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Predicting Minesoil Erosion Potential

PREDICTING MINESOIL EROSION POTENTIAL

by

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FOREWORD

The Federal Water Pollution Control Act Amendments of 1972, in part, stress the control of nonpoint source pollution. Sections 102 (C-1), 208 (b-2,F) and 304(e) authorize basin scale development of water quality control plans and provide for area-wide waste treatment management. The act and the amendments include, when warranted, waters from agriculturally and silviculturally related nonpoint sources, and requires the issuance of guidelines for both identifying and evaluating the nature and extent of nonpoint source pollutants and the methods to control these sources. Research program at the Northeast Watershed Research Center contributes to the aforementioned goals. The major objectives of the Center are to:

- study the major hydrologic and water-quality associated problems of the Northeastern U.S. and
- develop hydrologic and water quality simulation capability useful for land-use planning. Initial emphasis is on the hydrologically most severe land uses of the Northeast.

Within the context of the Center's objectives, stripmining for coal ranks as a major and hydrologically severe land use. In addition, once the site is reclaimed and the conditions of the mining permit are met, stripmined areas revert legally from point to nonpoint sources. As a result, the hydrologic, physical, and chemical behavior of the reclaimed

land needs to be understood directly and in terms of control practices before the goals of Sections 102, 208 and 304 can be fully met.

Signed:

Harry Pionke

H. B. Pionke
Director
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Research Center

ABSTRACT

Two experimental plots were instrumented with erosion pins to study the correspondence between point erosion and erosion over an area on strip mine soil. Using a rotating boom rainfall simulator, data were collected by sampling the runoff every five minutes for the duration of the rainfall. The amount of sediment eroded or deposited was measured after each simulated rainfall using erosion pins. These results were compared to the sediment load measured by runoff sampling, as well as to the predicted erosion using two analytical models, the Universal Soil Loss Equation (USLE) and an Erosion/Deposition (E/D) model. The E/D model was developed to be a more comprehensive model than the USLE, by including partial area concepts of hydrology and sediment transport equations. Erosion was predicted at specific points on each plot, then an overall value for erosion was estimated.

Comparisons were then made between amounts of soil eroded or deposited at a point using experimental techniques and numerical model predictions. Spatial structure of soil loss distribution is evaluated. Discrepancies between values observed at the pins and values expected based on model results and sediment yield sampling are explained by increases in turbulence and the amount of rain near the pins. Implications with regard to vegetation in the form of stalks are suggested.

CONCLUSIONS

Experimental plot studies were conducted to evaluate the applicability of erosion pins as point estimates of erosion. The data were compared with results predicted by USLE and EDM models and with the sediment load measured experimentally. For both plots, the erosion measured by the erosion pins was 90-95% higher than that measured by sampling runoff, or predicted by the EDM model. The causes for this difference were assumed to be the increase in runoff turbulence and wind velocity around the pins. EDM model produced comparable results. Protrusions are believed to increase the turbulence of runoff resulting in local scour around the pins. The hypothesis has implications with regard to the role of vegetation in erosion and potential effects on washoff from vegetation. In addition to the above measurements, soil erodibility factor (K) was calculated using the soil loss values measured from runoff sampling and from erosion pin data based either on the whole plot or 0.6 x 0.6 subarea length of slope. The results suggested that there is change in soil erodibility after disruption of soil and runoff erosivity component may vary as a function of surface roughness as well as obstacles such as plant stalks. Thus in general it can be concluded that:

- the assumption of erodibility value being the same for the disturbed material as for the undisturbed soil is not valid,
- erosion measured at specific points with erosion pins over-predicts areal erosion computed from runoff sampling,

- although USLE tends to overpredict erosion on plots as a whole because it does not account for deposition, results computed on the basis of individual subareas appear comparable,
- erosion deposition model predictions are close to values measured in runoff.

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SECTION 1

INTRODUCTION

1.1. NEED FOR STUDY

Strip mining for coal is a common activity in Pennsylvania's Appalachian region. Before reclamation of strip mined land, bare soil is exposed to wind and rain, and the erosion process commences. Erosion degrades the land by causing displacement of valuable topsoil, and can pollute streams by clogging them with sediment and reducing the stream's capacity to carry flood flows. As long as coal continues to be a valuable resource and strip mining continues, these environmental problems will exist. The severity of the problems can be diminished by proper planning of areas to be mined and by accurate prediction of soil erosion and sediment yield. A reclamation specialist utilizing this information can improve the planning and scheduling of reclamation operations to minimize the controls needed to prevent soil loss.

Several experimental methods and mathematical models have been developed to estimate strip mine erosion. Erosion pins were used by Sams (1982) to measure soil loss from strip mined land. The erosion pins, arranged on the study area, serve as fixed reference points in the landscape, from which soil loss or deposition can be measured. To supplement natural rainfall studies, or to obtain erosional information for a storm of desired energy and intensity, rainfall simulators have been used on small plots. To measure the areal erosion from the rainfall simulator plots, runoff samples can be taken and analyzed for sediment content.

In general, as required by law, PL 95-87, slope percentages and slope lengths of reclaimed areas are returned to the original, undisturbed condition. However, it is not known whether the soil erodibility following reclamation will be the same as before mining. The degree of stability associated with erodibility is an important question to be resolved when using predictive models to obtain accurate soil loss estimates for minesoils.

The most common model used to predict erosion is the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). However, some adaptations must be made to the USLE to apply it to strip mine sites, since it was originally developed for use on agricultural lands. The equation is used here to predict erosion at several points on the plots, then the values are averaged to obtain one areal soil loss value per plot.

An Erosion/Deposition (E/D) model that was developed by Khanbilvardi et al. (1983) incorporates more complex erosion mechanisms than the USLE to predict erosion. The model was developed to predict soil erosion from upland areas using the partial area concept, that is, the model does not consider the entire drainage area as contributing to erosion as most models do, but only certain portions of a watershed. The inputs to this model are from parameters measured at points throughout the study area, as well as areal values from the plot.

Accurate soil loss predictions can be extremely useful by enabling us to assess the impacts of mining and to develop effective plans to control soil loss and damage due to erosion. The hypothesis for this study is two-fold: 1) soil loss over an area can be predicted from point loss values and, 2) the established value for erodibility of undisturbed soil is the same or very similar to that of disturbed soil after mining.

1.2. Objectives

The specific objectives of this study include:

1) evaluate the erodibility of a minesoil using rainfall simulator plots,
2) measure erosion at specific points on rainfall simulator plots and compare the results to areal erosion values observed on the plots from runoff sampling,
3) predict the potential erosion on the plots using the USLE and compare the results to the erosion measured by runoff sampling, and
4) predict the potential erosion on the plots using the Erosion/Deposition model and compare the results to measured erosion on the plots.

SECTION 2

LITERATURE REVIEW

Sediment from stripmined areas is among sources of pollution and its prediction is highly beneficial as a management tool in developing plans to control sediment loss and erosion damage. This review of literature assembles information concerning soil erosion process, the use of rainfall simulator and erosion pins in erosion study, and soil loss determinations. For clarity, this chapter is divided into four sections: erosion processes, rainfall simulation, erosion pins, and predictive models.

2.1. EROSION PROCESSES

Erosion by rainfall and runoff is one of the most critical factors in the process of land form evolution. Erosion is a two step process: the detachment and the subsequent transport of detached soil. Detachment of soil particles can occur in two ways. Each raindrop can cause detachment, the erosive capacity of which depends on the kinetic energy per unit area of the individual drop (Ekern, 1951). Soil detachment can also occur by the shearing action of runoff water. The amount of soil that a given rainfall can detach depends on the rainfall intensity, the raindrop size distribution, the raindrop fall velocity, and other characteristics such as drop shape, impact angle, and the effect of wind (Meyer, 1963). The transport of soil can occur by raindrop splash or by overland flow of the runoff. Mutchler and Larson (1971) found that splash transport is absent when there is no water depth on the soil surface, but increases for shallow depths of water. However, splash transport probably decreases as the water depth increases to three waterdrop diameters.

The types of erosion associated with overland flow are sheet, rill and gully erosion. Sheet erosion removes soil rather uniformly from every part of the slope. When the flow begins to concentrate in small channels, rill erosion begins. If the volume of water is large, gullies may form from the downward cutting force of the water. This is called gully erosion.

Some basic factors which influence erosion include rainfall properties, soil properties, topography, land management and flow properties. Rainfall properties may be the most important of these because they include rainfall intensity, duration and frequency. Wischmeier and Smith (1978) used the rainfall intensity to determine the kinetic energy of the storm, then computed the product of the kinetic energy and the maximum thirty minute intensity to obtain the rainfall erosion index, which is used in predicting erosion. The rainfall erosion index values, or EI values, were based on 22 year station rainfall records. The sum of the storm EI values for a given time period is a measure of the erosive potential of the rainfall in that period. The average annual total of the storm EI values in a given area is the rainfall erosion index.

Soil properties that affect erosion include soil structure, texture, infiltration capacity, permeability, and erodibility. Erodibility is an inherent property of the soil that allows some soils to erode more easily than others when all other factors remain constant. Erodibility can be affected by particle size distribution, soil structure, organic matter and moisture content, and wetting and drying conditions (Foster and Meyer, 1977).

Soil erosion is strongly related to topography in terms of slope length and steepness. The elevation of the land determines the direction of the water flow and the rill patterns that will develop. Zingg (1940) found that on slopes of less than ten percent, erosion approximately doubled as slope

doubled. Zingg (1940) also developed the equation to model the effect of slope length on erosion per unit area for a given slope,

$$A = L^n \tag{2.1}$$

where

A = average erosion per unit area

L = slope length

n = a coefficient

Foster and Meyer (1972) showed that the value of n depends on the relative susceptibility of different soils to rilling and the resulting ratio of rill erosion to interrill erosion. They indicated that where soil loss is primarily from rills, n will approach one, but if the interrill erosion is dominent it will approach zero. Young and Mutchler (1969) also indicated that n increases with increasing slope length because rill erosion increases faster than interrill erosion. Smith and Zingg (1945) measured soil loss on several plots at intervals of ten feet and described the results with the equation,

$$Y = 0.016L^{0.057} \tag{2.2}$$

where

Y = average depth of soil loss (ft)

L = slope length (ft)

Land management refers to things such as land use, residual land use effects, and vegetative cover and structures used to control erosion. It is important to know how the land use will change the soil conditions. Activities such as strip mining disrupt existing land use and drastically

alter the soil in several ways; the soil layers below the topsoil become intermixed as the coal is mined, thus disturbing the natural soil layering. The natural structure is altered and after the soil is replaced, it has a higher bulk density because of compaction, and is also less porous. Therefore, post reclamation properties of the soil may cause different reactions to the erosive forces of rainfall than they did prior to mining.

Flow properties, particularly volume and velocity of overland flow, will determine the carrying capacity of the water. Increased velocity will increase the ability of the flow to transport soil.

2.2. RAINFALL SIMULATION

The factors mentioned are important when attempting to measure or quantify erosion. Field studies of natural rainfall and erosion often require long time periods of study to draw valid conclusions (Meyer, 1960). In order to speed data collection and supplement natural rainfall studies, rainfall simulators have been widely accepted as a useful tool for infiltration and erosion research (Bubenzer, 1980). Rainfall simulation is more efficient, more controlled, and more adaptable to lab or field research than natural rainfall studies.

Most simulators are developed to simulate natural rainfall. Several specific advantages of rainfall simulators include 1) storm intensity and duration control, 2) storm repeatability, 3) control of plot condition at the time of the storm event, and 4) speed of data collection (Bubenzer, 1980). The two main parts of a rainfall simulator are the nozzle or drop former, and the mechanism that applies the spray. Some researchers have stated that "the heart of any simulator is the drop forming method" (Mutchler and Hermsmeier, 1963). The drop former can determine the extent

to which rainfall can be duplicated and uniformly applied, because it controls the intensity, flow rate and spray pattern.

Meyer and McCune (1958) analyzed the design of rainfall simulators in their study. They found that the flat pattern VeeJet commercial spray nozzles best satisfied the needs of researchers by supplying reasonable intensity, drop size, drop velocity and distribution characteristics. The VeeJet nozzles have a high flow rate and produce a long, narrow spray that decreases in intensity with distance from the center. More precise rainfall simulation requires nozzles with lower flow rates and formation of larger drops at higher velocities (Mutchler and Hermsmeier, 1963).

2.3. EROSION PINS

One method to quantify erosion is the use of erosion pins. An erosion pin is a rod placed in the soil and is a fixed reference from which surface advance and retreat can be measured. Measurement of the erosion pin from the soil surface to the top of the pin may indicate whether soil loss or deposition is occurring in the pin area. Changes in pin height may occur due to natural processes such as freezing and thawing or wetting and drying, when the ground surface expands or contracts and alters the position of the pin.

Although the original erosion pins were wooden (Schumm, 1956a), most studies recommended the use of longer lasting, slimmer metal stakes (Colbert, 1956). Many researchers also have advocated the use of a permanent metal washer with the erosion pins. The washer aids in averaging out the roughness of the soil surrounding the erosion pin, thus allowing more accurate replication of pin measurements. However, a permanent washer influences the surrounding soil erosion because it prevents rain from striking the ground beneath the pin. After heavy

rains, the washers may be elevated a few millimeters above the surrounding soil. To avoid this problem, Schumm (1967) recommended use of a removable washer that could be lowered over the pin before measuring, and removed immediately afterward. The disadvantage of the removable washer is that the readings are more susceptible to differences caused by variable placement of the washer and compression of the washer into the soil.

The erosion pins can be used in one of two ways: they can be placed flush with the ground surface and returned to that position after every recording, or allowed to be exposed a few centimeters. If the pins are placed flush with the surface, they should be in an area where no deposition is expected. However, almost all slopes, even the shortest and most level, have some deposition.

Erosion pins can be placed in several patterns, such as a transect line, a grid pattern, or groups of pins at critical sites. Repeated measurements at each pin are desirable to maintain an accurate account of the erosional activity. The time intervals used by past researchers on natural rainfall erosion pin measurements range from seven days (Bridges, 1969) to more than one year (Schumm, 1956b).

Over the years, erosion pins have been shown to have several sources of error. These include 1) disturbance of the soil during pin placement, 2) disturbance of the natural soil erosion and water flow patterns by the erosion pin, 3) the effects of variations in the erosion pin's environment, 4) disturbance of the pin by the recorder, and 5) errors in recording (Haigh, 1978).

2.4. PREDICTIVE MODELS

The efforts of many researchers in predicting soil losses from farmland and agricultural watersheds have been reported since the 1930's. Rainfall simulation and erosion pin studies provide researchers with experimental methods of measuring soil erosion. Many studies have been done to determine accurate soil loss prediction equations to take the place of extensive field or laboratory work (Levesey, 1972; Holemam, 1972; Kimberlin and Moldenhauer, 1977). However, not all models are suitable for predicting strip mine erosion because of the unique conditions present at the mined site. In selecting an appropriate predictive model, important elements to be considered are time, watershed size, and sediment source (Onstad et al., 1977). Some models predict sediment yield on an annual basis. Others are designed to predict on a storm by storm basis at regular time intervals. Watershed size is important in selecting a model, because a model designed for a large watershed in which estimation errors and localized differences are evened out may not be accurate for a small watershed. Sediment source is an important factor because surface mined areas are more prone to sheet and rill flow than channel or streamflow. The model which has been the most readily usable to predict soil loss on mined and reclaimed land is the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978) in cooperation with many other researchers.

2.4.1. The Universal Soil Loss Equation

The USLE is

$$A = RKLSCP \tag{2.3}$$

where

A = average annual soil loss (Tons/acre)

R = rainfall factor (the number of rainfall erosion index units)

K = soil erodibility factor (the soil loss rate per erosion index unit for a specified soil as measured on a plot in continuous fallow, 72.6 feet long and with a 9% slope)

L = the slope length factor (the ratio of soil loss from the field slope length to that from a 72.6 foot length under the same conditions)

S = slope steepness factor (the ratio of soil loss from the field slope gradient to that from a 9% slope)

C = cover - management factor (the ratio of soil loss from an area with specific cover and management, to that from an area in continuous fallow)

P = support practice factor (the ratio of soil loss with a conservation practice to that with straight row farming up and down the slope).

The equation was developed based on 10,000 plot-years of soil loss data from 49 locations.

Although this equation is widely used and accepted, the USLE was originally intended for use on cultivated agricultural areas over a long period

of time, and is often misused by people who are only superficially familiar with the equation (Wischmeier, 1976). For large watersheds, where ample opportunity exists for eroded sediment to be deposited between the point of origin and the location where sediment yield predictions are desired, a delivery ratio must be used. However, the USLE and a delivery ratio "may not (be) designed for application to mined watersheds on a per storm basis" (Pionke and Rogowski, 1981). An appropriate procedure may be to recalibrate the USLE by use of standard plot studies as were used to calibrate the USLE to farmland. However, this involves many unanswered questions, such as the validity of extending small plot results to large watersheds, and the effects of variable erodibility and increased slope lengths and percentages found on reclaimed strip mines (Pionke and Rogowski, 1981). Also, there is little information on spoil settling and the unfavorable effects settling has on conservation practices.

Williams (1975) proposed a Modified Universal Soil Loss Equation (MUSLE), in which a runoff factor replaced the rainfall factor, R. This factor eliminates the need for a delivery ratio, but reflected the same watershed characteristics such as drainage area, stream slope and watershed shape. The MUSLE is

$$Y = 11.8(Q \times q_p)^{0.56} \times K \times LS \times C \times P \qquad (2.4)$$

where

Y = the sediment yield from an individual storm (T_m)

Q = the storm runoff volume (m^3)

q_p = the peak runoff rate (m^3/sec)

All other factors are the same as in the USLE.

Chukwuma et al. (1979) also developed a modified form of the USLE, which incorporated a two part runoff factor, one for sheet erosion and one for rill erosion. This model, used to predict sediment yield for single storm events, showed some improvement over the USLE predictions.

2.42. Erosion/Deposition Model

Another method of predicting erosion which incorporates the USLE and several other water flow and soil loss prediction equations is the Erosion/Deposition (E/D) model recently developed by Khanbilvardi et al. (1983). This model attempts to accurately describe the erosion-sedimentation process on upland areas, using the partial area concept. That is, the model does not consider the entire drainage area to contribute to erosion but rather only certain portions of the watershed. The computer model is applied to areas that have been divided into a grid, in which rill and interrill zones have been delineated. The USLE is used to predict the amount of sediment contributed from the interrill areas. The interrill erosion is carried with the rill flow. The actual amount of soil that will be transported off the site is dependent on the rill transport capacity. If the capacity of the rill flow is great enough to carry all the eroded soil, then the soil will be transported downslope and out of the area. Otherwise, the carrying capacity of the flow will limit the amount of soil transported, and the excess sediment will be deposited in the watershed.

The actual approach to the E/D model is a series of steps, starting with the simulation of rill development by the computer. After the rills have been defined, the contributing interrill areas are delineated. The amount of eroded soil from these areas is calculated and routed along the rill patterns. The rill transport capacity then determines the amount of soil carried out of the area or deposited in the watershed.

The experimental methods and computer models described in this section are useful in predicting strip mine soil erosion. Much work has been done in the past to discover better ways to predict, as precisely as possible, sediment yield from a mined watershed, and work is still continuing in this area. This study involves the use of several models and methods on a plot scale, and includes comparisons among all methods.

SECTION 3

MATERIALS AND METHODS

This chapter presents instrumentations and the methodology which were used for this study and is divided into six sections: materials, runoff analysis, erosion pins, evaluation of erodibility, USLE application, and Erosion/Deposition Model.

3.1. MATERIALS

The primary objective of this study was to determine the correspondence between point erosion and erosion over an area. To accomplish this objective, a rotating-boom rainfall simulator was set up and used on two experimental plots located at the field office of the Northeast Watershed Research Center (NWRC), Klingerstown, PA. The plots were 3 m by 9 m, had a slope of 6.5%, and were filled to the depth of 23 cm with Wharton silty clay loam. Plots borders were constructed from two 25 cm wide wooden planks buried to the depth of 12 cm below the soil surface. In determining particle size distribution, a soil sample was wet sieved through a 105 micron sieve. The particle size distribution of the sediment passing through the sieve was determined using a Sedigraph 5000 particle size analyzer. The soil was obtained from a topsoil pile at a strip mine site in Karthaus, PA. The topsoil, which is routinely piled separately from the lower soil horizons as part of the mining operation, was loaded into a truck and transported to Klingerstown. Bulk density measurements were taken at 33 locations at the strip mine using a gamma probe to obtain an estimate of the density of the soil after mining and reclamation. The topsoil was spread in the

experimental plots and compacted as closely as possible to the average bulk density of 1.40 g/cm^3 measured on the reclaimed strip mined area.

The rainfall simulator has ten booms, each 6 m long, with 30 VeeJet stainless steel nozzles located in the three patterns shown in Figure 3.1, which are attached as shown in Figure 3.2. When operating at maximum capacity, each spray nozzle covers an area of 5 m^2. The simulator was centered between the two plots, and then used to "rain" on the plots for two runs of 40 minutes each. The first run was made on dry soil, and the second on wet soil approximately ten minutes after the first run. This series of two runs was repeated three more times under the same sets of conditions. The average intensity of the artificial rain, 7.76 cm/hr, was determined by measuring the volume of water collected over the 80 minute time period, in catchment cans placed under the simulator at evenly spaced intervals. Special catchment cans were designed as shown in Figure 3.3, to determine if the pin had any effect on the amount of rain that fell directly in the pin area. The amount of water that fell into each compartment was measured, then the amount per unit area for both sections was determined and compared. The four runs were spaced over a period of one month during which the plots were covered with plastic sheets to prevent exposure to natural rainfall. The plots were kept free of vegetation for the course of the study.

3.2. RUNOFF ANALYSIS

As the artificial rainfall exceeded the infiltration into the plot, the runoff began. From the time the rainfall started, the runoff was sampled every five minutes to determine the concentration of soil coming off each plot. The five minute interval was found to be most practical experimentally, and the concentration of sediment during that interval was assumed to be fairly constant. The samples were then taken to the laboratory for analysis.

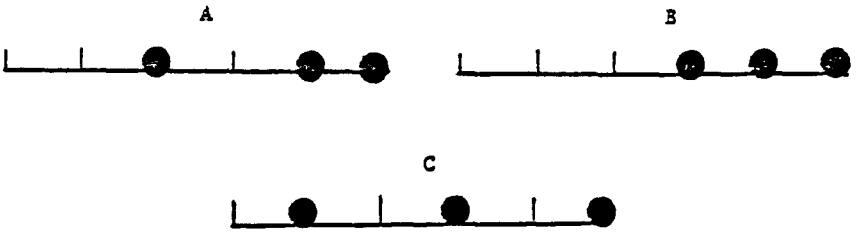

Figure 3.1. VeeJet nozzle patterns.

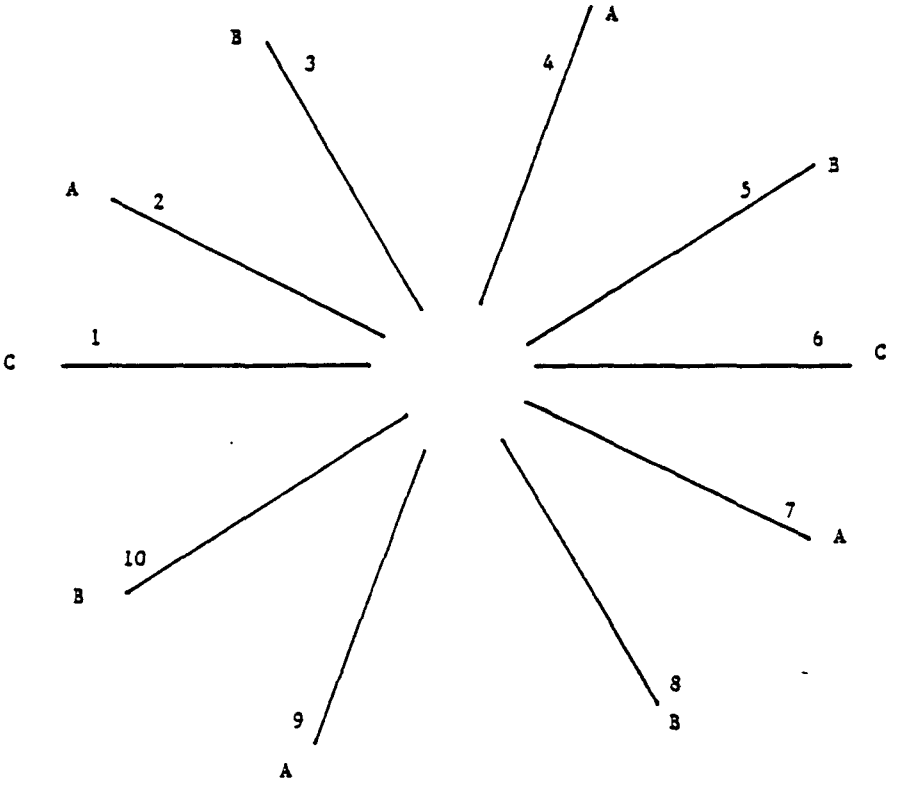

Figure 3.2. Nozzle attachment patterns.

a. Top view

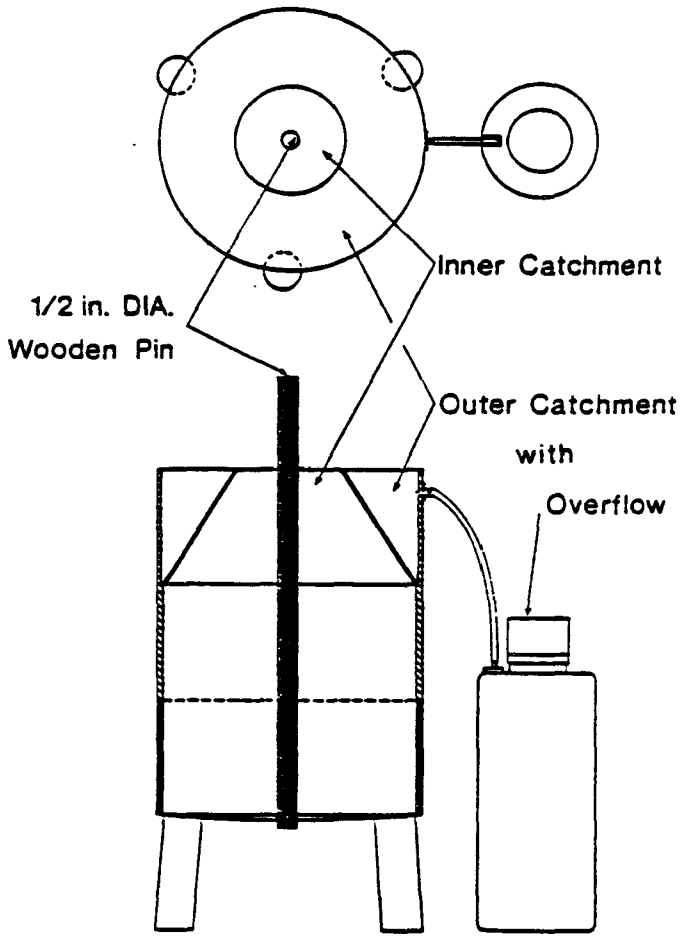

Figure 3.3. Compartmentalized catchment cans used with rainfall simulator.

They were allowed to settle for three days so the sediment could be separated from the runoff water. The water was decanted into a graduated cylinder, measured and recorded. The sediment left in the collection bottles was transferred to pre-weighed drying cans and dried in an oven at 105°C. After three days in the oven, the weight of the soil was determined and recorded. The data is contained in Appendix A.

The runoff rate was determined by using a 22.4 degree V-notch weir with a six hour water level recording chart. The runoff came off the plot into a trough, then into a barrel with a flotation device attached to the recorder, and through a weir. The weir was calibrated to determine the relationship between the chart height and the flow through height (head) by measuring the depth of water flowing over the weir, from the point of the V to the water level, then noting the corresponding chart reading. Measurements were taken several times, and the average from both plots was used as a conversion factor in determining flow rate (see Appendix B). The equation used to estimate flow rate was one developed by Lenz (1941):

$$V = 1.322 + \frac{0.522\ N}{3.281^{e} H_m^{\ e}} \tan(\theta/2)\ H_m^{\ 2.5} \qquad (3.1)$$

where

V = volume (cm^3/sec)

H_m = head in meters

$N = 0.035 + 0.033(\tan(\theta/2))^{-0.8}$

θ = total angle of V-notch

$e = 0.2475(\tan(\theta/2))^{0.09} + 0.34(\tan(\theta/2))^{0.035}$

which was recommended for weirs between 28 and 90 degrees. The weir used in the study was slightly smaller than the range given, so to check the accuracy of the prediction, the relationship between chart height and flow rate was determined by calibration of the weir. Water was allowed to flow through the weir and maintained at a given notch height. The flow rate for each notch height was computed by recording the time required to fill a given volume, then dividing the volume by the time. This procedure was repeated for six different notch heights, and the chart reading that corresponded to each

notch height and flow rate was noted and graphed in Figure 3.4. The calibration of the weir showed Lenz's equation to underpredict the flow rate by a factor of 1.8 (see Appendix B), so the calculations were done again, inserting this conversion factor into Lenz's equation. In this way, the rate and amount of runoff were determined.

