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Silvicultural Activities in Relation to Water Quality in Texas: An Assessment of Potential Problems and Solutions

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Between
Texas Department of Water Resources
And

Texas Agricultural Experiment Station
Texas Water Resources Institute
Texas A&M University System

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INTRODUCTION

Southern forests are expected to supply a large portion of the Nation's future timber requirement. Projected demands on southern forests continue to exceed allowable cut. As an outgrowth of this demand, intensive management of pine forests enabled the South to produce 45 percent of the Nation's timber harvest in 1970 (USDA, Forest Service, 1973). The Southern Forest Resource Analysis Committee (1969) stated that, if projected timber needs of the year 2000 are to be met, at least ten million acres of bare or poorly stocked land must be planted with pine by 1985 and another twenty million acres converted from low-grade hardwoods to pine. The challenge facing forestry in the South is how to meet this increased demand and maintain an acceptable forest environment in the face of increased taxes, rising labor and equipment costs and predicted petroleum shortages.

Undisturbed forests are generally recognized as primary sources of high quality water. Although the Federal Water Pollution Control Act Amendments of 1972 (Public Law No. 92-500) make pollution from forest practices increasingly more important, the effects of these practices on water quality are not known for East Texas.

The quality of streamflow from forested watersheds fluctuates constantly in response to natural stress, and can be influenced greatly by man's activities. Forest management practices can potentially influence the following water quality parameters: (1) sediment, (2) nutrients, (3) temperature, (4) dissolved oxygen/organic matter, and (5) introduced chemicals.

It must be realized from the onset that sediment due to geologic erosion is a natural component of fresh water streams and that high concentrations may have occurred naturally for short periods due to perturbations in the ecosystem such as wildfires. Sediment is not necessarily a pollutant and only becomes one when it can be demonstrated that it is exceeding natural levels and is interfering with the beneficial use of water. A certain amount of sediment and nutrients are needed in Gulf Bays and Estuaries to maintain their productivity (Mathewson and Minter, 1976; Diener, 1964; Ketchum, 1967).

Texas does not have a stream water quality standard for sediment and due to the complexities involved will probably not develop one. Thus, sediment as used in this report, becomes important: (1) as a carrier of plant nutrients and forest chemicals, and (2) in that practices which reduce sediment loss will usually reduce nutrient, organic matter and introduced chemical losses and prevent water temperature increases, as well.

This report is the result of an interagency contract between Texas Department of Water Resources, Texas Agricultural Experiment Station and Texas Water Resources Institute to: (1) develop an overview of commercial forests and forestry operations in Texas, (2) identify, describe and characterize control strategies for nonpoint sources of pollution from silvicultural activities, and (3) develop and demonstrate a methodology for selecting control strategies in given problem situations. The following topics are covered: (1) an overview of forestry in East Texas, (2) silvicultural practices and nonpoint sources of pollution, (3) control strategies, (4) methodology for the selection of control strategies, (5) institutional aspects of controlling silvicultural nonpoint source pollution, (6) ongoing research and research needs, and (7) hydrology of East Texas.

It is important to recognize that this report does not specify that nonpoint pollution from forestlands in East Texas is a problem. Likewise, the report does not set pollution control goals or criteria that should be met by a control plan, since this is the responsibility of the State.

In areas where a potential nonpoint pollution problem exists; the suggested control strategies should be useful in selecting control measures that are appropriate to the special conditions imposed by differences in climate, soil, topography, and forest practice.

A HISTORY OF FORESTRY IN TEXAS

Within the boundaries of Texas are lands rich in mineral and agricultural wealth. The tremendous economic importance of these two resources often overshadows another land-derived resource, the commercial forests of Texas. Nonetheless, forests and forestry have played an important role in the state's development. The importance of forestry to local economies, especially in East Texas, is equaled by the colorful history and personalities which led to the evolution of a forest conservation ethic in Texas. Much of this history has been discussed in A Short History of Forest Conservation in Texas: 1880-1940 (Maxwell and Martin, 1970), which serves as the basis for this section of the report.

Contradictory to the usual stereotype of dry, dusty rangeland, Texas is a state with abundant forest resources. All sections of the state have some timber growth, but it is the 37-county eastern portion of the state in which the great forests of commercial timber are found (figure 1). The pine and hardwood forests of Texas are the western perimeter of the southern forest region which extends eastward to the Atlantic coast, north to Arkansas, Tennessee and Virginia, and south to the Gulf of Mexico. Physiographically, the East Texas timberlands fall within the western Gulf Coastal Plain.

Early visitors and settlers in Texas were impressed with the majestic pine forests whose trees towered to 150 feet with stump diameters of up to 5 feet. These great pine stands were, reportedly, free of undergrowth which could hinder early travelers. Impressive as these early forests were, settlers typically regarded them as having little value and as a barrier to agriculture. The commercial value of the timberlands was recognized during the last quarter of the 19th century, a time in which the once abundant forest resources of the Lake States had been decimated by uncontrolled timber

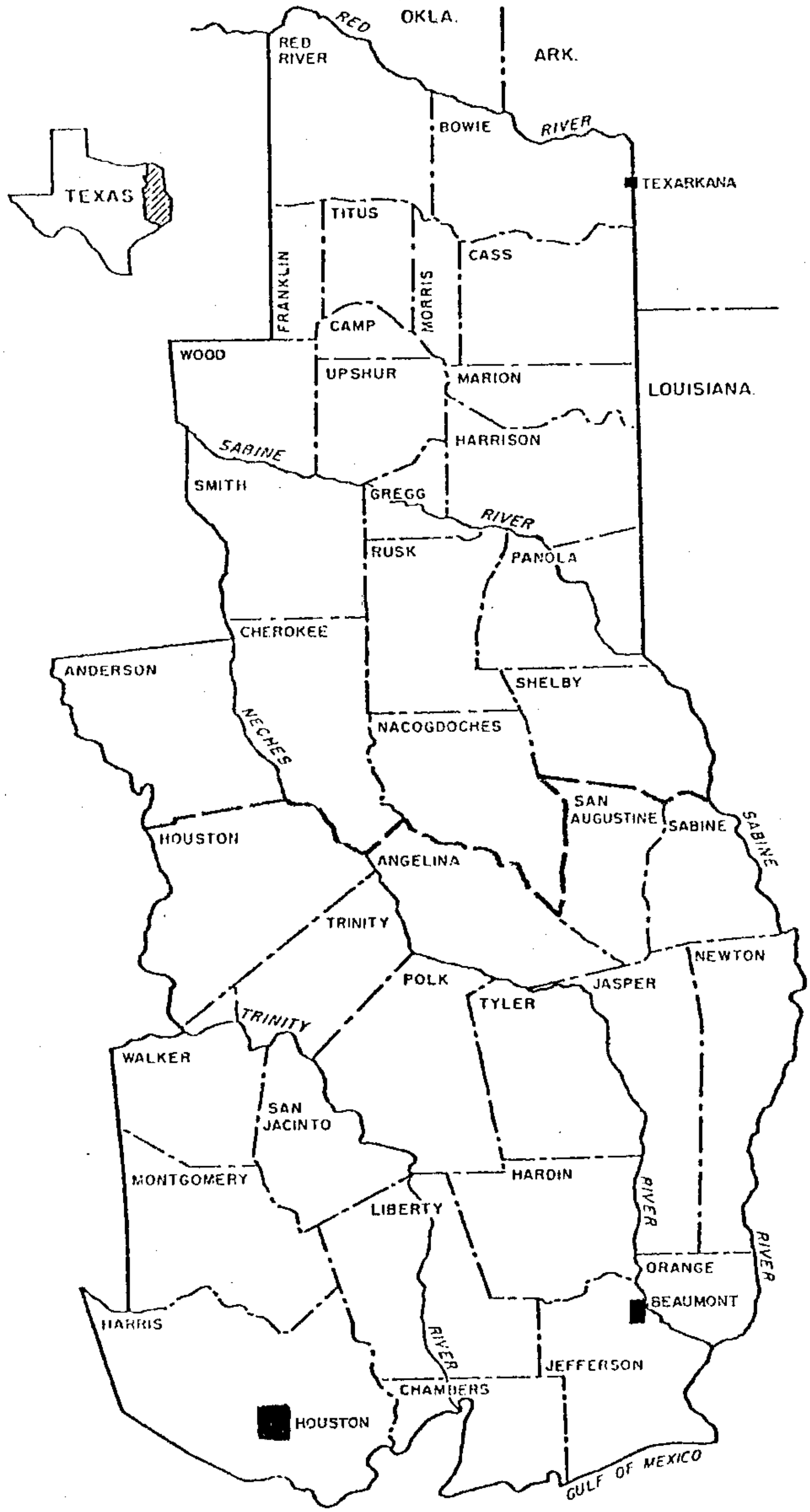

Figure 1 . Forested Counties of East Texas

harvesting and fires. Although there are many commercial hardwood tree species in East Texas, it was the three native species of pines -- loblolly, longleaf and shortleaf -- which attracted loggers.

The longleaf pine area originally covered about 5,000 square miles which included parts of Sabine, San Augustine, Nacogdoches, Angelina, Polk, Trinity, Tyler, Jasper, Newton, Orange and Hardin counties. The typical longleaf country was relatively open with deep, sandy, well-drained soils. On such terrain the longleaf grew to produce a park-like forest floor relatively free of shrub hardwoods.

The loblolly pine forest covered an area which extended from Jefferson, Chambers and Harris counties north to Walker County. In contrast to the sites occupied by the longleaf pine, loblolly flourished in areas which were poorly drained, and in which understory and brush were often present. It has been estimated that this early loblolly pine growth covered an area of about 7,000 square miles and, in addition, portions of Colorado, Fayette and Bastrop counties; a region called "the lost pines."

The shortleaf pine region covered the eastern section of the State to the north of the longleaf and loblolly region, and extended to the Red River, which borders Texas and Oklahoma. This region initially encompassed some 12,000 square miles and was the earliest region of commercial timber harvesting due to the railroad outlets to the north. The productivity of the shortleaf forests was less, on a per acre basis, than the longleaf or loblolly forests. As a result, tree farming in the northeast portion of the state was often a sideline activity for many landowners.

As late as 1880, the pine forests of East Texas were virtually untapped. Sawmills were few in number and, generally they were small business operations which supplied building materials for local use. Soon after the Civil War, a number of factors stimulated interest in the commercial exploitation of the

East Texas forests. Eastern forests had been exhausted and the forests of the Lake States were being rapidly depleted. Production of southern yellow pine lumber had become a profitable business in much of the Deep South. Also, the settlement of the Great Plains opened new markets for lumber. One of the most important factors which led to commercial interest in the Texas forests was the expansion of the nation's railroads. Fueled by government incentive programs, the railroads grew rapidly beginning in 1875, and within the next 30 years the East Texas forests were accessible to a number of major rail lines.

Lumbermen soon followed the railroads. Land was purchased for as little as 50 cents an acre, and within a few years some three dozen individuals emerged as latter-day fuedal barons. They built complete lumber manufacturing plants including mills, dry kilns, warehouses and tram roads. Also, towns were developed in which the houses, streets, commissary, schools and churches were company-dominated, and often company-owned. Many of the lumber barons were bold and purposeful entrepreneurs with traits of stubbornness and independence. Some, such as John Henry Kirby, W.T. Carter, and John Martin Thompson, were Texas born. Others, such as Henry J. Lutcher, G.B. Moore, T.L.L. Temple, Joseph H. Kurth, William H. Knox, David Wingate, E.B. Hayward and Robert A. Long, moved to Texas from other states or countries. Each of these men established an empire in excess of 100,000 acres.

A laissez-faire attitude prevailed as logging of the East Texas piney woods grew at an alarming rate. The annual timber harvest grew from 200 million board feet in 1870 to a high of over 2 billion board feet in 1910. The following years saw an erratic decline in timber production with annual harvests reaching a low of about 400 million board feet per year in the early 1930's. Between 1880 and 1930, the Texas lumber industry logged about 18 million acres of pine timber and produced 59 billion board feet of lumber.

By 1940, the unregulated harvesting of the timber resource caused the termination of most operations, reduced dozens of mills to ghost towns, and left thousands unemployed in the depths of the Great Depression. For its first 50 years, the history of lumbering in Texas had been no different from that in New England, the Lake States, or in the Southeast. As a result, the pine forests were all but destroyed.

The concern over rapidly dwindling timber resources in East Texas was recognized by the U. S. Bureau of Forestry as early as 1900. In 1917, J.H. Foster, Texas' first state forester, painted a gloomy picture of the condition of the forest resource. The fact that Texas did not become a wasteland of stumps was due almost entirely to the vision, courage, and efforts of W. Goodrich Jones. Although a banker and businessman by vocation, Jones accepted as a life-long challenge the conservation of the state's forest resources. At the request of the U. S. Bureau of Forestry, in 1898 he made a tour of east Texas to assess the timber resource. His dismal report stirred interest in many circles, and over the next half-century Jones mustered government and private support to restore the forests. Significant among his accomplishments was the formation of the Texas Forestry Association, lobbying for a state department of forestry, and hiring of the first state forester. The tireless efforts of W. Goodrich Jones are, in large part, responsible for the subsequent reforestation of East Texas.

