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Erosion and Sedimentation Damages and Economic Impacts of Potential 208 Controls: A Summary of Five Watershed Studies in Texas

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EXECUTIVE SUMMARY

This report summarizes results of economic analyses of erosion and sedimentation in five agricultural watersheds in Texas (see fig. 1). Economic analyses of the study areas considered both the on-farm economics of soil conservation and the economic consequences of various sedimentation control options. These topics were joined in the studies because they deal with different facets of the same problem. Unlike some potential pollutants, soil particles transported from a farmer's field thay may become a problem downstream are a valuable resource, not a waste product. Because soil is valuable in itself, some level of soil conservation is going to be economically desirable even if downstream damages are not present or are not considered by the farmer. Results of the studies show that soil conservation does indeed pay in many situations and that its value is greater the longer the planning horizon of a farmer. This suggests that an educational program in this regard may reduce sediment damage while increasing farm income at the same time.

Sediment can cause environmental damage (off-site costs) both directly and indirectly. Directly, the soil particles can cause environmental damage by filling up reservoirs and flood control structures and by deposition in other places. Indirectly, sediment can cause environmental costs by carrying plant nutrients that are potential pollutants. For the study watersheds, no evidence was found that the concentration of plant nutrients in the water posed health hazards to livestock or humans, nor caused undue eutrophication in the watersheds. Consequently, the study focused on off-site sediment damages resulting from shortened economic lives of reservoir and flood control structures and from sediment deposition in the watershed.

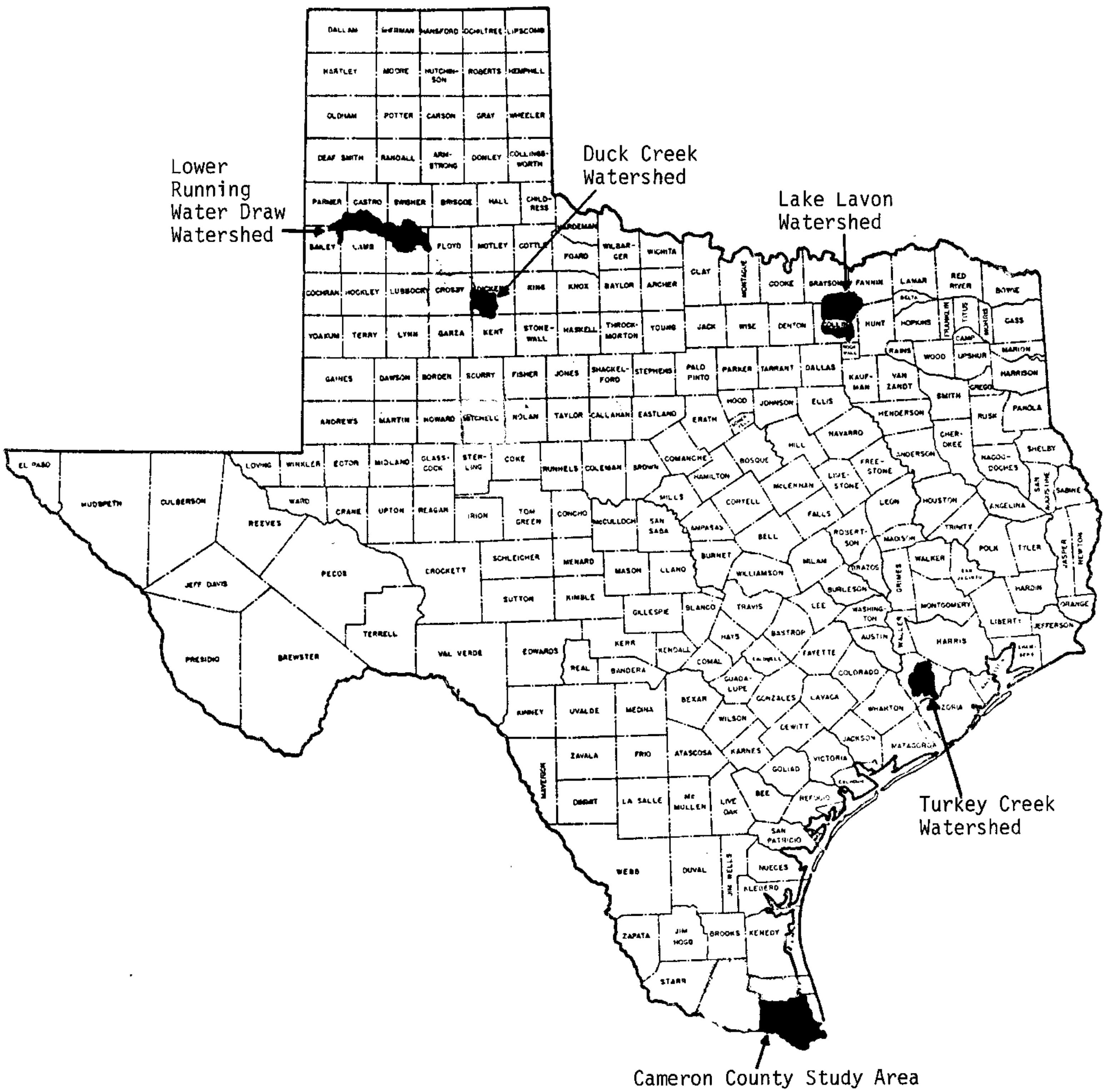

Figure 1. Location of the Study Area.

Annualized off-site sediment damages ranged from a high of 26 cents per ton of gross erosion in Lake Lavon watershed to 14 cents per ton of gross erosion in Duck Creek, to 13.5 cents per ton of gross erosion in Lower Running Water Draw, to a negligible amount in Turkey Creek and Cameron County. These estimates are considerably lower than off-site sediment damages in corn belt watersheds (Lee & Guntermann).

Policy Options for Controlling Sediment

Public policies that can be implemented to abate off-site sediment damages include direct regulation, provision of economic incentives, education, and public investment. For point sources of pollutants, regulations are typically directed toward the pollutant at or near the point of emission into waterways. However, this is infeasible with non-point sources such as sediment because they enter waterways at an infinite number of points. Hence, regulations must be directed toward the practices that cause erosion and thus sedimentation.

The economic incentive option includes alternatives such as Federal or State cost-sharing for adoption of conservation practices, and disincentives such as taxes or penalties on erosion. Education is a viable policy option in situations where producers are not adopting soil conservation practices that would be profitable. In these situations a successful education program would increase producer's income as well as reducing off-site sediment damages. Public investment could be used to pay for dredging sediment from reservoirs and flood control structures to prevent loss of flood control, water supply and recreational benefits.

Social benefits and costs of various policy options based on direct regulation, taxation, and provision of economic incentives were estimated for three watersheds: Lake Lavon, Duck Creek, and Lower Running Water Draw. Items considered in the benefit-cost analysis were: (a) farm income consequences; (b) off-site sediment damages abated; (c) governmental cost or revenue; and (d) administration and enforcement costs associated with each policy. The major conclusion of this social benefit and cost analysis is that off-site damages are not large enough to warrant controls on agricultural activities in any of the watersheds; that is, the costs to society of controls exceed the total benefits to society for all of the policy options considered. Another conclusion is that an education program that emphasizes the on-farm profitability of conservation practices may reduce sediment damages while simultaneously increasing farm income.

ACKNOWLEDGEMENTS

This report summarizes a series of detailed watershed studies funded by the Texas Soil and Water Conservation Board and the Texas Department of Water Resources on "Economic Impacts of Various Non-Point Source Agricultural Pollution Controls in Texas." The research was conducted under the auspices of the Texas Water Resources Institute, the Texas Agricultural Experiment Station and the Texas Agricultural Extension Service. The authors would like to express their appreciation to Dr. Jack Runkles, Director of The Texas Water Resources Institute, for assistance in organizing and carrying out the research project. Mr. Harvey Davis, Mr. G. E. Kretzschmar, Jr., and Mr. Charles Rothe of the Soil and Water Conservation Board were instrumental in organizing the project.

Credit is due a great number of people for assistance with the research itself. In particular, A. Ed Colburn, Extension Agronomist, and Henry C. Boqusch, Jr., Richard B. Heizer, John Kazda, Jack W. Stevens, Clifford L. Williams, Soil Conservation Service agronomists, are to be thanked for providing soils information, yield data, and soil loss factors. Norman Brints, Cecil A. Parker, and Ray W. Sammons of the Texas Agricultural Extension Service provided crop budgets and were helpful in adjusting them to the needs of the study. Dr. David Kissel, TAES Soil chemist at the Blackland Research Center, provided valuable soils inputs. Terrace cost data were furnished by Mr. Charles Rothe. Joe Cole, Pat Rich, and Charles W. Wendt provided useful information on the yield of crops grown in rotation with other crops. Appreciation is expressed to Mickey Melton, Phil Mueller, and Robert Wharton, Research Assistants in the Department of Agricultural Economics, for carrying out many of the tedious data handling aspects of this research.

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INTRODUCTION

Public Law 92-500 - the 1972 Federal Water Pollution Control Act Amendments - mandates the analysis of agricultural non-point source (NPS) pollution controls. This report summarizes the results of a set of studies of the economic impact of implementing potential agricultural NPS pollution controls in five Texas watersheds (see fig. 1). Extensive analyses were completed for Lake Lavon, Duck Creek, and Lower Running Water Draw Watersheds, while abbreviated analyses were completed for Cameron County and Turkey Creek study areas. These study areas were selected in consultation with the Texas Soil and Water Conservation Board and the Texas Department of Water Resources, and were considered as representative of the major agricultural areas in the state. Complete analyses of Cameron County and Turkey Creek were not done after it was determined that erosion and sedimentation were negligible problems.

Analyses of Lake Lavon, Duck Creek, and Lower Running Water Draw Watersheds focus on: (a) effects of erosion controls on farm income; (b) off-site sediment damages in the watersheds; and (c) costs of administering and enforcing alternative erosion-sedimentation controls. Erosion controls considered include possible regulatory programs as well as voluntary programs combined with economic incentives.

While the stimulus for this study was concern over potential pollution (an off-site problem) it can not, because of long-run farm income consequences, be separated from conservation problems (an on-farm problem). Thus, the study is as much an analysis of conservation economics as it is an analysis of environmental economics. Accordingly, the individual reports contain substantial information on the short and long-run on-farm benefits and costs of various soil conservation practices for all soil mapping units in three watersheds. Results are applicable to three Land Resource Areas in the state: High Plains, Rolling Plains, and Blackland Prairies.

DESCRIPTION OF THE WATERSHEDS

Lake Lavon watershed covers an area of 477,613 acres, which is primarily in Collin County, but also includes part of Grayson, Fannin and Hunt counties. Soils in this nearly level to rolling prairie can be divided into three principal soil groups: (1) bottomlands or alluvial soils (fine textured, slowly and moderately permeable) that are highly productive; (2) black, waxy upland soils (slowly permeable) that are used primarily for production of small grains and pasture, and (3) light-colored, deep and shallow upland soils over limestone and marble (moderately permeable). Individual soil mapping units and their extent in the watershed are given in Table 1.

In the past four years, 10 percent of the land in the watershed has been planted to cotton, 16 percent to small grains, 19 percent to feed grains, and the remainder to hay, pasture, and minor crops. Table 2 gives the approximate land use for the 1972-75 period. A very small amount of the cropland is irrigated.

Lavon dam, which is located about 25 miles northwest of Dallas, was constructed for water supply, flood control and recreational purposes in 1953. The dam was modified in 1974 to increase its capacity. The North Texas Municipal Water District has authorization to divert 50,000 acre-feet of water for municipal use, 8,000 acre-feet for industrial purposes, and 2,000 acre-

Table 1. Acreages of soils and percent cropped by soil mapping unit in Lavon watershed.[a]

Soil Mapping Unit	Table Abbrev.	Acreage	Percent Now Cropped
Austin silty clay, 1 - 3% slopes	AS13	31,000	40
Austin silty clay, 3 - 5% slopes, eroded	AS35	43,000	20
Austin silty clay, 5 - 8% slopes, eroded	AS58	19,000	0
Brackett soils	BRAC	8,500	5
Burleson clay, 0 - 1% slopes	BC01	2,500	60
Burleson clay, 1 - 3% slopes	BC13	5,600	60
Burleson clay, 2 - 4% slopes, eroded	BC24	1,500	50
Crockett soils, 2 - 5% slopes, eroded	CR25	1,000	0
Fairlie soils	FARL	37,000	50
Ferris clays, 5 - 12% slopes, severely eroded	F512	7,600	0
Frio clay loam, frequently flooded	FCLF	1,500	0
Frio clay loam, occasionally flooded	FCLC	4,400	30
Heiden clay, 3 - 5% slopes, eroded	HC35	31,000	40
Heiden clay, 5 - 8% slopes, eroded	HC58	23,000	0
Houston-Black clay, 0 - 1% slopes	HB01	36,000	60
Houston-Black clay, 2 - 3% slopes	HB23	137,000	60
Houston-Black clay, 2 - 4% slopes, eroded	HB24	19,000	30
Trinity clay, frequently flooded	TCFF	19,400	0
Trinity clay, occasionally flooded	TCOF	15,900	40
Wilson clay loam, 0 - 1% slopes	WC01	650	50
Wilson clay loam, 1 - 3% slopes	WC13	3,700	50
Total Acreage		448,250	

[a]Source: SCS Soil Survey Reports. Acreage estimates exclude land not used for crop production.

Table 2. Approximate average land use in Lavon watershed for the 1972-1975 period.[a]

Land Use	Acreage	Percentage
Cropland		
Cotton	49,843	10.4
Wheat, Small Grains	76,888	16.1
Grain Sorghum	91,641	19.2
Minor Crops	2,468	.5
	220,840	46.2
Hay	50,976	10.7
Pasture	167,524	35.1
Woodland	8,911	1.9
Miscellaneous[b]	29,362	6.1
Total	477,613	100.0

[a]Source: Soil Conservation Service.

[b]Includes roads, highways, railroad right-of-ways, towns, farmsteads, stream channels, etc.

Table 3. Nitrate concentrations in Lavon Reservoir.[a]

NO_3-N Concentration	Lake Lavon-Near Dam	Lake Lavon-East Fork Arm	Lake Lavon-Pilot Grove Arm
Average	.22	.21	.19
Maximum	.59	.49	.50
Minimum	.01	.03	.03
Sampling Period	5/72 to 7/77	9/73 to 4/77	9/73 to 1/77

[a]Source: Texas Water Quality Board (Now Department of Water Resources)

feet for domestic use. Since the reservoir was designed with a large sediment pool, silt has not significantly diminished the water supply and flood control capacity of the reservoir although it could in the future.

Lavon watershed is comprised of three Public Law 566 watershed project areas. These are Pilot Grove Creek, Sister Grove Creek, and the East Fork of the Trinity River. Construction of 191 flood control structures has been approved for these watersheds with 147 of the structures in place as of October, 1976. These flood control structures along with land treatment have reduced siltation of Lavon Reservoir.

Approximately 14 percent of the cropland is now terraced. However, in recent years much of the terraced land has not been farmed on the contour, thus reducing effectiveness of the terraces. Minimum tillage systems are not feasible on most of the soils. For this reason, such systems were not considered in this study.

Table 3 gives recent nitrate concentrations in three locations in Lavon Reservoir. Since the US Public Health standard for nitrates in drinking is 10 p.p.m. of NO_3-N, nitrates do not appear to pose a public health threat in Lavon watershed.

Lower Running Water Draw watershed is located in the Southern High Plains Land Resource Area. It covers an area of 220.29 square miles or 140,985 acres in Hale, Lamb, Swisher, and Castro Counties, Texas. Running Water Draw is the uppermost headwater tributary of the Brazos River. It begins about 25 miles northwest of Clovis, New Mexico, and flows east-southeastward approximately 150 miles crossing the High Plains section of the Great Plains province. It flows through the city of Plainview in Hale County, Texas and becomes the White River at the eastern edge of the High

Plains.