The final step in analyzing the runoff was to determine the depth of soil that had eroded from each plot, in order to compare this result to other methods of predicting erosion. For each sample collected, the eroded soil was computed by the equation:

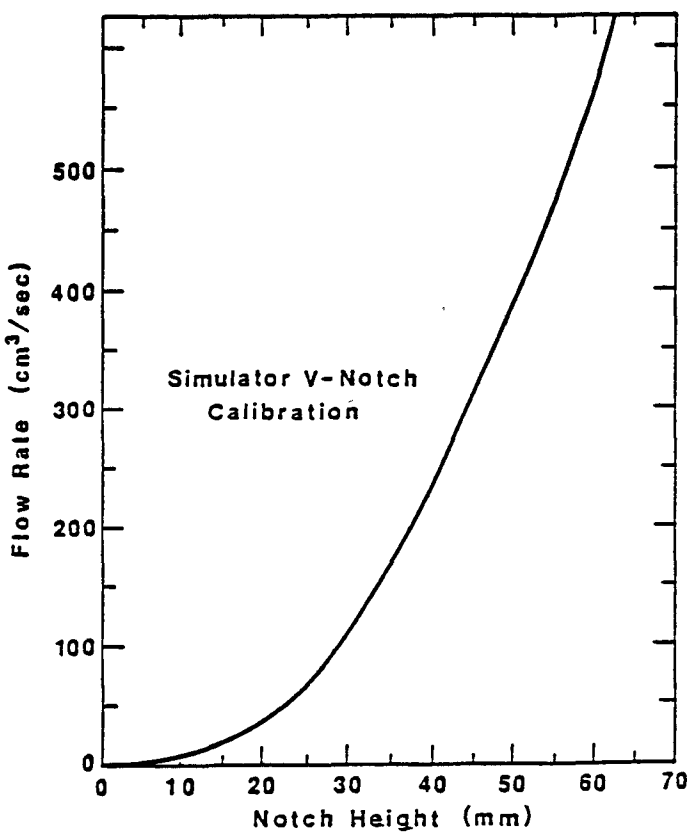

Figure 3.4. Rainfall simulator V-notch weir calibration.

SE = soil erosion (mm)

Δt = sample interval (sec)

C_s = soil concentration (g/cm^3)

Q = flow rate (cm^3/sec)

e = bulk density g/cm^3)

A = plot area (3.2)

A very small amount of soil was transported off the plot but was deposited on the lip of the trough rather than into the runoff. This soil was collected, dried, weighed and added to the sum of the samples for each plot and each simulated rainfall, to give the net erosion per plot. The experimental work resulted in four values per plot of measured soil loss from runoff sampling. These four values were added and compared to the soil loss predicted and measured by the other methods used in this study.

3.3. EROSION PINS

One of the experimental methods used in this study of predicting erosion over the area by point sampling is the technique of measuring erosion pins. The erosion pins are one meter long reinforcing rods that were pounded firmly into the soil, to avoid surface creep, leaving between five and ten centimeters of the pin exposed above the surface. Forty pins were placed on each plot, in ten rows of four each (Figure 3.5). Base measurements were taken for each erosion pin before any artificial rainfall was applied to the plot using a pin measuring device, a micrometer and a washer that was slipped over the pin, as shown in Figure 3.6. Following each simulated rainfall, the micrometer measured the changes in soil elevation at the pin.

To evaluate the areal soil loss from the pin measurements, the changes between readings from one run to the next were determined for each pin. The

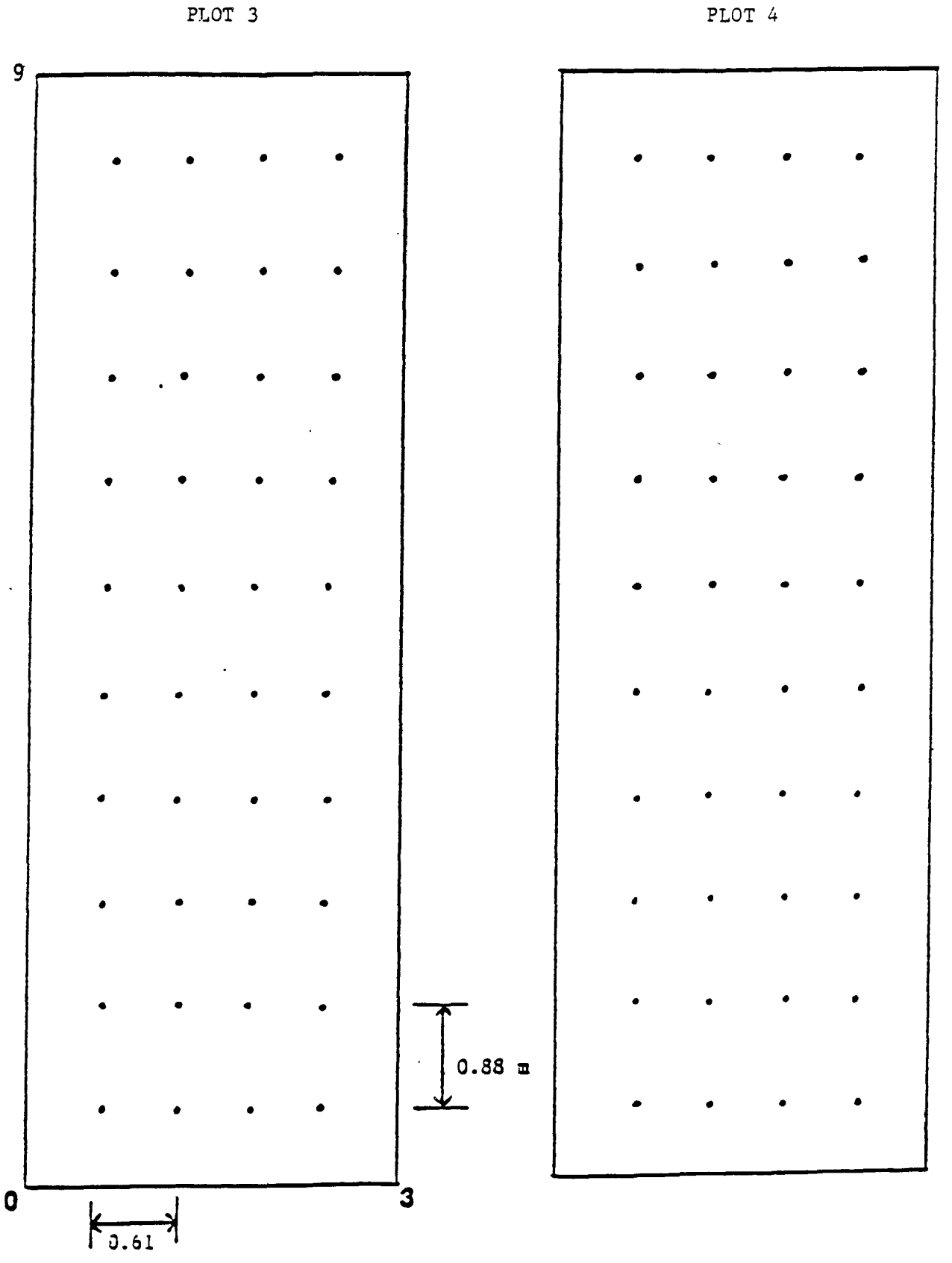

Figure 3.5. Plot dimensions (m) and location of erosion pins.

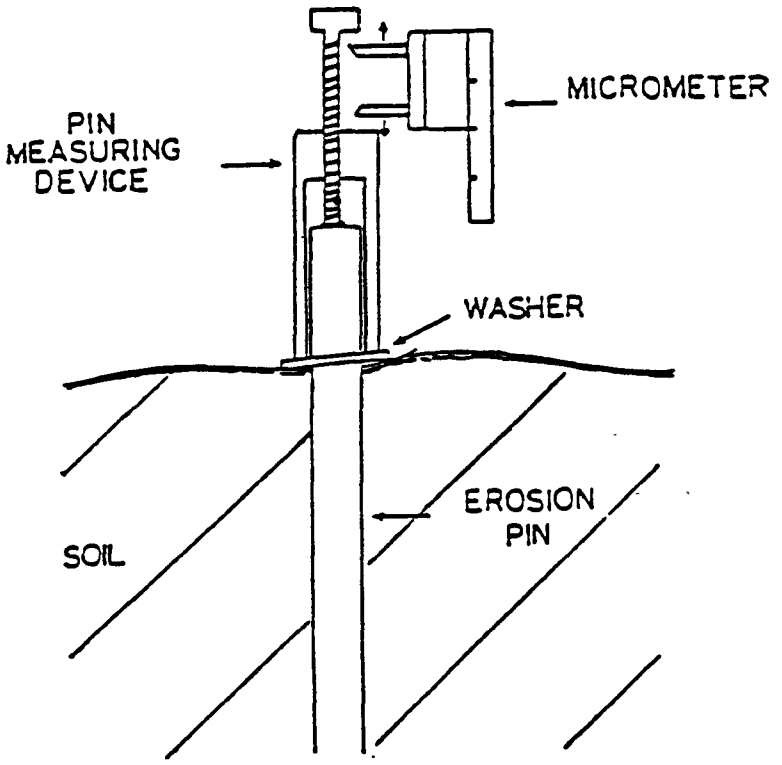

Figure 3.6. Diagram of erosion pin and measuring technique.

resultant changes in soil elevation at each pin (positive or negative) were then used in a contouring program SURFACE2, to contour erosion and deposition data (Sampson, 1978).

To compute the gross areal erosion from each plot for each rainfall, the generated grid matrices of 1800 values (30 x 60) were read using a computer program. Each estimated soil loss value was multiplied by the associated area of 23.5 in^2. The results were averaged to obtain one value for overall erosion for the four runs. These values can then be compared to the sediment measured by runoff sampling, and to soil loss predicted by the computer model and the USLE.

To study rill development on the rainfall simulator plots, cross-sectional measurements were taken before any artificial rainfall occurred, and none after the sequence of four, 80 minute rainfalls. One meter long reinforcing rods, identical to the erosion pins, were driven into the soil, leaving approximately ten centimeters exposed above the surface. The rods were placed in nine rows of two each, with 0.88 m between rows, and 1.83 m between the pins of each row. A horizontal bar was designed with silt openings to fit over the two pins in each row and was checked to be sure it was level before taking a reading (Figure 3.7). In this way, the measurement position was duplicated as closely as possible for the second set of readings. The bar was designed with openings 2.54 cm apart to enable passage of a metal ruler. The ruler was allowed to slide through each opening until it reached the soil surface, as shown in Figure 3.7, then a reading was taken of the distance from the soil surface to the cross section rod. The readings were repeated across the plot every 13 cm for all nine rows. Extensions were also made to measure from the right pin to the edge of the plot, and also for the left pin. These readings and the final readings were recorded, and the change in surface elevation was determined. Using the SURFACE2 graphics system, a surface topography map was created which shows the approximate location of rills. These rill locations will be compared to the location of rills predicted by a E/D computer model to be used in this study (Khanbilvardi et al., 1983).

3.4. EVALUATION OF ERODIBILITY

To obtain accurate soil loss estimates for minesoils, the soil erodibility must be known. The erodibility, which is an inherent property of the soil that allows some soils to erode more easily than others, when all other factors remain constant, was assumed to be maintained both before and after disruption of the soil. To test this assumption, the Universal

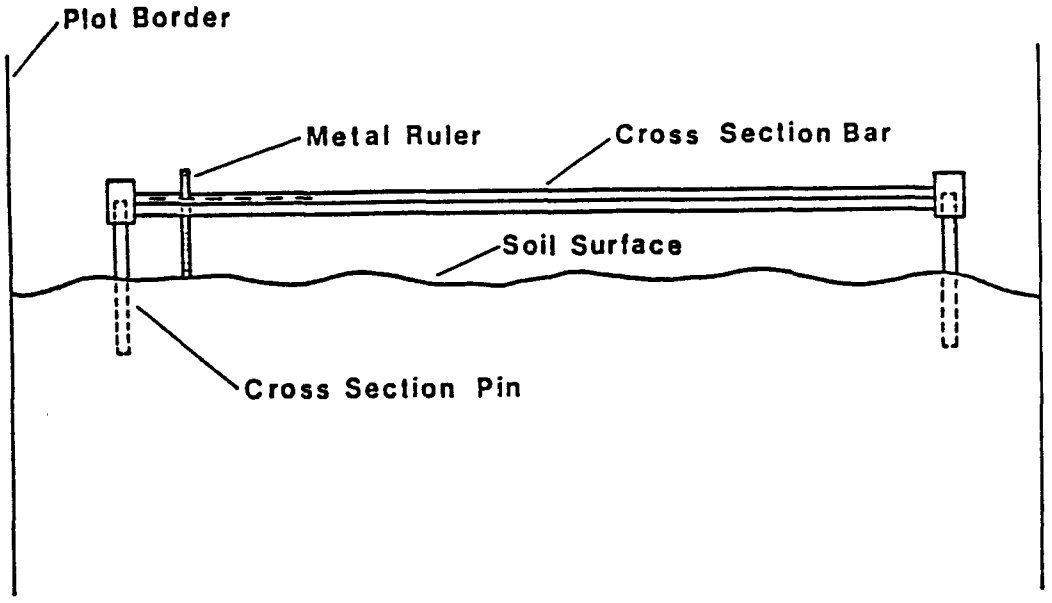

Figure 3.7. Diagram of cross section measuring device.

Soil Loss Equation or USLE (Wischmeier and Smith, 1978) was used. The USLE equation (2.3) has been the most readily usable model to predict soil loss on mined and reclaimed land. To solve for K, the soil erodibility, the equation was rewritten as K = A/RLSCP. The soil loss value, A, was obtained by measuring the sediment in the runoff from the rainfall simulator plots as described above, then converted to tons/acre. The rainfall erosivity value, R, was computed to reflect the intensity and energy of the rain storm supplied by the rainfall simulator.

The erosivity or erosion index (R in the USLE) is defined as the product of the energy and intensity. To use the USLE for predicting soil loss for an individual storm, as it is the case for this study, the R factor can be replaced by an energy-intensity (EI_{30}) interaction for that storm (Foster et al., 1982). The rainfall erosivity is then calculated as,

$$R = EI_{30}/100 \tag{3.3}$$

where

E = storm kinetic energy in metric ton-m per hectare per cm of rain = $210 + 89 \log I$,

I = rainfall intensity (cm/hr), and

I_{30} = maximum 30 minutes intensity (cm/hr).

The LS (slope-slope length) factor was determined by computing one value for the entire plot, using the equation derived by Wischmeier and Smith (1978);

$$LS = (L/22.13)^m(65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065) \tag{3.4}$$

where

L = total slope length in feet,

θ = angle of the slope,

m = 0.5 for slopes of 5% or more.

The cover factor (C) was set equal to 1.0 since there was no protective vegetative cover, and the P factor was also set to 1.0 since there was no conservation practice. Thus, we can solve for the K value since all other values are known. This K value can then be compared to the K value previously determined for Wharton silty clay loam by the Soil Conservation Service.

3.5. USLE APPLICATION

The USLE was also used in this study to predict erosion on the plots. Although the USLE has been widely used to predict strip mine erosion, it was originally intended for use on cultivated agricultural areas over a long period of time. Adaptations can be made to the equation so it can be applied to mining, but the factor values must be chosen carefully. For this study, values were obtained for all factors either experimentally or from established sources.

The USLE was used to predict erosion based on the characteristics of many small subwatersheds on the plot to obtain a prediction based on the plot as a whole.

Each plot was divided into a grid of 15 by 5 blocks, each block 0.61 x 0.61 meter square (Figure 3.8). The soil loss was predicted at the center of each of these squares using the USLE, resulting in 75 values in all. The R value was determined for the specific storm type supplied according to the method described previously. The cover and conservation factors were both equal to 1.0. The K value used in the prediction was the value established for that soil type by the Soil Conservation Service. The elevations were measured at each erosion pin, then elevations were estimated at the center of each square of the grid by linear interpolation (Appendix C). The distance between each elevation estimate was 0.61 meter, so slope percentages could be inserted into equation (3.4) to determine the LS value for each subarea. All the factor values were inserted into the USLE and 75 soil loss predictions were obtained. To obtain one erosion value per plot using the USLE, the 75 values were averaged. The SURFACE2 contouring program was used to create one contour map per plot of predicted soil loss values.

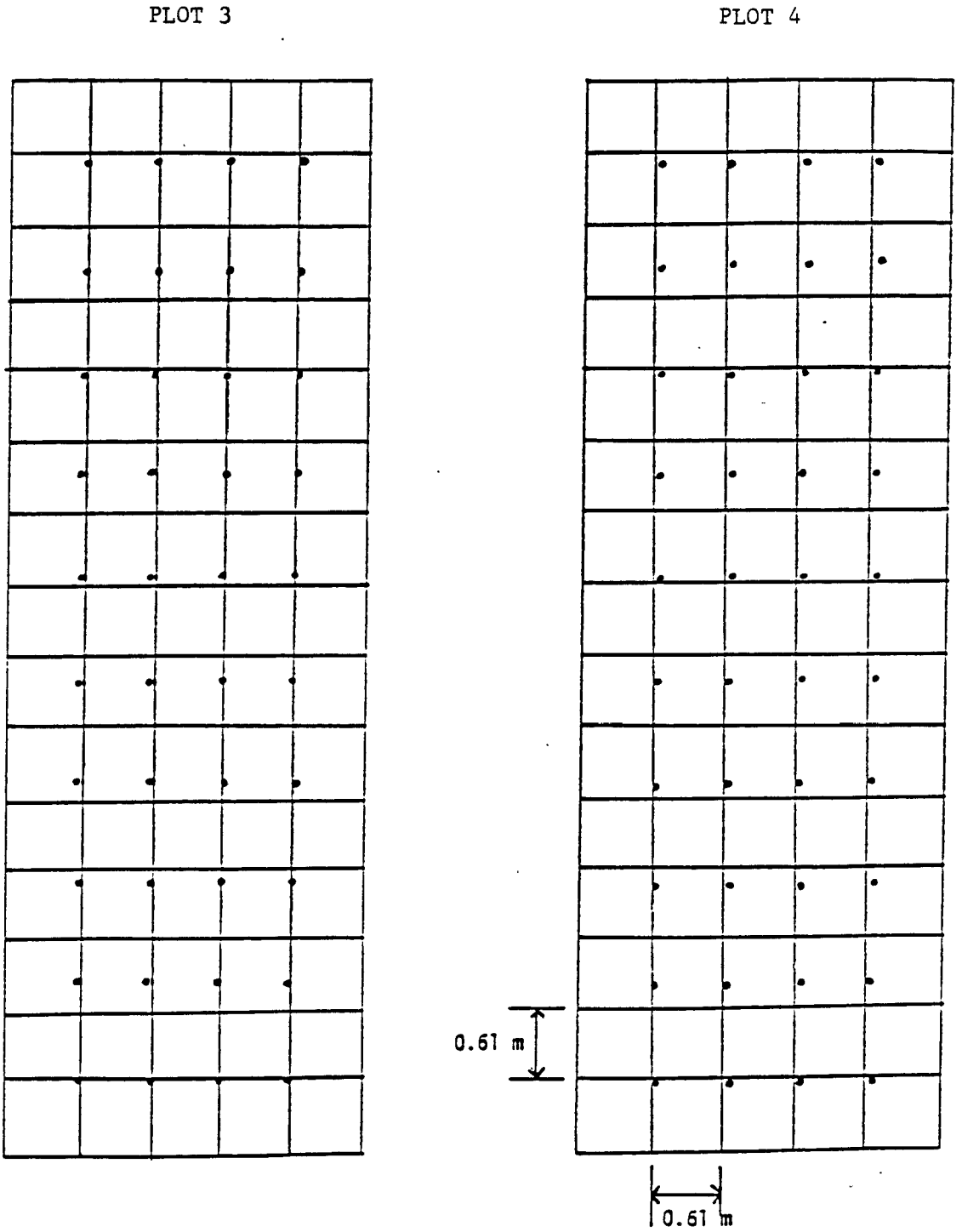

Figure 3.8. Location of erosion pins and subwatersheds for use in USLE and Erosion/Deposition Model.

The prediction from the "entire plot" values was a simple matter of multiplying the calculated R value, the LS value as described in the Evaluation of Erodibility section, the K value established by the Soil Conservation Service, and 1.0 for C and P. After conversions, a soil loss prediction in millimeters was obtained.

3.6. EROSION/DEPOSITION MODEL

The second computational method used to predict erosion is the Erosion/Deposition (E/D) Model developed by Khanbilvardi et al. (1983). To properly use this model, the study area was divided into homogeneous, equal size, square subwatersheds. Each subarea was 0.61 m by 0.61 m, and represented by a node point in the center. The input parameters were assumed to be constant for a given subarea. From the given information, rill sources and patterns were generated. The elevations, which had been estimated at the center of each subarea, are some of the key inputs to the model, since they determine the most likely direction of water flow in projecting rill pathways. The contributing areas to the rills are assumed to have sufficient runoff to transport the eroded soil to the rills. Therefore, the rills are assumed to be the only flow system responsible for transporting the detached soil down and off the plot. Erosion on the contributing areas was calculated using the USLE. A flow chart of the model is shown in Figure 3.9.

To route the eroded sediment, the sediment supply rate was balanced against the transport capacity of the rill flow. If the flow transport capacity exceeded the amount of sediment supplied, all the sediment would be carried by rill flow. Otherwise, the transport capacity of the rill flow would limit the amount of soil that would move downslope, and the excess sediment would be deposited on the plot.

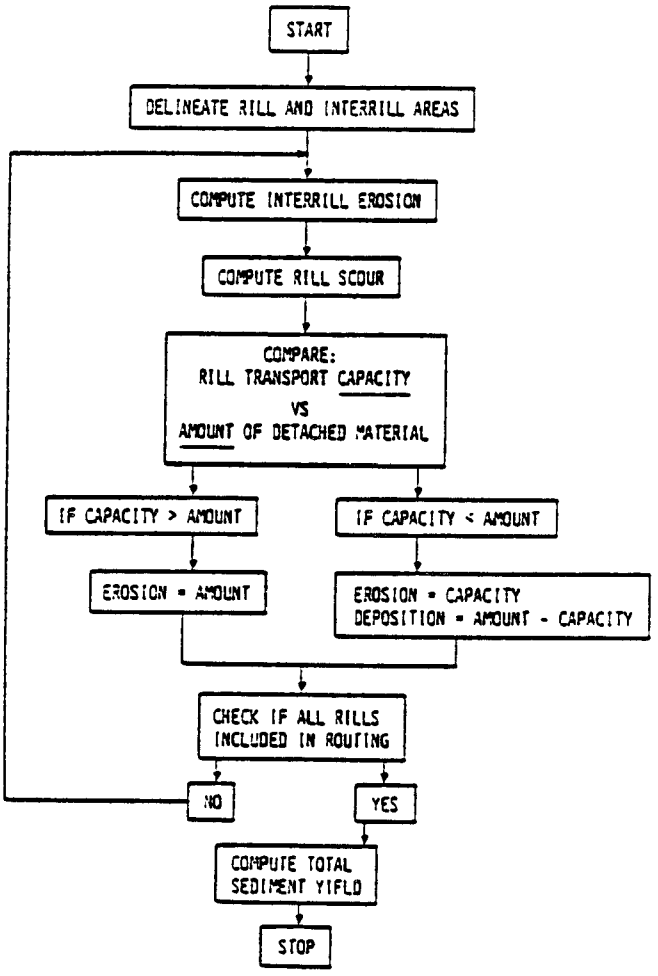

Figure 3.9. Flow chart of the Erosion/Deposition Model.

To compute infiltration and rainfall excess, the water content of the soil must be known. The initial moisture content was estimated in the model from the available moisture characteristic and one-third and fifteen bar water contents for the soil, which were determined experimentally to be 0.195 and 0.094 g H_2O/g of soil, respectively. The average particle diameter of 0.27 cm, which is needed in determining the amount of sediment that will be carried by rill flow, was also determined experimentally by dispersing, then wet sieving an 800 g sample of soil. The soil

permeability of 7×10^{-5} cm/sec was obtained from research done by Cunningham et al. (1977) on Pennsylvania soils developed from acid shale. The bulk density used, 1.40 g/cm^3, was measured on the plots. The rainfall erosivity and LS factor to be used in the USLE were determined by the procedure described in the previous section.

Each model component was computed, then the routing procedure (Foster and Meyer, 1972) of balancing the available sediment against the flow transport capacity was carried out for each plot. The model predicted the location and amount of erosion and deposition for the specified storm for both plots, and gave the amount of soil that would come off the plots from each rill outlet.

The final scour or deposition was printed in grid matrix form for all 75 points. The predicted amount of soil from each rill outlet was added to get the cumulative amount of soil to be eroded from the entire plot, then the average amount of soil over the plot was determined. These results were compared to the soil loss results from the USLE, erosion pin measurements, and runoff sampling. These comparisons are discussed in the next section.

SECTION 4

RESULTS AND DISCUSSION

4.1. RUNOFF ANALYSIS

The runoff rates, determined by the modified Lenz equation, sediment concentrations and depth of soil eroded from the plot as measured by runoff sampling, are shown in Appendix D. Each run consisted of parts A and B, each 40 minutes. The cumulative depths of soil for each run were averaged for each plot, shown in Table 4.1. The values for the four runs were averaged for each plot and displayed in Table 4.2 opposite sediment load, along with a summary of the other results.

TABLE 4.1. SEDIMENT LOAD MEASURED FROM RUNOFF SAMPLING (MM)

Plot Number	Run Number
3	1A + 1B = (0.1391 + 0.1076) = 0.25
	2A + 2B = (0.1787 + 0.1562) = 0.33
	3A + 3B = (0.0788 + 0.0848) = 0.16
	4A + 4B = (0.0688 + 0.0819) = 0.15
	$\bar{X}$ = 0.22 mm
4	1A + 1B = (0.0711 + 0.0299) = 0.10
	2A + 2B = (0.0734 + 0.0801) = 0.15
	3A + 3B = (0.0391 + 0.0276) = 0.07
	4A + 4B = (0.0362 + 0.0445) = 0.08
	$\bar{X}$ = 0.10 mm

An error analysis was performed on the final equation used in the calculation of soil depth eroded as measured by runoff sampling. Since total depth

TABLE 4.2. AVERAGE SOIL LOSS (MM) ON THE TWO EROSION PLOTS AS DETERMINED BY RUNOFF SAMPLING (1), PIN MEASUREMENTS (2), THE USLE (3), AND THE EROSION/DEPOSITION MODEL (EDM) UNADJUSTED (4), AND ADJUSTED (5) FOR SCOUR

Source	Plot 1	Plot 2
1. Sediment load (runoff sampling)	0.22	0.10
2. Erosion pins	2.23	1.36
3. USLE - based on		
i - plot	0.75	0.75
ii - subarea	0.15	0.13
4. EDM	0.24	0.37 (0.09)
5. EDM adjusted	1.15	1.66

equals the sum of sample interval depths, the total absolute error would be the sum of the absolute error in depth for each interval. The absolute error in sample interval depth can be found by determining the errors in each component of the equation, which are sample interval, concentration, flow, bulk density, and plot area. Conversion is a constant with no error. The following errors were determined:

sample interval	5 sec
bulk density	0.04 g/cm^3
plot area	64 cm^2
concentration	0.01 g/cm^3
flow	0.66 cm^3/sec

To determine the error in the flow measurements, the following steps were taken: assumed 0.10" error in reading chart and in measuring water level on the chart, head = (0.10)(0.0374) = 0.00374 m (see Appendix B), then flow

error was determined by inserting the value for head in the flow equation, equation (3.1), to give 0.66 cm^3/sec. Therefore, the sample interval depth error is

$$\frac{(5\ \text{sec})(0.01\ \text{g/cm}^3)(0.66\ \text{cm}^3/\text{sec})}{(0.04\ \text{g/cm}^3)(64\ \text{cm}^2)}$$

$$= 1.29 \times 10^{-2}\ \text{cm}$$

$$= 1.29 \times 10^{-3}\ \text{mm}$$

Therefore, the total error in depth = (1.29×10^{-3})(8 intervals) = 0.01 mm.

Runoff versus time was plotted for each run and was found to be quite variable (Figure 4.1). For the most part, the runoff rate peaked between five and ten minutes of the first run, and remained at that level for the second forty minute run. The average runoff to rainfall coefficient for both plots was determined to be 0.34, or approximately 34% of the rainfall was transported off the plot, and 66% infiltrated. The sediment concentrations were higher for the first two runs than the last two, which may indicate a large amount of fine particles were present initially, which were easily eroded. As erosion continued, the majority of the remaining particles were coarser, and were not detached as easily as the fines, or were more likely to be deposited on the plot rather than be transported off the plot. Another reason for variable sediment concentration may be that the soil was compacted more in some areas than others on the plot to start, then at a certain point during the rainfall, large clumps of soil came loose and were transported off the plot in the runoff. Large depressions were observed on the plots after certain runs, which may substantiate this hypothesis.