The Texas Forest Service also played an important role in forest conservation within the state. Tree nurseries established in 1926 and 1928 were producing one million pine seedlings by 1930, which were planted on cut-over lands. Their campaign of education, fire protection and reforestation did much to produce a vigorous second-growth pine forest within one generation after the close of the bonanza logging days.

The federal government also played a vital role in re-establishment of the East Texas forests. As part of the program to combat the Great Depression, the Civilian Conservation Corps established 17 camps in Texas. Soon these young men were performing a variety of tasks under the administration of the Texas Forest Service. At little cost to the state, the CCC made a valuable contribution to forest conservation in Texas. Also, in 1936 the federal government established the Texas National Forests. Under the direction of the U. S. Forest Service, about 650,000 acres of land were purchased and divided into four national forests. Most of the land was cut-over property obtained from timber companies. Under the CCC program, pine trees were planted on the new national forest lands and vigorous second-growth stands were established.

At the end of this story, we must go back to W. Goodrich Jones because it was he who would not let the forest conservation movement in Texas die. It was his vision and determination which set the Texas Forestry Association and the Texas Forest Service on the road to at least partial success in the areas of conservation, reforestation and forest management.

CURRENT FOREST RESOURCES OF TEXAS

The preceding section of this report, which dealt with the history of forestry in Texas, contained a discussion of the forests which the first settlers encountered. The 37-county area which comprises the state's commercial forestland was divided into three forested regions: the longleaf pine, loblolly pine, and shortleaf pine regions. The loblolly and longleaf regions occupied the southeastern portion of the State, while the shortleaf region occupied the northeastern sector. The dividing line between the sectors is an imaginary line that passes from east to west through Sabine, San Augustine, Angelina, and Houston counties. The primary difference between the two sectors, other than forest type, is the variation in per acre productivity of the timber stands. Historically the sector to the south has been found to have the higher rate of productivity. This is more than simply a point of academic interest, because it has, to a large extent, influenced the current picture of forest characteristics and ownership patterns.

Table 1 indicates that, within the forested East Texas counties, 56 percent of the total area, nearly 11 million acres, is occupied by commercial forests. Commercial forest lands are those which produce, or are capable of producing, crops of industrial wood. The remaining 44 percent of the land area is devoted to other land uses such as agriculture, urban, non-commercial forests and bodies of water. Examination of the acreage figures reveals that the counties with the largest proportion of their land in commercial forests are situated in the southeastern section of the state. Also, the data indicate that during the period 1965 to 1975, the total area of commercial forest fell by 5 percent. Thus, the general trend for the counties has been that of a shrinking forest land base. A few counties, all of which are located in the southeast, experienced modest gains in the area of commercial forests.

Table 2 indicates the distribution, by county, of four forest types:

Table 1 -- Total area, commercial forest land, and proportion of total area, 1975, and change since 1965[1]

County	Total area	Commercial forest Area	Commercial forest Proportion	Commercial forest Change since 1965
	- Thousand acres -		- - Percent - -	
Anderson	687.4	359.9	52	- 9
Angelina	551.7	390.4	71	+ 8
Bowie	590.7	266.8	45	- 11
Camp	123.5	51.0	41	- 4
Cass	617.6	428.4	69	+ 12
Chambers	560.0	33.6	6	- 5
Cherokee	675.2	390.6	58	+ 1
Franklin	187.5	56.4	30	- 24
Gregg	181.8	65.0	36	- 23
Hardin	574.1	498.8	87	- 1
Harris	1,129.6	165.0	15	- 11
Harrison	576.0	338.4	59	- 6
Houston	792.3	384.0	48	- 13
Jasper	624.7	520.8	83	- 4
Jefferson	643.8	50.4	8	- 7
Liberty	757.1	445.5	59	- 2
Marion	266.2	204.0	77	+ 6
Montgomery	697.6	504.4	72	- 11
Morris	169.0	73.2	43	- 13
Nacogdoches	617.6	383.4	62	- 4
Newton	609.9	565.6	93	+ 1
Orange	240.6	133.4	55	- 8
Panola	567.7	348.1	61	- 2
Polk	704.0	585.8	83	- 1
Red River	662.4	246.4	37	- 27
Rusk	604.2	291.4	48	- 4
Sabine	363.5	275.0	76	- 7
San Augustine	391.7	279.5	71	- 2
San Jacinto	399.4	290.7	73	- 7
Shelby	525.4	321.6	61	- 11
Smith	601.6	218.4	36	- 8
Titus	267.5	87.0	33	- 18
Trinity	453.1	363.0	80	+ 4
Tyler	597.8	536.9	90	- 3
Upshur	377.0	204.0	54	- 7
Walker	505.6	322.4	64	- 11
Wood	462.7	222.3	48	- 2
All counties	19,357.5	10,901.5	56	- 5

[1] Earles (1976), p.3.

Table 2 . Commercial forest land by forest type, 1975[1]

County	All Types	Pine	Pine-Hardwood	Upland Hardwoods	Bottomland Hardwoods
			Thousand acres		
Anderson	359.9	61.0	79.3	128.1	91.5
Angelina	390.4	224.0	89.6	51.2	25.6
Bowie	266.8	69.6	46.4	87.0	63.8
Camp	51.0	25.5	17.0	8.5	0.0
Cass	428.4	113.4	69.3	138.6	107.1
Chambers	33.6	33.6	0.0	0.0	0.0
Cherokee	390.6	107.1	126.0	113.4	44.1
Franklin	56.4	0.0	28.2	28.2	0.0
Gregg	65.0	10.0	5.0	20.0	30.0
Hardin	498.8	191.4	121.8	52.2	133.4
Harris	165.0	66.0	27.5	33.0	36.5
Harrison	338.4	126.9	79.9	98.7	32.9
Houston	384.0	162.0	126.0	60.0	36.0
Jasper	520.8	254.2	142.6	68.2	55.8
Jefferson	50.4	6.3	6.3	6.3	31.5
Liberty	445.5	66.0	77.0	60.5	242.0
Marion	204.0	78.0	66.0	36.0	24.0
Montgomery	504.4	260.0	166.4	57.2	20.8
Morris	73.2	24.4	24.4	6.0	18.3
Nacogdoches	383.4	167.4	75.6	97.2	43.2
Newton	565.6	280.0	123.2	78.4	84.0
Orange	133.4	34.8	29.0	34.0	34.8
Panola	348.1	153.4	59.0	64.0	70.8
Polk	585.8	377.0	110.2	58.0	40.6
Red River	246.4	44.8	22.4	106.4	72.8
Rusk	291.4	111.6	49.6	99.2	31.0
Sabine	275.0	159.5	77.0	33.0	5.5
San Augustine	279.5	136.5	78.0	19.5	45.5
San Jacinto	290.7	199.5	34.2	28.5	28.5
Shelby	321.6	127.3	113.9	60.3	20.1
Smith	218.4	61.6	16.8	100.8	39.2
Titus	87.0	5.8	17.4	46.4	17.4
Trinity	363.0	277.2	52.8	19.8	13.2
Tyler	536.9	241.9	141.6	100.3	53.1
Upshur	204.0	72.0	72.0	36.0	24.0
Walker	322.4	192.4	72.8	46.8	10.4
Wood	222.3	45.6	22.8	108.3	45.6
All Counties	10,901.5	4,567.7	2,467.0	2,191.8	1,675.0

[1]Adapted from Earles (1976) p. 5.

pine, pine-hardwood, upland hardwoods, and bottomland hardwoods. The names of the four forest types indicate the group of tree species (e.g. pines) which dominate that particular type. Of the four types, the pine and pine-hardwood represent those with the greatest commercial value. Following the bonanza logging period from 1880-1940, most of the reforestation activities involved the planting of pine seedlings in the counties of the southeastern portion of the state. This fact is reflected in the data, as these counties contain most of the pine and pine-hardwood forest types. Those counties with a predominance of bottomland hardwoods usually have an abundance of wetlands or rivers.

Table 3 indicates the sawtimber volume, in millions of board feet, by species group, for each of the 37 counties. Sawtimber trees represent the larger diameter trees of the forest. For softwoods (pines) the minimum sawtimber tree diameter is 9 inches with a minimum defect-free log 12 feet long, while for hardwoods the minimum diameter is 11 inches. For all counties, the softwood sawtimber volume is more than three times that of the hardwood volume. As might be expected, the counties with greatest softwood sawtimber volume are located in southeast Texas. Volume figures, such as those presented in the table, are often more descriptive of the timber resource than are acreage figures alone, because they indicate amount of wood available for commercial use.

Table 4 presents data regarding the number of cords of growing stock, by species group. A cord is an amount of wood which will occupy a space 4 feet by 4 feet by 8 feet. The cord is a common unit of measurement for wood destined to be used in pulp processing. Growing stock refers to live trees that are commercial species of desirable quality. For all of the 37 counties, the cordage of softwood is about twice that of the hardwoods. Those

Table 3 . Sawtimber volume on commercial forest land by species group, 1975[1]

County	All Species	Softwood	Hardwood
	million board feet		
Anderson	798.8	399.1	399.7
Angelina	1,959.7	1,672.7	287.0
Bowie	902.0	511.9	390.1
Camp	279.6	216.9	62.7
Cass	1,218.0	598.5	619.5
Chambers	123.5	99.7	23.8
Cherokee	1,218.7	911.3	307.4
Franklin	126.7	31.4	95.3
Gregg	104.8	26.1	78.7
Hardin	1,974.4	1,347.9	626.5
Harris	651.4	457.4	194.0
Harrison	885.9	573.7	312.2
Houston	1,717.0	1,443.3	273.7
Jasper	2,199.3	1,732.6	466.7
Jefferson	276.5	152.1	124.4
Liberty	1,625.8	876.2	749.6
Marion	611.9	433.4	178.5
Montgomery	2,640.8	2,322.0	318.8
Morris	199.5	107.5	92.0
Nacogdoches	1,279.2	966.7	312.5
Newton	2,641.5	1,965.7	675.8
Orange	510.0	322.2	187.8
Panola	1,614.8	1,266.6	348.2
Polk	3,257.9	2,886.1	371.8
Red River	490.3	178.0	312.3
Rusk	949.0	764.9	184.1
Sabine	1,896.6	1,612.8	283.8
San Augustine	1,404.2	1,163.0	241.2
San Jacinto	1,749.8	1,525.9	223.9
Shelby	1,289.3	963.9	325.4
Smith	448.8	207.3	241.5
Titus	139.5	27.9	111.6
Trinity	1,954.6	1,706.0	248.6
Tyler	2,931.4	2,264.9	666.5
Upshur	564.1	393.7	170.4
Walker	1,781.1	1,576.5	204.6
Wood	414.4	246.3	168.1
All counties	44,830.8	33,952.1	10,878.7

[1]Adapted from Earles (1976) p. 11.

Table 4 . Cordage of growing stock on commercial forest land by species group, 1975[1]

County	All species	Softwood	Hardwood
	---Thousand Cords---		
Anderson	3,351	1,363	1,988
Angelina	6,396	4,817	1,579
Bowie	3,575	1,675	1,900
Camp	994	685	309
Cass	5,710	2,404	3,306
Chambers	488	397	91
Cherokee	4,997	2,916	2,081
Franklin	612	137	475
Gregg	488	101	387
Hardin	8,008	4,381	3,627
Harris	2,336	1,406	930
Harrison	4,331	2,437	1,894
Houston	5,884	4,244	1,640
Jasper	7,976	5,392	2,384
Jefferson	1,039	423	616
Liberty	5,870	2,409	3,461
Marion	2,569	1,517	1,052
Montgomery	8,929	6,992	1,937
Morris	871	444	427
Nacogdoches	5,094	3,175	1,919
Newton	9,127	5,837	3,290
Orange	1,911	987	924
Panola	5,820	4,050	1,770
Polk	10,677	8,693	1,984
Red River	2,576	789	1,787
Rusk	3,960	2,656	1,304
Sabine	6,229	4,683	1,546
San Augustine	4,923	3,536	1,387
San Jacinto	5,670	4,513	1,157
Shelby	5,299	3,459	1,840
Smith	1,946	803	1,143
Titus	689	117	572
Trinity	6,110	4,995	1,115
Tyler	9,449	6,159	3,290
Upshur	2,537	1,609	928
Walker	5,461	4,476	985
Wood	1,724	791	933
All Counties	163,626	105,668	57,958

[1]Adapted from Earles (1976) p. 9.

counties in which the hardwood cordage is larger are generally characterized by wetlands or the presence of streams. The counties with the greatest number of softwood cords are located in the southeast.

Table 5 presents data concerning the acreage of different timber stand size classes. The sawtimber and poletimber classes have commercial value for lumber and pulpwood respectively. The sapling and seedling classes represent trees which are too small (diameter less than 5 inches) to have value as commercial timber. For all counties, the acreage of sawtimber-sized trees is about twice the acreage of poletimber trees. The deep southeast Texas counties contain the greatest concentration of sawtimber-sized trees.