Lower Running Water Draw watershed lies entirely within the High Plains Land Resource Area which is characterized by an extremely flat surface with a gradual slope towards the southeast at an average of 8 to 10 feet per mile. This plains surface in the area of the watershed in question, is interrupted only by many flat-bottomed basins or "playas" and the narrow entrenched valley of Running Water Draw.

Elevations within the watershed range from approximately 3,875 feet above mean sea level along the watershed divide at the western boundary of Castro County to approximately 3,265 feet in the valley floor at the eastern boundary of Hale County.

Surface materials consist of Recent and Pleistocene soil, slope wash, valley fill, and lake deposits of clay, silt and sand. The actual surface texture of soils in the watershed range from clay to fine sandy loam. The Amarillo fine sandy loam, Olton loam, and Pullman, Acuff, and Olton clay loams are soils that are nearly level to gently sloping. These soils are deep and slowly to moderately permeable. Potter loam and fine sandy loam are very shallow, strongly calcareous, slowly permeable, and occur on valley slopes up to 20 percent. Berda clay loam, and Mobeetie fine sandy loam, which are deep, calcareous, and moderately permeable make up the alluvial fans and footslopes in the valley. Spur and Bippus clay loams are deep, dark, slowly to moderately permeable bottomland soils, while Lofton clay loam and Randall clay and fine sandy loam are lakebed deposits in "playas". Individual soil mapping units and their extent in the watershed are given in Table 4.

As can be seen in Table 5, an estimated 71 percent of the watershed is

Table 4. Total and irrigated acreage by soil mapping unit in Running Water Draw watershed.[a]

Soil Series	Table Abbrev.	Total Acreage	Irri-gated Acres
Acuff loam, 0-1% slope	AL01	2,921	2,337
Acuff loam, 1-3% slope	AL13	3,929	1,965
Acuff loam, 3-5% slope	AL35	234	0
Amarillo fine sandy loam, 0-1% slope	AF01	122	92
Amarillo fine sandy loam, 1-3% slope	AF13	232	116
Amarillo fine sandy loam, 3-5% slope	AF35	36	0
Berda loam, 1-5% slope	BL15	2,140	0
Berda loam, 5-8% slope	BL58	1,943	0
Bippus fine sandy loam, 0-1% slope	BF01	367	92
Bippus fine sandy loam, 1-3% slope	BF13	367	0
Bippus loam, 0-1% slope	BI01	5,982	4,487
Bippus loam, 1-3% slope	BI13	1,678	420
Bippus and Spur soils	BSPU	1,430	0
Drake clay loam, 1-3% slope	DL13	179	90
Drake clay loam, 3-8% slope	DL38	302	0
Estacado loam, 0-1% slope	EL01	4,662	3,497
Estacado loam, 1-3% slope	EL13	5,298	3,444
Lipan soils	LIPN	503	0
Lofton clay loam	LOFL	3,793	3,034
Mansker loam, 0-3% slope	ML03	5,971	2,388
Mansker loam, 3-5% slope	ML35	3,938	0
Mansker-Berda soils	MANB	1,177	0
Mansker-Estacado soils	MANE	1,546	309
Olton loam, 0-1% slope	OL01	16,337	15,520
Olton loam, 1-3% slope	OL13	4,546	4,319
Olton loam, 3-5% slope	OL35	43	9
Posey fine sandy loam, 0-3% slope	PF03	1,833	1,466
Posey soils, 3-5% slope	PF35	400	0
Potter gravelly loam, 0-3% slope	PG03	870	0
Pullman clay loam, 0-1% slope	PL01	45,199	42,939
Pullman clay loam, 3-5% slope	PL35	1,906	1,525
Randall clay	RANC	3,811	0
Roscoe soils	ROSC	200	0
Zita loam, 0-1% slope	ZL01	192	173
Zita loam, 1-3% slope	ZL13	96	86
Total Acreage		123,183	88,308

[a]Source: SCS Soil Survey Reports.

Table 5. Average land use in Lower Running Water Draw watershed for the 1970-1975 period.[a]

Land Use	Acreage	Percent
Cropland		
Cotton	34,707	24.6
Grain Sorghum	44,307	31.4
Wheat, Small Grains	10,003	7.1
Corn	2,200	1.6
Soybeans	8,302	5.9
Minor Crops	500	.4
	100,019	71.0
Pasture and Rangeland	24,460	17.3
Miscellaneous[b]	16,506	11.7
Total	140,985	100.0

[a]Source: Soil Conservation Service.

[b]Includes roads, highways, railroad right-of-ways, towns, farmsteads, stream channels, etc.

in cropland. Twenty-five percent of the watershed is planted in cotton; 38 percent in feed grains; 6 percent in small grains; less than 1 percent in minor crops, 7 percent in pasture, 10 percent in rangeland, and 12 percent is in miscellaneous uses such as urban area, farmsteads, roads, railroads, and stream channels. Much of the cropland is irrigated and occurs primarily on the nearly level plains surface. However, there is some cropland acreage on the valley slopes.

Range sites in the watershed are Deep Hardland, Mixed Land, Shallow Land, and Bottomland. The predominant vegetation consists of the following types of grasses: blue grama, sideoats grama, buffalograss, little bluestem, vine mesquite, and western wheat grass. Other common vegetation includes scattered yucca, cholla, pricklypear, and sand sagebrush. If the range is grazed too closely, the better grasses die out, being replaced by less desirable vegetation such as sand dropseed, three-awn grasses, yucca, sand sagebrush, mesquite, and broom snake weed. Continued use for grazing during this stage will increase the chances of wind and water erosion.

Climate in the watershed is semiarid. Summers are warm and predominately clear, and winters usually are mild. Mean temperature ranges from 39 degrees Fahrenheit in January to 79 degrees in July. Normal growing season is from April through October or approximately 206 days. Average rainfall is between 17.5 and 19.0 inches. Most rainfall occurs between April and October with approximately 10 inches of snow falling each year. Hail storms often severely damage crops during spring and early summer. Tornadoes generally occur each year, while severe windstorms are common in the late spring.

The Lower Running Water Draw watershed is a Public Law 566 watershed project area. A system of land treatment measures and four floodwater retarding structures have been erected. Land treatment consists of measures, or combination of measures, which contribute directly to watershed protection, flood prevention, and sediment control. The four floodwater retarding structures have a combined storage capacity of 20,376 acre-feet including 13,082 acre-feet for floodwater detention and 7,294 acre-feet for sediment accumulation.

Duck Creek watershed encompasses an area of 208 square miles almost entirely in Dickens County, Texas. It consists of the main stream of Duck Creek from its origin, approximately four miles east of McAdoo, to the Dickens-Kent County line, and its major tributaries: Cottonwood Creek, Dockum Creek, Spade Draw, and Wilson Draw.

Topography of the watershed is varied and can be separated into three distinct areas: the Rolling Plains Land Resource Area; the High Plains Resource Area; and the Cap Rock Escarpment which separates the other two.

The High Plains Land Resource Area, which amounts to about 8 percent of the watershed, is characterized by a flat surface with a general southeastward slope. The surface contains many shallow depressions called playas, which are occasionally filled to overflowing by heavy rains. This causes a small portion of the High Plains to contribute water to Duck Creek as runoff spills over the Cap Rock Escarpment.

The Rolling Plains Land Resource Area has a surface that is gently sloping to rolling in the uplands with many nearly level areas in the broad alluvial valleys. It encompasses approximately 80 percent of the watershed.

The remaining twelve percent of the watershed is formed by the Cap Rock Escarpment which delineates the eastern edge of the High Plains. Slopes along the escarpment range up from 20 to 50 percent. Buttes, canyons, large gullies, and "arroyo like" channels, characteristic of the escarpment, exemplify the geologic instability of the area and the rapid rate of erosion.

Elevations in the watershed range from greater than 2,900 feet on the High Plains to about 2,140 feet on the flood plain at the Dickens-Kent County line.

The climate is warm and semi-arid. Mean monthly temperatures range from 42 degrees Fahrenheit in January to 82 degrees in July. The normal growing season is 242 days, extending from March 19 to November 16. The average annual rainfall is 21.36 inches with the heaviest rainfall period extending from April through October. The monthly average ranges from 2.96 inches in September to 0.55 inches in January. Much of the rain falls as intense local showers which result in rapid runoff and an increased potential for severe soil erosion.

The watershed soils are in general deep, fertile, moderately permeable fine sandy loams and clay loams in the valleys; very shallow to deep, moderately to very slowly permeable clay loams in the rolling uplands; very shallow to deep, moderately to somewhat rapidly permeable fine sandy loams and clay loams in the Cap Rock Escarpment; and shallow to deep, slowly to very slowly permeable clay loams on the High Plains. Dominant soil series are Spur, Miles, Abilene, Wichita, Weymouth, Vernon, Bippus, Mansker, Potter, and Pullman. Individual soils and extent of each are listed in Table 6.

Over the last five years approximately 20 percent of the watershed has been planted to cotton, 14 percent to sorghum, and 11 percent to wheat and other small grains. Only about 1200 acres are irrigated in the watershed. Table 7 lists the average land use pattern in the watershed for the 1970-1975 period.

Table 6. Acreages of cropland and rangeland in Duck Creek Watershed by soil mapping unit.[a]

Soil	Table Abbrev.	Acreage
Abilene clay loam, 0-1% slopes	AU01	2,960
Berda-Mansker complex, 3-8% slopes	BMCO	4,678
Berda-Potter association, 3-30% slopes	BPAS	4,061
Bippus clay loam, 1-3% slopes	BC13	548
Brownfield-Nobscot association	BNAU	5,623
Latom gravelly soils, 3-8% slopes	LG38	462
Lofton clay loam	LTCL	738
Mansker loam, 1-3% slopes	MK13	2,957
Mansker loam, 3-5% slopes	MK35	1,183
Meno fine sandy loam	MFSL	1,874
Meno loamy fine sand	MLFS	3,749
Miles fine sandy loam, 0-1% slopes	ML01	4,003
Miles fine sandy loam, 1-3% slopes	ML13	19,721
Miles fine sandy loam, 3-5% slopes	ML35	15,874
Miles fine sandy loam, 5-8% slopes	ML58	704
Miles loamy fine sand, 0-3% slopes	MS03	7,477
Miles loamy fine sand, 3-5% slopes	MS35	5,689
Miles soils, 2-6% slopes	MI26	704
Mobeetie fine sandy loam, 1-3% slopes	MB13	164
Mobeetie fine sandy loam, 3-5% slopes	MB35	384
Olton clay loam, 0-1% slopes	OC01	4,986
Olton clay loam, 1-3% slopes	OC13	10,969
Pullman clay loam, 0-1% slopes	PC01	7,793
Pullman clay loam, 1-3% slopes	PC13	1,063
Randall clay	RANC	689
Randall fine sandy loam	RANL	49
Rough broken land	RBLD	4,521
Spur clay loam	SPCL	899
Spur fine sandy loam	SPSL	1,499
Stanford clay 1-3% slopes	SC13	462
Tillman clay loam, 0-1% slopes	TC01	154
Tillman clay loam, 1-3% slopes	TC13	308
Vernon soils, 3-8% slopes	VN38	3,811
Vernon-Badland complex	VBCO	2,128
Weymouth clay loam, 1-3% slopes	WC13	3,511
Weymouth clay loam, 3-5% slopes	WC35	1,351
Woodward loam, 1-3% slopes	WL13	152
Woodward loam, 3-5% slopes	WL35	278
Woodward-Quinlan loam, 3-15% slopes	WQLM	1,414
Total Acreage		129,590

[a]Source: SCS Soil Survey Reports.

Table 7. Approximate land use in Duck Creek Watershed for the period of 1970-1975.[a]

Land Use	Acreage	Percent
Cropland		
Cotton	27,000	20.3
Grain Sorghum	19,000	14.3
Wheat, Small grains	15,000	11.3
Pasture and Minor Crops	3,500	2.6
	64,500	48.5
Rangeland	65,000	48.8
Miscellaneous[b]	3,600	2.7
Total	133,100	100.0

[a]Source: Soil Conservation Service.

[b]Includes roads, railroads, towns, stream channels, etc.

The Duck Creek watershed is a Public Law 566 watershed project area. A system of 12 floodwater retarding structures, 5 grade stabilization structures and 7 structures for streambank protection have been erected. The floodwater retarding structues have combined design storage capacity of 29,089 acre-feet of which 10,281 acre-feet is designated for sediment accumulation.

GROSS EROSION RATES

The universal soil loss equation was used to calculate gross soil loss in the watersheds. This equation is:

$$A = RK(LS)CP$$

where A is gross erosion in tons per acre; R is a rainfall erosivity index; K is a soil-erodibility factor; LS is a topographic factor that represents the combined effects of slope-length, and steepness; C is a cover and management factor; and P is a conservation practice factor. Value for all of these factors were furnished by the Soil Conservation Service and are given in the detailed individual watershed reports. Gross erosion rates for various crop rotation-conservation practice-soil combinations are given in Tables 8, 9, and 10, respectively for Lake Lavon, Lower Running Water Draw, and Duck Creek watersheds. Crop rotation codes used in Tables 8, 9, and 10 are as follows:

C = continuous cotton

S - continuous grain sorghum

W = continuous winter wheat

H = coastal bermuda hay

P = coastal bermuda pasture

CP = common bermuda pasture

NP = native pasture

R = native range

CN = continuous corn

SB = continuous soybeans

Conservation practice codes are:

SR = straight row cultivation

C = contour cultivation

T = terraces with contour cultivation

Table 8. Expected soil loss (tons/acre/year) for each crop rotation, soil mapping unit, and conservation practice in Lavon Reservoir Watershed.

Soil	Conservation Practice	Crop Rotations												
		C	S	W	H	P	CP	NP	C/C/S	C/S/S	C/W/W	S/W/W	C/S	C/S/W
AS13	SR	19.91	13.27	6.64	0.33	0.66	0.33	1.33	17.59	14.93	9.96	7.63	16.26	11.61
	C	11.95	7.96	3.98	0.20	0.40	0.20	0.80	10.55	8.96	5.97	4.58	9.76	6.97
	T	7.38	4.92	2.46	0.12	0.25	0.12	0.49	6.52	5.53	3.69	2.83	6.03	4.30
AS35	SR	44.51	29.67	14.84	0.74	1.48	0.74	2.97	39.31	33.38	22.25	17.06	36.35	25.96
	C	22.25	14.84	7.42	0.37	0.74	0.37	1.48	19.66	16.69	11.13	8.53	18.17	12.98
	T	10.83	7.22	3.61	0.18	0.36	0.18	0.72	9.57	8.13	5.42	4.15	8.85	6.32
AS58	SR	39.24	26.16	13.08	0.65	1.31	0.65	2.62	34.66	29.43	19.62	15.04	32.04	22.89
BRAC	SR	38.65	25.77	12.88	0.64	1.29	0.64	2.58	34.14	28.99	19.32	14.82	31.56	22.55
BC01	SR	9.96	6.64	3.32	0.17	0.33	0.17	0.66	8.79	7.47	4.98	3.82	8.13	5.81
BC13	SR	18.15	12.10	6.05	0.30	0.61	0.30	1.21	16.04	13.62	9.08	6.96	14.83	10.59
	C	10.89	7.26	3.63	0.18	0.36	0.18	0.73	9.62	8.17	5.45	4.18	8.90	6.35
	T	7.38	4.92	2.46	0.12	0.25	0.12	0.49	6.52	5.53	3.69	2.83	6.03	4.30
BC24	SR	18.74	12.49	6.25	0.31	0.62	0.31	1.25	16.55	14.05	9.37	7.18	15.30	10.93
	C	9.37	6.25	3.12	0.16	0.31	0.16	0.62	8.28	7.03	4.68	3.59	7.65	5.47
	T	8.49	5.66	2.83	0.14	0.28	0.14	0.57	7.50	6.37	4.25	3.25	6.93	4.95
CR25	SR	25.18	16.79	8.39	0.42	0.84	0.42	1.68	22.24	18.89	12.59	9.65	20.56	14.69
	C	12.59	8.39	4.20	0.21	0.42	0.21	0.84	11.12	9.44	6.30	4.83	10.28	7.34
	T	11.80	7.87	3.93	0.20	0.39	0.20	0.79	10.43	8.85	5.90	4.52	9.64	6.89
FARL	SR	19.32	12.88	6.44	0.32	0.64	0.32	1.29	17.07	14.49	9.66	7.41	15.78	11.27
	C	11.59	7.73	3.86	0.19	9.39	0.19	0.77	10.24	8.70	5.80	4.44	9.47	6.76
	T	7.38	4.92	2.46	0.12	0.25	0.12	0.49	6.52	5.53	3.69	2.83	6.03	4.30
F512	SR	39.24	26.16	13.08	0.65	1.31	0.65	2.62	34.66	29.43	19.62	15.04	32.04	22.89

Table 8. (continued).