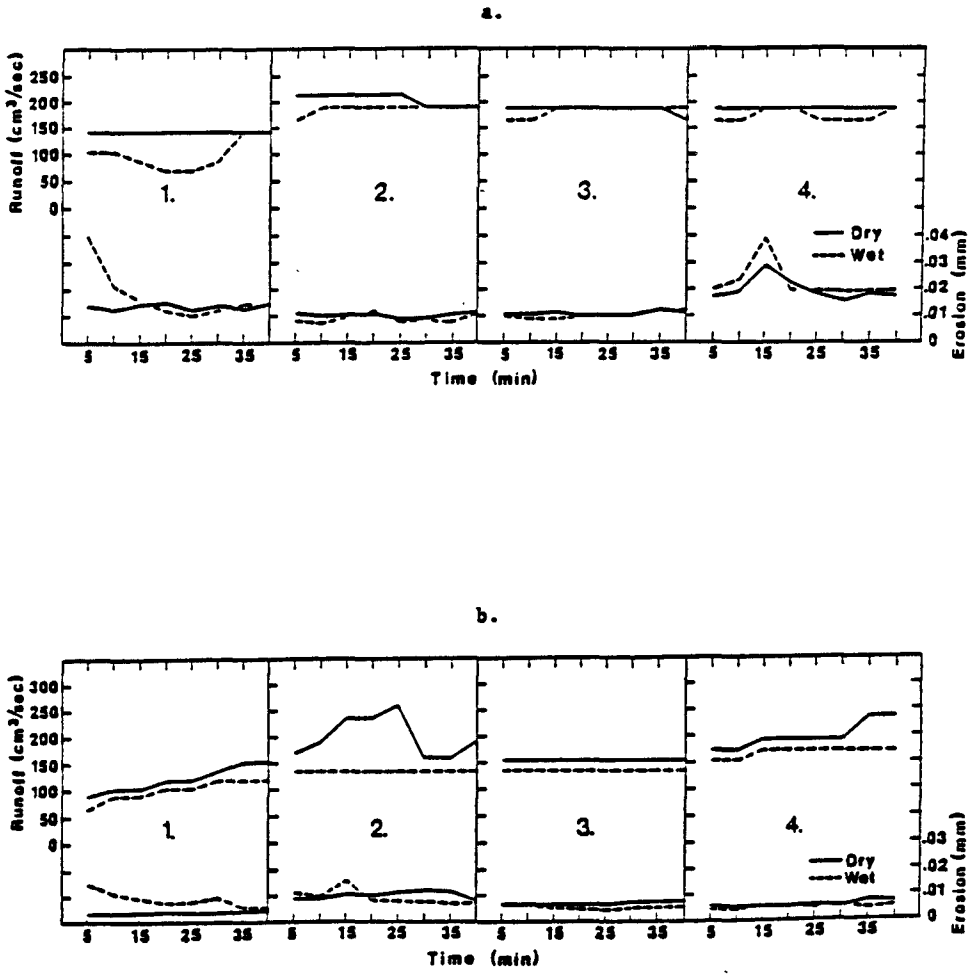

Figure 4.1. Runoff rates versus time, and erosion measured by runoff sampling versus time; plot 3 (a) and plot 4 (b), runs 1-4.

4.2. EROSION PINS

Creation of contour maps from the forty erosion pin measurements gave the areal distribution of the erosion, as shown in Figure 4.2 for run 1. The amount of surface decline for the four runs, obtained from pin measurements, were averaged for each plot. Erosion pin measurements were then used as point samples to create (Sampson, 1978) a mosaic map (Figure 4.3) of erosion (negative) and deposition (positive) on both plots. The pins measured both erosion and deposition, but the overall results for both plots indicated soil

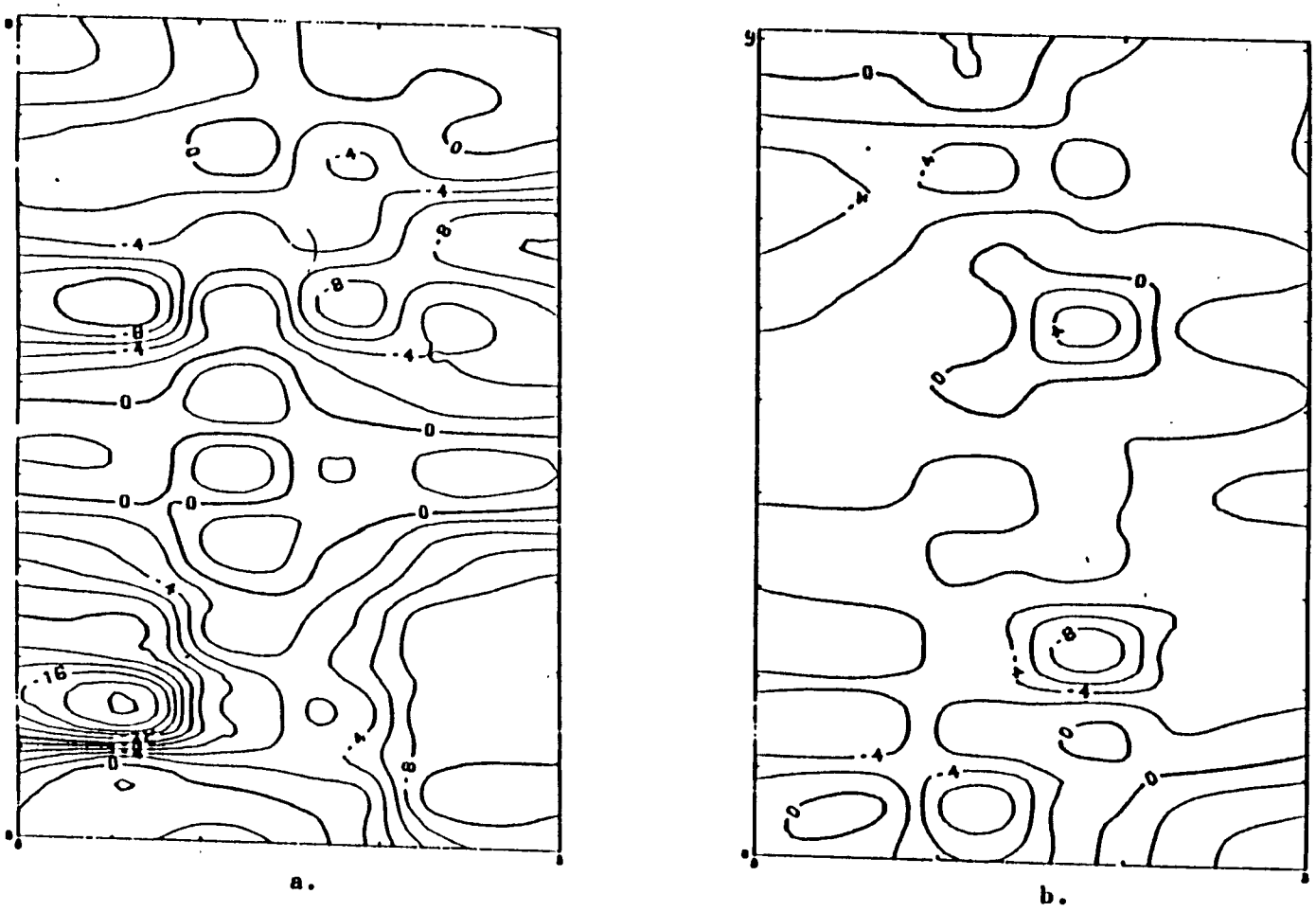

Figure 4.2. Erosion pin contour maps for plot 3 (a) and plot 4 (b) - run #1; erosion contours (mm); plot dimensions (m).

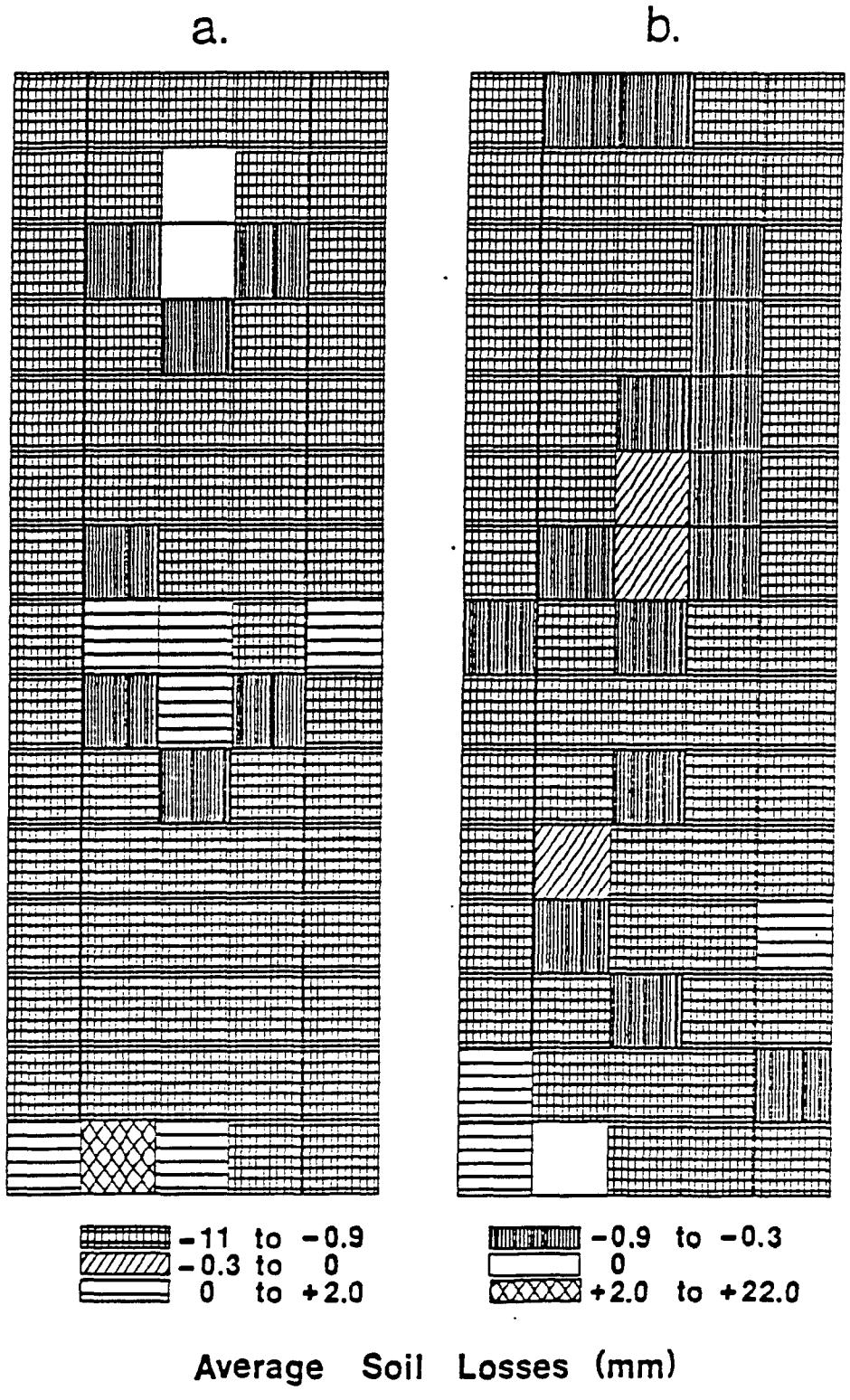

Figure 4.3. Mosaics of kriged values of erosion pin (mm) for plot 3 (a) and plot 4 (b).

loss for each run, shown in Table 4.3. The averages used in the final analysis can be seen in Table 4.2. The individual pin measurements can be seen in Appendix E. The error associated with the pin measurements was found to be 0.74 mm through repeated measurements of several pins. In addition to the error in the measurements, there was a great deal of variability in the experimental technique. The rainfall simulator had some operational problems which may have caused the differences in soil loss from one run to the next. A problem with the simulator was that rust formed on the inside of many of the pipes and nozzles, and caused improper spray application. The water flowing through the rusted pipes and nozzles trickled straight down rather than fan out, so distinct gullies were formed under the paths of the malfunctioning nozzles, which created more erosion than under the proper operating conditions. The nozzles were cleaned as thoroughly as possible in between runs, but it was impossible to remove the rust from the pipes. The nozzles became clogged during some runs more than others, resulting in high variability in the pin measurements.

TABLE 4.3. AVERAGE EROSION PIN MEASUREMENTS FOR PLOTS 3 AND 4

Plot No.	Run No.	Soil Loss (mm)
3	1	-3.52
	2	-1.38
	3	-2.97
	4	-1.04
		$\bar{X}$ = -2.23
4	1	-1.85
	2	-1.78
	3	-0.41
	4	-1.39
		$\bar{X}$ = -1.36

A second problem occurred at the end of each forty minute run when the simulator was turned off. Although the simulator was turned off firmly, the nozzles dripped for a few minutes, and caused increased soil detachment directly beneath the nozzle. Not all nozzles dripped, and the position in which the rotating booms came to a stop varied, so different areas received the additional impact each time. Occasionally, the dripping occurred directly on or around an erosion pin, which gave deceptively high values for erosion when the pin was measured. To circumvent this problem in successive runs, the water supply was shut down at the end of the forty minute run, but the booms continued to spin for a few minutes. In this way, the excess water was spread out over the plots with a low intensity rather than drip on specific areas and cause increased erosion.

The mean measured values from the erosion pins were approximately ten times greater than the mean values of sediment load measured by runoff sampling. Because of the somewhat large error associated with the erosion pin measurements, the runoff sampling results may be a bit closer than first appears. However, it would be inaccurate to say that the two measurements are comparable because of the considerable degree of variability.

A reason for the high soil loss values measured by the erosion pins, beyond those already mentioned, may be that the physical presence of the pin caused changes in water flow and soil loss patterns, and may even have increased erosion at the pin. Analysis of the compartmentalized catchment cans indicated that, in 83% of the measurements, more rain fell around the pin per unit area than outside the pin area (Table 4.4). This may have led to increased erosion at the pin simply because of the pin's presence.

A pin with a smaller circumference may cause less localized soil loss. These factors will be accounted for when using Erosion/Deposition Model to predict soil loss factor in this chapter.

TABLE 4.4. ANALYSIS OF RAINFALL IN COMPARTMENTALIZED CATCHMENT CANS TO DETERMINE THE EFFECT OF THE PIN ON RAIN FALLING PER UNIT AREA

Sample No.	Rain Around Pin (cm)	Rain Outside Pin (cm)
1	13.7	13.7
2	11.5	11.6
3	17.1	16.1
4	13.9	11.2
5	12.9	8.3
6	13.2	11.8

Concerning operator error, it is difficult to gather readings that are accurate to the nearest millimeter. Some recorded results were smaller than the experimental error in measuring the pins, which indicates that some apparent erosional values may actually have been only a result of operator error.

4.3. PREDICTION RESULTS

4.3.1. USLE Predictions

To determine one erosion value per plot using the USLE, contour maps (Figure 4.4) and mosaic map (Figure 4.5) were generated. These maps gave some idea of the areal distribution of the predicted soil loss. The agreement between the soil loss predicted by the USLE and the sediment load measured in runoff sampling was more satisfactory than between the pins and runoff sampling (Table 4.2). The USLE prediction for the entire plot values was much higher than the runoff sampling values, and fell in between the

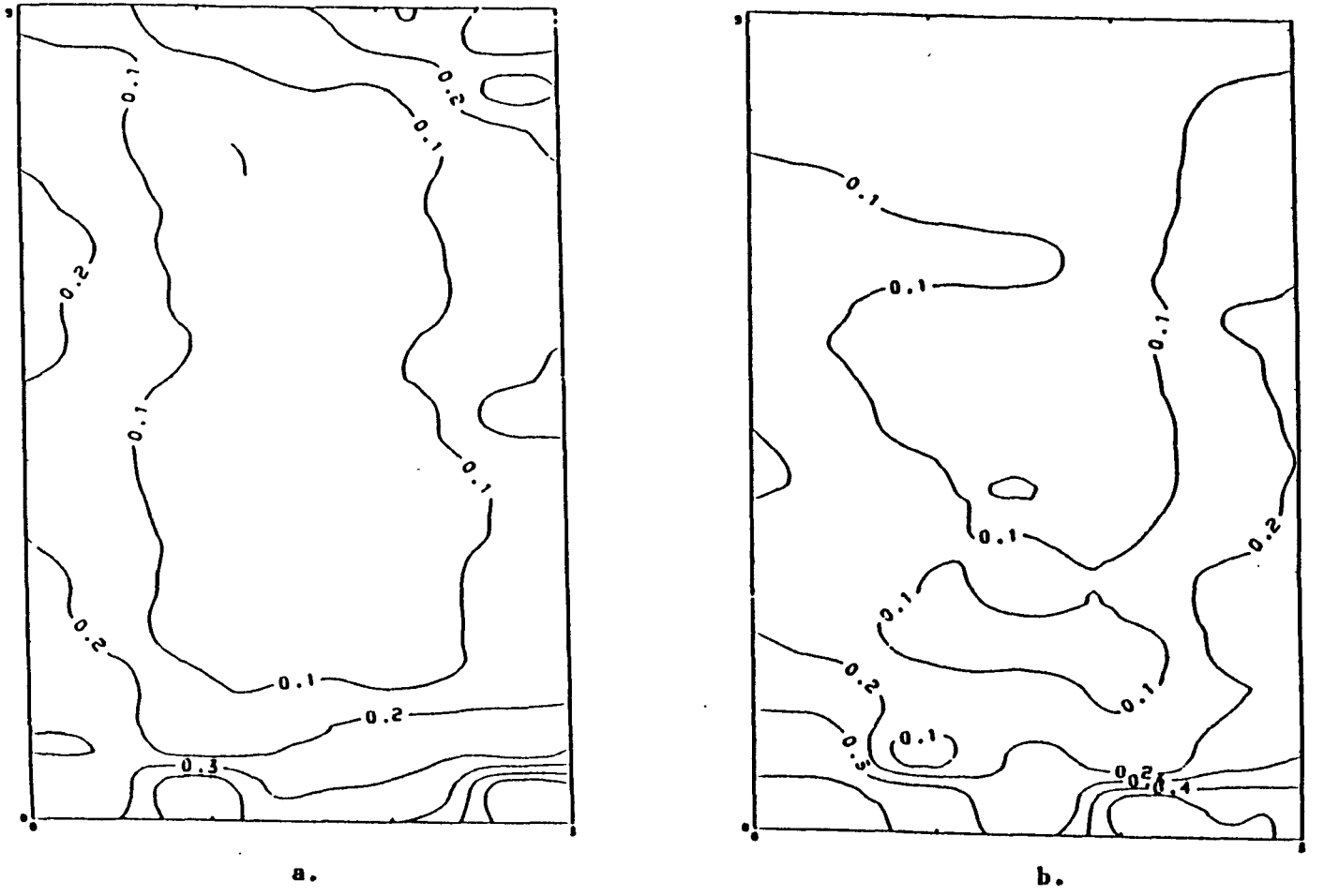

Figure 4.4. Contour maps of predicted erosion (mm) using the USLE, plot 3 (a) and plot 4 (b).

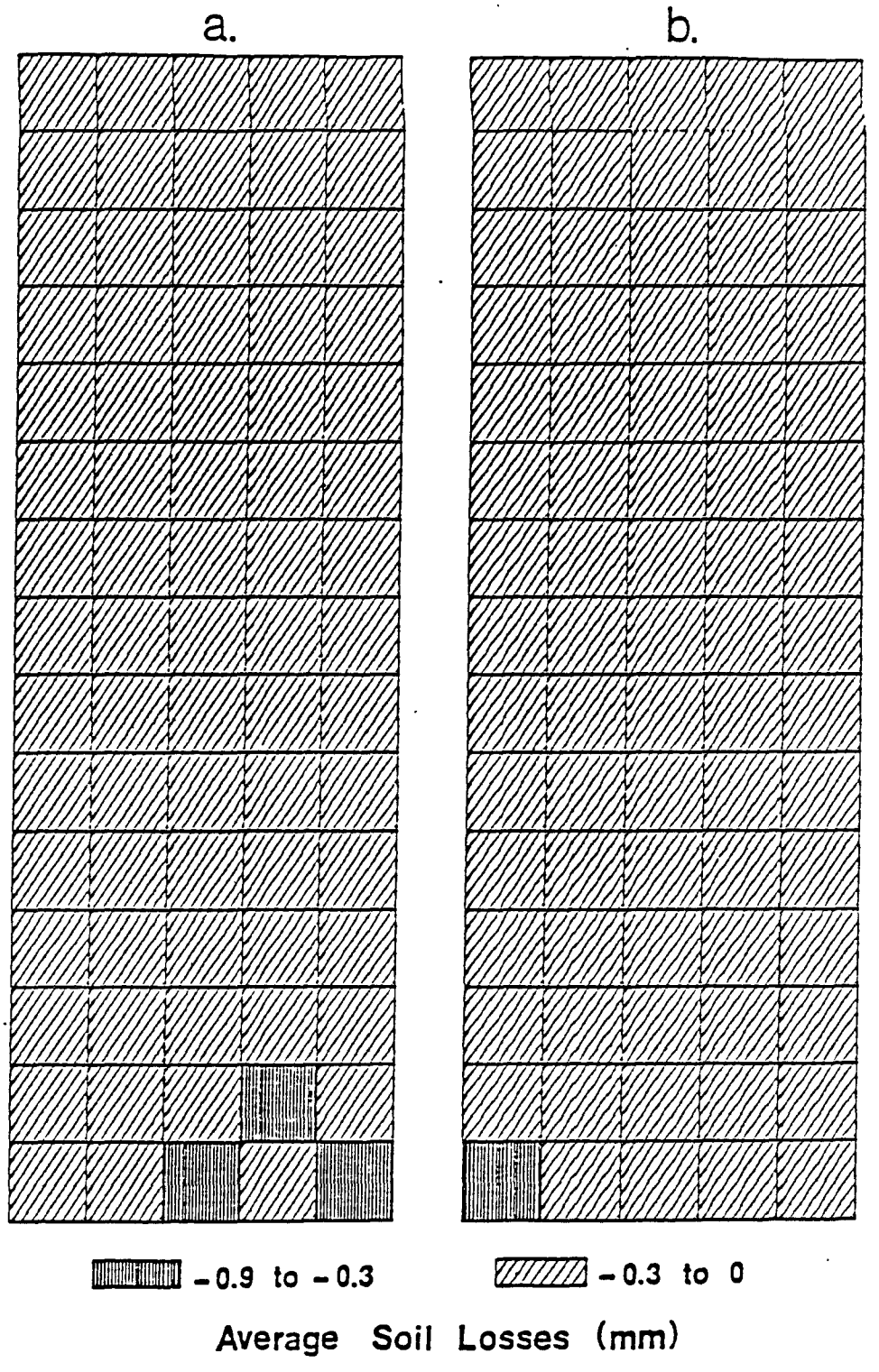

Figure 4.5. Mosaics of predicted soil loss (mm) by USLE for plot 3 (a) and plot 4 (b).

values for the erosion pins. In general, the USLE is expected to overpredict soil loss because the equation does not account for soil deposition on the slope or in depressions in the field. However, for the small plot scale used in this study, where very little deposition occurs, the equation should give a fairly good soil loss estimate. For the subareas, the equation underpredicted soil loss for plot 3 by a factor of 1.5, and overpredicted soil loss for plot 4 only 0.7 times. The plot value was about 7.7 and 17 times larger for plots 3 and 4, respectively. Therefore, the overprediction by USLE can be improved by using USLE separately for different subareas of the plot. The equation was designed to estimate the long term average annual soil loss, so when applying it to specific storms, the results must be interpreted cautiously. The predictions for plots 3 and 4 are the average soil loss values for numerous recurrences of the specific storm energy and intensity used in the study. As with any average, the soil loss from any one of these events may vary considerably.

4.3.2. Erosion/Deposition Model

When analyzing the predicted erosion from the E/D model and the measured erosion, a fairly good correspondence between the two was found. Mosaics were created (Figure 4.6) to display the predicted values. The average soil loss from each plot is given in Table 4.2. Although the plot 4 predicted value is over three times larger than the measured value, they become much closer when one considers a possible sink on the plot, such as a leak between the plot and runoff trough, or from the side boards of the plot. During run 2, a slight leak was observed on plot 3 between two side boards. It was quickly repaired and was not observed again, but may have had some impact on the measured sediment load. When first applying the model, the experimental value for average particle size diameter of 0.27 cm was used. This gave a

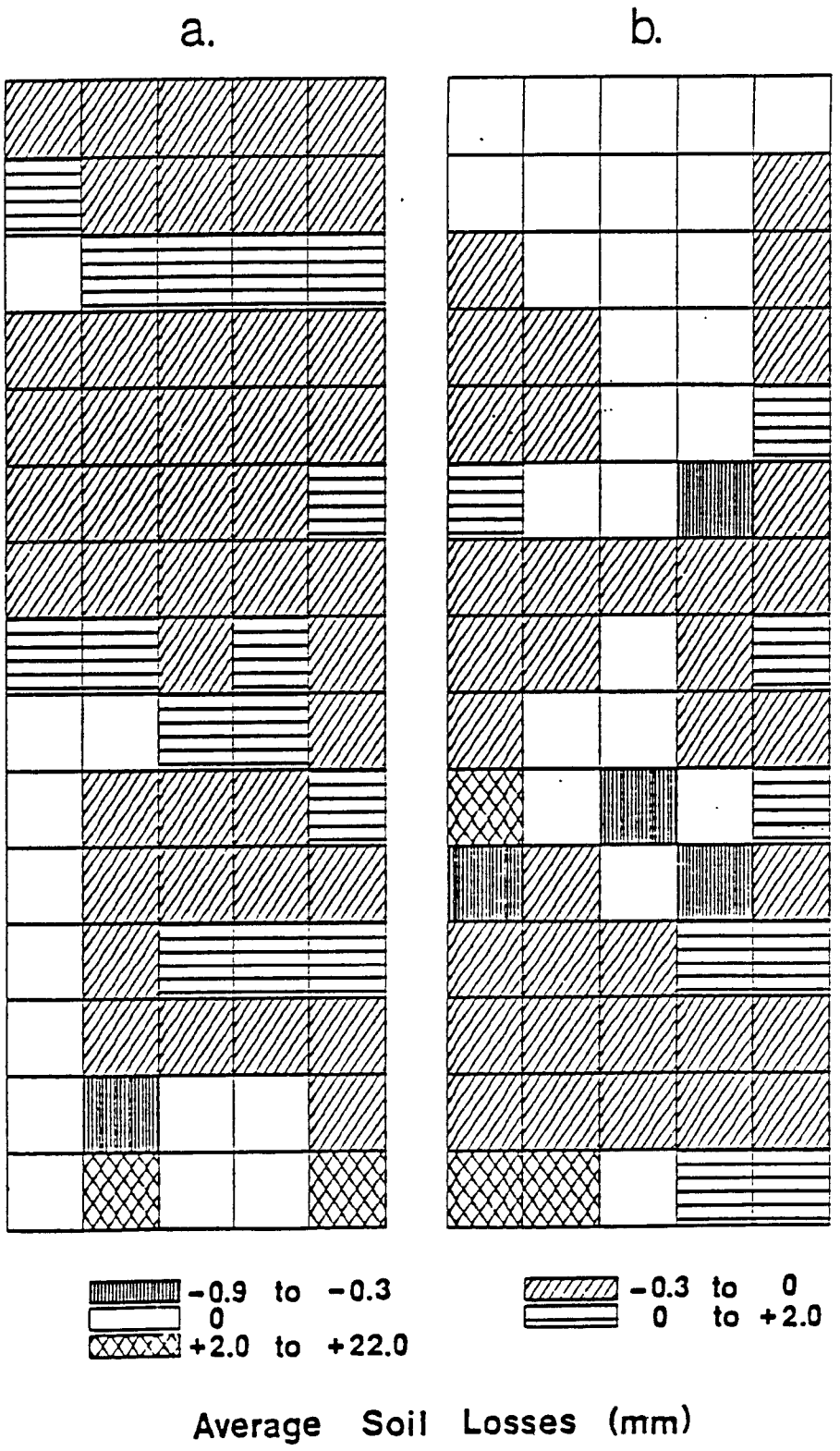

Figure 4.6. Mosaics of erosion (- ve) and deposition (+ ve) by EDM model for plot 3 (a) and plot 4 (b).

very large result for final scour and deposition off the plots. The computer model then used the D_{90} (90% finer by weight) particle size which was about 3.0 cm. Inserting this value into the computer model gave much more reasonable results, which were used in the final analysis. The computed value was used rather than the experimental value because it is likely that the smaller particles clumped together to form larger soil aggregates in the runoff, and resulted in a larger average particle diameter.

