many, fine roots; abrupt boundary
Bt1	8 to 25	Red (2.5YR 4/6) clay; weak, medium subangular blocky structure; friable consistence; common, fine roots; clear boundary
Bt2	25 to 64	Red (2.5YR 4/6) clay loam; moderate, medium subangular blocky structure; friable consistence; common, fine roots; many, thin, clay films on ped faces (10YR 4/6); few to many mica flakes; clear boundary
Bt3	64 to 81	Red (2.5YR 4/6) clay loam; moderate, medium subangular blocky structure; friable consistence; common, thin, clay films on ped faces (2.5YR 4/6); few mica flakes; clear boundary
BC	112+	Red (2.5YR 4/8) loam; weak, medium subangular blocky structure; very friable consistence; many, thin ,clay films on ped faces (2.5YR 4/6); common mica flakes

Profile description for UGA Dairy 2-3, toeslope position, Oglethorpe county Georgia.

Location: N 33˚ 54' 35" W 83˚ 15' 20"
Ground Cover: 99%
Slope: 9.2%

Horizon	Depth (cm)	Description
Ap	0 to 8	Dark reddish brown (2.5YR 3/4) clay loam; weak, moderate subangular blocky structure; friable consistence; many, fine roots; abrupt boundary
Bt1	8 to 20	Red (10R 4/6) sandy clay loam; weak, medium subangular blocky structure; firm consistence; few, fine roots; clear boundary
Bt2	20 to 36	Dark red (2.5YR 3/6) sandy clay loam; weak medium subangular blocky structure; friable consistence, few fine roots; clear boundary
Bt3	36 to 53	Red (2.5YR 4/8) clay; common, medium depletions (7.5YR 6/8); strong, medium angular blocky structure; friable consistence; few, fine roots; abrupt boundary
Bt4	76+	Red (2.5YR 4/8) clay; few, fine depletions (7.5YR 6/8); moderate, medium subangular blocky structure; friable consistence

Profile description for Davis Farm 1-1, summit position, Barrow county Georgia.

Location: N 34˚ 01' 27" W 83˚ 41' 22"
Ground Cover: 93%
Slope: 9.2%

Horizon	Depth (cm)	Description
Ap	0 to 8	Dark reddish brown (5YR 3/3) sandy loam; very friable consistence; weak, moderate subangular blocky structure; common, fine roots; abrupt boundary
BA	8 to 28	Reddish brown (5YR 4/4) sandy clay loam; weak, medium subangular blocky structure; friable consistence; few, fine roots; clear boundary
Bt	28 to 56	Dark red (2.5YR 3/6) clay; moderate, medium subangular blocky structure; friable consistence; clear boundary
BC	71+	Red (2.5YR 4/6) sandy clay loam; weak, medium subangular blocky structure; few, fine roots; many mica flakes

Profile description for Davis Farm 1-2, sideslope position, Barrow county Georgia.

Location: N 34˚ 01' 27" W 83˚ 41' 22"
Ground Cover: 96%
Slope: 8.3%

Horizon	Depth (cm)	Description
Ap	0 to 8	Very dark brown (7.5YR 2.5/3) sandy loam; very friable consistence; weak, granular structure; common, fine roots; abrupt boundary
AB	8 to 23	Dark brown (7.5YR 3/3) sandy loam; weak, medium subangular blocky structure; very friable consistence; few, fine roots; abrupt boundary
Bt	23 to 53	Red (2.5YR 4/6) clay; moderate, medium subangular blocky structure; common mica flakes; few, fine roots; friable consistence; clear boundary
BC	53 to 66	Dark red (2.5YR 3/6) sandy clay loam; moderate, medium subangular blocky structure; few, fine roots; many mica flakes, clear boundary
C	91+	Red (2.5YR 4/8) sandy loam; friable consistence; structureless saprolite

Profile description for Davis Farm 1-3, footslope position, Barrow county Georgia.

Location: N 34˚ 01' 27" W 83˚ 41' 22"
Ground Cover: 88%
Slope: 9.6%

Horizon	Depth (cm)	Description
Ap	0 to 8	Dark reddish brown (5YR 3/3) sandy loam; very friable consistence; weak, medium subangular blocky structure; many, fine roots; abrupt boundary
BA	8 to 23	Reddish brown (5YR 4/4) sandy clay loam; weak, medium subangular blocky structure; friable consistence; common, fine roots; clear boundary
Bt	23 to 76	Dark red (2.5YR 3/6) clay; moderate, medium subangular blocky structure; common mica flakes; few, fine roots; friable consistence; clear boundary
BC	114+	Dark red (2.5YR 3/6) sandy clay loam; weak, medium subangular blocky structure; many mica flakes

Profile description for Risse Farm 1-1, summit position, Oconee county Georgia.

Location: N 33˚ 45' 21" W 83˚ 22' 31"
Ground Cover: 97%
Slope: 5.8%

Horizon	Depth (cm)	Description
Ap	0 to 5	Reddish brown (2.5YR 4/4) sandy clay loam; moderate, granular structure; very friable consistence; many, fine roots; many, fine pores; abrupt boundary
Bt1	5 to 41	Red (2.5YR 4/8) clay; moderate, medium subangular blocky structure; friable consistence; few, fine roots; many, thin, clay films on ped faces (2.5YR 4/8); clear boundary
Bt2	41 to 66	Red (2.5YR 4/8) clay; moderate, medium subangular blocky structure; firm consistence; few, fine roots; few, thin, faint, clay films on ped faces (2.5YR 4/8); clear boundary
Bt3	66 to 94	Red (2.5YR 4/8) clay loam; moderate, medium subangular blocky structure; friable consistence, few, thin, faint, clay films on ped faces (2.5YR 4/6); clear boundary
BC	114+	Red (2.5 YR 4/6) clay loam; weak, coarse subangular blocky structure; very friable consistence

Profile description for Risse Farm 1-2 , sideslope position, Oconee county Georgia.

Location: N 33˚ 45' 21" W 83˚ 22' 31"
Ground Cover: 97%
Slope: 6.9%

Horizon	Depth (cm)	Description
Ap	0 to 8	Reddish brown (5YR 4/4) sandy loam; weak, medium subangular blocky structure; very friable consistence; many, fine roots; abrupt boundary
BA	8 to 23	Yellowish red (5YR 4/6) sandy clay loam; weak, medium subangular blocky structure; very friable consistence; few, fine roots; clear boundary
Bt1	23 to 61	Red (2.5YR 4/8) clay; moderate, medium subangular blocky structure; friable consistence; few, fine roots; few, thin, clay films on ped faces (2.5YR 4/8); clear boundary
Bt2	61 to 89	Red (2.5YR 4/8) sandy clay loam; moderate, medium subangular blocky structure; friable consistence; abrupt boundary
CB	127+	Red (2.5YR 4/8) clay loam; weak, medium subangular blocky structure; friable consistence

Profile description for Risse Farm 1-3, toeslope position, Oconee county Georgia.

