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THE EFFECTIVENESS OF A SEDIMENT AND EROSION CONTROL ORDINANCE: RICHLAND COUNTY, SOUTH CAROLINA

by

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The effectiveness of the Richland County Sediment and Erosion Control Ordinance is evaluated primarily through documentation of erosion and sediment response to suburban housing development. The Universal Soil Loss Equation (USLE) and the Modified Universal Soil Loss Equation (MUSLE) are used to predict soil erosion and sediment yield, respectively. Suspended sediment concentrations were monitored for three storms to test and compare the accuracy of predicted sediment yields. The USLE estimates for 1970 and 1990 indicate a two-fold increase in soil erosion potential, attributable primarily to construction activity. Observed sediment yields tended to be somewhat lower than those predicted by the MUSLE, but they are similar enough to support the use of the model to determine a first approximation of sediment yield. Observed sediment yields were about an order of magnitude less than estimated soil production in the basin suggesting sediment delivery ratios of only about 10%. This low ratio indicates a large amount of storage in the basin. Stream channel cross-section surveys reveal aggradation and sediment storage in channels, but channel dredging during this study prevented accurate determination of storage volumes. Housing and road construction disrupts the natural erosion-resistant surface and can accelerate erosion and delivery to channel systems.

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ABSTRACT

The effectiveness of the Richland County Sediment and Erosion Control Ordinance is evaluated primarily through documentation of erosion and sediment response to suburban housing development. The Universal Soil Loss Equation (USLE) and the Modified Universal Soil Loss Equation (MUSLE) are used to predict soil erosion and sediment yield, respectively. Suspended sediment concentrations were monitored for three storms to test and compare the accuracy of predicted ~~and~~ sediment yields.

The USLE estimates for 1970 and 1990 indicate a two-fold increase in soil erosion potential, attributable primarily to construction activity. Observed sediment yields tended to be somewhat lower than those predicted by the MUSLE, but they are similar enough to support the use of the model to determine a first approximation of sediment yield.

Observed sediment yields were about an order of magnitude less than estimated soil production in the basin suggesting sediment delivery ratios of only about 10%. This low ratio indicates a large amount of sediment storage in the basin. Stream channel cross-section surveys reveal aggradation and sediment storage in channels, but channel dredging during this study prevented accurate determination of storage volumes.

Housing and road construction disrupts the natural erosion-resistant surface and can initiate accelerated erosion and delivery of sediment to channel systems. Without adherence of contractors to preventative measures specified in approved erosion and sediment control plans, sediment production can be substantially increased even in areas of relatively stable soil such as this in the Sand Hills.

ACKNOWLEDGEMENTS

I would like to express my deepest and sincere gratitude to the members of my thesis committee for their total support, patience, encouragement, and understanding during all phases of my project. Special thanks to Dr. Allan James for helping me keep a positive attitude and to "think rain". I couldn't have tackled this bear without your help.

Thanks to Mungo Inc. for permitting me to use Winslow as a study site. Special thanks to Mr. Bill Dixon for providing plans and taking time from his busy schedule to help me in my project.

I would also like to thank Mr. Ralph Pearson and Jeff Boyer from the Richland County engineer's office for taking time from their busy schedule to enlighten me on sediment and erosion control in the county. Thanks to Mr. William H. Brown, Mr. George Derrick, Mel Gaddy, and Tom Margle for taking time to participate in my interview.

I owe my deepest and sincere thanks to my family for putting up with my "quest" for rain. I know it was hard to understand my obsession with rain and muddy water but, I am certain that one day, you still won't! I dedicate this thesis to Liz, Andy II, and Ben. I love all three of you!

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CHAPTER 1. INTRODUCTION

Soil erosion from land clearing and construction activities, contributes an estimated 600 million tons of sediment to our nation's streams annually (Mertes, 1989). The annual sediment production generated by these activities at a site can be equivalent to decades worth of sediment produced naturally or by agricultural activities (Wolman and Schick, 1967). Such sharp increases in sediment delivery changes the physical and biological characteristics of the stream channel. Environmental changes to receiving streams include channel aggradation and destabilization, and the eradication of fish and plant species due to increased turbidity and bottom sedimentation (Mertes, 1989; Wolman and Schick, 1967). These changes may also result in increased flooding and create a need for expensive remedial measures. In addition, the pollution is visually and aesthetically degrading (Leopold, 1978).

The cost of remedial measures such as channel dredging, flood control projects, sediment filtering from municipal water, and ecological programs is generally passed on to the taxpayer. These costs have resulted in the enactment of recent federal, state, and local legislation, governing land use activities that potentially contribute to soil erosion and sedimentation. Little has been done, however, to test the effectiveness of sediment and erosion control legislation by documenting the compliance or the physical effects in the field.

This study examines soil erosion and sediment yields produced in a small urbanizing basin in Richland County, South Carolina. Field, laboratory, and conventional models are employed to evaluate the importance of a housing development on sediment production, sediment delivery to the channel system, and sediment transport out of the basin. Compliance with the local ordinance is also evaluated along with viewpoints of county officials and engineers.

Local and Federal Regulations for Nonpoint Source Pollution

In order for a sediment and erosion control policy to be successful, the policy must include the following characteristics: it must be supported by sound scientific techniques; it must be based on some philosophy of ethics; and it must be supported by a commitment to implementation through suitable programs (Soil Conservation Society of America, 1976; Benner, 1972). Three common deficiencies are characteristic of inadequate programs: lack of administrative commitment, improper inspection techniques, and lack of enforcement for violation of the policy (Benner, 1972).

The need for implementation programs, inspection, and enforcement call for a strong involvement of local government in the sediment and erosion control planning process. There are several other reasons why the control of soil conservation programs should be in the hands of local officials (Arts, 1987). Federal funding for soil conservation programs has declined while state funding has increased. Implementation of the Federal Water Pollution Control Act requires the development of nonpoint source pollution control (NPS) programs at the state level, and, while the federal government has assumed authority over water policy, states have retained authority to establish land use policy. In order to meet federal water quality goals, soil erosion must be controlled. As the states assume this responsibility for soil conservation, it is appropriate to change the regulatory jurisdiction from federal and local to state and local (Arts, 1987).

In spite of arguments in favor of local jurisdiction over sediment regulation, much of the impetus for regulation has come from the federal government. Realization of the connections between NPS pollution and water quality have led to recent changes in Federal Water Quality policies concerning erosion and sediment regulations. These changes are driving pervasive changes in regulatory practices at the local level. The Water Pollution Act Amendments of 1972 initiated viable regulations on point source pollution, but it was not until the Clean Water Act of 1977 that NPS pollution was addressed (Dzurik, 1990). In the Clean Water Act, Congress defined Water Quality objectives and empowered the Army Corps of Engineers to regulate wetland protection (Sections 401 and 404). Section 208 of the Clean Water Act required proper control of NPS pollution produced by urban, mining, and construction but it failed to provide the Environmental Protection Agency with powers of implementation or enforcement.

Through the recent passage of the Water Quality Act of 1987, Congress directed state governments to conduct planning studies to identify NPS pollutant sources and abatement strategies and allocated $400 million to help states clean up problem areas (Dzurik, 1990). This legislation has led to revitalized interest in the problem of NPS pollution.

Sediment and Erosion Control In South Carolina

In 1971, the South Carolina General Assembly adopted the County Sediment Control Program Act. This act was intended to encourage South Carolina counties and municipalities to adopt local sediment and erosion control policies to govern land-disturbing activities and construction not covered by the South Carolina Erosion and Sediment Reduction Act (South Carolina, 1989). The 1971 act assigns the responsibility for (1) State Permanent Improvement Projects Program (PIP) to the States's Engineer Office, (2) projects outside of the PIP category to the South Carolina Land Resources Commission (SCLRC), and (3) highway construction projects to the South Carolina Department of Highways and Public Transportation (DHPT). Responsibility for construction activities that are not covered by a state agency is left to the counties. To date, only fifteen counties in South Carolina have adopted voluntary sediment and erosion control policy (South Carolina, 1989).

The Richland County Ordinance

The Richland County Sediment and Erosion Control Ordinance was enacted on December 23, 1980 for the purpose of controlling erosion and sedimentation produced by land clearing and construction activities. This ordinance outlines local sediment and erosion control policy, recommends sediment and erosion control measures, and details penalties for failure to comply with the ordinance.

(cont)

The primary objectives of this ordinance are to (1) insure that drainage channels remain clear of obstruction to storm water runoff, (2) control water pollution of streams and drainage channels by urban water runoff, and (3) prevent the encroachment into natural drainage channels by buildings or land improvements. (Richland County, 1981). Individuals and contractors must comply with the provisions of the ordinance (to pg 7) before being issued construction permits by the county. Paramount to the success of the ordinance is the Sediment and Erosion Control Plan, submitted by the contractor to the

County Engineer.

The Richland County Engineer has sole responsibility for approving sediment and erosion control plans and inspecting construction sites for compliance with the ordinance. The inspector compares the structures built on a site with those shown on the Sediment and Erosion Control Plan. To date, no contractor in gross violation of the ordinance has had to be fined or prosecuted; all responded quickly to letters issued by the County Attorney's office (Jeff Boyer, Personal Communication, 1990).

The permitting process marks an improvement insofar as it facilitates the identification of potential high sediment production areas by licensed professional engineers during the planning stage. The success of the ordinance should however, be measured in terms of the sediment actually produced at construction sites. The area and magnitude of soil erosion from construction sites suggests that the problem of sediment production from this source has not been resolved.

The construction trade in South Carolina employs 6.3 percent of non-farm workers and generates an estimated $2.2 billion dollars in revenues (South Carolina, 1989). This industry also generates a tremendous amount of sediment pollution as well as chemical contaminants in the form of petro-chemicals and fertilizers associated with the construction trade. A recent study conducted by the State of South Carolina, indicated that of the 332 water bodies in the state impacted by non-point source pollution, 14 percent were directly affected by construction activity (South Carolina, 1989).

Monitoring Erosion and Sediment Yields

(Cont

Rapid soil erosion occurs during summer months when rainfall is intense (Wolman and Schick, 1967). It is also during these summer months that construction activity is at it's highest peak. The quantity of sediment produced from construction areas has been shown to be from 2 to 200 times greater than for areas in a rural or wooded condition (Wolman and Schick, 1967). Very few studies document the amount of sediment that is produced by construction activity at a given site. Embler and Fletcher (1981) document increased stream turbidity and suspended solids produced by highway construction activity in Richland County, South Carolina. They used automated sediment sampling devices to document an increase in suspended sediment and turbidity in a stream adjacent to a construction site. Although the study area was much smaller than that used by Wolman and Schick (1967), the results were quite similar. Both studies detected a rapid increase in sediment concentrations directly attributed to early activity on the construction site. As construction activities diminished, sediment concentrations decreased but did not return to pre-construction measurements. Sediment and erosion rates could have been much lower if the contractor had implemented suggested erosion control measures (Embler and Fletcher, 1981).

In response to the mandate of the Federal Water Quality Act, the State of South Carolina, Department of Health and Environmental Control (DHEC) in cooperation with the Soil Conservation Commission of the SCLRCC , and several local universities, recently completed a comprehensive assessment of non-point source pollution and management programs for the state (South Carolina, 1989). Although the studies primarily focus on chemical and biological non-point source pollution, there is information on sediment and erosion control for construction sites and a detailed discussion on use of a Geographic Information System (GIS) to define potential non-point source pollution problems in South Carolina (South Carolina, 1989). This assessment also outlines long-term and short-term goals for the control of sediment and erosion produced by construction activity in an urbanizing area.

STATEMENT OF PURPOSE

The primary objective of this study is to determine the effectiveness of the Richland County Sediment and Erosion Control Ordinance in controlling the amount of erosion and sedimentation that occurs during various phases in the construction of a family housing sub-division. The effectiveness of the Richland County Sediment and Erosion Control Ordinance can only be based on the degree of contractor compliance with sediment and erosion control planning or through direct measurement of soil erosion and sediment yields. The county does not deploy personnel to sample storm-water for determination of suspended solids concentrations or to observe construction sites during rainstorms.

Effectiveness of the ordinance will be evaluated in terms of (1) erosion and sediment response, and (2) ordinance compliance. Field monitoring of erosion and sediment concentrations on and below the construction site was conducted to estimate erosion rates and sediment yields. These rates are compared to rates predicted by soil loss and sediment yield models for the same area under land use conditions both during construction and prior to construction in 1970. Compliance is evaluated by comparing the sediment and erosion control plan submitted to the County Engineer with actual sediment and erosion control structures on the site.

The secondary objective of this study is to develop county government and engineering firm perspectives concerning governmental control of sediment and erosion in Richland County. Local government officials, contractors, and consulting engineers, were interviewed to gather their collective perspective concerning the history of the ordinance as well as their opinions on the strengths and shortcomings of the ordinance, and recommendations to improve the ordinance.

Study Site Description

The study site is located in northern Richland County, 12.5 miles (20 km) northwest of Columbia, South Carolina. The Winslow Creek drainage basin is bordered to the north by Lee Road, to the south by Clemson Road, to the west by Longtown Road, and to the east by Hardscrabble Road (Figure 1-1). The basin is at elevations ranging from 305 feet (93 m) to 450 feet (137 m) along the northern half of the coastal plain known as the Sand Hills. The Sand Hills are characterized by the numerous springs and streams which are fed by groundwater throughout the year. Soils are well-drained at higher elevations and on side slopes but poorly-drained along valley bottoms (Lawrence, 1978).

This study is concerned with a 1.2 square mile (3.04 km^2) drainage basin which lies in the northeast corner of the larger Crane Creek drainage basin (Figure 1-2). The area is characterized by gentle slopes, thick deciduous woods and thickets along the creeks, and a mix of coniferous and deciduous trees at the higher elevations and slopes. Winslow Creek bisects the drainage basin beginning in the upper part of the basin near Lee Road and extending in a

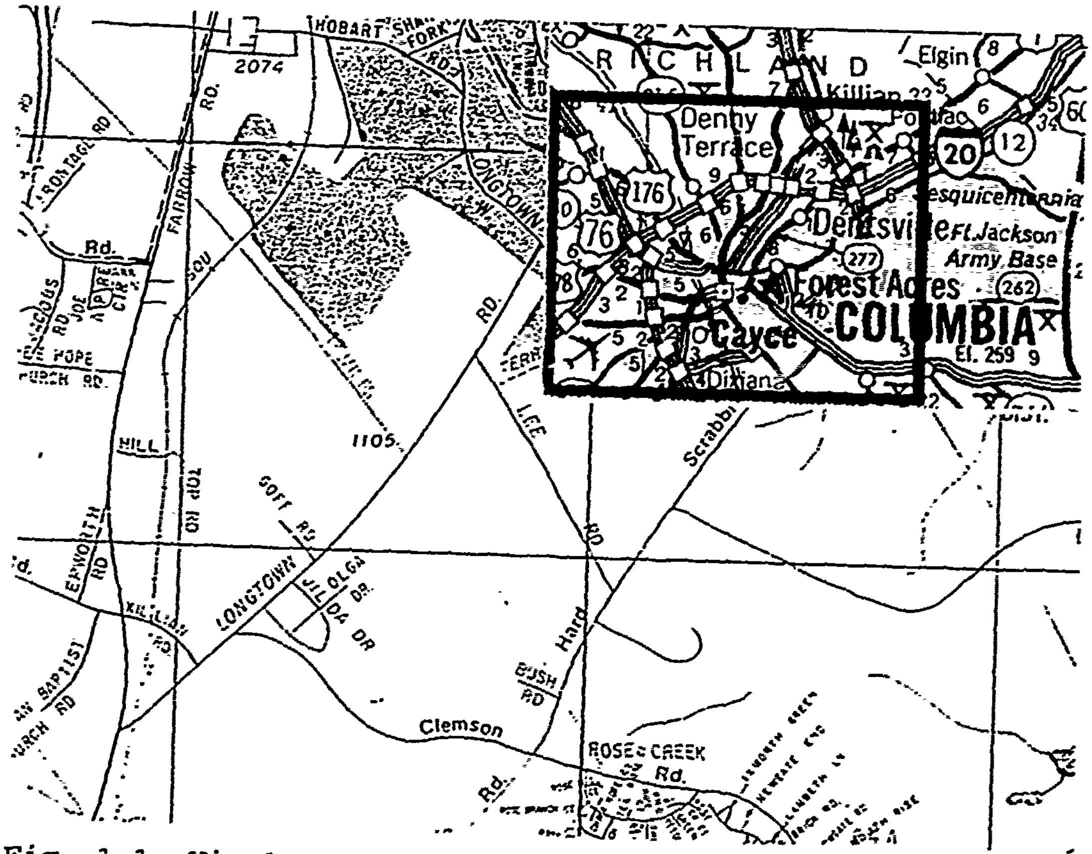
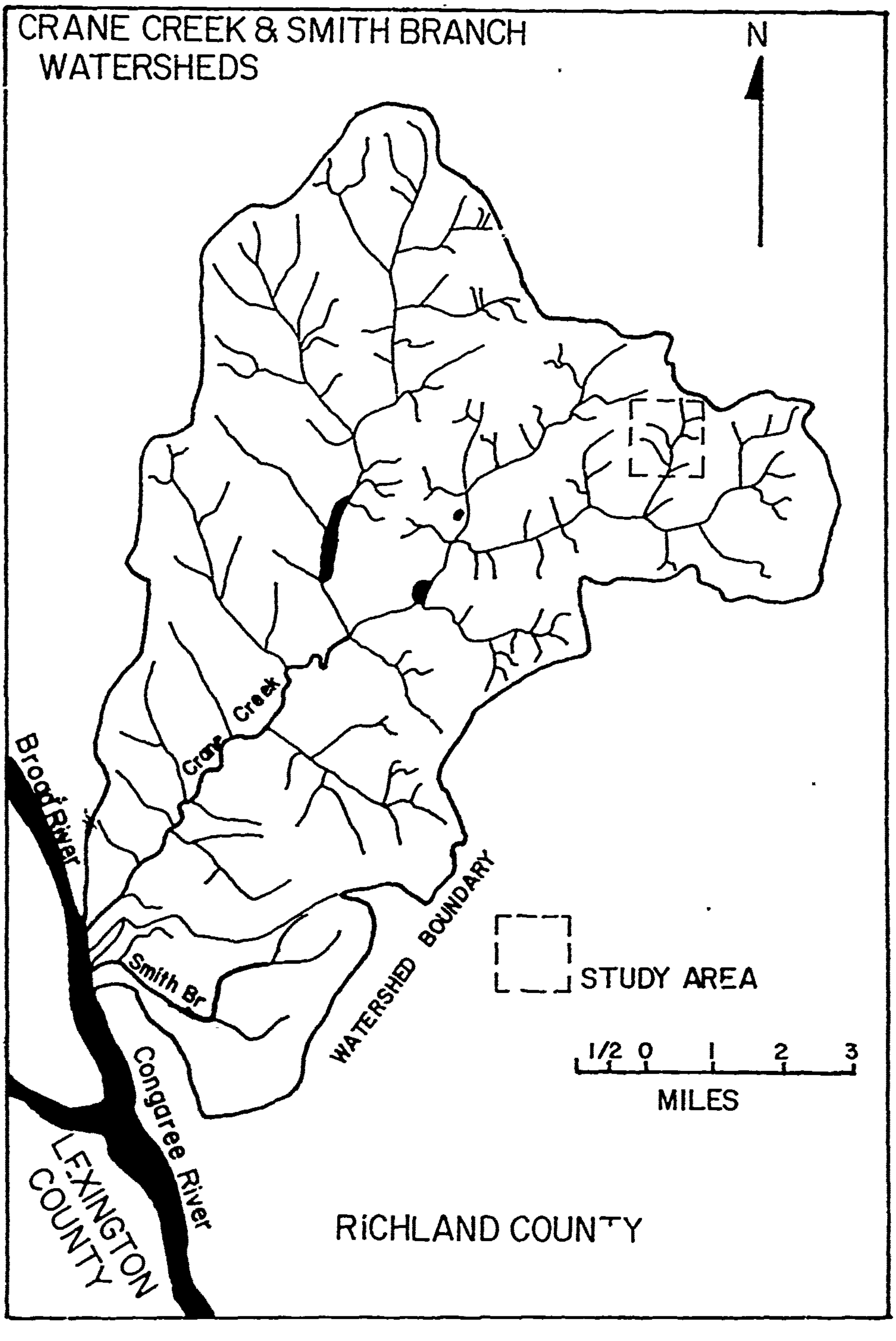


Fig. 1-1 Winslow Creek Study Site in Richland County.


CRANE CREEK & SMITH BRANCH
WATERSHEDS
N
Crane Creek
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Smith Br
Congaree River
WATERSHED BOUNDARY
STUDY AREA
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COUNTY
RICHLAND COUNTY

southerly direction for 7,000 feet (2,133 m) to Clemson Road (Figure 1-3). At Clemson Road, Winslow Creek drains the basin through a pair of concrete pipes approximately 30" and 36" in diameter (Photo 1-1).

Richland County is generally hot and humid in the summer with average daily temperatures ranging from 80-90°F (26-32°C). Rainfall for the summer months averages 5" per month (12.7 cm/mo) (Lawrence, 1978). Summer storms in the study area are typically convective storms although occasional frontal storms may pass through. The convective storms produce highly variable amounts and intensities of rainfall throughout the study area while frontal storms produced a more uniform rainfall.

Ninety percent of the area contained within the Winslow Creek drainage basin is currently being developed for single family housing. Before stream-side development along Winslow Creek could take place, Winslow Creek and it's tributaries were modified to, lower the water table and drain low lying-areas within the basin. Modifications increased the depth of some channels by as much as 10 feet (3 m) and width to as much 40 feet (12 m) (Photo 1-2).

Three major soil series are found in the Winslow Creek basin: the Johnston (Jo) series, Lakeland (LaB, LaD) series, and Pelion (PeB, PeD) series (Figure 1-4). The Lakeland and Pelion Series, characteristic of the Sand Hills, developed primarily on unconsolidated marine deposits

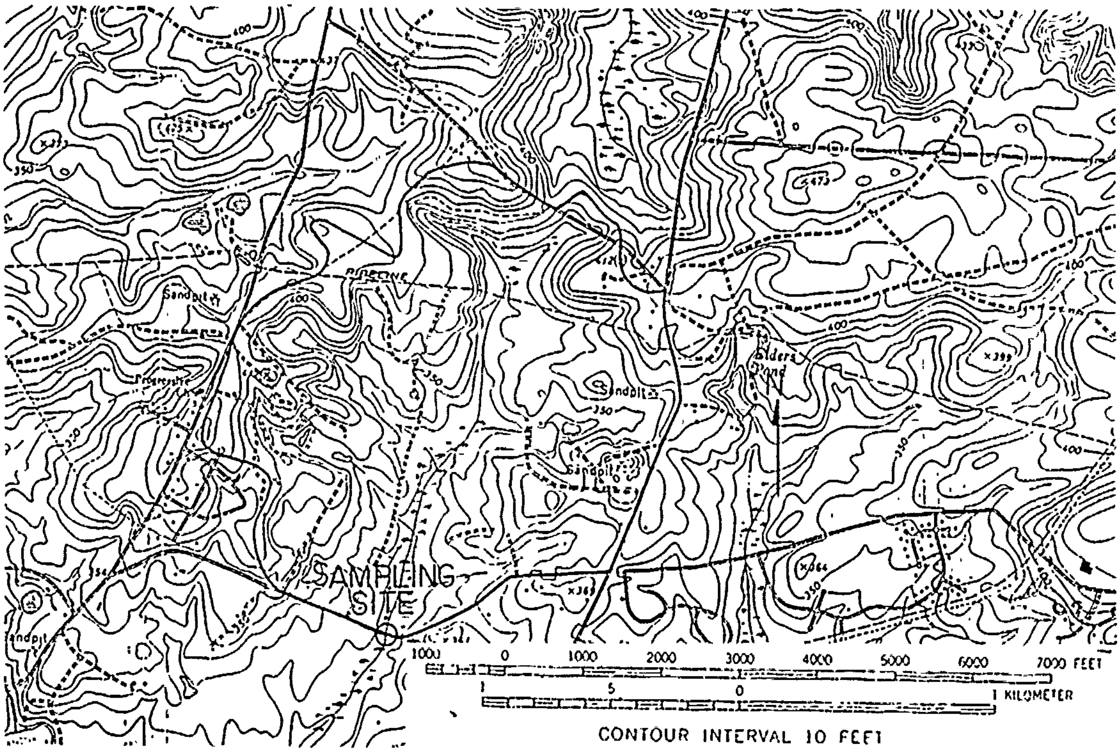

Fig. 1-3 Winslow Creek Drainage Basin.

Photo 1-1 Downstream section of 30" and 36" concrete pipes.

Photo 1-2 Upstream view of Moss Field Creek. Channel improvements include deepening and widening of channel.

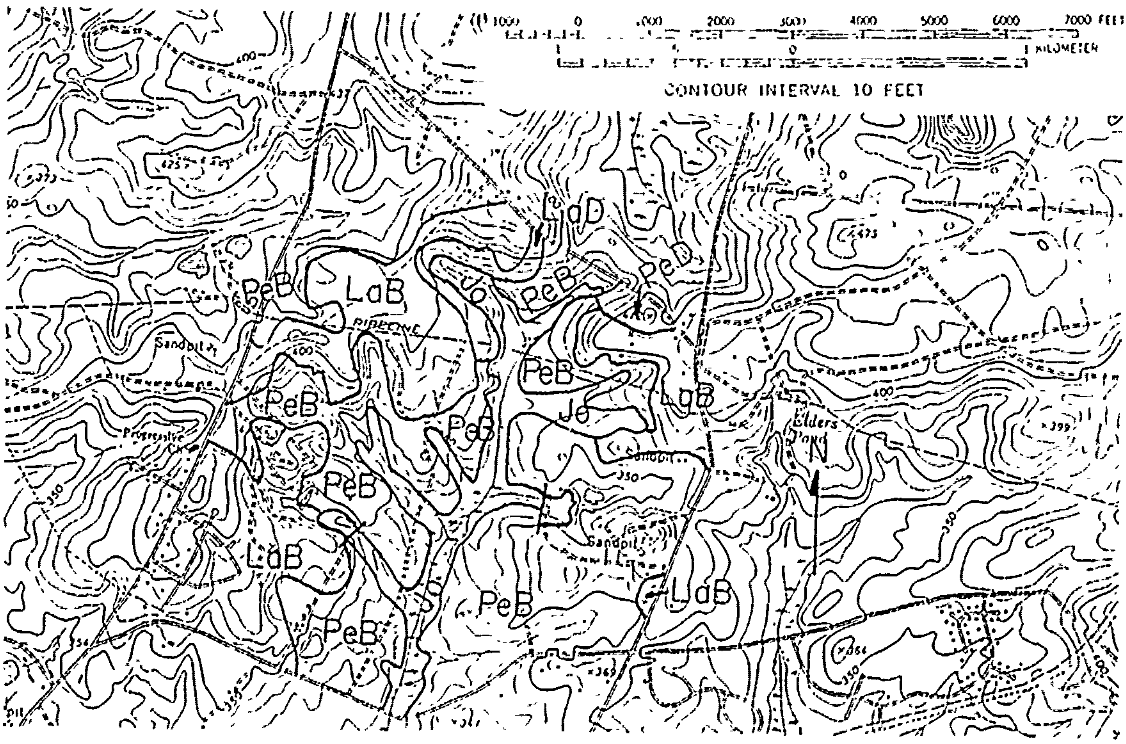

Fig. 1-4 Winslow Creek soils series map.

of light colored sands and kaolin clay (Lawrence, 1978). The Johnston (Jo) series are deep, very poorly drained soils that form in loamy fluvial and marine sediment (Lawrence, 1978) (Photo 1-3). These soils are found along stream channels and within the flood plain of the basin. The Lakeland (LaB, LaD) soils are deep, excessively drained, very permeable sandy soils formed in thick beds of sandy marine sediment (Lawrence, 1978). These soils are found on broad ridge tops and side slopes in the basin. The Pelion (PeB, PeD) soils are deep, moderately well drained permeable sandy soils. They are formed on thick beds of marine sediment found mainly on smooth and broken side slopes (Lawrence, 1978).

Photo 1-3 Typical Johnston Loam stripped of protective vegetation. Note standing water one-week after storm.

