EROSION CONTROL AND ABATEMENT PRACTICES FOR COUNTY ROAD SYSTEMS

Final Report
FY 1995 319(h)
EPA (CFDA 66.460)
TASK #900: OCC TASK #73

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SUMMARY

A demonstration project was conducted in McClain County to assess the effectiveness of erosion control and promote technology transfer. The project was a cooperative effort involving the University of Oklahoma (OU), Oklahoma Conservation Commission (OCC), McClain County Conservation District, Natural Resources Conservation Service (NRCS), McClain County Commissioners Office, and adjacent landowners. Two sites, designated Site 1 and Site 2, were studied; however, Site 1 became the primary focus of this effort due to time constraints and because little change was observed at Site 2 during pre-construction monitoring. Specific activities included: topographic surveying and soil sampling of the sites prior to erosion control, implementation of erosion control; and monitoring of the sites to quantify soil loss from channel cross-sections, rainfall, water quality (total solids and turbidity), water velocity, depth of flow, and visual appearance (photographs), before and after erosion control. In addition, assessment of local attitudes before and after erosion control was accomplished via a questionnaire and personal interviews. Technology transfer was achieved via presentations to target groups and development and circulation of an erosion control manual.

The topographic surveys revealed that both sites were in areas having substantial slopes (roadway and bar ditch) and characterized by deep, narrow bar ditches. Soil testing revealed that both sites had near surface soils susceptible to erosion. Major erosion at Site 1 was caused by mass wasting, while Site 2 did not show evidence of this. Site 2 proved more stable than initial impressions suggested and little change occurred at the site during pre-construction monitoring, which is attributed to the presence of weathered sandstone and stable vegetation in portions of the bar ditches. One area adjacent to the bar ditch at Site 2 was observed to have eroded during the project period and was targeted for limited erosion control.

Erosion control at Site 1 was extensive including: major earthwork and grading, applying two types of mulch cover (cotton burrs, hay), planting vegetation, and placing channel protection consisting of rock structures, erosion control blankets, a tire mattress and sod.

At Site 2, limited earthwork and grading, mulch cover (cotton burrs), and seeding was utilized. Generally, erosion control measures were successful; however, some problems were encountered that can be avoided in the future. In particular, the tire mattress proved less effective than expected and required sod cover to correct the problem. In addition, rock structures, although effective in the long term, required considerable maintenance initially because rock smaller than required was used. Both of these problems were overcome and valuable lessons were learned.

Monitoring at Site 1 before and after construction clearly indicated improvements due to erosion control; however, some methods appeared more reliable than others. Measurements of turbidity and total solids before construction at Site 1 and Site 2 were similar; however, evidence suggested erosion was occurring at a much greater rate at Site 1 due to mass wasting. This suggests that turbidity and total solids measured over the small scale involved in this project are not good indicators of erosion rate. On the other hand, turbidity and total solids data, although alone are not conclusive, did indicate substantial improvements after erosion control at Site 1. Difficulties were encountered in water sampling after construction because the flow in the channel tended to be very shallow and the soil bed was easily disturbed.

Measurements of velocity and channel depth were much less susceptible to uncertainties. These measurements indicated substantial improvements in channel performance (i.e. reduced velocity and depth of flow), which can be equated with reduced erosion.

Surveying techniques, using optical methods and bank pins, proved very effective at Site 1 for documenting soil loss in the channel and mass wasting. Furthermore, photographic evidence over the course of the project was effective in documenting site improvements.

Pre- and post-construction surveys of local attitudes indicated that perceptions of erosion control were favorable, although the survey response was limited. Of the approximately 30 surveys delivered to local residences, only three were returned during pre-construction and six were returned during post-construction. It was also learned that local personal relationships influence the way people respond to such surveys. Interviews with local residents were also helpful in assessing local attitudes.

Technology transfer was accomplished by working directly with the McClain County Commissioner's personnel, through technical presentations, and via circulation of a document entitled "Erosion Control on Unpaved County Roads, Guidelines for County Road Maintenance." This document was mailed to all of the county commissioners in Oklahoma with a letter of transmittal explaining its background and purpose. A presentation of the material covered in the manual was presented at the annual meeting of the Association of County Commissioners of Oklahoma, in November 1999. In addition, a project presentation was made at the annual meeting of the Oklahoma Clean Lakes Association in March 2000. Finally through this project, an alliance for continued cooperation between OU and OCC was forged to combat erosion problems on future projects in Unified Watershed areas.

ACKNOWLEDGEMENTS

A number of people from cooperating entities contributed to the success of this project. Funding and guidance was provided by EPA through OCC [FY 1995 319(h) EPA (CFDA 66.460) TASK #900: OCC TASK #73].

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1.0 INTRODUCTION

1.1 General

A demonstration project was conducted to address erosion problems along unpaved county roads in Oklahoma. The project was a cooperative effort involving the University of Oklahoma (OU), Oklahoma Conservation Commission (OCC), McClain County Conservation District, Natural Resources Conservation Service (NRCS), McClain County Commissioners Office, and adjacent landowners. Two sites were selected to demonstrate erosion control measures. Each site was monitored before and after implementation of erosion control measures. Monitoring included topographic surveys, water sampling during rainfall events for measurement of turbidity and total solids, water velocity measurements, rainfall measurements, measurements of soil loss in gullies via bank pins, and photography. In addition, local residents were given a survey to assess their attitudes about erosion along county roads prior to and after the implementation of erosion control measures. Technology transfer was accomplished through working directly with the McClain County Commissioner and his personnel, development and distribution of an erosion control manual, and presentations to targeted audiences.

1.2 Background

1.2.1 Causes of Erosion Along County Roads in Oklahoma

County roads in Oklahoma are numerous and are the primary routes of transportation in rural areas. These low cost, low volume roads are typically unpaved and have restrictive right-of-ways, on the order of 33 feet in McClain County for example. In many instances, these roadways serve as primary drainage conduits for adjacent farmlands resulting in significant volumes of runoff being diverted into roadside drainage channels ("bar ditches") that are less than adequate to handle the flow. Bar ditches along county roads are intended to drain the roadway, although in many areas they inadvertently drain adjacent fields. The problem is aggravated by the space restrictions imposed by the narrow right-of-way (ROW). Therefore, to address the severe erosion along county roads a proper approach must include reducing runoff from adjacent fields as well as providing better designed bar ditches to handle expected flows.

Many of Oklahoma's soils are fine grained and quite susceptible to erosion because they are predominantly cohesionless materials (silt and sand) or they are dispersive in nature. Dispersive clay soils are subject to colloidal erosion resulting from spontaneous deflocculation (dispersion) of clay particles in the presence of water. They are characterized by a relatively high percentage of sodium ions in the pore fluid. It is important to thoroughly characterize the nature of soils specific to an erosion problem to properly design control measures.

1.2.2 Consequences of Erosion along County Roads

Excessive erosion along county roads has several unwanted consequences: 1) threatens motorist safety; 2) soil loss on adjacent farmlands; 3) increased maintenance costs for the county, and 4) detrimental impacts on the waters receiving the roadway drainage.

Excessive erosion in bar ditches can undermine and collapse the shoulder and portions of the roadway, resulting in a serious threat to motorists. An example of the type of damage that can occur during a storm event is depicted in Figure 1.1. In addition to the impacts in actively eroding areas, the sediment deposited downstream, such as shown in Figure 1.2, can create serious problems. Overflow of sediment-clogged drainage channels results in flooding and washouts that can render the road unsafe and impassible. Beside the obvious impacts on safety, construction delays while remedying these problems can pose a nuisance to local travelers.

Landowners adjacent to erosion-impacted areas may be directly affected by flooding and the land destruction associated with excessive erosion. On the other hand, the county carries the burden associated with high maintenance costs along county roadways adjacent to erosion-impacted areas.

Siltation and suspended solids are primary non-point source pollution problems in many of Oklahoma's water bodies. In and of themselves, suspended and deposited soil particles are harmful to aquatic organisms and often these particles carry chemical pollutants as well. Primary sources of erosion-derived contaminants are the miles of county roads located in Oklahoma. Primary pollutants found in rural road runoff include sediment, oil, grease, and herbicides (State of Oklahoma, 1992). The effects of these pollutants on the environment and their adverse effects on human health are well documented.

1.3 Objectives

The primary objectives of this project were:

(a) Identify two test road sections that were severely eroded to serve as demonstration sites.
(b) Establish a cooperative effort between the local road commissioner, the soil conservation district, the University of Oklahoma and affected property owners.
(c) Assess the soil conditions through sampling and laboratory testing to assess erodibility.
(d) Measure current rate of soil loss and runoff velocity at the selected sites.
(e) Assess drainage and erosion patterns.
(f) Identify appropriate erosion control measures.
(g) Work with adjacent property owners and the county commissioner to institute best management practices (BMP) and erosion control in and adjacent to right of way.
(h) Develop a manual of guidelines for county commissioners to address erosion problems along rural roads and promote technology transfer.

Figure 1.1 Severe Erosion Damage Along the Shoulder of a County Road (looking north at Site 1).

Figure 1.2 Sediment Deposition in a Culvert Along a County Road due to Upstream Erosion (location is south of Site 1).

2.0 DESCRIPTION OF TEST SITES

2.1 General Description

Two demonstration sites were selected for this project, the locations are shown on Fig. 2.1. The selection of Site 2 was delayed because of unforeseen circumstances. After considerable effort, two sites were selected; however, a follow up visit to the second site revealed that extensive re-grading of the bar ditch and adjacent land was implemented without the knowledge of the project investigators. This site was disqualified because no pre-construction monitoring was performed before remedial work was implemented. While work on the first site was initiated, a second site was located approximately one mile from Site #1, as shown at Fig. 2.1. Because of this and other reasons discussed in subsequent sections, Site #1 was the focus of most of the effort associated with this project.

As shown in Fig. 1.1 and Figs. 2.2-2.4, prior to implementing erosion control, Site 1 was experiencing severe gully erosion along the roadside and on adjacent land. Bar ditches were severely eroded and in places were on the order of 8 to 10 feet deep as shown in Fig. 2.4. At Site #1 the pre-construction project area involved approximately 350 feet parallel to the roadway and extended laterally a distance of about 100 feet west of the roadway. The topographic map (relative elevations) of Site #1 shown Fig. 2.5, reveals the steep grades and gullies at the site. The slope of bar ditches in this area was as steep as 11%.

Site #2 extended approximately 1,200 feet parallel to the roadway, and about 120 feet wide as shown in Fig. 2.6, and is characterized by relatively steep grades. While the slope of the roadway in this area was significant, the bar ditches were eroding at a much slower rate than observed at Site 1. After monitoring Site 2, and due to time constraints for construction by the county commissioner, it was decided to focus on one particular area on the north side of the road shown Fig. 2.6. This area was devoid of vegetation and appeared to be eroding much faster than other areas on the site.

2.2 Soil Stratigraphy

Four hand-augered test borings were conducted at Site #1 located as shown in Fig. 2.5, and extended to depths of 5 to 7 feet. Borings 1 and 2 were conducted in spring 1997 while Borings 3 and 4 were conducted in fall 1997. Soil samples obtained were subjected to laboratory tests to determine natural moisture content, liquid limit, plastic limit, plasticity index, and grain-size distribution. In addition, double hydrometer and pinhole dispersion tests were conducted on selected samples to assess the dispersive character of fine-grained cohesive soils. Soil testing was carried out in general accordance with standards published by the American Society for Testing and Materials (ASTM).

Three hand-augered test borings located as shown in Fig. 2.6 were also conducted at Site 2 in fall 1997. Laboratory testing similar to Site 1 was conducted for Borings 2 and 3; Borings 1 and 2 had essentially the same soil profiles and so only samples from Boring 2 were tested. Tables 2.1 and 2.2 show results of laboratory soil tests and classifications, based on the Unified Soil Classification System (USCS), for Site #1 and Site #2.

<u>Site 1</u>

Site 1 soils generally consist of low to moderate plasticity sandy clay and silt in the upper layers with lean clay found in the bottom one to two feet of the test borings. Upper layers contain about 30-40 % sand, which would tend to make them more susceptible to erosion as compared to the underlying lean clay. These results are consistent with field observations in gullies showing soil underlain by weathered shale.

Double hydrometer dispersion values range from 21.7 % to 38.5 % at Site 1, being greater than 35 % for samples from the upper four feet of boring 1. Studies indicate that dispersion values exceeding 35 % may indicate a dispersive soil (ASTM 2000), suggesting Site 1 soils are susceptible to colloidal erosion. Furthermore, pinhole dispersion tests generally corroborate the double hydrometer results, indicating slightly to moderately dispersive soils at Site 1.

Based on observations at Site 1 and laboratory test data, it appears that the soils present are susceptible to erosion because of their slightly dispersive nature and the significant sand fraction present in upper layers. Observations in gullies at the test site suggest that the underlying weathered shale is more resistant to erosion than overlying soil layers.

Site 2

Site 2 soils generally consist of low to moderate plasticity sandy clay and non-plastic silty sand. In general the soils are less cohesive than Site 1 soils and contain greater amounts of fine sand. Double hydrometer dispersion values and pinhole dispersion tests generally suggest the soils are not subject to colloidal erosion (non-dispersive); however, because they are less cohesive, containing substantial fine sand and silt, they are susceptible to mechanical erosion. Observations along Site 2 reveal sandstone in the bottom of bar ditches, which seems to partly explain the presence of sandy soil. Generally this sandstone proved to be much more resistant to erosion compared to the overlying soil.

Table 2.1 Site 1 Soil Test Data and USCS Classification.