Location: N 33˚ 45' 21" W 83˚ 22' 31"
Ground Cover: 98%
Slope: 7.1%

Horizon	Depth (cm)	Description
Ap	0 to 8	Dark reddish brown (5YR 3/3) sandy loam; weak, granular structure; very friable consistence; many, fine roots; abrupt boundary
AB	8 to 23	Yellowish red (5YR 4/6) sandy loam; weak, medium subangular blocky structure; very friable consistence; few, fine, roots; clear boundary
Bt1	23 to 51	Red (2.5YR 4/8) sandy clay loam; weak, medium subangular blocky structure; very friable consistence; few, fine roots; clear boundary
Bt2	51 to 91	Red (2.5YR 4/8) clay; weak, medium subangular blocky structure; friable consistence, few, fine roots; clear boundary
Bt3	122+	Red (2.5YR 4/8) sandy clay loam; weak, medium subangular blocky structure; friable consistence

Sample ID	Depth	Horizon	Sand	Clay	Silt	pH
SPR 1-1	0-5	Ap	46.2	22.8	31.0	5.34
SPR 1-1	5-13	Bt1	14.9	49.4	35.8	5.29
SPR 1-1	13-28	Bt2	7.5	54.4	38.1	5.04
SPR 1-1	28-40	Bt2	26.7	44.8	28.4	4.47
SPR 1-1	40-48+	CB	14.4	42.7	42.9	4.41
SPR 1-2	0-5	Ap	51.5	14.4	34.1	5.16
SPR 1-2	5-10	BA	44.9	36.4	18.7	5.5
SPR 1-2	10-25	Bt1	39.0	43.7	17.3	6.02
SPR 1-2	25-36	Bt2	29.0	48.3	22.7	6.21
SPR 1-2	36-58	Bt3	17.8	47.9	34.3	6.54
SPR 1-2	58-66	Bt4	20.2	45.0	34.8	6.1
SPR 1-2	66-72+	C	41.6	28.4	30.0	5.39
SPR 1-3	0-5	Ap	57.5	36.9	5.6	5.1
SPR 1-3	10-18	BA	38.4	35.9	25.7	5.67
SPR 1-3	18-27	Bt1	41.9	20.9	37.2	6.08
SPR 1-3	27-34	Bt2	54.2	24.7	21.1	6.07
SPR 1-3	34-46	BC	3.3	22.2	74.5	5.9
MCK 1-1	0-6	Ap	52.4	10.9	36.7	5.35
MCK 1-1	6-16	Bt1	29.5	61.1	9.4	5.1
MCK 1-1	16-25	bt2	40.3	48.5	11.3	4.62
MCK 1-1	25-31	Bt3	49.7	39.9	10.5	4.56
MCK 1-1	31-38	BC	58.0	28.7	13.3	4.58
MCK 1-1	38-43+	C	75.6	13.5	10.9	4.55
MCK 1-2	0-6	Ap	69.8	10.4	19.8	4.75
MCK 1-2	6-15	Bt1	41.0	42.2	16.8	5.05
MCK 1-2	15-30	Bt2	33.7	53.7	12.6	5.13
MCK 1-2	30-43	Bt3	48.6	26.8	24.6	5.16
MCK 1-2	43-45+	CB	52.7	20.4	27.0	5.03
MCK 1-3	0-6	Ap	68.4	13.4	18.2	5.39
MCK 1-3	6-19	Bt1	59.6	25.3	15.2	5.32
MCK 1-3	19-26	Bt2	35.7	40.3	24.0	5.12
MCK 1-3	26-35	Bt3	34.2	46.0	19.8	5.18
MCK 1-3	35-37+					
UGD 1-1	0-6	Ap	33.9	30.6	35.5	4.06
UGD 1-1	6-21	Bt1	33.6	51.0	15.4	5.19
UGD 1-1	21-38	Bt2	23.8	66.3	9.9	5.36
UGD 1-1	38-45+	Bt3	21.4	65.4	13.2	5.23
UGD 1-2	0-6	Ap	49.7	26.2	24.1	5.08
UGD 1-2	6-16	Bt1	31.5	47.1	21.4	6.14
UGD 1-2	16-24	Bt2	29.6	56.5	14.0	5.67
UGD 1-2	24-37	Bt3	31.5	55.2	13.3	5.08
UGD 1-2	37-40+	Bt4	33.8	52.5	13.7	4.99
UGD 1-3	0-3	Ap	94.7	9.4	-4.1	4.32
UGD 1-3	3-6	BA	38.0	40.6	21.3	4.82
UGD 1-3	6-12	Bt1	28.3	57.8	13.9	5.51
UGD 1-3	12-21	Bt2	23.8	44.7	31.5	5.15
UGD 1-3	21-35+	Bt3	20.8	55.1	24.1	4.77

Sample ID	Depth	Horizon	Sand	Clay	Silt	pH
UGD 2-1	0-3	Ap	56.1	15.5	28.4	4.33
UGD 2-1	3-14	Bt1	23.2	54.7	22.1	5.32
UGD 2-1	14-24	Bt2	23.7	55.8	20.5	5.5
UGD 2-1	24-48+	CB	31.4	37.7	30.9	5.15
UGD 2-2	0-3	AP	54.4	16.0	29.6	5.13
UGD 2-2	3-10	Bt1	25.5	12.2	62.3	4.61
UGD 2-2	10-25	Bt2	25.8	58.4	15.8	4.67
UGD 2-2	25-32	Bt3	27.8	50.4	21.8	4.56
UGD 2-3	32-44+	BC	39.7	41.2	19.1	4.57
UGD 2-3	0-3	Ap	51.0	17.3	31.6	4.65
UGD 2-3	3-8	Bt1	46.0	40.1	14.0	
UGD 2-3	8-14	Bt2	41.0	47.9	11.1	6.28
UGD 2-3	14-21	Bt3	29.9	48.6	21.5	6.55
UGD 2-3	21-30+	Bt4	31.9	20.1	48.1	5.15
DAV 1-1	1-3	Ap	70.0	6.9	23.1	6.07
DAV 1-1	3-11	BA	72.4	18.1	9.6	5.59
DAV 1-1	11-22	Bt	36.9	53.2	9.9	5.73
DAV 1-2	22-28+	BC	56.1	33.7	10.2	5.4
DAV 1-2	0-3	Ap	70.9	8.3	20.8	5.85
DAV 1-2	3-9	AB	74.5	11.6	14.0	5.63
DAV 1-2	9-21	Bt	37.6	50.2	12.2	5.74
DAV 1-2	21-26	BC	52.1	38.8	9.2	5.66
DAV 1-3	26-36+	C	61.2	27.2	11.6	5.52
DAV 1-3	0-3	Ap	77.6	1.9	20.6	5.81
DAV 1-3	3-9	BA	62.4	14.7	22.9	5.87
DAV 1-3	9-30	Bt	26.0	60.5	13.5	5.89
DAV 1-3	30-45+	BC	37.0	49.6	13.5	5.1
RIS 1-1	0-2	Ap	49.6	22.6	27.8	5.35
RIS 1-1	2-16	Bt1	28.3	52.9	18.8	
RIS 1-1	16-26	Bt2	24.3	47.5	28.2	4.9
RIS 1-1	26-37	Bt3	28.2	39.1	32.8	5.36
RIS 1-1	37-48+	BC	30.5	35.0	34.5	5.7
RIS 1-2	0-3	Ap	51.7	18.1	30.2	5.98
RIS 1-2	3-9	BA	50.6	22.1	27.3	6.42
RIS 1-2	9-24	Bt1	36.0	21.9	42.1	5.33
RIS 1-3	24-35+	Bt2	36.0	42.1	21.9	5.35
RIS 1-3	0-3	Ap	77.1	4.7	18.3	5.71
RIS 1-3	3-9	AB	65.4	14.0	20.6	5.94
RIS 1-3	9-20	Bt1	46.1	35.1	18.8	5.38
RIS 1-3	20-36	Bt2	44.0	41.6	14.4	5.32
RIS 1-3	36-48+	Bt3	36.1	15.1	48.8	5.11