CHAPTER 2. METHODOLOGY

Standard field, laboratory, and analytical methods were employed to test the effectiveness of sediment and erosion control practices at a construction site in Richland County. These procedures were applied as rigorously as possible within the limitations of available resources. Cost, time, equipment, and manpower limitations required the selection of simple, inexpensive, manually operated devices for field and laboratory procedures. Nevertheless, this study presents a large number of direct measurements of precipitation, stream-flow sediment concentration, soil erosion, and channel changes that provide substantial documentation of the effectiveness of sediment and soil erosion control measures in the basin. In addition, conventional models are employed to obtain independent estimates of the effects of urbanization on sedimentation and soil erosion.

Precipitation Measurement

Measurement of rainfall duration, timing, and interval for each observed storm was required to calculate the rainfall erosivity factor (R) in the Universal Soil Loss Equation (USLE). Use of rainfall data from weather stations in the Columbia area would not have been appropriate due to the highly variable nature of precipitation. Isohyetal maps were constructed to compare the spatial variability of different storms and their effect on stream hydrograph response.

The location of the study site 12.5 miles northeast of Columbia did not permit around-the-clock monitoring of rainfall and storm-water sampling. Daily weather forecasts and television weather radar proved valuable in the monitoring and selection of potential storms. Convectional afternoon thunderstorms were selected for monitoring only if the weather forecast predicted a 50% or greater chance of thunderstorms or thundershowers for the Columbia metro area. Frontal storms were selected for monitoring based on the movement of cold fronts in the direction of the study site.

Eight non-recording rain gauges were set up near the ground surface with the apperature twelve inches above ground to measure the amount of precipitation for each observed storm. Gauges were placed at approximately uniformly-spaced intervals across the study site based on accessibility, lack of overhead obstructions, and location around the perimeter and interior of the drainage basin (Figure 2-1). Rainfall measurements were taken from gauge number 1, close to the sediment sampling station on Clemson Road, approximately every 5 minutes for the duration of each storm. Total rainfall in rain gauges 2 through 8 were recorded manually at the end of each storm.

Total rainfall volume for each storm was estimated

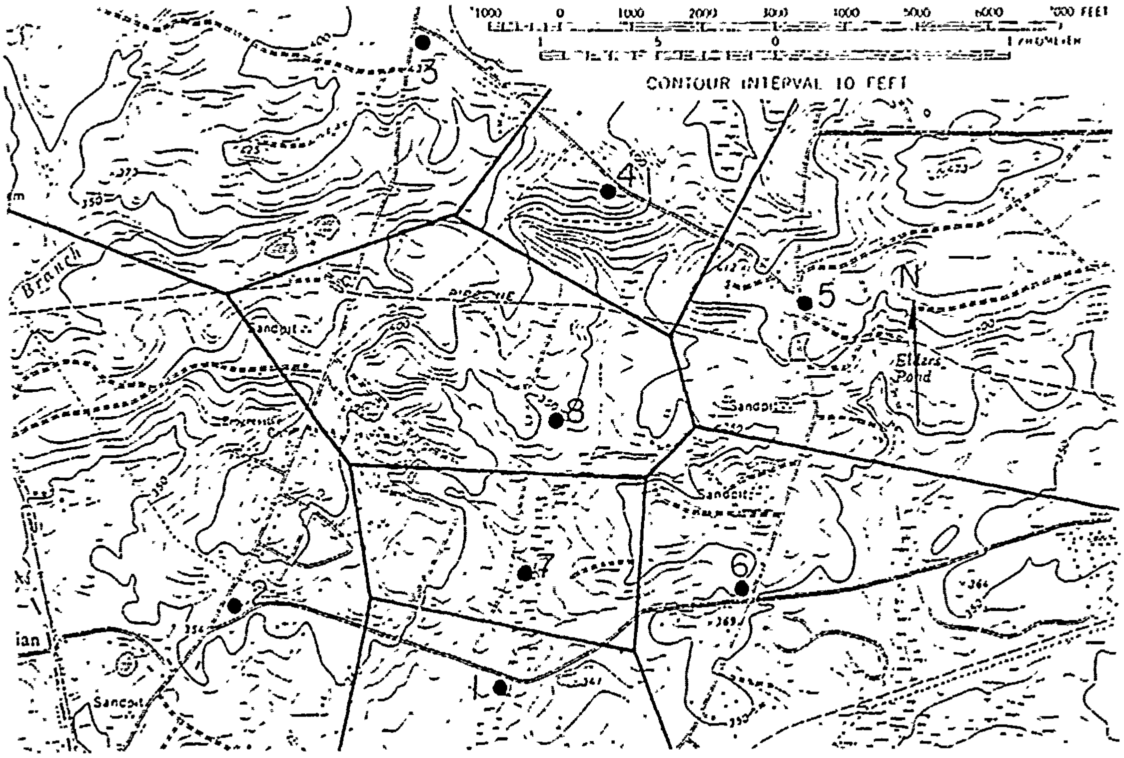

Fig. 2-1 Rain gauge locations and Thiessen polygons.

using a Thiessen-weighted average (Dunne and Leopold, 1978). Thiessen polygons were constructed around each rain gauge (Figure 2-1) to determine the proportion of basin area monitored by each gauge. These ratios were applied to total rainfall at each gauge to produce area-weighted rainfall values which were summed to provide an estimate of total rainfall over the basin for a given storm. Rainfall duration, rates, and intensity from gauge number 1 were then applied to the Thiessen-weighted rainfall values, resulting in storm rainfall duration-intensity plots for the entire basin which are superimposed over stream flow hydrographs (Figure 2-2). This procedure assumes that temporal variations in precipitation at each gauge were in sequence with gauge 1 at Clemson Road, and it scales this temporal variation to spatial patterns of total precipitation around the individual gauges.

Stream Velocity and Discharge Measurement

Stream velocity and discharge were calculated for each storm in order to construct stream hydrographs and provide the required runoff term, $95(Q * q_{p1})^{0.56}$ for the Modified Uniform Soil Loss Equation. These hygrographs were also used to calculate sediment yield using measured sediment concentrations for each storm. Comparison of observed sediment yields to predicted sediment using the MUSLE, provided an idea of the accuracy of the model.

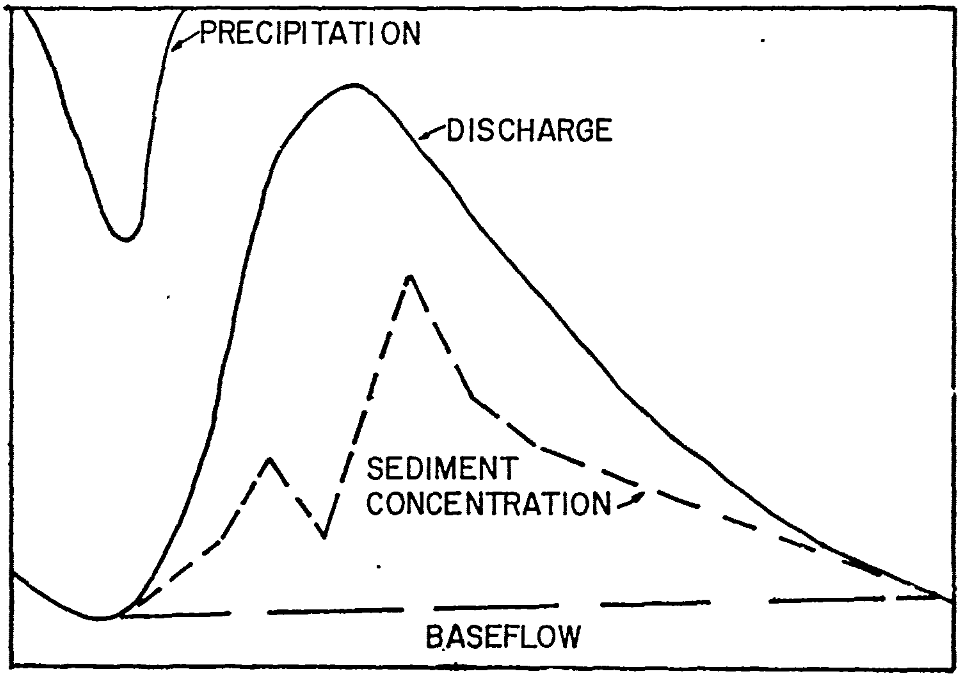

Fig. 2-2 Sample storm hydrograph.

Storm-water from the study site exits the drainage basin underneath Clemson Road through two adjacent 40-foot long (12 m) sections of 30" (76 cm) and 36" (91 cm) diameter pipe (Photo 1-1 and Figure 2-3). Stream velocity and discharge were estimated using the culvert dimensions, slopes, and roughness to develop the Manning and Continuity Equations, and to develop stage rating charts for the 30" and 36" pipes. Measurement of water depth for each pipe was taken with a staff gauge approximately every 5 minutes or whenever there was a 2" (5.1 cm) change in water depth. Depth of water for each culvert and time of measurement were manually recorded and applied to the stage rating charts to construct storm hydrographs for each observed storm. The Manning (Dunne and Leopold, 1978) was applied to both culvert geometries to estimate stream velocity:

$$u = \frac{R^{2/3}\ S^{1/2}}{n} \qquad \text{(Equation 2-1)}$$

where u is mean water velocity (ft s^{-1}), R is the hydraulic radius equal to the ratio of the cross-section area of flow to wetted perimeter (ft), S is the dimensionless energy gradient approximated by the slope of the water surface (Sw), and n is the resistance (roughness) coefficient. Elevation of the inlet and outlet section, and length of each pipe were surveyed with rod, level and tape to determine pipe gradients of 0.00875 and 0.00664 for the 30" and 36" pipes, respectively. These gradients allowed depth measurements to be converted to water surface slopes. Both

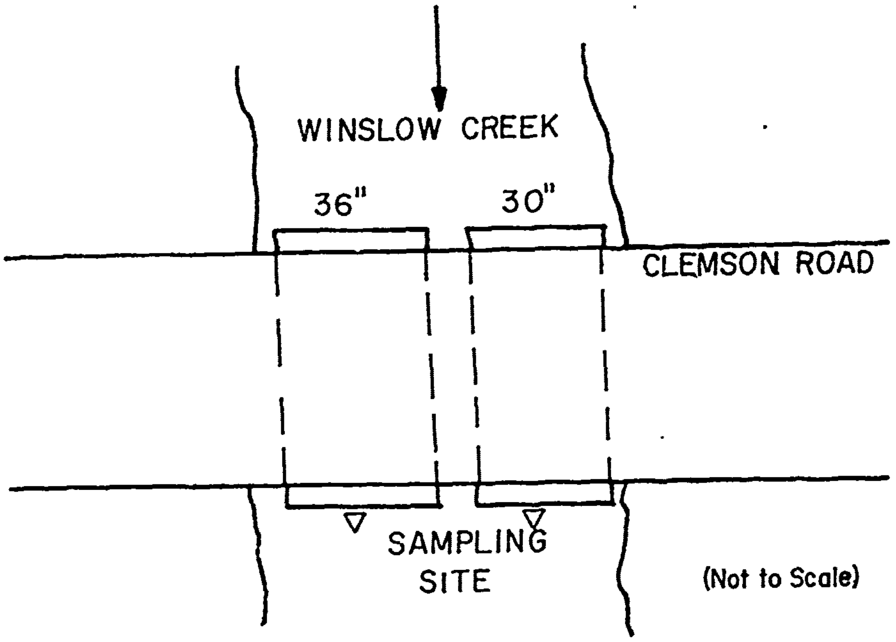

Fig. 2-3 Diagram of sampling station on Winslow Creek at Clemson Road.

pipes are approximately 25 to 30 years old and show signs of deterioration including differential settling, leakage, and spalling of interiors, and cracking. Based on these factors, a roughness coefficient of .017 was selected using the criteria established by Bodhaine (1986). The continuity equation (Dunne and Leopold, 1978) was applied to both culvert geometries to estimate discharge:

$$Q = Au = wdu \qquad \text{(Equation 2-2)}$$

where Q is discharge ($ft^3\ s^{-1}$), A is area (ft^2), w is top width (ft), and d is depth (ft). Only the 30" pipe required a correction factor for cross-sectional area based on a 1" layer of sediment that was present at the bottom of the pipe for all flows. Stage rating charts were constructed from pipe geometry where $L = f(a)$ and $a = f(\text{depth})$ (Potter, 1986) (Appendix A).

Suspended Sediment Measurements

Sediment concentrations were sampled and superimposed on stream hydrographs to determine the effect of construction activity on suspended sediment. Along with field notes, these hydrographs provide potential explanations of sediment sources and the degree of increased concentrations during the various phases of construction. Sediment concentration and hydrograph data are also used to calculate sediment yield for each observed storm in tons.

Storm-water sediment concentrations were sampled at the downstream sections of the 30" and 36" concrete pipes (Figure 2-3 and Photo 1-1). This site was selected on the basis of it's accessibility under high-water and adverse conditions and the ability to accurately estimate stream velocity and discharge at the pipes. Adverse effects of this sample site include a tendency for slack-water sedimentation upstream of the pipes and delivery of sediment from road side sources. These complications were unavoidable given the limitations of this project.

Storm-water was sampled from the 30" and 36" concrete pipe using the grab-sample technique of dipping an open one quart mason jar or 500 ml plastic bottle mid-depth into the flow. This method of surface sampling is preferred to that requiring heavy samplers because samples can be taken on short notice, storms of short duration can be monitored properly, and it is relatively inexpensive (Ward, 1984). The use of surface sampling has been shown to cause errors for coarse material, but is reasonably accurate for fine material (Ward, 1984). Samples from each pipe were taken approximately every 5 minutes, when the depth of water increased 2" or whenever there was a noticeable change in water turbidity or suspended sediment. Baseflow water samples were also taken to characterize baseflow sediment concentration for comparison with storm-water sediment concentration. The time, sampling site, and pipe diameter were recorded before samples were packed.

The evaporation method as outlined by Guy (1969) was used to determine sediment concentration (Appendix C). This method is superior to the filtration method when there are high concentrations of silt and clay in the samples (Guy, 1969). Gravity filtration through Whatman filter paper was attempted, but due to the high silt and clay content of sediment samples, the filter easily clogged.

Sediment rating curves were developed by plotting sediment concentration against the corresponding Qs. Although it is conventional to use log-log functions (Holeman, 1975), linear functions provided greater explanation of sediment concentration in the observed data and were used throughout this analysis. Rating curves were analyzed for sediment concentration and Q measurements in individual pipes and also *average sediment concentrations* in the combined flows of both pipes.

Soil Loss Estimation Using the USLE

Soil-loss estimates are calculated for 1970 and 1990 and are compared to determine the degree to which soil loss has increased as a result of urbanization. Particular attention will be focused on which sub-basins contribute the highest and lowest soil-loss estimates and possible explanations. Soil loss estimates (tons/acre) are also compared to observed and predicted sediment yields (tons/acre) to determine a first approximation of sediment storage in the basin.

The Universal Soil Loss Equation (USLE) provides a measure of soil loss from hill-slopes in a drainage basin (Wirschmier and Smith, 1965) (Dunne and Leopold, 1978):

$$A = R\ K\ L\ S\ C\ P \qquad \text{(Equation 2-3)}$$

where A is soil loss (tons per acre), R is the rainfall erosivity index, K is the soil erodibility index, L is the hill slope-length factor, S is the hill slope-gradient factor, C is the cropping-management factor, and P is the erosion control practice (Table 2-1) (Dunne and Leopold, 1978).

The USLE has several limitations that may adversely influence it's reliability for estimating soil-loss from a hill slope.

1. Estimates are based on soil-loss rates for small plots without accounting for deposition, so soil-loss may be over-predicted.

2. Soil loss rates are conventionally long term rates applied seasonally or annually to a hill slope, although the USLE can be used to estimate soil loss for individual storms (Lal, 1988).

3. Applying the USLE to a complex drainage basin requires the determination of soil loss rates for numerous small homogeneous plots and weighting the results.

Average values of R, K, LS, and CP over the entire basin will produce quite different results than the sum of erosion calculated over numerous individually computed plots. This spatially distributed method is very time consuming, however, requiring numerous calculations to determine USLE factors for several small polygons, perhaps hundreds in a small drainage basin.

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Table 2-1

USLE Parameters

USLE Factor	Application	Value
R	Entire Basin	Various[1]
K	Johnston Soil Series	.20
	Lakeland Soil Series	.10
	Pelion Soil Series	.15
LS	LS determined from topographic maps	Various
C	Bare Soil	1.0
	Trees and low brush	.042
	Pasture	.01
	Grass (Residential lot)	.003
	Woodland	.001
	Lakes[2]	0
P	Woodland-Pasture Woodlot	1.0
	Pasture-Grass	1.0
	Lakes[2] and Quarries[2]	0

Notes: [1] R values for 6 storms August 6 to October 10, 1990.

[2] Quarries are assumed internally drained and do not contribute sediment to stream network. Contribution of sediment from lakes is assumed 0.

Soil loss from hill slopes in the drainage basin is estimated for pre-construction (1970) and construction (1988 to 1989) land use conditions in the basin using the Universal Soil Loss Equation (USLE) in a spatially distributed method is used for erosivity (K), hill slope length-gradient factors (LS), and land use and erosion factors (CP), but a lumped method is used for rainfall intensity. Basin and sub-basin divides were delineated from the Blythewood topographic quadrangle (USGS, 1:24000, 1990) (Figure 2-4). Sub-basins are numbered I through X, but a mosaic of additional divisions was created for developed areas in the 1990 analysis. Road cuts, sub-division areas, and quarries were included as separate divisions to highlight the impact of these construction areas on soil-loss. Aerial photography for the study site (Photo 2-1 and 2-2), flown in 1970 and 1989, provided spatial and temporal information from which maps of soil, hydrologic, and urban change were constructed. From these maps, a series of overlays for rainfall, soils, land use, and vegetation were constructed to estimate soil erosion using USLE. Based on these overlays, a soil loss estimate was determined for each of the sub-basins. The sum of these soil losses provides an estimate of the total amount of soil lost for the basin in tons per acre for a particular storm.

The rainfall erosivity index (R), calculated for each storm and applied to the entire basin is calculated as the

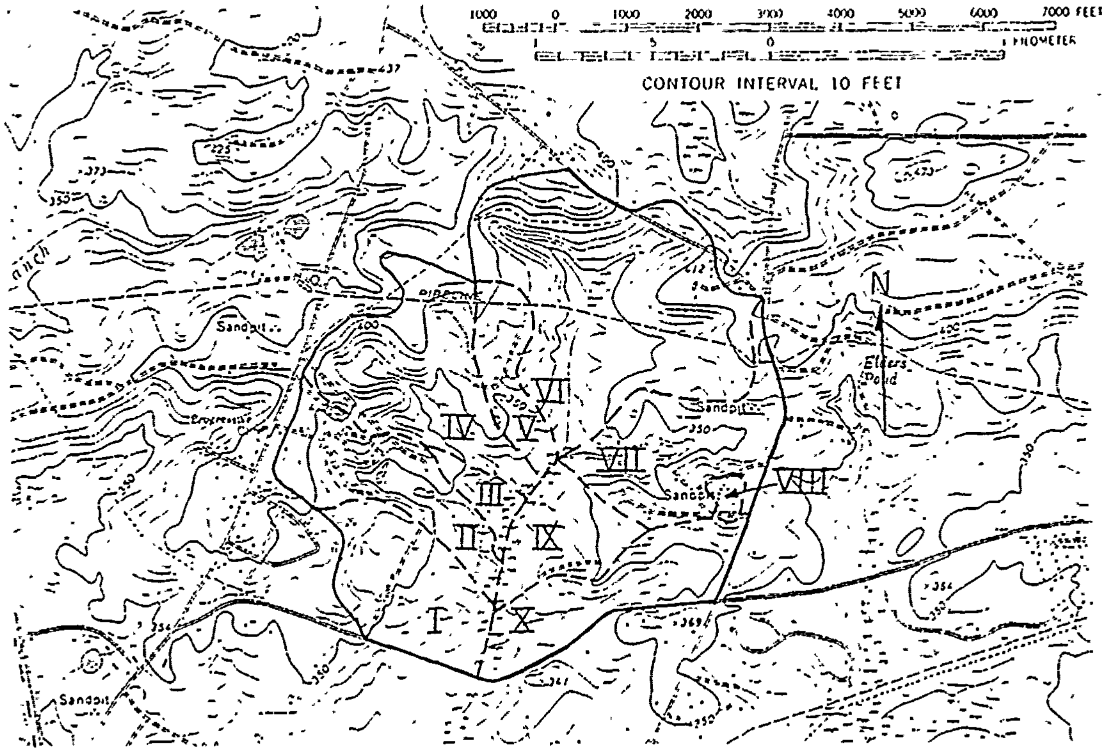


Fig. 2-4 Winslow Creek drainage basin and sub-basin delineation.

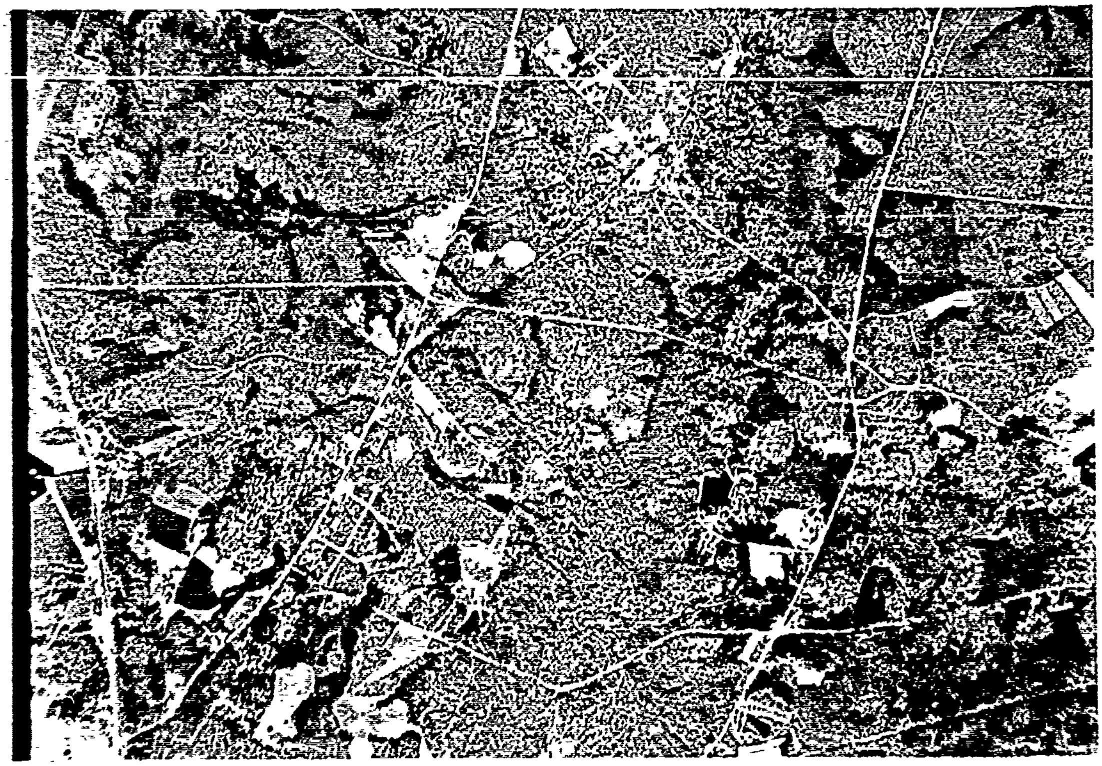


Photo 2-1 Aerial photograph of Winslow Creek area, 1970.

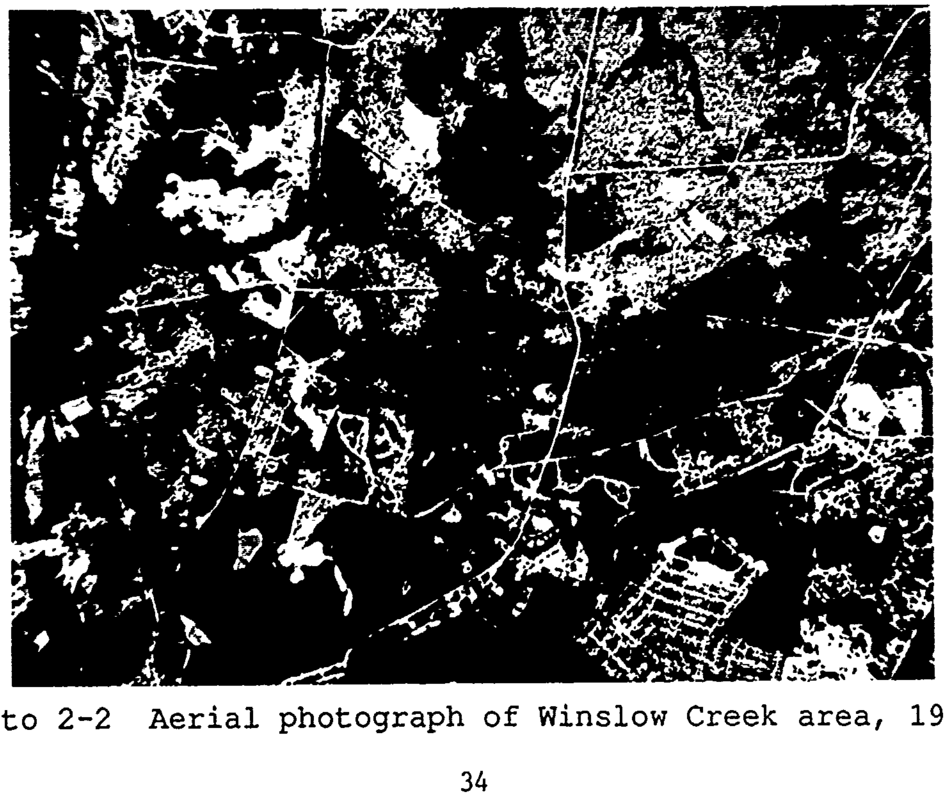


Photo 2-2 Aerial photograph of Winslow Creek area, 1989.

sum of rainfall energy and intensity products through time:

$$R = \frac{\sum_{i=1}^{n} E_i \, I_{30i}}{100} \qquad \text{(Equation 2-4)}$$

Where E is kinetic energy of a given time interval (foot-tons/acre), E_i is total kinetic energy of the storm (foot-tons/acre) and I_{30} is the maximum 30-minute intensity of the storm in inches per hour. The energy term of a given period, E_i, is calculated by the empirical relationship:

$$E_i = 916 + 331 \log_{10} I \qquad \text{(Equation 2-5)}$$

Where I is rainfall intensity for the given observed period. An erosivity index was constructed for each storm following the guidelines established by Lal (1988) to simplify calculations (Table 2-2). Rainfall total, intensity, and duration for six observed storms were used to calculate values of E and I_{30}. The 30-minute rainfall intensity, I_{30}, was determined from the index based on the maximum storm intensity for 30 minutes. Kinetic energies, E, were calculated for observed rainfall periods using equation 2-5. Total E and I_{30} were multiplied and divided by 100 (Equation 2-4) to determine the erosivity index for a single rainstorm (Appendix B).

Soil erodibility factors (K) were obtained from the South Carolina Land Resources Conservation Commission (SCLRCC). The K factors provided by the SCLRCC are based on the erodibility of the top few inches of soil in a soil

TABLE 2-2

Procedures for calculating rainfall erosivity index (R).

1. Determine storm duration (min), rainfall time intervals (min), and rainfall per time interval (in) from observed rainfall data. (Columns 1,2, and 3)
2. Calculate average storm intensity (in/hr). (AI)

   (.25 in/26 min) * 60 min/hr = .58 in/hr
3. Calculate rainfall intensity for each time interval (in/hr).

   (.17 in*60 min/hr)/8 min = 1.28 in/hr (Column 4)
4. Calculate Log value for each rainfall intensity (in/hr).

   LogI = Log (1.28) = .1072 (Column 5)
5. Calculate erosivity (E) per inch of rain for each time interval.

   916 + 331(.1072) = 951.48 (equation 2-5) (Column 6)
6. Calculate total E per inch of rain, for each rain interval.

   .17 in * 951.48 = 161.75 (Column 7, column 3 * column 6)
7. Sum Total E for the storm.

   Total E = 220.12 (Sum column 7)
8. Calculate I_{30}. Select most intense 30 minute period of rain and determine maximum 30 minute intensity in in/hr.