Boring	Sample Depth (ft.)	Sample Mid-Depth Relative Elevation (ft.)	Natural Moisture Content (%)	Sand Fraction (%)	Fines Fraction (%)	Clay-Size Fraction (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	USCS Group Symbol	USCS Group Name	Double Hydrometer Dispersion (%)	Pinhole Test Classification
1	0-1	-8.78	12.9	36.0	64.0	28.0	31.0	17.4	13.6	CL	Sandy lean clay	35.7	ND2[2]
	1-2	-9.78	14.9	36.0	64.0	29.0	32.5	16.4	16.1	CL	Sandy lean clay	37.4	ND3[3]
	2-2.5	-10.53	15.0	35.5	64.5	29.0	30.3	15.4	14.9	CL	Sandy lean clay	38.5	ND2
	2.5-3	-11.03	16.6	36.0	64.0	30.0	34.9	14.5	20.4	CL	Sandy lean clay	36.8	ND3
	3-4	-11.78	20.4	39.0	61.0	33.5	34.4	19.0	15.4	CL	Sandy lean clay	34.3	ND3
	4-5	-12.78	20.1	29.0	71.0	36.0	36.2	16.5	19.7	CL	Lean clay with sand	31.8	ND3
	5-6	-13.78	20.9	42.0	58.0	45.0	41.9	18.6	23.3	CL	Sandy lean clay	23.0	ND3
	6-7	-14.78	22.3	2.5	97.5	44.0	42.9	14.7	28.2	CL	Lean clay	21.7	ND3
2	0.5-1	0.62	14.1	36.0	64.0	24.0	34.7	17.7	17.0	CL	Sandy lean clay	---[1]	---
	1-2	-0.13	13.4	27.5	72.5	29.0	24.3	17.5	6.8	CL-ML	Silty clay with sand	---	---
	2-3	-1.13	18.6	27.5	72.5	29.0	33.1	17.5	15.6	CL	Lean clay with sand	---	---
	3-4	-2.13	18.6	7.5	92.5	32.5	35.4	15.8	19.6	CL	Lean clay	---	---
	4-5	-3.13	15.6	0.0	100.0	30.0	35.2	18.0	17.2	CL	Lean clay	---	---
3	0.5-1	-6.87	13.0	39.0	61.0	23.0	32.4	16.5	15.9	CL	Sandy lean clay	---	---
	1-2	-7.62	16.0	36.0	64.0	31.0	37.8	16.3	21.5	CL	Sandy lean clay	---	---
	2-3	-8.62	15.0	34.0	66.0	27.5	19.7	16.4	3.3	ML	Sandy silt	---	---
	3-4	-9.62	14.2	41.0	59.0	24.5	30.6	15.5	15.1	CL	Sandy lean clay	---	---
	4-5	-10.62	19.1	5.0	95.0	39.0	44.7	18.3	26.4	CL	Lean clay	---	---
4	0.5-1	-22.67	13.6	42.5	57.5	31.0	34.1	16.4	17.7	CL	Sandy lean clay	---	---
	1-2	-23.42	12.8	40.0	60.0	30.5	28.2	14.4	13.8	CL-ML	Sandy silty clay	---	---
	2-3	-24.42	20.0	36.9	63.1	32.5	31.7	15.1	16.6	CL	Sandy lean clay	---	---
	3-4	-25.42	19.0	40.0	60.0	34.0	35.4	15.3	20.1	CL	Sandy lean clay	---	---
	4-5	-26.42	21.2	7.5	92.5	41.5	32.9	8.0	24.9	CL	Lean clay	---	---

NOTES: [1] --- = "no test data", [2] ND2 = "non dispersive with very slight to no colloidal erosion tendencies", [3] ND3 = "slightly to moderately dispersive".

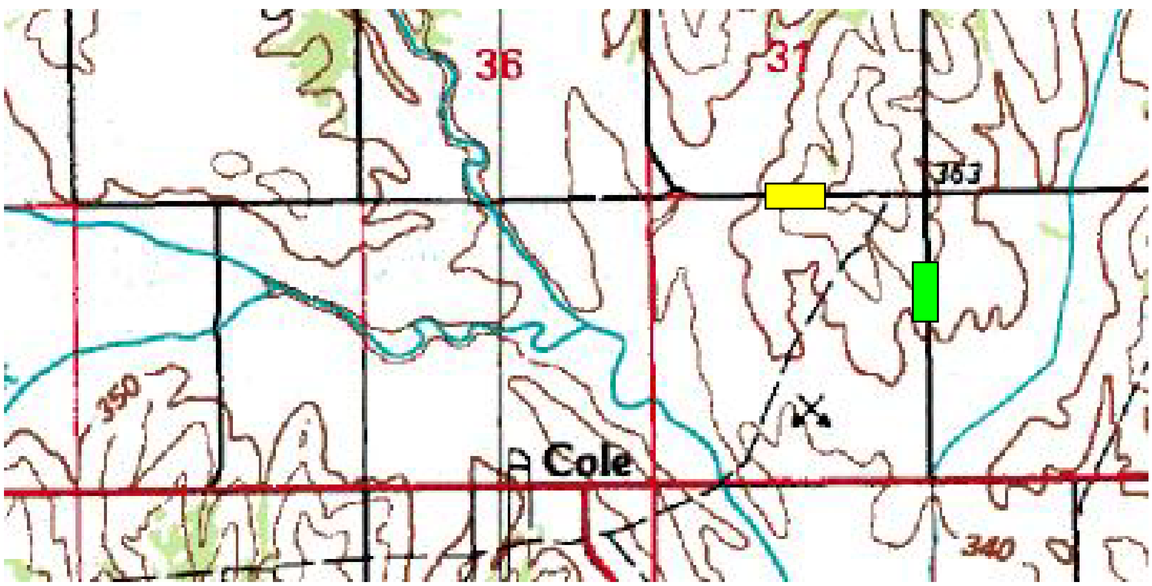
Table 2.2 Site 2 Soil Test Data and USCS Classification.

Boring	Sample Depth (ft.)	Sample Mid-Depth Relative Elevation (ft.)	Natural Moisture Content (%)	Sand Fraction (%)	Fines Fraction (%)	Clay-Size Fraction (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	USCS Group Symbol	USCS Group Name	Double Hydrometer Dispersion (%)	Pinhole Test Classification
2	0.5-1	2.9	14.1	35.0	65.0	22.0	28.3	17.5	10.8	CL	Sandy lean clay	---[2]	---
	1-2	2.15	18.4	52.3	47.8	15.0	NP[1]	NP	NP	SM	Silty sand	---	---
	2-3	1.15	18.6	38.0	62.0	22.0	26.4	15.2	11.2	CL	Sandy lean clay	---	---
	3-4	0.15	18.6	48.0	52.0	20.0	26.5	19.3	7.2	CL	Sandy lean clay	---	---
	4-5	-0.85	18.6	48.0	52.0	22.5	24.2	18.9	5.3	CL-ML	Sandy silty clay	---	---
3	0.5-1	26	3.0	69.0	31.0	14.5	NP	NP	NP	SM	Silty sand	---	---
	1-2	25.25	16.9	48.0	52.0	25.0	31.8	12.1	19.7	CL	Sandy lean clay	8.2	ND2[3]
	2-3	24.25	18.2	45.0	55.0	32.0	35.1	20.2	14.9	CL	Sandy lean clay	5.0	ND2
	3-4	23.25	16.0	53.5	46.5	21.0	26.2	18.5	7.7	SC	Clayey sand	7.3	ND2
	4-4.5	22.5	18.1	71.0	29.0	12.5	NP	NP	NP	SM	Silty sand	---	---
	4.5-5	22	14.8	73.0	27.0	10.5	NP	NP	NP	SM	Silty sand	---	---

NOTES: [1] NP = "non plastic", [2] --- = "no test data", [3] ND2 = "non dispersive with very slight to no colloidal erosion tendencies".

a)

b)



Site 1 (T 7N R 3W Section 6 on East Section Line)

Site 2 (T 7N R 3W Section 6 on North Section Line)
Note: Streams in b) are part of Walnut Creek system.

Figure 2.1 Location of Demonstration Sites in McClain County; a) Aerial Photo, b) Topographic Map (From USGS).

Figure 2.2 View of Site #1 Looking South Prior to Erosion Control.

Figure 2.3 View of Site #1 Looking North Prior to Erosion Control.

Figure 2.4 View of Gully at Site #1 Prior to Erosion Control (west side of road).

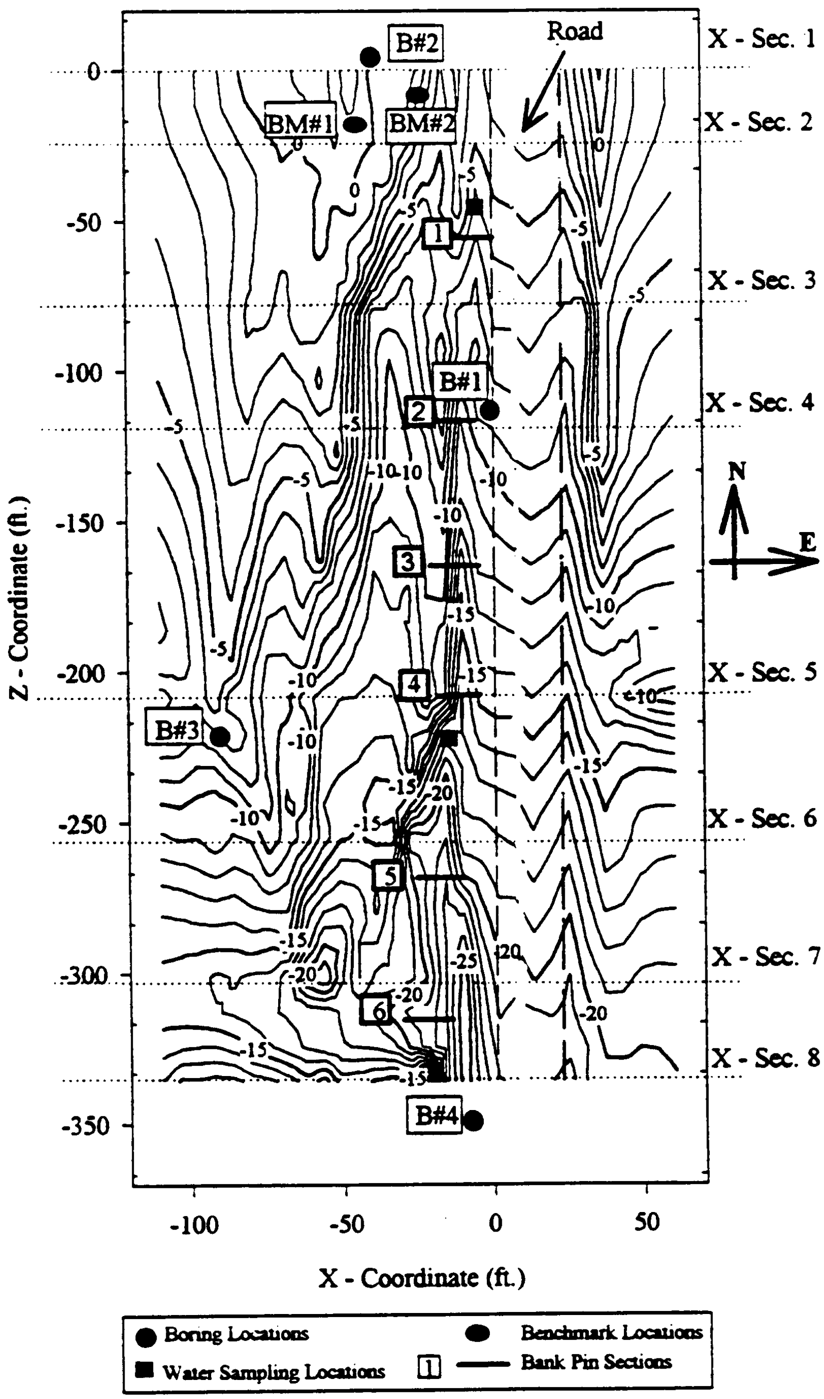


Figure 2.5 Topographic Map of Site 1.

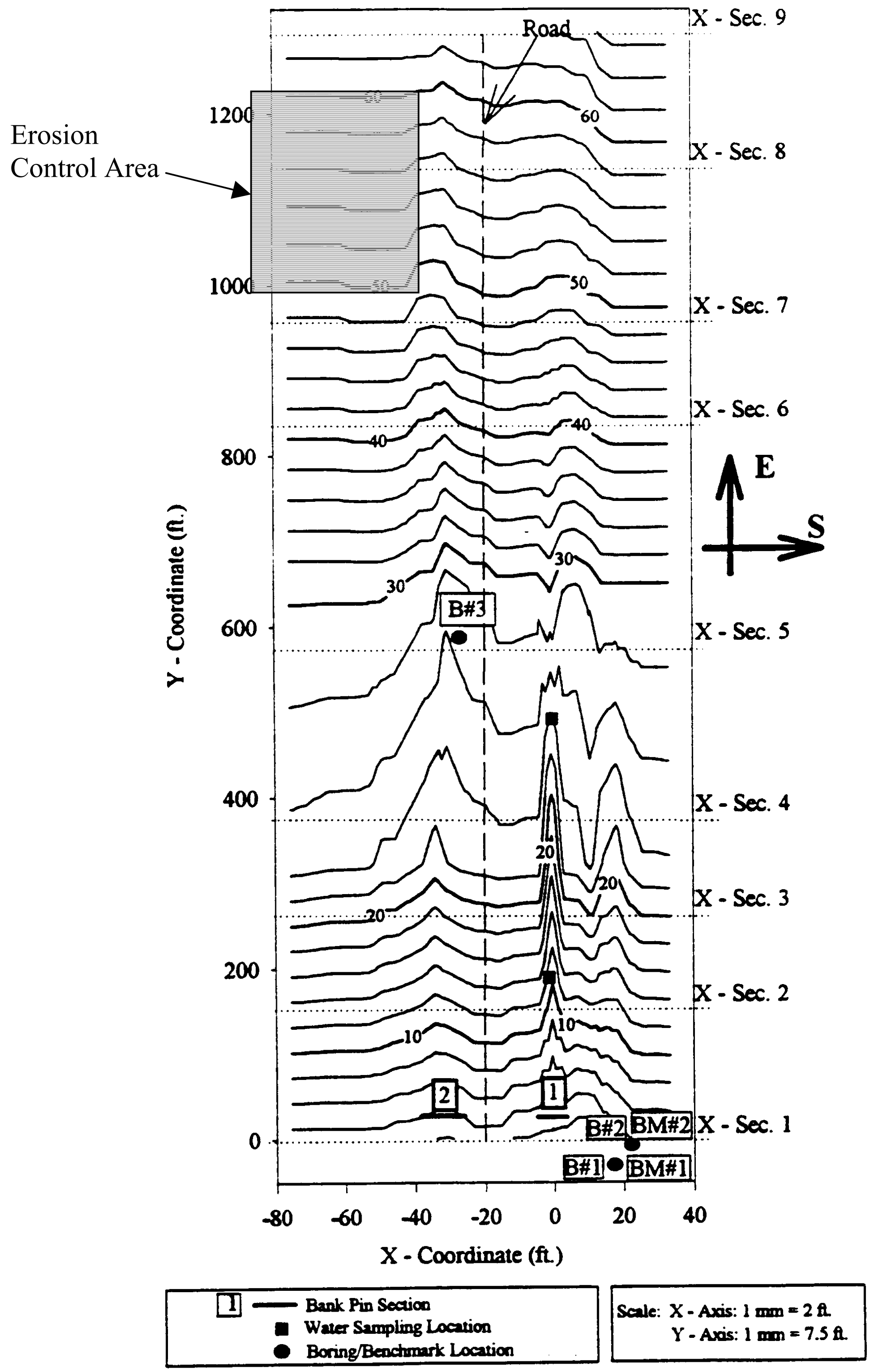


Figure 2.6 Topographic Map of Site 2.

3.0 EROSION CONTROL

Erosion control included earthwork, channel stabilization, and establishment of vegetation. Work at the sites was performed by the McClain County Commissioner's personnel with guidance and assistance provided by University of Oklahoma project members. Extensive work was performed at Site 1, but only limited work was performed at Site 2 due to time constraints of the County Commissioner. Furthermore, Site 1 was experiencing erosion at a significantly greater rate than Site 2 and was therefore the focus of most effort.