Soil	Conservation Practice	Crop Rotations												
		C	S	W	H	P	CP	NP	C/C/S	C/S/S	C/W/W	S/W/W	C/S	C/S/W
FCLF	SR	11.71	7.81	3.90	0.20	0.39	0.20	0.78	10.35	8.78	5.86	4.49	9.56	6.83
FCLO	SR	11.71	7.81	3.90	0.20	0.39	0.20	0.78	10.35	8.78	5.86	4.49	9.56	6.83
HC35	SR	27.52	18.35	9.17	0.46	0.92	0.46	1.83	24.31	20.64	13.76	10.55	22.48	16.06
	C	13.76	9.17	4.59	0.23	0.46	0.23	0.92	12.16	10.32	6.88	5.28	11.24	8.03
	T	10.83	7.22	3.61	0.18	0.36	0.18	0.72	9.57	8.13	5.42	4.15	8.85	6.32
HC58	SR	39.24	26.16	13.08	0.65	1.31	0.65	2.62	34.66	29.43	19.62	15.04	32.04	22.89
	C	19.62	13.08	6.54	0.33	0.65	0.33	1.31	17.33	14.71	9.81	7.52	16.02	11.44
	T	17.57	11.71	5.86	0.29	0.59	0.29	1.17	15.52	13.18	8.78	6.73	14.35	10.25
HB01	SR	9.96	6.64	3.32	0.17	0.33	0.17	0.66	8.79	7.47	4.98	3.82	8.13	5.81
HB23	SR	19.32	12.88	6.44	0.32	0.64	0.32	1.29	17.07	14.49	9.66	7.41	15.78	11.27
	C	9.66	6.44	3.22	0.16	0.32	0.16	0.64	8.54	7.25	4.83	3.70	7.89	5.64
	T	6.15	4.10	2.05	0.10	0.20	0.10	0.41	5.43	4.61	3.07	2.36	5.02	3.59
HB24	SR	20.50	13.66	6.83	0.34	0.68	0.34	1.37	18.10	15.37	10.25	7.86	16.74	11.96
	C	10.25	6.83	3.42	0.17	0.34	0.17	0.68	9.05	7.69	5.12	3.93	8.37	5.98
	T	8.49	5.66	2.83	0.14	0.28	0.14	0.57	7.50	6.37	4.25	3.25	6.93	4.95
TCFF	SR	11.71	7.81	3.90	0.20	0.39	0.20	0.78	10.35	8.78	5.86	4.49	9.56	6.83
TCOF	SR	11.71	7.81	3.90	0.20	0.39	0.20	0.78	10.35	8.78	5.86	4.49	9.56	6.83
WC01	SR	13.38	8.92	4.46	0.22	0.45	0.22	0.89	11.82	10.03	6.69	5.13	10.92	7.80
WC13	SR	25.97	17.31	8.66	0.43	0.87	0.43	1.73	22.94	19.48	12.98	9.95	21.21	15.15
	C	15.58	10.39	5.19	0.26	0.52	0.26	1.04	13.76	11.69	7.79	5.97	12.72	9.09
	T	9.91	6.61	3.30	0.17	0.33	0.17	0.66	8.76	7.44	4.96	3.80	8.10	5.78

Table 9. Expected soil loss (tons/acre/year) for each crop rotation, soil mapping unit, and conservation practice in Lower Running Water Draw Watershed.

Soil	Conservation Practice	Crop Rotation												
		C	S	W	R	CN	SB	C/W	C/S	S/W	C/S/W	C/CN	W/CN	CN/SB
AL01	SR	2.82	2.59	0.47	0.19	2.59	2.82	1.41	2.59	1.41	1.65	2.59	1.41	2.59
AL13	SR	4.03	3.70	0.67	0.27	3.70	4.03	2.02	3.70	2.02	2.35	3.70	2.02	3.70
	C	2.42	2.22	0.40	0.16	2.22	2.42	1.21	2.22	1.21	1.41	2.22	1.21	2.22
AL35	SR	7.06	6.47	1.18	0.47	6.47	7.06	3.53	6.47	3.53	4.12	6.47	3.53	6.47
AF01	SR	2.25	2.06	0.37	0.15	2.06	2.25	1.12	2.06	1.12	1.31	2.06	1.12	2.06
AF13	SR	5.70	5.23	0.95	0.38	5.23	5.70	2.85	5.23	2.85	3.33	5.23	2.85	5.23
	C	3.42	3.14	0.57	0.23	3.14	3.42	1.71	3.14	1.71	2.00	3.14	1.71	3.14
	T	2.38	2.19	0.40	0.16	2.19	2.38	1.19	2.19	1.19	1.39	2.19	1.19	2.19
AF35	SR	8.81	8.08	1.47	0.59	8.08	8.81	4.41	8.08	4.41	5.14	8.08	4.41	8.08
BL15	SR	7.06	6.47	1.18	0.47	6.47	7.06	3.53	6.47	3.53	4.12	6.47	3.53	6.47
BL58	SR	8.06	7.39	1.34	0.54	7.39	8.06	4.03	7.39	4.03	4.70	7.39	4.03	7.39
BF01	SR	2.42	2.22	0.40	0.16	2.22	2.42	1.21	2.22	1.21	1.41	2.22	1.21	2.22
BF13	SR	4.03	3.70	0.67	0.27	3.70	4.03	2.02	3.70	2.02	2.35	3.70	2.02	3.70
BI01	SR	3.23	2.96	0.54	0.22	2.96	3.23	1.61	2.96	1.61	1.88	2.96	1.61	2.96
BI13	SR	6.65	6.10	1.11	0.44	6.10	6.65	3.33	6.10	3.33	3.88	6.10	3.33	6.10
	C	3.99	3.66	0.67	0.27	3.66	3.99	2.00	3.66	2.00	2.33	3.66	2.00	3.66
	T	3.14	2.88	0.52	0.21	2.88	3.14	1.57	2.88	1.57	1.83	2.88	1.57	2.88
BSPU	SR	3.63	3.33	0.60	0.24	3.33	3.63	1.81	3.33	1.81	2.12	3.33	1.81	3.33

Table 9. (continued).

Soil	Conservation Practice	Crop Rotation												
		C	S	W	R	CN	SB	C/W	C/S	S/W	C/S/W	C/CN	W/CN	CN/SB
DL13	SR	6.05	5.54	1.01	0.40	5.54	6.05	3.02	5.54	3.02	3.53	5.54	3.02	5.54
	C	3.63	3.33	0.60	0.24	3.33	3.63	1.81	3.33	1.81	2.12	3.33	1.81	3.33
	T	3.02	2.77	0.50	0.20	2.77	3.02	1.51	2.77	1.51	1.76	2.77	1.51	2.77
DL38	SR	8.06	7.39	1.34	0.54	7.39	8.06	4.03	7.39	4.03	4.70	7.39	4.03	7.39
EL01	SR	3.43	3.14	0.57	0.23	3.14	3.43	1.71	3.14	1.71	2.00	3.14	1.71	3.14
EL13	SR	4.64	4.25	0.77	0.31	4.25	4.64	2.32	4.25	2.32	2.70	4.25	2.32	4.25
	C	2.78	2.55	0.46	0.19	2.55	2.78	1.39	2.55	1.39	1.62	2.55	1.39	2.55
	T	2.30	2.11	0.38	0.15	2.11	2.30	1.15	2.11	1.15	1.34	2.11	1.15	2.11
LIPN	SR	3.00	2.75	0.50	0.20	2.75	3.00	1.50	2.75	1.50	1.75	2.75	1.50	2.75
LOFL	SR	2.07	1.90	0.35	0.14	1.90	2.07	1.04	1.90	1.04	1.21	1.90	1.04	1.90
ML03	SR	6.05	5.54	1.01	0.40	5.54	6.05	3.02	5.54	3.02	3.53	5.54	3.02	5.54
	C	3.63	3.33	0.60	0.24	3.33	3.63	1.81	3.33	1.81	2.12	3.33	1.81	3.33
	T	3.02	2.77	0.50	0.20	2.77	3.02	1.51	2.77	1.51	1.76	2.77	1.51	2.77
ML35	SR	8.06	7.39	1.34	0.54	7.39	8.06	4.03	7.39	4.03	4.70	7.39	4.03	7.39
	C	4.03	3.70	0.67	0.27	3.70	4.03	2.02	3.70	2.02	2.35	3.70	2.02	3.70
MANB	SR	5.85	5.36	0.97	0.39	5.36	5.85	2.92	5.36	2.92	3.41	5.36	2.92	5.36
MANE	SR	4.23	3.88	0.71	0.28	3.88	4.23	2.12	3.88	2.12	2.47	3.88	2.12	3.88
	C	2.54	2.33	0.42	0.17	2.33	2.54	1.27	2.33	1.27	1.48	2.33	1.27	2.33
OL01	SR	3.92	3.59	0.65	0.26	3.59	3.92	1.96	3.59	1.96	2.38	3.59	1.96	3.59

Table 9. (continued).

Soil	Conservation Practice	Crop Rotation												
		C	S	W	R	CN	SB	C/W	C/S	S/W	C/S/W	C/CN	W/CN	CN/SB
OL13	SR	5.30	4.86	0.88	0.35	4.86	5.30	2.65	4.86	2.65	3.09	4.86	2.65	4.86
	C	3.18	2.91	0.53	0.21	2.91	3.18	1.59	2.91	1.59	1.85	2.91	1.59	2.91
	T	2.63	2.41	0.44	0.18	2.41	2.63	1.31	2.41	1.31	1.53	2.41	1.31	2.41
OL35	SR	9.22	8.45	1.54	0.61	8.45	9.22	4.61	8.45	4.61	5.38	8.45	4.61	8.45
	C	4.61	4.22	0.77	0.31	4.22	4.61	2.30	4.22	2.30	2.69	4.22	2.30	4.22
PF03	SR	4.32	3.96	0.72	0.29	3.96	4.32	2.16	3.96	2.16	2.52	3.96	2.16	3.96
	C	2.59	2.38	0.43	0.17	2.38	2.59	1.30	2.38	1.30	1.51	2.38	1.30	2.38
PF35	SR	6.91	6.34	1.15	0.46	6.34	6.91	3.46	6.34	3.46	4.03	6.34	3.46	6.34
	C	3.46	3.17	0.58	0.23	3.17	3.46	1.73	3.17	1.73	2.02	3.17	1.73	3.17
PG03	SR	4.03	3.70	0.67	0.27	3.70	4.03	2.02	3.70	2.02	2.35	3.70	2.02	3.70
PL01	SR	5.06	4.64	0.84	0.34	4.64	5.06	2.53	4.64	2.53	2.95	4.64	2.53	4.64
PL35	SR	9.06	8.30	1.51	0.60	8.30	9.06	4.53	8.30	4.53	5.28	8.30	4.53	8.30
	C	5.43	4.98	0.91	0.36	4.98	5.43	2.72	4.98	2.72	3.17	4.98	2.72	4.98
	T	4.16	3.81	0.69	0.28	3.81	4.16	2.08	3.81	2.08	2.42	3.81	2.08	3.81
RANC	SR	2.53	23.2	0.42	0.17	2.32	2.53	1.27	2.32	1.27	1.48	2.32	1.27	2.32
ROSC	SR	2.30	2.11	0.38	0.15	2.11	2.30	1.15	2.11	1.15	1.34	2.11	1.15	2.11
ZL01	SR	2.42	2.22	0.40	0.16	2.22	2.42	1.21	2.22	1.21	1.41	2.22	1.21	2.22
ZL13	SR	3.43	3.14	0.57	0.23	3.14	3.43	1.71	3.14	1.71	2.00	3.14	1.71	3.14
	C	2.06	1.88	0.34	0.14	1.88	2.06	1.03	1.88	1.03	1.20	1.88	1.03	1.88

Table 10. Expected soil loss (tons/acre/year) for each crop rotation, soil mapping unit, and conservation practice in Duck Creek Watershed.

Soil	CP	Crop Rotation							
		C	S	W	R	C/S	C/W	S/W	C/S/W
AU01	SR	5.59	4.30	1.29	0.34	3.87	3.01	2.58	3.01
BMCO	SR	22.01	16.93	5.08	1.35	15.24	11.85	10.16	11.85
	C	11.01	8.47	2.54	0.68	7.62	5.93	5.08	5.93
	T	7.64	5.88	1.76	0.47	5.29	4.12	3.53	4.12
BPAS	SR	39.75	30.58	9.17	2.45	27.52	21.40	18.35	21.40
	C	23.85	18.35	5.50	1.47	16.51	12.84	11.01	12.84
	T	10.70	8.23	2.47	0.66	7.41	5.76	4.94	5.76
BC13	SR	11.62	8.94	2.68	0.72	8.04	6.26	5.36	6.26
	C	6.97	5.36	1.61	0.43	4.83	3.75	3.22	3.75
	T	5.50	4.23	1.27	0.34	3.81	2.96	2.54	2.96
BNAU	SR	2.27	1.75	0.52	0.14	1.57	1.22	1.05	1.22
LG38	SR	19.92	15.32	4.60	1.23	13.79	10.73	9.19	10.73
LTCL	SR	4.19	3.23	0.97	0.26	2.90	2.26	1.94	2.26
MK13	SR	15.29	11.76	3.53	0.94	10.58	8.23	7.06	8.23
	C	7.64	5.88	1.76	0.47	5.29	4.12	3.53	4.12
	T	4.59	3.53	1.06	0.28	3.18	2.47	2.12	2.47
MK35	SR	29.05	22.34	6.70	1.79	20.11	15.64	13.41	15.64
	C	14.52	11.17	3.35	0.89	10.05	7.82	6.70	7.82
	T	6.42	4.94	1.48	0.40	4.45	3.46	2.96	3.46
MFSL	SR	4.46	3.43	1.03	0.27	3.08	2.40	2.06	2.40
MLFS	SR	6.77	5.21	1.56	0.42	4.69	3.65	3.12	3.65
	C	4.06	3.12	0.94	0.25	2.81	2.19	1.87	2.19
	T	3.01	2.32	0.70	0.19	2.09	1.62	1.39	1.62
ML01	SR	4.46	3.43	1.03	0.27	3.08	2.40	2.06	2.40
ML13	SR	8.12	6.25	1.87	0.50	5.62	4.37	3.75	4.37
	C	4.87	3.75	1.12	0.30	3.37	2.62	2.25	2.62
	T	3.62	2.78	0.83	0.22	2.50	1.95	1.67	1.95
ML35	SR	13.89	10.68	3.21	0.85	9.62	7.48	6.41	7.48
	C	6.95	5.34	1.60	0.43	4.81	3.74	3.21	3.74
	T	5.50	4.23	1.27	0.34	3.81	2.96	2.54	2.96
ML58	SR	24.90	19.15	5.75	1.53	17.24	13.41	11.49	13.41
MS03	SR	8.30	6.38	1.92	0.51	5.75	4.47	3.83	4.47
	C	4.98	3.83	1.15	0.31	3.45	2.68	2.30	2.68
	T	3.93	3.02	0.91	0.24	2.72	2.12	1.81	2.12
MS35	SR	11.58	8.90	2.67	0.71	8.01	6.23	5.34	6.23
MI26	SR	8.74	6.72	2.02	0.54	6.05	4.70	4.03	4.70
MB13	SR	4.72	3.63	1.09	0.29	3.27	2.54	2.18	2.54

Table 10. (continued).