   (.25 in/30min) * 60 min/hr = .50 in/hr
9. Calculate R.

$$R = \frac{\sum_{i=1}^{n} E_i \; I_{30i}}{100} = (220.12 * .50)/100 = 1.1$$

Time min 1	Time Int min 2	Rain Int in 3	Rain in/hr 4	Log I in/hr 5	E per in 6	Total E 7
0	0	0.00	0.00	0.00000	0.00	0.00
8	8	0.17	1.28	0.10720	951.48	161.75
17	9	0.05	0.33	-0.48150	756.62	37.83
26	9	0.03	0.20	-0.69900	684.63	20.54
31	5	0.00	0.00	0.00000	0.00	0.00
Total		0.25				220.12

AI = .58 I30 = .50 R = 1.10

series. Grading and construction activity result in the removal of the uppermost layer and, exposure of a much different subsurface material and soil compaction by the movement of heavy construction equipment, further changing the characteristic of the soil.

The length-slope factors (LS) were determined from 1:24,000 topographic map sheets and 1:600 construction drawings by computing the distance and gradient of the "predominant" slope; that is the upper, steeper segments of the hill slope (Dunne and Leopold, 1978). The appropriate LS factor was then calculated using the following equations (Wishcmeier and Smith, 1962):

$$L = (f/72.06) \qquad \text{(Equation 2-6)}$$

$$S = (0.52 + 0.36s + 0.52s^2)/6.613 \qquad \text{(Equation 2-7)}$$

where f = slope-length in feet and s is the predominant field slope expressed in percent.

The control practice factors (CP) were determined from aerial photography through differences in tonal variations between forest, pasture, grassland and verified through field observations. Values were assigned to each based on charts presented by Dunne and Leopold (1978). The cropping factor (C) is based on percent forested and urban areas recorded on the plot map for pre-construction and construction phases and is assumed equal to 1 where the land is freshly graded (Dunne and Leopold 1978). The erosion control practice (P) is adjusted for erosion control practices based on field observations.

As an independent check of erosion rates, erosion pins were placed in select areas in the drainage basin to measure soil erosion and deposition rates. The erosion pins are 10" galvanized nails with a washer fitted loosely around the stem of the nail to act as a guide for measuring soil erosion (Photo 2-3). They were placed at either the crest, mid-slope, or toe of a slope and marked with a red survey flag for identification purposes. The erosion pins at the crest of the slopes were driven into the soil until the washer came into contact with the soil. The erosion pins placed at mid-slope or toe positions, were driven only half way into the soil and the exposed portion of the nail was used to measure rates of deposition. Siting of the erosion pins was limited to channel bank slopes, freshly graded soil, and selected housing plots. Movement of heavy construction equipment throughout the site did not permit a thorough coverage in the basin. Several of the pins were vandalized or damaged by construction activity.

Sediment Yield Estimation Using the MUSLE

The amount of sediment yielded from an urbanizing drainage basin can be predicted using the Modified Universal Soil-Loss Equation (MUSLE). This model was developed for sediment yield prediction in a homogeneous watershed (Williams, 1975; South Carolina, 1989):

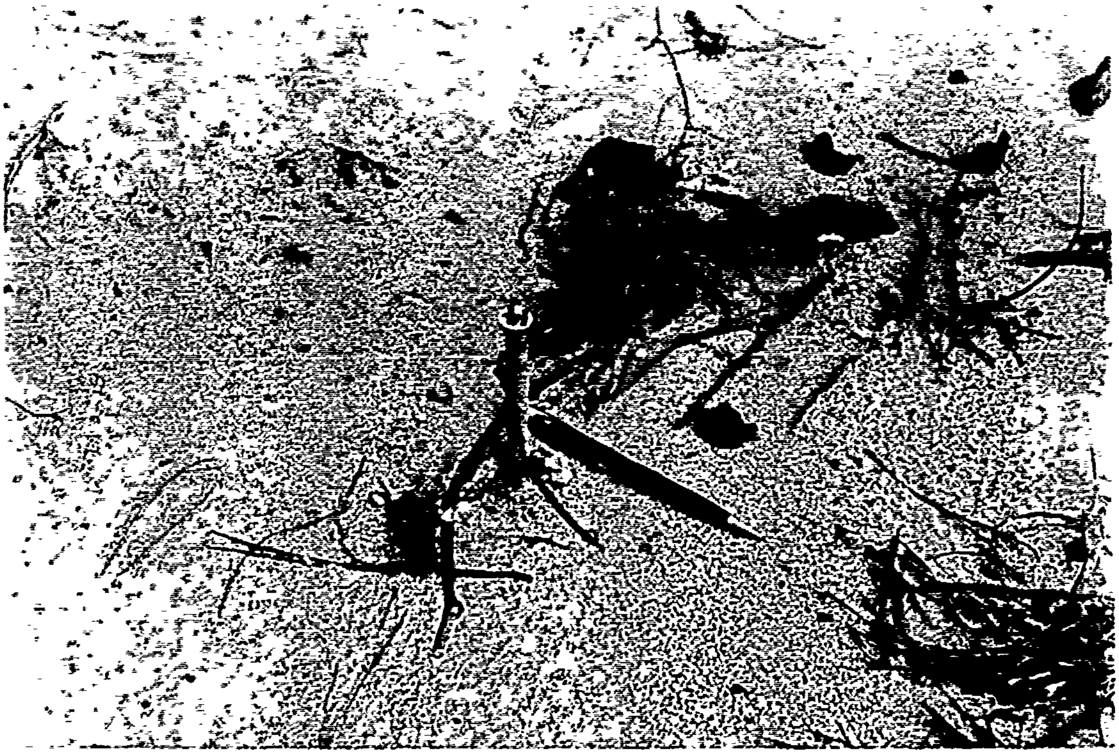


Photo 2-3 10" galvanized nail used as an erosion pin. Pin penetrates half its length to measure deposition.

$$Y = 95(Q * q_{pi})^{0.56} \ K \ (LS) \ CP \qquad \text{(Equation 2-8)}$$

where Y is single storm sediment yield in tons, Q is total storm runoff volume in acre-feet, and q_{pi} is peak instantaneous discharge in cfs. Discharge values on the receding limb of the hydrographs were extrapolated in cases where the last few minutes of the hydrograph were not available.

Peak discharge (q_{pi}) was determined directly from discharge measurements for both concrete pipes, and runoff volumes were determined by constructing storm hydrographs from the discharge data. Baseflow was separated from the hydrographs by drawing a line from point of increased flow on the hydrograph, increasing at a rate of .05 cfs per square mile of basin area (Dunne and Leopold, 1978). Removal or retention of base flow makes little difference on the results because base flow is generally a small proportion of flows.

The MUSLE equation uses the same values of K, LS, and CP as used in the USLE (Equation 2-3). Plot values are weighted for each sub-basin, summed, and multiplied by $95(Q * qpi)^{0.56}$ for an estimate of sediment yield in tons per storm. As with the USLE, all parameters are distributed except for the runoff term which is a lumped parameter substituted for rainfall intensity. Resulting sediment yields values are compared to values calculated from observed discharge and sediment concentration measurements.

Discharge and sediment concentration measurements were extrapolated for the last few minutes of the storms where data was not available.

Stream Channel Morphology

The USLE provides an estimate of upland soil losses while the MUSLE estimates the sediment leaving the basin. Ideally, disregarding potential errors, the difference between the USLE and MUSLE estimates can be explained by sediment storage in the basin. As an independent check on sediment storage in the channel system, erosion and deposition within stream channels of the basin were documented by the survey of 13 randomly selected channel cross-sections (Plate 1). Each cross-section was surveyed at least twice, initially on July 25, 1990 and again on October 20, 1990.

Each cross-section was carefully leveled with a transit and rod and tied to a stable bench mark on such features as a storm sewer or culvert headwall. Cross-section elevation and distance were measured every 1 or 3 feet depending on the relief. Re-surveyed cross-sections were plotted together and planimetered to determine net changes in area.

Interviews: Sediment and Erosion Control Policy

The Richland Sediment and Erosion Control Ordinance has been in effect for the past ten years since December 23,

1980. During this time, county officials and engineering firms responsible for submitting sediment and erosion control plans to the county for approval have undoubtedly developed an important perspective concerning the ordinance. To better understand this perspective, structured interviews were conducted with the County Engineer and four local engineering firms according to basic interview methods developed by Leedy (1980). The objectives of these interviews is to (1) gain the professional's perspective on sediment and erosion control in Richland County, (2) identify strengths and shortcomings in the ordinance, and (3) determine recommendations for improving the ordinance. The interview technique introduced information from personal experiences of professionals working closely to the problem and questions which would not be fully explained by a mailed questionnaire. Interviewees were selected based on their expertise, availability, and willingness to participate in the interview. The responses presented do not necessarily represent the opinions and concerns of all engineering firms in Richland County.

Two sets of interview questions, one for the County engineer and the other for the engineering firms, were developed and reviewed for clarity prior to conducting the interviews (Appendix D). These questions focus on sediment and erosion control in general, sediment and erosion control policy for Richland County, strengths and shortcomings of present practices and policy, and recommendations to improve the existing ordinance. Each interview was taped and transcripts were prepared and reviewed.

Chapter 3. Analysis

Precipitation Data

Six rainstorms between August 6, 1990 and October 10, 1990 were observed and measured using non-recording rain gauges positioned across the study site (Table 3-1). The magnitude of several other events which were not sampled due to the malfunctioning of a recording rain gauge and various logistical reasons, can be inferred by comparison with the University of South Carolina rain gauge 12 miles away (Figure 3-1). Rainfall duration, depth, volume, intensity, and other storm characteristics were recorded for each event. Most of these storms were thunderstorms of relatively short duration and accompanied by strong wind gusts and heavy rain.

Table 3-1

Date	Duration (min)	Depth (in)	*USC	Remarks
Aug 6, 90	30	.25	.23	Afternoon
Aug 8, 90	48	.49	2.01	Evening
Sep 8, 90	45	.19	0	Afternoon
Sep 9, 90	66	.58	0	Evening
Sep 22, 90	61	.39	.34	Morning
Oct 10, 90	227	2.52	1.56	Afternoon

*Thiessen weighted average for 8 rain gauges.

NOTE: Area of drainage basin is 767.67 acres.

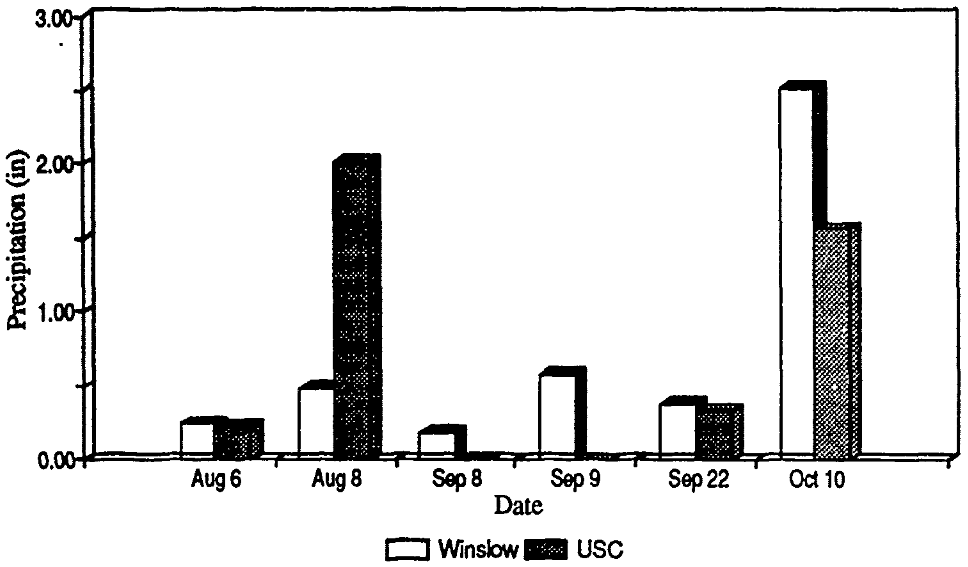


Fig. 3-1 Comparison of Winslow Creek and University of South Carolina rain gauge data.

Thunderstorms can be subdivided into two types (1) isolated convective thunderstorms produced within warm, humid air masses and (2) severe thunderstorms produced by forceful lifting of warm, moist air along the boundary of a cold front (Lutgens and Tarbuck, 1989). Isolated thunderstorms generally occur in the late afternoon or early evening hours during the spring and summer months when the earth's surface temperature is highest. Rainfall amounts and intensity for this type of storm are spatially variable and do not cover a wide area. An example of the spatial variability of an isolated thunderstorm is given by the rainfall measured for August 8, 1990 (Figure 3-2), which ranged from .35" to .70".

Thunderstorms produced by the forceful uplifting of warm, moist air along a cold front characteristically produce a more uniform rainfall along the frontal boundary and affect a much larger area than isolated thunderstorms (Lutgens and Tarbuck, 1989). The storm observed on September 22, 1990 is an example of a thunderstorm produced along an approaching cold front. The storm occurred in the early morning and produced from .31" to .50" of rainfall across the basin in a relatively uniform pattern (Figure 3-3).

The storm observed October 10, 1990 is not categorized as a thunderstorm. Rainfall from this storm was associated with the remnants of Tropical Storm Klaus which crossed the

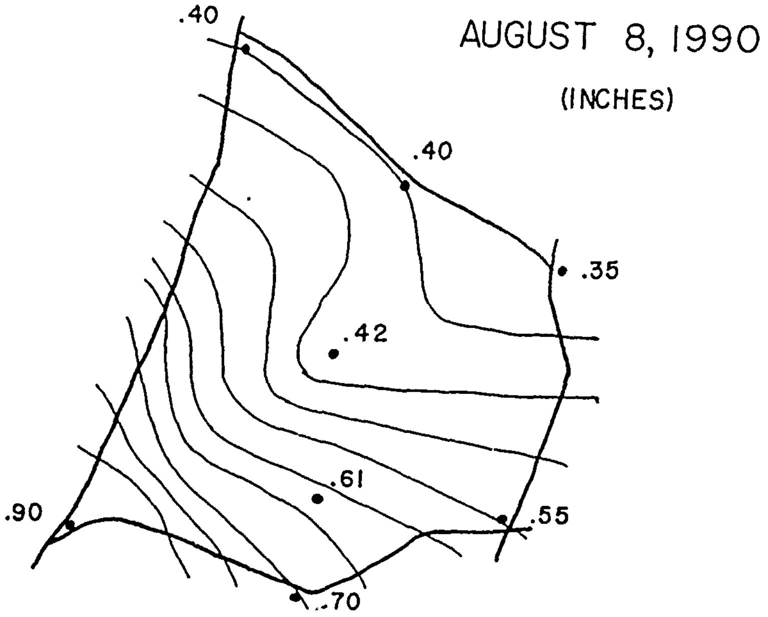


Fig. 3-2 Isohyetal map determined by visual interpolation for August 8, 1990 rainfall.

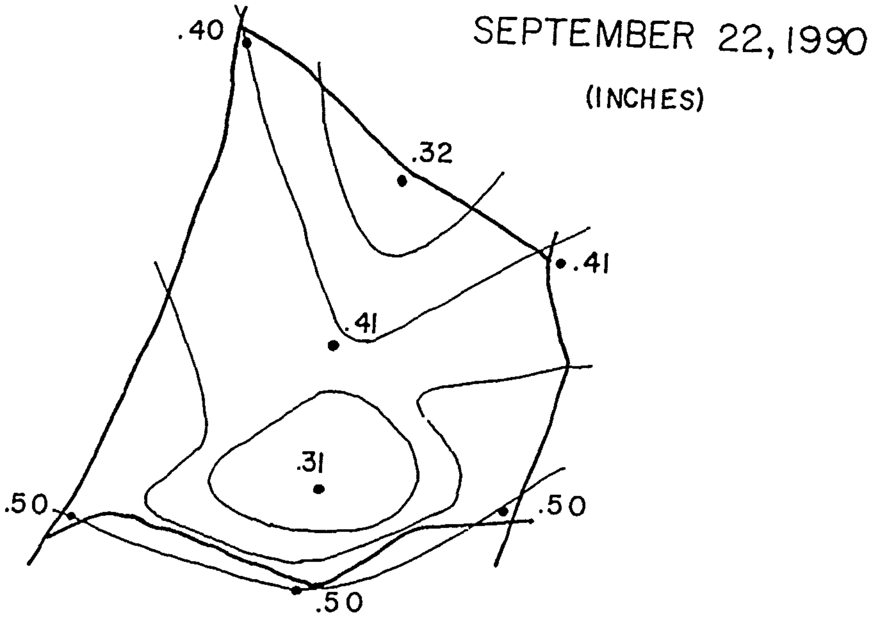


Fig. 3-3 Isoyhetal map determined by visual interpolation for September 22, 1990 rainfall.

southeast portion of the United States causing flooding throughout the state of South Carolina. Rain gauges on the site were checked several times during the storm and approximately 8 inches of rainfall were recorded for a 30-hour period. Measured rainfall for a 4-hour period during this storm ranged between 2.35" and 2.75". For the sake of comparison the two-year 6-hour rainfall in this part of South Carolina is between 2.5 and 3", the 10 year 6-hour rainfall is approximately 4", and the 100-year 24 hour rainfall is about 8" (Dunne and Leopold, 1978, pg. 61-63).

Storm Hydrograph Data

The spatial variability of rainfall had a pronounced effect on the characteristics of storm hydrographs produced by each storm. The location of the rainfall maximum recorded in the basin directly affected the time difference between the center of rainfall mass and peak runoff rate, the "lag to peak" time described by Dunne and Leopold (1978). For example, the September 8 storm produced a somewhat uniform rainfall across the basin. The lag to peak for the resulting storm hydrograph was approximately 68 minutes indicating that the large forested area above the developed area delayed the rate at which storm runoff was concentrated in the main channel (Table 3-2).

Table 3-2

Date	Depth (in)	Duration (min)	Intensity (in/hr)	Lag to Peak (min)	Rainfall Location
Aug 6	.25	30	.58	50	Heavy-Winslow
Aug 8	.49	48	.95	40	Heavy-Winslow
Sep 8	.17	45	.42	68	Uniform Rainfall
Sep 9	.58	66	.99	84	Hvy-Upper W. Basin
Sep 22	.39	61	.45	46	Heavy-Timbervale
Oct 10	2.52	227	.39	N/A	Uniform Rainfall

A much different relationship is identified where rainfall was non-uniform across the basin. For example, the August 8 storm produced almost 3 times as much rainfall as the September 8th storm with a greater proportion of rainfall over the developed area of the basin (Figure 3-2) (Table 3-2). The lag to peak for the resulting storm hydrograph , however, was only 40 minutes in spite of the increased peak discharge. This rapid hydrologic response was presumably due to increased areas of impervious surface, channelization, and storm sewers in the developed area. In contrast, the September 9th storm, which was centered over a rural portion the sub-basin (Figure 3-4), resulted in a long lag time (84 min) in spite of its high intensity (Table 3-2). Based on these observations of a few storms, uniform rainfall across the entire basin resulted in relatively long lag-to-peak times and rainfall centered over a developed

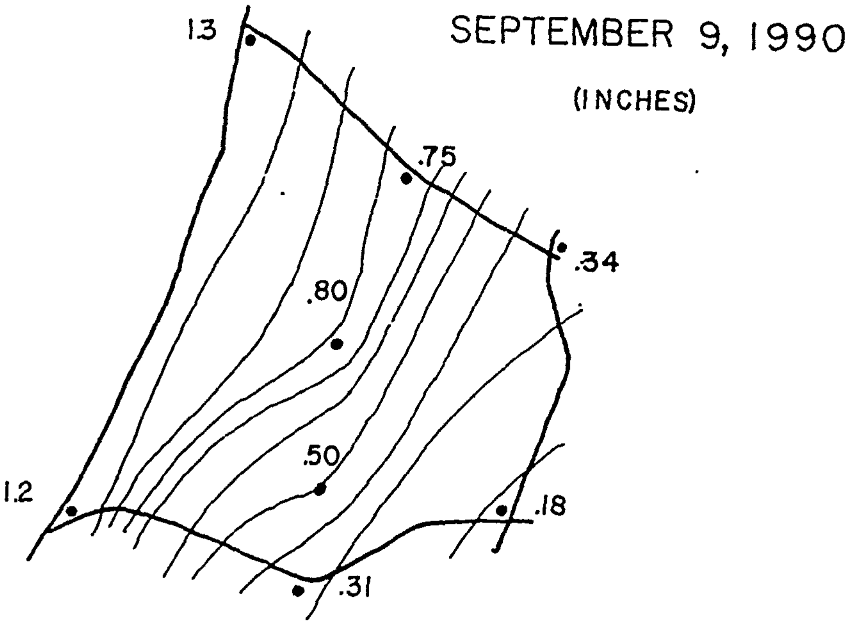


Fig. 3-4 Isoyhetal map determined by visual interpolation for September 9, 1990 rainfall.

portion of the basin resulted in much shorter lag-to-peak times (46-50 min). An increase in peak discharge for storms over developed areas is also apparent, but more data and scaling for rainfall volume are needed to validate this relationship.

Suspended Sediment Concentration

Suspended sediment concentrations were sensitive to changes in discharge and to the effects of channel dredging upstream. Increased sediment concentrations during the rising limb of the hydrographs were directly attributable to specific sediment sources along Clemson road very near the sampling site. These sediment-concentration peaks are identified, tracked over time, and related to specific construction activity. Sediment concentrations in 82 water samples collected at the basin mouth during six storms between August 6, 1990 and October 10, 1990 display a weak relationship with discharge.

Sediment concentrations, for the entire period of study expressed as the discharge-weighted sums observed in both pipes indicate a very high degree of scatter when plotted against total discharge through the pipes (Figure 3-5). At discharges greater than 20 cfs sediment concentration measurements (3 in each pipe) from the October flood are much lower than many of the low flows, presumably due to dilution during high water. For this reason, only the five

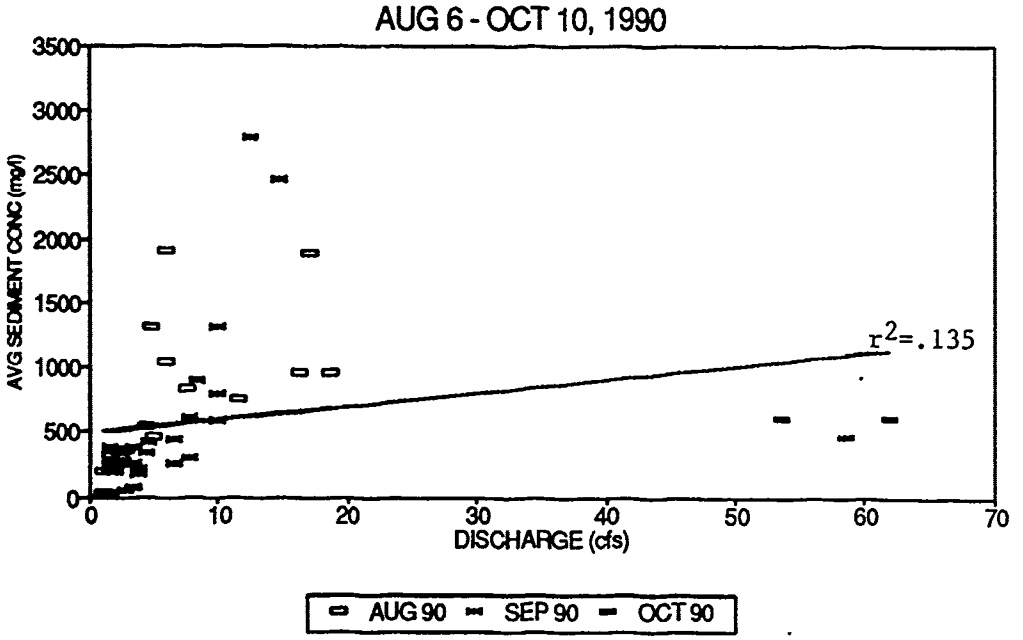


Fig. 3-5 Sediment concentration on discharge regression, August 6 - October 10, 1990.

storms between August 6 and September 22 are included in the following analysis.

There is a positive relationship between sediment concentration and discharge less than 20 cfs, particularly when concentrations in the two pipes are analyzed separately. Sediment concentrations of low flows were much higher in the 30" pipe than in the 36" pipe for all five storms (Figure 3-6), but both pipes show a positive correlation between sediment concentration and discharge. This correlation is weak in the 30" pipe date ($r^2 = .30$) but moderately strong ($r^2 = .49$) in the 36" pipe data. To identify sources of variation in sediment concentration independent of the variations due to discharge, the average sediment concentration for both pipes from the 5 storms was regressed on all measured discharges less than 20 cfs (Figure 3-7).

Examination of the regression residuals (errors in predicted sediment concentration) for each pipe during the period indicates both over-and under-prediction of sediment concentrations for all 5 storms (Figures 3-8 and 3-9). Variations in rainfall intensity, spatial variability, and duration may have contributed to these variations in sediment concentration in the rising and falling limbs.

The timing of sediment discharges can be related to local inputs from roadside ditches. Immediately upstream from the sampling site are two drainage ditches that run

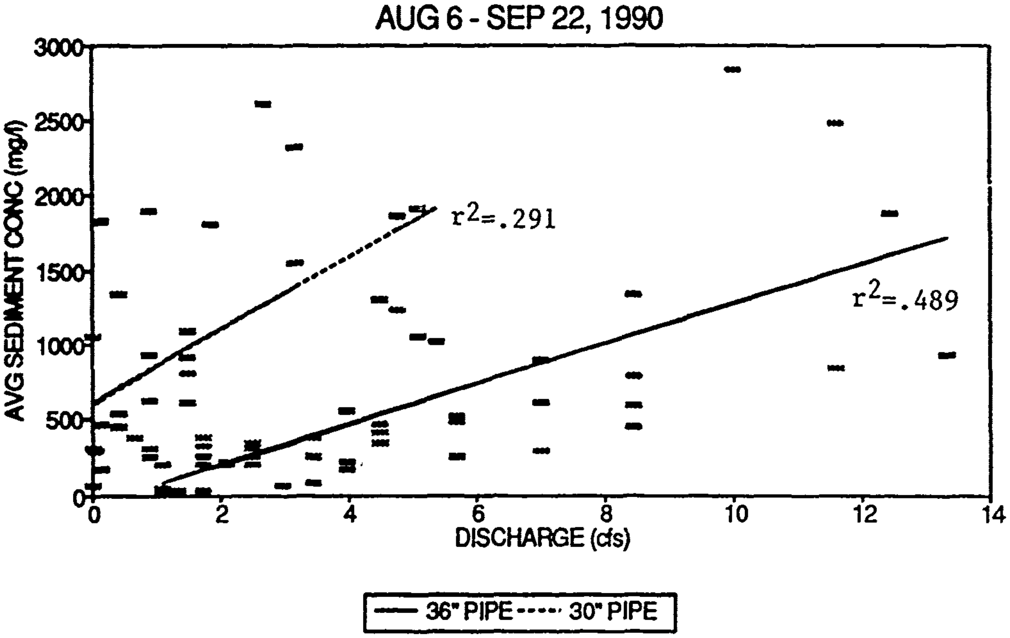


Fig. 3-6 Sediment concentration on discharge regression for 30" and 36" pipes, August 6 - September 22, 1990.

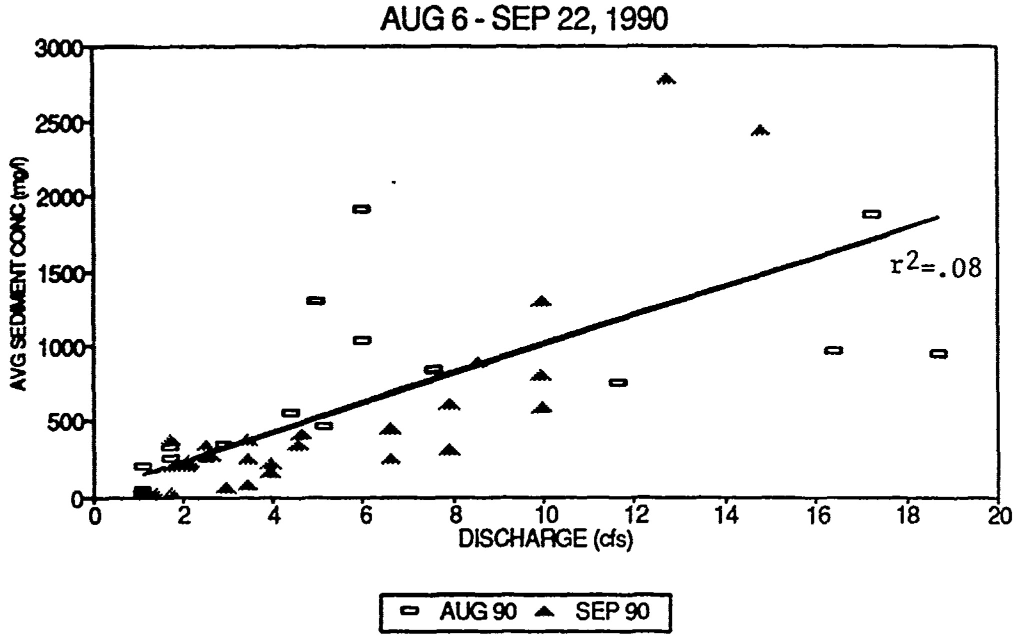


Fig. 3-7 Sediment concentration regression, August 6 - September 22, 1990.