APPENDIX B

RUNOFF PLOT SOIL SAMPLE ANALYSES

Sample ID	**Depth (cm)**	**Date**	**Gravimetric Water**	**pH**	**Mehlich III P (mg kg^{-1})**	**Water P (mg kg^{-1})**	**Bio P (mg kg^{-1})**	**Bio P Soil (mg kg^{-1})**
UGD1-1A	0-2	06/16/00	1.66	4.4	44.5	3.625	0.366	18.3
UGD1-1A	0-5	06/16/00	0.35	4.32	59.7	1.35	0.153	7.65
UGD1-1A	0-10	06/16/00	0.61	5.2	45.3	0.775	0.116	5.8
UGD1-1B	0-2	06/16/00	0.87	4.48	46.8	1.25	0.254	12.7
UGD1-1B	0-5	06/16/00	0.64	4.56	42.1	1.2	0.179	8.95
UGD1-1B	0-10	06/16/00	0.32	5.15	46.7	0.7	0.115	5.75
UGD1-2A	0-2	06/16/00	0.55	4.69	43.5	0	0.235	11.75
UGD1-2A	0-5	06/16/00	0.37	4.69	47.1	0.1	0.186	9.3
UGD1-2A	0-10	06/16/00	0.24	5.18	49.9	1.425	0.144	7.2
UGD1-2B	0-2	06/16/00	0.45	4.56	48.6	1.25	0.279	13.95
UGD1-2B	0-5	06/16/00	0.39	4.98	32.2	1.15	0.279	13.95
UGD1-2B	0-10	06/16/00	0.27	4.71	39.8	5.05	0.133	6.65
UGD1-3A	0-2	06/16/00	0.52	4.7	56.7	2.25	0.314	15.7
UGD1-3A	0-5	06/16/00	0.43	4.48	49.5	1.65	0.128	6.4
UGD1-3A	0-10	06/16/00	0.5	5.05	41.6	1.925	0.125	6.25
UGD1-3B	0-2	06/16/00	0.6	4.91	48.2	2.35	0.236	11.8
UGD1-3B	0-5	06/16/00	0.32	4.65	43.9	1.725	0.158	7.9
UGD1-3B	0-10	06/16/00	0.27	4.92	35.9	2.35	0.135	6.75
MCK1-1A	0-2	06/23/00	0.56	6.06	101	14.975	0.547	27.35
MCK1-1A	0-5	06/23/00	0.39	6.1	103.3	11.725	0.515	25.75
MCK1-1A	0-10	06/23/00	0.25	5.37	71.9	6.225	0.282	14.1
MCK1-1B	0-2	06/23/00	0.37	5.97	87.9	13.375	0.491	24.55
MCK1-1B	0-5	06/23/00	0.32	5.89	81	8.75	0.426	21.3
MCK1-1B	0-10	06/23/00	0.3	5.68	67	5.5	0.251	12.55
MCK1-2A	0-2	06/23/00	0.45	5.75	88.6	11.875	0.462	23.1
MCK1-2A	0-5	06/23/00	0.38	5.48	90.5	10.225	0.329	16.45
MCK1-2A	0-10	06/23/00	0.33	5.66	73.7	3.6	0.25	12.5
MCK1-2B	0-2	06/23/00	0.38	5.77	84.1	9.425	0.428	21.4
MCK1-2B	0-5	06/23/00	0.3	5.68	89.1	7.625	0.353	17.65
MCK1-2B	0-10	06/23/00	0.26	5.29	54.6	4.425	0.244	12.2
MCK1-3A	0-2	06/23/00	0.43	5.13	74.1	7.775	0.434	21.7
MCK1-3A	0-5	06/23/00	0.39	5.14	68.6	3.975	0.284	14.2
MCK1-3A	0-10	06/23/00	0.27	4.98	35	1.025	0.136	6.8
MCK1-3B	0-2	06/23/00	0.31	5.29	62.7	5.3	0.358	17.9
MCK1-3B	0-5	06/23/00	0.32	5.27	48.9	2.175	0.223	11.15
MCK1-3B	0-10	06/23/00	0.25	5.29	37.2	0.575	0.178	8.9

Sample ID	**Depth (cm)**	**Date**	**Gravimetric Water**	**pH**	**Mehlich III P (mg kg^{-1})**	**Water P (mg kg^{-1})**	**Bio P (mg kg^{-1})**	**Bio P Soil (mg kg^{-1})**
SPR1-1A	0-2	06/30/00	0.38	4.94	147.2	8.825	0.654	32.7
SPR1-1A	0-5	06/30/00	0.38	4.83	126.9	8.625	0.497	24.85
SPR1-1A	0-10	06/30/00	0.3	4.9	122.7	6.55	0.571	28.55
SPR1-1B	0-2	06/30/00	0.38	4.69	143	8.6	0.694	34.7
SPR1-1B	0-5	06/30/00	0.33	4.81	139.7	7.8	0.63	31.5
SPR1-1B	0-10	06/30/00	0.28	4.86	129.6	6.6	0.589	29.45
SPR1-2A	0-2	06/30/00	0.49	4.87	125.7	9.925	0.62	31
SPR1-2A	0-5	06/30/00	0.33	5.12	120.1	7.975	0.426	21.3
SPR1-2A	0-10	06/30/00	0.23	4.91	126.4	6	0.368	18.4
SPR1-2B	0-2	06/30/00	0.42	5.13	141.7	6.675	0.515	25.75
SPR1-2B	0-5	06/30/00	0.41	5	132.2	7.7	0.519	25.95
SPR1-2B	0-10	06/30/00	0.24	5.03	111.4	7.25	0.32	16
SPR1-3A	0-2	06/30/00	0.27	4.61	76.3	3.15	0.31	15.5
SPR1-3A	0-5	06/30/00	0.32	4.86	67.7	2.2	0.257	12.85
SPR1-3A	0-10	06/30/00	0.24	5.06	56	1.375	0.193	9.65
SPR1-3B	0-2	06/30/00	0.31	4.47	88.7	4.675	0.363	18.15
SPR1-3B	0-5	06/30/00	0.25	4.8	49.3	3.8	0.301	15.05
SPR1-3B	0-10	06/30/00	0.21	5.18	67.3	1.7	0.222	11.1
UGD2-1A	0-2	07/07/00	0.47	4.84	48.9	4.725	0.192	9.6
UGD2-1A	0-5	07/07/00	0.29	4.72	41.6	1.625	0.159	7.95
UGD2-1A	0-10	07/07/00	0.21	4.49	35.2	0.35	0.113	5.65
UGD2-1B	0-2	07/07/00	0.59	4.78	49.7	3.525	0.388	19.4
UGD2-1B	0-5	07/07/00	0.44	4.41	35	1	0.159	7.95
UGD2-1B	0-10	07/07/00	0.44	4.7	55.3	1.975	0.158	7.9
UGD2-2A	0-2	07/07/00	0.58	4.36	43.7	8.025	0.341	17.05
UGD2-2A	0-5	07/07/00	0.53	4.17	35.3	1.525	0.137	6.85
UGD2-2A	0-10	07/07/00	0.42	4.22	29.6	-0.05	0.096	4.8
UGD2-2B	0-2	07/07/00	0.62	4.39	29.5	4.525	0.315	15.75
UGD2-2B	0-5	07/07/00	0.37	4.48	27.6	1.175	0.177	8.85
UGD2-2B	0-10	07/07/00	0.3	4.64	30.5	0.075	0.115	5.75
UGD2-3A	0-2	07/07/00	0.49	5.04	39.1	5.9	0.262	13.1
UGD2-3A	0-5	07/07/00	0.41	5.11	28.9	2.35	0.135	6.75
UGD2-3A	0-10	07/07/00	0.23	5.28	27.9	0.3	0.081	4.05
UGD2-3B	0-2	07/07/00	0.33	4.59	31.5	3.55	0.219	10.95
UGD2-3B	0-5	07/07/00	0.21	4.74	24.6	0.975	0.126	6.3
UGD2-3B	0-10	07/07/00	0.19	5.37	28.5	-0.25	0.073	3.65