Soil	CP	Crop Rotation							
		C	S	W	R	C/S	C/W	S/W	C/S/W
MB35	SR	9.17	7.06	2.12	0.56	6.35	4.94	4.23	4.94
OC01	SR	5.59	4.30	1.29	0.34	3.87	3.01	2.58	3.01
OC13	SR	7.69	5.91	1.77	0.47	5.32	4.14	3.55	4.14
	C	4.61	3.55	1.06	0.28	3.19	2.48	2.13	2.48
	T	3.98	3.06	0.92	0.25	2.76	2.15	1.84	2.15
PC01	SR	6.29	4.84	1.45	0.39	4.35	3.39	2.90	3.39
PC13	SR	8.39	6.45	1.94	0.52	5.81	4.52	3.87	4.52
	C	5.03	3.87	1.16	0.31	3.48	2.71	2.32	2.71
	T	3.98	3.06	0.92	0.25	2.76	2.15	1.84	2.15
RANC	SR	5.59	4.30	1.29	0.34	3.87	3.01	2.58	3.01
RANL	SR	3.67	2.82	0.85	0.23	2.54	1.98	1.69	1.98
RBLD	SR	110.71	85.16	25.55	6.81	76.64	59.61	51.10	59.611
SPCL	SR	4.59	3.53	1.06	0.28	3.18	2.47	2.12	2.47
	C	2.75	2.12	0.64	0.17	1.91	1.48	1.27	1.48
	T	2.57	1.98	0.59	0.16	1.78	1.38	1.19	1.38
SPSL	SR	3.93	3.02	0.91	0.24	2.72	2.12	1.81	2.12
	C	2.36	1.81	0.54	0.15	1.63	1.27	1.09	1.27
	T	2.20	1.69	0.51	0.14	1.52	1.19	1.02	1.19
SC13	SR	5.24	4.03	1.21	0.32	3.63	2.82	2.42	2.82
	C	3.14	2.42	0.73	0.19	2.18	1.69	1.45	1.69
TC01	SR	5.94	4.57	1.37	0.37	4.11	3.20	2.74	3.20
TC13	SR	8.08	6.22	1.86	0.50	5.59	4.35	3.73	4.35
	C	4.85	3.73	1.12	0.30	3.36	2.61	2.24	2.61
VN38	SR	21.41	16.47	4.94	1.32	14.83	11.53	9.88	11.53
VBCO	SR	32.32	24.86	7.46	1.99	22.38	17.40	14.92	17.40
WC13	SR	11.18	8.60	2.58	0.69	7.74	6.02	5.16	6.02
	C	6.71	5.16	1.55	0.41	4.64	3.61	3.10	3.61
	T	6.29	4.84	1.45	0.39	4.35	3.39	2.90	3.39
WC35	SR	16.77	12.90	3.87	1.03	11.61	9.03	7.74	9.03
	C	8.39	6.45	1.94	0.52	5.81	4.52	3.87	4.52
	T	7.34	5.64	1.69	0.45	5.08	3.95	3.39	3.95
WL13	SR	9.78	7.53	2.26	0.60	6.77	5.27	4.52	5.27
	C	5.87	4.52	1.35	0.36	4.06	3.16	2.71	3.16
	T	5.50	4.23	1.27	0.34	3.81	2.96	2.54	2.96
WL35	SR	12.23	9.41	2.82	0.75	8.47	6.59	5.64	6.59
	C	6.12	4.70	1.41	0.38	4.23	3.29	2.82	3.29
WQLM	SR	36.69	28.22	8.47	2.26	25.40	19.76	16.93	19.76

ON FARM ECONOMICS OF SOIL CONSERVATION

Examination of the on-farm economics of soil conservation and thus the farm income consequences of non-point pollution controls requires an immense amount of technical and economic information specific to the watershed. The data required for an analysis of this type include: (a) expected yields of the relevant crops on each soil; (b) soil loss associated with each cropping practice on each soil; (c) effects of erosion on future crop yields; (d) effects of crop rotations on yields of individual crops; (e) basic production cost information; (f) additional cost for relevant conservation practices; and (g) expected current and future prices for crops. Data were combined to estimate the present value net return associated with a particular crop rotation-conservation practice-soil mapping unit combination for various time horizons up to 200 years.

Yield Loss Attributal to Erosion

All data used in computing present value net returns are reported in the individual watershed reports. However, the estimate of the effect of erosion on furture crop yield deserves emphasis here because of its critical impact on profitability. This is a critical relationship because a large percentage of the benefits from conservation practices arise from the relatively higher future crop yield resulting from that conservation practice. Unfortunately, very little experimental or field data on this important relationship are available. Consequently, for purposes of this study, it was necessary to develop estimates of this relationship for each soil mapping unit.

Yield loss attributal to topsoil loss depends to a certain extent on the suitability of the subsoil for crop production. Soils in the watershed were classified into one of three groups. Group A consists of soils that have subsoil that is unsuitable for field crop production. For this group, crop yield was assumed to be zero after all topsoil was eroded. Group B consists of soil series with subsoils that are slightly suitable for field crop production. It was assumed that crop yield on Group B soils would be 25 percent of the currently attainable yield after all the topsoil was eroded away. Group C consists of those soil series with subsoils that are somewhat more suitable for crop production. After the loss of all topsoil, yield in this group was assumed to be 50 percent of yields on noneroded sites. The group to which each soil belongs and initial average topsoil depth for each soil are shown in the individual reports.

Due to lack of experimental or field data on the relationship between topsoil thickness and yield, it was necessary to subjectively specify this relationship for each soil group. After considerable discussion with Soil Conservation Service and Texas A&M University scientists, the three relationships shown in Figure 2 were specified. The functions in Figure 2 have two important characteristics. One is that each function is expressed in terms of percent of topsoil lost and percent of initial yield attainable after erosion. This reflects the fact that the loss of one inch on an initially shallow soil will decrease yield more than the loss of one inch of an initially deep soil. For example, the loss of one inch of a soil in Group A with an initial depth of 20 inches will reduce yield by about 2 percent, while the loss of one inch on a soil with an initial depth of 5 inches will decrease yield by about 8 percent.

The second important characteristic of the functions in Figure 2 is that the loss of the last remaining topsoil will reduce yield by more than the loss of the upper portions of initial topsoil. For instance, the loss of

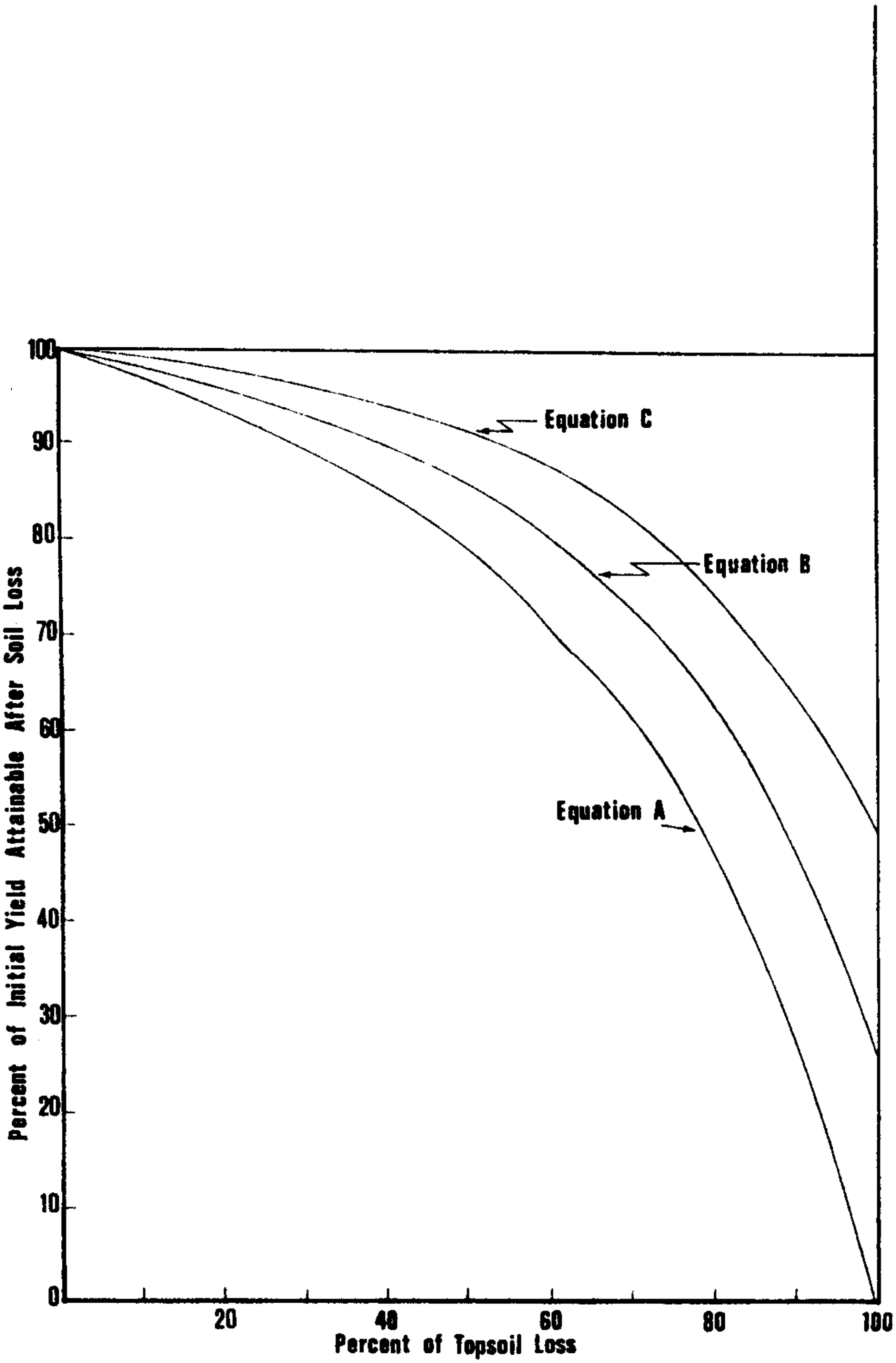

Figure 2. Relationships between yield and topsoil eroded.

the first 20 percent of topsoil in Group A will reduce yield by about 8 percent, while the loss of the last 20 percent of topsoil will reduce yield by about 46 percent. Because of the critical nature of the relationships shown in Figure 2, additional experimental and field research appears warranted.

Natural formation of topsoil over time was not considered in the model, at this is an extremely slow process for most soil situations. To the extent that topsoil formation occurs, the on-farm cost of erosion is slightly over-stated.

Appropriate Planning Horizon and Discounting Future Benefits and Costs

The effect of soil conservation and erosion control in the agricultural economy is only felt over a period of years as the mix of inputs change for a given output. Erosion carries away the topsoil reducing soil fertility and thus reducing crop yields. If erosion is slowed, future crop yields will be higher than they would otherwise have been given the same level of management.

Farmers make many short-run decisions because they are concerned with next year's income. On the surface this suggests that farmers would use a short time horizon for planning conservation practices. However, most farmers are concerned about the future value of their land in addition to income flow. Inasmuch as the agricultural component of land values is the capitalized value (present value) of a highest and best use profit stream into perpetuity, and given the limited alternate uses for agricultural land in most areas of Texas, the value of land is tied closely to its future agricultural productivity. Thus, it was important that this study consider not only present productivity but also the effect on future productivity, and hence land values, of cropping and conservation practices. Therefore, a long planning horizon is the only appropriate time period for determining what is the appropriate combination of crop rotations--conservation practices a landowner should employ. In order to emphasize this point and to demonstrate the importance of the length of the planning horizon, calculations were made for time horizons of 10, 100, and 200 years.

As a point of reference from wich to calculate the present value of future benefits and costs, 1977 was designated the base year. To make all future benefits and costs comparable to 1977 dollars, standard discounting procedures were used. The interest rate used for all parts of the study was 7.3 percent, which is a ten year average of the private rate charged by banks. An annual inflation rate of 5.8 percent was built into the computation of future prices and costs. This is a ten year average of the U.S. inflation rate.

Profitability of Conservation Practices

Profitability information for crop rotation-conservation practice combinations for each soil mapping unit in the study watersheds is given in the individual reports. Most profitable conservation practice by crop rotation for each soil mapping unit is indicated in Tables 11 through 16 for planning horizons of 100 and 200 years.

Cost-Sharing for Terrace Construction Cost

Most profitable conservation practices shown in Tables 11 through 16 were based on the assumption that farmers would pay the full cost of adopting a conservation practice. The Agricultural Stabilization and Conservation Service (ASCS) and the Soil Conservation Service (SCS) presently make a limited number of payments to farmers for 50 percent of the initial cost of constructing terraces. This type of payment would obviously make terracing a more attractive alternative to the farmer, but there are no instances where 50 percent cost sharing payments would make terracing profitable where it would not

Table 11. Most profitable conservation practice in Lavon Watershed by soil mapping unit and crop rotation with a 100 year planning horizon.

Soil	Most Profitable Conservation Practice For Crop Rotation:								
	C	S	W	C/C/S	C/S/S	C/W/W	S/W/W	C/S	C/S/W
AS13	T	C	SR	C	C	SR	SR	C	SR
AS35	T	T	C	T	T	T	C	T	T
AS58	--	--	--	--	--	--	--	--	--
BRAC	--	--	SR	--	--	--	--	--	--
BC01	SR	SR	SR	SR	SR	SR	SR	SR	SR
BC13	SR	SR	SR	SR	SR	SR	SR	SR	SR
BC24	--	C	C	--	--	--	C	--	--
CR25	--	TZ	CZ	--	--	--	CZ	--	--
FARL	SR	SR	SR	SR	SR	SR	SR	SR	SR
F512	--	--	--	--	--	--	--	--	--
FCLF	--	--	--	--	--	--	--	--	--
FCLC	SR	SR	SR	SR	SR	SR	SR	SR	SR
HC35	C	C	SR	C	C	C	SR	C	C
HC58	--	--	C	--	--	--	--	--	--
HB01	SR	SR	SR	SR	SR	SR	SR	SR	SR
HB23	C	C	SR	C	C	SR	SR	C	C
HB24	--	C	SR	--	--	--	C	--	--
TCFF	--	--	--	--	--	--	--	--	--
TCOF	SR	SR	SR	SR	SR	SR	SR	SR	SR
WC01	SR	SR	SR	SR	SR	SR	SR	SR	SR
WC13	Z	TZ	C	TZ	TZ	CZ	CZ	TZ	CZ

[a] T denotes terracing, C contouring, SR straight row, Z means yield in year 100 is zero for all systems, TZ means yield is zero in year 100 for all practices except terracing, and CZ means yield is zero in year 100 for straight row cultivation.