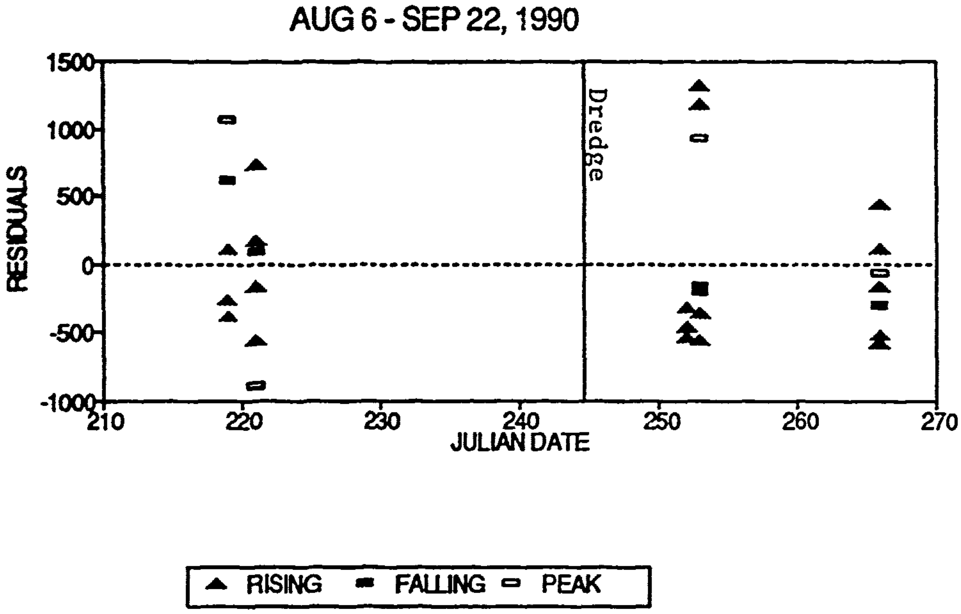


Fig. 3-8 Residuals for 30" pipe, August 6 - September 22, 1990.

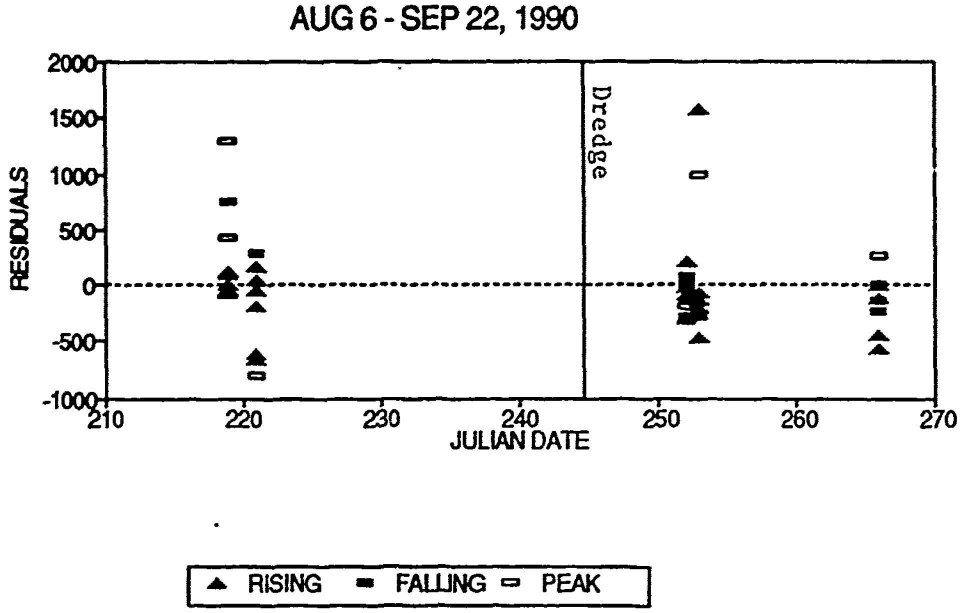


Fig. 3-9 Residuals for 36" pipe, August 6 - September 22, 1990.

parallel to Clemson Road (Figure 3-10). The right bank drainage ditch drains storm-water from Winslow Way from the west and enters Winslow Creek approximately 20′ upstream of Clemson Road from the east. As storm-water entered the upstream section of the two pipes, sediment plumes from the drainage ditches were visible during field sampling, on August 6th and 8th, and especially on September 8th and 9th after the right drainage ditch had been dredged. The first plume to reach the 36" pipe inlet flowed from the right channel-bank drainage ditch. Water upstream from the plume entrance point was generally clear. Arrival of the right-bank plume to the 36" pipe accounts for the initial increase in sediment concentration early in the hydrographs, typically within the first 20 minutes. When flow depth exceeded 5" the left pipe (30") also began to flow. The second sediment plume, flowing into Winslow Creek from the left-bank drainage ditch, generally arrived later, after 30 minutes and flowed directly int the left culvert (30").

Pre-dredge Period

The sediment concentration data suggest two periods of sediment loadings in the basin. These two periods are categorized as pre-dredge (August 6 and 8) and post-dredge (September 8 through 22) sediment concentrations based on the dredging of two channel sections in the basin on August 31, 1990. The two August storms represent sediment-

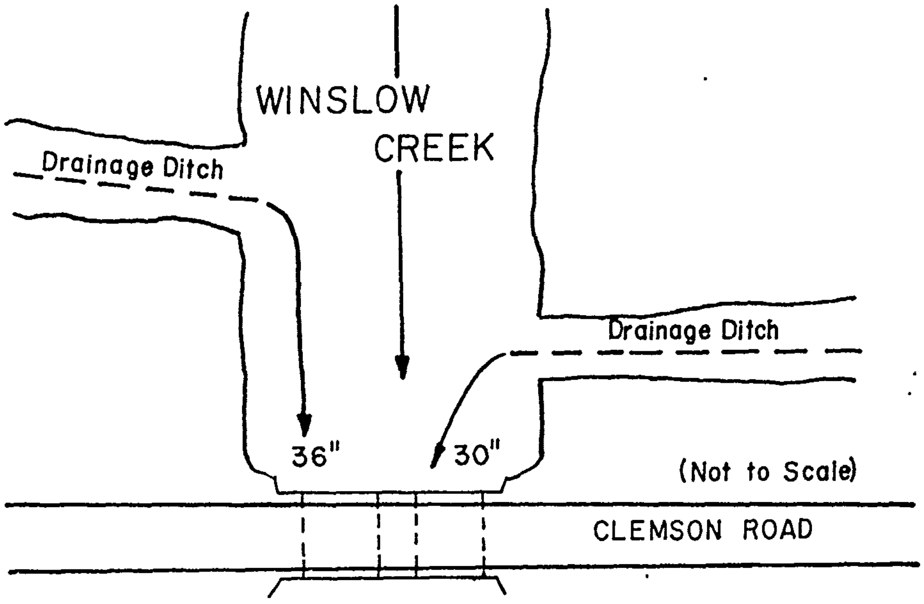


Fig. 3-10 Location of drainage ditches flowing into Winslow Creek upstream of sampling site.

concentration characteristics for the pre-dredge period and are used to compare later sediment concentrations. Average sediment concentrations (30" and 36" pipes) are superimposed on storm hydrographs to identify the timing of high sediment concentrations and allow the inference of sediment sources. The two August storms (Figures 3-11 and 3-12) show that sediment concentrations are clearly related to discharge in both of these high-water events. The sediment plumes from roadside drainage ditches help to explain the sediment concentration peak on the graphs (Figures 3-11 and 3-12). As discharge increased, the two distinct plumes began to mix and storm water just above the drainage ditch entrances became more turbid, indicating the arrival of sediment from higher in the basin.

Post-dredge Period

Two sections of channel in the drainage basin were dredged on August 31. A 100'X 10'X 3' section of Winslow Creek, just below cross-section 11, was dredged, removing approximately 3000 ft^3 of material to increase channel capacity and lower the channel-bed elevation below a sediment-clogged storm drain. In addition, the sodded, right-bank drainage ditch along Clemson Road was deepened by approximately one foot by removing the sodded channel bottom, exposing the bare soil to erosion. This increase in channel capacity was intended to clean out a sediment-filled

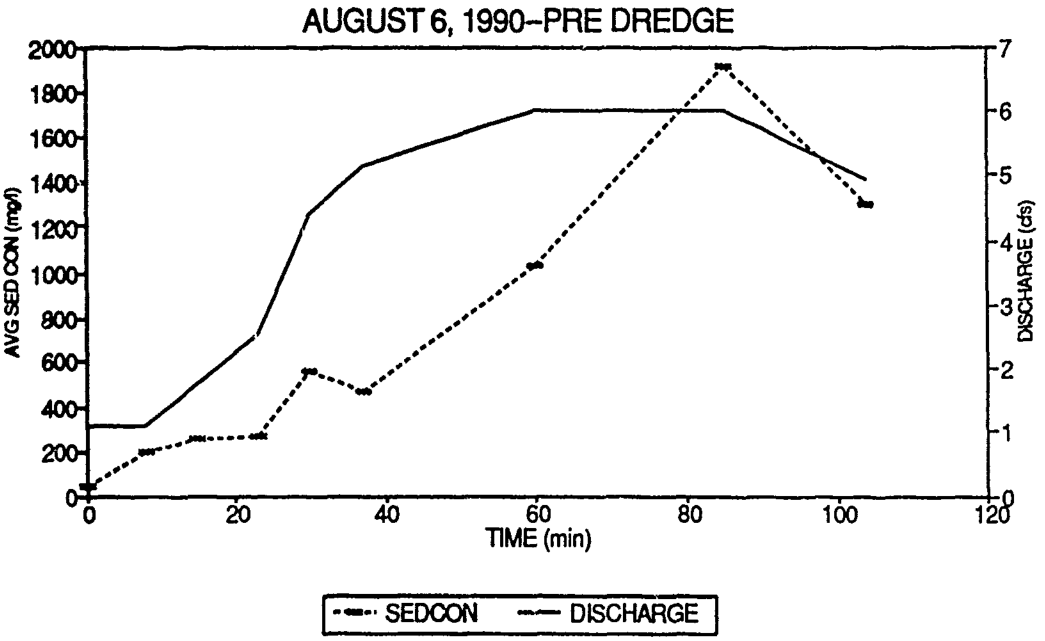


Fig. 3-11 Sediment concentration on stream hydrograph for Winslow Creek before dredging, August 6, 1990.

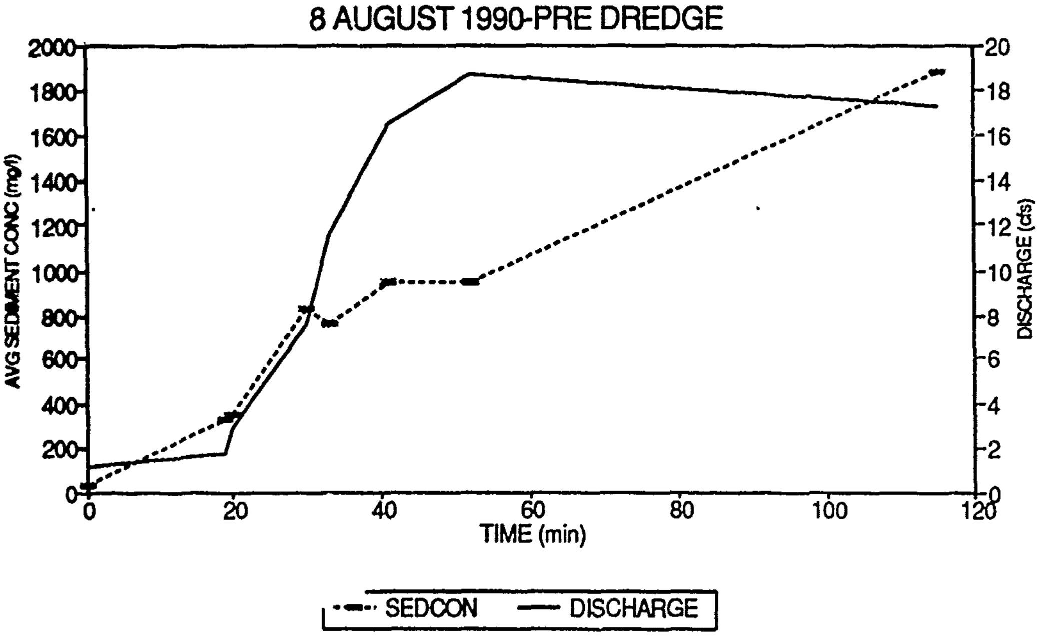


Fig. 3-12 Sediment concentration on stream hydrograph for Winslow Creek before dredging, August 8, 1990.

storm culvert passing underneath Winslow Way. The post-dredge period includes suspended sediment concentrations measured for storms on September 8, 9, and 22. Sediment concentrations for the storm on October 10, 1990 are incomplete and are not included in this analysis.

Sediment concentrations for post-dredge storms are shown in figures 3-13, 3-14, and 3-15. The small early sediment peak characteristic of the pre-dredge period appears considerably larger in the post-dredge period. The sediment produced from the freshly dredged right bank drainage ditch is clearly indicated by an early increase in sediment concentration. This trend is apparent in both September 8th and 9th storms. Early rising stages of the September 22, 1990 storm were not sampled.

Examination of the regression residuals for each pipe during the post-dredge hydrograph period indicates that 3 rising limb sediment concentrations for both pipes on September 9, 1990 are greater than predicted (Figures 3-8 and 3-9). Unlike sediment concentrations for rising limbs during the pre-dredge period, these high concentrations are directly attributable to sediment produced by storm water observed flowing through the freshly graded drainage ditch along Clemson Road. The early increase in sediment concentrations for the right pipe (36") shown as an average sediment concentration peak at ~ 15 minutes on figure 3-13, was due primarily, therefore, to removal of the sod from the

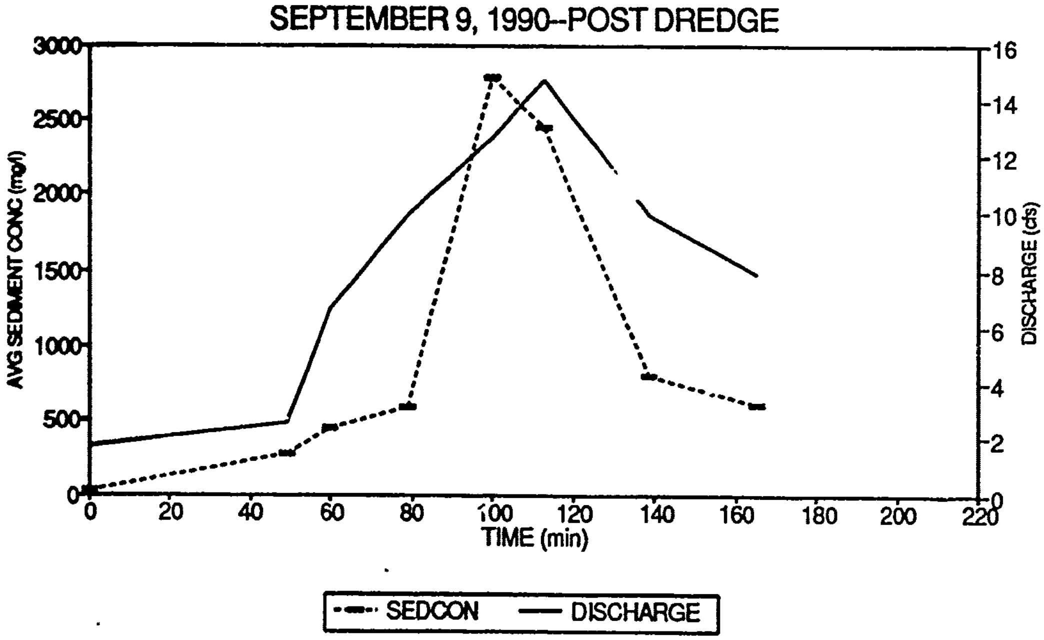


Fig. 3-14 Sediment concentration on stream hydrograph for Winslow Creek after dredging, September 9, 1990.

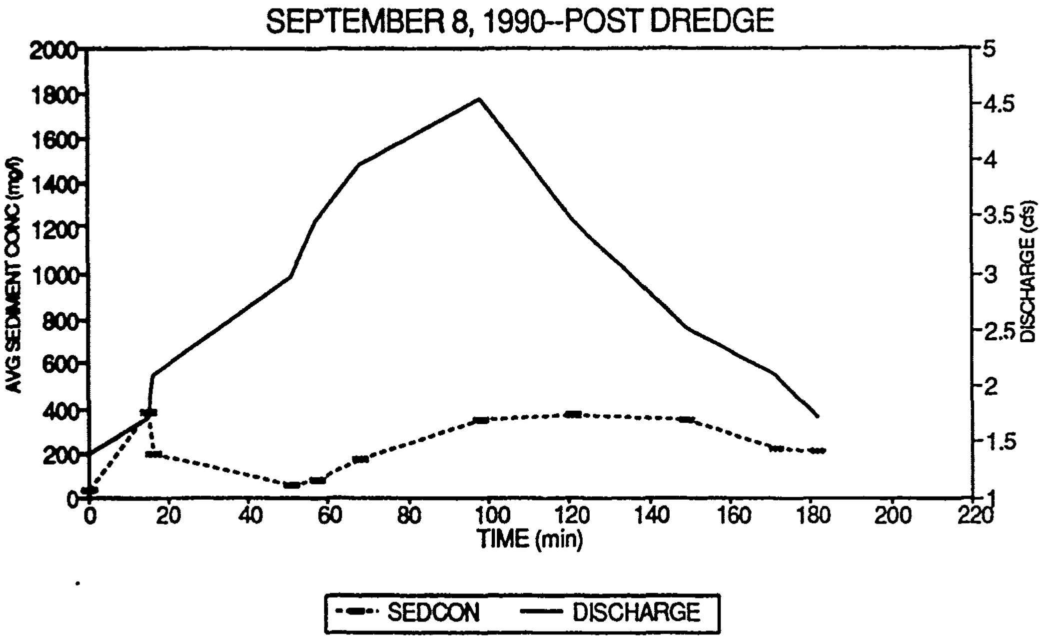


Fig. 3-13 Sediment concentration on stream hydrograph for Winslow Creek after dredging, September 8, 1990.

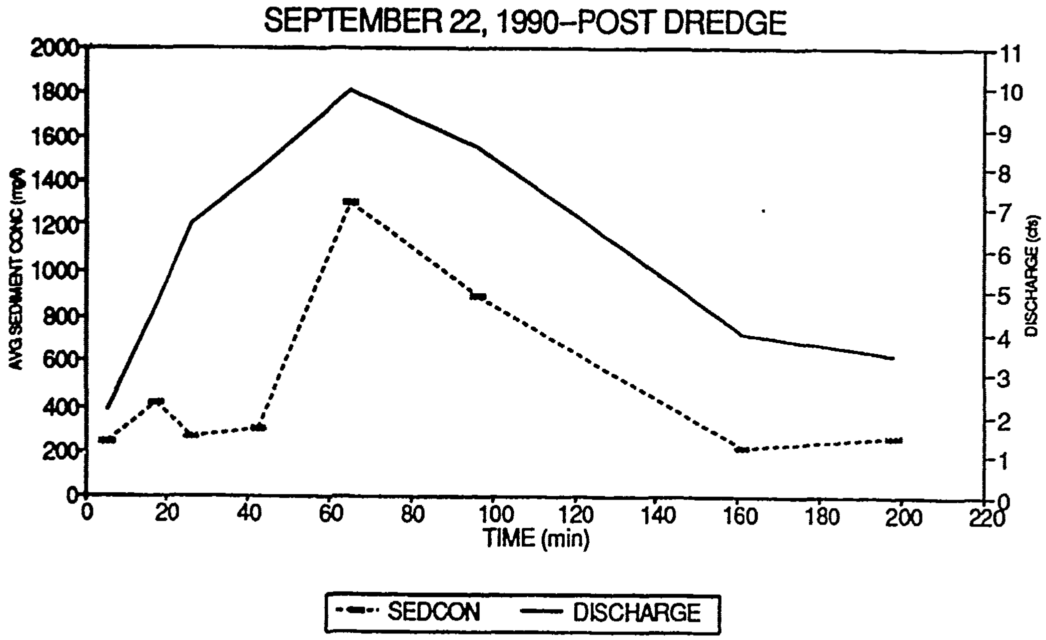


Fig. 3-15 Sediment concentration on stream hydrograph for Winslow Creek after dredging, September 22, 1990.

ditch bottom. This first sediment plume arrival during the September 8 storm was similar to those in August. During the September 9 storm, however, this plume arrived later, probably at about 50 minutes (Figure 3-14). This is due to the concentration of the rainfall in the upper portion of the basin on September 9. Rainfall for September 8 was more uniform across the basin, thus permitting a faster arrival time of sediment from the drainage ditches along Clemson Road.

Sediment concentrations in the left culvert (30") did not increase as sharply during the post-dredge events as they did in August. The two sediment plumes observed flowing into Winslow Creek for each September storm were also similar to those observed for storms in August. A large early average sediment concentration peak occurred on the September 22nd storm, but details are unknown because the early storm data are not available (Figure 3-15). The magnitude of the early peak inspite of modest precipitation intensity (Table 3-1) suggest a great importance of the ditch as a source of sediment.

In the main channel, flow velocities in the dredged portion of the channel were lowered, which presumably caused deposition of sediment that would have otherwise continued towards the basin outlet. During the post-dredge period there are, in fact, indications that suspended sediment concentrations increased just upstream from the sampling site, but that the "sink" created by the dredging caused the deposition of suspended sediment within that section of Winslow Creek. A decrease in September sediment concentration levels at Clemson Road for a given discharge is indicated by a comparison with the plot and regression for August storms (Figure 3-16). This relationship suggests the deposition of sediment into the sink during high flows.

As the dredged sink fills, suspended sediment concentrations downstream will presumably increase to pre-dredge concentrations over time. Field observations at the dredged site indicate that half the sink was filled by the September 9th storm and the October 10 storm filled most of the remaining exhumed volume. Field observations of this section of channel in December indicate continued infilling and a possible increase in channel-bed elevation.

Soil Loss Estimates for 1970

Results of the USLE calculations for six storms in 1970, calculated for each sub-basin, indicate that the highest soil-loss estimates were in areas of thinly vegetated Lakeland Soil on steep slopes. The lowest soil loss estimates occurred in areas of thickly vegetated Pelion and Johnston soils on low slopes (Appendix E-1). Erosion rates for a single storm varied from .00015 to .0186 ton/acre in the sub-basins (excluding quarries). These rates are relatively low compared to commonly recorded rates

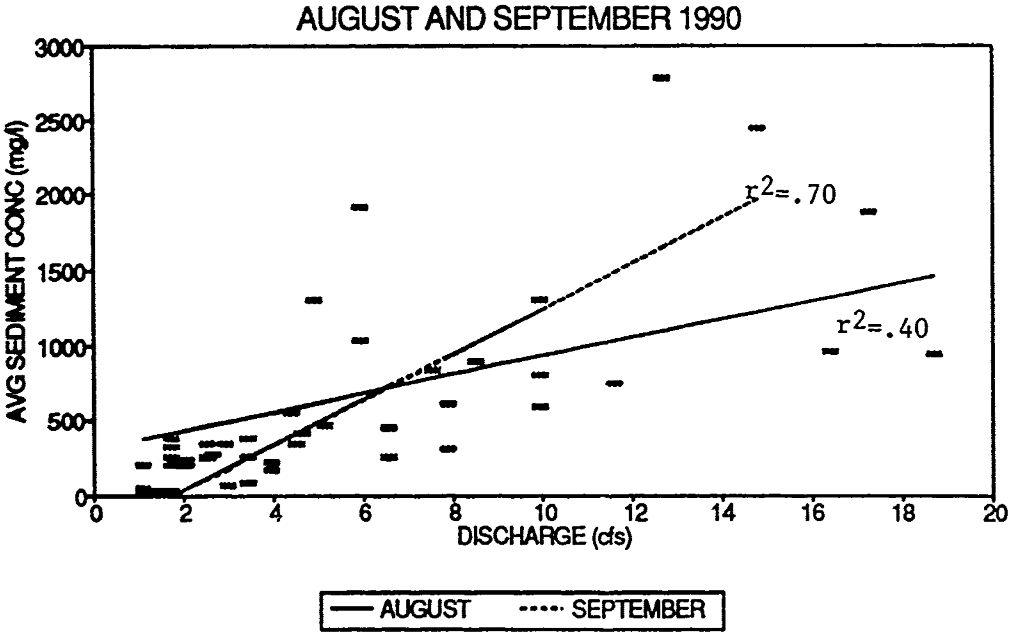


Fig. 3-16 Regression for pre-dredge and post-dredge sediment concentration on discharge, August and September, 1990.

elsewhere probably due to low erosivities of sandy soils of the Sand Hills (K= .1 to .2) and relatively dense vegetative cover.

The highest estimated soil loss occurred in sub-basin II. For example, the September 9, 1990 storm produced .58" of rain in a 66-minute period and generated an estimated soil loss of .059 tons/acre. The relatively high soil loss estimate for this sub-basin is attributable primarily to moderately erodible Lakeland soil series (K= .10), steep slopes up to 16% and thin vegetative cover. Similar erosive conditions are also found in sub-basins I, IV, V, and VI which also have relatively high soil-loss estimates.

The lowest estimated soil losses occurred in sub-basin IX. For example, the same September 9 storm would have generated an estimated soil loss of only .0015 tons/acre. This low estimate is attributable to the thick vegetative cover and low slopes no greater than 6%. Similar conditions are also found in sub-basins III, VII, VIII, and X. The Pelion and Johnston soil series common to these areas are more erosive than the Lakeland soil series (K = .15, .20, and .10, respectively), but the thick vegetation generally found on the Pelion and Johnston soils reduces the erodibility.

Table 3-3

1970 and 1990 Rainfall Volume and Estimated Soil Erosion

Date	Volume	Duration	I_{30}	Soil Loss		Change
	(in)	(min)	(in/hr)	(tons/acre)		
				1970	1990	
Aug 6	.25	30	.50	.0028	.0071	2.3
Aug 8	.49	48	.96	.0112	.0279	2.5
Sep 8	.17	45	.38	.0015	.0038	2.0
Sep 9	.58	66	1.12	.0157	.0391	2.4
Sep 22	.39	61	.66	.0056	.0139	2.3
Oct 10	2.52	227	.84	.0489	.1216	2.5
				.0857	.2134	2.2

Soil Loss Estimate for 1990

Since 1970, the basin has undergone several changes in land use. These changes were incorporated into the USLE parameters and their effects on soil erosion are clearly expressed. Most noticeable is urbanization occurring along Winslow Creek and in the southeast corner of the drainage basin (Photos 2-1 and 2-2). Approximately 100 of the 767.67 acres within the drainage basin were already developed by the beginning of the study and an additional 500 acres are planned for development as single-family housing in the future. It was hoped that construction activities would proceed at a rapid rate during the study, but an economic slump resulted in limited new construction during this period.

A large active quarry along the western interior boundary of the drainage basin has been established since 1970. Field observations indicate that this quarry is internally drained, and the assumption is made that sediment generated from the steep, unvegetated slopes is contained within the quarry.