Sample ID	Depth (cm)	Date	Gravimetric Water	pH	Mehlich III P (mg kg^{-1})	Water P (mg kg^{-1})	Bio P (mg kg^{-1})	Bio P Soil (mg kg^{-1})
DAV1-1A	0-2	07/14/00	0.6	6.12	344	22.1	1.303	65.15
DAV1-1A	0-5	07/14/00	0.34	5.68	373	21.15	1.242	62.1
DAV1-1A	0-10	07/14/00	0.29	5.73	258	13.4	0.658	32.9
DAV1-1B	0-2	07/14/00	0.57	5.82	314	19.475	1.346	67.3
DAV1-1B	0-5	07/14/00	0.43	5.43	308	19.525	0.972	48.6
DAV1-1B	0-10	07/14/00	0.31	5.66	325	16.15	0.898	44.9
DAV1-2A	0-2	07/14/00	0.51	5.83	330	25.8	1.483	74.15
DAV1-2A	0-5	07/14/00	0.32	5.51	323	16.875	0.865	43.25
DAV1-2A	0-10	07/14/00	0.24	5.61	327	14.45	0.697	34.85
DAV1-2B	0-2	07/14/00	0.49	6.03	431	24.425	1.494	74.7
DAV1-2B	0-5	07/14/00	0.31	5.56	294	21.875	0.993	49.65
DAV1-2B	0-10	07/14/00	0.48	5.67	302	20.35	1.098	54.9
DAV1-3A	0-2	07/14/00	0.73	6.2	296	24.175	1.42	71
DAV1-3A	0-5	07/14/00	0.64	5.83	253	17.925	1.159	57.95
DAV1-3A	0-10	07/14/00	0.25	5.68	215	12.1	0.753	37.65
DAV1-3B	0-2	07/14/00	0.78	5.91	392	18.825	1.713	85.65
DAV1-3B	0-5	07/14/00	0.55	5.55	295	9.475	1.132	56.6
DAV1-3B	0-10	07/14/00	0.3	5.69	286	4.55	1.216	60.8
RIS1-1A	0-2	07/21/00	0.57	5.3	126.6	34.45	0.824	41.2
RIS1-1A	0-5	07/21/00	0.47	5.79	107.3	15.6	0.55	27.5
RIS1-1A	0-10	07/21/00	0.31	6.16	82.4	5.6	0.288	14.4
RIS1-1B	0-2	07/21/00	0.57	5.39	141.4	33.725	1.041	52.05
RIS1-1B	0-5	07/21/00	0.3	5.69	120.6	26.075	0.672	33.6
RIS1-1B	0-10	07/21/00	0.2	5.53	96.5	10.175	0.364	18.2
RIS1-2A	0-2	07/21/00	0.34	5.41	160.6	16.075	0.762	38.1
RIS1-2A	0-5	07/21/00	0.27	5.21	147.1	5.575	0.587	29.35
RIS1-2A	0-10	07/21/00	0.17	5.61	100.3	2.15	0.318	15.9
RIS1-2B	0-2	07/21/00	0.53	5.22	135.8	17.75	0.685	34.25
RIS1-2B	0-5	07/21/00	0.24	5.06	137.8	13.225	0.555	27.75
RIS1-2B	0-10	07/21/00	0.35	5.42	110.6	4.875	0.339	16.95
RIS1-2A	0-2	07/21/00	0.64	5.42	198	22.8	0.686	34.3
RIS1-2A	0-5	07/21/00	0.34	4.97	172	8.175	0.482	24.1
RIS1-2A	0-10	07/21/00	0.26	5.1	115.8	6.325	0.413	20.65
RIS1-3A	0-2	07/21/00	0.82	5.16	188.1	23.3	0.68	34
RIS1-3A	0-5	07/21/00	0.18	5.14	198.8	14.775	0.617	30.85
RIS1-3A	0-10	07/21/00	0.29	5.39	153	11.125	0.457	22.85

APPENDIX C

FIELD RUNOFF ANALYSES

Sample ID	**Date**	**Volume (mL)**	**Total P (ppm)**	**Total P (ppm) Less Initial Well Water Total P**	**Flow Weighted TP**
UGD1-1A	6/12/2000	19000	0.459	0.365	0.378
UGD1-1B	6/12/2000	5400	0.517	0.423	
UGD1-2A	6/12/2000	90	0.273	0.179	0.453
UGD1-2B	6/12/2000	310	0.627	0.533	
UGD1-3A	6/12/2000	6440	0.663	0.569	0.536
UGD1-3B	6/12/2000	5100	0.588	0.494	
UGD1-1A	6/14/2000	26000	0.545	0.451	0.484
UGD1-1B	6/14/2000	18000	0.626	0.532	
UGD1-2A	6/14/2000	320	0.416	0.322	0.322
UGD1-2B	6/14/2000	0	0.000	-0.094	
UGD1-3A	6/14/2000	35000	0.579	0.485	0.484
UGD1-3B	6/14/2000	18500	0.575	0.481	
UGD1-1A	6/16/2000	29000	0.571	0.477	0.492
UGD1-1B	6/16/2000	29000	0.601	0.507	
UGD1-2A	6/16/2000	1730	0.455	0.361	0.358
UGD1-2B	6/16/2000	430	0.438	0.344	
UGD1-3A	6/16/2000	32500	0.408	0.314	0.329
UGD1-3B	6/16/2000	28500	0.441	0.347	
MCK1-1A	6/19/2000	22000	1.010	0.998	1.005
MCK1-1B	6/19/2000	25000	1.024	1.012	
MCK1-2A	6/19/2000	17000	1.154	1.142	1.130
MCK1-2B	6/19/2000	13500	1.127	1.115	
MCK1-3A	6/19/2000	16000	0.658	0.646	0.594
MCK1-3B	6/19/2000	20000	0.565	0.553	
MCK1-1A	6/21/2000	24000	0.835	0.823	0.825
MCK1-1B	6/21/2000	25000	0.838	0.826	
MCK1-2A	6/21/2000	16000	0.826	0.814	0.858
MCK1-2B	6/21/2000	16000	0.913	0.901	
MCK1-3A	6/21/2000	11000	0.537	0.525	0.532
MCK1-3B	6/21/2000	16000	0.549	0.537	
MCK1-1A	6/23/2000	27500	0.691	0.679	0.690
MCK1-1B	6/23/2000	28500	0.712	0.700	
MCK1-2A	6/23/2000	16500	0.620	0.608	0.678
MCK1-2B	6/23/2000	20000	0.747	0.735	
MCK1-3A	6/23/2000	14000	0.470	0.458	0.438
MCK1-3B	6/23/2000	17000	0.434	0.422	

Sample ID	Date	Volume (mL)	Total P (ppm)	Total P (ppm) Less Initial Well Water Total P	Flow Weighted TP
SPR1-1A	6/26/2000	22000	0.703	0.685	0.683
SPR1-1B	6/26/2000	30000	0.700	0.682	
SPR1-2A	6/26/2000	10000	0.697	0.679	0.737
SPR1-2B	6/26/2000	15000	0.794	0.776	
SPR1-3A	6/26/2000	21000	0.677	0.659	0.710
SPR1-3B	6/26/2000	18000	0.788	0.770	
SPR1-1A	6/28/2000	16000	0.578	0.560	0.559
SPR1-1B	6/28/2000	26000	0.576	0.558	
SPR1-2A	6/28/2000	15500	0.557	0.539	0.555
SPR1-2B	6/28/2000	13000	0.591	0.573	
SPR1-3A	6/28/2000	21000	0.513	0.495	0.489
SPR1-3B	6/28/2000	9000	0.492	0.474	
SPR1-1A	6/30/2000	26000	0.592	0.574	0.492
SPR1-1B	6/30/2000	29000	0.437	0.419	
SPR1-2A	6/30/2000	29000	0.517	0.499	0.538
SPR1-2B	6/30/2000	19500	0.614	0.596	
SPR1-3A	6/30/2000	28500	0.529	0.511	0.503
SPR1-3B	6/30/2000	13000	0.502	0.484	
UGD2-1A	7/3/2000	14000	0.747	0.653	0.794
UGD2-1B	7/3/2000	15000	1.019	0.925	
UGD2-2A	7/3/2000	21000	0.770	0.676	0.634
UGD2-2B	7/3/2000	24000	0.691	0.597	
UGD2-3A	7/3/2000	12000	0.689	0.595	0.654
UGD2-3B	7/3/2000	17000	0.789	0.695	
UGD2-1A	7/5/2000	20000	0.631	0.537	0.564
UGD2-1B	7/5/2000	19000	0.687	0.593	
UGD2-2A	7/5/2000	16000	0.654	0.560	0.560
UGD2-2B	7/5/2000		0.658	0.564	
UGD2-3A	7/5/2000	35000	0.605	0.511	0.496
UGD2-3B	7/5/2000	14500	0.553	0.459	
UGD2-1A	7/7/2000	18000	0.588	0.494	0.520
UGD2-1B	7/7/2000	21000	0.636	0.542	
UGD2-2A	7/7/2000	17000	0.529	0.435	0.453
UGD2-2B	7/7/2000	32000	0.556	0.462	
UGD2-3A	7/7/2000	37500	0.638	0.544	0.484
UGD2-3B	7/7/2000	20000	0.465	0.371	