Table 6 presents information concerning the distribution of commercial forest land in East Texas by ownership classes. The four ownership classes are national forest, which is land owned by the federal government; other public, which is mainly state or county-owned lands; forest industry, a class of land held by lumber and pulpwood processing companies; and other private land, which is held in relatively small parcels by individual owners.

The largest single ownership class is the small private landowner group which represents more than 60 percent of the total forest area. The distribution of small private ownerships is fairly even throughout the 37-county region. The myriad members of this ownership class have historically shown little interest in implementing forest management practices on their lands. As a result, the productivity of their lands rarely reaches its potential and, often, adequate plans are not made for reforestation of their lands following a timber harvest. Forest industry lands comprise nearly 35 percent of the total commercial forest land in East Texas. The greatest concentration of industrial ownership is in the southeastern portion of the state where industry is the predominant ownership class in nine counties. These lands are typically subject to intensive forest management practices, which include careful regulation

Table 5. Commercial forest land by stand-size class, 1975[1]

County	All classes	Sawtimber	Poletimber	Sapling and seedling	Nonstocked areas
	Thousand acres				
Anderson	359.9	140.3	122.0	91.5	6.1
Angelina	390.4	236.8	70.4	83.2	...
Bowie	266.8	139.2	92.8	34.8	...
Camp	51.0	42.5	...	8.5	...
Cass	428.4	170.1	163.8	94.5	...
Chambers	33.6	33.6	...	...	...
Cherokee	390.6	176.4	126.0	88.2	...
Franklin	56.4	18.8	28.2	9.4	...
Gregg	65.0	25.0	20.0	20.0	...
Hardin	498.8	237.8	121.8	133.4	5.8
Harris	165.0	115.5	27.5	11.0	11.0
Harrison	338.4	126.9	117.5	89.3	4.7
Houston	384.0	204.0	108.0	72.0	...
Jasper	520.8	266.6	124.0	130.2	...
Jefferson	50.4	37.8	6.3	6.3	...
Liberty	445.5	258.5	93.5	82.5	11.0
Marion	204.0	96.0	66.0	42.0	...
Montgomery	504.4	327.6	98.8	78.0	...
Morris	73.2	36.6	12.2	24.4	...
Nacogdoches	383.4	189.0	102.6	86.4	5.4
Newton	565.6	313.6	95.2	156.8	...
Orange	133.4	63.8	46.4	23.2	...
Panola	348.1	194.7	70.8	82.6	...
Polk	585.8	353.8	121.8	110.2	...
Red River	246.4	72.8	100.8	72.8	...
Rusk	291.4	142.6	80.6	68.2	...
Sabine	275.0	209.0	44.0	22.0	...
San Augustine	279.5	136.5	97.5	45.5	...
San Jacinto	290.7	210.9	51.3	28.5	...
Shelby	321.6	147.4	100.5	73.7	...
Smith	218.4	84.0	61.6	72.8	...
Titus	87.0	17.4	40.6	29.0	...
Trinity	363.0	237.6	46.2	72.6	6.6
Tyler	536.9	348.1	94.4	94.4	...
Upshur	204.0	96.0	72.0	30.0	6.0
Walker	322.4	228.8	46.8	46.8	...
Wood	222.3	74.1	39.9	96.9	11.4
All counties	10,901.5	5,810.1	2,711.8	2,311.6	68.0

[1] Adapted from Earles (1976), p.6.

Table 6 . Ownership of Commercial Forest Lands in East Texas counties[1]

County	Total Area	Forest Area	National Forest	Other Public	Forest Industry	Other Private
	- - - - - - - -	- - - - - -	Thousands	of acres	- - - - - -	- - - - - -
Anderson	687.4	359.9	0.0	26.2	79.3	254.4
Angelina	551.7	390.4	51.4	5.0	192.0	142.0
Bowie	590.7	266.8	0.0	50.2	17.4	199.2
Camp	123.5	51.0	0.0	0.3	0.0	50.7
Cass	617.6	428.4	0.0	18.6	94.5	315.3
Chambers	560.0	33.6	0.0	4.4	0.0	29.2
Cherokee	675.2	390.6	0.0	3.2	119.7	267.7
Franklin	187.5	56.4	0.0	0.1	0.0	56.3
Gregg	181.8	65.0	0.0	0.6	0.0	64.4
Hardin	574.1	498.8	0.0	0.3	348.0	150.5
Harris	1,129.6	165.0	0.0	2.1	11.0	151.9
Harrison	576.0	338.4	0.0	7.8	23.5	307.1
Houston	792.3	384.0	92.0	1.2	42.5	248.8
Jasper	624.7	520.8	19.6	10.8	359.6	130.8
Jefferson	643.8	50.4	0.0	0.0	0.0	50.4
Liberty	757.1	445.5	0.0	3.6	198.0	243.9
Marion	266.2	204.0	0.0	8.9	30.0	165.1
Montgomery	697.6	504.4	42.1	2.4	36.4	423.5
Morris	169.0	73.2	0.0	1.0	0.0	72.2
Nacogdoches	617.6	383.4	2.1	5.1	124.2	252.0
Newton	609.9	565.6	0.5	1.9	431.2	132.0
Orange	240.6	133.4	0.0	0.0	58.0	75.4
Panola	567.7	348.1	0.0	0.1	59.0	289.0
Polk	704.0	585.8	0.0	4.2	464.0	117.6
Red River	662.4	246.4	0.0	0.7	56.0	189.7
Rusk	604.2	291.4	0.0	0.5	18.6	272.3
Sabine	363.5	275.0	91.6	4.9	104.5	74.0
San Augustine	391.7	279.5	58.7	3.6	143.0	74.2
San Jacinto	399.4	290.7	55.6	0.3	79.8	155.0
Shelby	525.4	321.6	43.1	0.0	53.6	224.9
Smith	601.6	218.4	0.0	0.8	0.0	217.6
Titus	267.5	87.0	0.0	0.1	0.0	86.9
Trinity	453.1	363.0	66.9	0.8	191.4	103.9
Tyler	597.8	536.9	0.0	6.5	398.4	141.0
Upshur	377.0	204.0	0.0	1.0	0.0	203.0
Walker	505.6	322.4	49.1	3.2	20.8	249.3
Wood	462.7	222.3	0.0	0.1	5.7	216.5
All Counties	19,357.5	10,901.5	572.7	180.5	3,750.6	6,397.7

1 Adapted from Earles (1976), p.4.

of timber growth, yield and reforestation. The national forests of Texas account for a relatively small fraction of the total forest land area in the state. The U.S. Forest Service provides close scrutiny of any activities within its jurisdiction. Additionally, recent litigation has curtailed some forest management activities, including harvesting, within the Texas national forests.

Table 7 indicates the erosion hazard of forest lands in East Texas. Erosion hazard as used in this report is the potential susceptibility of soil to erosion if all the protective vegetation and litter were removed and the site placed in row crop agriculture. It does not refer to current erosion nor imply that forested soils of East Texas have an erosion problem. The data were compiled from estimates provided by various state and federal agency officials working in the counties (Texas Conservation Needs Committee 1970). About 43 percent of the total forest land area has soils which are classified as having a severe erosion hazard. The primary concentration of the potentially erodable soils is in the northeastern section of the state. Interestingly, the northeastern section, as previously indicated, is the area of least intensive forestry activity. Figure 2 indicates the location of those counties in which 50 percent or more of the forest lands are classified as having severe soil erosion hazard. The forests in the southeastern portion of the state are typically called "flatwoods", while the land in the northeastern section is characterized by sandy, rolling hills.

The data presented in this section of the report can be used to draw several conclusions about the current forest situation in East Texas. They suggest that the eastern tier of counties can be separated into a northern region and a southern region with the line of demarcation passing from east to west through Sabine, San Augustine, Angelina and Houston counties. The

Table 7 . Soil erosion hazard of East Texas commercial forest lands[1]

County	Commercial forest area	Moderate erosion hazard	Severe erosion hazard
	Thousand Acres		
Anderson	359.9	5.7	192.7
Angelina	390.4	11.3	142.4
Bowie	266.8	33.6	77.2
Camp	51.0	4.1	27.0
Cass	428.4	17.0	202.2
Chambers	33.6	0.0	5.2
Cherokee	390.6	18.8	220.5
Franklin	56.4	1.8	37.4
Gregg	65.0	7.4	43.8
Hardin	498.8	12.9	10.8
Harris	165.0	3.0	1.5
Harrison	338.4	42.3	194.4
Houston	384.0	47.8	178.0
Jasper	520.8	24.2	167.1
Jefferson	50.4	0.0	0.0
Liberty	445.5	53.1	5.9
Marion	204.0	8.3	94.5
Montgomery	504.4	24.3	97.9
Morris	73.2	2.8	36.6
Nacogdoches	383.4	26.9	237.3
Newton	565.6	36.3	174.2
Orange	133.4	0.9	4.4
Panola	348.1	18.0	127.7
Polk	585.8	29.6	286.1
Red River	246.4	5.4	94.4
Rusk	291.4	11.3	193.5
Sabine	275.0	7.3	108.9
San Augustine	279.5	3.8	137.6
San Jacinto	290.7	15.2	130.7
Shelby	321.6	18.2	187.5
Smith	218.4	4.8	137.4
Titus	87.0	2.6	34.9
Trinity	363.0	13.9	96.5
Tyler	536.9	21.7	212.8
Upshur	204.0	12.3	136.3
Walker	322.4	6.0	209.5
Wood	222.3	13.3	103.4
All Counties	10,901.5	565.9	4,348.2

[1]Adapted from Conservation Needs Inventory, Texas 1970, pp. 70-107.
Note: land capability class 2E was classified as moderate erosion hazard, while land capability classes 3 through 7 E were classified as severe erosion hazard. Erosion hazard is the potential susceptibility of soil to erosion with the protective vegetation and litter removed.

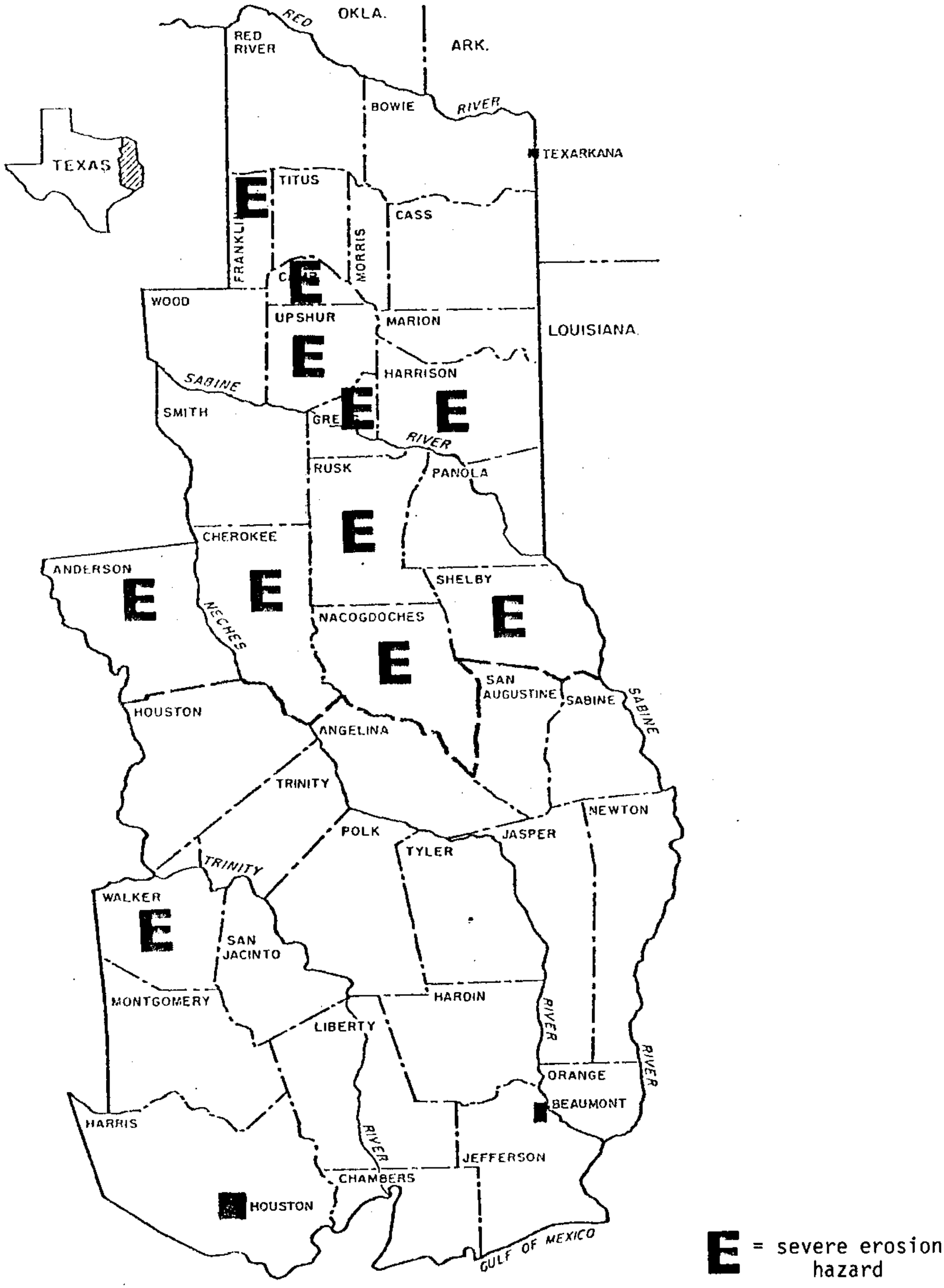

Figure 2 . Counties with fifty percent or more of forest lands classified as severe soil erosion hazard.

northern region is generally characterized as having the greater concentration of erodable soils and of small private ownerships, and a lesser level of intensive forest management and commercial timber. The southern portion of the 37-county area generally has the lesser concentration of erodable soils, and a greater amount of commercial timber, industrial ownership and intensive forest management.