The USLE soil-loss estimates for six storms in 1990, calculated for each sub-basin, indicate that the highest soil losses are in freshly-graded areas, primarily road cuts and unvegetated construction sites. In the subdivisions for example, the September 9, 1990 storm produced .58" of rain in a 66-minute period and generated an estimated soil loss of 1.236 and .206 tons/acre for the road cuts and the Winslow-Whitehurst subdivisions, respectively. The increased soil-loss estimates for these areas is attributable primarily to the lack of vegetative cover on steep slopes, such as those created by construction activity (Dunne and Leopold, 1978). Examples of these processes include sheetwash and gully erosion on a road cut parallel to a steep slope (Photo 3-1 and 3-2) and sheetwash and rill erosion on an unvegetated home site (Photo 3-3). Field observations and erosion pins placed at the base of these slopes verify the recent movement of sediment along the slope (Photo 3-4) (Table 3-4).

Photo 3-1 View up Winslow Way road cut, October 10, 1990. Sediment is transported directly into channel.

Photo 3-2 View down Winslow Way road cut. Winslow Creek in middle foreground flowing left to right.

Photo 3-3 Unvegetated homesite in subdivision. Notice rills and sediment collecting in the street.

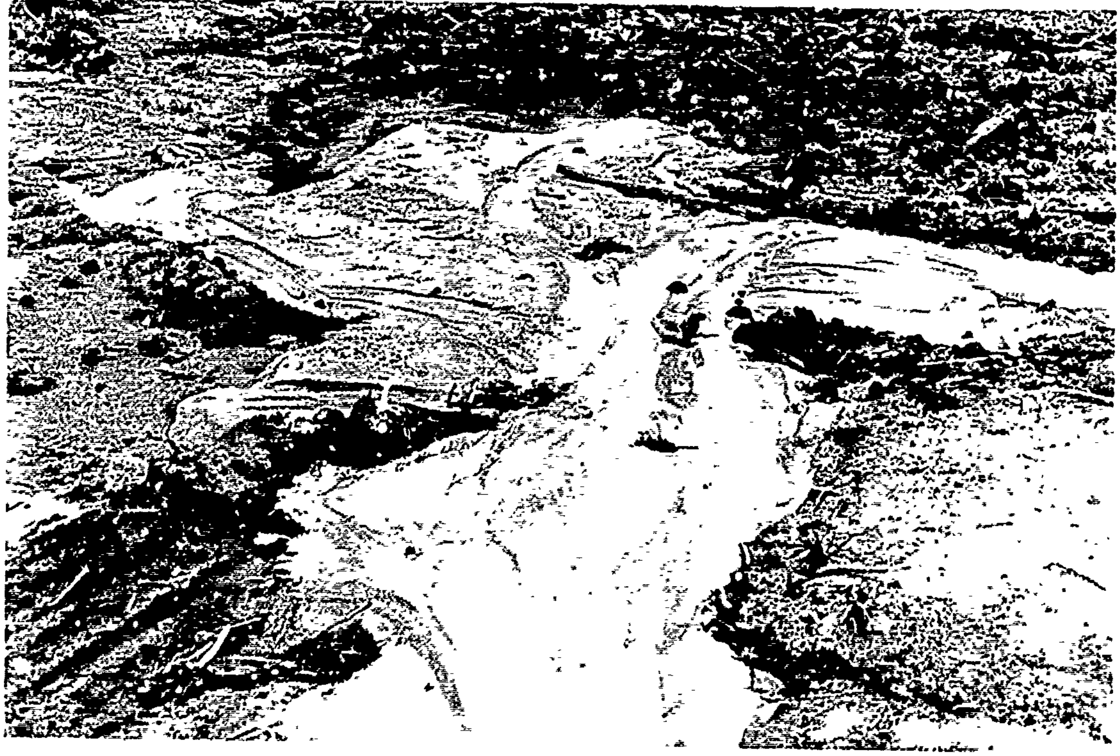


Photo 3-4 Erosion pin #9 buried by sediment originating from steep slope in background.

Spatially extensive high soil loss estimates occurred in sub-basins I, IV, and V. These high losses are attributable to steep slopes up to 16% and thin vegetative cover on moderately erodible Lakeland soils.

Table 3-4

Erosion Pin Placement and Results

Pin#	Location	Net Change (inches)	Remarks
3	Bottom of slope	+ .25	Left side of Road cut
9	Bottom of slope	+3.00	Active sediment plume

NOTE: Erosion pin locations are marked on photos 3-3 and 3-4. Measurements taken from July 25 through October 20.

The lowest soil-loss estimates occurred in vegetated areas and on paved surfaces. Over broad areas the lowest estimates occurred in sub-basins II, III, VI, VII, VIII, IX, and X (Appendix E-2). The Pelion and Johnston soils that dominate these sub-basins are more erodible than the Lakeland soil, but the thick vegetation generally found on these soils, reduces soil loss potential. Sub-basin I shifted from a zone of high erosion rates in 1970 to low rates in 1990 because of a change in land use from forrest and pasture to residential. Residential areas are separated from other land use classes to highlight the effect of urbanization on soil erosion.

Comparison of the USLE estimates for conditions in 1970 and 1990 provides a better understanding of how construction activity increases soil erosion potential (Table 3-5). Based on these initial estimates, soil erosion has increased in the basin by more than two-fold since 1970. Graded areas, cleared of vegetation and road cuts raised the potential for soil erosion in the basin.

Sediment Yield Estimates for 1990

The Modified Uniform Soil Loss Equation (MUSLE) predicts the sediment yield for a storm in a homogeneous watershed. To predict sediment yield for a heterogeneous watershed, sediment-routing procedures must be used. The MUSLE was used in this instance to establish a first approximation of sediment yield for the Winslow Creek basin. Sediment yields for three storms were calculated from measured peak discharge and runoff, together with the USLE parameters presented earlier (Table 2-1). These values of sediment yield predicted by the MUSLE are compared to sediment yields calculated from the sediment concentration data (Table 3-6) (Appendix F). The observed sediment yields tend to be less than predicted values or the three storms but are similar enough to suggest that the MUSLE provides a first approximation of predicted sediment yield for a small heterogeneous basin such as Winslow Creek.

Table 3-5

Sediment Yield

Date	Predicted			Observed		
	(tons)	(kg)	(ton/ac)	(tons)	(kg)	(tons/ac)
Sep 8, 90	.841	815	.0089	.270	246	.0004
Sep 9, 90	3.657	3547	.0048	3.727	3509	.0049
Sep 22, 90	2.413	2341	.0031	1.113	1298	.0001

Discrepancies in the predicted and observed values could have resulted from (1) extrapolation of unavailable discharge and sediment concentration data for the last few minutes of storm hydrographs, (2) application of the MUSLE to a heterogeneous basin, or inability of the MUSLE to adjust for enhanced channel storage due to dredging. Complete storm hydrographs and application of sediment routing procedures to predict sediment yield from a heterogeneous basin could increase reliability of results. Assuming that filling of the dredged main channel reach accounts for the difference between predicted and observed sediment yields, then filling by the September 8, 9, and 22 events would have been about .4, -.4, and .7 tons, respectively. This represents filling of only .7 tons, less than 1% of the approximately 150 tons dredged. Comparisons of sediment yields and soil erosion for the three storms (Tables 3-3 and 3-5) reveal that observed sediment yields (tons/acre) were about an order of magnitude less than estimated soil production in the basin. These numbers suggest a sediment delivery ratio of only about 10% which is quite low for such a small basin. To evaluate the plausibility of such a large storage of sediment, channel morphological changes are documented by surveying several stream cross-sections and calculating volume of stored sediment. 13 stream channel cross-sections were surveyed but, dredging of the main channel interrupted measurement of stored sediment. As a result, the cross-sections are used only to identify areas of aggradation and degradation within the channel system and determine a possible sediment source.

Stream Channel Change and Morphology

In order to relate soil erosion estimates to sediment yields in the basin, it is desirable to document changes in sediment storage in the basin. Repeated topographic surveys of 14 channel cross-sections in the Winslow Creek basin were performed to present evidence of channel aggradation and degradation for this purpose. The cross-section plots document channel erosion and deposition that occurred from July 25, 1990 to October 20, 1990 (Appendix G). The unanticipated dredging of a 100′ section of the main channel near cross-section 11 in August complicates interpretations of the channel change data, but provides an experiment of interest in its own right. Channel cross-section locations and conditions for the initial surveys are presented in table 3-6.

Profile comparisons of cross-sections 1 and 2 indicate substantial channel bed aggradation (Table 3-8). These cross-sections are located upstream and downstream, respectively, of the upper Winslow Way bridge across Winslow Creek in an as yet undeveloped section of the basin (Plate 1). Field observations indicate that little construction-induced sediment entered Winslow Creek above this point at the bottom of a steep road cut that runs perpendicular to the channel. Sediment generated from this road cut was observed being delivered directly into the channel between cross-sections 1 and 2, over its banks and through an unprotected storm sewer drop inlet (Photo 3-5). Channel-bed sediment at cross-section 1 above the bridge is finer textured than bed material at cross-section 2 which was presumably generated from the road (Table 3-7). Channel-bottom aggradation also occurred at cross-sections #3 and #4 on Moss Field Creek. The two sections on Thornfield Creek (#5 and #6) indicate a stable bed with very little accumulation of sediment.

Cross-sections 7 and 8, located upstream and downstream from the confluence of Winslow and Moss Field Creeks respectively, are the only cross sections that indicate net degradational change (Photos 3-6 and 3-7). The channel slope at cross-section 7 is perceptibly steeper than most other channel slopes in the basin. Channel erosion is

Table 3-6

Stream Channel Cross-section Locations and Channel Bank Characteristics

Cross Section	Location	Shape and Cover
1	Winslow Creek, 300' upstream from 48' pipe	Near-vertical, unvegetated
2	Winslow Creek, 300' downstream from 48" pipe	Near-vertical, unvegetated
3	Moss Field Creek, 300' downstream from Winslow Way	Parabolic, unvegetated
4	Moss Field Creek, 600' downstream from Winslow Way	Parabolic, unvegetated
5	Thornfield Creek, 200' upstream from culvert	Parabolic, vegetated
6	Thornfield Creek, 300' downstream from culvert	Parabolic, vegetated
7	Moss Field Creek, 100' upstream from confluence	Vee shaped, unvegetated
8	Winslow Creek, 10' downstream from confluence	Vee shaped, unvegetated
9	Winslow Creek, 300' downstream from cross-section #8	Parabolic, vegetated banks
10	Winslow Creek, 300' downstream from cross-section #9	Parabolic, vegetated banks
11	Winslow Creek, 100' upstream from dredging	Parabolic, vegetated banks
12	Whitehurst Creek, 300' upstream from culvert	Vee shaped, vegetated banks
13	Winslow Creek, upstream sections of concrete pipe	Parabolic, tall grasses

Table 3-7

Stream Channel Cross Section Morphology

Cross Section	Channel Slope %	Net Change sq ft	Channel Bed Texture % > .0049mm
1	0.50	1.22	82.00
2	0.50	0.1	99.59
3	0.02	-0.9	94.00
4	0.03	6.96	93.00
5	0.03	-5.6	91.00
6	0.04	0	88.00
7	2.00	-6.13	NA
8	0.57	-21.76	NA
9	0.57	15.79	98.20
10	0.38	0.61	99.62
11	0.33	1.74	99.72
12	0.03	-0.67	27.00
13	0.33	-1.2	81.00

Photo 3-5 Unprotected storm sewer drop inlet on Winslow Way road cut. Sediment flows freely into creek through this.

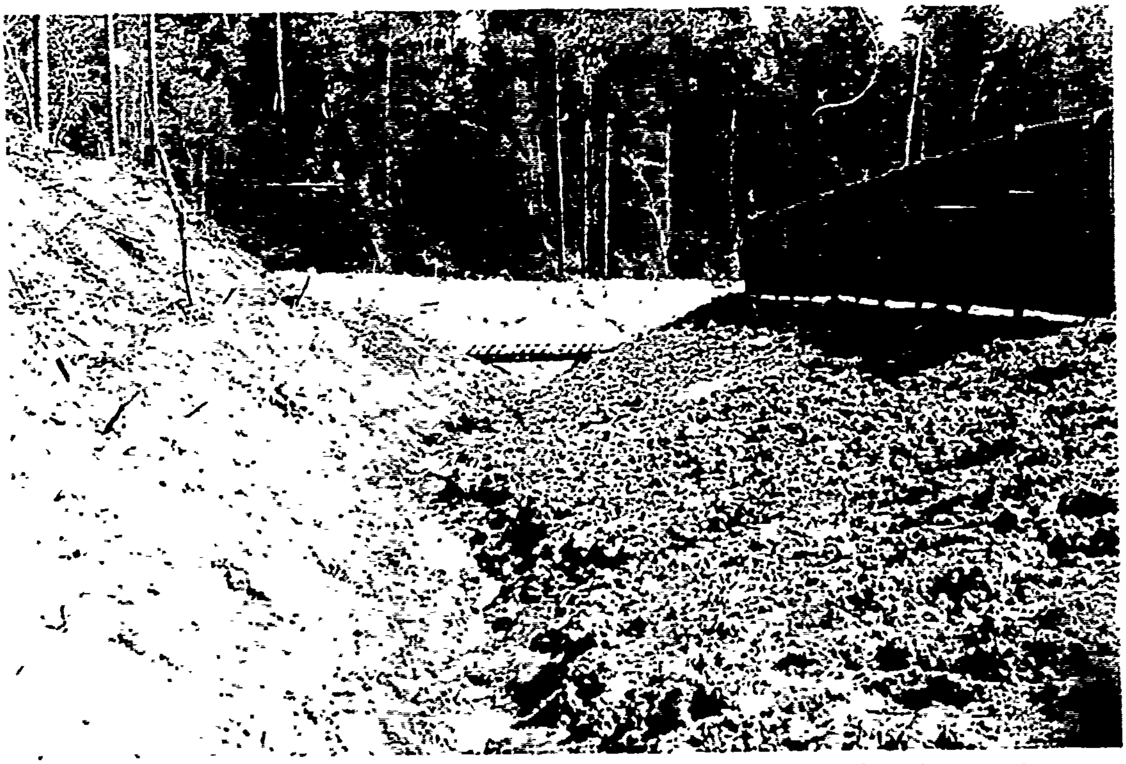


Photo 3-6 Channel cross-section #7 on Moss Field Creek. Notice large rills on channel banks and erosion in channel. August 23, 1990.

Photo 3-7 Confluence of Winslow and Moss Field Creeks. Cross-section #8 is just above slough on right side of photo. August 23, 1990.

apparently due to this steep slope and the introduction of runoff from a storm sewer less than 100′ upstream. Degradation at cross-section 8 is attributable to a steep channel slope and increased discharge from the confluence of Winslow and Moss Field creeks. Severe channel bank sloughing is occurring in this vicinity below the confluence of the two channels (Photo 3-8).

Cross-sections 9, 10, and 11 indicate net channel-bed aggradation particularly at sections 9 and 11 (Appendix G). These sections are located downstream from the Moss Field and Winslow Creek confluence in a 1,700-foot section of Winslow Creek (Photos 3-9 and 3-10). Aggradation is more pronounced in the lower reach of Winslow Creek at cross-sections 9, 10, and, 11. A combination of thick woods, tall grasses, and marked decrease in channel slope reduce flow velocity allowing the deposition of coarse material. Channel bed aggradation near cross-sections 9, 10, and, 11 was interrupted by dredging in the lower section as described in the next section.

Profile comparisons of cross-section 13 reveal little channel-bed aggradation (Appendix G). The suspended material that reaches this section of the channel is predominantly silt and clay. There may have been substantial volumes of overbank deposition of silts and clays in extensive thin deposits, but this would be very difficult to detect on the topographic survey. Field

Photo 3-8 Channel slough just below cross-section #8. Note gouging of channel bank caused by channel flow. August 23, 1990.

Photo 3-9 Cross-section #9. Sandy channel bottom bed material is approximately 2′ thick. Note bare channel banks. August 23, 1990.

Photo 3-10 View downstream to cross-section #11 on Winslow Creek. Note point bar consisting of coarse sand and gravel. August 23, 1990.

observations indicate that finer-grained sands are reaching this section of channel, but not in sufficient quantities to make a pronounced change in channel bed elevation.

Changes in stream channel morphology reveal several effects of urbanization. First, channel improvement including removal of vegetation, straightening of meanders, and channel enlargement, improved storm-water transport efficiency by reducing roughness coefficients, increasing flow velocities, and increasing channel capacities. Second, failure to reestablish vegetation on bare channel banks immediately after achieving final grade permitted bank erosion. Installation of sediment control devices on steep slopes adjacent to stream channels, would have reduced the amount of sediment that entered the channel from adjacent construction sites.

Effects of Channel Dredging

The stream network in the Winslow Creek drainage basin was channelized prior to housing construction to (1) drain low-lying areas within the basin, (2) lower the water table, and, (3) increase the channel capacity in anticipation of increased runoff from the subdivision. Winslow, Moss Field, Thornfield, and Whitehurst creeks were modified in this manner. Lake and Timbervale creeks were not (Plate 1).

After housing construction had begun and this study was in progress, a 100′ main channel section was further dredged on August 30, 1990. Dredging removed a 100′ x 10′ x 3′ volume of sediment and formed a sink that effectively stored coarse channel material, delaying its transport downstream. This late stage dredging proved necessary when aggradation of coarse material at the site, raised the main channel bed to an elevation where the storm drain began to fill with sediment and back up during storms. Following subsequent intense storms, the dredged section of channel had almost returned to its late stage pre-dredged elevation by October 20, 1990 but not to the level of the natural channel prior to the initial dredging. Presumably, when the dredged channel reach is completely in-filled to the level prior to all dredging, pronounced aggradation will continue and high sediment yields will proceed in the lower reaches of the basin.

Effectiveness of Bank Stabilization Practices

Channel banks throughout the basin were bare of any vegetation in early July with the exception of the lower and upper sections of Winslow Creek. On July 25th, the date of the initial survey, a contractor applied a liquified emulsion consisting of wood fiber and Bermuda-Weeping Love Grass seed mix to select channel banks within the subdivision (Photo 3-11). This method proved very effective at soil conservation where rills and gullies had not already formed.

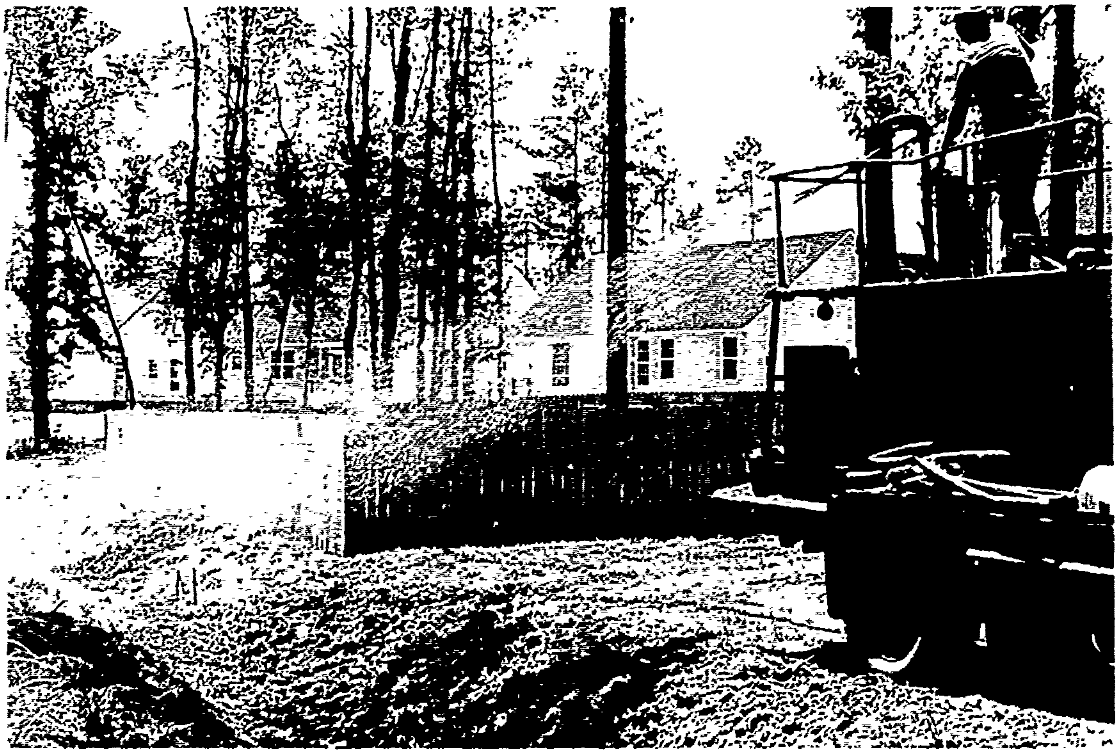


Photo 3-11 Contractor applying liquified seed emulsion to bare channel banks on Whitehurst Creek. July 25, 1990.

Cross-section site 5 channel banks were sprayed with a liquified seed emulsion on July 25, 1990, and grass grew quickly approximately 10" in 30 days (Photos 3-12 and 3-13). However, the contractor did not smooth the rills and gullies that had already formed on the channel banks. This allowed active rills and gullies to increase in size and continue to transport sediment into the channel. Cross section 6, 600' downstream, was also sprayed with seed emulsion (Photos 3-14 and 3-15). Channel banks were much smoother and did not have any large gullies or rills forming. The grass on this section of channel maintained the integrity of the channel banks as well as filtering coarse material produced from the construction sites located along the entire channel reach.

Sediment and Erosion Control Policy: A County and Engineering Perspective

There are several different perspectives on sediment and erosion control policy in Richland County. Distinctly different viewpoints were expressed by representatives of the county, engineering firms, contractors, and developers. For the purpose of this analysis, the county and engineering firm perspectives on sedimentation are examined to evaluate the state of sediment and erosion control policy in Richland County. The county officials characterize a perspective of those responsible for implementing policy including the review, approval, inspection, and enforcement of sediment

Photo 3-12 View upstream to cross-section #5 on Thornfield Creek. Note growth of grass seed emulsion. August 9, 1990.

Photo 3-13 View upstream to cross-section #5 on Thornfield Creek. Grass is approximately 12" tall. August 31, 1990.

Photo 3-14 View downstream to cross-section #6 on Thornfield Creek near log. Note growth of grass. August 8, 1990

Photo 3-15 View downstream to cross-section #6 on Thornfield Creek near log. Grass at cross-section is stabilizing channel banks. August 31, 1990.

and erosion control policy. The engineering firm personnel characterize a perspective of those who translate this policy into cost- effective strategies for the development, submission, and ultimate approval of sediment and erosion control plans for their clients.

The County Perspective

Sediment and erosion control policy in Richland County faces two problems: (1) a shortage of personnel to adequately inspect sediment and erosion control plans and (2) contractor apathy towards sediment and erosion control policy. The main problem with sediment and erosion control in Richland County is enforcement (Pearson, Personal Communication, 1990). There is one sediment and erosion control officer in the county whose primary responsibility is to review, recommend approval or disapproval, inspect, and enforce sediment and erosion control plans. Two engineering aides are also empowered to enforce sediment and erosion control in conjunction with their general subdivision inspection duties, but this task is primarily the responsibility of the sediment and erosion control officer (Pearson, Personal Communication, 1990). It is very difficult for one inspector to adequately inspect sixty to seventy active construction sites during the peak construction season for sediment and erosion control compliance and complete other duties assigned to him. It is pointless to attempt improvements to the ordinance, therefore, until compliance is achieved with the existing regulations (Pearson, Personal Communication, 1990).

Apathy towards sediment and erosion control can only be remedied by enforcing the existing policy, thus sending a clear signal to all parties that sediment and erosion control in Richland County is a serious concern. Some contractors view sediment and erosion control merely as a bureaucratic obstacle that has to be dealt with, and they emplace sediment and erosion control devices only as necessary to satisfy the inspector (Pearson, Personal Communication, 1990). The greatest strength of the ordinance, according to Mr. Pearson, is the handling of sediment and erosion control violations, that is, the issuance of stop-work orders and legal notices from the County Attorney's office, but this strength is severely limited by the inability to properly inspect sites.

The Engineering Firm Perspective

Engineering firms are employed by a contractor or developer to draft, submit, and obtain approval of sediment and erosion control plans for their projects. The approved plans generally comply with every aspect of the ordinance on paper, but on the site, control practices may appear quite different from the plans. Once the plans are approved, the contractor or developer may elect to modify sediment and erosion control plans to reduce costs, or to adjust to changing site conditions. Some contractors may deliberately avoid installing sediment and erosion control devices, knowing that the county will not have time to adequately inspect the implementation of sediment and erosion control plans. These deficiencies go unnoticed, unless an inspection is conducted or a complaint is received from a neighboring landowner. Most contractors respond quickly to sediment and erosion control plan deficiencies noted on site visits from the engineering firms or the county. Most engineering firms encourage their clients to comply with approved sediment and erosion control plans. In an isolated case, repeated unheeded requests from an engineering firm to a client to install sediment and erosion control devices, forced the engineering firm to report the violator to the county. Such incidents are rare, however, because engineering firms have a vested interest in maintaining an excellent client relationship. The experience of these engineering firms, as well as contractors and developers who deal with the ordinance on a daily basis, is a valuable resource that should be tapped before modifications to the ordinance are made.

Four engineering firms that work regularly with the Richland County Sediment and Erosion Control Ordinance clearly support the need for an enforceable sediment and erosion control policy. All four engineering firms agreed that sedimentation and soil erosion are important problems in Richland County. Increased urbanization in the past five years, erodible soils, steep slopes, failure to take preventive measures on construction sites, and failure to enforce existing sediment and erosion control policy were identified as significant contributing factors to sedimentation and erosion problems in the county. All four engineering firms were concerned with the effectiveness of their construction designs on sedimentation and soil-erosion abatement.

Strengths, shortcomings, and recommendations for improvements taken directly from engineer's interview transcriptions are summarized below.

Strengths of the Ordinance:

1. Inclusion of sediment and erosion control plans as part of the construction plans and not separately.

2. Assignment of a county sediment and erosion control officer to oversee the program.

3. Flexibility to adjust sediment and erosion control plans within the limits of the ordinance after consulting with the County Engineer.

Shortcomings of the Ordinance:

1. Indefinite language such as "as soon as practical" and "as soon as feasible" needs to be more definitive.

2. Lack of a *common sense clause*. If the ordinance is

Page 93 NOT AVAILA~~b~~ble

CHAPTER 4. CONCLUSION AND RECOMMENDATIONS

CONCLUSION

Sediment and erosion control policy in Richland County is much less effective than it could be, due to a shortage of trained county personnel to inspect approved sediment and erosion control plans. This shortage of inspectors limits the number of construction sites that are inspected and reinspected for ordinance compliance and directly affects the quality of sediment and erosion control in the county. Developers and contractors knowing that their site may never be inspected, may avoid installing or maintaining sediment and erosion control devices specified in the sediment and erosion control plans. Field observations and detailed analysis of suspended sediment concentrations, soil loss estimates, and stream channel morphology suggest that compliance with the approved sediment and erosion control plan for this site would substantially reduce soil erosion on construction sites and sedimentation of the stream channel system.

Suspended sediment concentration measurements reveal that channel dredging on Winslow Creek directly affected sediment concentration levels for storms after August 31, 1990. The dredging of the small drainage ditch along Clemson Road produced a much higher sediment concentration peak for low flows, than measured for storms prior to August

31. The dredging of a 100′ X 10′ X 3′ section of Winslow Creek near cross-section 11 appears to have decreased sediment concentration levels downstream. Flow velocities in this section of channel were lowered, forcing the premature deposition of sediment that would have otherwise continued towards the basin outlet. Field observations indicate that the bed of this dredged section of channel had almost returned to its pre-dredged elevation according to December, 1990 field observations.

Comparison of preconstruction (1970) and post-construction (1990) soil-loss estimates based on the USLE model reveal a two-fold increase in soil erosion. Road cuts and graded areas, cleared of vegetation were primarily responsible for increasing potential soil loss in the basin. Areas consisting of thinly-vegetated Lakeland soil on steep slopes also generated high soil-loss estimates. Field observations indicate that soil erosion is also severe on homesites that are not landscaped immediately after house construction. Unlandscaped homesites soon developed unsightly rills and gullies, requiring additional grading and expensive sodding or hydroseeding. Several homeowners laid sod to control soil erosion on their property after repeated attempts at conventional hand-seeding methods had failed.