Sample ID	Date	Volume (mL)	Total P (ppm)	Total P (ppm) Less Initial Well Water Total P	Flow Weighted TP
DAV1-1A	7/10/2000	7000	2.790	2.768	2.587
DAV1-1B	7/10/2000	10000	2.482	2.460	
DAV1-2A	7/10/2000	1800	1.249	1.227	1.171
DAV1-2B	7/10/2000	1200	1.108	1.086	
DAV1-3A	7/10/2000	2500	1.054	1.032	1.082
DAV1-3B	7/10/2000	700	1.283	1.261	
DAV1-1A	7/12/2000	12000	1.690	1.668	1.441
DAV1-1B	7/12/2000	14000	1.268	1.246	
DAV1-2A	7/12/2000	4000	0.884	0.862	0.790
DAV1-2B	7/12/2000	3000	0.715	0.693	
DAV1-3A	7/12/2000	13000	1.082	1.060	1.070
DAV1-3B	7/12/2000	6000	1.113	1.091	
DAV1-1A	7/14/2000	9000	1.488	1.466	1.259
DAV1-1B	7/14/2000	10000	1.094	1.072	
DAV1-2A	7/14/2000	3100	0.710	0.688	0.862
DAV1-2B	7/14/2000	3000	1.064	1.042	
DAV1-3A	7/14/2000	2500	0.786	0.764	1.030
DAV1-3B	7/14/2000	10000	1.119	1.097	
RIS1-1A	7/17/2000	13000	1.414	1.375	1.129
RIS1-1B	7/17/2000	13000	0.921	0.882	
RIS1-2A	7/17/2000	20000	1.253	1.214	1.174
RIS1-2B	7/17/2000	19000	1.170	1.131	
RIS1-3A	7/17/2000	9000	1.164	1.125	1.112
RIS1-3B	7/17/2000	6000	1.132	1.093	
RIS1-1A	7/19/2000	19000	0.791	0.752	0.805
RIS1-1B	7/19/2000	21000	0.892	0.853	
RIS1-2A	7/19/2000	22500	1.088	1.049	1.013
RIS1-2B	7/19/2000	18500	1.008	0.969	
RIS1-3A	7/19/2000	11000	0.870	0.831	0.790
RIS1-3B	7/19/2000	6000	0.755	0.716	
RIS1-1A	7/21/2000	17000	0.830	0.791	0.722
RIS1-1B	7/21/2000	23000	0.710	0.671	
RIS1-2A	7/21/2000	19500	0.906	0.867	0.829
RIS1-2B	7/21/2000	15500	0.820	0.781	
RIS1-3A	7/21/2000	16000	0.737	0.698	0.699
RIS1-3B	7/21/2000	10000	0.739	0.700	

Sample ID	Date	Volume (mL)	DRP (ppm)	DRP (ppm) Less Initial Well Water DRP	Flow Weighted DRP
UGD1-1A	6/12/2000	19000	0.464	0.370	0.336
UGD1-1B	6/12/2000	5400	0.309	0.215	
UGD1-2A	6/12/2000	90	0.167	0.073	0.261
UGD1-2B	6/12/2000	310	0.410	0.316	
UGD1-3A	6/12/2000	6440	0.753	0.659	0.440
UGD1-3B	6/12/2000	5100	0.257	0.163	
UGD1-1A	6/14/2000	26000	0.193	0.099	0.097
UGD1-1B	6/14/2000	18000	0.188	0.094	
UGD1-2A	6/14/2000	320	0.107	0.013	0.013
UGD1-2B	6/14/2000	0		-0.094	
UGD1-3A	6/14/2000	35000	0.203	0.109	0.108
UGD1-3B	6/14/2000	18500	0.199	0.105	
UGD1-1A	6/16/2000	29000	0.200	0.106	0.093
UGD1-1B	6/16/2000	29000	0.173	0.079	
UGD1-2A	6/16/2000	1730	0.079	-0.015	-0.017
UGD1-2B	6/16/2000	430	0.067	-0.027	
UGD1-3A	6/16/2000	32500	0.137	0.043	0.044
UGD1-3B	6/16/2000	28500	0.139	0.045	
MCK1-1A	6/19/2000	22000	0.867	0.855	0.634
MCK1-1B	6/19/2000	25000	0.451	0.439	
MCK1-2A	6/19/2000	17000	0.586	0.574	0.680
MCK1-2B	6/19/2000	13500	0.826	0.814	
MCK1-3A	6/19/2000	16000	0.067	0.055	0.047
MCK1-3B	6/19/2000	20000	0.053	0.041	
MCK1-1A	6/21/2000	24000	0.428	0.416	0.423
MCK1-1B	6/21/2000	25000	0.442	0.430	
MCK1-2A	6/21/2000	16000	0.341	0.329	0.364
MCK1-2B	6/21/2000	16000	0.410	0.398	
MCK1-3A	6/21/2000	11000	0.082	0.070	0.054
MCK1-3B	6/21/2000	16000	0.055	0.043	
MCK1-1A	6/23/2000	27500	0.594	0.582	0.545
MCK1-1B	6/23/2000	28500	0.522	0.510	
MCK1-2A	6/23/2000	16500	0.279	0.267	0.389
MCK1-2B	6/23/2000	20000	0.501	0.489	
MCK1-3A	6/23/2000	14000	0.076	0.064	0.051
MCK1-3B	6/23/2000	17000	0.052	0.040	

Sample ID	Date	Volume (mL)	DRP (ppm)	DRP (ppm) Less Initial Well Water DRP	Flow Weighted DRP
SPR1-1A	6/26/2000	22000	0.390	0.372	0.348
SPR1-1B	6/26/2000	30000	0.349	0.331	
SPR1-2A	6/26/2000	10000	0.337	0.319	0.363
SPR1-2B	6/26/2000	15000	0.411	0.393	
SPR1-3A	6/26/2000	21000	0.496	0.478	0.487
SPR1-3B	6/26/2000	18000	0.516	0.498	
SPR1-1A	6/28/2000	16000	0.236	0.218	0.222
SPR1-1B	6/28/2000	26000	0.242	0.224	
SPR1-2A	6/28/2000	15500	0.264	0.246	0.206
SPR1-2B	6/28/2000	13000	0.176	0.158	
SPR1-3A	6/28/2000	21000	0.130	0.112	0.122
SPR1-3B	6/28/2000	9000	0.163	0.145	
SPR1-1A	6/30/2000	26000	0.159	0.141	0.128
SPR1-1B	6/30/2000	29000	0.134	0.116	
SPR1-2A	6/30/2000	29000	0.564	0.546	0.483
SPR1-2B	6/30/2000	19500	0.408	0.390	
SPR1-3A	6/30/2000	28500	0.212	0.194	0.185
SPR1-3B	6/30/2000	13000	0.183	0.165	
UGD2-1A	7/3/2000	14000	0.543	0.449	0.635
UGD2-1B	7/3/2000	15000	0.903	0.809	
UGD2-2A	7/3/2000	21000	0.794	0.700	0.640
UGD2-2B	7/3/2000	24000	0.682	0.588	
UGD2-3A	7/3/2000	12000	0.710	0.616	0.566
UGD2-3B	7/3/2000	17000	0.624	0.530	
UGD2-1A	7/5/2000	20000	0.489	0.395	0.378
UGD2-1B	7/5/2000	19000	0.454	0.360	
UGD2-2A	7/5/2000	16000	0.232	0.138	0.138
UGD2-2B	7/5/2000		0.185	0.091	
UGD2-3A	7/5/2000	35000	0.477	0.383	0.295
UGD2-3B	7/5/2000	14500	0.177	0.083	
UGD2-1A	7/7/2000	18000	0.186	0.092	0.160
UGD2-1B	7/7/2000	21000	0.313	0.219	
UGD2-2A	7/7/2000	17000	0.197	0.103	0.114
UGD2-2B	7/7/2000	32000	0.214	0.120	
UGD2-3A	7/7/2000	37500	0.229	0.135	0.194
UGD2-3B	7/7/2000	20000	0.400	0.306	