Table 12. Most Profitable conservation practice in Lavon Watershed by soil mapping unit and crop rotation with a 200 year planning horizon.

Soil	Most Profitable Conservation Practice for Crop Rotation								
	C	S	W	C/C/S	C/S/S	C/W/W	S/W/W	C/S	C/S/S
AS13	T	T	C	T	T	C	C	T	C
AS35	T	T	T	T	T	T	T	T	T
AS58	--	--	--	--	--	--	--	--	--
BRAC	--	--	SR	--	--	--	--	--	--
BC01	SR	SR	SR	SR	SR	SR	SR	SR	SR
BC13	T	C	SR	T	C	SR	SR	C	C
BC24	--	C	C	--	--	--	C	--	--
CR25	--	Z	TZ	--	--	--	Z	--	--
FARL	C	SR	SR	C	SR	SR	SR	SR	SR
F512	--	--	--	--	--	--	--	--	--
FCLF	--	--	--	--	--	--	--	--	--
FCLC	SR	SR	SR	SR	SR	SR	SR	SR	SR
HC35	C	C	C	C	C	C	C	C	C
HC58	--	--	C	--	--	--	--	--	--
HB01	SR	SR	SR	SR	SR	SR	SR	SR	SR
HB23	T	C	C	T	T	C	C	T	C
HB24	--	C	C	--	--	--	C	--	--
TCFF	--	--	--	--	--	--	--	--	--
TCOF	SR	SR	SR	SR	SR	SR	SR	SR	SR
WC01	SR	SR	SR	SR	SR	SR	SR	SR	SR
WC13	Z	Z	TZ	Z	Z	Z	TZ	Z	Z

[a]T denotes terracing, C contouring, SR straight row, Z means yield in year 200 is zero for all systems, TZ means yield is zero in year 200 for all practices except terracing, and CZ means yield is zero in year 200 for straight row cultivation.

Table 13. Most profitable conservation practice in Lower Running Water Draw watershed by soil mapping unit and crop rotation with a 100 year planning horizon.

Soil	Crop Rotations																			
	Dryland								Irrigated											
	C	S	W	R	C/W	C/S	S/W	C/S/W	C	S	W	CN	SB	C/W	C/S	S/W	C/S/W	C/CN	W/CN	CN/SB
AL01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
AL13	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
AL35	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AF01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
AF13	SR	C	SR	SR	SR	SR	SR	SR	C	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
AF35	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BL15	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BL58	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BF01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
BF13	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BI01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
BI13	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
BSPU	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
DL13	--	SR	SR	SR	--	--	SR	--	--	SR	SR	--	--	--	--	SR	--	--	--	--
DL38	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
EL01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
EL13	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
LIPN	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
LOFL[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
ML03	SR	C	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
ML35	C	C	SR	SR	SR	C	SR	SR	--	--	--	--	--	--	--	--	--	--	--	--
MANB	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MANE	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
OL01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
OL13	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
OL35	--	SR	SR	SR	--	--	SR	--	--	SR	SR	--	--	--	--	SR	--	--	--	--
PF03	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	--	SR	SR	SR	SR	--	--	--
PF35	C	C	SR	SR	SR	C	SR	SR	--	C	SR	--	--	--	--	SR	--	--	--	--
PG03	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PL01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
PL35	SR	C	SR	SR	SR	C	SR	SR	C	C	SR	C	C	SR	C	SR	SR	C	SR	C
RANL	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
ROSC[b]	SR	SR	SR	SR	SR	SR	SR	SR	--	--	--	--	--	--	--	--	--	--	--	--
ZL01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
ZL13	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR

[a] C denotes contouring, SR straight row.

[b] Contouring and terracing infeasible due to flatness of land or shortness of average slope length.

Table 14. Most profitable conservation practice in Lower Running Water Draw Watershed by soil mapping unit and crop rotation with a 200 year planning horizon.

Soil	Crop Rotation																				
	Dryland								Irrigated												
	C	S	W	R	C/W	C/S	S/W	C/S/W	C	S	W	CN	SB	C/W	C/S	S/W	C/S/W	C/CN	W/CN	CN/SB
AL01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
AL13	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
AL35	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AF01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
AF13	SR	C	SR	SR	SR	SR	SR	SR	C	SR	SR	SR	--	SR	C	SR	SR	C	SR	--
AF35	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BL15	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BL58	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BF01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
BF13	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BI01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
BI13	C	C	SR	SR	SR	C	SR	SR	C	C	SR	C	C	SR	C	SR	SR	C	SR	C
BSPU	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
DL13	--	SR	SR	SR	--	--	SR	--	--	SR	SR	--	--	--	--	SR	--	--	--	--
DL38	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
EL01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
EL13	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
LIPN	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
LOFL[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
ML03	C	SR	SR	SR	SR	C	SR	SR	C	C	SR	C	--	SR	C	SR	SR	C	SR	--
ML35	C	C	SR	SR	C	C	C	C	--	Z	Z	--	--	--	--	--	Z	--	--	--
MANB	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MANE	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	SR	SR	SR	SR	SR	SR	--
OL01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
OL13	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
OL35	--	C	SR	SR	--	--	SR	--	--	C	SR	--	--	--	--	SR	--	--	--	--
PF03	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	--	--	SR	SR	SR	SR	--	--	--
PF35	C	C	SR	SR	SR	C	C	C	--	Z	Z	--	--	--	--	Z	--	--	--	--
PG03	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PL01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
PL35	C	C	SR	SR	SR	C	SR	C	C	C	SR	C	C	C	C	C	C	C	C	C
RANL	--	--	--	SR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
ROSC[b]	SR	SR	SR	SR	SR	SR	SR	SR	--	--	--	--	--	--	--	--	--	--	--	--
ZL01[b]	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
ZL13	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR

[a] C contouring, SR straight row, Z means yield in year 200 is zero for all systems.

[b] Contouring and terracing infeasible due to flatness of land or shortness of average slope length.

Table 15. Most profitable conservation practice[a] in Duck Creek Watershed by soil mapping unit and crop rotation with 100 year horizon.[a]

Soil	Crop Rotation							
	C	S	W	R	C/S	C/W	S/W	C/S/W
AU01[b]	SR	SR	SR	SR	SR	SR	SR	SR
BMCO	C	C	SR	SR	C	C	C	C
BPAS	Z	TZ	CZ	SR	TZ	TZ	TZ	TZ
BC13	C	SR	SR	SR	SR	SR	SR	SR
BNAU[b]	SR	SR	SR	SR	SR	SR	SR	SR
LG38	--	--	--	SR	--	--	--	--
LTCL[b]	SR	SR	SR	SR	SR	SR	SR	SR
MK13	T	C	SR	SR	C	C	C	C
MK35	T	C	C	SR	T	C	C	C
MFSL[b]	SR	SR	SR	SR	SR	SR	SR	SR
MLFS	SR	SR	SR	SR	SR	SR	SR	SR
ML01[b]		SR	SR	SR	SR	SR	SR	SR
ML13	C	SR	SR	SR	SR	SR	SR	SR
ML35	C	C	SR	SR	C	C	C	C
ML58	--	--	--	SR	--	--	--	--
MS03	SR	SR	SR	SR	SR	SR	SR	SR
MS35	--	--	--	SR	--	--	--	--
MI26	--	--	--	SR	--	--	--	--
MB13[b]	SR	SR	SR	SR	SR	SR	SR	SR
MB35[b]	--	SR	SR	SR	--	--	SR	--
OC01[b]	SR	SR	SR	SR	SR	SR	SR	SR
OC13	C	SR	SR	SR	SR	SR	SR	SR
PC01[b]	SR	SR	SR	SR	SR	SR	SR	SR
PC13	C	SR	SR	SR	SR	SR	SR	SR
RANC	--	--	--	SR	--	--	--	--
RANL	--	--	--	SR	--	--	--	--
RBLD	--	--	--	Z	--	--	--	--
SPCL	SR	SR	SR	SR	SR	SR	SR	SR
SPSL	SR	SR	SR	SR	SR	SR	SR	SR
SC13	SR	SR	SR	SR	SR	SR	SR	SR
TC01[b]	SR	SR	SR	SR	SR	SR	SR	SR
TC13	C	C	SR	SR	C	C	C	C
VN38	--	--	--	SR	--	--	--	--
VBCO	--	--	--	SR	--	--	--	--
WC13	C	C	SR	SR	C	SR	SR	SR
WC35	C	C	SR	SR	C	C	C	C
WL13	C	C	SR	SR	C	SR	SR	SR
WL35	C	C	SR	SR	C	C	SR	C
WQLM	--	--	--	SR	--	--	--	--

[a]T denotes terracing, C contouring, SR straight row, Z means yield in year 100 is zero for all systems, TZ means yield is zero in year 100 for all practices except terracing, and CZ means yield is zero in year 100 for straight row cultivation.

[b]Contouring and terracing infeasible due to flatness of land or shortness of average slope length.

Table 16. Most profitable conservation practice in Duck Creek Watershed by soil mapping unit and crop rotation with 200 year planning horizon.[a]

Soil	Crop Rotation							
	C	S	W	R	C/S	C/W	S/W	C/S/W
AU01[b]	SR	SR	SR	SR	SR	SR	SR	SR
BMCO	C	C	C	SR	C	C	C	C
BPAS	Z	Z	TZ	SR	Z	Z	Z	Z
BC13	C	C	SR	SR	C	C	SR	C
BNAU[b]	SR	SR	SR	SR	SR	SR	SR	SR
LG38	--	--	--	SR	--	--	--	--
LTCL[b]	SR	SR	SR	SR	SR	SR	SR	SR
MK13	T	C	C	SR	T	C	C	C
MK35	T	C	C	SR	T	T	C	T
MFSL[b]	SR	SR	SR	SR	SR	SR	SR	SR
MLFS	C	C	SR	SR	SR	SR	SR	SR
ML01[b]	SR	SR	SR	SR	SR	SR	SR	SR
ML13	C	C	SR	SR	C	C	SR	C
ML35	C	C	C	SR	C	C	C	C
ML58	--	--	--	SR	--	--	--	--
MS03	C	SR	SR	SR	SR	SR	SR	SR
MS35	--	--	--	SR	--	--	--	--
MI26	--	--	--	SR	--	--	--	--
MB13[b]	SR	SR	SR	SR	SR	SR	SR	SR
MB35[b]	--	SR	SR	SR	--	--	SR	--
OC01[b]	SR	SR	SR	SR	SR	SR	SR	SR
OC13	C	C	SR	SR	C	C	SR	C
PC01[b]	SR	SR	SR	SR	SR	SR	SR	SR
PC13	C	C	SR	SR	C	C	SR	C
RANC	--	--	--	SR	--	--	--	--
RANL	--	--	--	SR	--	--	--	--
RBLD	--	--	--	Z	--	--	--	--
SPCL	SR	SR	SR	SR	SR	SR	SR	SR
SPSL	SR	SR	SR	SR	SR	SR	SR	SR
SC13	SR	SR	SR	SR	SR	SR	SR	SR
TC01[b]	SR	SR	SR	SR	SR	SR	SR	SR
TC13	C	C	SR	SR	C	C	C	C
VN38	--	--	--	SR	--	--	--	--
VBCO	--	--	--	SR	--	--	--	--
WC13	C	C	SR	SR	C	C	C	C
WC35	C	C	SR	SR	C	C	C	C
WL13	C	C	SR	SR	C	C	C	C
WL35	C	C	SR	SR	C	C	C	C
WQLM	--	--	--	SR	--	--	--	--

[a]T denotes terracing, C contouring, SR straight row, Z means yield in year 200 is zero for all systems, TZ means yield is zero in year 200 for all practices except terracing, and CZ means yield is zero in year 200 for straight row cultivation.

[b]Contouring and terracing infeasible due to flatness of land or shortness of average slope length.

otherwise be profitable. However, cost-share payments may induce farmers to terrace where it is already profitable because such payments greatly ease the initial financial burden associated with constructing terraces. Therefore, cost sharing for conservation practices may have a more significant impact than one might otherwise surmise.

PUBLIC POLICY OPTIONS FOR NPS CONTROL

The previous section of this report focused on the on-farm economics of conservation aside from the NPS pollution issue. Let us now turn to the pollution question and consider whether controls are justified on economic grounds, on which control is economically the most efficient, and on implementing a control if a problem does exist.

In designing a NPS control plan, it is necessary to define the feasible control methods from a technical perspective. For control of sheet and rill erosion and the sediment resulting therefrom, control methods considered here are the conservation practices of contouring and terracing, and changes in land use such as shifting to a crop or crop rotation which causes less erosion. Mininum tillage systems were not considered because the systems are not currently considered feasible, or present management practices already incorporate many of the advantages of these systems.

Once these technical alternatives are specified it is necessary to determine a way of implementing a pollution control method. Standard policy options for implementing a control include regulation, provision of economic incentives, eduction, and public investment. For point sources of pollutants, regulations are typically directed toward the pollutant at the point of emission into waterways. However, this is not possible with NPS pollutants because they enter waterways at an infinite number of points. Hence, regulations must be directed toward the agricultural practices that cause or influence the NPS pollutants.

The economic incentive option includes alternatives such as Federal or State cost-sharing arrangements for conservation practices, and excise taxes on inputs such as fertilizers and pesticides or possibly on the soil lost from each farm acre. Education is a viable policy option in situations where producers or others are misusing inputs that cause pollution, or are not adopting conservation practices that would be profitable. In these situations, a successful education program would increase producer's income as well as reducing the environmental damages caused by misuse of agricultural chemicals and production practices. Public investment is appropriate for controls that are not appropriate for individuals, but that can be justified by governmental units. An example would be the construction of minicipal waste water treatment plants. In any particular NPS situation, a combination of the above policy options may provide the best solution to the problem.

The specific erosion-sedimentation control options considered for each of the three study watershed were:

1. Restricting soil loss to be no greater than the SCS tolerance or "T" limits for that soil type.
2. Restricting soil loss to be no greater than 2, 5, or 10 tons per acre.
3. Terracing subsidies or cost sharing arrangements for 50 and 100 percent of the additional cost for contouring.
4. Contouring subsidies or cost sharing arrangements for 50 to 100 percent of the additional cost for contouring.
5. Cost sharing or subsidies for 50 and 100 percent of the initial construction cost of terraces.
6. Restricting soil loss to be no greater than the SCS tolerance limit combined with a 50 percent terracing, contouring or terrace construction cost sharing arrangement.
7. Taxes on soil loss ranging up to 20 cents per ton.

8. A soil loss tax of X dollars per ton combined with a 50 percent terracing or contouring cost sharing arrangement.

These policy options are expected to cover the relevant range of alternatives. Specific options considered and their abbreviations are given in Table 17.

The soil loss tax policy, while probably not practical to implement, was considered because it is an economic efficiency norm for correcting for off-site sediment damages. Economic theory says that in a frictionless economy where all producers maximize profit, the "optimal" way to correct for off-site damages is to impose a tax on erosion exactly equal to marginal off-site damages at the socially optimal level of erosion. No other policy will give a socially more efficient (i.e. less costly from society's viewpoint) allocation of resources to crop production. Other requirements for this to be the most efficient policy for pollution abatement are that: (a) the administrative and enforcement costs to equal for all policies; and (b) the adminstrative and enforcement costs be less than the gains associated with a tax policy. Under these conditions, the tax policy can be used as a norm against which the other policies (which may be more practical and politically viable) can be evaluated.

To decide whether erosion-sedimentation control is justified on economic grounds and to identify the economically most efficient policy option, the following types of information are needed:

A. The off-side environmental damages that would be abated by the policy;
B. The private and social costs incurred by farmers and society when alternative policy options are implemented at various levels of control; and

Table 17. Alternate Control Options Modeled.