The results show that the mean measured values from erosion pins were approximately ten times greater than the mean values expected on the basis of sediment load measured in runoff. Strictly speaking, the two measurements are not comparable because of the considerable variability associated with pin data as contrasted with the averaging effects of runoff. Although in here the discussion is directed towards possible effects associated with man installed metal erosion pins, similar rationale may apply to growing plant stalks, stones and other surface protrusions. The presence of erosion pins could by itself be the reason for the higher soil loss values measured at the pins. Pins will cause flow disturbance and possibly create local "scour." Local scour would occur adjacent to the pin, and its magnitude would vary according to flow, pin condition, and sediment concentration in runoff. Pins will increase the flow velocity in the down-pin section and, therefore, increase the capacity of flow to carry more sediment than in the up-pin section of the flow path. Flow around a pin, however small in scale, creates eddy structure or a system of vortices. This behavior is the basic mechanism of local scour. The scour around a bridge pier is a large scale manifestation of local scour and has long been recognized by many researchers (Posey, 1949; Laursen and Toch, 1956). Carstens (1966) attempted to quantify

the local scour around a cylinder. He defined a sediment number (N) as,

$$N = \frac{V}{\sqrt{\left(\frac{\gamma_s}{\gamma_f} - 1\right) gd}} \tag{4.1}$$

where

V = mean velocity of the undisturbed flow (cm/sec)

g = acceleration of gravity (cm/sec^2)

d = mean sediment size (cm), and

γ_s and γ_f = specific weights of sediment and fluid (g/cm^3)

His results indicated that sediment number N for undisturbed flow is one-half of N for flow disturbed by a vertical bar. This suggests that maximum velocity around a cylinder in a two-dimensional flow may be approximately twice the undisturbed condition. Such increase in velocity which is an integral part of the flow system would be influenced by the pin physical characteristics. In general the depth of scour around a cylinder (d_s) can be related to the cylinder Reynolds Number (R_e) (Shen, 1971),

$$d_s = \alpha \left(R_e\right)^{\beta} \tag{4.2}$$

where

$$R_e = \frac{Vd_p}{\nu}$$

d_p = pin diameter (cm)

ν = flow kinematic viscosity

(cm^2/sec)

α and β = constants

In addition to the eddy system, the wind velocity and direction could increase the flow around the pins. Analysis of the data from compartmentalized catchment cans (Figure 3.3) showed that more rain fell immediately around the pins than outside the pin area and that the amount increased with wind speed (Figure 4.7). We would therefore expect erosion to increase around the pin due to a larger volume of flow.

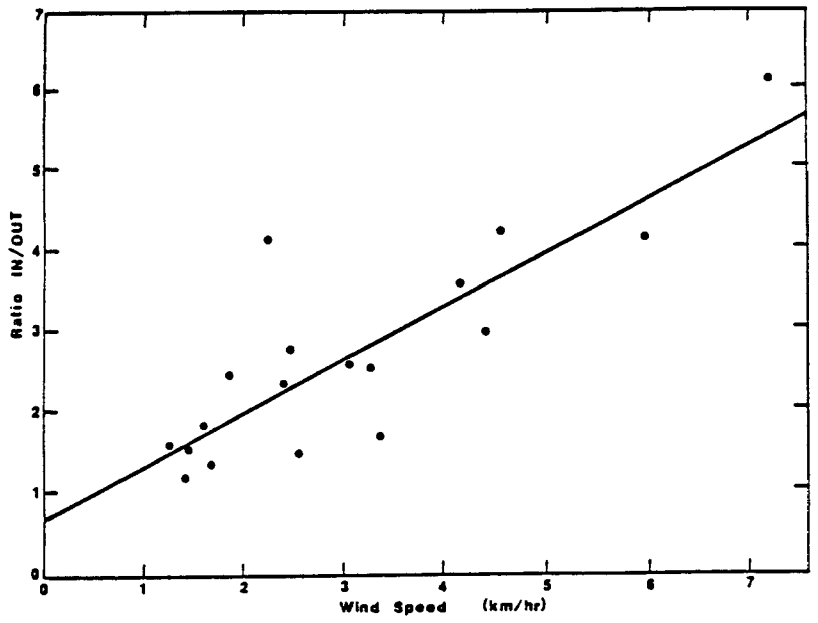

Figure 4.7. Wind effect on the rainfall ratio at catchment cans.

When the above factors were incorporated into the EDM model the adjusted output (Table 4.2) indicated a much closer agreement between the EDM predicted values (Figure 4.8) and measured erosion pin data. It appears, should appropriate parameters be available, a mathematical model such as an

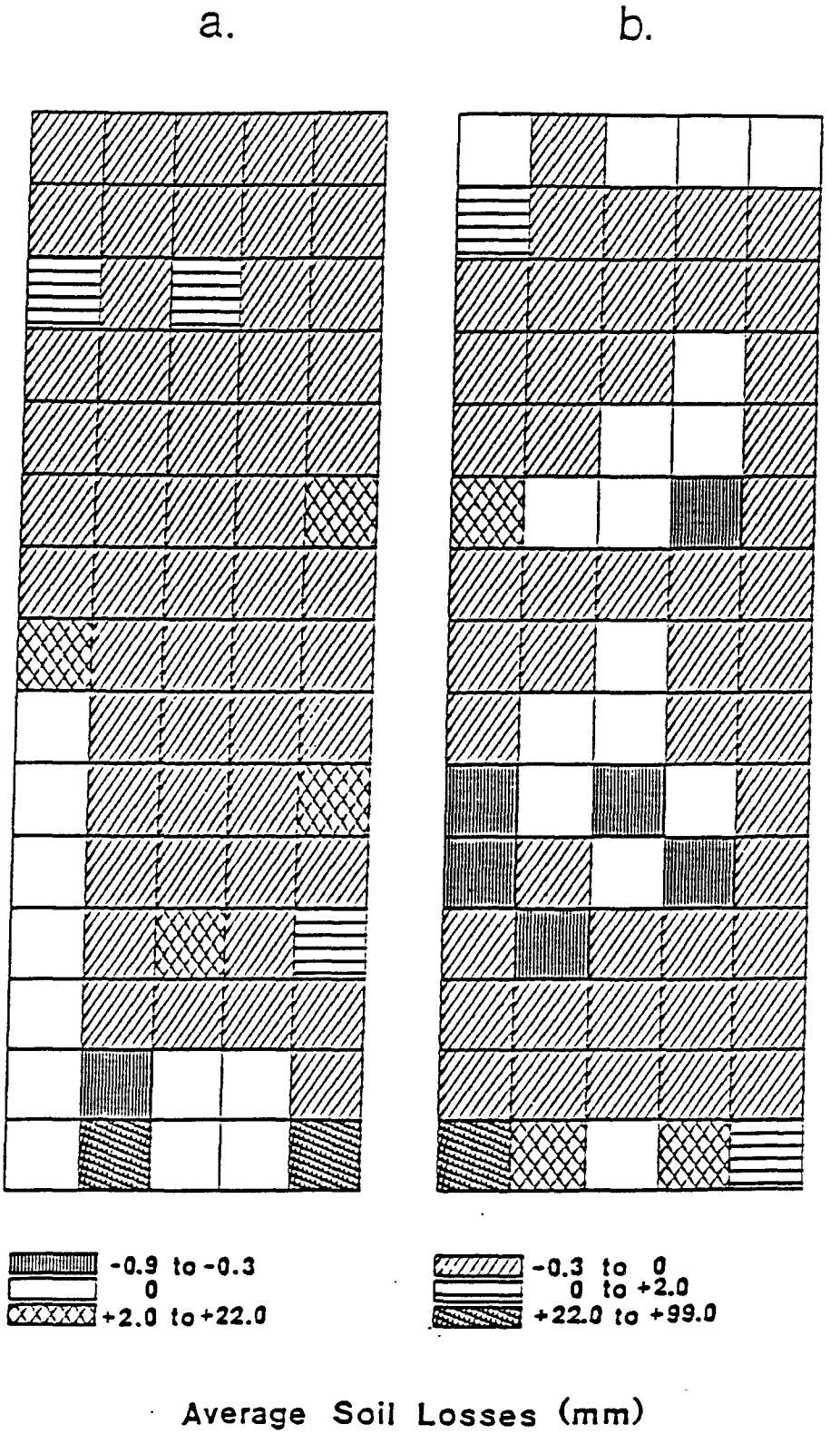

Figure 4.8. Mosaics of erosion (-) and deposition (+) calculated by EDM model adjusted for scour around pins for plot 3 (a) and plot 4 (b).

EDM model could be used to predict the local scour around the pins. The mechanism could be responsible for washoff and enhanced runoff concentration of topically applied sprays from growing vegetation. It may also point to a possible mechanism and location of erosion on vegetated areas with a high C factor.

There are several possible reasons for discrepancies between the two measurements. A major point about the model in general is there is less room for error when using the model on such small subwatersheds. Another reason for the discrepancy may be that the differences in soil compaction cause irregular soil loss patterns. The soil may have been compacted more in some areas than others, either due to the compaction done by hand in the beginning of the study, or due to natural settling. Thus, rills would be formed more easily in the areas of lesser compaction, although the computer model has no way of accounting for a variance such as this. Another irregularity that may occur that cannot be predicted by the model is the effect of raindrop splash on contributing areas. In a storm of fairly high intensity such as the one utilized in this study, the water-drop splash may cause soil to enter the rill channels from areas that are not adjacent to the rills. This situation would cause an underprediction, because the model only considers the amount of eroded soil in each rill to originate from either the rill itself, or interrill areas directly adjacent to the rills.

The cross section measurements gave some idea of where the rills develop by plotting the change in land elevation before and after the four rainfalls. Figure 4.9 shows deformation of the soil surface in plot 3 and 4 after the four simulated rainfalls. The rill (flow pathways) location predicted by the EDM model (Figure 4.10) were, then, compared to

the rills indicated by the cross section measurements taken on the plots (Figure 4.9). In general, the agreement between location of rills predicted by E/D model and observed at the site was satisfactory. However, some discrepancy existed, especially near the edge of the plots. It was observed during the experiment that some runoff did follow a path along the right edge of the plot, although the plot borders caused a channel to form directly adjacent to them that would not have formed naturally. This

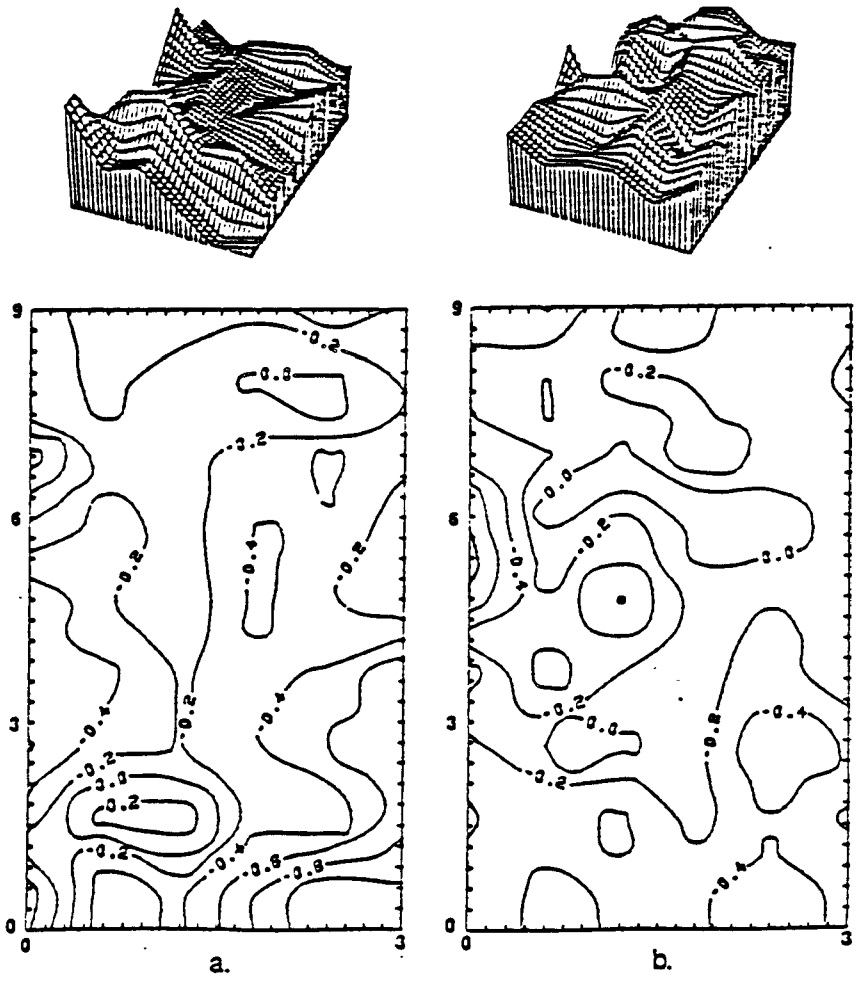

Figure 4.9. Topography (mm) of the 3 x 9 m plots after four rainfalls for plot 3 (a) and plot 4 (b).

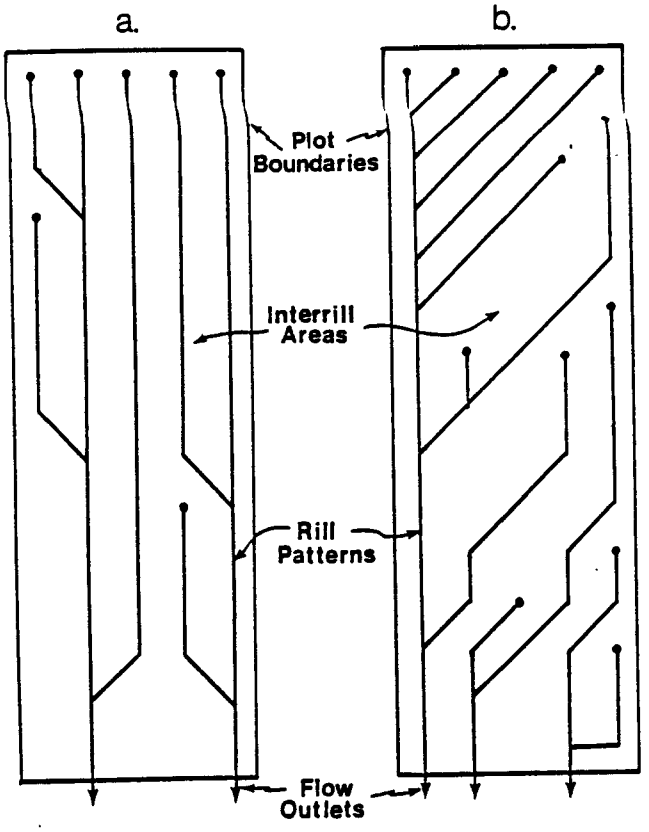

Figure 4.10. Predicted flow pathways (rills) for plot 3 (a) and plot 4 (b).

phenomena was also recognized by Hudson (1957). He stated that plot boundaries can actually activate erosion, then leave a channel which concentrates runoff and tends to scour.

4.4. ERODIBILITY EVALUATION

A major concern in correctly using the USLE is to quantify the relationship of soil erosion to erosivity of the eroding agents and to the erodibility of soil. These properties vary in space and time and they are affected by climate, soil, topography, cover, and management. For example, a soil highly susceptible to erosion by raindrops may not be susceptible to erosion by surface runoff. However, present descriptions of erosivity of raindrop impact

and surface runoff is gross and generally incomplete to use fundamental measures of soil erodibility. Most of the knowledge on soil erodibility is empirical, which makes it difficult to use in erosion prediction equation. For example, soil erodibility factor (K) used in this study was 0.32 which is an established value for the soil type by Soil Conservation Service. This value is normally assumed to be constant before and after soil disruption. To evaluate this assumption, the K value was determined by using the measured soil loss to solve the USLE.

The K value determined by runoff sampling was very low (Table 4.2). When the average L_S value S on each 0.6 x 0.6 m subarea (rather than L_S value for the plot) was used in calculations a more realistic value of K was obtained. However, when erosion pin data were used to calculate K value, a significant overprediction was observed (Table 4.2). This result indicates that the assumption of the erodibility of the disturbed soil being the same as the established value for undisturbed soil erodibility is not valid. Table 4.2 shows that K values obtained from erosion pins measurements were very large. This overprediction could be explained in part by the fact that pins presence greatly increase the runoff erosivity. Therefore, the value in Table 4.2 for erosion pins might have to be considered as a composite factor for soil erodibility and increase in runoff erosivity.

REFERENCES

1. Bridges, E. M. Eroded Soils of the Lower Swansea Valley. Soil Sci., 20(2):236-245, 1969.
2. Bubenzer, G. D. An Overview of Rainfall Simulators. Paper presented at 1980 meeting of the Am. Soc. of Agric. Engrs., San Antonio, Texas. Paper No. 80-2033, 1980.
3. Carstens, M. R. Similarity Laws for Localized Scour. Proc. Paper 4818, J. Hydraulic Division, ASCE 92(HY3):13-36, 1966.
4. Chukwuma, G. O., W. H. Edwards, and G. D. Schwab. Rainfall-Runoff Factor for Soil Loss from Small Watersheds. Paper presented at the 1979 meeting of the Am. Soc. of Agric. Engrs. and CSAE, June 24-27, University of Manitoba, Winnipeg, Canada, 1979.
5. Colbert, E. C. Rates of Erosion on the Chinle Formation. Plateau., 28(4):73-76, 1956.
6. Cunningham, R. L., E. J. Ciolkosz, R. P. Matelski, G. W. Petersen, and R. Pennock, Jr. Characteristics, Interpretations, and Uses of Pennsylvania Soils Developed from Acid Shale. Agricultural Experiment Station Report 362, 1977.
7. Ekern, P. C. Raindrop Impact as the Force Initiating Soil Erosion. Soil Sci. Soc. Am. Proc., 15:7-10, 1951.
8. Foster, G. R., and L. D. Meyer. A Closed-Form Soil Erosion Equation for Upland Areas. In: Sedimentation (Einstein), H. W. Shen (ed.), 1972. pp. 1-19.
9. Foster, G. R., and L. D. Meyer. Soil Erosion and Sedimentation by Water - An Overview. In: Proceedings National Symposium on Soil Erosion and Sedimentation by Water, Dec. 12-13, Chicago, Illinois, 1977.

10. Foster, G. R., F. Lombardi, and W. C. Moldenhauer. Evaluation of Rainfall-Runoff Erosivity Factors for Individual Storms. Trans. ASAE, 25(1):124-129, 1982.

11. Haigh, M. J. Evolution of Slopes on Artificial Landforms - Blaenavon, U.K. Research Paper No. 183, The University of Chicago, Department of Geography, Chicago, Illinois, 1978.

12. Holeman, J. N. Procedures Used in the SCS to Estimate Sediment Yield. Proceedings Sediment Yield Workshop, USDA Sedimentation Laboratory, Nov. 28-30, Oxford, Mississippi, 1972.

13. Hudson, N. W. The Design of Field Experiments on Soil Erosion. J. Agric. Eng. Res., 2(1):56-65, 1957.

14. Khanbilvardi, R. M., A. S. Rogowski, and A. C. Miller. Modeling Upland Erosion. Water Resour. Bull., 19(1):29-35, 1983.

15. Kimberlin, L. W., and W. C. Moldenhauer. Predicting Soil Erosion. Proceedings National Symposium on Soil Erosion and Sedimentation by Water, Dec. 12-13, Chicago, Illinois, 1977.

16. Laursen, E. M., and A. Toch. Bulletin No. 4. Iowa Highway Research Board, May 1956.

17. Lenz, A. T. Viscosity and Surface Tension Effects on V-Notch Weir Coefficients. In: Agriculture Handbook No. 224, Field Manual for Research in Agricultural Hydrology, Trans. ASCE, 108:759-802, 1941.

18. Levesey, R. H. Corps of Engineers Methods for Predicting Sediment Yield. Proceedings Sediment Yield Workshop, USDA Sedimentation Laboratory, Nov. 28-30, Oxford, Mississippi, 1972.

19. Meyer, L. Donald, and Donald L. McCune. Rainfall Simulator for Runoff Plots. Agr. Eng., 39(10):644-648, 1958.

20. Meyer, L. D. Use of the Rainulator for Runoff Plot Research. Soil Sci. Soc. Am. Proc., 24(4):319-322, 1960.

21. Meyer, L. D. Philosophy and Development of Simulated Rainfall for Erosion Control Research. Paper presented at the 1963 Winter Meeting of the Am. Soc. of Agric. Engrs., Dec. 10-13, Chicago, Illinois, 1963.

22. Mutchler, C. K., and L. K. Hermsmeier. Review of Rainfall Simulators. Paper presented at the 1963 Winter Meeting of the Am. Soc. of Agric. Engrs., Dec. 10-13, Chicago, Illinois, 1963.

23. Mutchler, C. K., and C. L. Larson. Splash Amounts from Waterdrop Impact on a Smooth Surface. Water Resour. Res., 7(1):195-200, 1971.

24. Onstad, C. A., C. K. Mutchler, and A. J. Bowie. Predicting Sediment Yield. Proceedings National Symposium on Soil Erosion and Sedimentation by Water, Dec. 12-13, Chicago, Illinois, 1977.

25. Pionke, H. B., and A. S. Rogowski. Implications of Water Quality on Reclaimed Lands. In: Economics, Ethics, Ecology: Roots of Productive Conservation, Walter E. Jeske (ed.), 35th Annual Meeting Soil Conservation Society of America, Aug. 3-6, Dearborn, Michigan, Soil Conservation Society of America, Ankeny, Iowa 50021, 1981. pp. 426-440.

26. Posey, C. J. Why Bridges Fail in Floods. Civil Engr., 19:42-90, 1949.

27. Sampson, R. J. Surface II Graphics System. Kansas Geological Survey, Lawrence, Kansas, 1978.

28. Sams, J. I. Erosion of Strip Mine Lands. Paper in Environmental Pollution Control, The Pennsylvania State University, University Park, Pennsylvania, 1982. 78 pp.

29. Schumm, S. A. Evolution of Drainage Systems and Slopes in Badlands of Perth Amboy, New Jersey. Geol. Soc. of Am., Bull. 67, 597-646, 1956a.

30. Schumm, S. A. The Role of Creep and Rainwash on the Retreat of Badland Slopes. Am. J. Sci., 254:693-706, 1956b.

31. Schumm, S. A. Erosion Measured by Stakes. Revue de Geomorphologie Dynamique, 17:161-162, 1967.

32. Shen, H. W. (ed.). River Mechanics. Colorado State University, Fort Collins, Colorado, 1971.

33. Smith, D. D., and A. W. Zingg. Investigation in the Erosion Control and Reclamation of Eroded Shelby and Related Soils at the Conservation Experiment Station, Bethany, MD. 1930-1942. USDA Tech. Bull. No. 833, 1945. 175 pp.

34. Williams, J. R. Sediment Routing for Agricultural Watersheds. Water Resour. Bull., 11(5):965-974, 1975.

35. Wischmeier, W. H. Use and Misuse of the Universal Soil Loss Equation. J. Soil Water Conserv., Jan./Feb., p. 5, 1976.

36. Wischmeier, W. H., and D. D. Smith. Predicting Rainfall Erosion Losses. U.S. Department of Agriculture, Science and Education Administration, Washington, D. C. Agriculture Handbook 537, 1978.

37. Young, R. A., and C. K. Mutchler. Soil Movement on Irregular Slopes. Water Resour. Res., 5(5):1084-1089, 1969.

38. Zingg, A. W. Degree and Length of Land Slope as it Affects Soil Loss in Runoff. Agr. Eng., 21(2):59-64, 1940.

APPENDIX A

RAINFALL SIMULATOR RUNOFF SAMPLING DATA

APPENDIX A: RAINFALL SIMULATOR RUNOFF SAMPLING DATA

DATA INPUT FROM RAINFALL SIMULATOR PLOT RUNOFF SAMPLES

LOC DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLGO92882	1A	3	1.45	5	650	19.5	1.00
KLGO92882	1A	3	1.45	10	700	11.4	1.00
KLGO92882	1A	3	1.45	15	660	8.7	0.95
KLGO92882	1A	3	1.45	20	750	8.6	0.90
KLGO92882	1A	3	1.45	25	750	7.5	0.90
KLGO92882	1A	3	1.45	30	680	6.8	0.95
KLGO92882	1A	3	1.45	35	520	5.0	1.10
KLGO92882	1A	3	1.45	40	830	6.8	1.10

LOC DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLGO92882	1A	4	1.45	5	550	14.9	0.70
KLGO92882	1A	4	1.45	10	610	8.4	0.80
KLGO92882	1A	4	1.45	15	655	7.7	0.90
KLGO92882	1A	4	1.45	20	650	5.3	0.90
KLGO92882	1A	4	1.45	25	635	5.9	0.95
KLGO92882	1A	4	1.45	30	620	5.7	0.90
KLGO92882	1A	4	1.45	35	675	5.8	0.90
KLGO92882	1A	4	1.45	40	700	5.5	0.90

LOC DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLGO92882	1B	3	1.45	5	630	5.6	1.10
KLGO92882	1B	3	1.45	10	810	5.9	1.10
KLGO92882	1B	3	1.45	15	810	6.7	1.10
KLGO92882	1B	3	1.45	20	775	6.9	1.10
KLGO92882	1B	3	1.45	25	770	5.5	1.10
KLGO92882	1B	3	1.45	30	740	6.2	1.10
KLGO92882	1B	3	1.45	35	750	5.5	1.10
KLGO92882	1B	3	1.45	40	775	6.6	1.10

LOC DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG092882	1B	4	1.45	5	625	2.6	0.30
KLG092882	1B	4	1.45	10	625	2.4	0.35
KLG092882	1B	4	1.45	15	710	2.7	0.35
KLG092882	1B	4	1.45	20	660	2.4	0.30
KLG092882	1B	4	1.45	25	650	2.3	0.30
KLG092882	1B	4	1.45	30	585	1.9	0.35
KLG092882	1B	4	1.45	35	780	2.5	1.00
KLG092882	1B	4	1.45	40	710	2.2	1.00

LOC DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG100582	2A	3	1.45	5	800	8.6	1.15
KLG100582	2A	3	1.45	10	780	8.4	1.20
KLG100582	2A	3	1.45	15	810	7.4	1.20
KLG100582	2A	3	1.45	20	740	7.0	1.20
KLG100582	2A	3	1.45	25	790	7.4	1.20
KLG100582	2A	3	1.45	30	810	7.4	1.20
KLG100582	2A	3	1.45	35	770	7.1	1.20
KLG100582	2A	3	1.45	40	800	7.3	1.20

LOC DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG100582	2A	4	1.45	5	760	7.3	0.95
KLG100582	2A	4	1.45	10	790	6.3	0.95
KLG100582	2A	4	1.45	15	790	10.5	0.95
KLG100582	2A	4	1.45	20	790	5.5	0.95
KLG100582	2A	4	1.45	25	750	5.0	0.95
KLG100582	2A	4	1.45	30	780	5.0	0.95
KLG100582	2A	4	1.45	35	770	4.4	0.95
KLG100582	2A	4	1.45	40	780	4.6	0.95

LOC DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG100582	2B	3	1.45	5	800	8.0	1.25
KLG100582	2B	3	1.45	10	830	7.1	1.25
KLG100582	2B	3	1.45	15	790	10.1	1.25
KLG100582	2B	3	1.45	20	770	7.4	1.25
KLG100582	2B	3	1.45	25	800	6.4	1.25
KLG100582	2B	3	1.45	30	750	5.6	1.20
KLG100582	2B	3	1.45	35	750	6.5	1.20
KLG100582	2B	3	1.45	40	770	6.3	1.20

LOC	DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG	100582	2B	4	1.45	5	780	4.5	1.05
KLG	100582	2B	4	1.45	10	780	4.0	1.10
KLG	100582	2B	4	1.45	15	780	3.9	1.20
KLG	100582	2B	4	1.45	20	710	3.4	1.20
KLG	100582	2B	4	1.45	25	715	3.5	1.25
KLG	100582	2B	4	1.45	30	750	3.6	1.30
KLG	100582	2B	4	1.45	35	740	3.3	1.30
KLG	100582	2B	4	1.45	40	770	6.3	1.20

LOC	DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG	101982	3A	3	1.45	5	810	4.2	1.15
KLG	101982	3A	3	1.45	10	800	3.7	1.15
KLG	101982	3A	3	1.45	15	790	3.3	1.20
KLG	101982	3A	3	1.45	20	760	3.3	1.20
KLG	101982	3A	3	1.45	25	800	3.7	1.20
KLG	101982	3A	3	1.45	30	750	3.7	1.20
KLG	101982	3A	3	1.45	35	780	4.4	1.20
KLG	101982	3A	3	1.45	40	800	4.7	1.20

LOC	DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG	101982	3A	4	1.45	5	790	3.6	0.95
KLG	101982	3A	4	1.45	10	740	3.4	0.95
KLG	101982	3A	4	1.45	15	800	3.3	0.95
KLG	101982	3A	4	1.45	20	820	3.1	0.95
KLG	101982	3A	4	1.45	25	780	2.9	0.95
KLG	101982	3A	4	1.45	30	780	3.1	0.95
KLG	101982	3A	4	1.45	35	780	3.1	0.95
KLG	101982	3A	4	1.45	40	760	3.1	0.95

LOC	DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG	101982	3B	3	1.45	5	800	4.1	1.20
KLG	101982	3B	3	1.45	10	830	4.2	1.20
KLG	101982	3B	3	1.45	15	800	4.3	1.20
KLG	101982	3B	3	1.45	20	800	3.8	1.20
KLG	101982	3B	3	1.45	25	640	3.1	1.20
KLG	101982	3B	3	1.45	30	770	3.8	1.20
KLG	101982	3B	3	1.45	35	820	4.8	1.20
KLG	101982	3B	3	1.45	40	790	4.6	1.15