Sample ID	Date	Volume (mL)	DRP (ppm)	DRP (ppm) Less Initial Well Water DRP	Flow Weighted DRP
DAV1-1A	7/10/2000	7000	1.412	1.390	1.399
DAV1-1B	7/10/2000	10000	1.427	1.405	
DAV1-2A	7/10/2000	1800	1.459	1.437	1.242
DAV1-2B	7/10/2000	1200	0.972	0.950	
DAV1-3A	7/10/2000	2500	0.527	0.505	0.555
DAV1-3B	7/10/2000	700	0.757	0.735	
DAV1-1A	7/12/2000	12000	1.009	0.987	1.138
DAV1-1B	7/12/2000	14000	1.289	1.267	
DAV1-2A	7/12/2000	4000	0.679	0.657	0.704
DAV1-2B	7/12/2000	3000	0.788	0.766	
DAV1-3A	7/12/2000	13000	0.457	0.435	0.473
DAV1-3B	7/12/2000	6000	0.578	0.556	
DAV1-1A	7/14/2000	9000	0.686	0.664	0.801
DAV1-1B	7/14/2000	10000	0.947	0.925	
DAV1-2A	7/14/2000	3100	0.292	0.270	0.380
DAV1-2B	7/14/2000	3000	0.516	0.494	
DAV1-3A	7/14/2000	2500	0.303	0.281	0.651
DAV1-3B	7/14/2000	10000	0.766	0.744	
RIS1-1A	7/17/2000	13000	0.518	0.479	0.515
RIS1-1B	7/17/2000	13000	0.589	0.550	
RIS1-2A	7/17/2000	20000	0.562	0.523	0.617
RIS1-2B	7/17/2000	19000	0.755	0.716	
RIS1-3A	7/17/2000	9000	0.688	0.649	0.697
RIS1-3B	7/17/2000	6000	0.808	0.769	
RIS1-1A	7/19/2000	19000	0.637	0.598	0.574
RIS1-1B	7/19/2000	21000	0.591	0.552	
RIS1-2A	7/19/2000	22500	1.027	0.988	0.724
RIS1-2B	7/19/2000	18500	0.443	0.404	
RIS1-3A	7/19/2000	11000	0.731	0.692	0.600
RIS1-3B	7/19/2000	6000	0.469	0.430	
RIS1-1A	7/21/2000	17000	0.466	0.427	0.441
RIS1-1B	7/21/2000	23000	0.491	0.452	
RIS1-2A	7/21/2000	19500	0.513	0.474	0.485
RIS1-2B	7/21/2000	15500	0.538	0.499	
RIS1-3A	7/21/2000	16000	0.338	0.299	0.276
RIS1-3B	7/21/2000	10000	0.277	0.238	

Sample ID	Date	Volume (mL)	BAP (ppm)	BAP (ppm) Less Initial Well Water BAP	Flow Weighted BAP
UGD1-1A	6/12/2000	19000	0.317	0.223	0.198
UGD1-1B	6/12/2000	5400	0.204	0.110	
UGD1-2A	6/12/2000	90	0.000	-0.094	0.228
UGD1-2B	6/12/2000	310	0.349	0.255	
UGD1-3A	6/12/2000	6440	0.310	0.216	0.182
UGD1-3B	6/12/2000	5100	0.232	0.138	
UGD1-1A	6/14/2000	26000	0.253	0.159	0.156
UGD1-1B	6/14/2000	18000	0.245	0.151	
UGD1-2A	6/14/2000	320	0.158	0.064	0.064
UGD1-2B	6/14/2000	0	0.000	-0.094	
UGD1-3A	6/14/2000	35000	0.279	0.185	0.177
UGD1-3B	6/14/2000	18500	0.257	0.163	
UGD1-1A	6/16/2000	29000	0.239	0.145	0.145
UGD1-1B	6/16/2000	29000	0.239	0.145	
UGD1-2A	6/16/2000	1730	0.139	0.045	0.044
UGD1-2B	6/16/2000	430	0.132	0.038	
UGD1-3A	6/16/2000	32500	0.141	0.047	0.066
UGD1-3B	6/16/2000	28500	0.181	0.087	
MCK1-1A	6/19/2000	22000	0.772	0.760	0.701
MCK1-1B	6/19/2000	25000	0.661	0.649	
MCK1-2A	6/19/2000	17000	0.617	0.605	0.639
MCK1-2B	6/19/2000	13500	0.693	0.681	
MCK1-3A	6/19/2000	16000	0.180	0.168	0.164
MCK1-3B	6/19/2000	20000	0.172	0.160	
MCK1-1A	6/21/2000	24000	0.556	0.544	0.508
MCK1-1B	6/21/2000	25000	0.486	0.474	
MCK1-2A	6/21/2000	16000	0.411	0.399	0.425
MCK1-2B	6/21/2000	16000	0.463	0.451	
MCK1-3A	6/21/2000	11000	0.154	0.142	0.132
MCK1-3B	6/21/2000	16000	0.137	0.125	
MCK1-1A	6/23/2000	27500	0.446	0.434	0.425
MCK1-1B	6/23/2000	28500	0.428	0.416	
MCK1-2A	6/23/2000	16500	0.359	0.347	0.380
MCK1-2B	6/23/2000	20000	0.419	0.407	
MCK1-3A	6/23/2000	14000	0.157	0.145	0.138
MCK1-3B	6/23/2000	17000	0.145	0.133	

Sample ID	Date	Volume (mL)	BAP (ppm)	BAP (ppm) Less Initial Well Water BAP	Flow Weighted BAP
SPR1-1A	6/26/2000	22000	0.340	0.322	0.325
SPR1-1B	6/26/2000	30000	0.346	0.328	
SPR1-2A	6/26/2000	10000	0.324	0.306	0.347
SPR1-2B	6/26/2000	15000	0.393	0.375	
SPR1-3A	6/26/2000	21000	0.353	0.335	0.369
SPR1-3B	6/26/2000	18000	0.427	0.409	
SPR1-1A	6/28/2000	16000	0.252	0.234	0.241
SPR1-1B	6/28/2000	26000	0.264	0.246	
SPR1-2A	6/28/2000	15500	0.291	0.273	0.253
SPR1-2B	6/28/2000	13000	0.248	0.230	
SPR1-3A	6/28/2000	21000	0.247	0.229	0.215
SPR1-3B	6/28/2000	9000	0.200	0.182	
SPR1-1A	6/30/2000	26000	0.213	0.195	0.181
SPR1-1B	6/30/2000	29000	0.186	0.168	
SPR1-2A	6/30/2000	29000	0.289	0.271	0.290
SPR1-2B	6/30/2000	19500	0.336	0.318	
SPR1-3A	6/30/2000	28500	0.253	0.235	0.228
SPR1-3B	6/30/2000	13000	0.231	0.213	
UGD2-1A	7/3/2000	14000	0.441	0.347	0.472
UGD2-1B	7/3/2000	15000	0.683	0.589	
UGD2-2A	7/3/2000	21000	0.431	0.337	0.308
UGD2-2B	7/3/2000	24000	0.376	0.282	
UGD2-3A	7/3/2000	12000	0.406	0.312	0.341
UGD2-3B	7/3/2000	17000	0.456	0.362	
UGD2-1A	7/5/2000	20000	0.374	0.280	0.300
UGD2-1B	7/5/2000	19000	0.415	0.321	
UGD2-2A	7/5/2000	16000	0.338	0.244	0.244
UGD2-2B	7/5/2000		0.322	0.228	
UGD2-3A	7/5/2000	35000	0.375	0.281	0.265
UGD2-3B	7/5/2000	14500	0.321	0.227	
UGD2-1A	7/7/2000	18000	0.300	0.206	0.230
UGD2-1B	7/7/2000	21000	0.344	0.250	
UGD2-2A	7/7/2000	17000	0.297	0.203	0.204
UGD2-2B	7/7/2000	32000	0.299	0.205	
UGD2-3A	7/7/2000	37500	0.363	0.269	0.237
UGD2-3B	7/7/2000	20000	0.270	0.176	