3.1 Construction Activities and Costs

Site 1

To demonstrate the costs associated with various erosion control activities associated with this project, details of expenditures at Site 1 are presented. Construction activities at Site 1 were carried out over 24 days according to the schedule shown in Table 3.1. Also, daily labor and equipment costs (for the county commissioner) are shown in Table 3.1, while material costs are in Table 3.2. The majority of cost is associated with heavy equipment usage ($10,236) followed by materials ($4,379) and labor ($2,817), bringing the total to $17,432 to implement erosion control at Site 1. These figures do not include the effort expended by University of Oklahoma (OU) personnel for planning or on-site labor. On-site Labor costs (due to OU contribution) are estimated at $500-$1,000 more than indicated in Table 3.1. In addition, as part of the efforts to mitigate damage along this roadway, a new culvert was installed approximately ¼ mile downstream from Site 1; the cost for this effort was in the neighborhood of about $700. Therefore, the approximate cost for construction of erosion control at Site 1, considering additional on-site labor (OU) and excluding culvert expenses, is in the neighborhood of $17,400. This equates to a construction cost of about $19 per linear foot of roadway (work was actually performed on 900 feet of roadway, extending beyond the limits monitored during pre-construction). This figure may be slightly higher considering that the round bales were donated to the project and some work performed by the farmer was not included in Tables 3.1 and 3.2.

Site 2

For reasons mentioned previously and subsequently explained in greater detail, work at Site 2 was limited to an area, approximately 200 ft. by 100 ft., adjacent to the bar ditch as shown in Fig. 2.6. Work was conducted over a period of about 3 days in early May 1999. The total cost to implement erosion control at this site was approximately $3,000. While work at this site was relatively limited compared to Site 1, the work had a positive effect on the site, demonstrating that even limited efforts to enhance vegetation can pay off.

3.2 Earthwork and Grading

Site 1

Due to the significant gullies at Site 1, it was determined that a substantial amount of earthwork and reshaping of the landscape was necessary to reduce the slope and prepare an adequate drainage channel along the roadway. A preliminary site-grading plan was developed and presented to the County Commissioner to guide the progress of earthwork. The resulting landscape attained the general features set forth in the plan that included flattening slopes and forming a single widened drainage way along the roadside. To achieve the necessary flattening of slopes, a number of trees were removed (some of these can be seen in Fig. 2.3); however, it was decided after deliberation with cooperating agencies that this would be the best course of action, particularly because many of the trees were being undermined by erosion as can be seen by the protruding roots in Fig. 2.4. In addition, the landowner moved a fence to the border of the work area for accessibility and to protect the area from livestock. Terraces on the adjacent farmland were built up to divert flow away from the work area. A photograph of the final grading of the site is shown in Fig. 3.1. Compared to Figs. 1.1 and 2.2-2.4, it can be seen that significant flattening of slopes and filling of gullies was achieved.

Major grading was accomplished using a bulldozer, while shaping of the drainage channel utilized a motorgrader and backhoe as well. Compaction during grading was accomplished using the bulldozer and sheepsfoot roller as shown in Fig. 3.2.

Site 2

Observations at Site 2 revealed an area on the north side of the road devoid of vegetation and experiencing significant erosion. Given the limited time that could be committed to construction, this area was targeted for grading and re-vegetation. This area was subjected to grading with a bulldozer to remove the shallow gullies and uneven ground surface prior to application of mulch and seed.

3.3 Planting Vegetation

Site 1

Following grading at Site 1, the entire site received an application of fertilizer as recommended by the district conservationist. Fertilizer was applied by the landowner using a spreader attached to the back of a tractor. A disc harrow was dragged across the site, also by the landowner, to scarify the soil and work in the fertilizer. Next the entire site was sprigged with Bermuda grass and covered with a layer of mulch. Two different kinds of mulch were used; old round bales of hay were donated from a local farm and used to cover half of the site while the other half was covered with cotton burrs from a local gin. In Figs. 3.3 and 3.4 are photographs of the site showing mulch cover with limited vegetation established.

Both types of mulch proved to be effective in protecting the slopes while vegetation was established. In fact, following the completion of construction at Site 1 during spring and early summer of 1998, it took about two years to fully establish vegetation due to drought conditions that prevailed after during the summer and fall of 1998. Some effort was made by the commissioner to periodically water the site using a water truck, particularly in the drainage channel area, but these efforts did not seem effective. Nevertheless, while the site was exposed to the elements devoid of vegetation for a prolonged period, the mulch cover proved effective. The success of the mulch cover is partly attributed to the use of the sheepsfoot roller that was dragged across the site, which proved very effective at anchoring the mulch to the underlying soil.

In addition to sprigging, periodically Bermuda grass seed was spread across the site and was effective in promoting re-vegetation. Areas of new grass were observed within one month in areas that had been seeded.

Site 2

A portion of the area indicated in Fig. 2.6 was covered with mulch (cotton burrs), fertilized and seeded with Bermuda grass. Portions not covered with mulch were fertilized and seeded with Bermuda grass to assess the effectiveness of the mulch, versus no mulch, in establishing vegetation.

3.4 Channel Protection

Of critical importance in preventing severe erosion of bar ditches is to provide adequate protection for exposed soil. To protect the drainage channel at Site 1 different strategies were used including rock structures, erosion control blankets, a tire mattress, and sod cover. The relative position of each of these features on the site is shown in Fig. 3.5

Rock Structures

Rock fill, with individual rock pieces sized appropriately for expected flow conditions, can be used to protect a channel bottom or side slope. Under certain conditions, rock fill can be placed at selected locations to effectively reduce water velocity, promote sedimentation and stabilize the channel bottom. These structures should be designed under the supervision of a certified erosion control specialist or civil engineer. In Fig. 3.6, a series of rock check structures placed every 50 feet at Site 1 are shown. These structures were used on the northern half of the site where the channel grade did not exceed about 2%. They were designed in consultation with personnel from the Oklahoma Conservation Commission. These structures should be built of rock of sufficient size to resist the water velocities expected, should be keyed into the bottom of the channel (i.e. placed in a trench), and should be inspected after rain events to ensure proper function. If not properly installed, water flow can short circuit around or under the structures and aggravate the erosion of the channel.

Rock structures were installed by first digging a shallow trench across the channel bottom. In plan view, the trench was formed as a shallow V-shape across the bottom of the channel with the apex of the "V" pointing upstream. Rock was then placed with the aid of a backhoe and final shaping was achieved manually. At channel margins the height of rock structures was even or slightly higher than the top of the channel and decreased to slightly above the channel bottom as shown in Fig. 3.6. Soil in the channel between rock structures was compacted and smoothed by "backblading" with the bucket of the backhoe.

Generally, the rock structures proved effective at reducing erosion in the channel where they were used; however, some problems were encountered that should be considered for future projects. First, the design called for rocks (riprap) with a nominal diameter of 12 inches, but the county commissioner was reluctant to haul rock of this size because of the damage it could cause to the dump truck. Thus, it was decided that 6-inch rock would be sufficient. Some of the rock was actually moved during high flow events and it took some time to maintain these structures; however, they were stabilized due to infilling from soil and vegetation. A second problem was that shortly after construction, during a large rain event, channel flow short-circuited around one the structures because it was too high. Some reshaping of this particular rock berm alleviated the problem. Finally, while these rock structures are durable, the commissioner has complained that they make mowing operations more difficult. In place of rock berms, a series of swells, terraces, or berms formed of soil can be used, generally spaced every 100 feet or so depending on the channel slope. It is likely, however, that soil berms will be subject to erosion until vegetation is established and some maintenance will be required. One way to protect soil berms would be to encapsulate them in erosion control blanket to provide protection while vegetation is established.

Rock was also used around the culvert at the outlet of Site 1 as shown in Fig. 3.7. Here the rock was placed over the erosion control blanket to provide further protection from increased water velocity occurring where the channel narrows as it approaches the culvert entrance.

Erosion Control Blankets

Three different erosion control blankets were used at the site, two composed primarily of natural fibers (one coconut and one straw) and the other composed of synthetic fibers (green polypropylene fiber mesh). The natural fiber blankets had a synthetic monofilament woven mesh (forming approximately 1 inch squares) that provided some stability. In Fig. 3.8, the polypropylene and coconut fiber mats are shown. Approximately 350 linear feet of the channel was covered by erosion control blankets, which were delivered in rolls 10 feet wide. After shaping the channel, anchor trenches at the top of each side of the channel were cut using a motorgrader and an anchor trench at the upstream end of the blankets was cut with a backhoe. Blankets were rolled out parallel to the longitudinal axis of the channel, three abreast, with an overlap of at least one foot. After compacting soil in the anchor trenches, metal pins were used to stake the overlapping portions of the blankets per the manufacturer's recommendations. To complete the installation, a thin layer of soil was spread over the top of the blankets. In Fig. 3.9 are photographs depicting the placement of soil cover over erosion control blankets.

Erosion control blankets were effective at protecting the soil; however, the polypropylene blanket proved far more durable over the two years during which vegetation was established. Both natural fiber blankets tended to degrade and break down under exposure to the environment, and some repairs were required.

Tire Mattresses Installation

Over a 150-feet section of the channel, scrap tires were used in an attempt to control erosion in the channel. Tires were arranged in rows across the channel bottom and wired together. The mattress was anchored in a trench at the upstream end of the tire section. Following completion of the mattress, soil was compacted in and around the tires and a thin cover of soil was compacted over the tires.

Some problems were encountered with the tire mattress that necessitated the use of sod cover in this section. After the tires had in been in place for approximately 2 months, it was observed that erosion was occurring in and around the tires. Part of this problem resulted because of the difficulty in trying to properly compact the soil in and around the tires. In addition, the prolonged drought conditions in summer and fall of 1998 prevented the establishment of vegetation. It was decided to add soil cover to the tires and place sod, which proved to be a very successful strategy.

Table 3.1 Chronology of Work Activities, Labor and Equipment Costs for Site 1

Day	Date	Activity	Major Equipment	Approximate Man Hours	Labor Costs	Equipment[2] Costs
1	4/29/1998	Earthwork	bulldozer, backhoe	16	$144	$712
2	5/4/1998	earthwork	motorgrader	4	$36	$172
3	5/6/1998	earthwork	bulldozer	4	$36	$140
4	5/7/1998	earthwork	bulldozer, motorgrader, backhoe	12	$108	$432
5	5/8/1998	earthwork	bulldozer, motorgrader	8	$72	$260
6	5/11/1998	earthwork	bulldozer, motorgrader	16	$144	$520
7	5/12/1998	fertilizer, discing, rock delivered, rock berms started	backhoe, dump truck	24	$216	$368
8	5/13/1998	tire mattress installed	bulldozer, motorgrader, backhoe	18	$171	$378
9	5/14/1998	sprigging by outside contractor[1]	---	---	---	---
10	5/20/1998	rock berms constructed, watering	bulldozer, backhoe, water truck	16	$144	$656
11	5/21/1998	work on rock berms, soil compaction, watering	bulldozer with sheepsfoot roller, water truck	16	$144	$502
12	5/28/1998	compaction, install erosion control blanket	bulldozer, motorgrader, backhoe	24	$216	$580
13	5/29/1998	work on erosion control blanket, watering	bulldozer, motorgrader, backhoe, water truck	18	$162	$598
14	6/1/1998	deliver more rock to site for outlet structure and rock berms	dump truck	4	$36	$116
15	6/2/1998	deliver and spread cotton burrs, watering	bulldozer, backhoe, water truck	32	$288	$1,056
16	6/4/1998	spread hay bales, roll-in with sheepsfoot	bulldozer with sheepsfoot roller, backhoe	20	$180	$968
17	6/5/1998	spread hay bales, roll-in with sheepsfoot, watering	bulldozer with sheepsfoot, backhoe, water truck	16	$144	$880
18	6/18/1998	watering	water truck	10	$90	$110
19	6/23/1998	maintenance	motorgrader, backhoe, dump truck	16	$144	$792
20	6/24/1998	maintenance	motorgrader, backhoe	16	$144	$560
21	7/16/1998	water site, install culvert and work on bar ditch south of site	water truck	16	$144	$120
22	3/26/1999	deliver soil to cover tire mattress prior to sod	front-end loader	4	$36	$198
23	3/31/1999	spread and compact soil prior to sod	backhoe	2	$18	$118
24	4/1/1999	sod placed over tire mattress area by outside contractor[1]	---	---	---	---
				312	$2,817	$10,236

Notes: [1] work done by subcontractors to the county commissioner show up as a lump sum charge in Table 3.2. [2] includes cost of mobilization.