LOC DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG101982	3B	4	1.45	5	760	3.3	1.00
KLG101982	3B	4	1.45	10	800	3.4	1.00
KLG101982	3B	4	1.45	15	700	3.0	1.00
KLG101982	3B	4	1.45	20	710	3.2	1.00
KLG101982	3B	4	1.45	25	710	3.4	1.00
KLG101982	3B	4	1.45	30	760	3.7	1.00
KLG101982	3B	4	1.45	35	740	3.8	1.00
KLG101982	3B	4	1.45	40	780	4.1	1.00

LOC DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG102682	4A	3	1.44	5	800	3.5	1.15
KLG102682	4A	3	1.44	10	860	3.3	1.15
KLG102682	4A	3	1.44	15	850	3.7	1.20
KLG102682	4A	3	1.44	20	770	4.4	1.20
KLG102682	4A	3	1.44	25	810	3.2	1.15
KLG102682	4A	3	1.44	30	810	3.6	1.15
KLG102682	4A	3	1.44	35	800	3.1	1.15
KLG102682	4A	3	1.44	40	830	4.1	1.20

LOC DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG102682	4A	4	1.42	5	830	2.6	1.00
KLG102682	4A	4	1.42	10	770	2.3	1.00
KLG102682	4A	4	1.42	15	830	2.5	1.05
KLG102682	4A	4	1.42	20	740	2.2	1.05
KLG102682	4A	4	1.42	25	720	2.2	1.05
KLG102682	4A	4	1.42	30	790	2.6	1.05
KLG102682	4A	4	1.42	35	790	2.4	1.05
KLG102682	4A	4	1.42	40	800	2.6	1.05

LOC DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG102682	4B	3	1.44	5	840	4.5	1.20
KLG102682	4B	3	1.44	10	830	4.1	1.20
KLG102682	4B	3	1.44	15	840	4.4	1.20
KLG102682	4B	3	1.44	20	800	4.2	1.20
KLG102682	4B	3	1.44	25	800	3.4	1.20
KLG102682	4B	3	1.44	30	760	3.3	1.20
KLG102682	4B	3	1.44	35	810	4.1	1.20
KLG102682	4B	3	1.44	40	820	4.5	1.20

LOC	DATE	RUN	PLOT	BULK DEN	TIME (MIN)	VOL (ML)	SOIL (G)	CHART READING (IN)
KLG	102682	48	4	1.42	5	820	2.7	1.05
KLG	102682	48	4	1.42	10	730	2.4	1.05
KLG	102682	48	4	1.42	15	800	2.4	1.10
KLG	102682	48	4	1.42	20	780	2.3	1.10
KLG	102682	48	4	1.42	25	810	2.6	1.10
KLG	102682	48	4	1.42	30	800	2.5	1.10
KLG	102682	48	4	1.42	35	780	2.7	1.20
KLG	102682	48	4	1.42	40	790	2.6	1.20

APPENDIX B

CALCULATIONS AND CALIBRATIONS TO DETERMINE RUNOFF

TABLE B1: Calculations and calibrations for determining flow

1) Conversion between chart height and notch height

Chart ht. (in.)	Notch ht. (in.)	Conversion factor ($m\ H_2O$/in. chart)
	Run #1	
1.55	2.00	0.0328
1.80	2.50	0.0353
1.85	2.60	0.0357
1.90	2.70	0.0361
	Run #2	
1.95	2.60	0.0339

Average conversion factor (from chart to notch) = 6.84

2) Sample calculation for conversion between notch reading and head (m) for Lenz's equation -

$$\frac{\text{Notch}}{\text{Chart}} = \frac{2.00\ \text{in}}{1.55\ \text{in}} = 1.29 \times 2.54\ \frac{\text{cm}}{\text{in}} \times \frac{1\ \text{m}}{100\ \text{cm}} = 0.0328\ \text{m}\ H_2O/\text{in. chart}$$

Averaged with measurements taken previous to study;
Conversion = 0.0374

Head (m) = (Chart meas. in inches)(0.0374)

TABLE B2: Calibration of weir to determine runoff

Sample comparison between predicted and measured runoff (cm^3/sec)

Date: 9-28-82 Run #1 Plot #3

Chart Reading (in)	Chart Reading (ft)	Notch Height (in)	Predicted Runoff (cm^3/sec)	Measured Runoff (cm^3/sec)
1"=0.20 ft			Lenz's Eqn.	see graph Fig. 4
1.00	0.20	1.38	84.5	155
1.00	0.20	1.38	84.5	155
0.95	0.19	1.30	74.7	130
0.90	0.18	1.23	65.5	110
0.90	0.18	1.23	65.5	110
0.95	0.19	1.30	74.7	130
1.10	0.22	1.50	106.4	205
1.10	0.22	1.50	106.4	205

Average difference between predicted and measured runoff for all measurements = 1.79 or 1.8

APPENDIX C

ELEVATION ESTIMATES FOR PLOTS 3 AND 4 (FT)

Plot 3 Column no.

Row	1	2	3	4	5
1	95.25	95.26	95.32	95.39	95.38
2	95.08	95.10	95.12	95.12	95.10
3	94.98	94.95	94.91	94.91	94.88
4	94.88	94.83	94.82	94.80	94.76
5	94.69	94.67	94.66	94.63	94.59
6	94.51	94.52	94.52	94.48	94.43
7	94.34	94.36	94.33	94.34	94.34
8	94.17	94.18	94.16	94.13	94.14
9	94.10	94.06	94.02	94.00	93.95
10	93.95	93.94	93.91	93.90	93.80
11	93.81	93.79	93.78	93.77	93.76
12	93.64	93.62	93.63	93.63	93.62
13	93.47	93.49	93.53	93.52	93.54
14	93.19	93.24	93.35	93.40	93.25
15	92.26	93.03	93.00	93.00	92.98

Plot 4

1	95.54	95.61	95.68	95.75	95.81
2	95.45	95.54	95.62	95.70	95.78
3	95.37	95.45	95.53	95.58	95.63
4	95.24	95.33	95.41	95.46	95.49
5	95.07	95.20	95.29	95.33	95.35
6	94.91	95.02	95.10	95.15	95.23
7	94.84	94.89	94.96	95.02	95.06
8	94.71	94.75	94.82	94.87	94.91
9	94.51	94.60	94.68	94.73	94.78
10	94.29	94.42	94.51	94.59	94.64
11	94.18	94.25	94.34	94.42	94.50
12	94.01	94.06	94.14	94.21	94.25
13	93.84	93.91	94.00	94.07	94.13
14	93.54	93.55	93.82	93.89	93.94
15	93.33	93.36	93.57	93.65	93.72

APPENDIX D

RUNOFF ANALYSIS

TABLE D1 : RUNOFF ANALYSIS - SEDIMENT MEASURED BY RUNOFF SAMPLING

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROS MM
KLG	92882	1A	3	5	152.15	30000.	0.0400
KLG	92882	1A	3	10	152.15	16286.	0.0216
KLG	92882	1A	3	15	134.44	13182.	0.0155
KLG	92882	1A	3	20	117.99	11467.	0.0119
KLG	92882	1A	3	25	117.99	10000.	0.0103
KLG	92882	1A	3	30	134.44	10000.	0.0117
KLG	92882	1A	3	35	191.57	8621.	0.0144
KLG	92882	1A	3	40	191.57	8193.	0.0137
							CUMA 0.1391

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROS MM
KLG	92882	1B	3	5	191.57	8116.	0.0137
KLG	92882	1B	3	10	191.57	7284.	0.0122
KLG	92882	1B	3	15	191.57	8272.	0.0139
KLG	92882	1B	3	20	191.57	8903.	0.0149
KLG	92882	1B	3	25	191.57	7143.	0.0121
KLG	92882	1B	3	30	191.57	8378.	0.0140
KLG	92882	1B	3	35	191.57	7333.	0.0124
KLG	92882	1B	3	40	191.57	8516.	0.0144
							CUMA 0.1076

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROS MM
KLG	100582	2A	3	5	213.32	10750.	0.0200
KLG	100582	2A	3	10	236.48	11410.	0.0236
KLG	100582	2A	3	15	236.48	19012.	0.0392
KLG	100582	2A	3	20	236.48	9459.	0.0196
KLG	100582	2A	3	25	236.48	9367.	0.0194
KLG	100582	2A	3	30	236.48	9136.	0.0189
KLG	100582	2A	3	35	236.48	9221.	0.0191
KLG	100582	2A	3	40	236.48	9125.	0.0189
							CUMA 0.1787

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	100582	2B	3	5	261.06	7500.	0.0169
KLG	100582	2B	3	10	261.06	8554.	0.0193
KLG	100582	2B	3	15	261.06	12785.	0.0288
KLG	100582	2B	3	20	261.06	9610.	0.0216
KLG	100582	2B	3	25	261.06	8000.	0.0180
KLG	100582	2B	3	30	236.48	7467.	0.0152
KLG	100582	2B	3	35	236.48	8667.	0.0177
KLG	100582	2B	3	40	236.48	8182.	0.0167
							CUMA
							0.1541

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	101982	3A	3	5	213.33	5185.	0.0095
KLG	101982	3A	3	10	213.33	4625.	0.0085
KLG	101982	3A	3	15	236.48	4177.	0.0085
KLG	101982	3A	3	20	236.48	4342.	0.0089
KLG	101982	3A	3	25	236.48	4625.	0.0094
KLG	101982	3A	3	30	236.48	4933.	0.0101
KLG	101982	3A	3	35	236.48	5641.	0.0115
KLG	101982	3A	3	40	236.48	5875.	0.0120
							CUMA
							0.0784

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	101982	3B	3	5	236.48	5125.	0.0104
KLG	101982	3B	3	10	236.48	5060.	0.0103
KLG	101982	3B	3	15	236.48	5375.	0.0110
KLG	101982	3B	3	20	236.48	4750.	0.0097
KLG	101982	3B	3	25	236.48	4844.	0.0099
KLG	101982	3B	3	30	236.48	4935.	0.0101
KLG	101982	3B	3	35	236.48	5854.	0.0119
KLG	101982	3B	3	40	213.33	5897.	0.0108
							CUMA
							0.0841

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	102682	4A	3	5	213.33	4375.	0.0081
KLG	102682	4A	3	10	213.33	3837.	0.0071
KLG	102682	4A	3	15	236.48	4353.	0.0089
KLG	102682	4A	3	20	236.48	5714.	0.0117
KLG	102682	4A	3	25	213.33	3951.	0.0073
KLG	102682	4A	3	30	213.33	4444.	0.0082
KLG	102682	4A	3	35	213.33	3875.	0.0072
KLG	102682	4A	3	40	236.48	4940.	0.0101
							CUMA
							0.0687

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	102682	4B	3	5	236.48	5357.	0.0110
KLG	102682	4B	3	10	236.48	4940.	0.0101
KLG	102682	4B	3	15	236.48	5238.	0.0108
KLG	102682	4B	3	20	236.48	5250.	0.0108
KLG	102682	4B	3	25	236.48	4250.	0.0087
KLG	102682	4B	3	30	236.48	4342.	0.0089
KLG	102682	4B	3	35	236.48	5062.	0.0104
KLG	102682	4B	3	40	236.48	5488.	0.0113
							CUMA
							0.0820

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	92882	1A	4	5	64.46	27091.	0.0151
KLG	92882	1A	4	10	88.85	13770.	0.0105
KLG	92882	1A	4	15	118.00	11756.	0.0120
KLG	92882	1A	4	20	118.00	8154.	0.0083
KLG	92882	1A	4	25	102.81	8613.	0.0076
KLG	92882	1A	4	30	118.00	9194.	0.0094
KLG	92882	1A	4	35	118.00	5630.	0.0057
KLG	92882	1A	4	40	118.00	5000.	0.0051
							CUMA
							0.0737

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	92882	1B	4	5	88.85	4160.	0.0032
KLG	92882	1B	4	10	102.81	3840.	0.0034
KLG	92882	1B	4	15	102.81	3803.	0.0034
KLG	92882	1B	4	20	118.00	3636.	0.0037
KLG	92882	1B	4	25	118.00	3538.	0.0036
KLG	92882	1B	4	30	134.44	3248.	0.0038
KLG	92882	1B	4	35	152.16	3205.	0.0042
KLG	92882	1B	4	40	152.16	3099.	0.0041
							CUMA
							0.0293

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	100582	2A	4	5	134.44	9605.	0.0111
KLG	100582	2A	4	10	134.44	7975.	0.0092
KLG	100582	2A	4	15	134.44	13291.	0.0154
KLG	100582	2A	4	20	134.44	6962.	0.0081
KLG	100582	2A	4	25	134.44	6667.	0.0077
KLG	100582	2A	4	30	134.44	6410.	0.0074
KLG	100582	2A	4	35	134.44	5714.	0.0066
KLG	100582	2A	4	40	134.44	5897.	0.0068
							CUMA
							0.0725

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	100582	2B	4	5	171.19	5769.	0.0085
KLG	100582	2B	4	10	191.57	5128.	0.0085
KLG	100582	2B	4	15	236.48	5000.	0.0102
KLG	100582	2B	4	20	236.48	4789.	0.0098
KLG	100582	2B	4	25	261.06	4895.	0.0110
KLG	100582	2B	4	30	287.10	4800.	0.0119
KLG	100582	2B	4	35	287.10	4459.	0.0110
KLG	100582	2B	4	40	236.48	8182.	0.0167
							CUMA
							0.0670

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	101982	3A	4	5	134.44	4810.	0.0056
KLG	101982	3A	4	10	134.44	4595.	0.0053
KLG	101982	3A	4	15	134.44	4125.	0.0048
KLG	101982	3A	4	20	134.44	3780.	0.0044
KLG	101982	3A	4	25	134.44	3718.	0.0043
KLG	101982	3A	4	30	134.44	3974.	0.0046
KLG	101982	3A	4	35	134.44	3974.	0.0046
KLG	101982	3A	4	40	134.44	4079.	0.0047
							CUMA
							0.0383

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	101982	3B	4	5	152.16	4342.	0.0057
KLG	101982	3B	4	10	152.16	4250.	0.0056
KLG	101982	3B	4	15	152.16	4286.	0.0056
KLG	101982	3B	4	20	152.16	4507.	0.0059
KLG	101982	3B	4	25	152.16	4789.	0.0063
KLG	101982	3B	4	30	152.16	4868.	0.0064
KLG	101982	3B	4	35	152.16	5135.	0.0067
KLG	101982	3B	4	40	152.16	5256.	0.0069
							CUMA
							0.0491

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	102682	4A	4	5	152.16	3133.	0.0042
KLG	102682	4A	4	10	152.16	2987.	0.0040
KLG	102682	4A	4	15	171.19	3012.	0.0045
KLG	102682	4A	4	20	171.19	2973.	0.0045
KLG	102682	4A	4	25	171.19	3056.	0.0046
KLG	102682	4A	4	30	171.19	3291.	0.0050
KLG	102682	4A	4	35	171.19	3038.	0.0046
KLG	102682	4A	4	40	171.19	3250.	0.0049
							CUMA
							0.0363

LOCATION	DATE	RUN	PLOT	TIME MIN	RUNOFF CM**3/SEC	CONC MG/L	EROSA MM
KLG	102682	4B	4	5	171.19	3293.	0.0050
KLG	102682	4B	4	10	171.19	3077.	0.0046
KLG	102682	4B	4	15	191.57	3000.	0.0051
KLG	102682	4B	4	20	191.57	2949.	0.0050
KLG	102682	4B	4	25	191.57	3210.	0.0054
KLG	102682	4B	4	30	191.57	3125.	0.0053
KLG	102682	4B	4	35	236.48	3462.	0.0072
KLG	102682	4B	4	40	236.48	3291.	0.0069
							CUMA
							0.0444

APPENDIX E

EROSION PIN MEASUREMENTS

TABLE E1 : INITIAL EROSION PIN MEASUREMENTS AND EROSION/DEPOSITION MEASURED IN RUNS 1 - 4

EROSION PIN DATA FROM RAINFALL SIMULATOR - INITIAL MEASUREMENTS

LOC	DATE	RUN	PIN ID	MEAS (MM)	PIN ID	MEAS (MM)	PIN ID	MEAS (MM)	PIN ID	MEAS (MM)	PIN ID	MEAS (MM)	PIN ID	MEAS (MM)
PLOT 1														
KLG	092182	0	301	112.29	301	216.19	3013	9.16	301	417.20	302	119.52	302	223.54
KLG	092182	0	302	316.00	302	415.70	3031	9.58	303	216.28	303	314.09	303	418.56
KLG	092182	0	304	118.60	304	219.18	304	311.02	304	414.07	305	111.60	305	220.30
KLG	092182	0	305	316.14	305	425.08	306	121.42	306	218.20	306	318.87	306	420.74
KLG	092182	0	307	121.04	307	221.80	307	317.01	307	414.28	308	112.68	308	212.84
KLG	092182	0	308	319.68	308	422.38	309	119.59	309	218.44	309	317.66	309	414.68
KLG	092182	0	310	117.49	310	217.74	310	317.52	310	422.17				
PLOT 2														
KLG	092182	0	401	116.94	4012	9.26	401	317.12	401	418.95	402	114.19	402	210.54
KLG	092182	0	4023	9.66	402	413.92	403	118.95	403	212.09	4033	9.86	4034	9.92
KLG	092182	0	404	116.04	4042	8.26	4043	7.93	404	411.60	405	114.95	405	211.72
KLG	092182	0	4053	9.96	405	414.41	4061	9.55	406	210.65	4063	8.16	406	414.49
KLG	092182	0	4071	8.91	4072	9.83	4073	9.22	4074	6.82	408	110.30	408	211.80
KLG	092182	0	4083	8.44	4084	6.52	4091	9.52	4092	8.72	409	310.28	4094	5.50
KLG	092182	0	410	117.04	410	216.88	410	323.34	410	410.22				

KEY: PIN ID 3011

PLOT RPDIWN NO

TABLE E2: EROSION/DEPOSITION MEASURED BY EROSION PINS (MM)

LOCATION	DATE	RUN*N	PIN PLOT	ROW	PIN	READING(MM)	EROS/DEP(MM)
KLG	92882	1	3	1	1	10.22	2.07
KLG	92882	1	3	1	2	16.20	-0.01
KLG	92882	1	3	1	3	10.40	-1.24
KLG	92882	1	3	1	4	28.48	-11.28
KLG	92882	1	3	2	1	39.82	-20.30
KLG	92882	1	3	2	2	29.34	-5.80
KLG	92882	1	3	2	3	18.19	-2.19
KLG	92882	1	3	2	4	24.88	-9.18
KLG	92882	1	3	3	1	20.00	-10.42
KLG	92882	1	3	3	2	17.20	-0.92
KLG	92882	1	3	3	3	17.90	-3.81
KLG	92882	1	3	3	4	28.14	-9.58
KLG	92882	1	3	4	1	22.16	-3.56
KLG	92882	1	3	4	2	16.08	3.10
KLG	92882	1	3	4	3	11.60	-0.58
KLG	92882	1	3	4	4	19.32	-5.25
KLG	92882	1	3	5	1	9.72	1.88
KLG	92882	1	3	5	2	23.58	-3.28
KLG	92882	1	3	5	3	14.06	2.08
KLG	92882	1	3	5	4	22.50	2.58
KLG	92882	1	3	6	1	22.52	-1.10
KLG	92882	1	3	6	2	14.53	3.67
KLG	92882	1	3	6	3	20.44	-1.57
KLG	92882	1	3	6	4	23.98	-3.24
KLG	92882	1	3	7	1	32.48	-11.44
KLG	92882	1	3	7	2	22.05	-0.25
KLG	92882	1	3	7	3	26.04	-9.03
KLG	92882	1	3	7	4	17.84	-3.56
KLG	92882	1	3	8	1	15.25	-2.57
KLG	92882	1	3	8	2	17.52	-4.68
KLG	92882	1	3	8	3	22.80	-3.12
KLG	92882	1	3	8	4	30.84	-8.46
KLG	92882	1	3	9	1	21.36	-1.77
KLG	92882	1	3	9	2	17.26	1.18
KLG	92882	1	3	9	3	21.70	-4.04
KLG	92882	1	3	9	4	14.88	-0.20
KLG	92882	1	3	10	1	22.98	-5.49
KLG	92882	1	3	10	2	20.11	-2.37
KLG	92882	1	3	10	3	16.57	0.95
KLG	92882	1	3	10	4	22.34	-0.17
						AVE =	-3.32
KLG	92882	1	4	1	1	16.49	0.45
KLG	92882	1	4	1	2	16.62	-7.36
KLG	92882	1	4	1	3	17.68	-0.56

LOCATION	DATE	RUN#N	PIN	READING(MM)	ERCS-DEF(MM)
KLG	92882	1	4 1 4	16.17	2.78
KLG	92882	1	4 2 1	19.91	-5.72
KLG	92882	1	4 2 2	11.74	-1.20
KLG	92882	1	4 2 3	9.43	0.23
KLG	92882	1	4 2 4	15.93	-2.01
KLG	92882	1	4 3 1	19.46	-0.51
KLG	92882	1	4 3 2	14.85	-2.76
KLG	92882	1	4 3 3	18.91	-9.05
KLG	92882	1	4 3 4	12.58	-2.66
KLG	92882	1	4 4 1	19.31	-3.27
KLG	92882	1	4 4 2	10.02	-1.76
KLG	92882	1	4 4 3	9.68	-1.75
KLG	92882	1	4 4 4	14.54	-2.94
KLG	92882	1	4 5 1	16.50	-1.55
KLG	92882	1	4 5 2	14.61	-2.89
KLG	92882	1	4 5 3	11.42	-1.46
KLG	92882	1	4 5 4	18.20	-3.79
KLG	92882	1	4 6 1	9.96	-0.41
KLG	92882	1	4 6 2	10.50	0.15
KLG	92882	1	4 6 3	9.84	-1.68
KLG	92882	1	4 6 4	15.70	-1.21
KLG	92882	1	4 7 1	10.44	-1.53
KLG	92882	1	4 7 2	11.36	-1.53
KLG	92882	1	4 7 3	4.50	4.72
KLG	92882	1	4 7 4	9.50	-2.68
KLG	92882	1	4 8 1	13.35	-3.05
KLG	92882	1	4 8 2	12.02	-0.22
KLG	92882	1	4 8 3	10.17	-1.73
KLG	92882	1	4 8 4	7.82	-1.30
KLG	92882	1	4 9 1	13.13	-3.61
KLG	92882	1	4 9 2	13.50	-4.78
KLG	92882	1	4 9 3	11.93	-1.65
KLG	92882	1	4 9 4	8.74	-3.24
KLG	92882	1	410 1	17.29	-0.25
KLG	92882	1	410 2	15.20	1.68
KLG	92882	1	410 3	25.56	-2.22
KLG	92882	1	410 4	13.27	-3.05
				AVE =	-1.88
KLG	100582	2	3 1 1	5.50	4.72
KLG	100582	2	3 1 2	14.94	1.26
KLG	100582	2	3 1 3	11.78	-1.38
KLG	100582	2	3 1 4	29.67	-1.19
KLG	100582	2	3 2 1	50.05	-10.23
KLG	100582	2	3 2 2	28.48	0.86
KLG	100582	2	3 2 3	20.36	-2.17
KLG	100582	2	3 2 4	27.14	-2.26
KLG	100582	2	3 3 1	25.31	-5.31

LOCATION	DATE	RUN*N	PIN	READING(MM)	EROS/DEP(MM)
KLG	100582	2	3 3 2	16.78	0.42
KLG	100582	2	3 3 3	16.02	1.22
KLG	100582	2	3 3 4	26.18	1.96
KLG	100582	2	3 4 1	22.90	-0.74
KLG	100582	2	3 4 2	12.91	3.17
KLG	100582	2	3 4 3	12.02	-0.42
KLG	100582	2	3 4 4	20.32	-1.00
KLG	100582	2	3 5 1	16.44	-6.72
KLG	100582	2	3 5 2	18.00	5.58
KLG	100582	2	3 5 3	10.50	3.56
KLG	100582	2	3 5 4	22.36	0.14
KLG	100582	2	3 6 1	20.31	2.21
KLG	100582	2	3 6 2	11.28	3.25
KLG	100582	2	3 6 3	26.78	-6.34
KLG	100582	2	3 6 4	24.04	-0.06
KLG	100582	2	3 7 1	36.04	-3.56
KLG	100582	2	3 7 2	26.20	-4.15
KLG	100582	2	3 7 3	25.64	0.40
KLG	100582	2	3 7 4	17.18	0.66
KLG	100582	2	3 8 1	16.10	-0.25
KLG	100582	2	3 8 2	17.23	0.29
KLG	100582	2	3 8 3	20.84	1.96
KLG	100582	2	3 8 4	31.29	-0.45
KLG	100582	2	3 9 1	20.86	0.50
KLG	100582	2	3 9 2	11.67	5.59
KLG	100582	2	3 9 3	20.60	1.10
KLG	100582	2	3 9 4	14.80	0.08
KLG	100582	2	310 1	25.64	-2.66
KLG	100582	2	310 2	21.60	-1.49
KLG	100582	2	310 3	16.10	0.47
KLG	100582	2	310 4	49.34	-27.00
				AVE =	-0.95
KLG	100582	2	4 1 1	13.86	2.63
KLG	100582	2	4 1 2	16.30	0.32
KLG	100582	2	4 1 3	28.14	-10.46
KLG	100582	2	4 1 4	18.08	-1.91
KLG	100582	2	4 2 1	24.86	-4.95
KLG	100582	2	4 2 2	12.93	-1.19
KLG	100582	2	4 2 3	11.25	-1.82
KLG	100582	2	4 2 4	19.93	-4.00
KLG	100582	2	4 3 1	20.78	-1.32
KLG	100582	2	4 3 2	11.79	3.06
KLG	100582	2	4 3 3	22.86	-3.95
KLG	100582	2	4 3 4	16.00	-3.42
KLG	100582	2	4 4 1	21.38	-2.07
KLG	100582	2	4 4 2	10.27	-0.25
KLG	100582	2	4 4 3	9.54	0.14
KLG	100582	2	4 4 4	15.60	-1.06
KLG	100582	2	4 5 1	19.35	-2.83

LOCATION	DATE	RUN#N	PIN	READING(MM)	EROS/DEP(MM)
KLG	100582	2	4 5 2	12.42	-3.81
KLG	100582	2	4 5 3	10.82	0.60
KLG	100582	2	4 5 4	19.90	-1.70
KLG	100582	2	4 6 1	9.88	0.08
KLG	100582	2	4 6 2	16.10	-5.60
KLG	100582	2	4 6 3	7.71	2.13
KLG	100582	2	4 6 4	22.86	-7.16
KLG	100582	2	4 7 1	10.45	-0.01
KLG	100582	2	4 7 2	12.96	-1.60
KLG	100582	2	4 7 3	5.90	-1.40
KLG	100582	2	4 7 4	12.34	-2.84
KLG	100582	2	4 8 1	15.70	-2.35
KLG	100582	2	4 8 2	12.37	-0.35
KLG	100582	2	4 8 3	11.08	-0.91
KLG	100582	2	4 8 4	5.60	2.22
KLG	100582	2	4 9 1	20.22	-7.09
KLG	100582	2	4 9 2	16.14	-2.64
KLG	100582	2	4 9 3	11.69	0.24
KLG	100582	2	4 9 4	12.28	-3.54
KLG	100582	2	410 1	18.02	-0.73
KLG	100582	2	410 2	14.16	1.04
KLG	100582	2	410 3	26.15	-0.59
KLG	100582	2	410 4	12.67	0.60
				AVE =	-1.71
KLG	101982	3	3 1 1	4.26	1.24
KLG	101982	3	3 1 2	18.94	-4.00
KLG	101982	3	3 1 3	11.20	0.58
KLG	101982	3	3 1 4	29.68	-0.01
KLG	101982	3	3 2 1	53.26	-3.21
KLG	101982	3	3 2 2	30.87	-2.39
KLG	101982	3	3 2 3	27.28	-6.92
KLG	101982	3	3 2 4	27.72	-0.58
KLG	101982	3	3 3 1	30.98	-5.67
KLG	101982	3	3 3 2	22.53	-5.80
KLG	101982	3	3 3 3	22.34	-6.32
KLG	101982	3	3 3 4	36.00	-9.82
KLG	101982	3	3 4 1	27.02	-4.12
KLG	101982	3	3 4 2	16.22	-3.31
KLG	101982	3	3 4 3	19.73	-7.76
KLG	101982	3	3 4 4	25.78	-5.46
KLG	101982	3	3 5 1	20.52	-4.08
KLG	101982	3	3 5 1	20.52	-4.08
KLG	101982	3	3 5 2	17.00	1.00
KLG	101982	3	3 5 3	12.59	-2.09
KLG	101982	3	3 5 4	22.06	0.30
KLG	101982	3	3 6 1	24.21	-3.90
KLG	101982	3	3 6 2	17.48	-6.20
KLG	101982	3	3 6 3	27.43	-0.65
KLG	101982	3	3 6 4	27.36	-3.32
KLG	101982	3	3 7 1	41.22	-5.18
KLG	101982	3	3 7 2	29.27	-3.07