EAST TEXAS TIMBER HARVEST TRENDS

The information presented in this section of the study is based primarily on data collected by the Texas Forest Service and presented in the annual report entitled Harvest Trends 1976 (Barron, 1977). The report is a summary of a census of the forest product industries regarding the amount of timber and other wood fiber produced in Texas and processed at each facility during 1976.

Forest product and harvesting trends in Texas for the period 1972-1976 are presented in Figure 3. 1976 totals for all products represented increases over the 1975 totals. However, the 1976 figures, with the exception of veneer logs, were less than that experienced during 1974, a year which saw the highest demand for forest products in recent years. The production of forest products in 1973 fell below that seen in 1974 but the 1973 totals, with the exception of sawlog production, were above the base year totals of 1972. Generally, the trend in the production of forest products has been on the upswing over the period 1972 to 1976. From year to year, however, fluctuations occur principally because of increases or decreases in the construction of apartments, single-family dwellings and non-industrial facilities. Construction activity was relatively low during 1973 and 1975 because of unfavorable interest rates and consumer expectations. 1976 saw a more favorable situation with regard to interest rates and, thus, construction and production of forest products began to rise.

Tables 8 and 9 indicate the actual 1976 harvest of pulpwood and sawlogs respectively, by county. Pine roundwood production accounts for slightly more than half of all wood fiber used for pulp production in Texas. In 1976, pine roundwood production decreased by 69,000 cords from the level achieved in 1975. Several mills increased their use of hardwoods, which resulted in a 37 percent increase in Texas hardwood roundwood production.

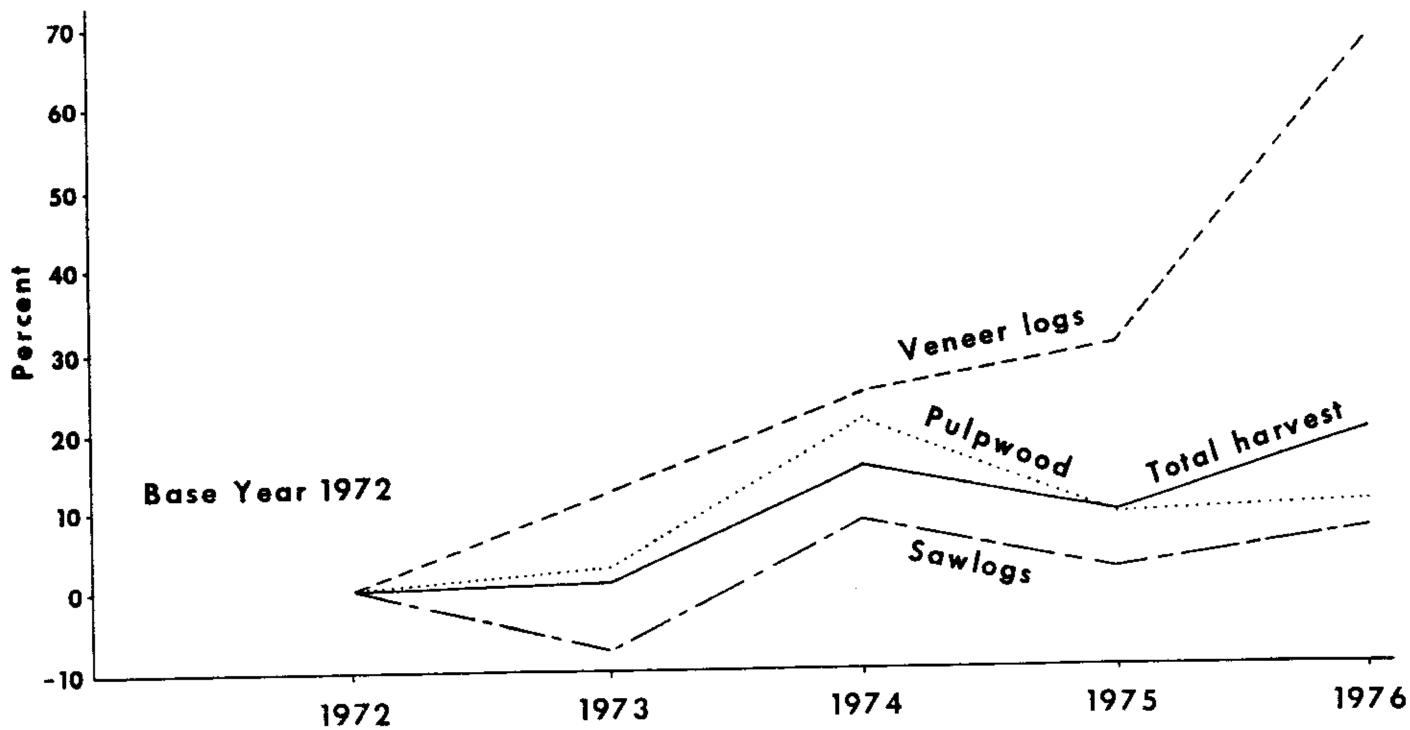

Figure 3 . Forest Product and Harvest Trends 1972-1976.
(Barron, 1977).

Table 8. Sawlog Production by County, 1976.[1]

County	All Species	Softwood	Hardwood
	---------------thousand board feet---------------		
Anderson	23,780	17,059	6,721
Angelina	48,240	37,257	10,983
Bowie	9,335	6,683	2,652
Camp	3,968	1,467	2,501
Cass	38,523	29,528	8,995
Chambers	1,674	1,674	0
Cherokee	37,145	31,701	5,444
Gregg	9,630	9,243	387
Grimes	4,020	4,020	0
Hardin	51,088	32,353	18,735
Harris	6,094	6,094	0
Harrison	17,958	14,083	3,875
Houston	42,938	42,803	135
Jasper	68,315	58,150	10,165
Leon	1,367	627	740
Liberty	55,356	51,605	3,751
Marion	22,719	19,191	3,528
Montgomery	39,861	39,146	715
Morris	8,373	6,443	1,930
Nacogdoches	21,914	18,503	3,411
Newton	40,576	36,424	4,152
Orange	15,347	12,154	3,193
Panola	40,574	36,033	4,541
Polk	76,932	75,173	1,759
Red River	29,467	25,360	4,107
Rusk	33,274	24,569	8,705
Sabine	19,573	19,050	523
San Augustine	16,786	15,936	850
San Jacinto	31,146	29,663	1,483
Shelby	44,299	42,279	2,020
Smith	11,342	8,305	3,037
Titus	3,782	1,749	2,033
Trinity	21,533	18,389	3,144
Tyler	56,193	40,645	15,548
Upshur	20,570	15,208	5,362
Walker	25,326	25,326	0
Wood	8,273	5,488	2,785
Other Counties	5,487	847	4,640
All Counties	1,012,778	860,228	152,550

[1] Barron, 1977.

Table 9. Round Pulpwood Production by County, 1976.[1]

County	All Species	Softwood	Hardwood
	----------	standard cords	----------
Anderson	26,049	24,520	1,529
Angelina	84,723	76,061	8,662
Bowie	47,990	31,911	16,079
Camp	32,510	29,703	2,807
Cass	123,771	90,615	33,156
Chambers	2,004	1,707	297
Cherokee	106,779	96,319	10,460
Franklin	1,554	1,088	466
Gregg	35,457	31,713	3,744
Grimes	9,789	9,662	127
Hardin	79,533	58,891	20,642
Harris	8,424	4,927	3,497
Harrison	143,596	130,252	13,344
Houston	66,785	55,770	11,015
Jasper	126,294	99,981	26,313
Jefferson	13,022	4,518	8,504
Leon	32	23	9
Liberty	56,639	44,329	12,310
Marion	88,137	66,426	21,711
Montgomery	54,783	48,709	6,074
Morris	22,051	17,413	4,638
Nacogdoches	86,740	72,632	14,108
Newton	94,913	58,291	36,622
Orange	10,205	7,283	2,922
Panola	97,930	89,207	8,723
Polk	130,321	104,697	25,624
Red River	14,366	7,917	6,449
Rusk	57,417	44,898	12,519
Sabine	34,478	27,783	6,695
San Augustine	79,547	60,749	18,798
San Jacinto	35,495	32,223	3,272
Shelby	162,415	140,340	22,075
Smith	52,862	51,477	1,385
Titus	5,890	5,721	169
Trinity	183,590	176,874	6,716
Tyler	110,151	92,489	17,662
Upshur	41,776	38,796	2,980
Walker	38,846	30,376	8,470
Waller	27	27	0
Wood	18,056	15,418	2,638
Other Counties	714	213	501
All Counties	2,385,661	1,981,949	403,712

[1] Barron, 1977.

Texas lumber production climbed in 1976 to 990 million board feet which is near the record set in 1972. The 1976 production represents a 16 percent increase over the preceding year. Total pine production was up 20 percent from 1975, but hardwood fell slightly. 1977 is forecast as a year of more housing starts than experienced in 1976, thus, sawlog production should likewise increase.

Pulpmills, sawmills and plywood plants were the major consumers of wood during 1976. A total of 170 Texas mills used 435 million cubic feet of roundwood and 83 million cubic feet of chips and sawdust to produce wood products. This does not include wood fiber used to make particle board or wood residues used for fuel. Wood treating plants and other wood-using industries also received timber harvested in Texas during 1976. These other industries manufacture charcoal, cedar products, and other specialty items. Texas was a net exporter of 30.4 million cubic feet of raw wood in 1976, or a volume equal to 6 percent of the total harvest. A map depicting the location of the primary wood using plants that utilized Texas timber in 1976 is presented in Figure 4.

Predictions made at the beginning of this year suggest a growth in the national economy during 1977 of the magnitude of 5.5 percent in real GNP and 1.76 million units in housing starts. Reasons given for increased building construction in 1977 include strong deposit growth at savings banks, commercial banks, insurance companies and pension funds, and a decline in interest rates. The coming year should provide more stimulus for production of building products due to increases in housing starts. Pulp and paper production should show considerable increases in 1977 as a result of continued general economic growth.

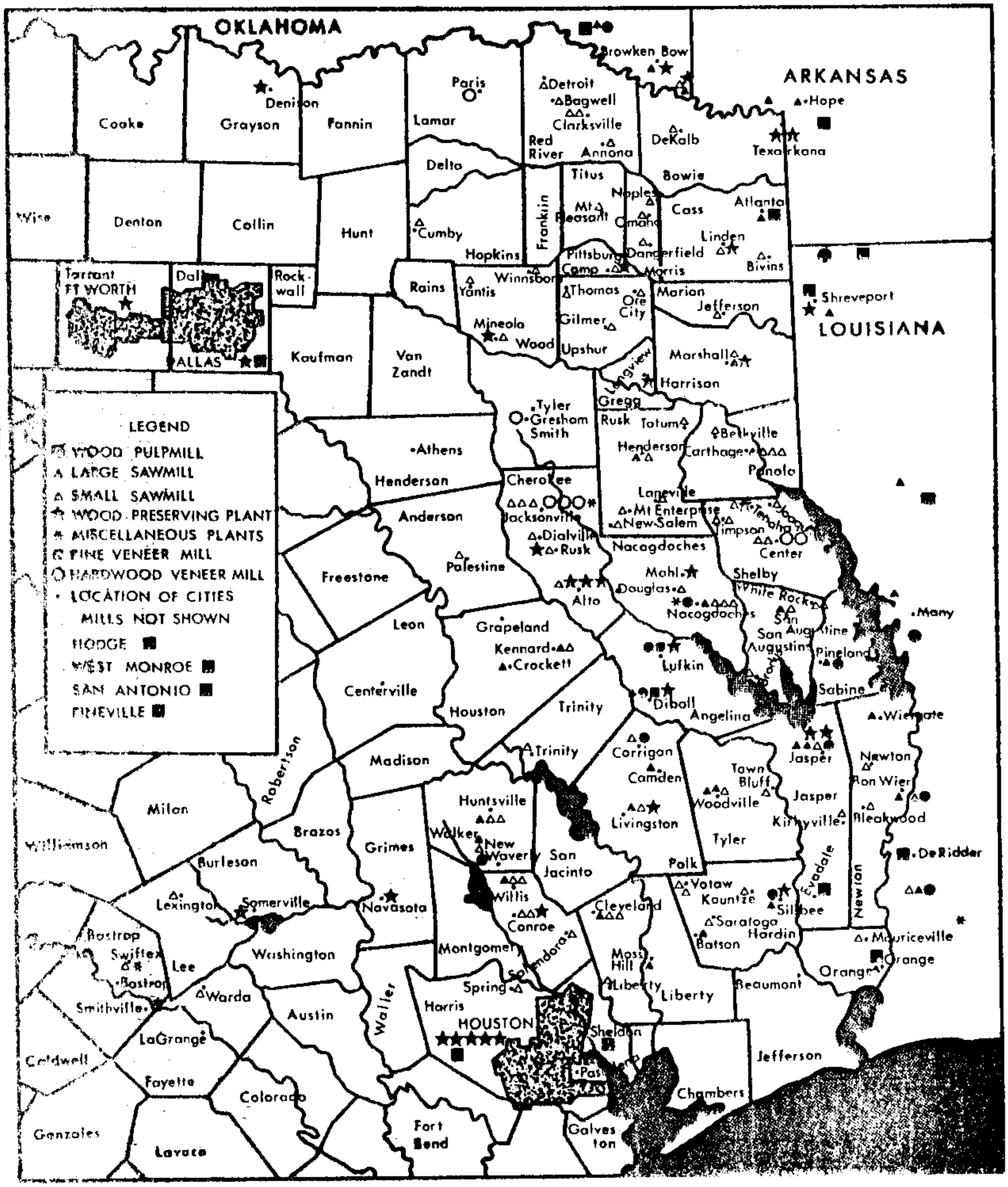

Figure 4. Primary Wood Using Plants That Utilized Texas Timber in 1976. (Barron, 1977).