The sediment budget equation can be simply expressed as:

$$I = O \pm \Delta S$$

where I is sediment production (input), O is sediment yield (output), and ΔS is change in storage. This equation shows that soil loss should equal, sediment yield plus or minus changes in storage (assuming that other sediment inputs and outputs such as aeolian processes are negligible). Comparisons of sediment yields and soil erosion estimates for the three storms reveal that observed sediment yields are about an order of magnitude less than estimated soil loss. A sediment delivery ratio of 10% suggests a large volume of sediment storage in the basin. It is surmised from field observations, independent checks with erosion pins, and topographic surveys that sediment is being stored in the stream channel system, at the toe of slopes, and as overbank deposits in the lower section of Winslow Creek. The stream channel cross-sections would have provided an accurate estimate of sediment storage had the channel system not been disturbed by the channel dredging.

Topographic surveys of channel cross-sections reveal that sediment deposition is pronounced at the upper Winslow Way bridge site and in the lower section of Winslow Creek, and channel-bed erosion is most pronounced just upstream and downstream of the Winslow and Moss Field creek confluence. Deposition in the lower section of Winslow Creek was affected by channel dredging, but field observations indicate a 2 to 3 foot deep accumulation of sandy material has filled much of this depression. Deposition in this section of channel is pronounced due to a marked decrease in channel gradient and increase in channel roughness as the stream flows through thick woods. Measured depths of channel-bed erosion near the Winslow and Moss Field Creek confluence average 1 to 1.5 feet, attributable to steep channel slopes and increased discharges, respectively.

Revegetation of channel banks, where properly implemented, maintained channel-bank integrity and filtered coarse sediment produced from adjacent construction sites. Erosion pins placed mid-slope on vegetated channel banks indicated little or no soil loss at these sites. Channel banks that were not vegetated were severely rilled and gullied, and erosion pins placed on such slopes indicated .25 to .50 inch losses of soil.

Personal interviews with professionals involved in sediment and erosion control planning reveal that the infrequent inspection of sediment and erosion control plans is the primary shortcoming of the ordinance. The technical requirements, administrative procedures, and penalties assessed for the violation of the ordinance are adequate and supported by the county and local engineering firms. Penalties mean little; however, if compliance with sediment and erosion control policy is infrequently or never checked. Assigning additional county personnel to the Sediment and Erosion Control Officer or requiring other county inspectors to report on compliance would improve the effectiveness of the ordinance. Richland County and the engineering firms expressed an interest in participating in a review of the ordinance if changes were contemplated. Both agreed that sediment and erosion control workshops were not worthwhile unless totally supported by all interested parties.

RECOMMENDATIONS

The results of this study are not necessarily representative of the overall condition of sediment and erosion control policy throughout Richland County. Nonetheless, detailed study of this site has identified several recommendations that will improve sediment and erosion control planning in the county and limit sedimentation and soil erosion that is occurring on the study site.

Sediment and Erosion Control Policy

1. Assign additional personnel to inspect sediment and erosion control plans. Continue to pursue the idea of assigning sediment and erosion control responsibilities to building inspectors.

2. Develop and implement an inspection checklist to standardize inspections, facilitate reinspections, and document specific violations for possible punitive action.

3. Consider changing the ordinance to reflect input

from professionals that have worked with the ordinance for the past ten years. The South Carolina Land Resources Conservation Commission and other state agencies are available to lend support and assistance.

Winslow Creek Sediment and Soil Erosion Control

1. Educate construction foremen on the value of installing and maintaining sediment and erosion control devices throughout the duration of a construction project. Early control of soil erosion and sedimentation will reduce the requirements and cost of channel maintenance and potential lawsuits from adjacent landowners.

2. Inspect and maintain all sediment and erosion control devices on a daily basis.

3. Check all areas on the construction site immediately after a storm and install additional sediment and erosion control devices and repair those damaged by the storm.

4. Landscape all homesites immediately after the houses are built.

5. Revegetate bare channel banks immediately after final grading when channel banks are smooth.

6. Inspect the stream channel system periodically to identify potential problems and take immediate corrective action.

APPENDIX A. STAGE RATING CHARTS FOR CONCRETE PIPES.

Concrete Pipe (30"), Winslow Creek

Depth in	Q cfs
1	0.000
2	0.125
3	0.427
4	0.891
5	1.509
6	2.276
7	3.182
8	4.220
9	5.378
10	6.647
11	8.014
12	9.467
13	10.994
14	12.581
15	14.214
16	15.877
17	17.556
18	19.233
19	20.892
20	22.513
21	24.076
22	25.560
23	26.941
24	28.192
25	29.280
26	30.167
27	30.798
28	31.093
29	30.884
30	28.924

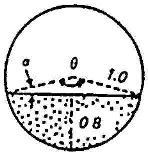
Note: 1" sediment in pipe.
Q is adjusted accordingly.

Concrete Pipe (36"), Winslow Creek

Depth in	Q cfs
1	0.057
2	0.250
3	0.592
4	1.085
5	1.727
6	2.516
7	3.446
8	4.512
9	5.707
10	7.023
11	8.453
12	9.987
13	11.617
14	13.332
15	15.121
16	16.975
17	18.882
18	20.830
19	22.807
20	24.800
21	26.796
22	28.781
23	30.740
24	32.657
25	34.516
26	36.300
27	37.989
28	39.562
29	40.996
30	42.263
31	43.329
32	44.153
33	44.674
34	44.801
35	44.330
36	41.660

Solution. Calculate the geometric properties

$$\alpha = \sin^{-1}\frac{0.2}{1.0} = 11.54°.$$



$$\therefore \theta = 156.9°$$

$$A = \pi \times 1^2 \times \frac{156.9}{360} - 0.2 \times \cos 11.54° \times \frac{1}{2} \times 2 = 1.174 \text{ m}^2.$$

$$P = \pi \times 2 \times \frac{156.9}{360} = 2.738 \text{ m}.$$

Using a Manning n for concrete pipe of $n = 0.015$, we have

$$Q = \frac{1.0}{n} AR^{2/3}S^{1/2}$$

$$= \frac{1.0}{0.015} \times 1.174 \times \left(\frac{1.174}{2.738}\right)^{2/3} \times 0.001^{1/2} = 1.41 \text{ m}^3/\text{s}.$$

A 2-m-dia concrete pipe transports water at a depth of 0.8 m. What is the flow rate if the slope is 0.001? (Potter, 1986)

APPENDIX B. RAINFALL EROSIVITY FOR OBSERVED STORMS.

August 6, 90

Time min	Time Int min	Rain Int in	Rain in/hr	Log I in/hr	E per in	Total E [1]
0	0	0.00	0.00	0.00000	0.00	0.00
8	8	0.17	1.28	0.10720	951.48	161.75
17	9	0.05	0.33	-0.48150	756.62	37.83
26	9	0.03	0.20	-0.69900	684.63	20.54
31	5	0.00	0.00	0.00000	0.00	0.00
Total		0.25				220.12

AI = .58 I30 = .50 R = 1.10

August 8, 90

Time min	Time Int min	Rain Int in	Rain in/hr	Log I in/hr	E per in	Total E
0	0	0.00	0.00	0.00000	0.00	0.00
6	6	0.07	0.70	-0.15490	864.73	60.53
13	7	0.07	0.60	-0.22180	842.58	58.98
17	4	0.07	1.05	0.02120	923.02	64.61
23	6	0.15	1.50	0.17610	974.29	146.14
27	4	0.10	1.50	0.17610	974.29	97.43
31	4	0.03	0.45	-0.34680	801.21	24.04
48	17	0.00	0.00	0.00000	0.00	0.00
Total		0.49				451.73

AI = .95 I30 = .96 R = 4.34

September 8, 90

Time min	Time Int min	Rain Int in	Rain in/hr	Log I in/hr	E per in	Total E
0	0	0.00	0.00	0.00000	0.00	0.00
17	17	0.00	0.00	0.00000	0.00	0.00
32	15	0.16	0.64	-0.19380	851.85	136.30
44	12	0.03	0.15	-0.82390	643.29	19.30
60	0	0.00	0.00	0.00000	0.00	0.00
Total		0.19				155.60

AI = .42 I30 = .38 R = .59

NOTE: [1] See Table 2-2 for definitions and explanations.

APPENDIX B. RAINFALL EROSIVITY FOR OBSERVED STORMS.

September 9, 90

Time min	Time Int min	Rain Int in	Rain in/hr	Log I in/hr	E per in	Total E
0	0	0.000	0.00	0.00000	0.00	0.00
9	9	0.190	1.26	0.10040	949.23	180.35
14	5	0.020	0.24	-0.62000	710.78	14.22
22	8	0.000	0.00	0.00000	0.00	0.00
24	2	0.050	1.50	0.17610	974.29	48.71
29	5	0.110	1.32	0.12060	955.92	105.15
34	5	0.094	1.13	0.05310	933.58	87.76
37	3	0.094	1.88	0.27420	1006.76	94.64
43	6	0.019	0.19	-0.72120	677.28	12.87
46	3	0.000	0.00	0.00000	0.00	0.00
		0.577				543.70

AI = .99 I30 = 1.12 R = 6.09

September 22, 90

Time min	Time Int min	Rain Int in	Rain in/hr	Log I in/hr	E per in	Total E
0	0	0.00	0.00	0.00000	0.00	0.00
5	5	0.08	0.94	-0.02690	907.10	70.75
19	14	0.16	0.70	-0.15490	864.73	141.82
24	5	0.07	0.84	-0.07570	890.94	62.37
52	28	0.08	0.17	-0.76960	661.26	51.58
61	9	0.00	0.00	0.00000	0.00	0.00
Total		0.39				326.52

AI = .45 I30 = .66 R = 2.16

October 10, 90

Time min	Time min	Rain Int in	Rain in/hr	Log I in/hr	E per in	Total E
173	173	2.42	0.84	-0.07570	890.94	2156.07
211	38	0.10	0.16	-0.07960	889.65	88.97
227	16	0.00	0.00	0.00000	0.00	0.00
Total		2.52				2245.04

AI = .39 I30 = .84 R = 18.93

APPENDIX C. SEDIMENT CONCENTRATION LAB PROCEDURES

The following procedures outline the evaporation method of determining the sediment concentrations in mg/l for all storm water samples.

1. All sample jars and bottles are thoroughly inspected for breakage and cleanliness. Bottles that pass inspection are weighed on the electronic balance with lid off to establish tare weight in grams. Bottle numbers and tare weight are recorded on the USGS sediment concentration laboratory form. Sample jars are tightly capped and stored for later use.

2. Storm water sample jars are inspected and any foreign debris is removed. The sample is then weighed on the electronic balance with the lid off. The gross sediment weight in grams is noted and recorded on the laboratory form. Net water sample weight is gross sample weight minus sample bottle tare weight. The samples are tightly capped and stored in a cool, dark, and dry place to prevent evaporation and organism growth.

3. Store samples undisturbed for approximately 14 days to permit visible suspended sediment to settle to the bottom of the jar. Winslow Creek samples contained a high silt and clay content which required the additional time.

4. After the visible sediment settles out, decant the sediment free water was from the jar using a rubber squeeze bulb taking care not to disturb the sediment at the bottom

of the jar. 20 to 25 ml of water is allowed to remain with the sediment should a dissolved-solids correction factor be required.

5. The sediment at the bottom of the jar is washed into a previously tared 250 ml beaker with distilled water, taking extreme care not to lose any sediment.

6. The distilled water-sediment mixture is oven dried for approximately 24 hours at 85°C. When all visible moisture is evaporated, the temperature of the oven is raised to 110^{oC} for one hour to ensure complete evaporation of all moisture.

7. The dry samples are allowed to cool to room temperature in a desiccator. The cooled sample is then weighed on an electronic balance to the nearest .001 g. The tare weight of the beaker is subtracted from the dry sediment weight for net sediment weight in grams.

8. Net sediment weight is divided by net water sample weight for sediment concentration in ppm (mg/l). Net sediment weights larger than 16000 require a correction facto to convert to mg/l (Guy, 1969; Ward, 1984). Sediment concentrations are recorded on the USGS laboratory form and all entries are checked for accuracy.

9. Remove the dried sediment from the beaker and analyze it under a microscope to determine particle size and mineral type. The color of the dry sediment is approximated using the Munsell Soil Color Charts. Sediment samples are labeled

and packed away for later analysis.

10. All glassware is thoroughly washed, air dried, reweighed and stored.

APPENDIX D-1. COUNTY INTERVIEW QUESTION SHEET

Interviewee: Mr. Ralph Pearson, Richland County Engineer

Soil Erosion and Sedimentation In General

1. In your opinion, is soil erosion and sedimentation a problem in Richland County? Why?
2. Of the two, which is the most damaging to the environment? Why?

The Richland County Sediment and Erosion Control Ordinance

1. What regulations existed in Richland County prior to the adoption of the ordinance in 1980?
2. Who authored the document and what review process did the document go through, to include assistance from the local universities, government agencies, and public review before being adopted? Was this effective or detrimental?
3. What are the strengths, shortcomings of the ordinance? What changes would you like to make?
4. Given your present resources (personnel, budget, and work schedule) do you feel that there is adequate enforcement at the county level? What suggestions would you make to improve enforcement?
5. If there were future plans to review the existing ordinance, would you include interested parties (SCLRCC, contractors, engineering firms, and the public) in the planning and final review process? What difficulties would you encounter if any?

6. Have there been any major violations of the ordinance? How were they discovered? What action was taken? Did the violator respond?

County, Contractor, and State Government Relationships

1. In your opinion, are contractors concerned about soil erosion and sedimentation? Are they responsive to problems encountered before and during construction?

2. Is the SCLRCC assistance beneficial to your request for support? What assistance have they provided? What other state agency has provided assistance to the county in the past?

3. Do you find the SCS manual helpful for soil erosion and sedimentation planning? What is the contractor/engineer response to the methods in the manual?

4. What part does the local SCS have in sediment erosion planning in the county and what assistance do they provide?

Other Questions

1. Other locations, Maryland and Illinois require mandatory workshops for all persons involved in sediment and erosion control planning to attend certification workshops before they can participate in sediment and soil erosion planning. Would this work in Richland County? Why?

2. What difficulties would you face if water quality standards for suspended solids were mandated for sediment and erosion control planning in the future?

APPENDIX D-2. ENGINEERING FIRM INTERVIEW QUESTION SHEET

Engineering Firm Interview Sheet

Participants:

Mr. Bill Brown, Civil Engineering of Columbia
Mr. George Derrick, B. P. Barber and Associates
Mr. Mel Gaddy, R. M. Gaddy and Associates
Mr. Tom Margle, Post, Buckley, Schuh and Jernigan

Soil Erosion and Sedimentation In General

1. Is soil erosion and sedimentation a problem in Richland County? Why?

2. How important is it to you that soil erosion and sedimentation be control in the county? Why?

3. Are existing local, state, and federal regulations concerning soil erosion and sedimentation adequate? Why?

The Richland County Sediment and Erosion Control Ordinance

1. Prior to the adoption of the Richland County Sediment and Erosion Control Ordinance on December 23, 1980, what policy was in effect, if any?

2. When the ordinance was developed by the county, were contractors or engineers outside the county involved in it's development?

3. Would you participate in a review of the ordinance if the county were to announce changes?

4. What strengths, shortcomings, and recommendations would

you make to change the ordinance?

Other Questions

1. Some states use tax breaks, benefits, and other incentives to contractors or developers that go above the requirements to support sedimentation and soil erosion policy. Which ones are best for the county and what others would you suggest?

2. Would mandatory workshops for the certification of all personnel involved in sediment and erosion control in the county be beneficial? Why?

3. As the ordinance reads, violations are identified during county inspections or complaints received from landowners adjacent to or downstream from a construction site. How and when are you notified of the problem?

4. What is your response to the attachment of a mandatory water quality standard to sediment and soil erosion control planning?

APPENDIX E-1. USLE SOIL LOSS ESTIMATES FOR 1970.

SUB-BASIN	Ac	% AREA	K	LS	C	P	Ac*K*LS*CP	Aug 6 R = 1.10 Tons	Tons/Acre
I. Whitehurst and Winslow subdivisions									
Jo	4.44	5.95	0.20	0.33	0.001	1	0.00029	0.00032	
PeB	41.26	55.34	0.15	1.04	0.001	1	0.00644	0.00708	
Lake	1.78	2.39	0.00	0.00	0.000	0	0.00000	0.00000	
Pasture	2.27	3.04	0.15	1.43	0.010	1	0.00487	0.00536	
LaB	21.27	28.53	0.10	1.38	0.042	1	0.12328	0.13561	
Pasture	3.54	4.75	0.10	1.43	0.010	1	0.00506	0.00557	
Subtotal	74.56	100.00						0.15394	0.00206
II. Whitehurst Creek subbasin									
Jo	7.43	10.39	0.20	0.43	0.001	1	0.00064	0.00070	
Lake	1.85	2.58	0.00	0.00	0.000	0	0.00000	0.00000	
PeB1	13.03	18.19	0.15	1.68	0.001	1	0.00328	0.00361	
PeB2	4.65	6.49	0.15	1.56	0.001	1	0.00109	0.00120	
Peb3	7.44	10.39	0.15	2.61	0.001	1	0.00291	0.00320	
LaB	33.50	46.77	0.10	4.91	0.042	1	0.69084	0.75992	
Pasture	3.72	5.19	0.10	1.43	0.010	1	0.00532	0.00585	
Subtotal	71.62	100.00						0.77449	0.01081
III. Mid-section of Winslow subdivision									
Jo	6.00	27.30	0.20	0.19	0.001	1	0.00023	0.00025	
PeB	9.98	45.40	0.15	1.52	0.001	1	0.00228	0.00250	
Pasture	6.00	27.30	0.15	1.43	0.010	1	0.01287	0.01416	
Subtotal	21.98	100.00						0.01691	0.00077
IV. Thornfield Creek subbasin									
Jo	10.84	9.37	0.20	1.57	0.001	1	0.00340	0.00374	
PeB1	4.92	4.25	0.15	0.17	0.001	1	0.00013	0.00014	
PeB2	48.22	41.68	0.15	1.90	0.001	1	0.01374	0.01512	
Pasture	5.92	5.12	0.15	0.61	0.010	1	0.00542	0.00596	
LaB1	7.85	6.78	0.10	3.33	0.042	1	0.10979	0.12077	
LaB2	37.95	32.80	0.10	1.33	0.042	1	0.21199	0.23319	
Subtotal	115.70	100.00						0.37891	0.00357
V. Moss Field Creek subbasin									
Jo	3.96	10.62	0.20	0.64	0.001	1	0.00051	0.00056	
PeB	13.73	36.83	0.15	1.77	0.001	1	0.00365	0.00401	
LaB	19.59	52.55	0.10	1.04	0.042	1	0.08557	0.09413	
Subtotal	37.28	100.00						0.09869	0.00265

APPENDIX E-1. USLE SOIL LOSS ESTIMATES FOR 1970.

SUB-BASIN	Ac	% AREA	K	LS	C	P	Ac*K*LS*CP	Aug 6 R = 1.10 Tons	Tons/Acre
VI. Upper Winslow Creek basin									
Jo	37.52	16.66	0.20	1.30	0.001	1	0.00976	0.01073	
PeB1	11.57	5.14	0.15	1.17	0.001	1	0.00203	0.00223	
PeB2	22.64	10.06	0.15	2.41	0.001	1	0.00818	0.00900	
PeB3	32.79	14.56	0.15	1.60	0.001	1	0.00787	0.00866	
PeB4	14.80	6.57	0.15	1.78	0.001	1	0.00395	0.00435	
LaB1	38.32	17.02	0.10	1.27	0.042	1	0.20440	0.22484	
LaB2	38.32	17.02	0.10	1.97	0.042	1	0.31706	0.34877	
LaD	18.55	8.24	0.10	2.52	0.002	1	0.00935	0.01028	
PeD	10.65	4.73	0.15	2.74	0.001	1	0.00438	0.00481	
Subtotal	225.16	100.00						0.62367	0.00277
VII. Lake Creek subbasin									
Jo	4.21	4.41	0.20	0.20	0.001	1	0.00017	0.00019	
PeB	74.07	77.56	0.15	2.74	0.001	1	0.03044	0.03349	
Lake1	4.39	4.60	0.00	0.00	0.000	0	0.00000	0.00000	
Lake2	2.37	2.48	0.00	0.00	0.000	0	0.00000	0.00000	
LaB	10.46	10.95	0.10	1.20	0.042	1	0.05272	0.05799	
Subtotal	95.50	100.00						0.09166	0.00096
VIII. Inactive quarry									
Quarry	9.18	100.00	0.15	1.11	1.000	0	0.00000	0.00000	
Subtotal	9.18	100.00						0.00000	0.00000
IX. Mid-section Winslow basin									
Jo	9.54	18.82	0.20	0.67	0.001	1	0.00128	0.00141	
PeB	41.15	81.18	0.15	1.86	0.001	1	0.01148	0.01263	
Subtotal	50.69	100.00						0.01404	0.00028
X. Timbervale Creek subbasin									
Jo	3.67	5.57	0.20	0.29	0.001	1	0.00021	0.00023	
PeB	54.07	81.92	0.15	1.17	0.001	1	0.00949	0.01044	
Quarry	5.50	8.33	0.15	1.17	1.000	0	0.00000	0.00000	
Plot	0.92	1.39	0.15	0.86	0.010	1	0.00119	0.00131	
LaB	1.84	2.79	0.10	1.80	0.042	1	0.01391	0.01530	
Subtotal	66.00	100.00						0.02728	0.00041
TOTALS	767.67	100.00						2.17959	0.00284

APPENDIX E-1. USLE SOIL LOSS ESTIMATES FOR 1970.

SUB-BASIN	Aug 8		Sep 8		Sep 9	
	R = 4.34		R = .59		R = 6.09	
	Tons	Tons/Acre	Tons	Tons/Acre	Tons	Tons/Acre
I. Whitehurst and Winslow subdivisions						
Jo	0.00127		0.00017		0.00178	
PeB	0.02793		0.00380		0.03920	
Lake	0.00000		0.00000		0.00000	
Pasture	0.02113		0.00287		0.02965	
LaB	0.53504		0.07274		0.75078	
Pasture	0.02197		0.00299		0.03083	
Subtotal	0.60735	0.00815	0.08257	0.00111	0.85225	0.01143
II. Whitehurst Creek subbasin						
Jo	0.00277		0.00038		0.00389	
Lake	0.00000		0.00000		0.00000	
PeB1	0.01425		0.00194		0.02000	
PeB2	0.00472		0.00064		0.00663	
Peb3	0.01264		0.00172		0.01774	
LaB	2.99823		0.40759		4.20720	
Pasture	0.02309		0.00314		0.03240	
Subtotal	3.05571	0.04267	0.41541	0.00580	4.28785	0.05987
III. Mid-section of Winslow subdivision						
Jo	0.00099		0.00013		0.00139	
PeB	0.00988		0.00134		0.01386	
Pasture	0.05586		0.00759		0.07838	
Subtotal	0.06672	0.00304	0.00907	0.00041	0.09362	0.00426
IV. Thornfield Creek subbasin						
Jo	0.01477		0.00201		0.02073	
PeB1	0.00054		0.00007		0.00076	
PeB2	0.05964		0.00811		0.08369	
Pasture	0.02351		0.00320		0.03299	
LaB1	0.47649		0.06478		0.66862	
LaB2	0.92003		0.12507		1.29101	
Subtotal	1.49499	0.01292	0.20324	0.00176	2.09781	0.01813
V. Moss Field Creek subbasin						
Jo	0.00220		0.00030		0.00309	
PeB	0.01582		0.00215		0.02220	
LaB	0.37137		0.05049		0.52112	
Subtotal	0.38939	0.01045	0.05294	0.00142	0.54640	0.01466

APPENDIX E-1. USLE SOIL LOSS ESTIMATES FOR 1970.

SUB-BASIN	Aug 8		Sep 8		Sep 9	
	R = 4.34		R = .59		R = 6.09	
	Tons	Tons/Acre	Tons	Tons/Acre	Tons	Tons/Acre
VI. Upper Winslow Creek basin						
Jo	0.04234		0.00576		0.05941	
PeB1	0.00881		0.00120		0.01237	
PeB2	0.03552		0.00483		0.04984	
PeB3	0.03415		0.00464		0.04793	
PeB4	0.01715		0.00233		0.02407	
LaB1	0.88709		0.12060		1.24479	
LaB2	1.37604		0.18707		1.93089	
LaD	0.04058		0.00552		0.05694	
PeD	0.01900		0.00258		0.02666	
Subtotal	2.46068	0.01093	0.33452	0.00149	3.45289	0.01534
VII. Lake Creek subbasin						
Jo	0.00073		0.00010		0.00103	
PeB	0.13212		0.01796		0.18540	
Lake1	0.00000		0.00000		0.00000	
Lake2	0.00000		0.00000		0.00000	
LaB	0.22880		0.03110		0.32106	
Subtotal	0.36165	0.00379	0.04916	0.00051	0.50748	0.00531
VIII. Inactive quarry						
Quarry	0.00000		0.00000		0.00000	
Subtotal	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
IX. Mid-section Winslow basin						
Jo	0.00555		0.00075		0.00779	
PeB	0.04983		0.00677		0.06992	
Subtotal	0.05537	0.00109	0.00753	0.00015	0.07770	0.00153
X. Timbervale Creek subbasin						
Jo	0.00092		0.00013		0.00130	
PeB	0.04118		0.00560		0.05779	
Quarry	0.00000		0.00000		0.00000	
Plot	0.00515		0.00070		0.00723	
LaB	0.06037		0.00821		0.08471	
Subtotal	0.10763	0.00163	0.01463	0.00022	0.15103	0.00229
TOTALS	8.59949	0.01120	1.16905	0.00152	12.06702	0.01572

APPENDIX E-1. USLE SOIL LOSS ESTIMATES FOR 1970.

SUB-BASIN	Sep 22		Oct 10	
	R = 2.16		R = 18.93	
	Tons	Tons/Acre	Tons	Tons/Acre
I. Whitehurst and Winslow subdivisions				
Jo	0.00063		0.00555	
PeB	0.01390		0.12184	
Lake	0.00000		0.00000	
Pasture	0.01052		0.09217	
LaB	0.26629		2.33371	
Pasture	0.01093		0.09583	
Subtotal	0.30227	0.00405	2.64910	0.03553
II. Whitehurst Creek subbasin				
Jo	0.00138		0.01210	
Lake	0.00000		0.00000	
PeB1	0.00709		0.06216	
PeB2	0.00235		0.02060	
Peb3	0.00629		0.05514	
LaB	1.49221		13.07754	
Pasture	0.01149		0.10070	
Subtotal	1.52081	0.02123	13.32823	0.18610
III. Mid-section of Winslow subdivision				
Jo	0.00049		0.00432	
PeB	0.00491		0.04307	
Pasture	0.02780		0.24363	
Subtotal	0.03321	0.00151	0.29102	0.01324
IV. Thornfield Creek subbasin				
Jo	0.00735		0.06443	
PeB1	0.00027		0.00237	
PeB2	0.02968		0.26015	
Pasture	0.01170		0.10254	
LaB1	0.23715		2.07833	
LaB2	0.45790		4.01295	
Subtotal	0.74405	0.00643	6.52077	0.05636
V. Moss Field Creek subbasin				
Jo	0.00109		0.00960	
PeB	0.00787		0.06901	
LaB	0.18483		1.61982	
Subtotal	0.19380	0.00520	1.69842	0.04556

APPENDIX E-1. USLE SOIL LOSS ESTIMATES FOR 1970.

SUB-BASIN	Sep 22		Oct 10	
	R = 2.16		R = 18.93	
	Tons	Tons/Acre	Tons	Tons/Acre
VI. Upper Winslow Creek basin				
Jo	0.02107		0.18467	
PeB1	0.00439		0.03844	
PeB2	0.01768		0.15493	
PeB3	0.01700		0.14897	
PeB4	0.00854		0.07480	
LaB1	0.44150		3.86927	
LaB2	0.68485		6.00194	
LaD	0.02019		0.17698	
PeD	0.00945		0.08286	
Subtotal	1.22467	0.00544	10.73286	0.04767
VII. Lake Creek subbasin				
Jo	0.00036		0.00319	
PeB	0.06576		0.57628	
Lake1	0.00000		0.00000	
Lake2	0.00000		0.00000	
LaB	0.11387		0.99796	
Subtotal	0.17999	0.00188	1.57743	0.01652
VIII. Inactive quarry				
Quarry	0.00000		0.00000	
Subtotal	0.00000	0.00000	0.00000	0.00000
IX. Mid-section Winslow basin				
Jo	0.00276		0.02420	
PeB	0.02480		0.21733	
Subtotal	0.02756	0.00054	0.24153	0.00476
X. Timbervale Creek subbasin				
Jo	0.00046		0.00403	
PeB	0.02050		0.17963	
Quarry	0.00000		0.00000	
Plot	0.00256		0.02247	
LaB	0.03005		0.26332	
Subtotal	0.05357	0.00081	0.46945	0.00711
TOTALS	4.27993	0.00558	37.50882	0.04886

APPENDIX E-2. USLE SOIL LOSS ESTIMATES FOR 1990.