Table 3.2 Summary of Expenses at Site 1

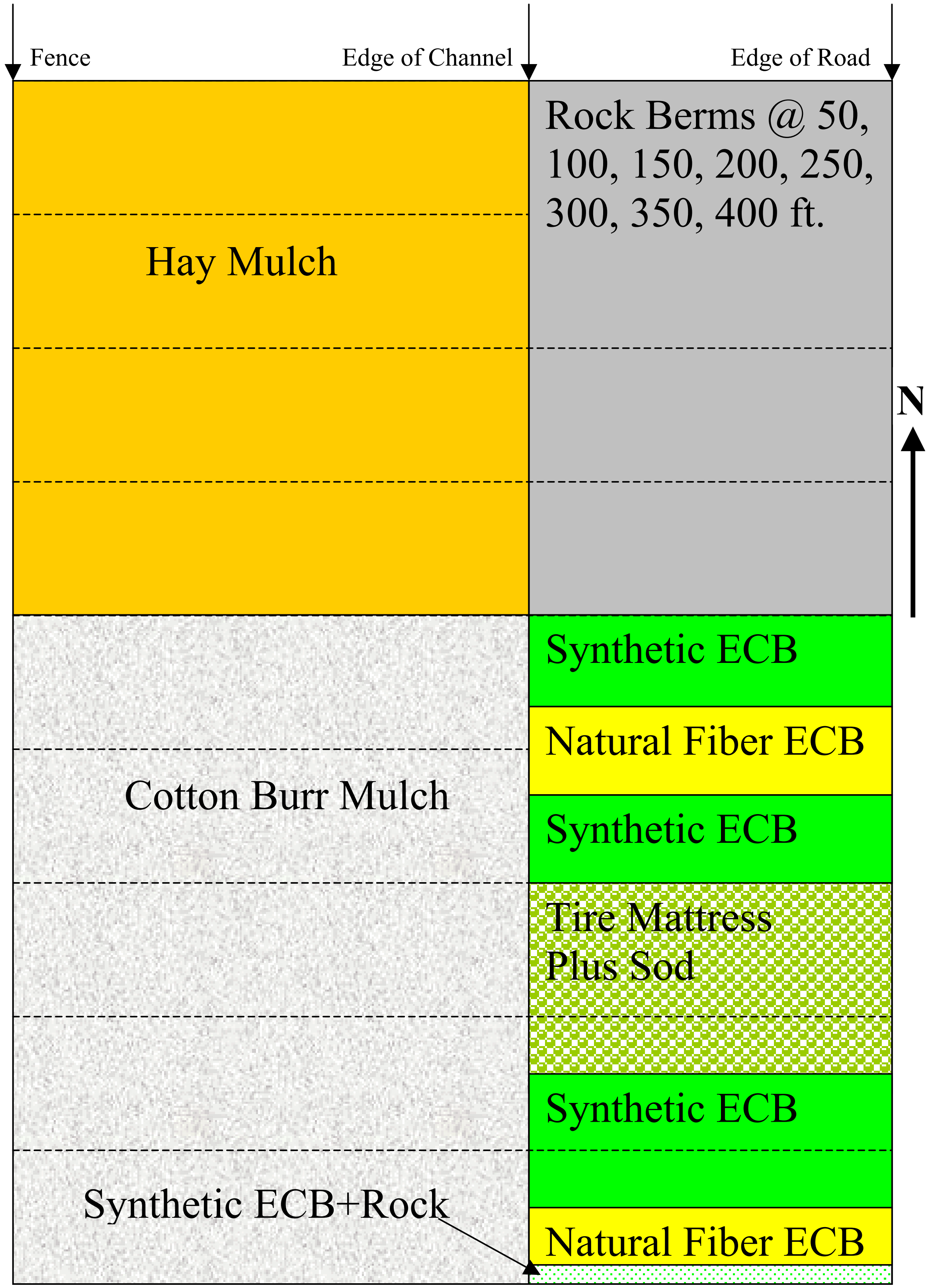
Item	Description	Quantity	Unit	Unit Cost	Total Cost
1	hay bales for temporary erosion control	50	each	$ 3.00	$ 150.00
2	rock (6-inch surge stone)	53.86	ton	$ 4.00	$ 215.44
3	Fertilizer	2230	lb.	$ 0.12	$ 258.68
4	Bermuda grass seed	10	lb.	$ 3.32	$ 33.23
5	wire for tire mattress	1	roll	$ 34.95	$ 34.95
6	miscellaneous supplies	1	lump sum	$ 38.00	$ 38.00
7	Sprigging	1	lump sum	$ 600.00	$ 600.00
8	polypropylene erosion control blanket	7	roll	$ 123.30	$ 863.10
9	coconut fiber erosion control blanket	3	roll	$ 123.30	$ 369.90
10	straw mat erosion control blanket	3	roll	$ 77.40	$ 232.20
11	cotton burrs	14	load	$ 20.00	$ 280.00
12	46-foot corrugated metal culvert + accessories	1	lump sum	$ 382.80	$ 382.80
13	crushed limestone for culvert installation	60	ton	$ 2.60	$ 156.00
14	Sod	4500	sq. ft.	$ 0.17	$ 765
					$ 4,379.30

Figure 3.1 View of Site 1 Looking South after Earthwork and Grading.

Figure 3.2 Compaction at Site 1 with Bulldozer and Sheepsfoot Roller.

Figure 3.3 Cotton Burr Mulch at Site 1 with Limited Vegetation.

Figure 3.4 Hay Mulch at Site 1 with Limited Vegetation.



Notes: 1) not to scale, 2) dashed lines 100 ft. apart.

Figure 3.5 Schematic Showing Layout of Site 1 Erosion Control.

Figure 3.6 Rock Berms Placed at Site 1.

Figure 3.7 Rock Placed to Protect Soil Near Culvert Entrance. [Arrow points to culvert]

Figure 3.8 Erosion Control Blankets at Site 1.

Figure 3.9 Soil Cover Placed Over Erosion Control Blankets.

4.0 SITE MONITORING

To determine the success of erosion control measures a number of approaches were used to monitor sites before and after construction. Monitoring included topographic surveying, bank pin measurements, measurements of water velocity, turbidity and total solids measurements, and photography. In collecting field data, an attempt was made to arrive at the sites during peak flow conditions; however, this proved to be very difficult given the unpredictable nature of rain events. Monitoring of sites necessarily included a rain gage at Site 1 to determine the daily rainfall. This chapter explains the extent to which each of these monitoring methods was used at each demonstration site and describes the outcome from this monitoring as related to success of erosion control.

4.1 Topographic Survey and Bank Pin Measurements

An optical survey was conducted at Sites 1 and 2 for the purpose of planning monitoring and erosion control activities. At Site 1, the primary focus of the demonstration project, eight cross-sections were surveyed on approximately 50-foot intervals along the most severely impacted stretch of roadway. Survey data was input into graphing software (SigmaPlot) and a topographic map was generated. Relative elevations shown on the topographic map in Fig. 2.5 are given in units of feet and are referenced to one of the two semi-permanent benchmarks that were established at the site. At Site 2, a similar survey was conducted, utilizing nine cross-sections over a distance of approximately 1300 feet, as shown in Fig. 2.6.

At Site 1, bank pins were installed at six locations in the roadside gully as indicated on Fig. 2.5. Bank pins consisted of 2- or 4-foot long sections of #4 reinforcing steel bars that were either driven vertically or horizontally in the channel bank. The pins were driven so that the end was nearly flush with the soil surface. Coincident with bank pin installation, the cross-section of the gully at each pin-section was determined by optical surveying. After rainfall events, measurements of the protrusion of each bar were made to determine how much soil had been eroded. The change in channel cross-section at pin locations was then determined by subtracting the protrusion of each pin from either the initial horizontal or vertical coordinate determined by optical surveying. Bank pin cross-sections corresponding to dates on which measurements were made are presented in Figs. 4.1-4.6.

Bank pin measurements were made between the beginning of March and early October 1997. Sections 3, 4 and 5 show substantial down cutting, on the order of 0.5-1 ft., in the bottom of the channel, while the remaining sections show little change. At section 3 some deposition was also noted. Results from pin-section measurements are consistent with mass wasting observed along portions of the gully, where undercutting at the base of the channel caused the sides of the bank to collapse. When this happens, the loose soil in the bottom of the channel is rapidly carried downstream. A dramatic example of mass wasting was captured using optical surveying.

In Figure 4.7 are shown results of optical survey measurements at cross-section 4 located as shown in Fig. 2.5. The gully was surveyed on October 18, 1996 and then again on November 15, 1997 and June 10, 1997. During the first 65 days of this time frame approximately 11 inches of rainfall were recorded. As shown in Fig. 4.7, in one month a volume of soil with a width and depth of about six feet was eroded from the channel.

The bank pin measurements and cross-section survey are dramatic examples of the rate of erosion at Site 1. At Site 2, little change was observed in the bank-pin cross-sections located as shown in Fig. 2.6.

4.2 Monitoring During Rainfall Events

Site 1

During rainfall events, measurements of surface water velocity and depth of flow were made at upstream and downstream locations before and after erosion control was implemented. Velocity measurements were made initially by injecting methylene blue dye (1,000 ppm) into the stream and recording the travel time over a fixed distance; however, it was found that the dye was difficult to observe. An alternative method using a surface float (ping pong ball) was used for the majority of measurements. Generally, the velocities determined by the two methods are consistent. Average velocity measurements were determined from at least 3 trials each at upstream and downstream locations. In some cases during post-construction monitoring, velocity data was not obtained because the depth of flow was not great enough and vegetation in the channel interfered with measurements.

Six 1 quart mason jar samples were collected, 3 each at upstream and downstream locations. Samples were collected by submerging a jar at the center of the stream while keeping the jar opening facing upstream. During pre-construction sampling, depths of flow were 6-7 inches, whereas during post-construction, flow depths of 2 inches and less were encountered at downstream locations. Pre-construction samples, therefore, are more representative of water in the upper layers of flow, whereas post-construction samples represent nearly the entire depth of flow. Post-construction sampling necessarily involved a greater risk in disturbing the streambed and may explain some of the elevated values of total solids seen in some post-construction samples.

Samples were brought back to the laboratory for determination of turbidity and total solids. Testing was performed in general accordance with standard EPA methods 160.2 and 180.1 for total solids and turbidity, respectively. From each jar sample, three samples were extracted for turbidity and total solids determination in most cases. In some cases where the sample size was limited, the entire sample was used to determine total solids. Turbidity data for two events (10/29/99, 2/17/99) was not obtained because of a malfunction of the turbidimeter.

Results of monitoring and lab testing during rainfall events are presented in Table 4.1. It is important to note that while efforts were made to arrive at the sites during periods of substantial flow, the unpredictable nature of rainfall events precluded precise timing in this regard. In addition, the upstream locations were different before and after construction because the erosion control extended about 400 feet north of the section of roadway studied during the pre-construction phase. The upstream sampling location during post-construction was actually in an area with less slope and wider channel than the pre-construction location. This may partly explain the difference in upstream total solids and turbidity measurements before and after construction. Considering this, the downstream total solids determinations are probably more representative of the erosion before and after erosion control. Obviously, there are many factors that influence the total solids measurements; nevertheless, there are trends in the data that seem to be consistent with the sequence of events at Site 1, which show the positive effects of erosion control. Furthermore, reductions in total solids are consistent with other site measurements.

In Fig. 4.8, downstream total solids, daily rainfall, and flow depths are plotted against time. The site history shown at the top of the graphs helps to explain the trends seen in the data. For the most part, daily rainfall on average is similar during the three phases of the project, while there is a distinct difference in the depth of flow recorded. This is consistent with the widening of the channel during construction, which tended to spread out the flow. Total solids increase during the post-construction phase when little vegetation was established in the channel and then decrease, with the exception of one event, during the post-construction phase when vegetation was well established. It is believed that this exception is due to the difficulty in sampling shallow flows and the disturbance that can occur to sediment in the channel bottom. A comparison of upstream and downstream solids for the data point in question (12/31/99 in Table 4.1) shows a downstream total solids much larger than the upstream, which tends to corroborate the premise that the "spike" is not representative. If it is accepted that this "spike" in the data (denoted by a question mark in Fig. 4.8) is not representative, then the total solids data suggest that the total solids, and hence erosion, was reduced due to erosion control once vegetation was established. The rise in total solids during post-construction is explained by the fact that soil in the channel bottom was exposed prior to vegetation and subject to greater disturbance when sampling from the shallow flow.

The sequence of photographs in Figs. 4.9-4.12 shows the conditions of the channel during each project phase. Note in comparing Figs. 4.10 and 4.11, that the soil covering the erosion control blanket (Fig. 4.10) has been eroded away (Fig. 4.11), which may partly explain the increase in total solids during post-construction before vegetation was established. Probably less soil cover could have been used over the erosion control blankets. Also, in comparing Figs. 4.9 and 4.11, the effect of channel widening is apparent. Fig. 4.12 shows the channel after vegetation is well established.

A plot of total solids versus daily rainfall is shown in Figs. 4.13. A distinct trend between rainfall and total solids appears for the first two project phases, which suggests the sampling times were consistent with average or peak flows. For the last phase, a trend is not distinct. Generally, the total solids data point towards successful erosion control, which tends to be corroborated by turbidity and velocity data.

Turbidity data is shown in Fig. 4.14. The data indicate a decrease in turbidity for samples collected after construction. The turbidity data is not consistent with the elevated solids shown in Fig. 4.8 for the second phase of the project, which may indicate that the elevated solids in phase 2 resulted from coarser particles that were not detected by the turbidimeter (i.e. the coarse particles settled out of the column prior to measurement).

Surface water velocity measurements are summarized in Figs. 4.15 and 4.16. Significantly lower velocities were measured during post-construction compared to pre-construction for similar size rainfall events. Furthermore, there is a decrease in velocity from the second to third phase of the project. This is consistent with increased channel roughness resulting from vegetation. Given the uncertainties with solids and turbidity data, the significant decrease in water velocity is a clear indication of success because erosive forces are proportional to velocity.

<u>Site 2</u>

Monitoring at Site 2 was initiated at the points indicated in Fig. 2.6. Initial visual inspections of Site 2 revealed that the bar ditch on the south side of the road was more severely eroded than the north side. However, after monitoring for a little over one year (8/26/97-10/15/98) the south side appeared to have experienced little erosion damage. This can be explained by the presence of bedrock in the bottom of the channel and the presence of vegetation on the banks. Turbidity and total solids measurements during the pre-construction phase from upstream and downstream locations on the south side of the road at Site 2 are similar to those for the same events at Site 1. However, the severe undermining and mass wasting in bar ditches at Site 1 did not occur at Site 2. This comparison shows that turbidity and total solids measurements alone are not indicators of severe erosion when measured over durations and distances of the scale involved in this project (Site 1: 175 ft., Site 2: 300 ft.) during pre-construction.

It was decided that the best course of action was not to disturb the south side of the road since the rate of erosion was significantly less than observed at Site 1 during the same time frame. Furthermore, the county commissioner had expended considerable time on Site 1 and was reluctant to undertake the same level of effort at Site 2. While the south side of the road was relatively stable, an area to the north of the road at Site 2 was experiencing significant erosion during the project period and was targeted for remedial work. The area involved was approximately 200 feet by 100 feet adjacent to the bar ditch as shown in Fig. 2.6. This area was devoid of vegetation and shallow gullies were developing. The bar ditch in this area was underlain by sandstone that was relatively resistant to erosion. Modifications to this site consisted of reshaping the bar ditch, grading the area adjacent to bar ditch and establishing vegetation. Because no improvements were made south of the roadway, no post-construction data was obtained. However, the success of remedial work on the north side of the road is evidenced through photographs.

4.3 Photographic Record

Site 1

Over the course of this project extensive photographic documentation was accumulated. The photographs shown in Figs. 1.1, 2.2-2.4, and 4.9-4.12, are a dramatic illustration of the improvements due to erosion control. Additional photographs shown in Figs. 4.18 and 4.19 show comparison pictures before and after erosion control, further demonstrating the success of the measures employed.

Site 2

Photographs of Site 2 approximately 1.5 months and 1.5 years after erosion control are shown in Figs. 4.20-4.23. These pictures illustrate that where cottons burrs were placed vegetation was rapidly established. Areas that received only fertilizer and seed appear bare in Figs. 4.20 and 4.22; however, by about 1.5 years after erosion control these areas acquired significant vegetation as shown in Figs. 4.21 and 4.23. Thus, it can be concluded that the cottons burrs can provide vegetation in a relatively shorter time period, which may be important where erosion is severe.