Sample ID	Date	Volume (mL)	BAP (ppm)	BAP (ppm) Less Initial Well Water BAP	Flow Weighted BAP
DAV1-1A	7/10/2000	7000	1.413	1.435	1.364
DAV1-1B	7/10/2000	10000	1.293	1.315	
DAV1-2A	7/10/2000	1800	0.853	0.875	0.855
DAV1-2B	7/10/2000	1200	0.803	0.825	
DAV1-3A	7/10/2000	2500	0.667	0.689	0.697
DAV1-3B	7/10/2000	700	0.702	0.724	
DAV1-1A	7/12/2000	12000	1.181	1.203	1.049
DAV1-1B	7/12/2000	14000	0.895	0.917	
DAV1-2A	7/12/2000	4000	0.553	0.575	0.554
DAV1-2B	7/12/2000	3000	0.503	0.525	
DAV1-3A	7/12/2000	13000	0.501	0.523	0.568
DAV1-3B	7/12/2000	6000	0.645	0.667	
DAV1-1A	7/14/2000	9000	0.925	0.947	0.799
DAV1-1B	7/14/2000	10000	0.644	0.666	
DAV1-2A	7/14/2000	3100	0.375	0.397	0.477
DAV1-2B	7/14/2000	3000	0.537	0.559	
DAV1-3A	7/14/2000	2500	0.432	0.454	0.748
DAV1-3B	7/14/2000	10000	0.800	0.822	
RIS1-1A	7/17/2000	13000	0.590	0.551	0.561
RIS1-1B	7/17/2000	13000	0.610	0.571	
RIS1-2A	7/17/2000	20000	0.776	0.737	0.698
RIS1-2B	7/17/2000	19000	0.695	0.656	
RIS1-3A	7/17/2000	9000	0.700	0.661	0.633
RIS1-3B	7/17/2000	6000	0.630	0.591	
RIS1-1A	7/19/2000	19000	0.520	0.481	0.516
RIS1-1B	7/19/2000	21000	0.587	0.548	
RIS1-2A	7/19/2000	22500	0.651	0.612	0.630
RIS1-2B	7/19/2000	18500	0.690	0.651	
RIS1-3A	7/19/2000	11000	0.539	0.500	0.486
RIS1-3B	7/19/2000	6000	0.498	0.459	
RIS1-1A	7/21/2000	17000	0.537	0.498	0.446
RIS1-1B	7/21/2000	23000	0.446	0.407	
RIS1-2A	7/21/2000	19500	0.616	0.577	0.585
RIS1-2B	7/21/2000	15500	0.633	0.594	
RIS1-3A	7/21/2000	16000	0.497	0.458	0.440
RIS1-3B	7/21/2000	10000	0.451	0.412	

Site ID	Overall Height of Runoff (cm)	DRP(mg L-1) / runoff(cm)	TP (mg L-1) / runoff(cm)	BAP (mg L-1) / runoff(cm)
UGD1-1	6.32	0.022	0.074	0.025
UGD1-2	0.144	0.172	2.548	0.447
UGD1-3	6.302	0.017	0.066	0.020
MCK1-1	7.6	0.070	0.109	0.071
MCK1-2	4.95	0.095	0.177	0.096
MCK1-3	4.7	0.011	0.112	0.031
SPR1-1	7.45	0.031	0.078	0.033
SPR1-2	5.1	0.074	0.116	0.058
SPR1-3	5.525	0.050	0.104	0.050
UGD2-1	5.35	0.069	0.114	0.060
UGD2-2	5.5	0.061	0.099	0.046
UGD2-3	6.8	0.046	0.077	0.040
DAV1-1	3.1	0.357	0.548	0.342
DAV1-2	0.805	0.847	1.103	0.721
DAV1-3	1.735	0.314	0.609	0.372
RIS1-1	5.3	0.096	0.161	0.094
RIS1-2	5.75	0.107	0.176	0.111
RIS1-3	2.9	0.165	0.29	0.17

APPENDIX D

INDOOR RUNOFF ANALYSES

Sample ID	Date	Volume (mL)	Total P (ppm)	Total P (ppm) Less Initial Well Water Total P	Flow Weighted TP
UGD1-1A	6/20/2000	98.73	0.096	0.028	0.092
UGD1-1B	6/20/2000	68.81	0.252	0.184	
UGD1-2A	6/20/2000	205.33	0.103	0.035	0.025
UGD1-2B	6/20/2000	565.58	0.089	0.021	
UGD1-3A	6/20/2000	38.45	0.276	0.208	0.128
UGD1-3B	6/20/2000	101.94	0.166	0.098	
UGD1-1A	6/22/2000	243.69	0.23	0.162	0.161
UGD1-1B	6/22/2000	93.66	0.225	0.157	
UGD1-2A	6/22/2000	83.24	0.177	0.109	0.209
UGD1-2B	6/22/2000	958.28	0.286	0.218	
UGD1-3A	6/22/2000	150.38	0.255	0.187	0.211
UGD1-3B	6/22/2000	48.25	0.352	0.284	
MCK1-1A	6/27/2000	86.58	0.535	0.467	0.286
MCK1-1B	6/27/2000	464.65	0.32	0.252	
MCK1-2A	6/27/2000	493.77	0.787	0.719	0.610
MCK1-2B	6/27/2000	365.04	0.531	0.463	
MCK1-3A	6/27/2000	68.25	0.374	0.306	0.182
MCK1-3B	6/27/2000	352.22	0.226	0.158	
MCK1-1A	6/29/2000	64.74	0.436	0.368	0.429
MCK1-1B	6/29/2000	566.38	0.504	0.436	
MCK1-2A	6/29/2000	1160.87	0.558	0.49	0.427
MCK1-2B	6/29/2000	974.82	0.421	0.353	
MCK1-3A	6/29/2000	440.1	0.276	0.208	0.234
MCK1-3B	6/29/2000	1526.62	0.31	0.242	
SPR1-1A	7/4/2000	66.96	0.418	0.35	0.238
SPR1-1B	7/4/2000	81.07	0.214	0.146	
SPR1-2A	7/4/2000	922.02	0.509	0.441	0.365
SPR1-2B	7/4/2000	365.71	0.24	0.172	
SPR1-3A	7/4/2000	132.42	0.416	0.348	0.283
SPR1-3B	7/4/2000	147.25	0.292	0.224	
SPR1-1A	7/6/2000	274.89	0.187	0.119	0.126
SPR1-1B	7/6/2000	109.57	0.212	0.144	
SPR1-2A	7/6/2000	1494.15	0.472	0.404	0.767
SPR1-2B	7/6/2000	895.22	1.441	1.373	
SPR1-3A	7/6/2000	116.47	0.665	0.597	0.355
SPR1-3B	7/6/2000	282.82	0.323	0.255	