SILVICULTURAL PRACTICES AND NON-POINT SOURCES OF POLLUTION

Introduction

Silviculture encompasses several interrelated forestry practices, each of which may have an impact on water quality. These practices are divergent in nature, consequently the following discussion will isolate each one and treat it independently. Within each section the nature of the practice, the extent to which it is employed in Texas, and its potential water quality impacts are considered.

Information concerning the extent to which each practice is used in Texas was gathered from questionnaires distributed to industry and governmental representatives involved in East Texas forestry. Information about the potential water quality impacts is the culmination of an extensive literature review coupled with the authors' estimation as to the relevance of the various studies to Texas. Five potential types of nonpoint source parameters are considered in this review - sediment, nutrients, organics, temperature, and introduced chemicals.

Forest Ownership

As a point of departure, it is essential to identify the three forest ownership classes in East Texas and to briefly consider what their forest management objectives are. The first, forest industry, owns 35 percent of the commercial forest which amounts to about 3,750,600 acres. Additional acreage is controlled under long-term lease agreements and through cooperative management agreements with non-industrial private forest landowners. Their land is concentrated mainly in southeast Texas and includes forests managed on a continuous basis primarily as a raw material base for their manufacturing facilities.

Private non-industrial forest land represents over 60 percent of the forested area of Texas. Most of the landowners in this category own an average of 100 acres or less. There are no accurate estimates on the number of private non-industrial forest landowners, but it could exceed 400,000. Also, many of these people have their residences away from their forested property in places such as Houston and Beaumont.

It has been one of the goals of the forestry profession to encourage better management on non-industrial lands in order to increase wood fiber production. However, for several reasons, the small landowner is not always responsive: (1) he may feel that growing trees commercially would not be a profitable investment, (2) he may feel that growing trees is not compatible with his primary ownership objectives, and (3) he typically lacks any technical knowledge about forest management. It is estimated that only about 20 percent of the private non-industrial forest landowners in East Texas practice some form of continuous forest management. Regarding these owners, pines as opposed to hardwoods are the preferred species.

Public forest ownership in Texas includes four state forests managed by the Texas Forest Service, four national forests managed by the U. S. Forest Service, and various nurseries and orchards. The amount of land managed by the Texas Forest Service (7,512 acres owned and 1,927 acres leased) is small compared to the amount of land managed by the U. S. Forest Service (661,280 acres). Thus, information describing public forest management practices will emphasize those practices used by the U. S. Forest Service.

Water Quality Parameters

Sediment

Sediment is defined as solid material, both mineral and organic, that has been eroded from its original source by water, wind, ice, or some other geologic agent and is being transported or has come to rest on the earth's surface (Soil Conservation Society of America, 1970).

Erosion that occurs under natural environmental conditions of climate and vegetation, undisturbed by man, is called geological, natural, or normal erosion. Estimates of annual rates of geologic deposition in the United States range from less than 0.30 to 0.70 tons per acre (Menard, 1961; Smith and Stamey, 1965). The more rapid erosion that is primarily a result of activities of man is called accelerated erosion (Soil Conservation Society of America, 1970).

There are three basic types of erosion on forested watersheds. Surface erosion is the detachment and removal of individual soil particles or small aggregates from the land surface. It results in sheet erosion, rills, and gullies, and is caused by the action of raindrops, thin film flow, or concentrated surface runoff over the watersheds. Mass movement, such as landslides and slumps, is an important form of erosion in mountainous country. Channel cutting or the detachment and movement of material from a stream channel, may result in the movement of individual particles, as the grains of shifting sandbars, or in mass movement, as when a large part of an under cut bank may fall and be swept downstream in a flood (Satterlund, 1972). Sediment produced as a result of erosion may be deposited in places other than a stream.

Sediment concentrations in rivers of the United States range from 200 to 50,000 parts per million (Glymph and Carson, 1968). The amount of sediment moved by flowing water has been reported to average at least 4 billion tons per year, with about one billion tons reaching major streams (Freeman and Bennett, 1969). Estimates ascribe about 30 percent of this country's total sediment to geologic erosion and about 50 percent to erosion of agricultural lands (Wadleigh, 1968).

Although sediment is a natural component of fresh water and many streams in Texas naturally have fairly high concentrations of sediment, large man caused increases may impair the beneficial use of water by: (1) carrying plant nutrients and forest chemicals, (2) adversely affecting the aquatic environment, (3) reducing the recreational value, and (4) increasing water treatment costs (Holt, Johnson, and McDowell, 1973; Stanford, England, and Taylor, 1970; Satterlünd, 1972). The impacts of increased sediment on the beneficial use of water in East Texas are not well documented with research.

Nutrients

Undisturbed forested watersheds are primary sources of high-quality water (Satterlund, 1972; Corbett et al., 1975). Mineral and organic nutrients continually enter the forest soil by: (1) decomposition and weathering of mineral rock; (2) atmospheric inputs; and 3) biological inputs. Nutrients are continually lost from the soil in an undisturbed forest by: 1) natural soil erosion, 2) leaching of dissolved nutrients; 3) uptake into plants, and 4) volatilization to the atmosphere by fire. This process results in a small outflow of nutrients from the forest to the sea. The amount of nutrients leaving a watershed fluctuates constantly in response to natural stress, but is subject to additional losses resulting from timber harvesting and residue removal or treatment (Moore and Norris, 1974; Corbett et al., 1975). The quantity of nutrients in streams evidently increases when the rate of decomposition of residues exceeds the uptake by vegetation and the exchange capacity of the soil (Rothacher and Lopushinsky, 1974). The results from five small undisturbed watersheds of loblolly pine, planted to control erosion in northern Mississippi, showed that the annual inputs from rainfall and dry fallout of nitrate and ammonia nitrogen, inorganic phosphate, calcium, and potassium exceeded the losses as dissolved constituents in intermittent stormflows (Ursic, 1974).

There is relatively little data available concerning nutrients in undisturbed forested watersheds in Texas. Examples used pertain mainly to areas outside the State. However, one environmental impact study does provide some insight into the nutrient status of East Texas forested areas. In the Blue Hills Nuclear Power Plant Experimental Study, by Inglis, Irby, and Moehring (1973), data was collected concerning nutrients from three relatively undisturbed areas in East Texas. Nitrate-, nitrite-, ammonia-nitrogen, orthophosphate, total inorganic phosphate, sulfate, and chloride concentrations. were studied in streams running through these areas. Nitrite-nitrogen values were very low at all stations ranging from 0.00 to 0.07 mg/l with the majority being 0.00. Nitrate-nitrogen concentrations ranged from 0.00 to 1.00 mg/l. The unusually high values at one sampling point were due to occasional fertilizer runoff. Concentrations of ammonia varied from 0.00 to 2.00 mg/l. Orthophosphate concentrations ranged from a low of 0.03 to a high of 0.15 mg/l. There was a tendency for higher values at stations with greater discharge. Total inorganic phosphates followed trends similar to those for orthophosphate. Concentrations varied from 4 to 7 mg/l. Chloride concentrations were similar for all stream stations. Stream concentrations seemed to be connected to rainfall. Apparently, chloride was washed into the stream during times of higher discharge which made the concentrations per unit volume of water lower. When the discharge of the stream subsequently dissipated, the chloride concentrations per volume of water increased. Chloride concentrations ranged from 0.00 to 15 mg/l, with the majority of samples between 5 and 10 mg/l.

There have been many studies done concerning nutrient levels from forested watersheds outside Texas. Likens et al. (1970) reported pretreatment maximum concentrations of nitrate-nitrogen to be 0.5 mg/l at the Hubbard Brook Experimental Forest in New Hampshire. In a West Virginia study where a 33-66 ft. wide buffer strip was left after harvesting, nitrate-nitrogen levels in stream-water following harvesting varied from 0.18 mg/l to 0.49 mg/l. Phosphate concentration increased while sulfate concentrations decreased. There were negligible changes in calcium, magnesium, sodium, potassium, iron, copper, zinc, manganese, and ammonium-nitrogen (Aubertin and Patric, 1972). It seems apparent that even after harvesting, if a buffer strip is left bordering a stream and the area is revegetated rapidly, nutrient concentrations are increased only slightly if at all. Douglass and Swank (1975) also reported nitrate-nitrogen levels from undisturbed forested watersheds in North Carolina to be 0.002 to 0.013 mg/l.

According to the U. S. Environmental Protection Agency's "Quality Criteria for Water" (1976), nitrate-nitrogen concentrations above 10 mg/l may be hazardous for human use. Ammonia is a compound present in most waters as a normal biological degradation product of nitrogenous organic matter. The toxicity of ammonia is very much dependent upon pH as well as the concentration of total ammonia. A standard of 0.002 mg/l of un-ionized ammonia has been set in order to protect the most sensitive freshwater aquatic life. Total phosphate concentrations should not exceed 0.05 mg/l in any stream at the point where it enters any lake or reservoir. Total residual chlorine concentrations should not exceed 0.01 mg/l in order to protect freshwater and marine organisms. However, EPA points out that chlorine is not a natural constituent of water. Free available chlorine (HOCl and OCl^-) and combined available chlorine (Mono- and di-chloramines) appear transiently in surface or ground waters as a result of disinfection of domestic sewage or from industrial processes that use chlorine for bleaching operations or to control organisms that grow in cooling water systems. Limits set for sulfide were 0.002 mg/l undissociated H_2S for fish and other aquatic life (fresh and marine water). Hydrogen sulfide is a biologically active compound that is found primarily as an anaerobic degradation product of both organic sulfur compounds and organic sulfates. Sulfides are constituents of many industrial wastes such as those from tanneries, paper mills, chemical plants, and gas works.

Undisturbed forests should never yield nutrient concentrations greater than those presently proposed as standards by the U. S. Environmental Protection Agency. However, Duffy et al. (1978)[1/] measured some phosphorus concentrations from undisturbed forested watersheds in Northern Mississippi that approached EPA Standards.

Stream Temperature

The temperature of small headwater streams of forested areas is an important determinant of overall water quality. Temperature acts not only to control the metabolic rates and functions of stream flora and fauna but also serves to maintain community structure. Without a fairly consistent temperature pattern in a stream, species composition begins to change. In particular, microorganisms at the base of the food chain may be directly affected; if this occurs, eventually all higher organisms in the food pyramid will also be affected by changes in microbial populations.

Increased water temperature can be either beneficial or detrimental. For streams that are cooler than optimum, a moderate increase in temperature could increase productivity and have a beneficial effect on the aquatic environment. However, streams having temperatures that approach critical threshold limits

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1/ Duffy, P. D., J. D. Schreiber, D. C. McClurkin, and L. L. McDowell. 1978. Aqueous- and sediment-phase phosphorus yields from five Southern pine watersheds. Accepted for publication in J. En. Quality.

during the summer months may be increased beyond these thresholds; the result could be detrimental to aquatic organisms.

Removal of shading vegetation as a result of timber harvesting increases stream temperatures because of increased exposure of solar radiation. The magnitude of the impact is a function of percentage of canopy removed, length of time of full exposure, streambed material, area exposed, discharge, and initial temperature.