SUB-BASINS	Ac	% Area	K	LS	C	P	Ac*K*LS*CP	Aug 6 R = 1.10 Tons	Tons/Acre
I. Winslow and Whitehurst subdivision									
PeB	10.37	28.96	0.15	0.83	0.001	1	0.00129	0.00142	
Lake	0.95	2.65	0.00	0.00	0.000	0	0.00000	0.00000	
LaB	18.84	52.61	0.10	1.86	0.042	1	0.14718	0.16190	
Quarry	5.65	15.78	0.10	2.18	1.000	0	0.00000	0.00000	
Subtotal	35.81	100.00						0.16332	0.00456
II. Whitehurst Creek subbasin and active quarry									
Jo	5.43	9.24	0.20	0.99	0.001	1	0.00108	0.00118	
PeB1	9.03	15.36	0.15	2.10	0.001	1	0.00284	0.00313	
PeB2	1.81	3.08	0.15	3.12	0.001	1	0.00085	0.00093	
Quarry	8.13	13.83	0.15	2.21	1.000	0	0.00000	0.00000	
Lab Quarry	10.87	18.50	0.10	3.30	1.000	0	0.00000	0.00000	
Quarry	7.23	12.30	0.10	1.87	1.000	0	0.00000	0.00000	
Quarry	14.46	24.60	0.10	1.11	1.000	0	0.00000	0.00000	
PeB3	1.81	3.09	0.10	1.14	0.001	1	0.00021	0.00023	
Subtotal	58.77	100.00						0.00547	0.00009
III. Mid-section Winslow subdivision									
PeB	3.67	100.00	0.15	1.08	0.001	1	0.00059	0.00065	
Subtotal	3.67	100.00						0.00065	0.00018
IV. Thornfield Creek subbasin									
Jo	8.59	7.80	0.20	1.51	0.001	1	0.00259	0.00285	
PeB1	53.12	48.20	0.15	1.47	0.001	1	0.01171	0.01288	
PeB2	1.25	1.13	0.15	2.62	0.001	1	0.00049	0.00054	
LaB1	40.05	36.35	0.10	2.52	0.042	1	0.42389	0.46628	
LaB2	7.18	6.52	0.10	1.88	0.042	1	0.05669	0.06236	
Subtotal	110.19	100.00						0.54492	0.00495
V. Moss Field Creek subbasin									
Jo	1.90	5.52	0.20	1.17	0.001	1	0.00044	0.00049	
LaB	19.19	55.70	0.10	1.60	0.042	1	0.12896	0.14185	
PeB	13.36	38.78	0.15	1.17	0.001	1	0.00234	0.00258	
Subtotal	34.45	100.00						0.14492	0.00421
VI. Upper section Winslow basin									
Jo	37.52	16.66	0.20	1.30	0.001	1	0.00976	0.01073	
PeB1	11.57	5.14	0.15	1.17	0.001	1	0.00203	0.00223	
PeB2	22.64	10.06	0.15	2.41	0.001	1	0.00818	0.00900	
PeB3	32.79	14.56	0.15	1.60	0.001	1	0.00787	0.00866	
PeB4	14.80	6.58	0.15	1.78	0.001	1	0.00395	0.00435	
LaB1	33.22	14.75	0.10	1.27	0.042	1	0.17720	0.19492	
LaB2	38.32	17.02	0.10	1.97	0.042	1	0.31706	0.34877	
LaD	18.55	8.24	0.10	2.52	0.002	1	0.00935	0.01028	
PeD	10.65	4.73	0.15	2.74	0.001	1	0.00438	0.00481	
Res	2.55	1.13	0.15	0.86	0.010	1	0.00329	0.00362	
Res	2.55	1.13	0.15	0.86	0.010	1	0.00329	0.00362	
Subtotal	225.16	100.00						0.60099	0.00267

APPENDIX E-2. USLE SOIL LOSS ESTIMATES FOR 1990.

SUB-BASINS	Ac	% Area	K	LS	C	P	Ac*K*LS*CP	Aug 6 R = 1.10 Tons	Tons/Acre
VII. Lake Creek subbasin									
Jo	4.18	4.38	0.20	0.20	0.001	1	0.00017	0.00018	
PeB	74.61	78.13	0.15	2.74	0.001	1	0.03066	0.03373	
Lake1	4.18	4.37	0.00	0.00	0.000	0	0.00000	0.00000	
Lake2	2.15	2.25	0.00	0.00	0.000	0	0.00000	0.00000	
LaB	8.22	8.61	0.10	0.37	0.042	1	0.01277	0.01405	
Res	2.16	2.26	0.10	0.86	0.003	1	0.00056	0.00061	
Subtotal	95.50	100.00						0.04858	0.00051
VIII. Inactive quarry									
PeB	9.18	100.00	0.15	1.11	1.000	0	0.00000	0.00000	
Subtotal	9.18	100.00						0.00000	0.00000
IX. Mid-section Winslow basin									
Jo	9.54	18.82	0.20	0.67	0.001	1	0.00128	0.00141	
PeB	41.15	81.18	0.15	1.86	0.001	1	0.01148	0.01263	
Subtotal	50.69	100.00						0.01404	0.00028
X. Timbervale subbasin									
Jo	7.26	11.00	0.20	0.29	0.001	1	0.00042	0.00046	
PeB	47.38	71.79	0.15	1.17	0.001	1	0.00832	0.00915	
LaB	2.65	4.01	0.10	1.80	0.042	1	0.02003	0.02204	
Res	8.71	13.20	0.10	1.15	0.003	1	0.00300	0.00331	
Subtotal	66.00	100.00						0.03495	0.00053
Subdivision Roadcuts									
Whitehurst subdivision									
Peb	1.38	15.37	0.15	0.72	1.000	1	0.14904	0.16394	
Winslow Way									
PeB	0.43	4.79	0.15	0.33	1.000	1	0.02129	0.02341	
LaB	0.43	4.79	0.10	1.00	1.000	1	0.04300	0.04730	
PeB	1.72	19.15	0.15	2.84	1.000	1	0.73272	0.80599	
Jo	0.43	4.79	0.20	0.52	1.000	1	0.04472	0.04919	
PeD	0.86	9.58	0.15	0.81	1.000	1	0.10449	0.11494	
PeD	0.86	9.58	0.15	1.16	1.000	1	0.14964	0.16460	
PeD	1.72	19.14	0.15	1.57	1.000	1	0.40506	0.44557	
Kentshire Road									
PeB	1.15	12.81	0.15	1.00	1.000	1	0.17250	0.18975	
Subtotal	8.98	100.00						2.00470	0.22324

APPENDIX E-2. USLE SOIL LOSS ESTIMATES FOR 1990.

SUB-BASINS	Ac	% Area	K	LS	C	P	Ac*K*LS*CP	Aug 6 R = 1.10 Tons	Tons/Acre
Winslow Subdivision									
I.									
PeB	14.81	29.82	0.15	1.04	0.010	1	0.02310	0.02541	
PeB1	0.27	0.54	0.15	0.71	1.000	1	0.02876	0.03163	
PeB2	0.21	0.42	0.15	1.04	1.000	1	0.03276	0.03604	
PeB3	0.21	0.42	0.15	0.36	1.000	1	0.01134	0.01247	
II.									
PeB	2.76	5.56	0.15	0.18	1.000	1	0.07452	0.08197	
Jo	2.55	5.13	0.20	0.43	1.000	1	0.21930	0.24123	
Jo1	0.21	0.42	0.20	0.77	1.000	1	0.03234	0.03557	
Jo2	0.21	0.42	0.20	0.59	1.000	1	0.02478	0.02726	
III.									
Jo	2.30	4.63	0.20	0.26	0.010	1	0.00120	0.00132	
PeB	1.98	3.99	0.15	0.18	0.001	1	0.00005	0.00006	
PeB2	0.64	1.29	0.15	1.08	1.000	1	0.10368	0.11405	
IV.									
Jo	1.37	2.76	0.20	1.57	1.000	1	0.43018	0.47320	
Jo	1.37	2.76	0.20	2.08	1.000	1	0.56992	0.62691	
PeB	0.04	0.08	0.15	1.69	1.000	1	0.01014	0.01115	
Wetland									
Jo	1.84	3.72	0.20	0.33	1.000	1	0.12144	0.13358	
Paved Surfaces									
	18.89	38.04	0.00	0.00	0.000	0	0.00000	0.00000	
Subtotal	49.66	100.00						1.85186	0.03729
Subdivision Grassed Areas									
I. PeB	11.54	58.85	0.15	1.04	0.003	1	0.00540	0.00594	
II. PeB	3.50	17.85	0.15	0.18	0.003	1	0.00028	0.00031	
III. PeB	3.20	16.31	0.15	0.18	0.003	1	0.00026	0.00029	
IV. Jo	1.37	6.99	0.20	1.69	0.003	1	0.00139	0.00153	
Subtotal	19.61	100.00						0.00807	0.00041
TOTALS	767.67							5.42246	0.00706

APPENDIX E-2. USLE SOIL LOSS ESTIMATES FOR 1990.

SUB-BASINS	Aug 8		Sep 8		Sep 9	
	R = 4.34		R = .59		R = 6.09	
	Tons	Tons/Acre	Tons	Tons/Acre	Tons	Tons/Acre
I. Winslow and Whitehurst subdivision						
PeB	0.00560		0.00076		0.00786	
Lake	0.00000		0.00000		0.00000	
LaB	0.63875		0.08684		0.89631	
Quarry	0.00000		0.00000		0.00000	
Subtotal	0.64436	0.01799	0.08760	0.00245	0.90418	0.02525
II. Whitehurst Creek subbasin and active quarry						
Jo	0.00467		0.00063		0.00655	
PeB1	0.01234		0.00168		0.01732	
PeB2	0.00368		0.00050		0.00516	
Quarry	0.00000		0.00000		0.00000	
Lab Quarry	0.00000		0.00000		0.00000	
Quarry	0.00000		0.00000		0.00000	
Quarry	0.00000		0.00000		0.00000	
PeB3	0.00090		0.00012		0.00126	
Subtotal	0.02158	0.00037	0.00293	0.00005	0.03029	0.00052
III. Mid-section Winslow subdivision						
PeB	0.00258		0.00035		0.00362	
Subtotal	0.00258	0.00070	0.00035	0.00010	0.00362	0.00099
IV. Thornfield Creek subbasin						
Jo	0.01126		0.00153		0.01580	
PeB1	0.05083		0.00691		0.07133	
PeB2	0.00213		0.00029		0.00299	
LaB1	1.83968		0.25009		2.58149	
LaB2	0.24605		0.03345		0.34526	
Subtotal	2.14995	0.01951	0.29227	0.00265	3.01687	0.02738
V. Moss Field Creek subbasin						
Jo	0.00193		0.00026		0.00271	
LaB	0.55967		0.07608		0.78535	
PeB	0.01018		0.00138		0.01428	
Subtotal	0.57178	0.01660	0.07773	0.00226	0.80233	0.02329
VI. Upper section Winslow basin						
Jo	0.04234		0.00576		0.05941	
PeB1	0.00881		0.00120		0.01237	
PeB2	0.03552		0.00483		0.04984	
PeB3	0.03415		0.00464		0.04793	
PeB4	0.01715		0.00233		0.02407	
LaB1	0.76903		0.10455		1.07912	
LaB2	1.37604		0.18707		1.93089	
LaD	0.04058		0.00552		0.05694	
PeD	0.01900		0.00258		0.02666	
Res	0.01428		0.00194		0.02003	
Res	0.01428		0.00194		0.02003	
Subtotal	2.37117	0.01053	0.32235	0.00143	3.32728	0.01478

APPENDIX E-2. USLE SOIL LOSS ESTIMATES FOR 1990.

SUB-BASINS	Aug 8		Sep 8		Sep 9	
	R = 4.34		R = .59		R = 6.09	
	Tons	Tons/Acre	Tons	Tons/Acre	Tons	Tons/Acre
VII. Lake Creek subbasin						
Jo	0.00073		0.00010		0.00102	
PeB	0.13308		0.01809		0.18675	
Lake1	0.00000		0.00000		0.00000	
Lake2	0.00000		0.00000		0.00000	
LaB	0.05544		0.00754		0.07779	
Res	0.00242		0.00033		0.00339	
Subtotal	0.19167	0.00201	0.02606	0.00027	0.26895	0.00282
VIII. Inactive quarry						
PeB	0.00000		0.00000		0.00000	
Subtotal	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
IX. Mid-section Winslow basin						
Jo	0.00555		0.00075		0.00779	
PeB	0.04983		0.00677		0.06992	
Subtotal	0.05537	0.00109	0.00753	0.00015	0.07770	0.00153
X. Timbervale subbasin						
Jo	0.00183		0.00025		0.00256	
PeB	0.03609		0.00491		0.05064	
LaB	0.08695		0.01182		0.12201	
Res	0.01304		0.00177		0.01830	
Subtotal	0.13790	0.00209	0.01875	0.00028	0.19351	0.00293
Subdivision Roadcuts						
Whitehurst subdivision						
Peb	0.64683		0.08793		0.90765	
Winslow Way						
PeB	0.09238		0.01256		0.12963	
LaB	0.18662		0.02537		0.26187	
PeB	3.18000		0.43230		4.46226	
Jo	0.19408		0.02638		0.27234	
PeD	0.45349		0.06165		0.63634	
PeD	0.64944		0.08829		0.91131	
PeD	1.75796		0.23899		2.46682	
Kentshire Road						
PeB	0.74865		0.10178		1.05053	
Subtotal	7.90945	0.88079	1.07525	0.11974	11.09875	1.23594

APPENDIX E-2. USLE SOIL LOSS ESTIMATES FOR 1990.

SUB-BASINS	Aug 8		Sep 8		Sep 9	
	R = 4.34		R = .59		R = 6.09	
	Tons	Tons/Acre	Tons	Tons/Acre	Tons	Tons/Acre
Winslow Subdivision						
I.						
PeB	0.10027		0.01363		0.14070	
PeB1	0.12480		0.01697		0.17512	
PeB2	0.14218		0.01933		0.19951	
PeB3	0.04922		0.00669		0.06906	
II.						
PeB	0.32342		0.04397		0.45383	
Jo	0.95176		0.12939		1.33554	
Jo1	0.14036		0.01908		0.19695	
Jo2	0.10755		0.01462		0.15091	
III.						
Jo	0.00519		0.00071		0.00728	
PeB	0.00023		0.00003		0.00033	
PeB2	0.44997		0.06117		0.63141	
IV.						
Jo	1.86698		0.25381		2.61980	
Jo	2.47345		0.33625		3.47081	
PeB	0.04401		0.00598		0.06175	
Wetland						
Jo	0.52705		0.07165		0.73957	
Paved Surfaces						
	0.00000		0.00000		0.00000	
Subtotal	7.30642	0.14713	0.99327	0.02000	10.25256	0.20646
Subdivision Grassed Areas						
I. PeB	0.02344		0.00319		0.03289	
II. PeB	0.00123		0.00017		0.00173	
III. PeB	0.00112		0.00015		0.00158	
IV. Jo	0.00603		0.00082		0.00846	
Subtotal	0.03182	0.00162	0.00433	0.00022	0.04466	0.00228
TOTALS	21.39407	0.02787	2.90841	0.00379	30.02071	0.03911

APPENDIX E-2. USLE SOIL LOSS ESTIMATES FOR 1990.

SUB-BASINS	Sep 22		Oct 10	
	R = 2.16		R = 18.93	
	Tons	Tons/Acre	Tons	Tons/Acre
I. Winslow and Whitehurst subdivision				
PeB	0.00279		0.02444	
Lake	0.00000		0.00000	
LaB	0.31790		2.78608	
Quarry	0.00000		0.00000	
Subtotal	0.32069	0.00896	2.81052	0.07848
II. Whitehurst Creek subbasin and active quarry				
Jo	0.00232		0.02035	
PeB1	0.00614		0.05385	
PeB2	0.00183		0.01604	
Quarry	0.00000		0.00000	
Lab Quarry	0.00000		0.00000	
Quarry	0.00000		0.00000	
Quarry	0.00000		0.00000	
PeB3	0.00045		0.00391	
Subtotal	0.01074	0.00160	0.09414	0.00160
III. Mid-section Winslow subdivision				
PeB	0.00128		0.01125	
Subtotal	0.00128	0.00035	0.00128	0.00307
IV. Thornfield Creek subbasin				
Jo	0.00560		0.04911	
PeB1	0.02530		0.22173	
PeB2	0.00106		0.00930	
LaB1	0.91560		8.02422	
LaB2	0.12246		1.07320	
Subtotal	1.07002	0.00971	9.37756	0.08510
V. Moss Field Creek subbasin				
Jo	0.00096		0.00842	
LaB	0.27855		2.44115	
PeB	0.00506		0.04438	
Subtotal	0.28457	0.00826	2.49395	0.07239
VI. Upper section Winslow basin				
Jo	0.02107		0.18467	
PeB1	0.00439		0.03844	
PeB2	0.01768		0.15493	
PeB3	0.01700		0.14897	
PeB4	0.00854		0.07480	
LaB1	0.38274		3.35431	
LaB2	0.68485		6.00194	
LaD	0.02019		0.17698	
PeD	0.00945		0.08286	
Res	0.00711		0.06227	
Res	0.00711		0.06227	
Subtotal	1.18012	0.00524	10.34244	0.04593

APPENDIX E-2. USLE SOIL LOSS ESTIMATES FOR 1990.

SUB-BASINS	Sep 22		Oct 10	
	R = 2.16		R = 18.93	
	Tons	Tons/Acre	Tons	Tons/Acre
VII. Lake Creek subbasin				
Jo	0.00036		0.00317	
PeB	0.06624		0.58048	
Lake1	0.00000		0.00000	
Lake2	0.00000		0.00000	
LaB	0.02759		0.24181	
Res	0.00120		0.01055	
Subtotal	0.09539	0.00100	0.83601	0.00875
VIII. Inactive quarry				
PeB	0.00000		0.00000	
Subtotal	0.00000	0.00000	0.00000	0.00000
IX. Mid-section Winslow basin				
Jo	0.00276		0.02420	
PeB	0.02480		0.21733	
Subtotal	0.02756	0.00054	0.24153	0.00476
X. Timbervale subbasin				
Jo	0.00091		0.00797	
PeB	0.01796		0.15741	
LaB	0.04327		0.37924	
Res	0.00649		0.05688	
Subtotal	0.06863	0.00104	0.60150	0.00911
Subdivision Roadcuts				
Whitchurst subdivision				
Peb	0.32193		2.82133	
Winslow Way				
PeB	0.04598		0.40293	
LaB	0.09288		0.81399	
PeB	1.58268		13.87039	
Jo	0.09660		0.84655	
PeD	0.22570		1.97800	
PeD	0.32322		2.83269	
PeD	0.87493		7.66779	
Kentshire Road				
PeB	0.37260		3.26543	
Subtotal	3.93650	0.43836	34.49907	3.84177

APPENDIX E-2. USLE SOIL LOSS ESTIMATES FOR 1990.

SUB-BASINS	Sep 22		Oct 10	
	R = 2.16		R = 18.93	
	Tons	Tons/Acre	Tons	Tons/Acre
Winslow Subdivision				
I.				
PeB	0.04990		0.43735	
PeB1	0.06211		0.54433	
PeB2	0.07076		0.62015	
PeB3	0.02449		0.21467	
II.				
PeB	0.16096		1.41066	
Jo	0.47369		4.15135	
Jo1	0.06985		0.61220	
Jo2	0.05352		0.46909	
III.				
Jo	0.00258		0.02264	
PeB	0.00012		0.00101	
PeB2	0.22395		1.96266	
IV.				
Jo	0.92919		8.14331	
Jo	1.23103		10.78859	
PeB	0.02190		0.19195	
Wetland				
Jo	0.26231		2.29886	
Paved Surfaces				
	0.00000		0.00000	
Subtotal	3.63638	0.07323	31.86881	0.64174
Subdivision Grassed Areas				
I. PeB	0.01167		0.10224	
II. PeB	0.00061		0.00537	
III. PeB	0.00056		0.00491	
IV. Jo	0.00300		0.02630	
Subtotal	0.01584	0.00081	0.13881	0.00708
TOTALS	10.64774	0.01387	93.30563	0.12154

APPENDIX F. MUSLE SEDIMENT YIELD ESTIMATES FOR 1990.

SUB-BASINS			Total Sediment Yield		
	K*LS*CP Wtd Plot	K*LS*CP Wtd Basin	Sep 8 109.85 TONS	Sep 9 546.7 TONS	Sep 22 347.6 TONS
I. Winslow and Whitehurst subdivision					
PeB	0.000036		0.840815	3.657392	2.412933
Lake	0.000000				
LaB	0.004110				
Quarry	0.000000				
Subtotal		0.000193			
II. Whitehurst Creek subbasin and active quarry					
Jo	0.000018				
PeB1	0.000048				
PeB2	0.000014				
Quarry	0.000000				
Lab Quarry	0.000000				
Quarry	0.000000				
Quarry	0.000000				
PeB3	0.000004				
Subtotal		0.000006			
III. Mid-section Winslow subdivision					
PeB	0.000162				
Subtotal		0.000001			
IV. Thornfield Creek subbasin					
Jo	0.000024				
PeB1	0.000106				
PeB2	0.000004				
LaB1	0.003847				
LaB2	0.000515				
Subtotal		0.000645			
V. Moss Field Creek subbasin					
Jo	0.000013				
LaB	0.003743				
PeB	0.000068				
Subtotal		0.000003			
VI. Upper section Winslow basin					
Jo	0.000043				
PeB1	0.000009				
PeB2	0.000036				
PeB3	0.000035				
PeB4	0.000018				
LaB1	0.000787				
LaB2	0.001408				
LaD	0.000042				
PeD	0.000019				
Res	0.000015				
Res	0.000015				
Subtotal		0.000712			

APPENDIX F. MUSLE SEDIMENT YIELD ESTIMATES FOR 1990.

			Total	Sediment	Yield
SUB-BASINS			Sep 8	Sep 9	Sep 22
	K*LS*CP	K*LS*CP	109.85	546.7	347.6
	Wtd Plot	Wtd Basin	TONS	TONS	TONS
I. Winslow and Whitehurst subdivision					
PeB	0.000036		0.840815	3.657392	2.412933
Lake	0.000000				
LaB	0.004110				
Quarry	0.000000				
Subtotal		0.000193			
II. Whitehurst Creek subbasin and active quarry					
Jo	0.000018				
PeB1	0.000048				
PeB2	0.000014				
Quarry	0.000000				
Lab Quarry	0.000000				
Quarry	0.000000				
Quarry	0.000000				
PeB3	0.000004				
Subtotal		0.000006			
III. Mid-section Winslow subdivision					
PeB	0.000162				
Subtotal		0.000001			
IV. Thornfield Creek subbasin					
Jo	0.000024				
PeB1	0.000106				
PeB2	0.000004				
LaB1	0.003847				
LaB2	0.000515				
Subtotal		0.000645			
V. Moss Field Creek subbasin					
Jo	0.000013				
LaB	0.003743				
PeB	0.000068				
Subtotal		0.000003			
VI. Upper section Winslow basin					
Jo	0.000043				
PeB1	0.000009				
PeB2	0.000036				
PeB3	0.000035				
PeB4	0.000018				
LaB1	0.000787				
LaB2	0.001408				
LaD	0.000042				
PeD	0.000019				
Res	0.000015				
Res	0.000015				
Subtotal		0.000712			

APPENDIX F. MUSLE SEDIMENT YIELD ESTIMATES FOR 1990.

SUB-BASINS			Sep 8	Sep 9	Sep 22
	K*LS*CP	K*LS*CP	109.85	546.7	347.6
	Wtd Plot	Wtd Basin	TONS	TONS	TONS
Winslow Subdivision					
I.					
PeB	0.000465				
PeB1	0.000579				
PeB2	0.000660				
PeB3	0.000228				
II.					
PeB	0.001501				
Jo	0.004416				
Jo1	0.000651				
Jo2	0.000499				
III.					
Jo	0.000024				
PeB	0.000001				
PeB2	0.002088				
IV.					
Jo	0.008663				
Jo	0.011476				
PeB	0.000204				
Wetland					
Jo	0.002445				
Paved Surfaces					
	0.000000				
Subtotal		0.002193			
Subdivision Grassed Areas					
I. PeB	0.000275				
II. PeB	0.000014				
III. PeB	0.000013				
IV. Jo	0.000071				
Subtotal		0.000010			
TOTALS		0.006244			

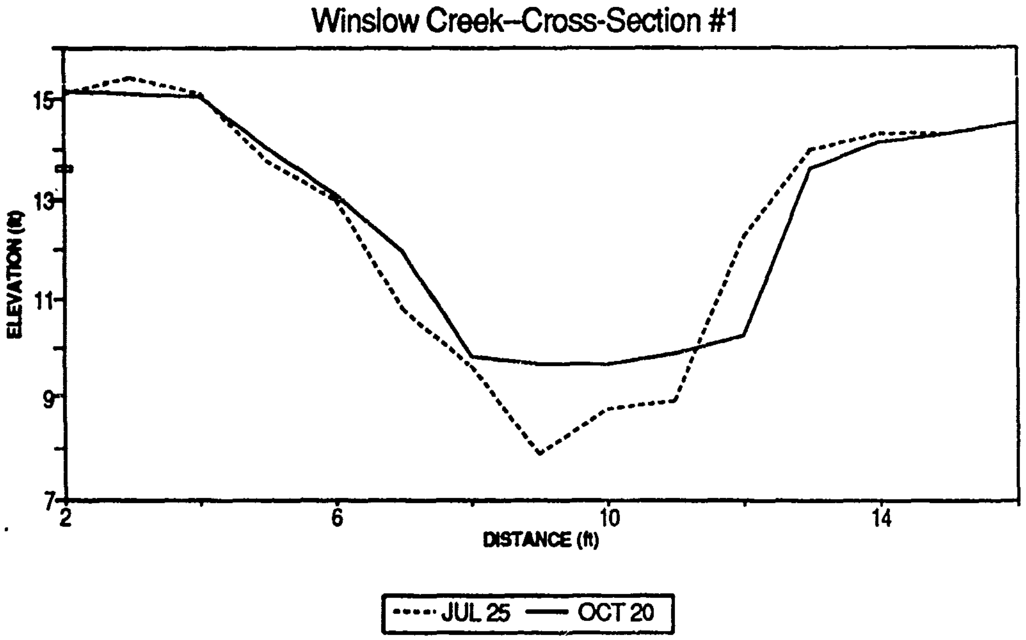


Fig. G-1 Upper basin section of Winslow Creek upstream from 48" culvert. Net channel change is +1.22.

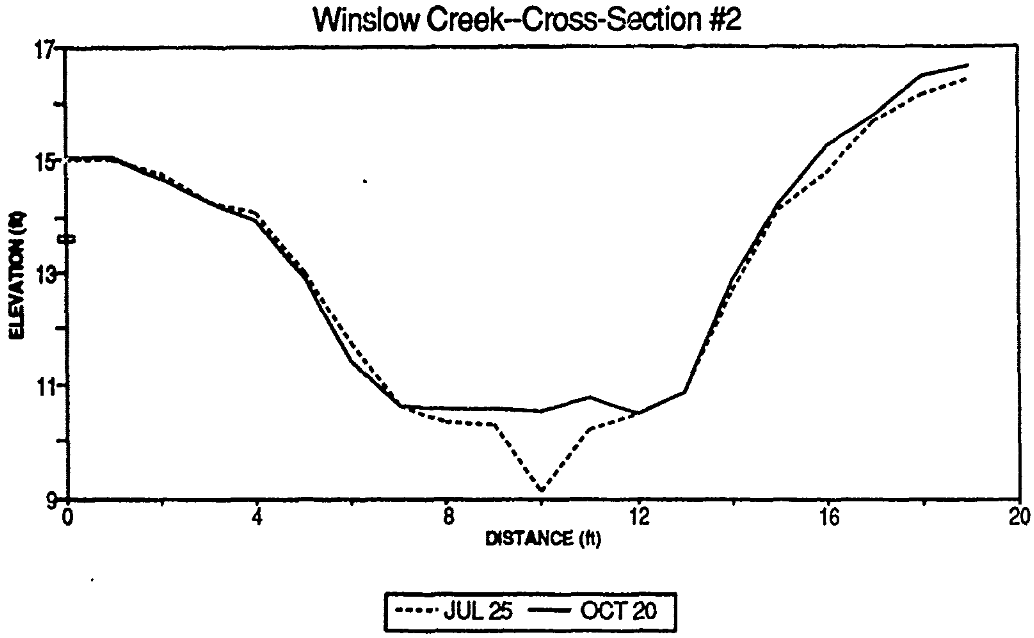


Fig. G-2 Upper basin section of Winslow Creek downstream from 48" culvert. Net channel change is +.1 square feet.