Sample ID	Date	Volume (mL)	Total P (ppm)	Total P (ppm) Less Initial Well Water Total P	Flow Weighted TP
UGD2-1A	7/11/2000	149.66	0.149	0.081	0.082
UGD2-1B	7/11/2000	241.51	0.15	0.082	
UGD2-2A	7/11/2000	54.25	0	0	0.278
UGD2-2B	7/11/2000	127.93	0.346	0.278	
UGD2-3A	7/11/2000	114.36	0.294	0.226	0.226
UGD2-3B	7/11/2000	42.13	0	0	
UGD2-1A	7/13/2000	76.43	0.446	0.378	0.248
UGD2-1B	7/13/2000	445.41	0.294	0.226	
UGD2-2A	7/13/2000	42.84	0.426	0.358	0.222
UGD2-2B	7/13/2000	151.72	0.252	0.184	
UGD2-3A	7/13/2000	45.84	0	0	0.050
UGD2-3B	7/13/2000	94.52	0.118	0.05	
DAV1-1A	7/18/2000	309.39	1.273	1.205	0.882
DAV1-1B	7/18/2000	214.41	0.483	0.415	
DAV1-2A	7/18/2000	70.01	0	0	0.305
DAV1-2B	7/18/2000	190.21	0.373	0.305	
DAV1-3A	7/18/2000	176.4	0.437	0.369	0.376
DAV1-3B	7/18/2000	86.6	0.457	0.389	
DAV1-1A	7/20/2000	292.09	0.636	0.568	0.471
DAV1-1B	7/20/2000	402.01	0.468	0.4	
DAV1-2A	7/20/2000	24.21	0	0	0.676
DAV1-2B	7/20/2000	44.4	0.744	0.676	
DAV1-3A	7/20/2000	141.72	0.273	0.205	0.268
DAV1-3B	7/20/2000	181.22	0.386	0.318	
RIS1-1A	8/2/2000	301.59	0.815	0.747	0.566
RIS1-1B	8/2/2000	191.31	0.349	0.281	
RIS1-2A	8/2/2000	1323.53	1.826	1.758	1.572
RIS1-2B	8/2/2000	216.71	0.501	0.433	
RIS1-3A	8/2/2000	397	0.666	0.598	0.801
RIS1-3B	8/2/2000	697.21	0.985	0.917	
RIS1-1A	8/4/2000	827.89	0.622	0.554	0.495
RIS1-1B	8/4/2000	216.41	0.336	0.268	
RIS1-2A	8/4/2000	1796.71	1.253	1.185	1.124
RIS1-2B	8/4/2000	121.14	0.293	0.225	
RIS1-3A	8/4/2000	507.51	0.522	0.454	0.514
RIS1-3B	8/4/2000	869.01	0.617	0.549	

SAMPLE ID	**DATE**	**DRP (ppm)**	**DRP (ppm) Less Initial Water Sample**	**DRP (ppm) no (-)**	**Flow Weighted DRP**
UGD1-1A	6/20/2000	0.05	-0.02	0.00	0.00
UGD1-1B	6/20/2000	0.04	-0.03	0.00	
UGD1-2A	6/20/2000	0.05	-0.02	0.00	0.00
UGD1-2B	6/20/2000	0.04	-0.03	0.00	
UGD1-3A	6/20/2000	0.00	0.00	0.00	0.00
UGD1-3B	6/20/2000	0.03	-0.04	0.00	
UGD1-1A	6/22/2000	0.03	-0.04	0.00	0.00
UGD1-1B	6/22/2000	0.02	-0.05	0.00	
UGD1-2A	6/22/2000	0.03	-0.04	0.00	0.00
UGD1-2B	6/22/2000	0.06	-0.01	0.00	
UGD1-3A	6/22/2000	0.03	-0.03	0.00	0.00
UGD1-3B	6/22/2000	0.04	-0.03	0.00	
MCK1-1A	6/27/2000	0.12	0.06	0.06	0.12
MCK1-1B	6/27/2000	0.21	0.14	0.14	
MCK1-2A	6/27/2000	0.27	0.20	0.20	0.17
MCK1-2B	6/27/2000	0.20	0.13	0.13	
MCK1-3A	6/27/2000	0.11	0.04	0.04	0.05
MCK1-3B	6/27/2000	0.12	0.05	0.05	
MCK1-1A	6/29/2000	0.12	0.05	0.05	0.31
MCK1-1B	6/29/2000	0.41	0.35	0.35	
MCK1-2A	6/29/2000	0.29	0.23	0.23	0.23
MCK1-2B	6/29/2000	0.30	0.24	0.24	
MCK1-3A	6/29/2000	0.12	0.05	0.05	0.08
MCK1-3B	6/29/2000	0.15	0.08	0.08	
SPR1-1A	7/4/2000	0.07	0.00	0.00	0.00
SPR1-1B	7/4/2000	0.05	-0.02	0.00	
SPR1-2A	7/4/2000	2.14	2.07	2.07	1.82
SPR1-2B	7/4/2000	1.24	1.17	1.17	
SPR1-3A	7/4/2000	0.35	0.28	0.28	0.82
SPR1-3B	7/4/2000	1.37	1.30	1.30	
SPR1-1A	7/6/2000	0.20	0.14	0.14	0.10
SPR1-1B	7/6/2000	0.09	0.03	0.03	
SPR1-2A	7/6/2000	1.24	1.17	1.17	1.21
SPR1-2B	7/6/2000	1.34	1.28	1.28	
SPR1-3A	7/6/2000	0.44	0.37	0.37	0.51
SPR1-3B	7/6/2000	0.63	0.56	0.56	

SAMPLE ID	DATE	DRP (ppm)	DRP (ppm) Less Initial Water Sample	DRP (ppm) no (-)	Flow Weighted DRP
UGD2-1A	7/11/2000	0.14	0.07	0.07	0.06
UGD2-1B	7/11/2000	0.13	0.06	0.06	
UGD2-2A	7/11/2000	0.07	0.00	0.00	0.00
UGD2-2B	7/11/2000	0.07	0.00	0.00	
UGD2-3A	7/11/2000	0.07	0.00	0.00	0.00
UGD2-3B	7/11/2000	0.08	0.01	0.01	
UGD2-1A	7/13/2000	0.07	0.00	0.00	0.02
UGD2-1B	7/13/2000	0.10	0.03	0.03	
UGD2-2A	7/13/2000	0.07	0.00	0.00	0.00
UGD2-2B	7/13/2000	0.07	0.00	0.00	
UGD2-3A	7/13/2000	0.04	-0.03	0.00	0.00
UGD2-3B	7/13/2000	0.04	-0.03	0.00	
DAV1-1A	7/18/2000	0.83	0.76	0.76	0.54
DAV1-1B	7/18/2000	0.29	0.22	0.22	
DAV1-2A	7/18/2000	0.18	0.11	0.11	0.13
DAV1-2B	7/18/2000	0.21	0.14	0.14	
DAV1-3A	7/18/2000	0.19	0.13	0.13	0.12
DAV1-3B	7/18/2000	0.18	0.11	0.11	
DAV1-1A	7/20/2000	0.60	0.53	0.53	0.39
DAV1-1B	7/20/2000	0.35	0.28	0.28	
DAV1-2A	7/20/2000	0.00	0.00	0.00	0.00
DAV1-2B	7/20/2000	0.00	0.00	0.00	
DAV1-3A	7/20/2000	0.24	0.17	0.17	0.46
DAV1-3B	7/20/2000	0.76	0.69	0.69	
RIS1-1A	8/2/2000	0.33	0.26	0.26	0.20
RIS1-1B	8/2/2000	0.17	0.10	0.10	
RIS1-2A	8/2/2000	1.20	1.13	1.13	0.99
RIS1-2B	8/2/2000	0.20	0.13	0.13	
RIS1-3A	8/2/2000	0.29	0.22	0.22	0.29
RIS1-3B	8/2/2000	0.40	0.33	0.33	
RIS1-1A	8/4/2000	0.25	0.18	0.18	0.16
RIS1-1B	8/4/2000	0.15	0.08	0.08	
RIS1-2A	8/4/2000	0.73	0.66	0.66	0.63
RIS1-2B	8/4/2000	0.20	0.13	0.13	
RIS1-3A	8/4/2000	0.24	0.18	0.18	0.20
RIS1-3B	8/4/2000	0.29	0.22	0.22	

Site ID	Overall Height of Runoff (cm)	TP (mg L-1) / cm of RF	DRP (mg L-1) / cm of RF
UGD1-1	0.316	0.437	0.000
UGD1-2	1.133	0.115	0.000
UGD1-3	0.212	0.833	0.000
MCK1-1	0.739	0.490	0.306
MCK1-2	1.872	0.256	0.114
MCK1-3	1.492	0.151	0.047
SPR1-1	0.333	0.473	0.228
SPR1-2	2.298	0.272	
SPR1-3	0.424	0.766	
UGD2-1	0.571	0.310	0.072
UGD2-2	0.235	0.889	0.001
UGD2-3	0.186	0.555	0.006
DAV1-1	0.761	0.851	0.596
DAV1-2	0.206	1.303	0.505
DAV1-3	0.366	0.864	0.846
RIS1-1	0.961	0.539	0.179
RIS1-2	2.161	0.612	0.365
RIS1-3	1.544	0.938	0.157