Increased stream temperatures that occur naturally or as a result of man's activities can affect fish populations in several ways, many of which are detrimental. For example, high temperature kills fish directly, decreases the dissolved oxygen concentration, increases the susceptibility of fish to disease by increasing bacteriological activity, affects the quantity of food available, and alters the feeding activities of fish (USDA, Forest Service, 1977).

Dissolved Oxygen/Organic Matter

Like temperature, dissolved oxygen is an element critical for the existence of a healthy stream environment. Dissolved oxygen concentrations in small forest streams help to determine the character and productivity of the aquatic ecosystem in that fish and other aquatic organisms are dependent on it for survival, growth and development.

Forest practices can potentially reduce the concentration of dissolved oxygen present in the water below the lethal limit for some aquatic species. Such practices do this by increasing the amount of organic matter entering the stream, by increasing water temperature (USDA, Forest Service, 1977), and in some cases, by the addition of high nitrogen and phosphorus concentrations which stimulate growth of organisms that use oxygen.

Introduced Chemicals

Fertilization - Introduced nutrients enter a watercourse by direct application of the fertilizer to the water surface or by leaching and subsequent subsurface flow of dissolved compounds or decomposition products. The potential for direct application of fertilizer to a water surface is normally restricted to aerial applications. Inputs of fertilizers directly to water surfaces can be minimized or eliminated by ground applications. Almost all of the fertilizer applied to a site reaches the forest floor with no appreciable loss due to volatilization or interception by forest canopy, assuming the canopy is dry and the fertilizer is in granular or pellet form. If the fertilizer is applied as a powder or sprayed as a liquid, considerable loss to volatilization and interception is possible.

Once on the forest floor there is normally no loss of fertilizer via overland flow. As discussed in Appendix I, Hydrology, it can be assumed that there will be no overland flow from an undisturbed forest or for a disturbed forest that has a developed organic layer. Surface flow will occur only on roads, skid trails, landings, and other compacted areas with exposed mineral soil. However, fertilizers might be a problem if applied following drastic site preparation that causes subsequent overland flow.

The form of nitrogen applied determines to a large extent the amount of nitrogen that will be leached from the site and enter a watercourse. It is generally acknowledged that urea is retained in the upper soil horizons while less ammonium nitrogen is retained. Nitrate-nitrogen is quite mobile and susceptible to being leached from the rooting zone. Phosphorus, however, is readily utilized or fixed and only insignificant quantities are lost from the treated area by leaching (USDA, Forest Service, 1977).

Pesticides - Pesticides are defined as chemical or biological agents used to control or modify pests. Those most commonly used in forest management are herbicides and insecticides; however, fungicides and rodenticides may be used. Their impact on water quality depends primarily on four factors: 1) mobility, 2) persistence, 3) accuracy of placement, and 4) orientation to streams. Research findings and long history of use have established that most forest chemicals offer minimum potential for pollution of the aquatic environment when they are used properly (Norris and Moore, 1976).

Herbicides are commonly used in forest management to control undesirable vegetation. Some other minor uses in the forest environment are to control vegetation along roads or rights-of-way, to maintain wildlife habitats, to control aquatic vegetation, and for vegetation manipulation along riparian zones. Phenoxy herbicides (especially 2,4-D and 2,4,5-T) are most frequently applied to control broad-leaved plants. Less selective herbicides such as atrazine, picloram, and arsenicals are also used. Most herbicides do not biomagnify (USDA, Forest Service, 1977).

Insecticide use on forest lands has been tightly regulated in recent years. Insecticides most commonly used are the various organo-phosphates and carbonates. Both groups involve a very large number of compounds with a wide variation in toxicity, persistence, and mobility. Generally most of these compounds are relatively immobile and short lived. Chlorinated hydrocarbons, however, are strictly regulated because of their persistence, toxicity and biomagnification in aquatic systems. Chlorinated hydrocarbons are no longer used except in rare instances, and then only after U. S. Environmental Protection Agency approval.

Fungicides, including carbonates which are considered relatively safe, are not commonly used in forest management. Their greatest impact on water quality may be in their possible effect on microbial activity and subsequent chemical transformations.

Rodenticides, like fungicides, are not generally used in forest management. Presently, only endrin is in use to prevent damage during reforestation efforts. Endrin is applied to seeds in a concentration of 0.5 percent of seed weight; the seeds are then aerially distributed at the rate of one-half to one pound per acre (3 to 6 gm/ha). Endrin has been recovered from streams after such applications at a maximum concentration of 0.070 ppb, decreasing to the detection limit of 0.001 ppb in 10 days. In general, aerially applied rodenticides do not constitute an appreciable toxic hazard to aquatic systems or water supplies (USDA, Forest Service, 1977).

Pesticides that are registered and used as prescribed by federal and state law should result in no significant impact to the aquatic environment.

Access Systems

Description of Practices

Management of a forest usually begins with the development of a road system to provide access to the forest property. As management activities intensify the road network expands. Road systems are basically of two types. All-weather roads are roads with some system of maintenance, designed according to engineering specifications encompassing specific drainage and surfacing characteristics. Temporary access roads are roads not intended for all-weather use, designed with minimum engineering specifications for drainage and surfacing and little or no provisions for maintenance.

Planning is logically the first step that is undertaken when initiating or extending forest access systems. During this process, the location, size, type, and purpose of the road is determined. The next phase of operation is on-the-ground construction. Road construction includes preparation of the planned road right-of-way and involves among other things, cutting and filling slopes, terracing, grading, outsloping and insloping. Drainage devices must also be installed to prevent concentration of water and to disperse water onto stabilized land areas. Drainage measures include dips, water bars, cross drains, variations in grade and slope, ditches and culverts; fords, culverts, and bridges are needed where access systems cross streams. Upon completion of the road a maintenance program is usually in order for all permanent roads. Maintenance duties may include inspection and repair of drainage systems, cut and embankment slopes, and road surfaces.

State-of-the-Art in Texas

Within this section, a discussion is presented concerning permanent and temporary access roads as they are dealt with by forest landholders in East Texas. Forest landholders have been divided into three ownership classes: 1.) industrial, 2.) private non-industrial, and 3.) public. With regard to the industrial ownership class, the discussion will distinguish between the practices applied on 1.) land held in fee-simple, 2.) land held under cooperative management agreements, and 3.) land held under long-term leases.

On industrially held forestlands it is estimated that approximately 255 miles per year of permanent access roads are built on lands in fee simple ownership; 5 miles per year on land held under long-term lease; and 5 miles per year on land held under cooperative management agreement. Construction of these roads is accomplished primarily by forest industry personnel. Costs of constructing permanent roads range from about $5,700/mile in the flatwoods to $6,300/mile in upland areas. In all three management categories, the company engineers or foresters supervise road location and construction. On land in fee simple ownership, an on-site engineering or location survey is normally carried out before road construction begins. However, on lands held under long-term lease or cooperative management agreement, this on-site activity is not usually employed. In those instances where an engineering or location survey is conducted, factors such as drainage characteristics of the site, soil characteristics, and expected traffic are considered. On lands under fee simple ownership, an attempt is usually made to locate roads on ridges or at least along the contour of the landscape. However, this practice is not used as frequently on lands held under lease or management agreement. In all cases, road surfaces are usually crowned or outsloped; activity is minimized in stream channels and wet areas; and culverts or bridges are installed at water crossings. Roadside buffer strips are used in some situations, but cut and fill areas associated with roads are seldom seeded to grass to minimize soil movement. The need for road maintenance is usually determined by an annual inspection. Maintenance usually includes regrading road surfaces and opening drainage ditches.

It is estimated that about 1,540 miles of temporary access roads are built each year on lands under fee-simple ownership. On lands held under lease or management agreement the figures are 20 miles and 43 miles, respectively. There is usually little supervision provided in locating and constructing these roads. Also, little effort is made to minimize soil loss.

It is estimated that, on publicly-held forest lands, approximately 20 miles of permanent access roads are built each year. This small figure results from the fact that the system of permanent access roads is already well established and few additional roads need to be constructed. Construction of permanent roads is done almost entirely by private contractors. Construction costs range from about $35,000/mile in upland areas to $45,000/mile in the flatwoods area of Southeast Texas. Supervision of location and construction is done by U.S. Forest Service or Texas Forest Service personnel. Before road construction begins, an on-site engineering or location survey is conducted. Factors such as drainage characteristics, soil characteristics, and expected traffic are considered in determining road location. In addition, an attempt is usually made to locate roads on ridgetops. When ridgetops are not utilized, roads are oriented along the contour of the terrain. In terms of construction standards, road surfaces are always crowned or outsloped. Bridges or culverts are installed whenever a road intersects a stream channel. Cut and fill slopes are always seeded to grass to minimize erosion. Roadside buffer strips are usually used to filter out any sediment that might be emitted from the roads. Finally, the need for maintenance is usually determined by an annual road inspection by Texas Forest Service or U.S. Forest Service personnel. Road maintenance activities usually include regrading road surfaces and opening drainage ditches.

It is estimated that about 2,500 miles of temporary access roads are built annually on public forest lands in East Texas. Standards for temporary road construction (on USFS lands) are a part of the sales contract and each location is approved and flagged by a Forest Officer prior to construction. In most cases a sales administrator is present during construction. After completion of a timber harvest operation, the following actions are normally taken: (1) water bars are constructed across road surfaces, (2) traffic is restricted, and (3) road surfaces are seeded with grass.

Estimates of the mileage of permanent and temporary access roads constructed each year on that portion of the forest land base which is held by private non-industrial owners are simply not available. Some portion of this road construction activity is reflected in the figures reported by industry for those lands which it manages under long-term lease or cooperative management agreement -- but exactly what portion is being accounted for is unknown.

Potential Environmental Impacts

Sediment

Most of the literature and research concerning the impacts of roads on sediment production has originated from the mountainous regions of the West and Northeast. The limited research which has been done in the Southeast pertains mostly to the mountain regions of North Carolina and Virginia. The extent to which such findings apply to the relatively level forests of East Texas remains to be determined by future research. This fact should be kept in mind as the material on access systems is reviewed.

Access systems, both permanent and temporary, will increase surface erosion by baring soil and concentrating runoff. Road construction removes all forest litter, and this, coupled with the soil compaction that can result from using heavy equipment reduces the infiltration rate. Thus, water can collect on the road surface and run over exposed soils, carrying with it loosened soil particles (Kochenderfer, 1970). The casting of road fills also exposes large quantities of soil to potential erosion by rain drop impact and increased surface runoff (Packer, 1967). Road construction activities can also accentuate the problem of mass wasting of slopes. While this may be a concern in some areas, it is not considered to be a problem in East Texas because of the gentle terrain.

Considerable evidence from the Northwest suggests that roads are the primary source of accelerated erosion and sediment caused by silvicultural activities. To illustrate, Packer and Christensen (1964) found that in a mountainous region of Idaho, as much as 90 percent of the sediment produced by erosion on timber sale areas came from roads. Also in a mountainous region of Idaho, Megahan and Kidd (1972) reported that sediment produced by surface erosion from roads was 200 times greater than yield from undisturbed areas.

These results are in rather dramatic contrast with the admittedly limited evidence which is available for conditions in the Piedmont and Coastal Plain regions of the southeast. This is reflected by the data in Table 10.

Evidence from those studies which have been conducted indicates that the magnitude of the sediment problems which can result from road construction activities can be significantly influenced by a number of variables which are at least partially subject to human control. These variables include road location; road design standards, particularly those relating to drainage facilities; measures taken to stabilize exposed areas; and the frequency of maintenance activities.

An analysis of the sediment yields observed following logging road construction on three Zena Creek watersheds in Idaho, with those observed following the construction of truck haul roads on the H. J. Andrews Experimental Forest in western Oregon, provides a good illustration of the need to consider proper road location and design. On the Zena Creek watersheds, sediment yields of 12,400, 8,900, and 89 tons per square mile were observed following road construction (Copeland, 1963). Furthermore, relatively high sediment levels persisted for several years. In contrast, on the H. J. Andrews Experimental Forest, stream turbidity increased from a previous 6 year maximum of 200 ppm to a level of 1,780 ppm following road construction (USDA, Forest Service, 1961). While this is a substantial increase, in this instance sediment yields are being expressed in terms of only parts per million instead of tons per square mile. In addition, at H. J. Andrews, sediment yields returned to predisturbance levels within two years.

The primary reason for the observed difference in the amount of sediment that was produced in these two cases appears to be the attention that was given to determining proper road location and design. The roads at Zena Creek were

TABLE 10: Approximate impacts of selected forest management activities upon average annual suspended sediment (Dissmeyer, 1972)

Forest Management Activity	Rotation-Years 6/			
	20	30	40	60
	ppm	ppm	ppm	ppm
Mechanical Site Preparation 1/	1109	739	555	370
Fire	55 2/	36 2/	41 3/	27 3/
Thinning	Trace	Trace	Trace	Trace
No Recent Activity	Trace	Trace	Trace	Trace
Harvest Cut	1	1	1	1
Skid Trails	18	11	9	20 5/
Spur Roads 4/	2	1	1	5 5/
Total	1185	788	607	423

1/ Site prepared using KG Blade and Windrowing debris, exposing 85% mineral soil.