LOCATION	DATE	RUN#N	PIN	READING (MM)	EROS/DEP (MM)
KLG	101982	3	3 7 3	32.04	-6.40
KLG	101982	3	3 7 4	23.60	-6.42
KLG	101982	3	3 8 1	19.10	-3.00
KLG	101982	3	3 8 2	18.96	-1.73
KLG	101982	3	3 8 3	22.55	-1.71
KLG	101982	3	3 8 4	42.35	-11.06
KLG	101982	3	3 9 1	24.70	-3.84
KLG	101982	3	3 9 2	18.32	-5.65
KLG	101982	3	3 9 3	21.56	-0.96
KLG	101982	3	3 9 4	15.61	-0.81
KLG	101982	3	310 1	26.84	-1.20
KLG	101982	3	310 2	21.36	0.24
KLG	101982	3	310 3	17.06	-0.96
KLG	101982	3	310 4	41.80	7.54
				AVE =	-3.19
KLG	101982	3	4 1 1	11.70	2.16
KLG	101982	3	4 1 2	17.03	-0.73
KLG	101982	3	4 1 3	33.72	-5.52
KLG	101982	3	4 1 4	19.56	-1.48
KLG	101982	3	4 2 1	26.86	-2.00
KLG	101982	3	4 2 2	13.27	-0.34
KLG	101982	3	4 2 3	10.96	0.29
KLG	101982	3	4 2 4	21.02	-1.09
KLG	101982	3	4 3 1	19.15	1.63
KLG	101982	3	4 3 2	10.72	1.07
KLG	101982	3	4 3 3	23.84	-0.98
KLG	101982	3	4 3 4	16.01	-0.01
KLG	101982	3	4 4 1	19.68	1.70
KLG	101982	3	4 4 2	6.86	3.41
KLG	101982	3	4 4 3	11.42	-1.83
KLG	101982	3	4 4 4	15.05	0.55
KLG	101982	3	4 5 1	21.37	-2.04
KLG	101982	3	4 5 2	20.75	-2.33
KLG	101982	3	4 5 3	13.16	-2.34
KLG	101982	3	4 5 4	19.78	0.12
KLG	101982	3	4 6 1	8.92	0.96
KLG	101982	3	4 6 2	12.00	4.10
KLG	101982	3	4 6 3	6.83	0.88
KLG	101982	3	4 6 4	22.90	-0.04
KLG	101982	3	4 7 1	12.05	-1.60
KLG	101982	3	4 7 2	9.80	3.16
KLG	101982	3	4 7 3	5.50	0.40
KLG	101982	3	4 7 4	12.20	0.14
KLG	101982	3	4 8 1	14.14	1.56
KLG	101982	3	4 8 2	14.18	-1.81
KLG	101982	3	4 8 3	11.57	-0.49
KLG	101982	3	4 8 4	6.02	-0.42
KLG	101982	3	4 9 1	18.34	1.88

LOCATION	DATE	RUN*N	PIN	READING(MM)	EROS/DEP(MM)
KLG	101982	3	4 9 2	17.56	-1.42
KLG	101982	3	4 9 3	8.52	3.17
KLG	101982	3	4 9 4	10.93	1.35
KLG	101982	3	410 1	19.86	-1.84
KLG	101982	3	410 2	19.11	-4.95
KLG	101982	3	410 3	30.53	-4.38
KLG	101982	3	410 4	16.90	-4.23
				AVE =	-0.33
KLG	102682	4	3 1 1	1.00	3.26
KLG	102682	4	3 1 2	22.13	-3.19
KLG	102682	4	3 1 3	15.79	-4.59
KLG	102682	4	3 1 4	31.04	-1.36
KLG	102682	4	3 2 1	54.26	-1.00
KLG	102682	4	3 2 2	29.62	1.25
KLG	102682	4	3 2 3	31.33	-4.05
KLG	102682	4	3 2 4	28.90	-1.18
KLG	102682	4	3 3 1	33.14	-2.16
KLG	102682	4	3 3 2	23.30	-0.72
KLG	102682	4	3 3 3	25.61	-3.27
KLG	102682	4	3 3 4	37.25	-1.25
KLG	102682	4	3 4 1	37.81	-10.79
KLG	102682	4	3 4 2	16.00	0.22
KLG	102682	4	3 4 3	21.56	-1.78
KLG	102682	4	3 5 1	21.21	-0.69
KLG	102682	4	3 5 2	14.74	2.26
KLG	102682	4	3 5 3	16.03	-3.44
KLG	102682	4	3 5 4	26.29	-4.23
KLG	102682	4	3 6 1	24.80	-0.59
KLG	102682	4	3 6 2	15.44	2.04
KLG	102682	4	3 6 3	31.70	-4.27
KLG	102682	4	3 6 4	30.20	-2.84
KLG	102682	4	3 7 1	42.18	-0.96
KLG	102682	4	3 7 2	31.26	-1.99
KLG	102682	4	3 7 3	32.37	-0.33
KLG	102682	4	3 7 4	21.29	2.31
KLG	102682	4	3 8 1	20.06	-0.96
KLG	102682	4	3 8 2	21.34	-2.38
KLG	102682	4	3 8 3	18.57	3.98
KLG	102682	4	3 8 4	42.10	0.25
KLG	102682	4	3 9 1	25.21	-0.51
KLG	102682	4	3 9 2	18.26	0.06
KLG	102682	4	3 9 3	24.15	-2.59
KLG	102682	4	3 9 4	17.19	-1.58
KLG	102682	4	310 1	26.19	0.65
KLG	102682	4	310 2	23.30	-1.94
KLG	102682	4	310 3	17.49	-0.43
KLG	102682	4	310 4	36.94	4.86
				AVE =	-1.09

LOCATION	DATE	RUN#N	PIN	READING(MM)	ERROR/DEP(MM
KLG	102682	4	4 1 1	11.24	0.46
KLG	102682	4	4 1 2	17.10	-0.07
KLG	102682	4	4 1 3	36.78	-3.06
KLG	102682	4	4 1 4	21.52	-1.96
KLG	102682	4	4 2 1	28.20	-1.34
KLG	102682	4	4 2 2	13.36	-0.09
KLG	102682	4	4 2 3	11.00	-0.04
KLG	102682	4	4 2 4	22.96	-1.94
KLG	102682	4	4 3 1	21.17	-2.02
KLG	102682	4	4 3 2	9.92	0.30
KLG	102682	4	4 3 3	24.56	-0.72
KLG	102682	4	4 3 4	14.64	1.37
KLG	102682	4	4 4 1	21.98	-2.30
KLG	102682	4	4 4 2	10.32	-3.46
KLG	102682	4	4 4 3	12.54	-1.12
KLG	102682	4	4 4 4	19.20	-4.15
KLG	102682	4	4 5 1	22.02	-0.65
KLG	102682	4	4 5 2	21.38	-0.63
KLG	102682	4	4 5 3	11.37	1.79
KLG	102682	4	4 5 4	22.17	-2.39
KLG	102682	4	4 6 1	12.27	-3.35
KLG	102682	4	4 6 2	15.41	-3.41
KLG	102682	4	4 6 3	6.61	0.22
KLG	102682	4	4 6 4	24.42	-1.52
KLG	102682	4	4 7 1	13.42	-1.37
KLG	102682	4	4 7 2	16.01	-6.21
KLG	102682	4	4 7 3	5.37	0.13
KLG	102682	4	4 7 4	14.05	-1.35
KLG	102682	4	4 8 1	18.07	-3.93
KLG	102682	4	4 8 2	14.73	-0.35
KLG	102682	4	4 8 3	13.18	-1.61
KLG	102682	4	4 8 4	6.58	-0.56
KLG	102682	4	4 9 1	20.48	-2.14
KLG	102682	4	4 9 2	20.36	-2.30
KLG	102682	4	4 9 3	9.74	-1.22
KLG	102682	4	4 9 4	11.79	-0.86
KLG	102682	4	410 1	21.32	-1.46
KLG	102682	4	410 2	16.73	2.38
KLG	102682	4	410 3	32.14	-1.61
KLG	102682	4	410 4	17.56	-0.66

AVE = -1.35

APPENDIX F

CROSS SECTION MEASUREMENTS

TABLE #1: CROSS SECTION DATA - CENTER SECTION - INITIAL MEASUREMENTS

LOC	DATE	RUN	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)
PLOT 3														
KLG100482		1	3101	7.00	3105	6.65	3110	6.54	3115	6.25	3120	6.05	3125	5.95
KLG100482		1	3130	5.85	3135	1111	3140	5.95	3145	6.25	3150	6.20	3155	6.35
KLG100482		1	3160	6.55	3165	6.75	3169	7.10	3201	7.45	3205	7.30	3210	7.65
KLG100482		1	3215	7.75	3220	7.50	3225	7.55	3230	7.40	3235	1111	3240	6.20
KLG100482		1	3245	6.15	3250	6.15	3255	6.35	3260	6.55	3265	6.65	3269	6.70
KLG100482		1	3301	6.7	3305	6.55	3310	6.35	3315	6.35	3320	6.25	3325	6.15
KLG100482		1	3330	5.80	3335	1111	3340	6.05	3345	6.20	3350	6.40	3355	6.50
KLG100482		1	3360	6.30	3365	6.25	3369	6.30	3401	6.50	3405	6.25	3410	5.80
KLG100482		1	3415	5.85	3420	5.93	3425	6.05	3430	6.13	3435	1111	3440	6.25
KLG100482		1	3445	6.40	3450	6.50	3455	6.50	3460	6.55	3465	6.70	3469	6.75
KLG100482		1	3501	6.30	3505	6.30	3510	6.30	3515	6.30	3520	6.55	3525	6.70
KLG100482		1	3530	6.65	3535	1111	3540	7.05	3545	7.05	3550	7.25	3555	7.35
KLG100482		1	3560	7.35	3565	7.35	3569	7.40	3601	6.70	3605	6.55	3610	6.75
KLG100482		1	3615	6.70	3620	6.10	3625	6.05	3630	6.10	3635	1111	3640	6.60
KLG100482		1	3645	6.85	3650	6.85	3655	6.80	3660	6.75	3665	6.95	3669	7.15
KLG100482		1	3701	6.85	3705	6.50	3710	6.50	3715	6.55	3720	6.55	3725	6.50
KLG100482		1	3730	6.45	3735	1111	3740	6.33	3745	6.55	3750	7.05	3755	7.15
KLG100482		1	3760	7.15	3765	7.15	3769	7.40	3801	5.95	3805	5.62	3810	5.50
KLG100482		1	3815	5.80	3820	6.10	3825	6.55	3830	6.60	3835	1111	3840	6.40
KLG100482		1	3845	6.42	3850	6.50	3855	6.38	3860	6.33	3865	6.58	3869	6.85
KLG100482		1	3901	6.60	3905	6.65	3910	6.85	3915	7.10	3920	6.95	3925	6.80
KLG100482		1	3930	6.85	3935	1111	3940	6.80	3945	7.10	3950	7.10	3955	6.98
KLG100482		1	3960	6.80	3965	6.80	3969	7.50						
PLOT 4														
KLG100482		1	4101	7.50	4105	7.12	4110	6.70	4115	5.65	4120	5.75	4125	5.60
KLG100482		1	4130	5.68	4135	1111	4140	5.45	4145	5.25	4150	5.05	4155	5.15
KLG100482		1	4160	5.21	4165	5.18	4169	5.03	4201	7.80	4205	7.60	4210	7.43
KLG100482		1	4215	7.30	4220	7.37	4225	6.84	4230	6.85	4235	1111	4240	6.23
KLG100482		1	4245	6.00	4250	5.48	4255	4.80	4260	4.65	4265	4.95	4269	4.95
KLG100482		1	4301	7.30	4305	7.05	4310	6.85	4315	6.60	4320	6.65	4325	6.55

LOC	DATE	RUN	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)
KLG100482		1	4330	6.40	4335	1111	4340	6.08	4345	5.70	4350	5.35	4355	5.08
KLG100482		1	4360	6.95	4365	4.70	4369	4.73	4401	7.35	4405	7.15	4410	6.50
KLG100482		1	4415	6.13	4420	5.65	4425	5.95	4430	6.00	4435	1111	4440	5.65
KLG100482		1	4445	5.02	4450	5.25	4455	5.25	4460	4.95	4465	4.85	4469	4.65
KLG100482		1	4501	8.03	4505	7.70	4510	7.65	4515	7.08	4520	6.97	4525	6.80
KLG100482		1	4530	6.95	4535	1111	4540	6.40	4545	6.28	4550	6.00	4555	5.98
KLG100482		1	4560	6.00	4565	6.10	4569	6.00	4601	8.25	4605	8.20	4610	7.90
KLG100482		1	4615	7.60	4620	7.15	4625	6.90	4630	6.50	4635	1111	4640	6.20
KLG100482		1	4645	6.03	4650	6.00	4655	5.92	4660	5.95	4665	5.85	4669	5.65
KLG100482		1	4701	7.20	4705	6.80	4710	6.48	4715	5.95	4720	6.15	4725	5.98
KLG100482		1	4730	5.50	4735	1111	4740	5.28	4745	5.25	4750	5.15	4755	5.32
KLG100482		1	4760	5.65	4765	5.40	4769	5.25	4801	7.45	4805	7.45	4810	6.79
KLG100482		1	4815	6.40	4820	6.20	4825	6.10	4830	6.05	4835	1111	4840	5.60
KLG100482		1	4845	5.60	4850	5.46	4855	5.35	4860	5.22	4865	5.00	4869	5.00
KLG100482		1	4901	6.40	4905	6.25	4910	6.05	4915	5.78	4920	5.50	4925	5.40
KLG100482		1	4930	5.10	4935	1111	4940	4.70	4945	4.48	4950	4.15	4955	4.15
KLG100482		1	4960	4.09	4965	4.10	4969	3.97						

TABLE F2: CROSS SECTION DATA FROM RUNS 1 - 4, CENTER SECTION

LOCATION	DATE	RUN*N	PIN PLOT ROW LOC	READING(IN)	EROS/DEP IN)
KLG	102782	2	3 1 1	7.44	-0.44
KLG	102782	2	3 1 5	7.24	-0.59
KLG	102782	2	3 1 10	7.05	-0.51
KLG	102782	2	3 1 15	6.55	-0.30
KLG	102782	2	3 1 20	6.35	-0.30
KLG	102782	2	3 1 25	6.30	-0.35
KLG	102782	2	3 1 30	6.37	-0.52
KLG	102782	2	3 1 35	11.11	0.0
KLG	102782	2	3 1 40	6.67	-0.72
KLG	102782	2	3 1 45	7.03	-0.78
KLG	102782	2	3 1 50	7.25	-1.05
KLG	102782	2	3 1 55	7.33	-0.98
KLG	102782	2	3 1 60	7.75	-1.20
KLG	102782	2	3 1 65	7.80	-1.05
KLG	102782	2	3 1 69	7.95	-0.85
KLG	102782	2	3 2 1	8.39	-0.94
KLG	102782	2	3 2 5	7.50	-0.20
KLG	102782	2	3 2 10	7.36	0.29
KLG	102782	2	3 2 15	7.28	0.47
KLG	102782	2	3 2 20	7.20	0.30
KLG	102782	2	3 2 25	7.20	0.35
KLG	102782	2	3 2 30	6.40	1.00
KLG	102782	2	3 2 35	11.11	0.0
KLG	102782	2	3 2 40	6.58	-0.38
KLG	102782	2	3 2 45	6.48	-0.33
KLG	102782	2	3 2 50	6.50	-0.35
KLG	102782	2	3 2 55	6.70	-0.35
KLG	102782	2	3 2 60	6.78	-0.23
KLG	102782	2	3 2 65	6.85	-0.20
KLG	102782	2	3 2 69	6.93	-0.23
KLG	102782	2	3 3 1	6.98	-0.28
KLG	102782	2	3 3 5	6.83	-0.22
KLG	102782	2	3 3 10	6.65	-0.30
KLG	102782	2	3 3 15	6.62	-0.27
KLG	102782	2	3 3 20	6.55	-0.30
KLG	102782	2	3 3 25	6.35	-0.20
KLG	102782	2	3 3 30	6.22	-0.42
KLG	102782	2	3 3 35	11.11	0.0
KLG	102782	2	3 3 40	6.43	-0.38
KLG	102782	2	3 3 45	6.58	-0.38
KLG	102782	2	3 3 50	6.68	-0.28
KLG	102782	2	3 3 55	6.70	-0.20
KLG	102782	2	3 3 60	6.90	-0.60
KLG	102782	2	3 3 65	6.90	-0.65
KLG	102782	2	3 3 69	6.75	-0.45
KLG	102782	2	3 4 1	6.60	-0.10

LOCATION	DATE	RUN#N	PIN	READING(IN)	EROS/DEP(IN)
KLG	102782	2	3 4 5	6.40	-0.13
KLG	102782	2	3 4 10	6.25	-0.45
KLG	102782	2	3 4 15	6.10	-0.25
KLG	102782	2	3 4 20	6.24	-0.31
KLG	102782	2	3 4 25	6.22	-0.17
KLG	102782	2	3 4 30	6.30	-0.17
KLG	102782	2	3 4 35	11.11	0.0
KLG	102782	2	3 4 40	6.77	-0.52
KLG	102782	2	3 4 45	6.75	-0.35
KLG	102782	2	3 4 50	6.70	-0.20
KLG	102782	2	3 4 55	6.95	-0.45
KLG	102782	2	3 4 60	6.98	-0.43
KLG	102782	2	3 4 65	6.93	-0.23
KLG	102782	2	3 4 69	6.90	-0.15
KLG	102782	2	3 5 1	6.55	-0.25
KLG	102782	2	3 5 5	6.57	-0.27
KLG	102782	2	3 5 10	6.52	-0.22
KLG	102782	2	3 5 15	6.50	-0.20
KLG	102782	2	3 5 20	6.55	0.0
KLG	102782	2	3 5 25	6.75	-0.05
KLG	102782	2	3 5 30	6.80	-0.15
KLG	102782	2	3 5 35	11.11	0.0
KLG	102782	2	3 5 40	6.87	0.12
KLG	102782	2	3 5 45	7.50	-0.45
KLG	102782	2	3 5 50	7.75	-0.50
KLG	102782	2	3 5 55	7.63	-0.28
KLG	102782	2	3 5 60	7.58	-0.23
KLG	102782	2	3 5 65	7.62	-0.33
KLG	102782	2	3 5 69	7.72	-0.32
KLG	102782	2	3 6 1	7.28	-0.52
KLG	102782	2	3 6 5	7.00	-0.45
KLG	102782	2	3 6 10	7.03	-0.28
KLG	102782	2	3 6 15	6.65	0.05
KLG	102782	2	3 6 20	6.10	0.0
KLG	102782	2	3 6 25	6.17	-0.12
KLG	102782	2	3 6 30	6.27	-0.17
KLG	102782	2	3 6 35	11.11	0.0
KLG	102782	2	3 6 40	7.18	-0.58
KLG	102782	2	3 6 45	7.26	-0.41
KLG	102782	2	3 6 50	7.06	-0.21
KLG	102782	2	3 6 55	7.03	-0.23
KLG	102782	2	3 6 60	7.13	-0.38
KLG	102782	2	3 6 65	7.40	-0.45
KLG	102782	2	3 6 69	7.53	-0.38
KLG	102782	2	3 7 1	6.92	-0.07
KLG	102782	2	3 7 5	6.80	-0.30
KLG	102782	2	3 7 10	6.65	-0.15
KLG	102782	2	3 7 15	6.70	-0.15
KLG	102782	2	3 7 20	6.82	-0.27
KLG	102782	2	3 7 25	6.63	-0.13
KLG	102782	2	3 7 30	6.50	-0.05
KLG	102782	2	3 7 35	11.11	0.0

LOCATION	DATE	RUN#N	PIN	READING(IN)	EROS/SUP(IN)
KLG	102782	2	3 7 40	6.35	-0.02
KLG	102782	2	3 7 45	6.85	-0.30
KLG	102782	2	3 7 50	7.05	0.0
KLG	102782	2	3 7 55	7.30	-0.15
KLG	102782	2	3 7 60	7.58	-0.43
KLG	102782	2	3 7 65	7.92	-0.77
KLG	102782	2	3 7 69	7.95	-0.55
KLG	102782	2	3 8 1	5.88	0.07
KLG	102782	2	3 8 5	5.70	-0.08
KLG	102782	2	3 8 10	5.76	-0.26
KLG	102782	2	3 8 15	6.00	-0.20
KLG	102782	2	3 8 20	6.50	-0.40
KLG	102782	2	3 8 25	6.60	-0.05
KLG	102782	2	3 8 30	6.58	0.02
KLG	102782	2	3 8 35	11.11	0.0
KLG	102782	2	3 8 40	6.55	-0.15
KLG	102782	2	3 8 45	6.40	0.02
KLG	102782	2	3 8 50	6.35	0.15
KLG	102782	2	3 8 55	6.10	0.28
KLG	102782	2	3 8 60	6.28	0.05
KLG	102782	2	3 8 65	6.42	0.16
KLG	102782	2	3 8 69	6.50	0.35
KLG	102782	2	3 9 1	7.00	-0.40
KLG	102782	2	3 9 5	7.15	-0.50
KLG	102782	2	3 9 10	7.25	-0.40
KLG	102782	2	3 9 15	7.31	-0.21
KLG	102782	2	3 9 20	7.20	-0.25
KLG	102782	2	3 9 25	7.15	-0.35
KLG	102782	2	3 9 30	6.98	-0.13
KLG	102782	2	3 9 35	11.11	0.0
KLG	102782	2	3 9 40	7.08	-0.28
KLG	102782	2	3 9 45	7.36	-0.26
KLG	102782	2	3 9 50	7.32	-0.22
KLG	102782	2	3 9 55	7.22	-0.24
KLG	102782	2	3 9 60	7.40	-0.60
KLG	102782	2	3 9 65	7.80	-1.00
KLG	102782	2	3 9 69	7.30	-0.30
KLG	102782	2	4 1 1	7.85	-0.35
KLG	102782	2	4 1 5	7.72	-0.60
KLG	102782	2	4 1 10	7.15	-0.45
KLG	102782	2	4 1 15	6.45	-0.80
KLG	102782	2	4 1 20	6.00	-0.25
KLG	102782	2	4 1 25	6.17	-0.37
KLG	102782	2	4 1 30	6.00	-0.32
KLG	102782	2	4 1 35	11.11	0.0
KLG	102782	2	4 1 40	5.75	-0.30
KLG	102782	2	4 1 45	5.60	-0.35
KLG	102782	2	4 1 50	5.50	-0.45
KLG	102782	2	4 1 55	5.43	-0.28
KLG	102782	2	4 1 60	5.75	-0.54

LOCATION	DATE	RUN#N	PIN	READING (IN)	EROS DEP (IN)
KLG	102782	2	4 1 65	5.55	-0.37
KLG	102782	2	4 1 69	5.42	-0.33
KLG	102782	2	4 2 1	7.91	-0.11
KLG	102782	2	4 2 5	7.70	-0.10
KLG	102782	2	4 2 10	7.75	-0.32
KLG	102782	2	4 2 15	7.28	-0.58
KLG	102782	2	4 2 20	7.58	-0.21
KLG	102782	2	4 2 25	7.27	-0.43
KLG	102782	2	4 2 30	7.05	-0.20
KLG	102782	2	4 2 35	11.11	0.0
KLG	102782	2	4 2 40	6.45	-0.22
KLG	102782	2	4 2 45	6.13	-0.13
KLG	102782	2	4 2 50	5.55	-0.07
KLG	102782	2	4 2 55	4.98	-0.18
KLG	102782	2	4 2 60	5.03	-0.32
KLG	102782	2	4 2 65	5.15	-0.20
KLG	102782	2	4 2 69	5.00	-0.05
KLG	102782	2	4 3 1	7.35	-0.05
KLG	102782	2	4 3 5	7.38	-0.33
KLG	102782	2	4 3 10	6.85	0.0
KLG	102782	2	4 3 15	6.65	-0.05
KLG	102782	2	4 3 20	6.55	0.10
KLG	102782	2	4 3 25	6.50	0.05
KLG	102782	2	4 3 30	6.40	0.0
KLG	102782	2	4 3 35	11.11	0.0
KLG	102782	2	4 3 40	6.20	-0.12
KLG	102782	2	4 3 45	5.84	-0.14
KLG	102782	2	4 3 50	5.52	-0.17
KLG	102782	2	4 3 55	5.40	-0.32
KLG	102782	2	4 3 60	5.32	1.63
KLG	102782	2	4 3 65	4.90	-0.20
KLG	102782	2	4 3 69	5.05	-0.32
KLG	102782	2	4 4 1	7.45	-0.10
KLG	102782	2	4 4 5	7.40	-0.25
KLG	102782	2	4 4 10	7.00	-0.50
KLG	102782	2	4 4 15	6.42	-0.29
KLG	102782	2	4 4 20	6.00	-0.35
KLG	102782	2	4 4 25	6.15	-0.20
KLG	102782	2	4 4 30	6.00	0.0
KLG	102782	2	4 4 35	11.11	0.0
KLG	102782	2	4 4 40	5.62	0.03
KLG	102782	2	4 4 45	5.12	-0.10
KLG	102782	2	4 4 50	5.43	-0.18
KLG	102782	2	4 4 55	5.45	-0.20
KLG	102782	2	4 4 60	5.28	-0.33
KLG	102782	2	4 4 65	5.58	-0.73
KLG	102782	2	4 4 69	5.07	-0.42
KLG	102782	2	4 5 1	8.24	-0.21
KLG	102782	2	4 5 5	7.95	-0.25
KLG	102782	2	4 5 10	7.88	-0.23
KLG	102782	2	4 5 15	7.50	-0.42
KLG	102782	2	4 5 20	7.23	-0.28

LOCATION	DATE	RUN#N	PIN	READING (IN)	EROS/DEP IN
KLG	102782	2	4 5 25	7.42	-0.62
KLG	102782	2	4 5 30	7.25	-0.30
KLG	102782	2	4 5 35	11.11	0.0
KLG	102782	2	4 5 40	6.40	0.0
KLG	102782	2	4 5 45	6.18	0.10
KLG	102782	2	4 5 50	6.07	-0.07
KLG	102782	2	4 5 55	6.13	-0.15
KLG	102782	2	4 5 60	6.18	-0.18
KLG	102782	2	4 5 65	6.12	-0.02
KLG	102782	2	4 5 69	6.06	-0.06
KLG	102782	2	4 6 1	8.38	-0.13
KLG	102782	2	4 6 5	8.15	0.05
KLG	102782	2	4 6 10	7.90	0.0
KLG	102782	2	4 6 15	7.55	0.05
KLG	102782	2	4 6 20	7.48	-0.33
KLG	102782	2	4 6 25	7.22	-0.32
KLG	102782	2	4 6 30	6.67	-0.17
KLG	102782	2	4 6 35	11.11	0.0
KLG	102782	2	4 6 40	5.80	0.40
KLG	102782	2	4 6 45	5.95	0.08
KLG	102782	2	4 6 50	5.93	0.07
KLG	102782	2	4 6 55	5.85	0.07
KLG	102782	2	4 6 60	5.78	0.17
KLG	102782	2	4 6 65	5.75	0.10
KLG	102782	2	4 6 69	5.55	0.10
KLG	102782	2	4 7 1	7.75	-0.55
KLG	102782	2	4 7 5	7.47	-0.67
KLG	102782	2	4 7 10	6.70	-0.22
KLG	102782	2	4 7 15	6.32	-0.37
KLG	102782	2	4 7 20	6.15	0.0
KLG	102782	2	4 7 25	5.92	0.06
KLG	102782	2	4 7 30	5.52	-0.02
KLG	102782	2	4 7 35	11.11	0.0
KLG	102782	2	4 7 40	5.78	-0.50
KLG	102782	2	4 7 45	5.64	-0.39
KLG	102782	2	4 7 50	5.50	-0.35
KLG	102782	2	4 7 55	5.70	-0.38
KLG	102782	2	4 7 60	5.76	-0.11
KLG	102782	2	4 7 65	5.60	-0.20
KLG	102782	2	4 7 69	5.45	-0.20
KLG	102782	2	4 8 1	7.75	-0.30
KLG	102782	2	4 8 5	7.35	0.10
KLG	102782	2	4 8 10	6.78	0.01
KLG	102782	2	4 8 15	6.60	-0.20
KLG	102782	2	4 8 20	6.40	-0.20
KLG	102782	2	4 8 25	6.38	-0.28
KLG	102782	2	4 8 30	6.38	-0.33
KLG	102782	2	4 8 35	11.11	0.0
KLG	102782	2	4 8 40	6.13	-0.53
KLG	102782	2	4 8 45	5.77	-0.17
KLG	102782	2	4 8 50	5.60	-0.14
KLG	102782	2	4 8 55	5.45	-0.10

LOCATION	DATE	RUN#N	PIN	READING IN.	EROS/DEP(IN)
KLG	102782	2	4 8 60	5.22	0.0
KLG	102782	2	4 8 65	5.05	-0.05
KLG	102782	2	4 8 69	5.10	-0.10
KLG	102782	2	4 9 1	6.77	-0.37
KLG	102782	2	4 9 5	6.70	-0.45
KLG	102782	2	4 9 10	6.47	-0.42
KLG	102782	2	4 9 15	6.15	-0.37
KLG	102782	2	4 9 20	5.75	-0.35
KLG	102782	2	4 9 25	5.38	0.02
KLG	102782	2	4 9 30	5.05	0.05
KLG	102782	2	4 9 35	11.11	0.0
KLG	102782	2	4 9 40	4.43	0.27
KLG	102782	2	4 9 45	4.28	0.20
KLG	102782	2	4 9 50	4.09	0.06
KLG	102782	2	4 9 55	4.25	-0.10
KLG	102782	2	4 9 60	4.27	-0.18
KLG	102782	2	4 9 65	4.30	-0.20
KLG	102782	2	4 9 69	4.60	-0.63