Control	Table Abbrev.
Annual soil loss less than SCS Tolerance limit (T)	SL < T
Annual soil loss less than 2 tons per acre	SL < 2
Annual soil loss less than 5 tons per acre	SL < 5
Annual soil loss less than 10 tons per acre	SL < 10
Subsidy equal to 50 percent of annual terracing costs	TR 50
Subsidy equal to 100 percent of annual terracing costs	TR 100
Subsidy equal to 50 percent of annual contouring costs	C 50
Subsidy equal to 100 percent of annual contouring costs	C 100
Subsidy equal to 50 percent of the initial cost of constructing terraces	ITR 50
Subsidy equal to 100 percent of the initial cost of constructing terraces	ITR 100
Soil loss < T, 50% terracing costs subsidy	SL < T, TR 50
Soil loss < T, 50% contouring costs subsidy	SL < T, C 50
Soil loss < T, 50% initial terrace construction costs subsidy	SL < T, IT 50
Soil loss < 5, 50% terracing costs subsidy	SL < 5, TR 50
Soil loss < 5, 50% contouring costs subsidy	SL < 5, C 50
Soil loss < 5, 50% initial terrace construction costs subsidy	SL < 5, IT 50
A tax on annual soil loss of 8 cents per ton	TX 8
A tax on annual soil loss of 10 cents per ton	TX 10
A tax on annual soil loss of 12 cents per ton	TX 12
A tax on annual soil loss of 14 cents per ton	TX 14
A tax on annual soil loss of 16 cents per ton	TX 16
A tax on annual soil loss of 18 cents per ton	TX 18
A tax on annual soil loss of 20 cents per ton	TX 20
A 8 cent tax on soil loss with a 50% subsidy on terracing or contouring costs	TX 8, 50 T&C
A 10 cent tax on soil loss with a 50% subsidy on terracing or contouring costs	TX 10, 50 T&C
A 12 cent tax on soil loss with a 50% subsidy on terracing or contouring costs	TX 12, 50 T&C
A 14 cent tax on soil loss with a 50% subsidy on terracing or contouring costs	TX 14, 50 T&C
A 16 cent tax on soil loss with a 50% subsidy on terracing or contouring costs	TX 16, 50 T&C
A 18 cent tax on soil loss with a 50% subsidy on terracing or contouring costs	TX 18, 50 T&C
A 20 cent tax on soil loss with a 50% subsidy on terracing or contouring costs	TX 20, 50 T&C

C. The implementation, administrative and enforcement costs associated with each policy.

These benefits and cost components, once combined, indicate whether a particular policy at a specific level of control is justified on economic efficiency grounds. Of course, in deciding between policies, the distributional or equity aspects and political acceptability must also be considered.

Estimates of the above economic impacts for the policy options listed previously are presented in the sections which follow.

OFF-SITE SEDIMENT DAMAGES

Sediment can cause off-site damages both directly and indirectly. Sediment may indirectly contribute to pollution (an off-site cost) by carrying into water bodies plant nutrients that pose health hazards or cause undesirable eutrophication. No evidence was found that plant nutrients are at a high enough level in the watersheds to cause human or livestock health hazards or cause undue eutrophication of water bodies. Consequently, analysis in the study areas focused on sediment per se as the main cause of off-site damages.

Sediment damages were attributed to the following factors: (a) the cost of removing sediment from flood control structures in a watershed by draining and then cleaning sediment out; (b) the cost of dredging sediment from any reservoir in the watershed; and (c) the sediment component of flood damage and the damage associated with sediment that remains in the watershed. Computational formula and damage estimates for each of these components follow.

Cost of Removing Sediment from Flood Control Structures

For this component of damages, it was assumed that the sediment pool in a flood control structure would be allowed to completely fill. The before sediment recuced the flood control capacity of the structure, the structure would be drained in a dry period and the sediment removed by bulldozing or a similar operation. SCS engineers estimate that this type of operation would cost about $1.01 per ton of sediment removed. With N as the life of a sediment pool, it was assumed that a structure would be cleaned every N years. N was computed by the following formula:

$$N = \frac{KC_{RS}}{G_e A_N D_R T_E}$$

where

N is the life of the sediment pool in years;

C_{RS} is the capacity of the sediment pool in acre-feet;

G_e is the gross erosion based on particular crop rotations, tillage system, conservation practice, and management level for the watershed in tons/acre/year;

A_N is the net drainage area in acres;

D_R is the delivery ratio used to convert gross erosion to sediment delivered;

T_E is trap efficiency of the reservoir; and

K is the conversion constant from acre-feet to tons.

Values for C_{RS}, A_N, and D_R were obtained from appropriate PL-566 watershed work plans. K was assumed to equal 1920 tons per acre-foot, and T_E equal to .95.

The present value cost of removing sediment from flood control structures in the watershed into perpetuity is given by the formula:

$$PV = \sum_{S=1}^{191} \sum_{t=1}^{\infty} \left(\frac{1}{1+i}\right)^{N_s} C_r C_{RS,S} K$$

$$= \sum_{S=1}^{191} \left[\frac{\left(\frac{1}{1+i}\right)^{N_s}}{1 - \left(\frac{1}{1+i}\right)^{N_s}} \right] C_r C_{RS,S} K$$

where

PV = present value cost

C_r = per ton cost of removing sediment from a flood control structure (=\$1.01).

N_s = life of the sediment pool of the S^{th} structure

i = interest rate

$C_{RS,S}$ = capacity of the sediment pool in the S^{th} structure in acre-feet.

The annualized cost of removing sediment from flood control structures is:

$$D_{FS} = i \cdot PV = i \cdot \sum_{S=1}^{191} \left[\frac{\left(\frac{1}{1+i}\right)^{N_s}}{1 - \left(\frac{1}{1+i}\right)^{N_s}} \right] C_r C_{RS,S} K$$

where

D_{FS} = annualized cost of removing sediment from all flood control structures in the watershed.

Estimates of D_{FS} for various levels of erosion are given in Tables 18 through 20.

Cost of Dredging a Reservoir

Annualized off-site sediment damages attributal to the siltation of a reservoir were based on the cost of dredging the sediment pool each time the pool filled. Computation of the time required for the sediment pool to fill is more complicated than for a flood control structure because the calculation of sediment input is more complicated. Sediment input into the reservoir can be conceptualized as the sum of two components. One component is sediment originating in sub-watersheds that drain into flood control structures, while the other component is that originating in sub-watersheds not protected by flood control structures. Other things equal, sediment input into a reservoir from a sub-watershed protected by a flood control structure is less than that from an unprotected sub-watershed because the flood control structure traps sediment. Assuming that the trap efficiency of these structures is .95 and that the gross erosion rate is the same for all sub-watersheds, the total annual sediment input into a reservoir can be computed as:

$$S = .05\ D_R A_F G_E + D_R A_{NF} G_E$$

where

S = annual sediment input into the reservoir

D_R = delivery ratio

G_E = gross erosion rate in tons per acre

A_F = acreage in the watershed protected by flood control structures other than the reservoir

A_{NF} = acreage not protected by flood control structures.

Based on this, the time required for the sediment pool in the reservoir to fill can be calculated as:

$$N = \frac{C_{RS} K}{S}$$

where

N = years required for the sediment pool to fill, with average gross erosion in the watershed equal to G_E

C_{RS} = capacity of the sediment pool in acre-feet

K = constant for converting acre-feet to tons.

To compute the cost of dredging Lavon, it was assumed that a small portable dredge with a 10" line would be used. Operating costs for this type of dredge are about $240/hour, with 200 cubic yards/hour dredged.* Assuming that the average density of sediment is 1.19 T/cubic yard, the cost per ton of sediment dredged is $1.01.

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*The assistance of the Galveston and Ft. Worth branches of the US Army Corp of Engineers in obtaining this cost estimate is gratefully acknowledged.

The present value cost of dredging Lavon every N years into perpetuity is given by the formula:

$$PV = \sum_{t=1}^{\infty} \left(\frac{1}{1+i}\right)^N C_d C_{RS} K = \left[\frac{\left(\frac{1}{1+i}\right)^N}{1 - \left(\frac{1}{1+i}\right)^N}\right] C_d C_{RS} K$$

where

PV = present value cost

C_d = per ton cost of dredging sediment

i = interest rate

C_{RS} and K as previously defined

The annualized cost of dredging sediment from Lavon Reservoir is:

$$D_L = i \cdot PV = iC_d C_{RS} K \left[\frac{\left(\frac{1}{1+i}\right)^N}{1 - \left(\frac{1}{1+i}\right)^N}\right]$$

Table 18 gives estimated value of D_L for different erosion levels.

Estimates of other damages (D_S) for recent erosion rates were obtained directly from the PL-566 watershed work plans. For other erosion rates these damages were assumed proportional to total erosion. Off-site sediment damages per ton of soil in Lake Lavon, Duck Creek, and Lower Running Water Draw watersheds are shown in Figure 3, while total damages for various amounts of gross erosion are given in Tables 18 through 20. Off-site damages per ton of soil are lower with low average gross erosion rates. This is because a low average rate of erosion will not fill sediment pools in flood control structures and reservoirs until relatively far into the future. This reduces annualized off-site damages relative to what they would be with a higher average erosion rate.

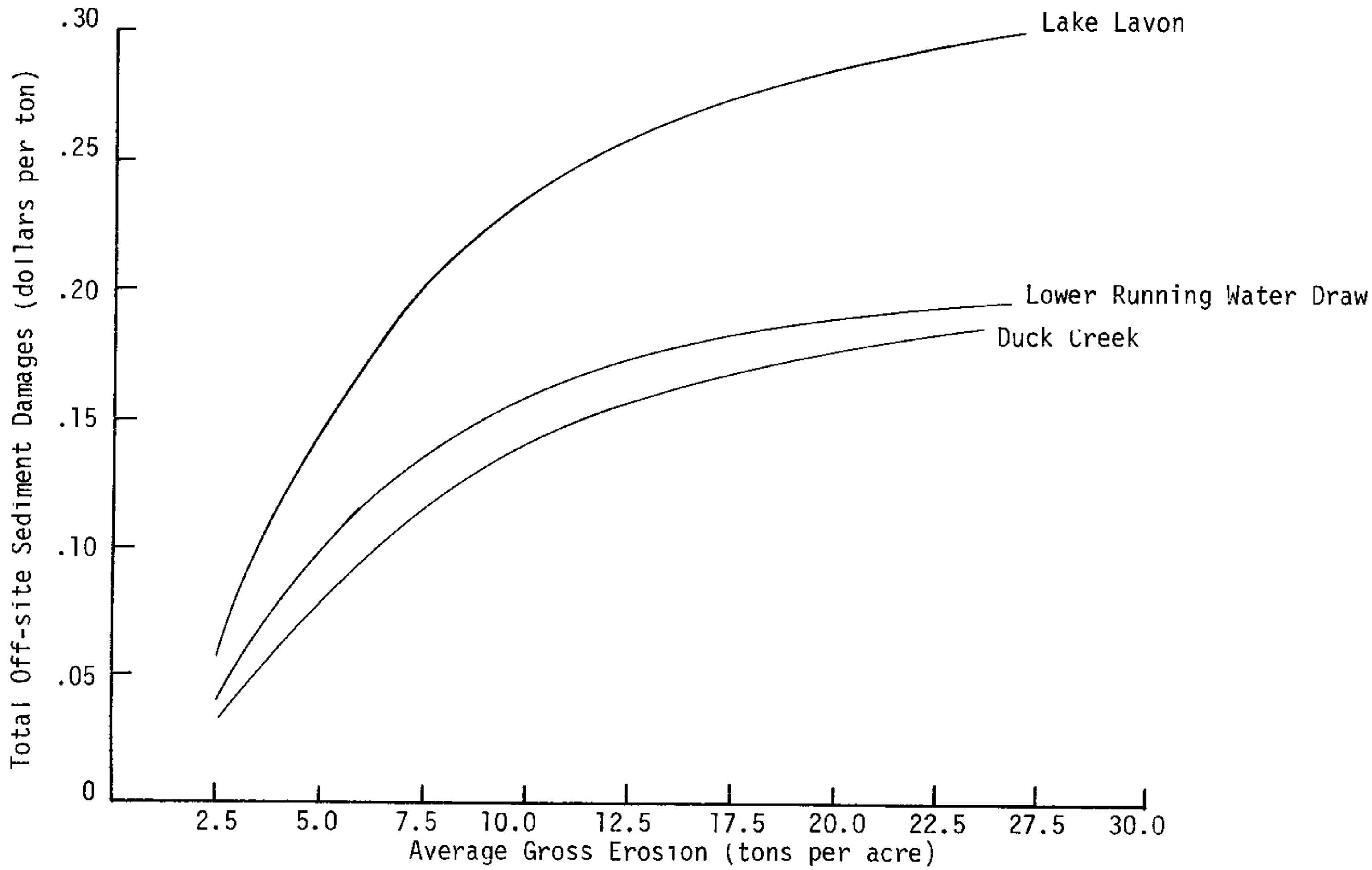

Figure 3. Total off-site sediment damages as related to gross erosion.

Table 18. Annualized off-site damages in Lavon reservoir for various gross erosion levels.

	Damages (Dollars) Associated With Gross Erosion (1000 Tons) Of:							
Damage Component	1,194	2,388	3,582	4,776	5,970	7,164	8,358	9,552
Lavon Reservoir (D_L)	6,912	91,856	239,890	413,435	600,180	792,302	990,888	1,189,706
Flood Control Structures (D_{FS})	55,766	238,332	450,014	670,024	894,188	1,118,697	1,344,919	1,576,342
Other (D_S)	8,684	17,368	26,052	34,736	43,420	52,104	60,788	69,472
Total Damages	71,362	347,556	715,956	1,118,195	1,537,788	1,963,103	2,396,595	2,835,520

Table 19. Annualized off-site sediment damages in Lower Running Water Draw watershed for various gross erosion levels.

	Damages (Dollars) associated with Gross Erosion (1000 tons) of:						
Damage Component	352	705	1,057	1,410	1,762	2,115	2,467
Flood Control Structures (D_{FS})	14,621	72,574	142,838	216,743	292,736	369,701	446,713
Other (D_S)	414	827	1,241	1,655	2,069	2,482	2,896
Total Damages	15,035	73,401	144,079	218,398	294,805	372,183	449,609

Table 20. Annualized off-site sediment damages in Duck Creek watershed for various gross erosion levels.

	Damages (Dollars) Associated with Gross Erosion (1000 Tons) of:						
Damage Component	333	666	998	1,333	1,666	1,988	2,330
Flood Control Structures (D_{FS})	4,406	41,208	97,357	160,336	226,846	294,826	363,948
Other (D_S)	6,039	12,078	18,117	24,156	30,195	36,234	42,273
Total Damages	10,445	53,286	115,474	184,492	257,041	331,060	406,221

ECONOMIC CONSEQUENCES OF NPA POLLUTION CONTROL POLICIES

To calculate the economic consequences of various control options it was necessary to make certain basic assumptions. These assumptions can be critical to the results of the study and must be kept in mind if the report is to be correctly interpreted. These assumptions include: (a) relative expected prices will remain constant; (b) expected present value of profit is a good indicator of farmers' decision criteria; (c) farm profits, government cost or revenue and sediment damage abatement have the same social value weights; and (d) farmers will act rationally and in their own self interest.

Assumption (a) rules out any large technological breakthroughs that would drastically change production costs or the yield of one crop in relation to the others. It also rules out the discovery of presently unknown ways to cheaply restore the soil fertility of eroded soils or to remove sediment from waterways at little or no cost. Furthermore, major changes in crop prices relative to the general price structure would invalidate the conclusions of this study. If crop prices fell relative to other prices, off-site damages would carry significantly more weight and greater erosion control would be socially beneficial. On the other hand, if relative crop prices rise, off-site damages would become less important and the optimal erosion would depend on the on-farm trade-offs between present production and future production.