2/ Two burns during rotation.

3/ Three burns during rotation.

4/ Temporary truck trails abandoned after logging.

5/ Harvesting sawlogs results in more skid trails and spur roads, therefore the approximated impact is higher than in shorter rotations.

6/ As the forest rotation becomes shorter, the impacts are increased because disturbances become more frequent and occupy a larger portion of the watershed.

built across steep slopes on highly erodible soils. Drainage facilities were inadequate. By comparison, the roads at H. J. Andrews were built on gentler topography and more stable soils. They were also carefully located away from streams and they were properly drained.

Determination of proper road location and design is largely a product of good planning. The consequence of improper planning can be a road which is longer than necessary, which traverses areas which are too steep and/or unstable, which is located too close to streams, or which makes an excessive number of stream crossings.

A route reconnaissance should be conducted in order to provide necessary data to the planning process. This entails examining the entire area surrounding the proposed road project. Alternative routes can be identified and their relative merits in terms of economics, service and ecological impact, can be assessed. It is at the planning and reconnaissance level that first evaluations of soil erodibility, and the potential for sediment transport can be made. The amount of individual talent required for a reconnaissance will vary with the extent of the proposed road, the relative sensitivity of the area, the knowledge of the personnel, and the amount of data already available (EPA, 1975). Failure to consider all route alternatives may result in future excessive costs far beyond any savings effected by not accomplishing a complete reconnaissance (USDI, BLM, 1962) According to Kidd and Kochenderfer (1973), proper road location is the key to: 1) minimum soil erosion, 2) more efficient logging operations, 3) less wear and tear on equipment, and 4) lower operating costs.

Road construction necessitates exposure of bare soil, and in mountainous or hilly terrain or areas of highly erodable soil the amount of soil exposed can be substantial because of cut and fill areas. In such situations, even if a road is properly located, erosion can still be a problem is no measures are taken to stabilize the exposed areas. Slope stabilization in these extreme areas can be accomplished by various means such as seeding, mulching and/or mechanical devices. These various methods work to reduce erosion by reducing the velocity of surface runoff, by increasing infiltration, and by minimizing the impact of raindrops.

In the Northwest, Dyrness (1970) studied soil stabilizing treatments consisting of various combinations of seeding, fertilizing, mulching, and surface netting. He found that soil losses were greatest from those treatments that did not include a straw mulch. A further study by Bethlahmy and Kidd (1966) showed that in the Intermountain region, most erosion on fill slopes occurred during the first 3 months; thereafter, erosion declined markedly as the seeded slopes became revegetated (Table 11). Larse (1970) has summarized the conditions needed to achieve the best results when seeding slopes in the Northwest:

1. Properly condition the slope to provide a seedbed.
2. Seed as soon as possible after disturbance.
3. Use seed adapted to the site.
4. Seed at the optimum time for establishment.
5. Use proper types and amounts of fertilizers.
6. Mulch as needed.
7. Periodically refertilize.

The positive environmental impacts of precautions exercised during road construction can be off-set if permanent roads are not periodically maintained. Larse (1970) has stated that a planned program of regular maintenance is necessary to preserve a road in its "as built" condition -- and if such maintenance is not performed, or if it is improperly performed, the result will be the deterioration of the road due to climatic erosive forces as well as use. Rothacher and Glazebrook (1968) indicate that failure or impairment of road drainage facilities can significantly increase erosion activity. Concentrations of water can be diverted directly onto road surfaces or adjacent fill slopes.

In conclusion to this discussion of the potential impacts of road construction on sediment production, it is perhaps appropriate to note that the situation in East Texas is such that most activities should not cause problems. The primary reasons are the gentler terrain and the rapid rate of natural revegetation.

Nutrients.

Nutrient losses are usually found to be associated with sediment, and will not be discussed separately.

Organics.

In some instances where roads are constructed adjacent to stream channels the organic loading could increase. Otherwise, road construction should have little or no effect on stream organics.

Temperature.

Shade removal as a result of stream crossings or other construction in the immediate vicinity of streams may influence stream temperature. However, unless a substantial segment of the stream is exposed, the temperature effect should be negligible because any increase will disappear as the water flows into shaded areas.

Introduced Chemicals.

Road construction should have no impact on introduced chemicals unless chemical surfacing compounds and/or soil stabilizers are carelessly applied on roads adjacent to streams.

TABLE 11. Comparison of cumulative erosion from treated plots on a steep road fill (in 1,000 lbs. per acre) (Bethlanmy and Kidd, 1966).

Cumulative elapsed time (days)	Cumulative precipitation	Control plot	Group A (seed, fertilizer)		Group B (seed, fertilizer, mulch)		Group C (seed, fertilizer, mulch, netting)	
			Plot number					
			2	4	3	8	5	6
17	1.41	31.9	38.7	38.0	0.1	32.6	0	0
80	4.71	70.0	99.2	85.7	7.4	34.6	0.9	0
157	12.46	72.2	100.2	86.9	11.1	35.1	1.1	0
200	15.25	79.1	101.0	97.6	11.4	35.7	1.1	0
255	17.02	82.3	102.8	88.8	11.5	35.8	1.1	0
322	20.40	84.2	104.7	89.4	11.9	36.0	1.1	0

Regeneration Systems

Description of Practices

A regeneration system is a technique for establishing a new forest stand. Such systems are of four types: the selection system, the shelterwood system, the seed tree system, and the clearcut system. The first three systems, while they involve only partial removal of the existing stand, represent increasingly heavy cuts. The last system, as the name implies, involves complete removal of the existing stand. It is appropriate to note that in areas where natural regeneration is used it is necessary to expose the mineral soil for the establishment of a new stand.

With the selection system, the mature timber is removed either as single scattered trees or in small groups. Such cuttings are repeated indefinitely with the deliberate purpose and effect of creating or maintaining an uneven-aged stand. The process depends on periodically establishing reproduction and making it free to grow so that new age classes are continually being established. The method is usually associated with natural reproduction, but there is no reason why planting or artificial seeding could not be used. True selection cutting is typically accomplished by cutting the older or largest trees. The seed and any protection necessary for natural reproduction is provided by the trees that remain around the openings (Smith, 1962).

The shelterwood method involves the gradual removal of the entire stand in a series of partial cuttings which extend over a fraction of the rotation. Natural reproduction starts under the protection of the older stand and is finally released when it becomes desirable to give the new crop full use of the growing space. The most fundamental characteristic of the shelterwood method is the establishment of a new crop before completion of the preceding rotation.

Within the framework of the shelterwood method, it is possible to achieve wide variation in the relative degrees of shelter and exposure both in space and time. Adjustments can be made to meet the environmental requirements of almost all species except those that are exceedingly intolerant of shade or root competition, such as southern pine. The shelterwood method represents an efficient use of growing stock. Space is made available for reproduction by cutting trees that no longer increase in value; trees left serve as a source of seed or protection for the new stand, and have the capacity to increase in value at an attractive rate. These two sets of objectives are readily combined because the trees of greatest quality are likely to be those that will provide the most seed and also grow most rapidly in value (Smith, 1962).

The seed tree system is so named because, following the harvest, certain seed trees are left standing, singly or in groups, for the purpose of furnishing seed to restock the area naturally. Only a small proportion of the original stand is left. After the new crop is established, these seed trees may be removed in a second cutting. The seed tree method is most applicable to even-aged stands in which all trees are of merchantable size. If natural regeneration is to be used, this method has an advantage over clearcutting in that there are fewer restrictions on the size and arrangement of cutting areas since adjacent stands are not relied upon as sources of seed. It has been used successfully in loblolly pine (Wahlenberg, 1960) and shortleaf pine (Liming, 1945; Dale, 1958).

Clearcutting is best applied in a forest having virtually all merchantable trees. Reproduction is by planting, direct seeding or by natural means. Clearcutting is often used since it allows for mechanical site preparation and planting of superior seed stock, thereby reducing the necessary rotation length and also creating more productive stands. This is made possible by the fact that southern pines respond well to this system since they are shade intolerant species capable of establishment on bare soils in direct sunlight.

When seeds from the area can be depended upon or when the area is to be planted, the system can be used freely. However, when seeding from adjacent areas, several precautions must be taken: 1) the area must not be too wide to be adequately seeded; 2) if the area cannot be counted upon to reproduce effectively in one year, plans should be made to delay cutting adjacent timber for some time (often ten years); and 3) successive cutting areas should be arranged with reference to slopes and roads so that there will be little skidding through young reproduction. In all instances, cutting areas should be arranged to minimize wind-throw (Baker, 1934).

State-of-the-Arts in Texas

Industrially controlled forestland in East Texas is managed primarily for pine pulpwood and/or sawtimber. Only about 12 percent is managed for hardwood pulpwood and/or sawtimber. Table 12 shows the estimated acreages of sawtimber and pulpwood size material which receive a final harvest cut each year by means of the various regeneration systems. The information is presented for each land management category. As indicated by the table, clearcutting is the predominant regeneration system. The average size of clearcuts for lands held under lease or management agreement are 25 and 40 acres respectively. However, clearcuts are often as large as 300 acres on lands under fee-simple ownership. Seed tree and shelterwood harvesting are done in limited amounts. Harvesting activities are carried out throughout the year, but about 66 percent is done between the months of March and August.

Table 12. Estimated acreage of sawtimber and pulpwood sized material annually receiving a final harvest cut on industrially managed forestland in East Texas, by regeneration system and land management category.

Regeneration System	Land in Fee Simple		Land Under Lease		Land Under Mgmt. Agreement	
	Sawtimber	Pulpwood	Sawtimber	Pulpwood	Sawtimber	Pulpwood
Clearcut	68,014	29,538	200	0	0	0
Seed tree	1,301	167	0	0	80	0
Shelterwood	700	0	500	0	500	0
Selection[1]	49,900	25,800	1,000	1,000	4,300	9,000

[1]The figure for selection cutting is exaggerated. Since the trend in forest industry is toward even-aged management, many areas that were selectively cut in the past will be clearcut in the future. In this sense, the figures reported for the selection system can be viewed as representing intermediate cuts made in the process of converting to the even-aged system.

Publicly owned forests in East Texas are managed for both pine and hardwood. On the national forests, about 70 percent of the area is managed with pine as the predominant species, and 30 percent with hardwoods as the predominant species. About 90 percent of the growing stock is utilized for sawtimber and 10 percent for pulpwood. The average size regeneration area is about 50 acres for pine and 25 acres for hardwoods. Clearcutting is the predominant harvesting system employed (3,500 acres/yr.). The seed tree and shelterwood regeneration systems are used in limited amounts (1,500-2,000 acres/yr.). In addition, about 30,000 acres are annually thinned. Generally, harvesting of trees is carried on during all months of the year. However, about 60 percent is done between March and August. (Note: these figures do not take into account the current court imposed restrictions on timber cutting on national forest lands).

In harvesting private non-industrial land, approximately 65 percent of the trees are utilized for sawtimber and the remainder for pulpwood. Each year, it is estimated that 104,000 acres of trees are harvested for sawtimber and another 52,000 acres for pulpwood. Again, the predominant regeneration system is clearcutting. The selection and seed tree systems are also employed, but in limited amounts. The average size clearcut area is about 60 acres.

Approximately 353,500 acres of trees are harvested in East Texas each year (Table 13). Of these acres it is estimated that 192,768 are clearcut, 127,413 are selectively harvested and 32,919 are harvested by the seed tree and shelterwood systems. As a comparison, irrigated and dry field cropland in Texas is estimated to be 27,185,784 acres and in the 37 East Texas Counties to be 538,307 acres (Texas Conservation Needs Committee, 1970). Thus in East Texas there is about twice as many acres in field crop agriculture as are being harvested for timber. Each year a different 353,500 acres are harvested for timber; whereas, approximately the same 538,307 acres in field crops are harvested each year. Forested areas are clearcut only about every 35 years and selective harvesting occurs every 10 to 15 years.

Table 13. Estimated acreage of sawtimber and pulpwood sized material annually receiving a final harvest cut on industrially, private non-industrially and publicly managed forestland in East Texas by regeneration system.

Regeneration System	Sawtimber	Pulpwood	Total
Clearcut	134,054	58,714	192,768
Seed tree	14,410	3,293	17,703
Shelterwood	12,090	3,126	15,216
Selection[1/]	74,941	52,872	127,413
Total	235,495	118,005	353,500

[1/] As noted in the footnote to the preceding table, the figures reported for the selection regeneration system largely relfect intermediate cuts.

Potential Environmental Impacts

Sediment

The effect of forest cutting on sediment production is determined by those factors associated with natural features of the watershed as well as land use practices. Some forest sites can undergo severe treatments with little increase in sediment production, while others produce large amounts of sediment after slight disturbance. This difference in hydrologic behavior can usually be attributed to differences in climate, geology, soils, and/or topography. Vegetation tends to balance these variations in ways that promote soil stability. Normal sediment production from undisturbed natural forests in the South is considered to be 13 pounds per-acre-inch of stormflow (Ursic, 1975).