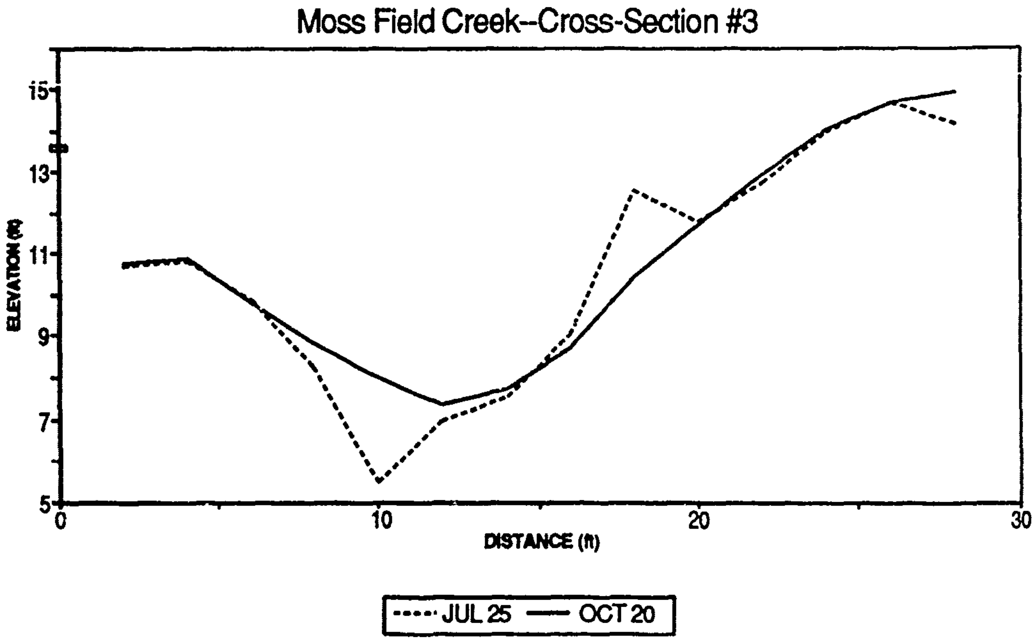


Fig. G-3 Upper section of Moss Field Creek. Net channel change is -0.9 square feet.

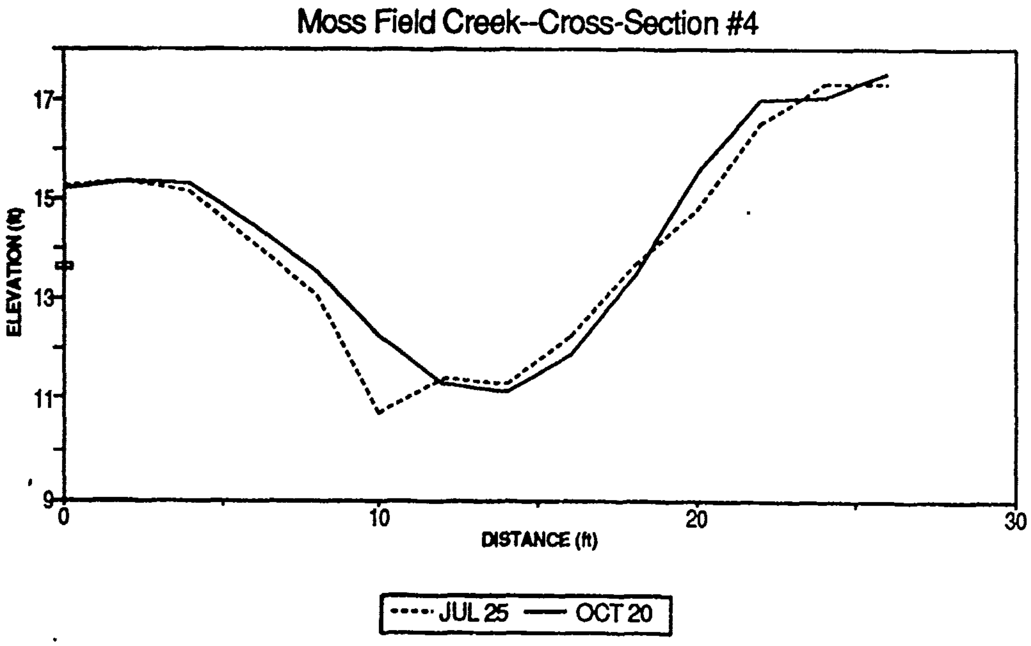


Fig. G-4 Middle section of Moss Field Creek. Net channel change is +6.96 square feet.

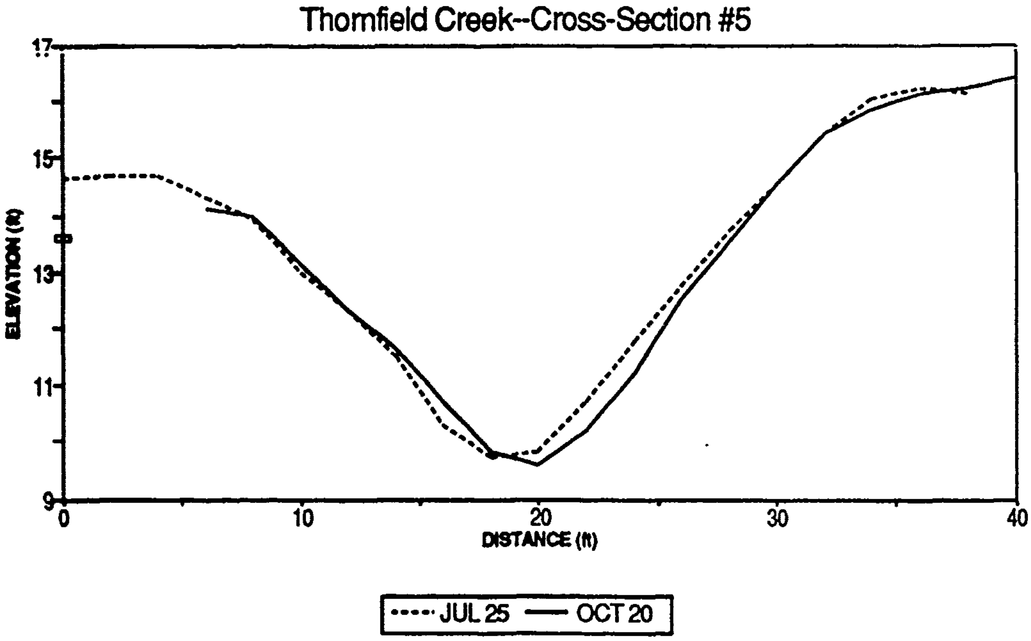

Thornfield Creek--Cross-Section #5

Fig. G-5 Upper section of Thornfield Creek. Channel banks sprayed with grass seed. Net channel change is -5.6 square feet.

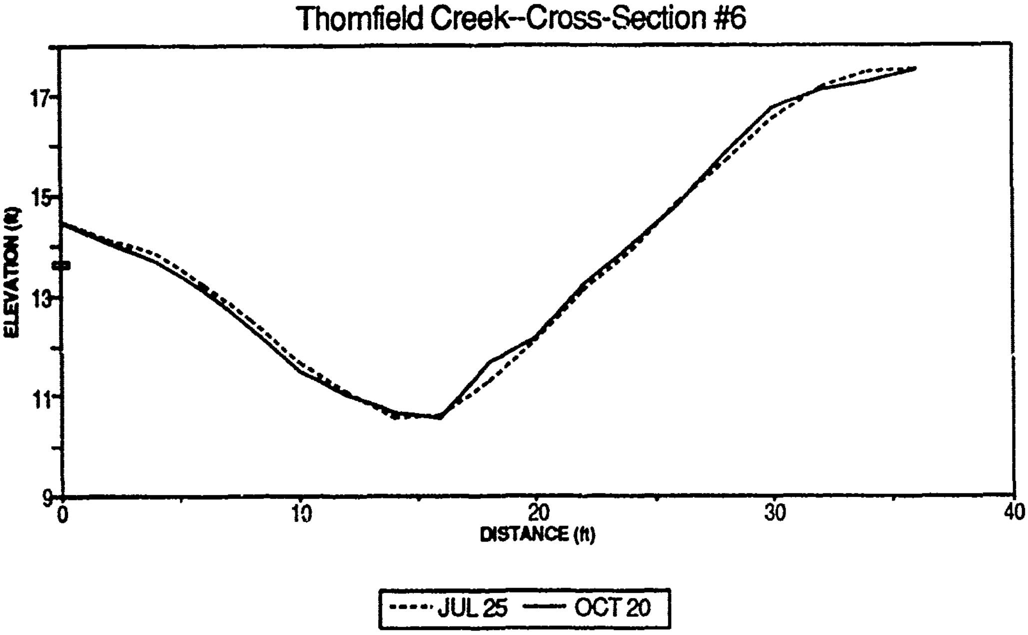

Thornfield Creek--Cross-Section #6

Fig. G-6 Lower section of Thornfield Creek. Channel banks sprayed with grass seed. Net channel change is 0.

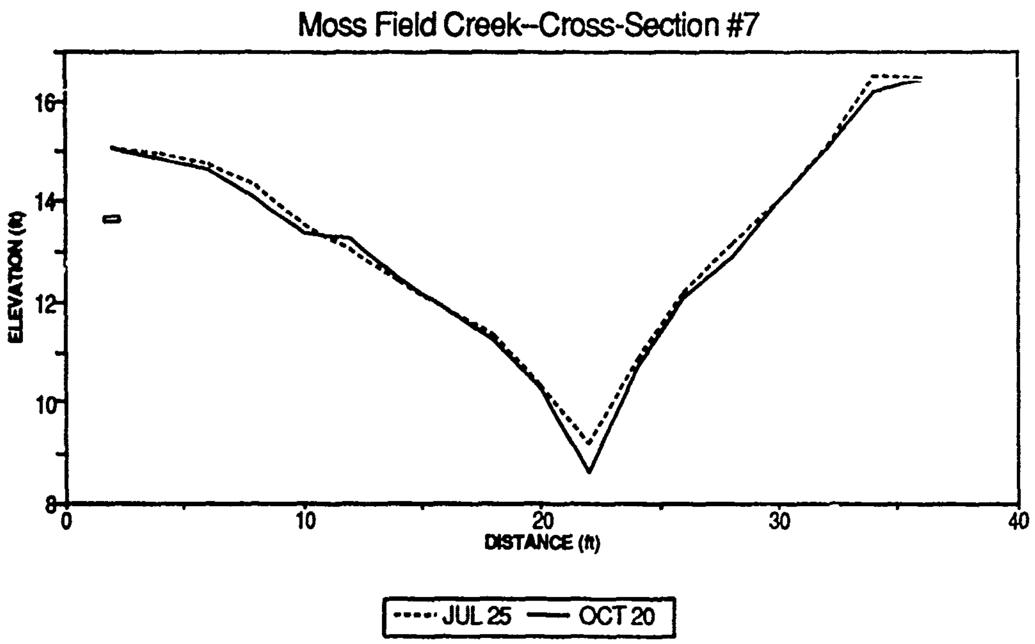


Fig. G-7 Lower section of Moss Field Creek 100′ upstream from confluence. Net channel change is -6.13 square feet.

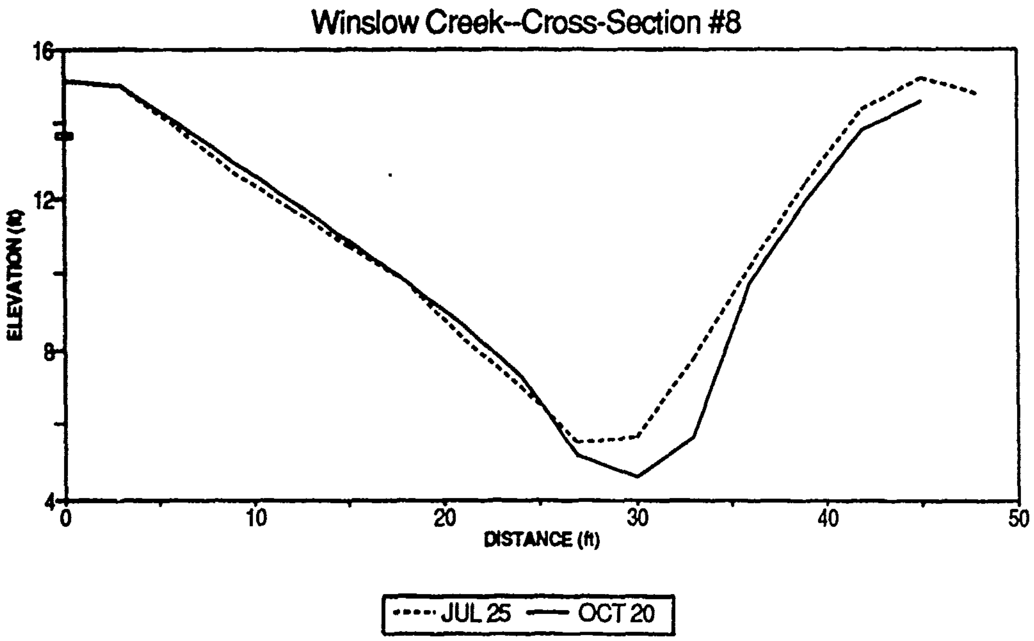


Fig. G-8 Mid-section of Winslow Creek 10′ downstream from confluence. Net channel change is -21.67 square feet.

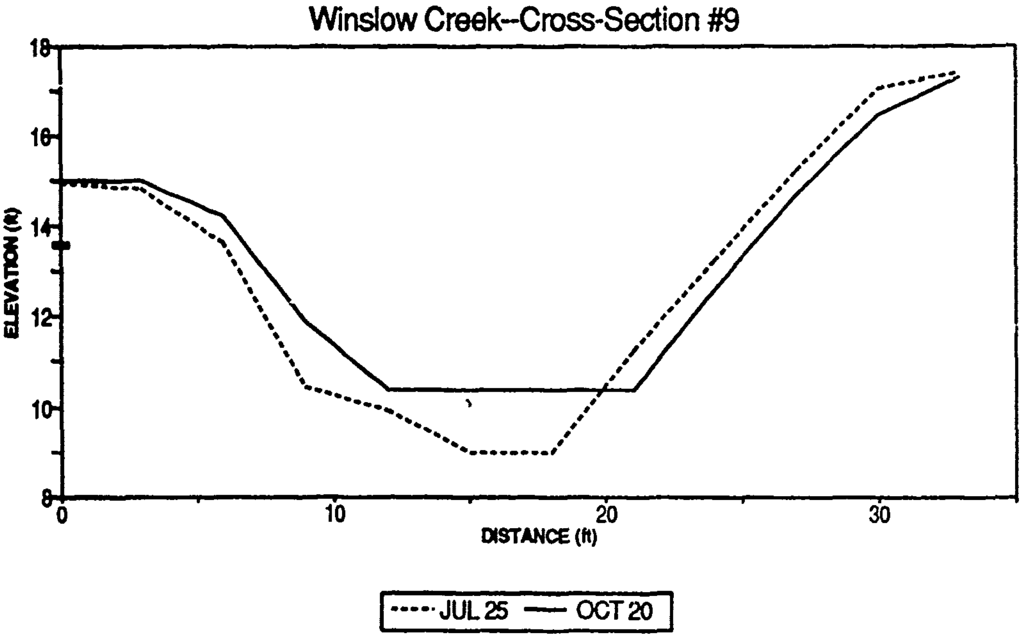

Winslow Creek--Cross-Section #9

Fig. G-9 Mid-section of Winslow Creek. Most noticeable increase in sandy bed material. Net channel change is +15.79 square feet.

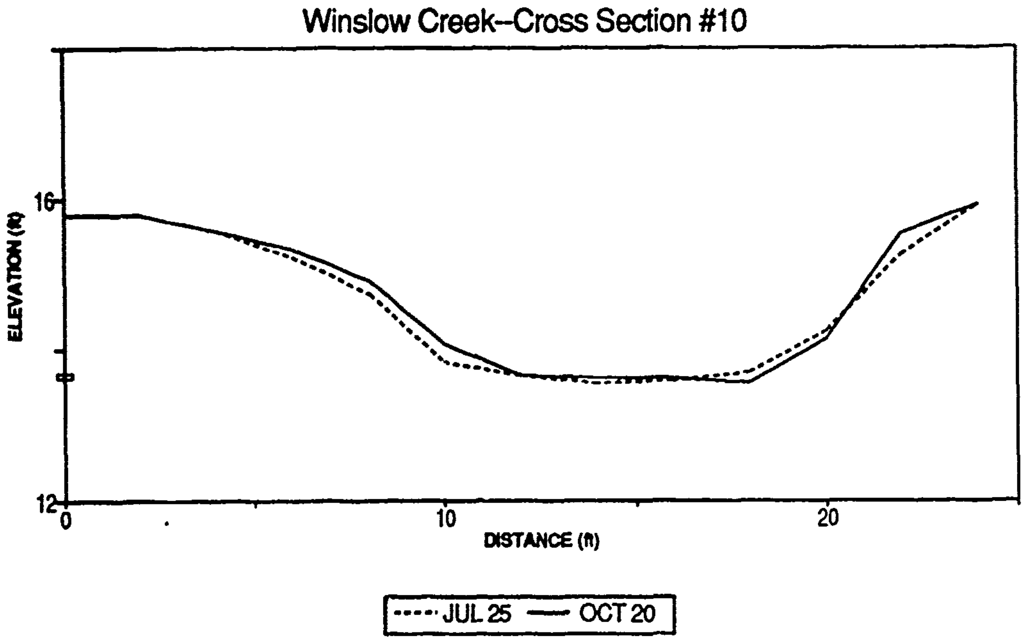

Winslow Creek--Cross Section #10

Fig. G-10 Lower section of Winslow Creek 200′ upstream from dredged section. Net channel change is +.61 square feet.

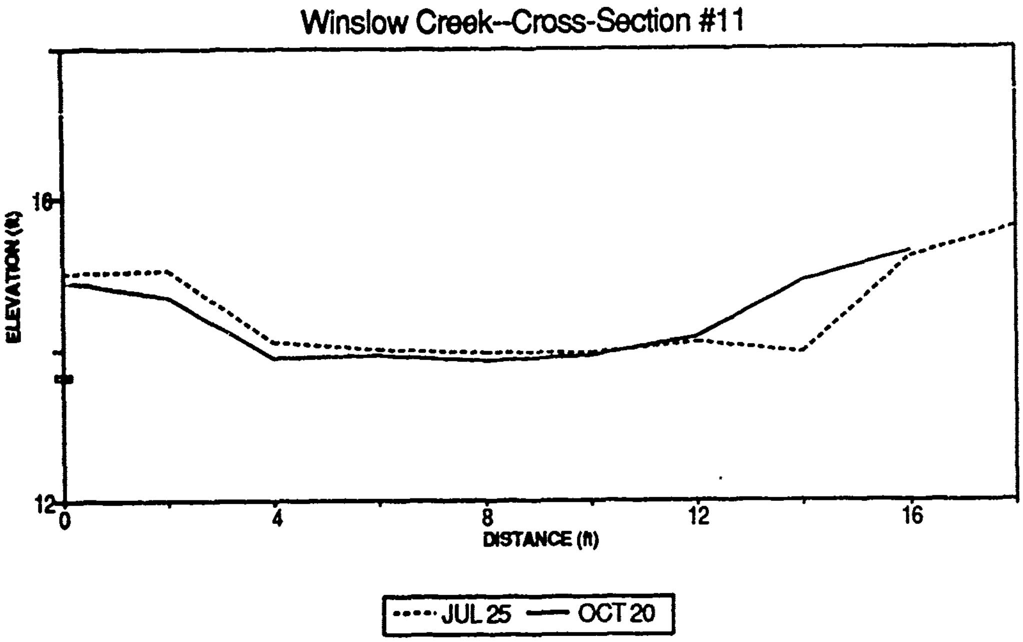


Fig. G-11 Lower section of Winslow Creek just upstream from dredged area. Net channel change is +1.74 square feet.

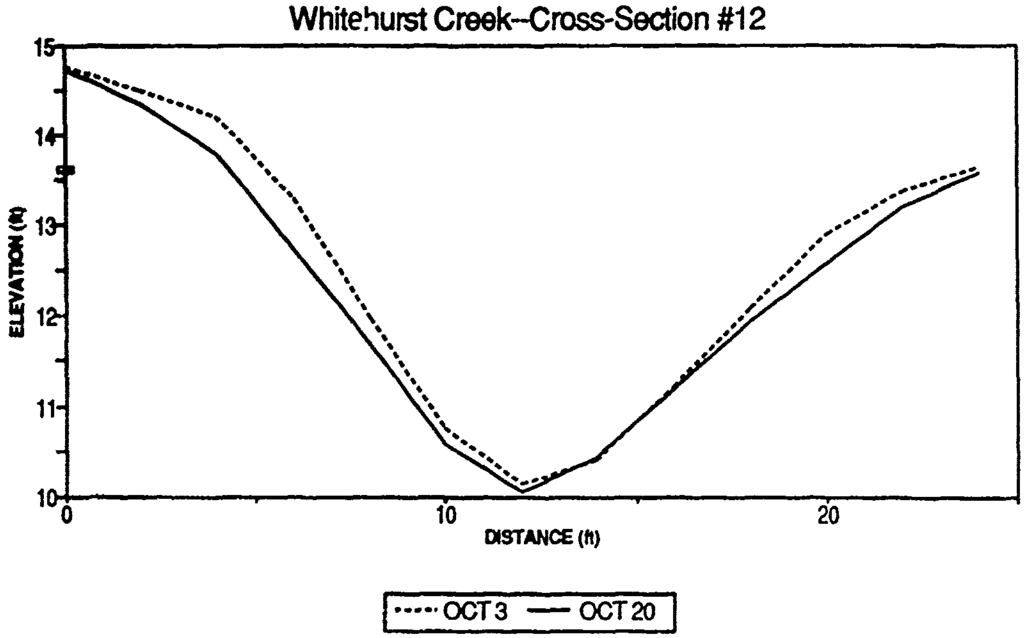


Fig. G-12 Mid-section of Whitehurst Creek. Channel banks sprayed with grass seed. Net channel change is -.67 square feet.

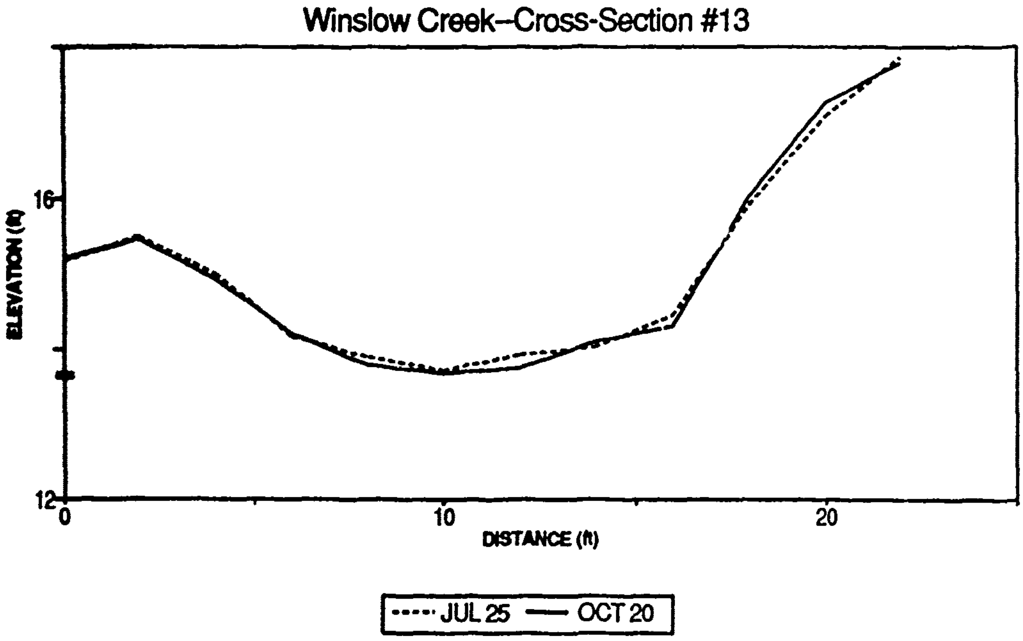


Fig. G-13 Outlet section of Winslow Creek. Net channel change is -1.2 square feet.

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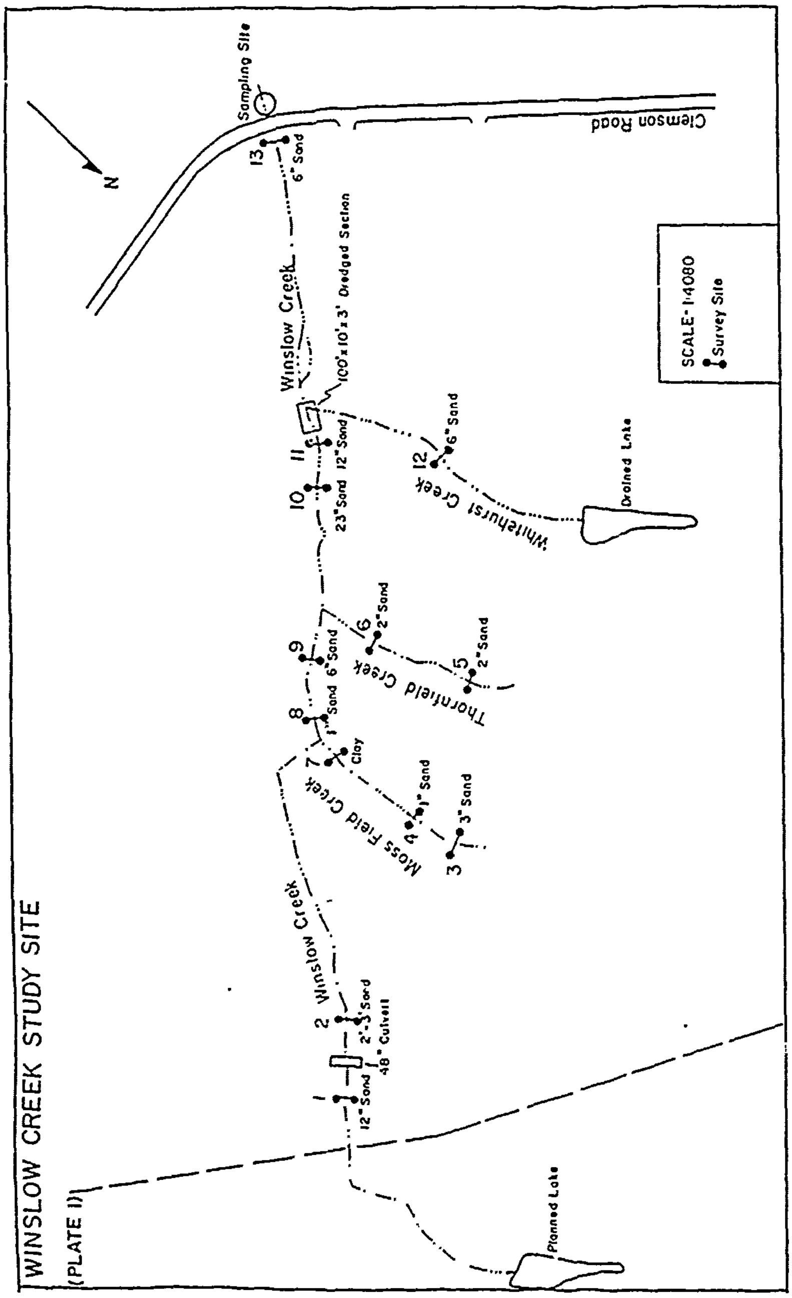

WINSLOW CREEK STUDY SITE

(PLATE I)