The second assumption (b) asserts that the shifts in cropping patterns will take place, as this is the decision criteria built into the model. Farmers have other criteria besides profit that they base their decisions on. These other criteria might include; personal preference for one crop over another, preference for leisure rather than more profit, varying estimates of risk and uncertainty, and others. While these other criteria play a part in farmers decisions, it is a general assumption of economics that expected profit is the most important consideration and focusing on it alone will yield generally accurate results.

The third assumption (c) is the rationale behind the net social benefit calculation. It indicates that for the purposes of this study "government" is considered only as a point of accounting, i.e. a frictionless point of transfer for part of the jointly held social welth. Net social benefit does not change if money transfers from farm income to government or vice versa. Also, it implies that farm income is equal in social desirability to a similar dollar amount of off-site sediment damage abatement. This can be defended by noting that if the dollar value of the off-site damages have been correctly estimated, then it would be better for farmers as a group to pay for the damages directly rather than lose a greater amount of profits than the value of the damages abated.

The last assumption rules out ignorance of, or uncertainty about the most profitable cropping system--conservation practice. It also implies the assumption that financing will be available for any necessary equipment shifts or terrace construction. Neither of these conditions will always be met and that failure will reduce the actual change caused by implementation of any of the control options specified.

Because the benefits of soil conservation accrue over time, rather than immediately, the length of a farmer's planning horizon also influences the crops that will be grown and the conservation practices employed. This, in turn, influences the estimated economic impact of NPS control options. Due uncertainty about the length of farmers' planning horizons, estimated effects are shown for three horizons. These are 10 years, 100 years, and 200 years. Results based on these planning horizons will likely bracket the actual economic impact of the erosion controls considered.

Administrative and Enforcement Costs

The cost of administering and enforcing any of the NPS controls considered here has been estimated to range between $0.05 and $1.00 per acre with an average of $0.21 per acre.* The largest component of this cost estimate is based on the amount of technical assistance that would be required to implement the policies. The $0.21 average figure would apply to Duck Creek and Lower Running Water Draw watersheds, while administrative and enforcement costs in Lake Lavon watershed would be about $0.50 per acre. Cost would be higher in Lavon because of smaller farm size and a higher erosion potential. Total annual administrative and enforcement costs for the agricultural land will be $224,125 for Lavon, $25,868 for Lower Running Water Draw, and $27,217 for Duck Creek. While there will be slight cost differences between policies, these figures give a rough floor to the administration and enforcement costs.

Effects of NPS Controls in Lavon Watershed

Estimated effects of various erosion-sedimentation control policies on farm income, government cost or revenue, soil loss, off-site sediment damages abated, and net social benefits in Lavon watershed are shown in Table 21 for a planning horizon of 10 years. With only a ten year planning horizon, terracing and contouring were found to be unprofitable in the benchmark model

* G. E. Kretzschmar, Jr., Texas Soil and Water Conservation Board, personal communication.

Table 21. Major economic consequences of NPS control options in Lavon watershed assuming farmers have a 10 year planning horizon.

Control Option	Change in Annualized Farm Income ($1000)	Gov't Cost(-) or Revenue (+) ($1000)	Change in Gross Soil Loss (1000 T)	Offsite Sediment Damages Abated ($1000)	Net Social Benefits Excluding Administrative Costs ($1000)
SL < T	-4349.44	0.0	3295.07	913.77	-3435.67
SL < 2	-4483.13	0.0	3473.50	942.27	-3540.86
SL < 5	-3894.08	0.0	3147.58	887.85	-3006.23
SL < 10	-600.30	0.0	1476.11	476.19	-124.11
TR 50	0.0	0.0	0.0	0.0	0.0
TR 100	9.01	-42.18	72.48	24.72	- 8.45
C 50	2.06	-7.80	31.39	10.72	4.98
C 100	136.77	-811.47	1578.60	506.34	-168.36
IT 50	0.0	0.0	0.0	0.0	0.0
IT 100	0.0	0.0	0.0	0.0	0.0
SL < T, TR 50	-3207.84	-1201.70	3295.07	913.77	-3495.77
SL < T, C 50	-4331.63	-28.87	3255.96	907.10	-3453.40
SL < T, IT 50	-3835.34	-4990.22	3308.54	916.04	-7909.53
SL < 5, TR 50	-2880.90	-1066.51	3147.58	887.85	-3059.56
SL < 5, C 50	-3839.89	-65.26	3089.17	877.01	-3028.14
SL < 5, IT 50	-3440.26	-4405.10	3147.58	887.85	-6957.50
TX 8	-302.75	302.75	0.0	0.0	-0.00
TX 10	-378.44	378.44	0.0	0.0	-0.00
TX 12	-454.12	454.12	0.0	0.0	0.00
TX 14	-529.81	529.81	0.0	0.0	0.00
TX 16	-605.50	605.50	0.0	0.0	0.00
TX 18	-681.19	681.19	0.0	0.0	-0.00
TX 20	-756.37	750.60	31.39	10.72	4.95
TX 8, 50 T&C	-296.93	216.45	350.34	118.54	38.07
TX 10, 50 T&C	-365.63	285.13	350.34	118.54	38.04
TX 12, 50 T&C	-434.29	353.81	350.34	118.54	38.07
TX 14, 50 T&C	-502.96	422.49	350.34	118.54	38.08
TX 16, 50 T&C	-571.65	491.17	350.34	118.54	38.07
TX 18, 50 T&C	-639.49	76.49	1431.40	462.89	-100.11
TX 20, 50 T&C	-686.56	123.55	1431.40	462.89	-100.12

solution (Table 21). The distribution of crop acreage in the benchmark solution was reasonably close to actual crop acreage in recent years.

The first column of Table 21 gives the estimated farm income effect of the policies. For example, a restriction that per acre soil loss not exceed the SCS tolerance (T) limits, would decrease annualized farm income in the watershed by $4,349,440. Since this policy does not involve a tax or subsidy, the government cost is zero (column 2). The limit to T values would reduce soil loss in the watershed by 3295 thousand tons, which decreases off-site sediment damages by $913,770 annually. The final column gives net social benefits excluding any adminsitrative or enforcement costs. The number in this column is calculated by summing off-site sediment damages abated plus government revenue, minus government cost and the change in annualized farm income. For the example considered, net social benefits decline by $3,435,670 plus the administration and enforcement costs amounting to roughly $224,125, for a total decrease of over $3.6 million. Net social welfare declines with the restriciton because the loss in net farm income of the policy exceeds the off-site sediment damages abated.

From Table 21 it can be seen that the only policy that shows a positive social benefit aside from administration and enforcement costs is a tax on soil loss equal to 20 cents per ton. However, the benefit figure for this policy is not large enough to offset the associated administration and enforcement costs. Thus, we must conclude that if farmers have a 10 year planning horizon, it would <u>not</u> be to society's advantage to impose a control on erosion.

Model results for a planning horizon of 100 years are given in Table 22 while results for a 200 year horizon are given in Table 23. Benchmark model results are similar to those for a 10 year horizon, except that with the longer

Table 22. Major economic consequences of NPS control options in Lavon watershed assuming farmers have a 100 year planning horizon.

Control Option	Change in Annualized Farm Income ($1000)	Gov't Cost (-) or Revenue (+) ($1000)	Change in Gross Soil Loss (1000 T)	Offsite Sediment Damages Abated ($1000)	Net Social Benefits Excluding Administrative Costs ($1000)
SL < T	-2343.33	0.0	1842.55	425.40	-1917.93
SL < 2	-2449.60	0.0	1875.04	430.35	-2019.25
SL < 5	-2013.31	0.0	1681.59	399.28	-1614.03
SL < 10	-0.93	0.0	6.52	1.90	.97
TR 50	0.0	0.0	0.0	0.0	0.0
TR 100	376.88	-1321.04	1231.37	313.23	- 630.93
C 50	339.25	-339.25	0.0	0.0	0.0
C 100	724.16	-809.02	37.44	10.85	-74.0
IT 50	0.0	0.0	0.0	0.0	0.0
IT 100	0.0	0.0	0.0	0.0	0.0
SL < T, TR 50	-1636.91	-743.59	1842.55	425.40	-1955.11
SL < T, C 50	-2336.75	-6.57	1842.55	425.40	-1917.93
SL < T, IT 50	-2253.04	-4906.40	1842.55	425.40	-6734.04
SL < 5, TR 50	-1385.82	-660.52	1681.59	399.28	-1647.07
SL < 5, C 50	-1970.35	-42.96	1681.59	399.28	-1614.03
SL < 5, IT 50	-1933.79	-4321.28	1681.59	399.28	-5855.79
TX 8	-175.01	175.00	0.0	0.0	0.00
TX 10	-218.74	218.74	0.0	0.0	0.00
TX 12	-262.49	262.49	0.0	0.0	0.00
TX 14	-306.23	306.23	0.0	0.0	0.00
TX 16	-349.86	348.94	6.52	1.90	.98
TX 18	-393.49	392.55	6.52	1.90	.96
TX 20	-437.10	436.17	6.52	1.90	.97
TX 8, 50 T&C	169.90	-207.23	82.30	23.77	-13.55
TX 10, 50 T&C	127.81	-165.13	82.30	23.77	-13.55
TX 12, 50 T&C	85.71	123.02	82.30	23.77	-13.54
TX 14, 50 T&C	43.60	-80.92	82.30	23.77	-13.55
TX 16, 50 T&C	1.63	-39.86	88.82	25.64	-12.59
TX 18, 50 T&C	-40.35	2.11	88.82	25.64	-12.60
TX 20, 50 T&C	-82.32	44.08	88.82	25.64	-12.60

Table 23. Major economic consequences of NPS control options in Lavon watershed assuming farmers have a 200 year planning horizon.

Control Option	Change in Annualized Farm Income ($1000)	Gov't Cost (-) or Revenue (+) ($1000)	Change in Gross Soil Loss (1000 T)	Offsite Sediment Damages Abated ($1000)	Net Social Benefits Excluding Administrative Costs ($1000)
SL < T	-1461.47	0.0	1465.83	319.50	-1141.98
SL < 2	-1564.80	0.0	1498.32	324.45	-1240.35
SL < 5	-1148.93	0.0	1304.87	293.38	-855.55
SL < 10	0.0	0.0	0.0	0.0	0.0
TR 50	427.07	-645.11	943.47	225.73	7.59
TR 100	1061.92	-1452.18	1051.66	247.22	-143.04
C 50	368.54	-375.63	-287.90	-80.26	-87.35
C 100	750.45	-764.41	-274.35	-76.39	-90.35
IT 50	18.29	-1217.54	0.0	0.0	-1199.26
IT 100	36.58	-2435.09	0.0	0.0	-2398.51
SL < T, TR 50	-771.68	-726.09	1465.83	319.50	-1178.28
SL < T, C 50	-1454.90	-6.57	1465.83	319.50	-1141.97
SL < T, IT 50	-1387.81	-4906.40	1465.83	319.50	-5974.71
SL < 5, TR 50	-536.08	-645.11	1304.87	293.38	-887.81
SL < 5, C 50	-1105.97	-42.96	1304.87	293.38	-855.55
SL < 5, IT 50	-1084.05	-4321.28	1304.87	293.38	-5111.95
TX 8	-143.44	141.56	41.23	11.11	9.23
TX 10	-178.80	176.94	41.23	11.11	9.26
TX 12	-214.16	212.33	41.23	11.11	9.29
TX 14	-249.52	247.72	41.23	11.11	9.31
TX 16	-284.86	283.11	41.23	11.11	9.36
TX 18	-320.22	318.50	41.23	11.11	9.39
TX 20	-351.31	165.19	984.69	234.04	47.92
TX 8, 50 T&C	396.83	-623.07	998.25	236.74	10.50
TX 10, 50 T&C	380.75	-606.82	998.25	236.74	10.57
TX 12, 50 T&C	364.67	-590.57	998.25	236.74	10.84
TX 14, 50 T&C	348.58	-574.33	998.25	236.74	10.99
TX 16, 50 T&C	332.53	-558.08	998.25	236.74	11.19
TX 18, 50 T&C	316.43	-541.83	998.25	236.74	11.34
TX 20, 50 T&C	300.34	-525.58	998.25	236.74	11.49

planning horizon, part of the land was terraced. Consequently, estimated erosion in the watershed was lower.

For either of the long planning horizons, the estimated impact of NPS policies on farm income was not quite as severe as was found for the 10 year horizon. This result was obtained because some conservation was profitable without controls and thus to satisfy a policy, smaller adjustments were required. Also, the longer planning horizon shows the future benefits attributed to conservation.

As with the 10 year planning horizon, the net social benefits excluding administration and enforcement cost are negative for most policies and slightly positive for a few. However, the expected administration and enforcement costs would more than offset the small benefits, suggesting that erosion controls are not warranted under existing economic conditions in Lavon watershed.

Effects of NPS Controls in Lower Running Water Draw

Estimated effects of various erosion sedimentation control policies on farm income, government cost or revenue, soil loss, off-site sediment damages abated, and net social benefits are shown in Table 24 through 26 for a planning horizons of 10, 100 and 200 years, respectively.

With a 200 year planning horizon, the change in annualized farm income is not as drastic nor is the change in net social benefit as with the shorter time horizons. This is because the longer time period allows the requirements or advantages of the various controls to work in adjusted crop patterns and applied conservation practices. Over a long time period, future yield effects of reduced soil erosion work in conjunction with the sediment abatement action of the control options to demonstrate the actual long term effects of the various controls. As would be expected from economic theory, the soil loss

Table 24. Major economic consequences of NPS control options in Lower Running Draw watershed assuming farmers have a 10 year planning horizon.

Control Option	Change in Annualized Farm Income ($1000)	Gov't Cost (-) or Revenue (+) ($1000)	Change in Gross Soil Loss (1000 T)	Offsite Sediment Damages Abated ($1000)	Net Social Benefits Excluding Administrative Costs ($1000)
SL < T	-61.44	0.0	14.59	2.60	-58.85
SL < 2	-1869.46	0.0	218.65	36.40	-1833.05
SL < 4	-346.51	0.0	106.74	18.48	-328.03
SL < 6	0.0	0.0	0.0	0.0	0.0
TR 50	0.0	0.0	0.0	0.0	0.0
TR 100	0.0	0.0	0.0	0.0	0.0
C 50	0.0	0.0	0.0	0.0	0.0
C 100	2.52	-46.33	11.34	2.02	-41.78
IT 50	0.0	0.0	0.0	0.0	0.0
IT 100	0.0	0.0	0.0	0.0	0.0
SL < T, TR 50	-45.73	-36.21	14.71	2.62	-79.32
SL < T, C 50	-55.87	-5.57	14.59	2.60	-58.85
SL < T, IT 50	-61.44	0.0	14.59	2.60	-58.85
SL < 2, TR 50	-1835.87	-58.68	219.12	36.47	-1858.08
SL < 2, C 50	-1841.89	-36.31	215.71	35.95	-1842.25
SL < 2, IT 50	-1865.55	-37.96	218.65	36.40	-1867.10
TX 4	-13.52	13.52	0.0	0.0	0.00
TX 6	-20.27	20.28	0.0	0.0	0.00
TX 8	-27.04	27.04	0.0	0.0	0.00
TX 10	-33.79	33.79	0.0	0.0	0.00
TX 12	-40.55	40.55	0.0	0.0	0.00
TX 16	-54.07	54.07	0.0	0.0	0.00
TX 20	-67.58	67.59	0.0	0.0	0.00
TX 4, 50 T&C	-13.52	13.52	0.0	0.0	0.00
TX 6, 50 T&C	-20.27	20.28	0.0	0.0	0.00
TX 8, 50 T&C	-27.04	27.04	0.0	0.0	0.00
TX 10, 50 T&C	-33.79	33.79	0.0	0.0	0.00
TX 12, 50 T&C	-40.55	40.55	0.0	0.0	0.00
TX 16, 50 T&C	-54.07	54.07	0.0	0.0	0.00
TX 20, 50 T&C	-67.58	67.59	0.0	0.0	0.00

Table 25. Major economic consequences of NPS control options in Lower Running Water Draw watershed assuming farmers have a 100 year planning horizon.