TABLE F3: CROSS SECTION DATA - RIGHT SECTION - INITIAL MEASUREMENTS(IN)

KEY: PIN ID 3101

PR LO ON T LOCATION

LOC DATE	RUN	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)
KLG100482	1	3101	8.10	3102	8.05	3103	8.05	3104	8.18	3105	7.90	3106	7.85
KLG100482	1	3107	7.75	3108	7.70	3109	7.50	3110	7.45	3111	7.45	3112	7.40
KLG100482	1	3113	7.45	3114	7.38	3115	7.40	3116	7.40	3117	7.40	3118	7.40
KLG100482	1	3119	1111	3201	8.70	3202	8.75	3203	8.65	3204	8.55	3205	8.55
KLG100482	1	3206	7.80	3207	8.30	3208	8.25	3209	8.30	3210	7.70	3211	7.55
KLG100482	1	3212	7.25	3213	7.18	3214	7.15	3215	7.10	3216	7.00	3217	6.95
KLG100482	1	3218	6.90	3219	1111	3301	6.55	3302	7.45	3303	7.55	3304	7.65
KLG100482	1	3305	7.50	3306	7.60	3307	7.50	3308	7.55	3309	7.50	3310	7.32
KLG100482	1	3311	7.30	3312	7.30	3313	7.05	3314	6.70	3315	6.65	3316	6.50
KLG100482	1	3317	6.40	3318	6.40	3319	1111	3320	1111	3401	6.00	3402	6.20
KLG100482	1	3403	6.25	3404	6.20	3405	6.20	3406	6.25	3407	6.20	3408	6.20
KLG100482	1	3409	6.15	3410	6.15	3411	6.20	3412	6.23	3413	6.30	3414	6.30
KLG100482	1	3415	6.32	3416	6.40	3417	6.40	3418	6.45	3419	6.50	3501	8.25
KLG100482	1	3502	8.25	3503	8.25	3504	8.25	3505	8.25	3506	8.03	3507	8.05
KLG100482	1	3508	7.93	3509	7.88	3510	7.80	3511	7.80	3512	7.80	3513	7.75
KLG100482	1	3514	7.73	3515	7.73	3516	7.60	3517	7.60	3518	7.50	3519	7.50
KLG100482	1	3601	7.35	3602	7.35	3603	7.35	3604	7.40	3605	7.35	3606	7.42
KLG100482	1	3607	7.35	3608	7.45	3609	7.45	3610	7.40	3611	7.45	3612	7.40
KLG100482	1	3613	7.50	3614	7.52	3615	7.60	3616	7.55	3617	7.47	3618	7.53
KLG100482	1	3619	7.44	3620	1111	3701	7.70	3702	7.65	3703	7.60	3704	7.60
KLG100482	1	3705	7.58	3706	7.55	3707	7.55	3708	7.60	3709	7.50	3710	7.58
KLG100482	1	3711	7.55	3712	7.55	3713	7.45	3714	7.40	3715	7.35	3716	7.40
KLG100482	1	3717	7.25	3718	7.25	3719	1111	3720	1111	3801	7.93	3802	7.90

LOC	DATE	RUN	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)
KLG100482		1	3803	7.72	3804	7.80	3805	7.60	3806	7.40	3807	7.33	3808	7.20
KLG100482		1	3809	7.08	3810	6.97	3811	7.08	3812	6.95	3813	7.08	3814	7.00
KLG100482		1	3815	7.07	3816	7.00	3817	6.85	3818	6.82	3819	1111	3901	7.75
KLG100482		1	3902	7.80	3903	7.85	3904	7.80	3905	8.00	3906	8.00	3907	8.07
KLG100482		1	3908	7.95	3909	7.93	3910	7.90	3911	7.80	3912	7.83	3913	7.80
KLG100482		1	3914	7.70	3915	7.50	3916	7.59	3917	7.60	3918	1111	3919	1111
KLG100482		1	3920	1111	4101	4.95	4102	4.95	4103	4.88	4104	4.90	4105	4.60
KLG100482		1	4106	4.50	4107	4.70	4108	4.73	4109	4.84	4110	4.87	4111	4.90
KLG100482		1	4112	4.85	4113	4.90	4114	4.82	4115	4.80	4116	4.76	4117	4.80
KLG100482		1	4118	4.73	4119	1111	4201	5.06	4202	5.18	4203	5.15	4204	5.20
KLG100482		1	4205	5.30	4206	5.55	4207	5.45	4208	5.50	4209	5.45	4210	5.40
KLG100482		1	4211	5.55	4212	5.50	4213	5.45	4214	5.50	4215	5.45	4216	5.50
KLG100482		1	4217	5.50	4218	5.40	4219	1111	4301	5.75	4302	5.80	4303	5.70
KLG100482		1	4304	5.55	4305	5.35	4306	5.17	4307	5.23	4308	5.38	4309	5.25
KLG100482		1	4310	5.35	4311	5.30	4312	5.30	4313	5.26	4314	5.26	4315	5.30
KLG100482		1	4316	5.25	4317	5.30	4318	5.18	4319	5.40	4401	5.60	4402	5.30
KLG100482		1	4403	5.20	4404	5.37	4405	5.25	4406	5.28	4407	5.18	4408	5.34
KLG100482		1	4409	5.47	4410	5.56	4411	5.55	4412	5.75	4413	5.90	4414	5.92
KLG100482		1	4415	5.95	4416	5.95	4417	6.00	4418	1111	4419	1111	4501	4.70
KLG100482		1	4502	4.82	4503	5.00	4504	4.95	4505	5.03	4506	5.10	4507	5.13
KLG100482		1	4508	5.20	4509	5.20	4510	5.32	4511	5.40	4512	5.50	4513	5.55
KLG100482		1	4514	5.55	4515	5.63	4516	5.60	4517	5.35	4518	5.27	4519	1111
KLG100482		1	4520	1111	4601	6.00	4602	5.65	4603	5.58	4604	5.10	4605	4.75
KLG100482		1	4606	4.60	4607	4.85	4608	4.85	4609	4.93	4610	4.88	4611	5.04
KLG100482		1	4612	5.05	4613	5.18	4614	5.30	4615	5.33	4616	5.30	4617	5.45
KLG100482		1	4618	5.45	4619	1111	4701	4.50	4702	4.55	4703	4.55	4704	4.40
KLG100482		1	4705	4.50	4706	4.55	4707	4.55	4708	4.55	4709	4.75	4710	4.80
KLG100482		1	4711	4.90	4712	4.90	4713	4.90	4714	5.05	4715	5.10	4716	5.10
KLG100482		1	4717	5.14	4718	1111	4719	1111	4720	1111	4801	5.07	4802	5.30
KLG100482		1	4803	5.22	4804	5.22	4805	5.22	4806	5.28	4807	5.25	4808	5.05
KLG100482		1	4809	5.15	4810	5.12	4811	5.15	4812	5.18	4813	5.14	4814	5.00
KLG100482		1	4815	5.04	4816	5.08	4817	5.08	4818	5.15	4819	1111	4901	4.20
KLG100482		1	4902	4.25	4903	4.10	4904	4.30	4905	4.30	4906	4.25	4907	4.24
KLG100482		1	4908	4.35	4909	4.35	4910	4.28	4911	4.15	4912	4.15	4913	4.00
KLG100482		1	4914	3.90	4915	4.00	4916	3.90	4917	3.80	4918	1111	4919	1111

TABLE F4: CROSS SECTION DATA FROM RUNS 1 - 4, RIGHT SECTION

LOCATION	DATE	RUN*N	PIN PLOT	ROW	LOC	READING(IN)	EROS/DEP(IN)
KLG	102782	2	3	1	1	8.12	-0.02
KLG	102782	2	3	1	2	8.18	-0.13
KLG	102782	2	3	1	3	8.13	-0.08
KLG	102782	2	3	1	4	8.13	0.05
KLG	102782	2	3	1	5	8.22	-0.32
KLG	102782	2	3	1	6	8.29	-0.44
KLG	102782	2	3	1	7	8.23	-0.48
KLG	102782	2	3	1	8	8.38	-0.68
KLG	102782	2	3	1	9	8.45	-0.95
KLG	102782	2	3	1	10	8.50	-1.05
KLG	102782	2	3	1	11	8.50	-1.05
KLG	102782	2	3	1	12	8.66	-1.26
KLG	102782	2	3	1	13	8.76	-1.31
KLG	102782	2	3	1	14	9.02	-1.64
KLG	102782	2	3	1	15	8.85	-1.45
KLG	102782	2	3	1	16	9.13	-1.73
KLG	102782	2	3	1	17	9.16	-1.76
KLG	102782	2	3	1	18	9.10	-1.70
KLG	102782	2	3	1	19	11.11	0.0
KLG	102782	2	3	2	1	7.15	1.55
KLG	102782	2	3	2	2	7.32	1.43
KLG	102782	2	3	2	3	7.26	1.39
KLG	102782	2	3	2	4	7.50	1.05
KLG	102782	2	3	2	5	7.62	0.93
KLG	102782	2	3	2	6	7.81	-0.01
KLG	102782	2	3	2	7	8.05	0.25
KLG	102782	2	3	2	8	8.30	-0.05
KLG	102782	2	3	2	9	8.38	-0.08
KLG	102782	2	3	2	10	8.45	-0.75
KLG	102782	2	3	2	11	8.58	-1.03
KLG	102782	2	3	2	12	8.82	-1.57
KLG	102782	2	3	2	13	8.75	-1.57
KLG	102782	2	3	2	14	8.90	-1.75
KLG	102782	2	3	2	15	9.10	-2.00
KLG	102782	2	3	2	16	9.10	-2.10
KLG	102782	2	3	2	17	9.11	-2.16
KLG	102782	2	3	2	18	9.10	-2.20
KLG	102782	2	3	2	19	11.11	0.0
KLG	102782	2	3	3	1	6.93	-0.38
KLG	102782	2	3	3	2	6.98	0.47
KLG	102782	2	3	3	3	7.25	0.30
KLG	102782	2	3	3	4	7.30	0.35
KLG	102782	2	3	3	5	7.37	0.13
KLG	102782	2	3	3	6	7.40	0.20
KLG	102782	2	3	3	7	7.59	-0.09
KLG	102782	2	3	3	8	7.88	-0.33

LOCATION	DATE	RUN#N	PIN	READING(IN)	EROS/DEP(IN)
KLG	102782	2	3 3 9	7.76	-0.86
KLG	102782	2	3 3 10	8.02	-0.70
KLG	102782	2	3 3 11	7.90	-0.60
KLG	102782	2	3 3 12	7.92	-0.62
KLG	102782	2	3 3 13	7.94	-0.89
KLG	102782	2	3 3 14	8.00	-1.30
KLG	102782	2	3 3 15	8.00	-1.35
KLG	102782	2	3 3 16	7.95	-1.45
KLG	102782	2	3 3 17	7.98	-1.58
KLG	102782	2	3 3 18	7.75	-1.35
KLG	102782	2	3 3 19	11.11	0.0
KLG	102782	2	3 3 20	11.11	0.0
KLG	102782	2	3 4 1	6.88	-0.88
KLG	102782	2	3 4 2	6.75	-0.55
KLG	102782	2	3 4 3	6.73	-0.48
KLG	102782	2	3 4 4	6.68	-0.48
KLG	102782	2	3 4 5	6.65	-0.45
KLG	102782	2	3 4 6	6.65	-0.40
KLG	102782	2	3 4 7	6.65	-0.45
KLG	102782	2	3 4 8	6.75	-0.55
KLG	102782	2	3 4 9	6.94	-0.79
KLG	102782	2	3 4 10	6.94	-0.79
KLG	102782	2	3 4 11	6.71	-0.51
KLG	102782	2	3 4 12	7.17	-0.94
KLG	102782	2	3 4 13	7.20	-0.90
KLG	102782	2	3 4 14	7.24	-0.94
KLG	102782	2	3 4 15	7.25	-0.93
KLG	102782	2	3 4 16	7.21	-0.81
KLG	102782	2	3 4 17	7.20	-0.80
KLG	102782	2	3 4 18	7.15	-0.70
KLG	102782	2	3 4 19	7.00	-0.50
KLG	102782	2	3 5 1	7.80	0.45
KLG	102782	2	3 5 2	7.72	0.53
KLG	102782	2	3 5 3	7.70	0.55
KLG	102782	2	3 5 4	7.68	0.57
KLG	102782	2	3 5 5	7.74	0.51
KLG	102782	2	3 5 6	7.72	0.31
KLG	102782	2	3 5 7	7.67	0.38
KLG	102782	2	3 5 8	7.78	0.15
KLG	102782	2	3 5 9	7.76	0.12
KLG	102782	2	3 5 10	7.81	-0.01
KLG	102782	2	3 5 11	7.90	-0.10
KLG	102782	2	3 5 12	7.87	-0.07
KLG	102782	2	3 5 13	7.90	-0.15
KLG	102782	2	3 5 14	7.93	-0.20
KLG	102782	2	3 5 15	8.00	-0.27
KLG	102782	2	3 5 16	8.00	-0.40
KLG	102782	2	3 5 17	8.00	-0.40
KLG	102782	2	3 5 18	8.03	-0.53
KLG	102782	2	3 5 19	8.02	-0.52
KLG	102782	2	3 6 1	7.58	-0.23
KLG	102782	2	3 6 2	7.53	-0.15
KLG	102782	2	3 6 3	7.55	-0.20

LOCATION	DATE	RUN#N	PIN	READING(IN)	EROS.DEP.(IN)
KLG	102782	2	3 6 4	7.60	-0.20
KLG	102782	2	3 6 5	7.62	-0.27
KLG	102782	2	3 6 6	7.60	-0.13
KLG	102782	2	3 6 7	7.50	-0.15
KLG	102782	2	3 6 8	7.48	-0.03
KLG	102782	2	3 6 9	7.50	-0.05
KLG	102782	2	3 6 10	7.46	-0.06
KLG	102782	2	3 6 11	7.43	0.02
KLG	102782	2	3 6 12	7.47	-0.07
KLG	102782	2	3 6 13	7.43	0.07
KLG	102782	2	3 6 14	7.50	0.02
KLG	102782	2	3 6 15	7.44	0.16
KLG	102782	2	3 6 16	7.38	0.17
KLG	102782	2	3 6 17	7.44	0.03
KLG	102782	2	3 6 18	7.55	-0.02
KLG	102782	2	3 6 19	7.47	-0.03
KLG	102782	2	3 6 20	11.11	0.0
KLG	102782	2	3 7 1	7.90	-0.20
KLG	102782	2	3 7 2	7.98	-0.33
KLG	102782	2	3 7 3	7.95	-0.35
KLG	102782	2	3 7 4	7.90	-0.30
KLG	102782	2	3 7 5	7.93	-0.35
KLG	102782	2	3 7 6	7.89	-0.34
KLG	102782	2	3 7 7	7.85	-0.30
KLG	102782	2	3 7 8	7.83	-0.23
KLG	102782	2	3 7 9	7.88	-0.38
KLG	102782	2	3 7 10	7.85	-0.27
KLG	102782	2	3 7 11	7.88	-0.33
KLG	102782	2	3 7 12	7.82	-0.27
KLG	102782	2	3 7 13	7.83	-0.38
KLG	102782	2	3 7 14	7.76	-0.36
KLG	102782	2	3 7 15	7.75	-0.40
KLG	102782	2	3 7 16	7.72	-0.32
KLG	102782	2	3 7 17	7.74	-0.49
KLG	102782	2	3 7 18	7.65	-0.40
KLG	102782	2	3 7 19	11.11	0.0
KLG	102782	2	3 7 20	11.11	0.0
KLG	102782	2	3 8 1	6.62	1.31
KLG	102782	2	3 8 2	6.70	1.20
KLG	102782	2	3 8 3	6.75	0.97
KLG	102782	2	3 8 4	6.90	0.90
KLG	102782	2	3 8 5	6.86	0.74
KLG	102782	2	3 8 6	6.97	0.43
KLG	102782	2	3 8 7	6.98	0.35
KLG	102782	2	3 8 8	7.00	0.20
KLG	102782	2	3 8 9	7.05	0.03
KLG	102782	2	3 8 10	7.20	-0.23
KLG	102782	2	3 8 11	7.25	-0.17
KLG	102782	2	3 8 12	7.42	-0.47
KLG	102782	2	3 8 13	7.42	-0.34
KLG	102782	2	3 8 14	7.51	-0.51

LOCATION	DATE	RUN#N	PIN	READING.IN.	EROS/DEP IN.
KLG	102782	2	3 8 15	7.55	-0.48
KLG	102782	2	3 8 16	7.64	-0.64
KLG	102782	2	3 8 17	7.55	-0.70
KLG	102782	2	3 8 18	7.65	-0.83
KLG	102782	2	3 8 19	11.11	0.0
KLG	102782	2	3 9 1	8.03	-0.28
KLG	102782	2	3 9 2	8.12	-0.32
KLG	102782	2	3 9 3	8.05	-0.20
KLG	102782	2	3 9 4	8.13	-0.33
KLG	102782	2	3 9 5	8.23	-0.23
KLG	102782	2	3 9 6	8.27	-0.27
KLG	102782	2	3 9 7	8.33	-0.26
KLG	102782	2	3 9 8	8.30	-0.35
KLG	102782	2	3 9 9	8.22	-0.29
KLG	102782	2	3 9 10	8.24	-0.34
KLG	102782	2	3 9 11	8.18	-0.38
KLG	102782	2	3 9 12	8.18	-0.35
KLG	102782	2	3 9 13	8.16	-0.36
KLG	102782	2	3 9 14	8.10	-0.40
KLG	102782	2	3 9 15	8.08	-0.58
KLG	102782	2	3 9 16	8.10	-0.51
KLG	102782	2	3 9 17	8.00	-0.40
KLG	102782	2	3 9 18	11.11	0.0
KLG	102782	2	3 9 19	11.11	0.0
KLG	102782	2	3 9 20	11.11	0.0
				AVE =	-0.33
KLG	102782	2	4 1 1	5.00	-0.05
KLG	102782	2	4 1 2	5.08	-0.13
KLG	102782	2	4 1 3	4.98	-0.10
KLG	102782	2	4 1 4	5.10	-0.20
KLG	102782	2	4 1 5	5.10	-0.50
KLG	102782	2	4 1 6	5.20	-0.70
KLG	102782	2	4 1 7	5.08	-0.38
KLG	102782	2	4 1 8	5.11	-0.38
KLG	102782	2	4 1 9	5.10	-0.26
KLG	102782	2	4 1 10	5.20	-0.33
KLG	102782	2	4 1 11	5.07	-0.17
KLG	102782	2	4 1 12	5.00	-0.15
KLG	102782	2	4 1 13	5.10	-0.20
KLG	102782	2	4 1 14	5.14	-0.32
KLG	102782	2	4 1 15	5.09	-0.29
KLG	102782	2	4 1 16	5.00	-0.24
KLG	102782	2	4 1 17	5.00	-0.20
KLG	102782	2	4 1 18	5.02	-0.29
KLG	102782	2	4 1 19	11.11	0.0
KLG	102782	2	4 2 1	5.50	-0.44
KLG	102782	2	4 2 2	5.53	-0.35
KLG	102782	2	4 2 3	5.58	-0.43
KLG	102782	2	4 2 4	5.60	-0.40

LOCATION	DATE	RUN#N	PIN	READING(IN	ERROR/DEP 1
KLG	102782	2	4 2 5	5.54	-0.04
KLG	102782	2	4 2 6	5.56	-0.01
KLG	102782	2	4 2 7	5.60	-0.15
KLG	102782	2	4 2 8	5.56	-0.06
KLG	102782	2	4 2 9	5.53	-0.08
KLG	102782	2	4 2 10	5.57	-0.17
KLG	102782	2	4 2 11	5.63	-0.08
KLG	102782	2	4 2 12	5.58	-0.08
KLG	102782	2	4 2 13	5.75	-0.30
KLG	102782	2	4 2 14	5.60	-0.10
KLG	102782	2	4 2 15	5.60	-0.15
KLG	102782	2	4 2 16	5.57	-0.07
KLG	102782	2	4 2 17	5.75	-0.25
KLG	102782	2	4 2 18	5.66	-0.26
KLG	102782	2	4 2 19	11.11	0.0
KLG	102782	2	4 3 1	5.55	0.20
KLG	102782	2	4 3 2	5.40	0.40
KLG	102782	2	4 3 3	5.40	0.30
KLG	102782	2	4 3 4	5.44	0.11
KLG	102782	2	4 3 5	5.40	-0.05
KLG	102782	2	4 3 6	5.43	-0.26
KLG	102782	2	4 3 7	5.43	-0.20
KLG	102782	2	4 3 8	5.47	-0.09
KLG	102782	2	4 3 9	5.65	-0.40
KLG	102782	2	4 3 10	5.72	-0.37
KLG	102782	2	4 3 11	5.73	-0.43
KLG	102782	2	4 3 12	5.80	-0.50
KLG	102782	2	4 3 13	5.80	-0.54
KLG	102782	2	4 3 14	5.60	-0.34
KLG	102782	2	4 3 15	5.52	-0.22
KLG	102782	2	4 3 16	5.95	-0.70
KLG	102782	2	4 3 17	5.75	-0.45
KLG	102782	2	4 3 18	5.90	-0.72
KLG	102782	2	4 3 19	5.80	-0.40
KLG	102782	2	4 4 1	5.50	0.10
KLG	102782	2	4 4 2	5.52	-0.28
KLG	102782	2	4 4 3	5.93	-0.73
KLG	102782	2	4 4 4	6.00	-0.63
KLG	102782	2	4 4 5	6.00	-0.75
KLG	102782	2	4 4 6	5.85	-0.57
KLG	102782	2	4 4 7	5.72	-0.54
KLG	102782	2	4 4 8	5.62	-0.28
KLG	102782	2	4 4 9	5.55	-0.08
KLG	102782	2	4 4 10	5.58	-0.02
KLG	102782	2	4 4 11	5.38	0.17
KLG	102782	2	4 4 12	5.36	0.39
KLG	102782	2	4 4 13	5.15	0.75
KLG	102782	2	4 4 14	5.40	0.52
KLG	102782	2	4 4 15	5.33	0.62
KLG	102782	2	4 4 16	5.28	0.67

LOCATION	DATE	RUN*N	PIN	READING(IN)	EPOS-DEF (I
KLG	102782	2	4 4 17	5.31	0.69
KLG	102782	2	4 4 18	11.11	0.0
KLG	102782	2	4 4 19	11.11	0.0
KLG	102782	2	4 5 1	6.08	-1.32
KLG	102782	2	4 5 2	6.07	-1.25
KLG	102782	2	4 5 3	6.02	-1.02
KLG	102782	2	4 5 4	5.86	-0.91
KLG	102782	2	4 5 5	5.95	-0.92
KLG	102782	2	4 5 6	5.83	-0.73
KLG	102782	2	4 5 7	5.80	-0.67
KLG	102782	2	4 5 8	5.68	-0.42
KLG	102782	2	4 5 9	5.60	-0.40
KLG	102782	2	4 5 10	5.50	-0.18
KLG	102782	2	4 5 11	5.40	0.0
KLG	102782	2	4 5 12	5.42	0.08
KLG	102782	2	4 5 13	5.44	0.11
KLG	102782	2	4 5 14	5.30	0.25
KLG	102782	2	4 5 15	5.28	0.35
KLG	102782	2	4 5 16	5.35	0.25
KLG	102782	2	4 5 17	5.20	0.15
KLG	102782	2	4 5 18	5.20	0.07
KLG	102782	2	4 5 19	11.11	0.0
KLG	102782	2	4 5 20	11.11	0.0
KLG	102782	2	4 6 1	5.47	0.53
KLG	102782	2	4 6 2	5.52	0.13
KLG	102782	2	4 6 3	5.48	0.10
KLG	102782	2	4 6 4	5.37	-0.27
KLG	102782	2	4 6 5	5.35	-0.60
KLG	102782	2	4 6 6	5.33	-0.73
KLG	102782	2	4 6 7	5.27	-0.42
KLG	102782	2	4 6 8	5.08	-0.23
KLG	102782	2	4 6 9	5.10	-0.17
KLG	102782	2	4 6 10	5.03	-0.15
KLG	102782	2	4 6 11	5.00	0.04
KLG	102782	2	4 6 12	5.03	0.02
KLG	102782	2	4 6 13	5.02	0.16
KLG	102782	2	4 6 14	5.17	0.13
KLG	102782	2	4 6 15	5.20	0.13
KLG	102782	2	4 6 16	5.18	0.12
KLG	102782	2	4 6 17	5.18	0.27
KLG	102782	2	4 6 18	5.20	0.25
KLG	102782	2	4 6 19	11.11	0.0
KLG	102782	2	4 7 1	5.05	-0.55
KLG	102782	2	4 7 2	5.00	-0.45
KLG	102782	2	4 7 3	4.90	-0.35
KLG	102782	2	4 7 4	4.90	-0.50
KLG	102782	2	4 7 5	4.87	-0.37
KLG	102782	2	4 7 6	4.87	-0.32
KLG	102782	2	4 7 7	4.80	-0.25
KLG	102782	2	4 7 8	4.83	-0.28
KLG	102782	2	4 7 9	4.85	-0.10

LOCATION	DATE	RUN#N	PIN	READING(IN)	SPEC DIST (...
KLG	102782	2	4 7 10	4.90	-0.11
KLG	102782	2	4 7 11	4.92	-0.08
KLG	102782	2	4 7 12	4.95	-0.05
KLG	102782	2	4 7 13	4.86	0.14
KLG	102782	2	4 7 14	4.86	0.14
KLG	102782	2	4 7 15	4.95	0.13
KLG	102782	2	4 7 16	4.90	0.20
KLG	102782	2	4 7 17	4.90	0.24
KLG	102782	2	4 7 18	11.11	0.0
KLG	102782	2	4 7 19	11.11	0.0
KLG	102782	2	4 7 20	11.11	0.0
KLG	102782	2	4 8 1	5.22	-0.15
KLG	102782	2	4 8 2	5.21	0.09
KLG	102782	2	4 8 3	5.18	0.04
KLG	102782	2	4 8 4	5.25	-0.03
KLG	102782	2	4 8 5	5.28	-0.06
KLG	102782	2	4 8 6	5.28	0.0
KLG	102782	2	4 8 7	5.30	-0.05
KLG	102782	2	4 8 8	5.29	-0.24
KLG	102782	2	4 8 9	5.32	-0.17
KLG	102782	2	4 8 10	5.38	-0.28
KLG	102782	2	4 8 11	5.48	-0.33
KLG	102782	2	4 8 12	5.55	-0.37
KLG	102782	2	4 8 13	5.60	-0.46
KLG	102782	2	4 8 14	5.70	-0.70
KLG	102782	2	4 8 15	5.62	-0.62
KLG	102782	2	4 8 16	5.63	-0.55
KLG	102782	2	4 8 17	5.45	-0.37
KLG	102782	2	4 8 18	5.35	-0.20
KLG	102782	2	4 8 19	11.11	0.0
KLG	102782	2	4 9 1	4.30	-0.10
KLG	102782	2	4 9 2	4.45	-0.20
KLG	102782	2	4 9 3	4.46	-0.38
KLG	102782	2	4 9 4	4.45	-0.15
KLG	102782	2	4 9 5	4.47	-0.17
KLG	102782	2	4 9 6	4.45	-0.20
KLG	102782	2	4 9 7	4.49	-0.25
KLG	102782	2	4 9 8	4.50	-0.15
KLG	102782	2	4 9 9	4.50	-0.15
KLG	102782	2	4 9 10	4.45	-0.17
KLG	102782	2	4 9 11	4.35	-0.20
KLG	102782	2	4 9 12	4.35	-0.20
KLG	102782	2	4 9 13	4.17	-0.17
KLG	102782	2	4 9 14	4.10	-0.20
KLG	102782	2	4 9 15	4.12	-0.12
KLG	102782	2	4 9 16	3.97	-0.07
KLG	102782	2	4 9 17	3.81	-0.01
KLG	102782	2	4 9 18	11.11	0.0
KLG	102782	2	4 9 19	11.11	0.0
					AVE = -0.13

TABLE F5: CROSS SECTION DATA - LEFT SECTION - INITIAL MEASUREMENTS (IN)