Table 4.1 Site 1 Water Monitoring Data

Period	Date	Daily Rainfall (in.)	Upstream Velocity (ft./sec.)	Downstream Velocity (ft./sec.)	Upstream Depth (in.)	Downstream Depth (in.)	Upstream Turbidity (NTU)	Downstream Turbidity (NTU)	Upstream Total Solids (%)	Downstream Total Solids (%)
Pre-Construction	4/5/1997	2.0	---[1]	---	---	---	164	150	0.32	0.48
	4/25/1997	1.0	3.1[2]	2.9[2]	7.0	7.0	220	198	0.14	0.21
	8/26/1997	0.5	2.3[2]	1.3[2]	6.3	6.0	194	176	0.10	0.17
	9/10/1997	1.5	3.8[2]	3.1[2]	7.2	7.0	242	225	0.23	0.30
	9/17/1997	0.9	3.0	2.5	7.0	6.5	205	187	0.12	0.20
	10/5/1997	0.4	1.8	0.9	6.0	6.0	188	169	0.07	0.12
	10/9/1997	1.3	3.5	3.0	7.0	7.0	232	211	0.19	0.26
Post-Construction	9/28/1998	1.3	1.0	1.5	4.5	0.6	44	63	0.37	0.53
	10/2/1998	0.9	1.1	1.4	3.8	0.5	45	62	0.20	0.32
	10/15/1998	1.0	1.3	1.4	4.0	0.3	47	54	0.33	0.44
	6/21/1999	1.7	---	0.9	---	2.0	74	50	0.27	0.19
	10/29/1999	0.6	---	---	---	---	---	---	0.04	0.04
	12/3/1999	1.1	0.0	0.4	1.8	1.6	47	49	0.04	1.71
	2/17/2000	1.6	---	0.1	2.0	0.9	---	---	0.07	0.03

NOTES: [1] --- = "no test data", [2] velocity determined by dye injection, all others by surface float technique.

Table 4.2 Site 2 Water Monitoring Data

Period	Date	Daily Rainfall (in.)	Upstream Velocity (ft./sec.)	Downstream Velocity (ft./sec.)	Upstream Depth (in.)	Downstream Depth (in.)	Upstream Turbidity (NTU)	Downstream Turbidity (NTU)	Upstream Total Solids (%)	Downstream Total Solids (%)
Pre-Construction	8/26/1997	0.5	2.0[1]	1.1[1]	4.5	4.0	187	213	0.09	0.15
	9/10/1997	1.5	3.4[1]	2.1[1]	5.0	4.5	236	253	0.11	0.16
	9/17/1997	0.9	2.4	1.2	5.0	4.0	195	232	0.17	0.22
	10/9/1997	1.3	3.2	2.1	5.0	4.0	225	247	0.22	0.25
	10/15/1998	1.0	2.4	1.9	4.1	3.8	215	252	0.18	0.22

NOTES: [1] velocity determined by dye injection, all others by surface float technique.

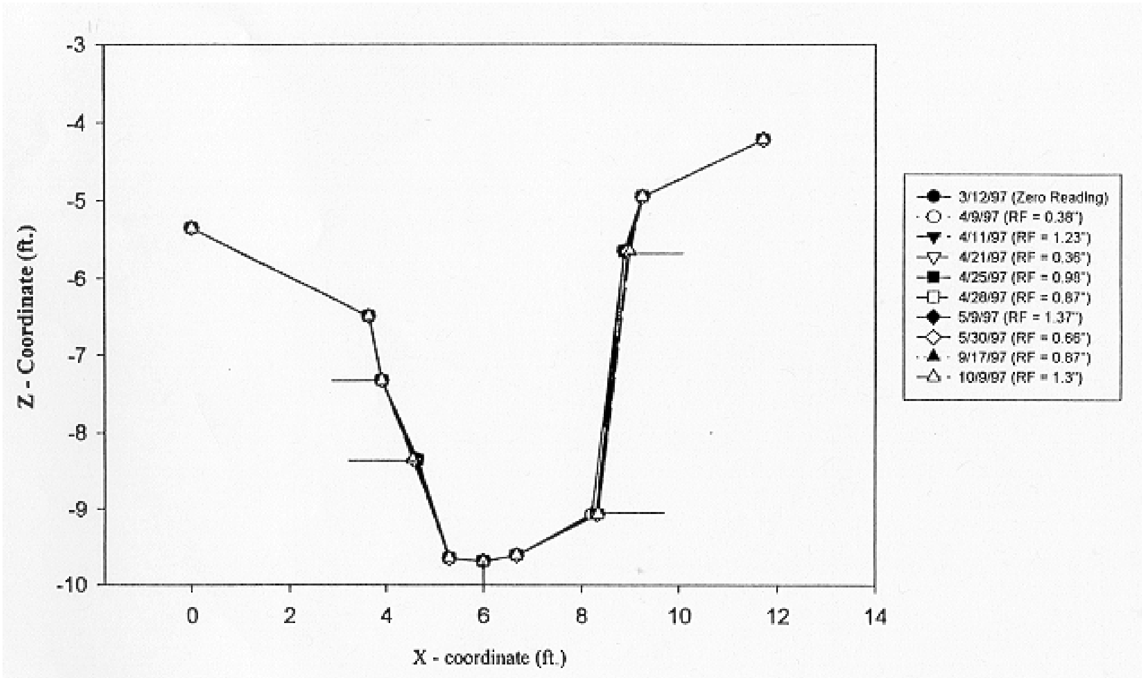


Figure 4.1 Bank Pin-Section 1 at Site 1.

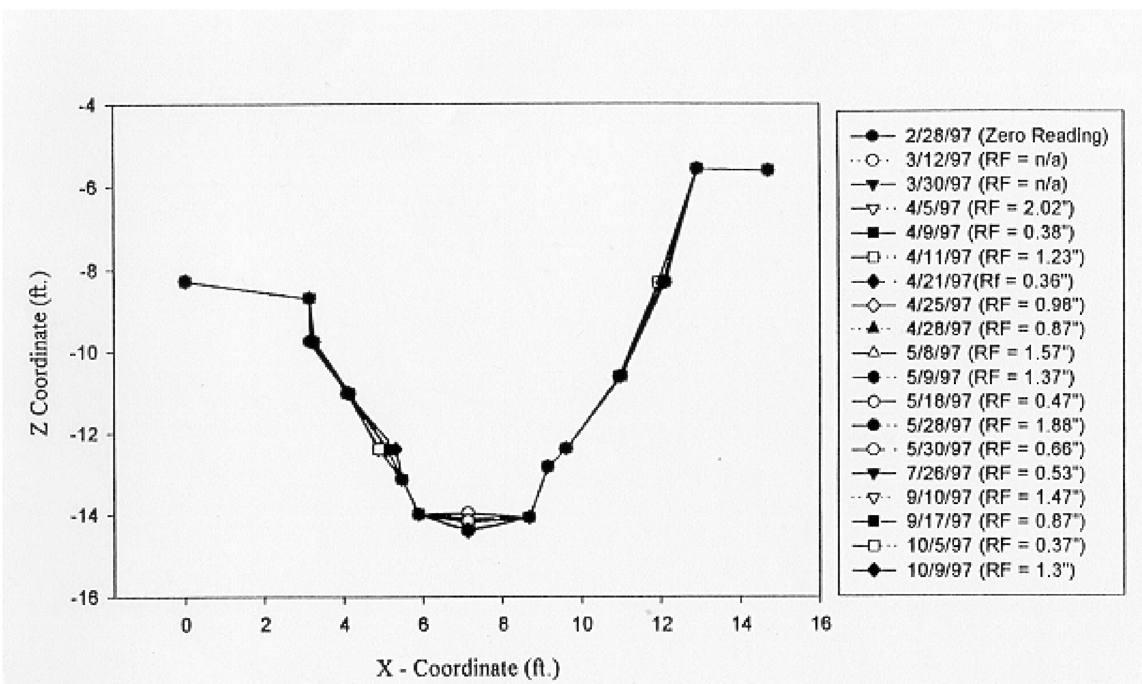


Figure 4.2 Bank Pin-Section 2 at Site 1.

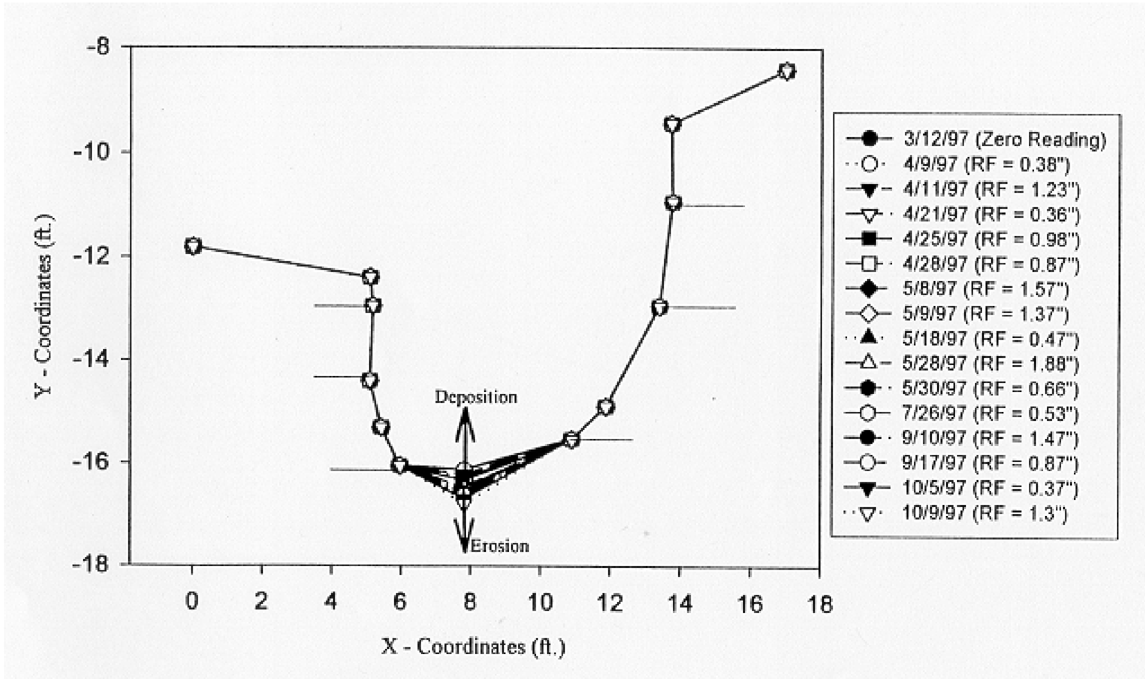


Figure 4.3 Bank Pin-Section 3 at Site 1.

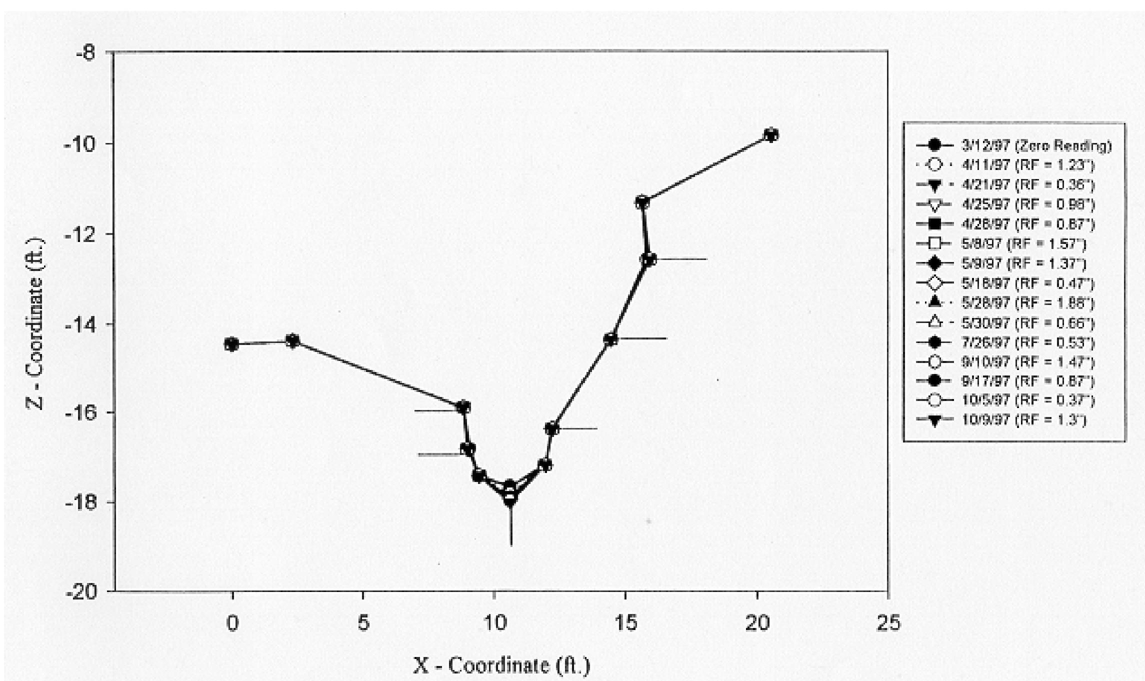


Figure 4.4 Bank Pin-Section 4 at Site 1.

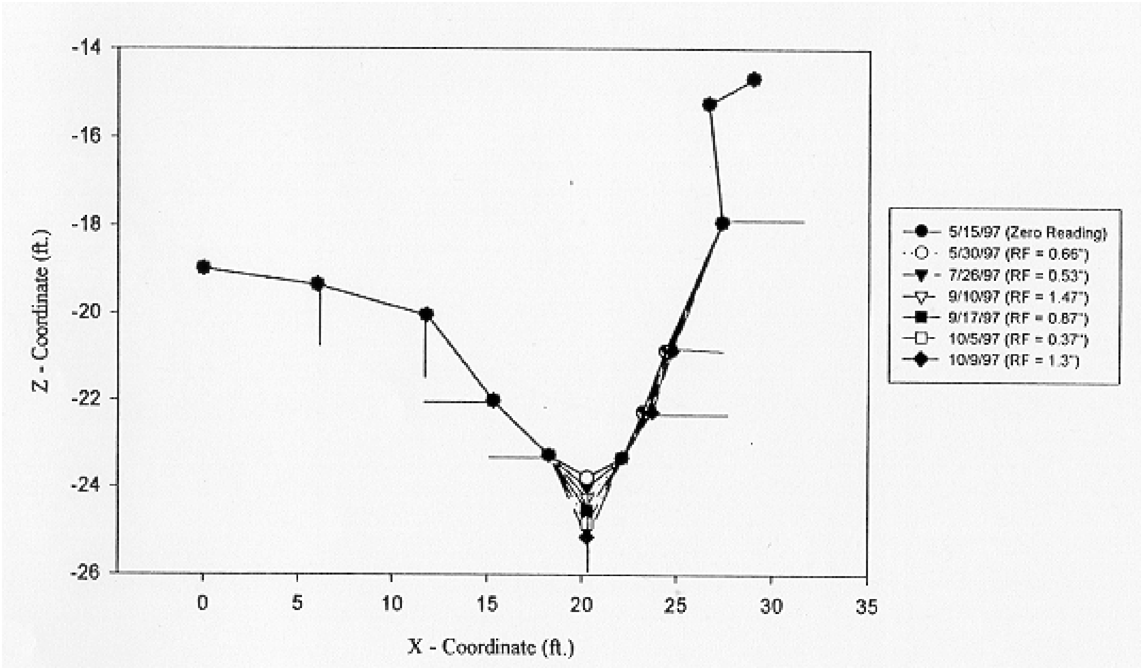


Figure 4.5 Bank Pin-Section 5 at Site 1.