Control Option	Change in Annualized Farm Income ($1000)	Gov't Cost (-) or Revenue (+) ($1000)	Change in Gross Soil Loss (1000 T)	Offsite Sediment Damages Abated ($1000)	Net Social Benefits Excluding Administrative Costs ($1000)
SL < T	-18.37	0.0	14.59	2.60	-15.77
SL < 2	-1395.94	0.0	218.07	36.30	-1359.64
SL < 4	-95.71	0.0	106.74	18.48	-77.24
SL < 6	0.0	0.0	0.0	0.0	0.0
TR 50	0.0	0.0	0.0	0.0	0.0
TR 100	26.17	-182.68	33.04	5.85	-150.66
C 50	10.04	16.51	8.32	1.48	-4.99
C 100	54.28	-123.57	25.38	4.50	-64.78
IT 50	0.0	0.0	0.0	0.0	0.0
IT 100	0.0	0.0	0.0	0.0	0.0
SL < T, TR 50	-12.35	-30.03	14.71	2.62	-39.77
SL < T, C 50	-11.16	-10.14	17.35	3.09	-18.21
SL < T, IT 50	-18.37	0.0	14.59	2.60	-15.77
SL < 2, TR 50	-1375.31	-48.03	218.54	36.37	-1386.97
SL < 2, C 50	-1370.95	-25.14	218.05	36.30	-1359.79
SL < 2, IT 50	-1395.24	-37.96	218.07	36.30	-1396.90
TX 4	-13.49	13.49	0.0	0.0	0.00
TX 6	-20.23	20.23	0.0	0.0	0.00
TX 8	-26.99	26.99	0.0	0.0	0.00
TX 10	-33.74	33.74	0.0	0.0	0.00
TX 12	-40.48	40.48	0.0	0.0	0.00
TX 16	-53.97	53.98	0.0	0.0	0.00
TX 20	-67.47	67.47	0.0	0.0	0.00
TX 4, 50 T&C	-3.12	3.35	8.32	1.48	-4.98
TX 6, 50 T&C	-9.70	3.23	8.32	1.48	-4.98
TX 8, 50 T&C	-16.28	9.81	8.32	1.48	-4.99
TX 10, 50 T&C	-22.86	16.40	8.32	1.48	-4.99
TX 12, 50 T&C	-29.44	22.98	8.32	1.48	-4.99
TX 16, 50 T&C	-42.50	30.57	10.86	1.93	-10.00
TX 20, 50 T&C	-55.57	43.63	10.86	1.93	-10.00

Table 26. Major economic consequences of NPS control options in Lower Running Water Draw watershed assuming farmers have a 200 year planning horizon.

Control Option	Change in Annualized Farm Income ($1000)	Gov't Cost (-) or Revenue (+) ($1000)	Change in Gross Soil Loss (1000 T)	Offsite Sediment Damages Abated ($1000)	Net Social Benefits Excluding Administrative Costs ($1000)
SL < T	-2.16	0.0	2.53	0.42	-1.74
SL < 2	-1197.55	0.0	112.69	18.05	-1179.50
SL < 4	-8.40	0.0	7.86	1.31	-7.09
SL < 6	0.0	0.0	0.0	0.0	0.0
TR 50	0.0	0.0	0.0	0.0	0.0
TR 100	41.41	-210.02	23.79	3.94	-164.67
C 50	12.66	-21.67	-3.97	-0.66	-9.47
C 100	69.18	-123.57	10.56	1.76	-52.62
IT 50	0.0	0.0	0.0	0.0	0.0
IT 100	0.0	0.0	0.0	0.0	0.0
SL < T, TR 50	-2.16	0.0	2.53	0.42	-1.74
SL < T, C 50	7.98	-10.14	2.53	0.42	-1.74
SL < T, IT 50	-2.16	0.0	2.53	0.42	-1.74
SL < 2, TR 50	-4183.69	-17.81	113.04	18.10	-1183.41
SL < 2, C 50	-1172.58	-25.14	112.68	18.05	-1179.67
SL < 2, IT 50	-1196.98	-37.96	112.69	18.05	-1216.88
TX 4	-9.22	9.22	0.0	0.0	0.00
TX 6	-13.83	13.83	0.0	0.0	0.00
TX 8	-18.45	18.45	0.0	0.0	0.00
TX 10	-23.06	23.05	0.0	0.0	0.00
TX 12	-27.66	27.66	0.0	0.0	0.00
TX 16	-36.88	36.88	0.0	0.0	0.00
TX 20	-46.11	46.11	0.0	0.0	0.00
TX 4, 50 T&C	3.43	-12.23	-3.97	-0.66	-9.47
TX 6, 50 T&C	-1.29	-7.51	-3.97	-0.66	-9.47
TX 8, 50 T&C	-6.02	-2.80	-3.97	-0.66	-9.48
TX 10, 50 T&C	-10.73	1.60	-3.86	-0.65	-9.78
TX 12, 50 T&C	-15.44	6.31	-3.86	-0.65	-9.78
TX 16, 50 T&C	-24.80	8.05	-0.95	-0.16	-16.92
TX 20, 50 T&C	-34.13	17.36	-0.95	-0.16	-16.92

tax options had the highest net social benefit of the options tested. Nonetheless, even they were not large enough to defray the expected administration costs of even the simplest tax scheme.

Results for all planning horizons show the same pattern that was found for Lavon; namely, the control options examined either fail to reduce erosion or are exceedingly expensive to society.

Effect of NPS Controls in Duck Creek Watershed

Tables 27 through 29 show the estimated economic impacts of various erosion-sedimentation controls on farm income, governmental cost or revenue, soil loss, off-site sediment damages abated, and net social benefits for planning horizons of 10, 100, and 200 years, respectively. As with the other watersheds, the social benefits associated with any of the control options examined were not large enough to offset administrative and enforcement costs associated with the options.

Table 27. Major economic consequences of NPS control options in Duck Creek Watershed assuming farmers have a 10 year planning horizon.

Control Option	Change in Annualized Farm Income ($1000)	Gov't Cost (-) or Revenue (+) ($1000)	Change in Gross Soil Loss (1000 T)	Offsite Sediment Damages Abated ($1000)	Net Social Benefits Excluding Administrative Costs ($1000)
SL < T	-60.09	0.0	73.54	12.82	-47.27
SL < 2	-680.85	0.0	242.86	39.20	-641.65
SL < 5	-35.37	0.0	59.71	10.47	-24.90
SL < 10	0.0	0.0	0.0	0.0	0.0
TR 50	0.0	0.0	0.0	0.0	0.0
TR 100	0.0	0.0	0.0	0.0	0.0
C 50	0.0	0.0	0.0	0.0	0.0
C 100	2.10	-75.43	70.73	12.34	-60.99
IT 50	0.0	0.0	0.0	0.0	0.0
IT 100	0.0	0.0	0.0	0.0	0.0
SL < T, TR 50	-59.23	-0.91	73.54	12.82	-47.31
SL < T, C 50	-52.21	-7.88	73.54	12.82	-47.27
SL < T, IT 50	-59.65	-4.19	73.54	12.82	-51.03
SL < 5, TR 50	-35.37	0.0	59.71	10.47	-24.90
SL < 5, C 50	-23.63	-11.74	59.71	10.47	-24.90
SL < 5, IT 50	-35.37	0.0	59.71	10.47	-24.90
TX 4	-14.50	14.50	0.0	0.0	0.00
TX 6	-21.74	21.74	0.0	0.0	0.00
TX 8	-28.99	28.99	0.0	0.0	0.00
TX 10	-36.24	36.24	0.0	0.0	0.00
TX 12	-43.49	43.49	0.0	0.0	0.00
TX 16	-57.99	57.99	0.0	0.0	0.00
TX 20	-72.48	72.48	0.0	0.0	0.00
TX 4, 50 T&C	-14.50	14.50	0.0	0.0	0.00
TX 6, 50 T&C	-21.74	21.74	0.0	0.0	0.00
TX 8, 50 T&C	-28.99	28.99	0.0	0.0	0.00
TX 10, 50 T&C	-36.24	36.24	0.0	0.0	0.00
TX 12, 50 T&C	-43.49	43.49	0.0	0.0	0.00
TX 16, 50 T&C	-57.99	57.99	0.0	0.0	0.00
TX 20, 50 T&C	-72.48	72.48	0.0	0.0	0.00

Table 28. Major economic consequences of NPS control options in Duck Creek Watershed assuming farmers have a 100 year planning horizon.

Control Option	Change in Annualized Farm Income ($1000)	Gov't Cost (-) or Revenue (+) ($1000)	Change in Gross Soil Loss (1000 T)	Offsite Sediment Damages Abated ($1000)	Net Social Benefits Excluding Administrative Costs ($1000)
SL < T	-26.52	0.0	61.85	10.69	-15.83
SL < 2	-496.95	0.0	254.64	40.13	-456.82
SL < 5	-10.24	0.0	47.97	8.34	-1.91
SL < 10	0.0	0.0	0.0	0.0	0.0
TR 50	0.0	0.0	0.0	0.0	0.0
TR 100	4.48	-23.17	13.25	2.33	-16.36
C 50	9.90	-29.78	41.31	7.20	-12.68
C 100	47.35	-82.71	61.45	10.62	-24.74
IT 50	0.0	0.0	0.0	0.0	0.0
IT 100	0.0	0.0	0.0	0.0	0.0
SL < T, TR 50	-26.04	-0.50	61.85	10.69	-15.86
SL < T, C 50	-12.60	-33.80	103.15	17.52	-28.87
SL < T, IT 50	-26.44	-4.19	61.85	10.69	-19.95
SL < 5, TR 50	-10.24	0.0	47.97	8.34	-1.91
SL < 5, C 50	7.54	-37.66	89.28	15.25	-14.86
SL < 5, IT 50	-10.24	0.0	47.97	8.34	-1.91
TX 4	-13.79	12.57	30.79	5.39	4.17
TX 6	-20.07	18.86	30.79	5.39	4.17
TX 8	-26.36	25.14	30.79	5.39	4.17
TX 10	-32.64	31.43	30.79	5.39	4.17
TX 12	-38.93	37.72	30.79	5.39	4.17
TX 16	-51.49	50.21	31.28	5.47	4.19
TX 20	-64.00	62.25	33.85	5.91	4.17
TX 4, 50 T&C	-2.23	-18.86	72.10	12.41	-8.68
TX 6, 50 T&C	-7.69	-13.40	72.10	12.41	-8.68
TX 8, 50 T&C	-12.93	-17.19	89.28	15.25	-14.87
TX 10, 50 T&C	-18.04	-12.08	89.28	15.25	-14.87
TX 12, 50 T&C	-23.16	-6.96	89.28	15.25	-14.87
TX 16, 50 T&C	-33.38	3.19	89.77	15.33	-14.85
TX 20, 50 T&C	-43.55	12.89	92.34	15.76	-14.90

Table 29. Major economic consequences of NPS control options in Duck Creek Watershed assuming farmers have a 200 year planning horizon.

Control Option	Change in Annualized Farm Income ($1000)	Gov't Cost (-) or Revenue (+) ($1000)	Change in Gross Soil Loss (1000 T)	Offsite Sediment Damages Abated ($1000)	Net Social Benefits Excluding Administrative Costs ($1000)
SL < T	-16.40	0.0	47.47	7.81	-8.60
SL < 2	-425.25	0.0	189.72	28.93	-396.33
SL < 5	-6.51	0.0	47.97	7.89	1.38
SL < 10	0.0	0.0	0.0	0.0	0.0
TR 50	0.0	0.0	0.0	0.0	0.0
TR 100	26.48	-174.75	60.63	9.91	-138.36
C 50	29.43	-37.70	14.17	2.37	-5.90
C 100	68.49	-82.80	17.14	2.86	-11.45
IT 50	0.0	0.0	0.0	0.0	0.0
IT 100	0.0	0.0	0.0	0.0	0.0
SL < T, TR 50	-15.94	-0.49	47.47	7.81	-8.62
SL < T, C 50	17.05	-33.69	54.72	8.97	-7.67
SL < T, IT 50	-16.34	-4.19	47.47	7.81	-12.73
SL < 5, TR 50	-6.51	0.0	47.97	7.89	1.38
SL < 5, C 50	28.22	-37.70	44.96	7.41	-2.07
SL < 5, IT 50	-6.51	0.0	47.97	7.89	1.38
TX 4	-11.07	9.69	37.82	6.25	4.87
TX 6	-15.40	12.69	68.74	11.19	8.47
TX 8	-19.63	16.91	68.74	11.19	8.47
TX 10	-23.86	21.14	68.74	11.19	8.47
TX 12	-28.09	25.37	68.74	11.19	8.47
TX 16	-36.49	33.51	70.73	11.51	8.53
TX 20	-44.86	41.89	70.73	11.51	8.53
TX 4, 50 T&C	18.82	-28.29	44.96	7.41	-2.07
TX 6, 50 T&C	14.62	-25.44	75.88	12.31	1.49
TX 8, 50 T&C	10.53	-21.38	76.02	12.33	1.49
TX 10, 50 T&C	6.45	-17.29	76.02	12.33	1.49
TX 12, 50 T&C	2.48	-10.59	86.29	13.93	5.82
TX 16, 50 T&C	-5.22	-3.13	88.15	14.22	5.87
TX 20, 50 T&C	-12.90	4.55	88.15	14.22	5.87

CONCLUSIONS

This report summarizes economic analyses of erosion and sedimentation in five Texas watersheds. Analyses focused on both the on-farm economics of soil conservation and the economic consequences of various non-point source pollution control options. These topics are joined in this study because they deal with different facets of the same problem. Unlike some pollutants, the sediment that is transported from farmers' fields to become a problem downstream is a valuable resource, not a waste product. Because the soil is valuable in itself, some level of soil conservation practice is going to be economically desirable even if the downstream pollution damages are not considered by the farmer. Results of the study show that soil conservation does indeed pay in many situations and that its value is greater, the longer the planning horizon of the decision maker. To the extent that farmers are not presently employing the most profitable conservation practice, an educational program in this area may reduce sediment damage while increasing farm income at the same time.

The second part of the analyses dealt with the total economic impact of various soil loss control options. Options based on regulations, taxation, economic incentive and combinations thereof were modeled. Given the estimate of off-site sediment damages and the assumptions of the model, the analyses suggest that regulatory erosion-sedimentation controls or subsidies are not presently warranted from a social welfare viewpoint in Lavon, Duck Creek, Lower Running Water Draw, Cameron County, or Turkey Creek watersheds. It should be noted that the estimate of off-site damages is imprecise at best, and assumes that plant nutrients transported by sediment do not pose health hazards nor cause undesirable eutrophication in the watersheds. However, close examination of Tables 21 through 29 reveals that estimates of off-site sediment damages and the estimate of administration and enforcement costs would have to be substantially in error to change the basic conclusions of this study.

REFERENCES

Lee, M. T. and K. Guntermann, "A Procedure for Estimating Off-Site Sediment Damage Costs and an Empirical Test," Water Resources Bulletin, Vol. 12, No. 3, June 1976.