KEY: PIN ID 3101

PR LOW LOCATION

LOC	DATE	RUN	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)
KLG100482		1	3101	7.05	3102	7.00	3103	7.30	3104	7.30	3105	7.30	3106	7.55
KLG100482		1	3107	7.70	3108	7.70	3109	7.60	3110	7.70	3111	7.70	3112	7.65
KLG100482		1	3113	7.65	3114	7.65	3115	7.65	3116	7.50	3117	7.38	3118	7.40
KLG100482		1	3119	7.40	3201	6.95	3202	7.20	3203	7.18	3204	7.15	3205	7.25
KLG100482		1	3206	7.15	3207	7.10	3208	7.10	3209	7.18	3210	7.25	3211	7.30
KLG100482		1	3212	7.25	3213	7.30	3214	7.40	3215	7.40	3216	7.50	3217	7.60
KLG100482		1	3218	7.60	3219	7.55	3301	5.50	3302	5.70	3303	5.65	3304	6.00
KLG100482		1	3305	6.15	3306	6.20	3307	6.15	3308	6.30	3309	6.35	3310	6.35
KLG100482		1	3311	6.30	3312	6.30	3313	6.30	3314	6.30	3315	6.30	3316	6.35
KLG100482		1	3317	6.40	3318	6.40	3319	6.50	3320	6.50	3401	5.55	3402	5.65
KLG100482		1	3403	5.80	3404	6.05	3405	6.05	3406	6.15	3407	6.25	3408	6.25
KLG100482		1	3409	6.30	3410	6.35	3411	6.20	3412	6.25	3413	6.35	3414	6.35
KLG100482		1	3415	6.30	3416	6.25	3417	6.30	3418	6.25	3419	6.25	3501	6.00
KLG100482		1	3502	6.13	3503	6.30	3504	6.45	3505	6.50	3506	6.45	3507	6.60
KLG100482		1	3508	6.65	3509	6.65	3510	6.63	3511	6.65	3512	6.68	3513	6.64
KLG100482		1	3514	6.50	3515	6.50	3516	6.50	3517	6.38	3518	6.45	3519	1111
KLG100482		1	3601	6.85	3602	7.00	3603	7.15	3604	6.90	3605	6.90	3606	6.85
KLG100482		1	3607	6.90	3608	6.90	3609	6.90	3610	6.90	3611	6.93	3612	6.90
KLG100482		1	3613	6.92	3614	6.85	3615	6.95	3616	6.90	3617	6.83	3618	6.85
KLG100482		1	3619	6.70	3620	6.80	3701	7.68	3702	8.05	3703	8.05	3704	8.10
KLG100482		1	3705	8.25	3706	8.55	3707	8.50	3708	8.50	3709	8.55	3710	8.40
KLG100482		1	3711	8.40	3712	8.20	3713	8.05	3714	7.85	3715	7.70	3716	7.63
KLG100482		1	3717	7.48	3718	7.48	3719	7.45	3720	7.35	3801	6.93	3802	6.93

LOC	DATE	RUN	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)	PIN ID	MEAS (IN)
KLG	100482	1	3803	6.95	3804	6.88	3805	6.85	3806	6.85	3807	6.85	3808	6.70
KLG	100482	1	3809	6.55	3810	6.65	3811	6.55	3812	6.55	3813	6.49	3814	6.38
KLG	100482	1	3815	6.30	3816	6.18	3817	6.13	3818	6.15	3819	6.00	3901	8.90
KLG	100482	1	3902	8.90	3903	8.95	3904	8.98	3905	8.95	3906	8.65	3907	8.68
KLG	100482	1	3908	8.50	3909	8.50	3910	8.43	3911	8.32	3912	8.20	3913	8.10
KLG	100482	1	3914	8.10	3915	7.93	3916	7.80	3917	7.73	3918	7.65	3919	7.60
KLG	100482	1	3920	7.50	4101	9.50	4102	9.50	4103	9.55	4104	9.55	4105	9.48
KLG	100482	1	4106	9.40	4107	9.28	4108	9.00	4109	9.08	4110	8.73	4111	8.70
KLG	100482	1	4112	8.50	4113	8.55	4114	8.35	4115	8.30	4116	8.30	4117	8.15
KLG	100482	1	4118	8.08	4119	8.03	4201	10.10	4202	10.03	4203	9.85	4204	9.95
KLG	100482	1	4205	9.80	4206	9.63	4207	9.55	4208	9.43	4209	9.43	4210	9.00
KLG	100482	1	4211	8.85	4212	8.85	4213	8.70	4214	8.50	4215	8.45	4216	8.30
KLG	100482	1	4217	8.25	4218	8.18	4219	8.20	4301	8.75	4302	8.75	4303	8.75
KLG	100482	1	4304	8.64	4305	8.55	4306	8.45	4307	8.43	4308	8.38	4309	8.30
KLG	100482	1	4310	8.25	4311	8.20	4312	8.20	4313	8.18	4314	8.05	4315	8.05
KLG	100482	1	4316	7.95	4317	7.95	4318	7.95	4319	7.90	4401	10.00	4402	10.00
KLG	100482	1	4403	9.90	4404	9.85	4405	9.75	4406	9.70	4407	9.66	4408	9.60
KLG	100482	1	4409	9.50	4410	9.40	4411	9.18	4412	9.00	4413	8.95	4414	8.80
KLG	100482	1	4415	8.55	4416	8.44	4417	8.58	4418	8.62	4419	8.48	4501	8.82
KLG	100482	1	4502	8.88	4503	8.88	4504	9.00	4505	8.95	4506	9.20	4507	9.00
KLG	100482	1	4508	8.80	4509	8.85	4510	8.70	4511	8.48	4512	8.25	4513	8.28
KLG	100482	1	4514	8.28	4515	8.10	4516	7.90	4517	7.85	4518	7.73	4519	7.65
KLG	100482	1	4520	7.58	4601	9.67	4602	9.68	4603	9.70	4604	9.80	4605	9.80
KLG	100482	1	4606	9.75	4607	9.65	4608	9.55	4609	9.40	4610	9.20	4611	9.15
KLG	100482	1	4612	9.00	4613	9.00	4614	8.85	4615	8.75	4616	8.70	4617	8.65
KLG	100482	1	4618	8.30	4619	8.40	4701	9.43	4702	9.25	4703	9.25	4704	9.20
KLG	100482	1	4705	9.15	4706	8.98	4707	8.73	4708	8.75	4709	8.45	4710	8.45
KLG	100482	1	4711	8.50	4712	8.35	4713	8.05	4714	8.15	4715	8.05	4716	7.95
KLG	100482	1	4717	7.90	4718	7.65	4719	7.65	4720	7.62	4801	9.20	4802	9.37
KLG	100482	1	4803	9.32	4804	9.32	4805	8.75	4806	8.65	4807	8.45	4808	8.10
KLG	100422	1	4809	8.00	4810	8.00	4811	7.82	4812	7.80	4813	7.50	4814	7.65
KLG	100482	1	4815	7.48	4816	7.52	4817	7.60	4818	7.60	4819	7.60	4901	6.60
KLG	100482	1	4902	6.75	4903	6.80	4904	6.75	4905	6.75	4906	6.75	4907	6.63
KLG	100482	1	4908	6.73	4909	6.75	4910	6.60	4911	6.60	4912	6.60	4913	6.50
KLG	100482	1	4914	6.63	4915	6.65	4916	6.60	4917	6.54	4918	6.65	4919	6.60

TABLE F6: CROSS SECTION DATA FROM RUNS 1 - 4, LEFT SECTION

LOCATION	DATE	RUN*N	PIN PLOT	ROW	LOC	READING (IN)	EROS/DEP (IN)
KLG	102782	2	3	1	1	7.48	-0.43
KLG	102782	2	3	1	2	7.40	-0.40
KLG	102782	2	3	1	3	7.56	-0.26
KLG	102782	2	3	1	4	7.64	-0.34
KLG	102782	2	3	1	5	7.65	-0.35
KLG	102782	2	3	1	6	7.48	0.07
KLG	102782	2	3	1	7	7.54	0.16
KLG	102782	2	3	1	8	7.50	0.20
KLG	102782	2	3	1	9	7.47	0.13
KLG	102782	2	3	1	10	7.38	0.32
KLG	102782	2	3	1	11	7.40	0.30
KLG	102782	2	3	1	12	7.28	0.37
KLG	102782	2	3	1	13	7.27	0.38
KLG	102782	2	3	1	14	7.27	0.38
KLG	102782	2	3	1	15	7.25	0.40
KLG	102782	2	3	1	16	7.20	0.30
KLG	102782	2	3	1	17	7.15	0.23
KLG	102782	2	3	1	18	7.16	0.24
KLG	102782	2	3	1	19	7.23	0.17
KLG	102782	2	3	2	1	8.10	-1.15
KLG	102782	2	3	2	2	8.00	-0.80
KLG	102782	2	3	2	3	7.90	-0.72
KLG	102782	2	3	2	4	7.60	-0.45
KLG	102782	2	3	2	5	7.78	-0.53
KLG	102782	2	3	2	6	7.60	-0.45
KLG	102782	2	3	2	7	7.54	-0.44
KLG	102782	2	3	2	8	7.55	-0.45
KLG	102782	2	3	2	9	7.58	-0.40
KLG	102782	2	3	2	10	7.55	-0.30
KLG	102782	2	3	2	11	7.96	-0.66
KLG	102782	2	3	2	12	8.14	-0.89
KLG	102782	2	3	2	13	8.24	-0.94
KLG	102782	2	3	2	14	8.16	-0.76
KLG	102782	2	3	2	15	8.15	-0.75
KLG	102782	2	3	2	16	8.08	-0.58
KLG	102782	2	3	2	17	8.10	-0.50
KLG	102782	2	3	2	18	7.65	-0.05
KLG	102782	2	3	2	19	7.55	0.0
KLG	102782	2	3	3	1	6.85	-1.35
KLG	102782	2	3	3	2	6.78	-1.08
KLG	102782	2	3	3	3	6.76	-1.11
KLG	102782	2	3	3	4	6.78	-0.78
KLG	102782	2	3	3	5	6.73	-0.58
KLG	102782	2	3	3	6	6.70	-0.50
KLG	102782	2	3	3	7	6.76	-0.61
KLG	102782	2	3	3	8	6.80	-0.50

LOCATION	DATE	RUN*N	PIN	READING (IN)	EROS/DEP (IN)
KLG	102782	2	3 3 9	6.90	-0.55
KLG	102782	2	3 3 10	6.97	-0.62
KLG	102782	2	3 3 11	7.13	-0.83
KLG	102782	2	3 3 12	7.15	-0.85
KLG	102782	2	3 3 13	7.25	-0.95
KLG	102782	2	3 3 14	7.28	-0.98
KLG	102782	2	3 3 15	7.30	-1.00
KLG	102782	2	3 3 16	7.40	-1.05
KLG	102782	2	3 3 17	7.47	-1.07
KLG	102782	2	3 3 18	7.48	-1.08
KLG	102782	2	3 3 19	7.30	-0.80
KLG	102782	2	3 3 20	6.87	-0.37
KLG	102782	2	3 4 1	6.68	-1.13
KLG	102782	2	3 4 2	6.68	-1.03
KLG	102782	2	3 4 3	6.75	-0.95
KLG	102782	2	3 4 4	6.70	-0.65
KLG	102782	2	3 4 5	6.77	-0.72
KLG	102782	2	3 4 6	6.78	-0.63
KLG	102782	2	3 4 7	6.85	-0.60
KLG	102782	2	3 4 8	6.74	-0.49
KLG	102782	2	3 4 9	6.80	-0.50
KLG	102782	2	3 4 10	6.75	-0.40
KLG	102782	2	3 4 11	6.00	0.20
KLG	102782	2	3 4 12	6.70	-0.45
KLG	102782	2	3 4 13	6.60	-0.25
KLG	102782	2	3 4 14	6.58	-0.23
KLG	102782	2	3 4 15	6.58	-0.28
KLG	102782	2	3 4 16	6.48	-0.23
KLG	102782	2	3 4 17	6.45	-0.15
KLG	102782	2	3 4 18	6.34	-0.09
KLG	102782	2	3 4 19	6.24	0.01
KLG	102782	2	3 5 1	6.95	-0.95
KLG	102782	2	3 5 2	6.87	-0.74
KLG	102782	2	3 5 3	6.93	-0.63
KLG	102782	2	3 5 4	7.08	-0.83
KLG	102782	2	3 5 5	7.08	-0.58
KLG	102782	2	3 5 6	7.10	-0.65
KLG	102782	2	3 5 7	7.12	-0.52
KLG	102782	2	3 5 8	7.21	-0.56
KLG	102782	2	3 5 9	7.20	-0.55
KLG	102782	2	3 5 10	7.23	-0.60
KLG	102782	2	3 5 11	7.26	-0.61
KLG	102782	2	3 5 12	7.38	-0.70
KLG	102782	2	3 5 13	7.39	-0.75
KLG	102782	2	3 5 14	7.35	-0.85
KLG	102782	2	3 5 15	7.32	-0.82
KLG	102782	2	3 5 16	7.34	-0.84
KLG	102782	2	3 5 17	7.15	-0.77
KLG	102782	2	3 5 18	7.08	-0.63
KLG	102782	2	3 5 19	11.11	0.0
KLG	102782	2	3 6 1	7.29	-0.44
KLG	102782	2	3 6 2	7.20	-0.20
KLG	102782	2	3 6 3	7.20	-0.05

LOCATION	DATE	RUN*N	PIN	READING (IN)	EROS. DEP (IN)
KLG	102782	2	3 6 4	6.78	0.12
KLG	102782	2	3 6 5	7.12	-0.22
KLG	102782	2	3 6 6	7.15	-0.30
KLG	102782	2	3 6 7	7.10	-0.20
KLG	102782	2	3 6 8	7.13	-0.23
KLG	102782	2	3 6 9	7.13	-0.23
KLG	102782	2	3 6 10	6.95	-0.05
KLG	102782	2	3 6 11	7.04	-0.11
KLG	102782	2	3 6 12	6.95	-0.05
KLG	102782	2	3 6 13	6.97	-0.05
KLG	102782	2	3 6 14	6.98	-0.13
KLG	102782	2	3 6 15	6.98	-0.03
KLG	102782	2	3 6 16	6.95	-0.05
KLG	102782	2	3 6 17	7.05	-0.22
KLG	102782	2	3 6 18	6.98	-0.13
KLG	102782	2	3 6 19	6.97	-0.27
KLG	102782	2	3 6 20	6.75	0.05
KLG	102782	2	3 7 1	7.20	0.48
KLG	102782	2	3 7 2	7.20	0.85
KLG	102782	2	3 7 3	7.34	0.71
KLG	102782	2	3 7 4	7.39	0.71
KLG	102782	2	3 7 5	7.48	0.77
KLG	102782	2	3 7 6	7.59	0.96
KLG	102782	2	3 7 7	7.65	0.85
KLG	102782	2	3 7 8	7.75	0.75
KLG	102782	2	3 7 9	7.85	0.70
KLG	102782	2	3 7 10	7.90	0.50
KLG	102782	2	3 7 11	7.98	0.42
KLG	102782	2	3 7 12	7.99	0.21
KLG	102782	2	3 7 13	7.95	0.10
KLG	102782	2	3 7 14	7.89	-0.04
KLG	102782	2	3 7 15	7.90	-0.20
KLG	102782	2	3 7 16	7.90	-0.27
KLG	102782	2	3 7 17	7.96	-0.48
KLG	102782	2	3 7 18	7.94	-0.46
KLG	102782	2	3 7 19	7.95	-0.50
KLG	102782	2	3 7 20	7.80	-0.45
KLG	102782	2	3 8 1	6.20	0.73
KLG	102782	2	3 8 2	6.31	0.62
KLG	102782	2	3 8 3	6.30	0.65
KLG	102782	2	3 8 4	6.34	0.54
KLG	102782	2	3 8 5	6.48	0.37
KLG	102782	2	3 8 6	6.52	0.33
KLG	102782	2	3 8 7	6.55	0.30
KLG	102782	2	3 8 8	6.60	0.10
KLG	102782	2	3 8 9	6.70	-0.15
KLG	102782	2	3 8 10	6.74	-0.09
KLG	102782	2	3 8 11	6.70	-0.15
KLG	102782	2	3 8 12	6.78	-0.23
KLG	102782	2	3 8 13	6.82	-0.33
KLG	102782	2	3 8 14	6.80	-0.42

LOCATION	DATE	RUN#N	PIN	READING(IN)	EROS/DEP IN
KLG	102782	2	3 8 15	6.86	-0.56
KLG	102782	2	3 8 16	6.90	-0.72
KLG	102782	2	3 8 17	6.90	-0.77
KLG	102782	2	3 8 18	6.90	-0.75
KLG	102782	2	3 8 19	6.84	-0.84
KLG	102782	2	3 9 1	7.90	1.00
KLG	102782	2	3 9 2	7.90	1.00
KLG	102782	2	3 9 3	7.90	1.05
KLG	102782	2	3 9 4	8.02	0.96
KLG	102782	2	3 9 5	8.22	0.73
KLG	102782	2	3 9 6	8.27	0.38
KLG	102782	2	3 9 7	8.45	0.23
KLG	102782	2	3 9 8	8.50	0.0
KLG	102782	2	3 9 9	8.50	0.0
KLG	102782	2	3 9 10	8.47	-0.04
KLG	102782	2	3 9 11	8.65	-0.33
KLG	102782	2	3 9 12	8.68	-0.48
KLG	102782	2	3 9 13	8.73	-0.63
KLG	102782	2	3 9 14	8.75	-0.65
KLG	102782	2	3 9 15	8.68	-0.75
KLG	102782	2	3 9 16	8.76	-0.96
KLG	102782	2	3 9 17	8.90	-1.17
KLG	102782	2	3 9 18	9.00	-1.35
KLG	102782	2	3 9 19	8.83	-1.23
KLG	102782	2	3 9 20	8.75	-1.25
				AVE =	-0.28
KLG	102782	2	4 1 1	8.53	0.97
KLG	102782	2	4 1 2	8.44	1.06
KLG	102782	2	4 1 3	8.56	0.93
KLG	102782	2	4 1 4	8.60	0.95
KLG	102782	2	4 1 5	8.58	0.90
KLG	102782	2	4 1 6	8.75	0.65
KLG	102782	2	4 1 7	8.80	0.48
KLG	102782	2	4 1 8	8.90	0.10
KLG	102782	2	4 1 9	8.85	0.23
KLG	102782	2	4 1 10	8.98	-0.25
KLG	102782	2	4 1 11	9.05	-0.35
KLG	102782	2	4 1 12	8.95	-0.45
KLG	102782	2	4 1 13	8.90	-0.35
KLG	102782	2	4 1 14	8.89	-0.54
KLG	102782	2	4 1 15	8.85	-0.55
KLG	102782	2	4 1 16	8.85	-0.55
KLG	102782	2	4 1 17	8.87	-0.72
KLG	102782	2	4 1 18	9.03	-0.95
KLG	102782	2	4 1 19	8.90	-0.87
KLG	102782	2	4 2 1	8.28	1.82
KLG	102782	2	4 2 2	8.42	1.61
KLG	102782	2	4 2 3	8.50	1.35

LOCATION	DATE	RUN#N	PIN	READING(IN)	ERCS/DEP(IN)
KLG	102782	2	4 2 4	8.56	1.39
KLG	102782	2	4 2 5	8.60	1.20
KLG	102782	2	4 2 6	8.65	0.96
KLG	102782	2	4 2 7	8.95	0.60
KLG	102782	2	4 2 8	9.03	0.40
KLG	102782	2	4 2 9	9.03	0.40
KLG	102782	2	4 2 10	9.18	-0.18
KLG	102782	2	4 2 11	9.20	-0.35
KLG	102782	2	4 2 12	9.32	-0.47
KLG	102782	2	4 2 13	9.55	-0.85
KLG	102782	2	4 2 14	9.85	-1.35
KLG	102782	2	4 2 15	10.23	-1.78
KLG	102782	2	4 2 16	10.55	-2.25
KLG	102782	2	4 2 17	10.48	-2.23
KLG	102782	2	4 2 18	10.48	-2.30
KLG	102782	2	4 2 19	10.25	-2.05
KLG	102782	2	4 3 1	8.10	0.65
KLG	102782	2	4 3 2	8.20	0.55
KLG	102782	2	4 3 3	8.20	0.55
KLG	102782	2	4 3 4	8.24	0.40
KLG	102782	2	4 3 5	8.33	0.22
KLG	102782	2	4 3 6	8.37	0.08
KLG	102782	2	4 3 7	8.36	0.07
KLG	102782	2	4 3 8	8.44	-0.06
KLG	102782	2	4 3 9	8.50	-0.20
KLG	102782	2	4 3 10	8.50	-0.25
KLG	102782	2	4 3 11	8.68	-0.48
KLG	102782	2	4 3 12	8.80	-0.60
KLG	102782	2	4 3 13	9.00	-0.82
KLG	102782	2	4 3 14	9.30	-1.25
KLG	102782	2	4 3 15	9.35	-1.30
KLG	102782	2	4 3 16	9.58	-1.63
KLG	102782	2	4 3 17	9.60	-1.65
KLG	102782	2	4 3 18	9.55	-1.60
KLG	102782	2	4 3 19	9.62	-1.72
KLG	102782	2	4 4 1	8.04	1.96
KLG	102782	2	4 4 2	8.08	1.92
KLG	102782	2	4 4 3	8.30	1.60
KLG	102782	2	4 4 4	8.55	1.30
KLG	102782	2	4 4 5	8.70	1.05
KLG	102782	2	4 4 6	8.67	1.03
KLG	102782	2	4 4 7	9.00	0.66
KLG	102782	2	4 4 8	9.00	0.60
KLG	102782	2	4 4 9	9.33	0.17
KLG	102782	2	4 4 10	9.30	0.10
KLG	102782	2	4 4 11	9.45	-0.27
KLG	102782	2	4 4 12	9.47	-0.47
KLG	102782	2	4 4 13	9.55	-0.60
KLG	102782	2	4 4 14	9.75	-0.95
KLG	102782	2	4 4 15	9.90	-1.35
KLG	102782	2	4 4 16	9.77	-1.33

LOCATION	DATE	RUN*N	PIN	READING(IN)	EROS/DEP(IN)
KLG	102782	2	4 4 17	9.75	-1.17
KLG	102782	2	4 4 18	9.88	-1.26
KLG	102782	2	4 4 19	9.95	-1.47
KLG	102782	2	4 5 1	8.55	0.27
KLG	102782	2	4 5 2	8.60	0.28
KLG	102782	2	4 5 3	8.65	0.23
KLG	102782	2	4 5 4	8.67	0.33
KLG	102782	2	4 5 5	8.75	0.20
KLG	102782	2	4 5 6	8.80	0.40
KLG	102782	2	4 5 7	9.05	-0.05
KLG	102782	2	4 5 8	9.10	-0.30
KLG	102782	2	4 5 9	9.38	-0.53
KLG	102782	2	4 5 10	9.41	-0.71
KLG	102782	2	4 5 11	9.52	-1.04
KLG	102782	2	4 5 12	9.70	-1.45
KLG	102782	2	4 5 13	9.98	-1.70
KLG	102782	2	4 5 14	10.05	-1.77
KLG	102782	2	4 5 15	10.33	-2.23
KLG	102782	2	4 5 16	10.75	-2.85
KLG	102782	2	4 5 17	10.82	-2.97
KLG	102782	2	4 5 18	11.12	-3.39
KLG	102782	2	4 5 19	11.25	-3.60
KLG	102782	2	4 5 20	11.29	-3.71
KLG	102782	2	4 6 1	8.72	0.95
KLG	102782	2	4 6 2	8.79	0.89
KLG	102782	2	4 6 3	8.84	0.86
KLG	102782	2	4 6 4	9.00	0.80
KLG	102782	2	4 6 5	9.05	0.75
KLG	102782	2	4 6 6	9.07	0.68
KLG	102782	2	4 6 7	9.25	0.40
KLG	102782	2	4 6 8	9.50	0.05
KLG	102782	2	4 6 9	10.00	-0.60
KLG	102782	2	4 6 10	10.40	-1.20
KLG	102782	2	4 6 11	10.60	-1.45
KLG	102782	2	4 6 12	10.78	-1.78
KLG	102782	2	4 6 13	11.10	-2.10
KLG	102782	2	4 6 14	11.27	-2.42
KLG	102782	2	4 6 15	11.35	-2.60
KLG	102782	2	4 6 16	11.30	-2.60
KLG	102782	2	4 6 17	11.15	-2.50
KLG	102782	2	4 6 18	11.33	-3.03
KLG	102782	2	4 6 19	11.30	-2.90
KLG	102782	2	4 7 1	8.05	1.38
KLG	102782	2	4 7 2	7.98	1.27
KLG	102782	2	4 7 3	8.11	1.14
KLG	102782	2	4 7 4	8.15	1.05
KLG	102782	2	4 7 5	8.28	0.87
KLG	102782	2	4 7 6	8.30	0.68
KLG	102782	2	4 7 7	8.38	0.35
KLG	102782	2	4 7 8	8.46	0.29
KLG	102782	2	4 7 9	8.58	-0.13

LOCATION	DATE	RUN*N	PIN	READING(IN)	EROS.DEP(IN)
KLG	102782	2	4 7 10	8.73	-0.28
KLG	102782	2	4 7 11	8.80	-0.30
KLG	102782	2	4 7 12	9.03	-0.68
KLG	102782	2	4 7 13	9.07	-1.02
KLG	102782	2	4 7 14	9.15	-1.00
KLG	102782	2	4 7 15	9.20	-1.15
KLG	102782	2	4 7 16	9.30	-1.35
KLG	102782	2	4 7 17	9.45	-1.55
KLG	102782	2	4 7 18	9.48	-1.83
KLG	102782	2	4 7 19	9.48	-1.83
KLG	102782	2	4 7 20	9.56	-1.94
KLG	102782	2	4 8 1	8.20	1.00
KLG	102782	2	4 8 2	8.15	1.22
KLG	102782	2	4 8 3	8.05	1.27
KLG	102782	2	4 8 4	8.10	1.22
KLG	102782	2	4 8 5	8.10	0.65
KLG	102782	2	4 8 6	8.00	0.65
KLG	102782	2	4 8 7	7.95	0.50
KLG	102782	2	4 8 8	7.95	0.15
KLG	102782	2	4 8 9	8.15	-0.15
KLG	102782	2	4 8 10	8.15	-0.15
KLG	102782	2	4 8 11	8.26	-0.44
KLG	102782	2	4 8 12	8.40	-0.60
KLG	102782	2	4 8 13	8.41	-0.91
KLG	102782	2	4 8 14	8.84	-1.19
KLG	102782	2	4 8 15	9.35	-1.27
KLG	102782	2	4 8 16	9.40	-1.88
KLG	102782	2	4 8 17	9.50	-1.90
KLG	102782	2	4 8 18	9.68	-2.08
KLG	102782	2	4 8 19	9.55	-1.95
KLG	102782	2	4 9 1	7.55	-0.95
KLG	102782	2	4 9 2	7.45	-0.70
KLG	102782	2	4 9 3	7.00	-0.20
KLG	102782	2	4 9 4	7.00	-0.25
KLG	102782	2	4 9 5	6.90	-0.15
KLG	102782	2	4 9 6	7.04	-0.29
KLG	102782	2	4 9 7	7.02	-0.39
KLG	102782	2	4 9 8	7.20	-0.47
KLG	102782	2	4 9 9	7.65	-0.90
KLG	102782	2	4 9 10	7.90	-1.30
KLG	102782	2	4 9 11	7.40	-0.80
KLG	102782	2	4 9 12	7.35	-0.75
KLG	102782	2	4 9 13	7.40	-0.90
KLG	102782	2	4 9 14	7.50	-0.87
KLG	102782	2	4 9 15	7.80	-1.15
KLG	102782	2	4 9 16	8.13	-1.53
KLG	102782	2	4 9 17	8.30	-1.76
KLG	102782	2	4 9 18	8.18	-1.53
KLG	102782	2	4 9 19	8.23	-1.68
				AVE =	-0.48

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		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) D. L. Jones, R. M. Khanbilvardi, and A. S. Rogowski		8. PERFORMING ORGANIZATION REPORT NO. 7
9. PERFORMING ORGANIZATION NAME AND ADDRESS Northeast Watershed Research Center USDA-ARS, 110 Research Building A University Park, Pennsylvania 16802		10. PROGRAM ELEMENT NO.
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		14. SPONSORING AGENCY CODE EPA/600/16

15. SUPPLEMENTARY NOTES

This project is part of the EPA-planned and coordinated Federal Interagency Energy/Environment R&D Program.

16. ABSTRACT

Two experimental plots were instrumented with erosion pins to study the correspondence between point erosion and erosion over an area on strip mine soil. Using a rotating boom rainfall simulator, data were collected by sampling the runoff every five minutes for the duration of the rainfall. The amount of sediment eroded or deposited was measured after each simulated rainfall using erosion pins. These results were compared to the sediment load measured by runoff sampling, as well as to the predicted erosion using two analytical models, the Universal Soil Loss Equation (USLE) and an Erosion/Deposition (E/D) model. The E/D model was developed to be a more comprehensive model than the USLE, by including partial area concepts of hydrology and sediment transport equations. Erosion was predicted at specific points on each plot, then an overall value for erosion was estimated.

Comparisons were then made between amounts of soil eroded or deposited at a point using experimental techniques and numerical model predictions. Spatial structure of soil loss distribution is evaluated. Discrepancies between values observed at the pins and values expected based on model results and sediment yield sampling are explained by increases in turbulence and the amount of rain near the pins. Implications with regard to vegetation in the form of stalks are suggested.

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Ecology Environments Earth Atmosphere Environmental Engineering Geography	Hydrology, Limnology Biochemistry Earth Hydrosphere Combustion Refining	Energy Conversion Physical Chemistry Materials Handling Inorganic Chemistry Organic Chemistry Chemical Engineering		6F 8A 8F 8H 10A 10B 7B 7C 13B
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