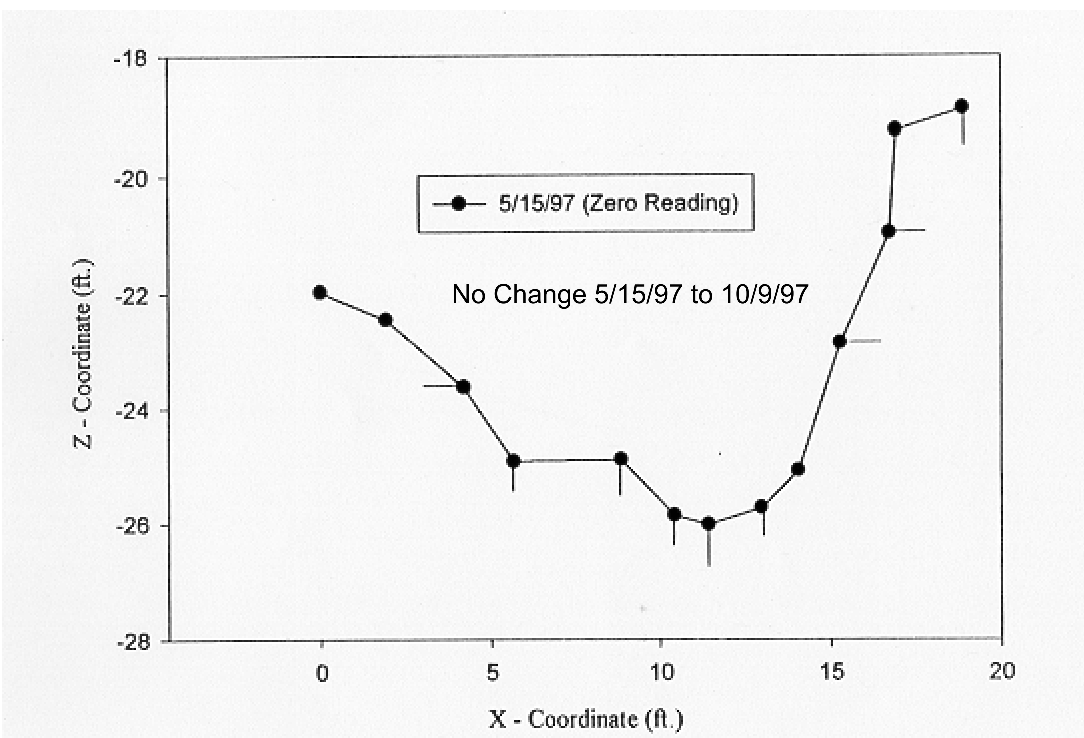


Figure 4.6 Bank Pin-Section 6 at Site 1.

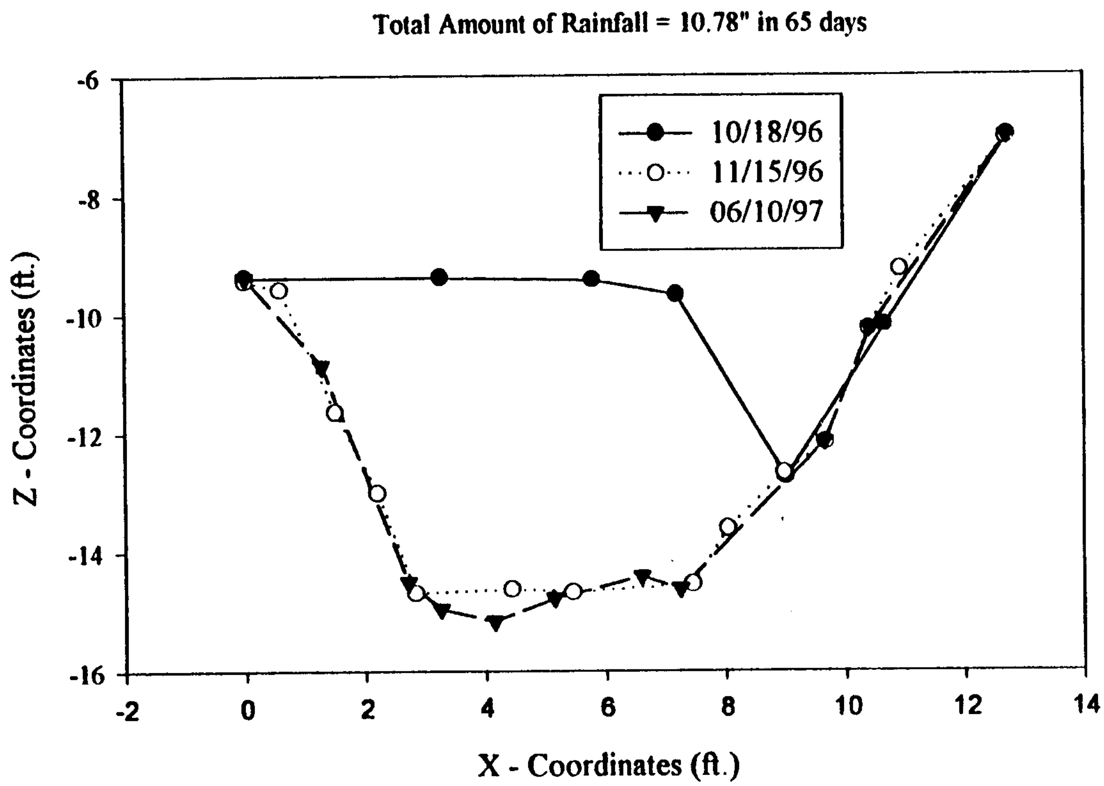


Figure 4.7 Mass Wasting Measured via Surveying at Cross-Section No. 4 at Site 1.

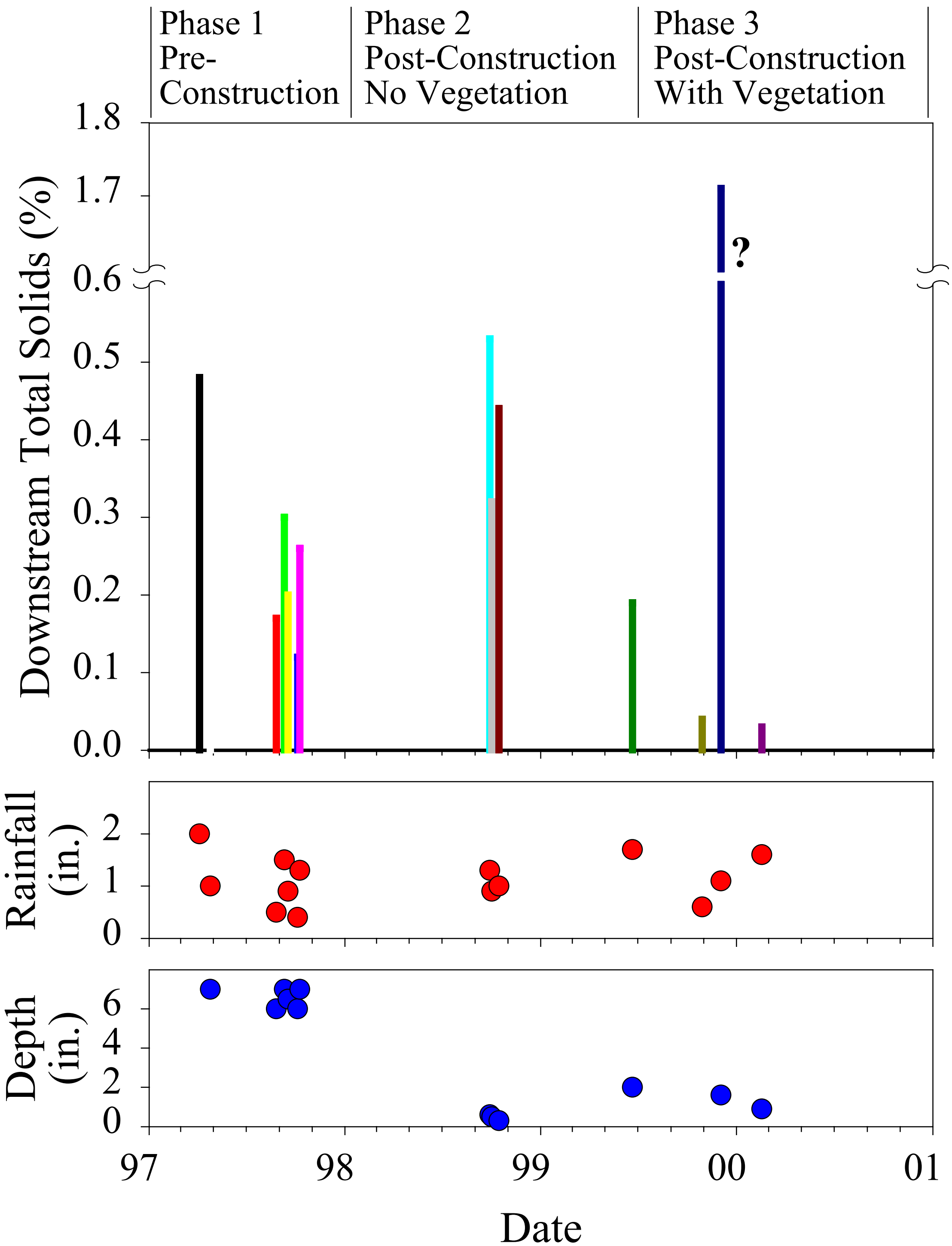


Figure 4.8 Downstream Total Solids Data for Site 1.

Figure 4.9 Flow in Channel Prior to Erosion Control, Looking South at Site 1 (Spring 1997).

Figure 4.10 Condition of Channel 2 Months after Construction, Looking North at Site 1 (Summer 1998).

Figure 4.11 Condition of Channel 5 Months after Construction, Looking South at Site 1 (Fall 1998).

Figure 4.12 Condition of Channel Approximately 2.5 Years after Construction, Looking North at Site 1 (Fall 2000).

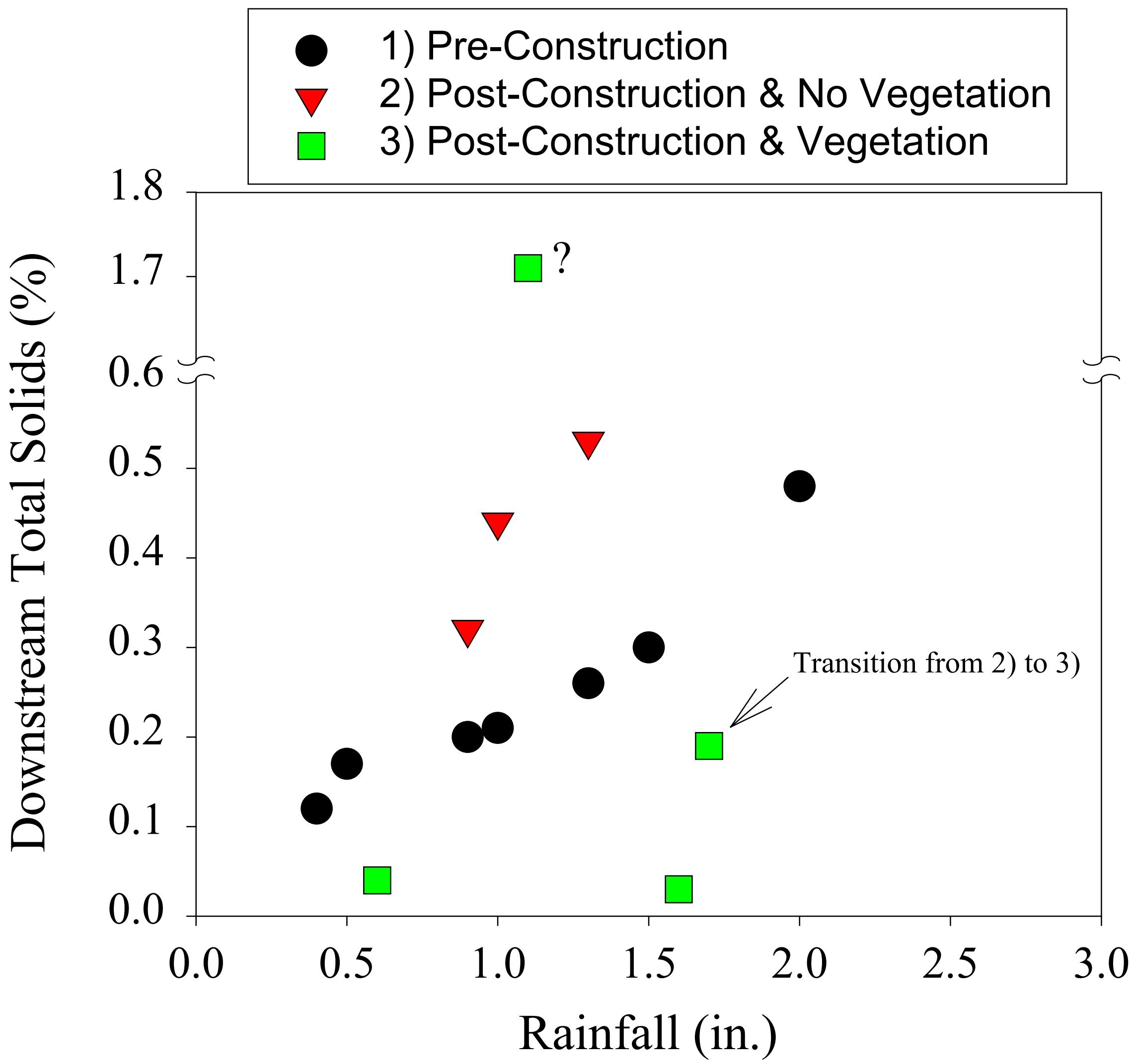


Figure 4.13 Downstream Total Solids Versus Rainfall at Site 1.

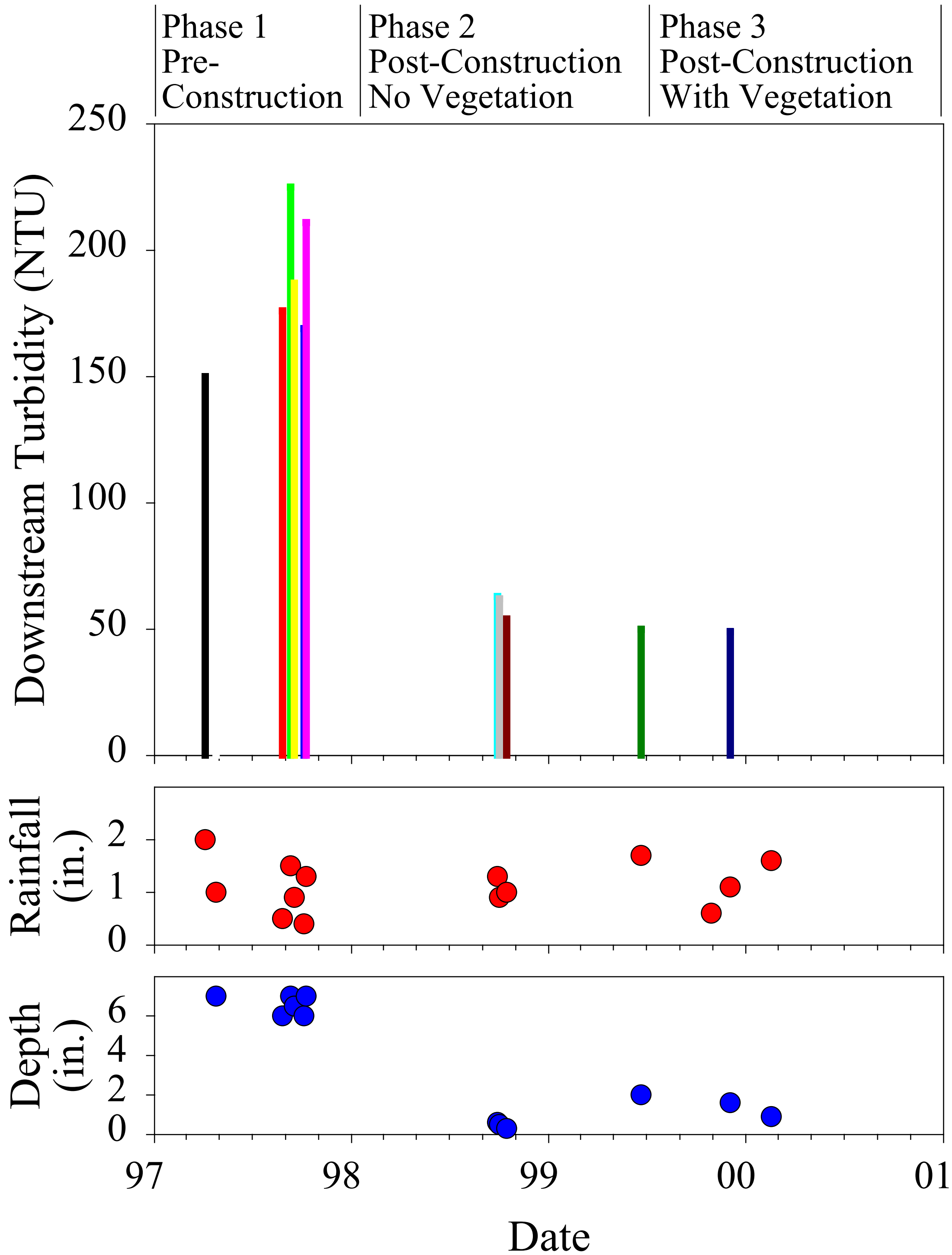


Figure 4.14 Downstream Turbidity Data for Site 1.

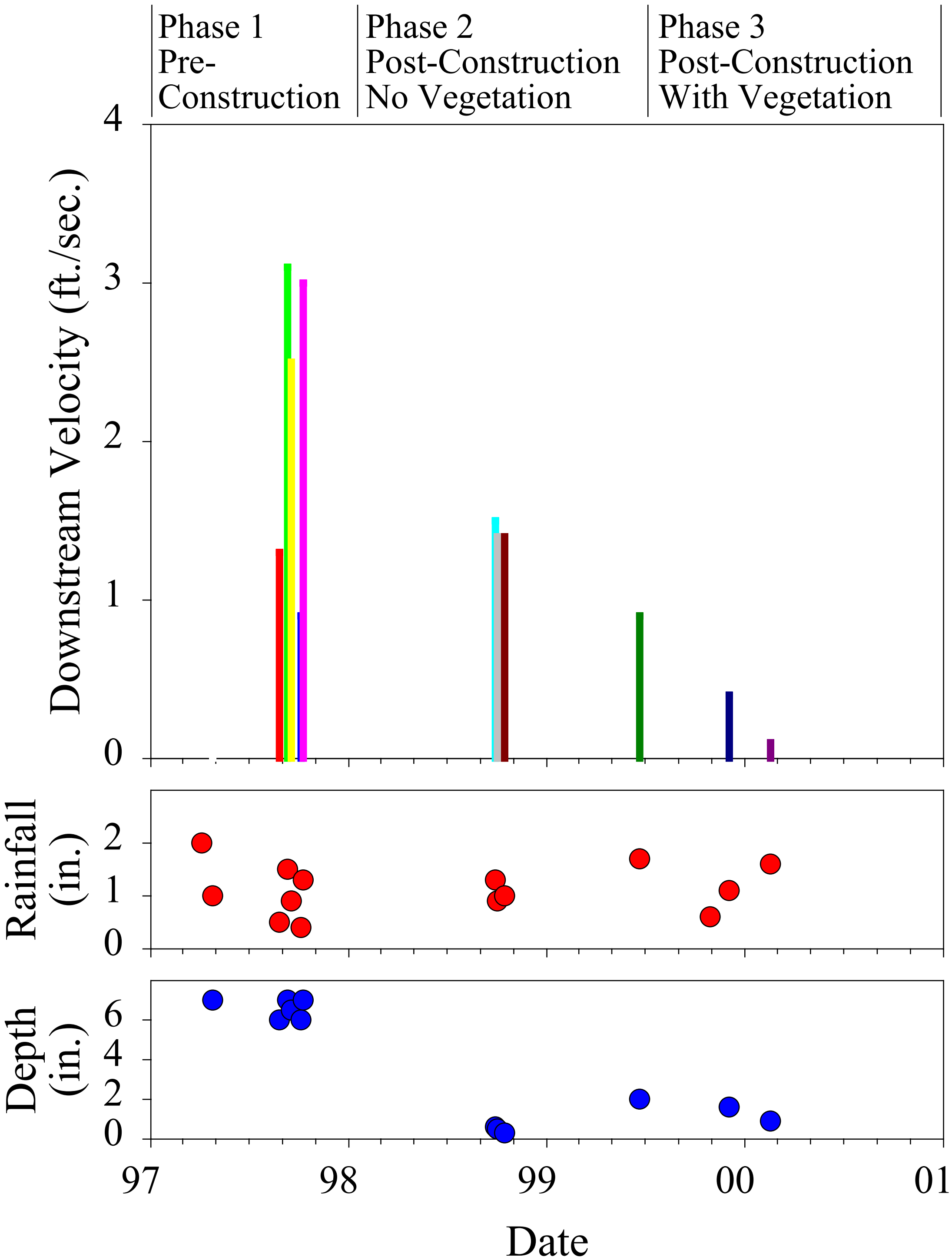


Figure 4.15 Downstream Surface Velocity Data for Site 1.

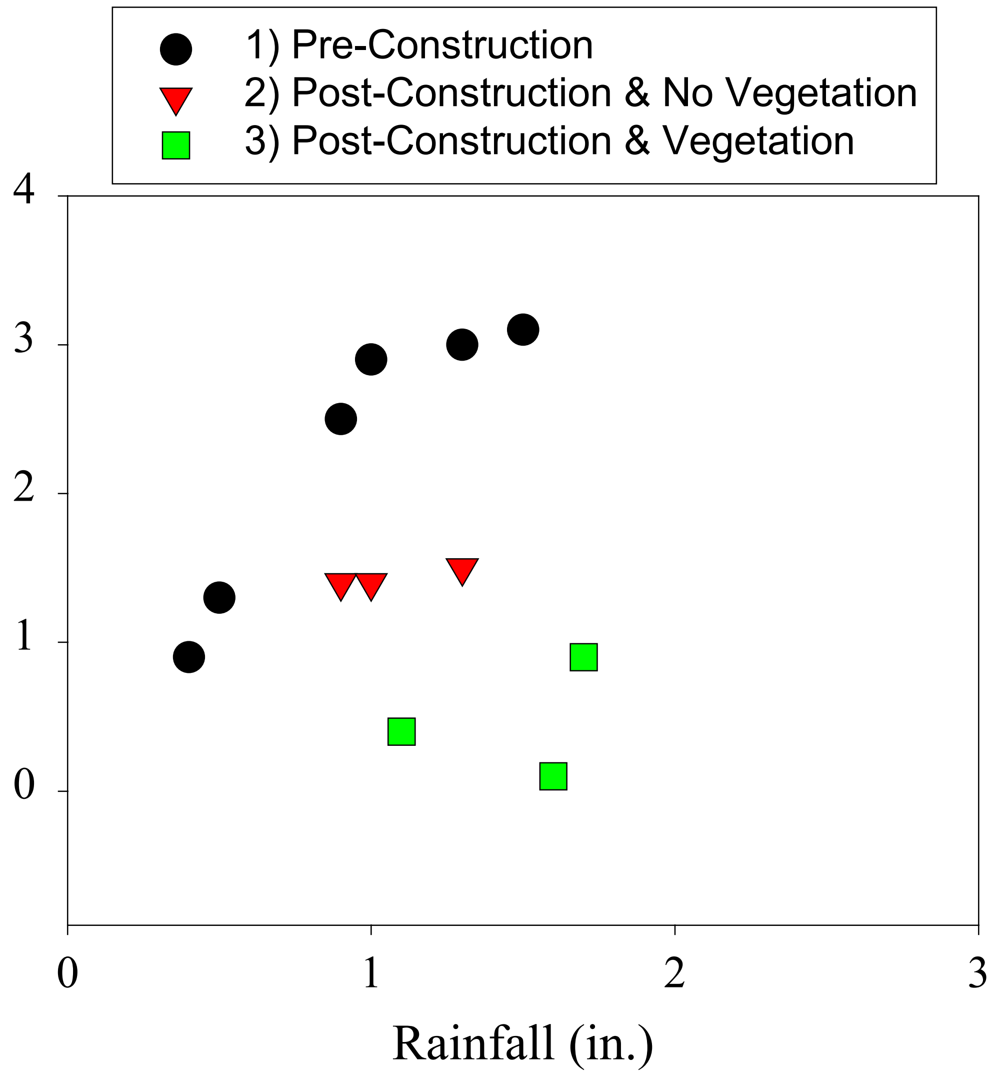


Figure 4.16 Downstream Surface Velocity Versus Rainfall at Site 1.

a)

b)

Figure 4.17 Site 1 Looking North from Similar Positions a) Before (Spring 97) and b) After Erosion Control (Fall 2000) [note position of telephone pole].

a)

b)

Figure 4.18 Site 1 Looking South a) Before (Fall 1996) and b) After Erosion Control (Fall 2000) [note position of pine tree in upper left corner of a)].

a)

b)

Figure 4.19 View from North End of Site 1 after Erosion Control (Fall 2000): a) Looking South, b) Looking North.

Figure 4.20 Site 2 Looking East 1.5 Months After Erosion Control (Spring 1999). [Note area of thick vegetation (arrow) where cotton burrs were placed.]

Figure 4.21 Site 2 Looking East About 1.5 Years After Erosion Control (Fall 2000). [Note vegetation (arrows) in vicinity of telephone pole and along road not observed in Fig. 4.20]

Figure 4.22 Site 2 Looking West 1.5 Months After Erosion Control (Spring 1999). [Note area of thick vegetation (arrow) where cotton burrs were placed.]

Figure 4.23 Site 2 Looking West About 1.5 Years After Erosion Control (Fall 2000). [Note vegetation (arrows) in vicinity of telephone pole and along road not observed in Fig. 4.22]

5.0 ATTITUDE SURVEYS OF LOCAL RESIDENTS BEFORE AND AFTER EROSION CONTROL

5.1 Pre-construction Attitude Survey

Pre-project attitudes were obtained in two ways: first, through conversations with landowners and the county commissioner, and second, through a questionnaire distributed to approximately thirty residences within approximately two miles of the demonstration sites. Questionnaires were distributed just prior to commencing construction activities in early May 1998.

Discussions with landowners revealed that problems of greatest concern depend on the position of their property relative to the area where active erosion is occurring. The property associated with Site 1 had severe active gully erosion adjacent to the road, which made the property unusable from an agricultural perspective. The rate of soil loss and hence growth of unusable acreage was the main concern to this farmer. He has fully supported this project from the outset and has cooperated by agreeing (via contract) to remove fences and allow for major construction activities on his property. The biggest problem affecting landowners downstream from the erosion-impacted site is flooding that occurs when the carrying capacity of downstream gullies is exceeded due to sedimentation. One property owner indicated that on more than one occasion the floodwater backed up into his well house, contaminating his water supply. Both upstream and downstream landowners indicated that road hazards, particularly deep roadside gullies and flooded roads, are a major concern. Generally, there seemed to be a feeling of frustration regarding what could be done to overcome erosion problems, and that the county commissioner is limited in his ability to remedy erosion related problems. For the county commissioner's input, he expressed the problem as one of available resources. He has a limited budget and his primary duty is to maintain safe roads. Thus, he does not have the ability to routinely implement significant erosion control measures. He simply does what he can to correct problems as they arise. For example, a motorgrader is routinely used to clean out gullies rather than the preferred and more costly alternative (over the short term), which is to eliminate the source of erosion altogether. Thus, eventually the gullies fill up and the process is repeated.

Response to the County Roads Erosion Survey was limited. While only three of the thirty questionnaires were returned, the responses give some insight about people's perception of the erosion problem. Results are summarized in Table 5.1. Some points of interest regarding the responses follow.

- The erosion problem cited most often is soil loss from property adjacent to the county right of way due to erosion in bar ditches; next came flooding problems and traffic disruption followed by surface water contamination.
- Erosion problems are perceived as being quite serious.
- Perceived major impacts include threats to the safety of motorists, degradation of the aesthetic quality of the landscape, and threats to surface water quality. Less frequently cited impacts include increased tax burden and direct costs to landowners.
- For some people, erosion is perceived to impact their life with every significant rainfall.
- Erosion problems seem most severe during spring and winter.
- Causes of erosion cited most often include improper maintenance of bar ditches and easily eroded soil. Other perceived causes include narrow and steep bar ditches. Interestingly, none of the respondents seemed to think too much water is being diverted from private property into bar ditches; however, two of the three indicated that landowners should due more to limit the amount of runoff from private property into bar ditches.
- All respondents believe in a cooperative approach to minimizing the county roads erosion problems.
- All respondents were receptive to allowing the county to go beyond the right-of-way to construct proper bar ditches, and felt that bar ditches should be better maintained to preserve vegetation.
- Comments suggest that people would like more attention focused on the rural road erosion problems by state and county officials.

5.2 Post-construction Attitude Survey

Post-project attitudes were assessed using a questionnaire distributed to approximately thirty residences within approximately two miles of the demonstration sites. Questionnaires were distributed during the summer of 1999.

Six persons completed and returned questionnaires. Responses given in Table 5.2 indicate that people generally have a favorable impression of the project. Some points of interest regarding the responses follow.

- Generally, people had a more favorable impression of Site #1 compared to Site #2; however, Site #1 was more visible and was the primary focus of activities.
- One person responded unfavorably to Site #1; however, it is known that this individual harbored resentment for the farmer whose land was included in Site #1. Therefore, this response is considered biased. The nature of the comments shown in Table 5.2, reflect this person's bias.
- The most visible benefit of erosion control measures is reduction of soil loss, while the least visible is improvement in surface water quality.
- At Site #1 the quality of construction was perceived to be very good while at Site #2, people were generally neutral. One person felt that not enough was done at Site #2.
- People lean toward the belief that spending money up front on construction is better than frequently recurring maintenance costs.
- There is general consensus that cooperation between landowners, county commissioners, and conservation district personnel is important for solving erosion problems along county roads.

In addition to the questionnaire, discussions with the county commissioner and landowner involved at Site 1 gave the impression that they were very favorable toward this project. During a post-construction visit to Site 1, the landowner was encountered in the process of applying fertilizer to the site, an activity initiated and paid for on his own. This clearly demonstrates that landowners have a genuine interest in preserving improvements gained through erosion control.

Table 5.1 Results of the Pre-Construction County Roads Erosion Survey

Question	**Answers (Number of affirmative responses shown in parentheses)**
1) Which of the following problems result from erosion along county roads in the area close to where you live. **(circle all that apply)**	a) Disruption to traffic on county roads due to erosion damage. **(2)** b) Flooding of county roads due to sediment clogged drainage ditches. **(2)** c) Flooding of private property. **(2)** d) Soil loss from property adjacent to the county right-of-way due to erosion in bar ditches. **(3)** e) Contamination of surface water in the area (ponds, creeks, etc.). **(1)** f) Others **(0)**
2) How serious are these problems when they occur?	a) Very serious **(2)** b) Somewhat serious **(1)** c) Not serious **(0)**
3) What impacts do the problems caused by erosion along county roads have in your area? **(circle all that apply)**	a) They threaten the safety of motorists. **(2)** b) They increase maintenance costs and pose a burden to taxpayers. **(1)** c) They are costly to landowners adjacent to county roads. **(1)** d) They degrade the beauty of the landscape. **(2)** e) Eroded soil threatens surface water quality and the natural environment of surface water bodies (ponds, streams, etc.). **(2)** f) Others **(0)**
4) On average, how frequently does erosion along county roads impact your life?	a) With every significant rainfall **(2)** b) Sometimes **(0)** c) Rarely **(1)** d) Almost never **(0)**
5) During what seasons do problems resulting from erosion most often occur? **(circle all that apply)**	a) Spring **(3)** b) Summer **(2)** c) Fall **(1)** d) Winter **(3)**
6) What are the main causes of erosion along county roads in your area? **(circle all that apply)**	a) Bar ditches are too narrow. **(1)** b) Bar ditches are not properly maintained. **(3)** c) Roads and bar ditches are too steep in certain areas. **(1)** d) Soil in certain areas is easily eroded by moving water. **(3)** e) Too much water resulting from rainfall on property next to county roads is being diverted to the bar ditches. **(0)** f) Others **(0)**

Table 5.1 (cont.)

Question	Answers (Number of affirmative responses shown in parentheses)
7) What should be done to correct erosion impacted areas along county roads? **(circle all that apply)**	a) The county should address the problem within the county right-of-way. **(2)** b) Landowners should address the problems on their property as they see fit. **(2)** c) The county commissioner, local conservation agencies, and the landowner whose property is impacted by the erosion should work together to solve the problem within and beyond the county right-of-way. **(3)** d) Others **(0)**
8) What specific actions do you think should be used to prevent and correct erosion problems along county roads? **(circle all that apply)**	a) Landowners adjacent to county roads should attempt to limit the amount of rainwater that is diverted to bar ditches from their property (using terraces, drainage ways, retention ponds, etc.) **(2)** b) Where persistent erosion problems occur, landowners should allow the county to construct properly widened bar ditches that extend beyond the county right-of-way. **(3)** c) County maintenance of bar ditches should be better controlled to prevent destruction of vegetation that resists erosion. **(3)** d) Others **(0)**
9) Please provide any additional comments that you may have.	• "I appreciate the fact that someone out there actually cares enough to look into this situation. This is an on-going problem that has been around forever with so very little help from anybody." • "Our road has been taken care of only this year but before it was terrible – every time it rained forget it!!"

Table 5.2 Results of the Post-Construction County Roads Erosion Survey

Question	**Answers** (Numbers in parentheses are individual responses. Number after parentheses is the mean of responses not including the highest and lowest values.)
1) The methods employed at Project Site #1 have: a) Reduced traffic disruption on county roads due to erosion damage. b) Reduced flooding of county roads due to sediment clogged ditches. c) Reduced flooding of private property. d) Reduced soil loss from property adjacent to eroding bar ditches. e) Reduced Contamination of local ponds, creeks, etc.	**1) Possible Reponses: 1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree, 5= Strongly Disagree.** a) (3, 1, 4, 1, 1, 5) 2.3 b) (2, 1, 3, 1, 1, 5) 1.8 c) (3, 1, 3, 1, 1, 5) 2.0 d) (1, 1, 2, 1, 1, 3) 1.3 e) (2, 3, 3, 3, 1, 3) 2.8
2) The methods employed at Project Site #2 have: a) Reduced traffic disruption on county roads due to erosion damage. b) Reduced flooding of county roads due to sediment clogged ditches. c) Reduced flooding of private property. d) Reduced soil loss from property adjacent to eroding bar ditches. e) Reduced Contamination of local ponds, creeks, etc.	**2) Possible Reponses: 1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree, 5= Strongly Disagree.** a) (3, 3, 3, 3, 3, 1) 3 b) (2, 3, 3, 3, 2, 2) 2.5 c) (2, 3, 3, 3, 2, 3) 2.8 d) (1, 1, 3, 1, 2, 3) 1.8 e) (2, 3, 3, 3, 2, 3) 2.8
3) The overall quality of construction at Project Site #1 is satisfactory.	**3) Possible Reponses: 1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree, 5= Strongly Disagree.** (1, 1, 2, 1, 1, 3) 1.3
4) The overall quality of construction at Project Site #2 is satisfactory.	**4) Possible Reponses: 1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree, 5= Strongly Disagree.** (1, 2.5, 3, 2.5, 4, 2) 2.5
5) An initial expenditure of funds for construction projects such as these is a better alternative than frequently recurring maintenance costs.	**5) Possible Reponses: 1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree, 5= Strongly Disagree.** (2, 1, 3, 1, 1, 3, 3) 2.5
6) Considering the effectiveness of this project, landowners should cooperate with the county commissioner and local conservation agencies to help solve problems associated with erosion along county roads.	**6) Possible Reponses: 1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree, 5= Strongly Disagree.** (1, 1, 2, 1, 1, 3) 1.3
7) Below, please provide any additional comments that you may have.	**7) In same order as above.** (No comments, No comments, No comments, No comments, "At #2 should have sprigged or sodded and would have done better job. Have used tires on his own property with sod and it worked.", "Site 1 had very little to do with road, it was mostly for the benefit of the farmer. Site 2 was a good project."

6.0 TECHNOLOGY TRANSFER

Technology transfer was accomplished through working directly with the county commissioner and his personnel. Through participation in this project, they gained valuable insight into construction and maintenance methods for controlling erosion.

A document entitled “Erosion Control on Unpaved County Roads, Guidelines for County Road Maintenance” was produced and distributed to county commissioners in Oklahoma. The guidelines provide background on the problems caused by erosion along county roads, present causes of erosion, and provide strategies for addressing problems.

On November 9, 2000, a presentation entitled “Erosion Control Along Unpaved County Roads” was delivered at the Annual Meeting of the Association of County Commissioners of Oklahoma (ACCO). The presentation focused on the contents of the aforementioned erosion control guidelines. In addition, other sources of assistance to address these problems were presented.

On March 1, 2001, a similarly titled presentation was delivered at the annual meeting of the Oklahoma Clean Lakes Association. This presentation focused on the McClain County demonstration sites and results of the water quality data collected from Site #1.

In addition to the activities mentioned above, an alliance was forged between OU and OCC. Through this alliance, OU will assist with future roadside erosion educational efforts in Unified Watershed Areas; such efforts will be contracted on an as needed basis.

7.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A demonstration project was conducted in McClain County to assess the effectiveness of erosion control and promote technology transfer. Two sites, designated Site 1 and Site 2, were studied; however, Site 1 became the primary focus of this effort for reasons described previously and reiterated in this chapter. Specific activities included:

a) Topographic surveying and soil sampling of the sites prior to erosion control.
b) Design and construction of erosion control.
c) Monitoring of the sites to quantify soil loss from channel cross-sections, rainfall, water quality (total solids and turbidity), water velocity, depth of flow, and visual appearance (photographs), before and after erosion control.
d) Assessment of local attitudes before and after erosion control via a questionnaire and personal interviews.
e) Technology transfer via presentations to target groups and development and circulation of an erosion control manual.

During this project several conclusions were made in regard to each of the above activities and several lessons were learned, as follows.

a) The topographic surveys revealed that both sites were in areas having substantial slopes (roadway and bar ditch) and deep v-shaped bar ditches. Near surface soils at Site 1 were primarily sandy clays and laboratory tests revealed this soil was slightly to moderately dispersive. Surface soils were underlain by weathered shale that appeared to be more resistant to erosion compared to the overlying soil. Near surface soils at Site 2 were composed primarily of sandy clay and silty sand, being generally more cohesionless than Site 1 soils. Clayey soils at Site 2 were generally characterized as non-dispersive; however, the cohesionless soils at this site, composed of fine sand and silt, are susceptible to erosion. Site 2 soils were underlain by weathered sandstone, which exhibited significant resistance to erosion.

b) Erosion control at Site 1 was extensive including: major earthwork and grading, applying two types of mulch cover (cotton burrs, hay), planting vegetation, and placing channel protection consisting of rock structures, erosion control blankets, a tire mattress and sod. At Site 2, limited earthwork and grading, mulch cover (cotton burrs), and seeding was utilized. Generally, erosion control measures were successful; however, some problems were encountered that can be avoided in the future. First, the tire mattress covered with soil was not effective in controlling erosion while vegetation was being established; after ten months, more soil cover and sod was placed over the tires. This combination of tires and sod has worked very well. Second, the rock berms (weir shaped) were constructed in the channel where slopes were less than 2%. The berms were designed for 12-inch stone but 6-inch was allowed; this proved to be a mistake as some of the smaller rock was carried downstream. This problem, while only associated with large rainfall events, required unnecessary maintenance continuing until soil and vegetation were established around the berms. While the rock berms were very effective once they were stable, the county commissioner complained about difficult mowing in these areas. In the future, soil berms covered with erosion control mat could be an effective alternative.

c) Monitoring at Site 1 before and after construction clearly indicated improvements due to erosion control; however, some methods appeared more reliable than others. Measurements of turbidity and total solids before construction at Site 1 and Site 2 were similar; however, evidence suggested erosion was occurring at a much greater rate at Site 1, due to mass wasting. This suggests that turbidity and total solids measured over the small scale involved in this project are not good indicators of erosion rate. On the other hand, turbidity and total solids data, although alone not conclusive, did indicate substantial improvements after erosion control. Difficulties were encountered in water sampling after construction because the flow in the channel tended to be very shallow and the soil bed was easily disturbed.

Measurements of velocity and channel depth were much less susceptible to uncertainties. These measurements indicated substantial improvements in channel performance (i.e. reduced velocity and depth of flow), which can be equated with reduced erosion.

Surveying techniques, using optical methods and bank pins, proved very effective at Site 1 for documenting soil loss in the channel and mass wasting. Furthermore, photographic evidence over the course of the project proved to be very effective in documenting site improvements.

d) In addition to monitoring methods above, success of the erosion control measures was also demonstrated by the reduction in emergency maintenance at the sites. In the two years prior to erosion control, the county commissioner made at least two emergency repairs due to damage from storm events. In each case, substantial soil loss from bar ditches occurred and damage to the roadway posed a threat to motorist safety. In three years following erosion control, no major damage occurred and only minor maintenance was required; there was no emergency maintenance required to fix dangerous road conditions.

e) Pre- and post-construction surveys of local attitudes indicated that perceptions of erosion control were favorable, although the survey response was limited. Of the approximately 30 surveys delivered to local residences, only three were returned during pre-construction and six were returned during post-construction. It was also learned that local personal relationships influence the way people respond to such surveys. Interviews with local residents were also helpful in assessing local attitudes.

f) Technology transfer was accomplished by working directly with the McClain County Commissioner's personnel, through technical presentations, and via circulation of a document entitled "Erosion Control on Unpaved County Roads, Guidelines for County Road Maintenance." This document was mailed to all of the county commissioners in Oklahoma with a letter of transmittal explaining its background and purpose. A presentation of the material covered in the manual was presented at the annual meeting of the Association of County Commissioners of Oklahoma, in November 1999. In addition, a project presentation was made at the annual meeting of the Oklahoma Clean Lakes Association in March 2000. Finally through this project, an alliance for continued cooperation between OU and OCC was forged to combat erosion problems on future projects in Unified Watershed areas.

In summary, the project was overall a success, although, the project took considerably more time than originally planned. This was due to initial project constraints (QAPP), difficulties with project selection (one initially selected site was disqualified after some time), and primarily difficulty in coordinating all of activities required (pre-construction monitoring, construction, post-construction), many of which were constrained by the season and weather. In addition, it is desirable to implement erosion control while vegetation has a chance to quickly establish (spring or early summer). This, however, coincides with the busy time of year for county road crews, which may influence the ability of the commissioner to handle more than one such project in a short time frame. Such was the case with this project. Therefore, future projects might include single sites in two or three counties, thus spreading around the effort and knowledge.

In the future, it would be more appropriate to allow three years for such a project, beginning with initiation of pre-construction monitoring; this provides one year for pre-construction monitoring, a few months for construction (should be spring, early summer), followed by at least 1.5 years for post-construction monitoring.

The major obstacles to implementing erosion control include available time and the costs associated with heavy equipment, materials, and manpower. In addition, county commissioners cannot spend county money on private property, which limits erosion control to the right-of-way unless handled by landowners. Landowners, however, seldom have the resources available to address such problems in proper fashion. One solution to help address this problem is to establish a state fund for erosion control projects. County commissioners and landowners, together, would submit a proposal through their conservation district to solicit funds for erosion control on and adjacent to the county road right-of-way. Proposals would have to detail erosion control to be employed, thereby allowing for evaluation and assistance from state conservationists. As the program matures, erosion control technology transfer would be enhanced throughout Oklahoma. As demonstrated by this project, a few thousand dollars can go a long way depending on the scale of the project; thus, an annual expenditure of $100,000 (by the state) could result in implementation of erosion control at 10-20 locations (assuming some matching requirements).

8.0 REFERENCES

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