From the outset, it should also be made clear that disturbances associated with forest cutting may be attributable to improper harvesting techniques, and the type of equipment used during harvesting (Campbell et al., 1973; Dickerson, 1968; Hatchel et al., 1970; Moehring and Rawls, 1970). While it's difficult to isolate the potential environmental impacts of timber cutting from those that result from the subsequent phases of a harvesting operation, it appears that except under very unusual conditions of soils and topography, timber cutting by itself should cause very few pollution problems. This fact should be kept in mind when reviewing the following material. It should also be kept in mind when reviewing whether or not to impose any limitations on the use of different regeneration systems.

The potential of forest cutting to increase sediment production appears to be related to two things: (1) removal of the timber stand exposes the forest floor to direct raindrop impact, and (2) the reduced evaporational and transpirational losses that accompany removal of the timber stand cause soils to reach their saturation levels more quickly. With regard to the first factor, Meyer and Monke (1965) point out that if an exposed area is not rapidly invaded by grasses or herbacious plants, direct raindrop impact can seal the soil surface, thus reducing infiltration and increasing overland flow and sediment yields. With regard to the second factor, numerous studies have shown that soil moisture increases following removal of forest vegetation (Metz and Douglass, 1959; Lull and Fletcher, 1962; Troendle, 1970). Areas of diminished cover, particularly those adjacent to streams, reach saturation soon after rainfall begins, causing overland flow and initiating sheet and rill erosion (Kirby and Chorley, 1967).

Few investigators have addressed partial regeneration systems, consequently specific information concerning sediment production in partial cuts is limited. However, Rothacher (1976) suggests that, in general, the larger the proportion of the forest removed in one operation, the greater the disturbance at that time.

Numerous investigators have studied the impacts of clearcutting on sediment production, but with variable results. For example, Harris (1977) reported an increase in sediment yield from clearcut watersheds in Oregon, of 181 percent over a seven-year post-harvesting period. By comparison, Brown and Krygier (1971) found that, on the Oregon coast, clearcutting alone did not produce significant increases in suspended sediment concentration at any time.

To further illustrate, the Eel River Basin of northern California has the highest rate of sediment yield of any basin of comparable size in the United States. Nonetheless, a 1966 study conducted on the Eel and Mad Rivers showed the suspended sediment in streams that was attributable to clearcut harvesting impacts, was no higher than that produced by the blacktailed deer residing in the watersheds. Nearly two thirds of the sediment came from streambeds and banks (American Forest Institute, No Date). In another study, Fredriksen (1970) found that for 2 years following clear-cutting in a watershed in the Pacific Northwest, there was no change in the suspended sediment concentration compared with a control stream.

The variability in the research data is a reflection of the broad range of factors which interact to determine what the impact of clear-cutting will be on erosion and increased sediment. Factors such as topography, soil characteristics, size of the clearcut area, method of timber removal, and promptness of natural revegetation will all play a role. To illustrate, at the Fernow Experimental Watershed in West Virginia, a clearcut area produced only slight increases in water turbidity. The area was logged using carefully planned and maintained roads as well as retaining streamside buffer strips (large trees were selectively cut in the buffer strips). Road gradients were restricted to 10 percent or less and the roads were outsloped. During construction, broadbase dips, culverts and gravel were used to control erosion and after harvesting the roads were seeded to grass. During clearcutting, nonstorm turbidity averaged 6 JTU (Jackson Turbidity Units) with a maximum of 90 JTU during stormflow. One year after harvesting, turbidity averaged 5 JTU for non-stormflow and 35 JTU for stormflow (Aubertin and Patric, 1972).

While the water quality impacts of forest cutting may be somewhat uncertain, it seems fairly evident that such cutting normally increases streamflow. Swank (1972) reported that when a mature hardwood forest in the Appalachian Highland is clearcut, an increase in streamflow of approximately 11.5 acre inches can be expected the first year after cutting. Experimental data show that even greater increases may occur when coniferous forests are clearcut. Rogerson (1966) found that in northern Arkansas, in upland hardwood forests, the maximum soil water deficit on clearcut areas was 3 inches and on forested areas was 10.5 inches. Hibbert (1966) reported that at the Coweeta Hydrologic Laboratory in western North Carolina, the increase in streamflow after removal of hardwood cover was proportional to the amount of cover removed. However, Swank (1972) points out that as the forest on a clearcut area regrows, the evaporating surface area increases and increased streamflow diminishes in subsequent years.

Nutrients

As was true in the case of sediment, studies that have sought to evaluate the impact of forest cutting on nutrient concentrations in streamflow have been largely restricted to the clearcut regeneration system.

One of the most frequently cited studies pertaining to the potential impacts of clearcutting on stream nutrient concentrations, was a study conducted at the Hubbard Brook Experimental Forest in New Hampshire. There a 39-acre watershed was completely clearcut. Felled trees and other woody vegetation were left on site, and regrowth of vegetation was prevented by herbicide control (Likens et al., 1970). Following treatment, the concentration of some nutrients increased to alarmingly high levels. Nitrate-nitrogen increased from a pretreatment maximum of 0.5 ppm to a maximum 20 ppm after treatment. Ions such as calcium, magnesium, and potassium increased their concentrations 5 to 30 times while sulfate decreased its concentration by 3 to 4 ppm after treatment (Pierce et al., 1972; Hornbeck et al., 1975). Although this experiment was not designed to simulate a normal forest harvesting operation these substantial nutrient increases attracted widespread attention to clearcutting and its impact on water quality.

The increased nutrient concentrations observed at Hubbard-Brook have been attributed to: (1) accelerated organic matter decomposition and subsequent leaching of nutrients by exposure of the site to increased amounts of heat and water, (2) acceleration of the nitrification process, (3) blocking of the uptake of available nutrients that normally would have occurred had the vegetation been allowed to regrow, and (4) the fact that soils in the study area are possibly low in their ability to retain nutrients (Pierce et al., 1972; Reinhart, 1973; Corbett et al., 1975).

Clearcut harvesting, without subsequent herbicidal treatment, on an experimental watershed in the White Mountain National Forest in New Hampshire showed nutrient concentrations in streams to be much lower than those observed at Hubbard-Brook. Average nitrate-nitrogen concentrations in streamflow from seven harvested watersheds ranged from 1.3 to 4.5 ppm. Measurements made below the clearcut areas were considerably lower in nutrients due to the dilution provided by essentially nutrient-free water from areas not cut. Nitrate-nitrogen concentrations from one 160-acre clearcut watershed were 1.5 times greater than found from the total drainage area of 240 acres (160 cut, 80 uncut) (Pierce et al., 1972; Corbett et al., 1975).

Results from a West Virginia study also differed significantly from the Hubbard-Brook findings. A buffer strip 33 to 66 feet wide was left along each side of the perennial stream flowing through the study watershed. In addition, soil conditions were different than those found at Hubbard-Brook. Dissolved solids in the stream were virtually unaffected by clearcutting. Minor changes in nutrients did occur. However, they were generally slight, irregular and short-lived. Average nitrate-nitrogen concentration in streamwater the first year after clearcutting was only 0.18 ppm for the growing season and 0.49 for the dormant season. Phosphate concentration showed slight increases while sulfate concentration decreased. There were negligible changes in calcium, magnesium, sodium, potassium, iron, copper, zinc, manganese, and ammonium-nitrogen (Aubertin and Patric, 1972). Researchers attributed the success in avoiding damage to water quality to careful road management, retention of a buffer strip along the streams, and rapid regrowth of vegetation after clearcutting.

Results from experimental watersheds at the Coweeta Hydrologic Laboratory in North Carolina have shown that clearcutting does not cause long term losses of nutrients by erosion or leaching. Calcium was the only cation studied whose concentrations were appreciably higher than that of undisturbed forests, and then only on watersheds that received lime application during their treatment. Maximum concentration of nitrate-nitrogen in streamflow was 1.23 ppm on a grass-to-forest succession watershed. After a hardwood-to-pine conversion, nitrate-nitrogen concentrations of 0.25 ppm were observed in streamflow, as compared with 0.002 to 0.013 ppm for undisturbed watersheds. The concentration of all cations and anions in streamflow from treated watersheds was quite low, and Douglass and Swank (1975) concluded that the increased export of nutrients is insufficient to create pollution problems for drinking water.

A three-phase experiment on the Leading Ridge Watersheds at Pennsylvania State University (Corbett et al., 1975) showed that clearcutting of upland hardwoods had little effect on the concentrations of selected nutrients in streamflow the first and second years after treatment. Phase one consisted of removal of all timber on the lower portion of Leading Ridge Watershed 2, during the winter of 1966-67. During the winter of 1971-72, phase two of the experiment expanded the clearcut area toward the middle-slope portion of the watershed. During the summers of 1967, 1968, and 1969, stump sprouts in the phase one area were controlled with herbicides. In the summer of 1974 phase three was an aerial application of herbicides applied to both the phase one and phase two areas. The purpose of the herbicide treatment was to deaden both woody and herbaceous vegetation as part of a water-yield experiment.

During the second year after cutting, there was a slight decrease in streamflow calcium and sulfate concentrations and a slight increase in the nitrate-nitrogen concentration (Table 14). As indicated in Table 15, the reduction in calcium and sulfate concentrations persisted, and there was an even larger increase in nitrate-nitrogen. Average nitrate-nitrogen concentrations increased to 2.08 ppm during the seven month period after the herbicide treatment (Lynch et al., 1975; Corbett et al., 1975).

Fredriksen (1972) reported that nitrogen concentrations in a stream flowing from a clearcut watershed in the Pacific Northwest were double the concentrations of a stream in a similar undisturbed watershed. Phosphorus concentrations, however, were about the same in both cases. Although nutrient losses have been found to increase sharply after cutting, decreases to pre-cutting levels are achieved when new vegetation heals the effect of disturbance (Harris, 1977).

Table 14. Average nutrient concentration of streamwater on partially clearcut and control Leading Ridge Watershed, Pennsylvania, October 1973 to May 1974 (Corbett et al., 1975).

Element	Watershed	
	Control (ppm)	Clearcut (ppm)
Calcium	4.32	2.28
Magnesium	1.53	1.24
Potassium	1.09	1.15
Sodium	1.00	0.90
Sulfate	6.10	6.43
Nitrate-Nitrogen	0.01	0.10

Table 15. Average nutrient concentration of streamflow on partially clearcut - herbicide treated and control Leading Ridge Watersheds, Pennsylvania, June to December 1974 (Corbett, et al., 1975).

Element	Watershed	
	Control (ppm)	Clearcut-Herbicide (ppm)
Calcium	6.28	2.32
Magnesium	2.30	2.06
Potassium	1.13	1.58
Sodium	1.16	0.96
Sulfate	7.23	4.68
Nitrate-Nitrogen	0.08	2.08

Many people are concerned that nutrient losses due to removal of trees by clearcutting will reduce soil fertility. However, Robert Tarrant, principal soil scientist for the Pacific Northwest Forest and Range Experiment Station, testified before the Senate Subcommittee on Public Lands in May, 1971, that "on the basis of currently available information, we find no drastic or irreversible depletion of forest soil nutrient reserve caused by timber removal. Nutrient outflows are small compared to the total nutrient reserve in the soil." A study in Washington showed that about 10 percent of the available soil nitrogen was accumulated in Douglas fir trees growing for 35 years. However, on the average only 24 percent was in the wood of the trunk, 15 percent was in the bark. The major part of the trees' nutrient content was in the needles, twigs, branches, and roots, and normally this material remains on the site after harvest (American Forest Institute, No Date).

Temperature

The effect of timber removal on water temperature is related to the amount of stream surface area exposed to direct sunlight -- or in other words, to the amount and distribution of forest cover removed.

Helvey (1972) reported that during late summer, when streams in north central Washington were exposed to direct insolation, maximum daily stream temperature was increased by as much as 10^{0}F. Fredriksen (1972) reported temperature increases of as much as 28^{0}F, with the highest temperatures being observed in areas where all streamside vegetation had been removed. Swift and Messer (1971) found that in the mountains of North Carolina, summer water temperatures did not significantly change when total basal area of a stand was reduced by 22 percent.

The concept of leaving a strip of relatively undisturbed vegetation along stream banks has gained a great deal of attention as a method to protect stream temperature. Weekly maximum stream temperatures in a West Virginia study were essentially the same during summer months for a control watershed and a clearcut watershed with a buffer strip. The clearcut watershed averaged 0.8°F higher stream temperature than the control. However, during the same period a clearcut watershed that had no buffer strip averaged 11°F higher than the control (Bengeyfield, 1973).

Brazier and Brown (1973) evaluated buffer strips for stream temperature control in Oregon. They found that the maximum shading ability of a buffer strip was reached within a width of 80 feet and that 90 percent of that maximum was reached within 55 feet of the stream. Buffer strips 100 to 200 feet wide usually assures water temperature protection, but generally include more timber in the strip than is necessary.

The effect of timber harvesting on stream temperature in East Texas is not known. However, it is generally agreed that: (1) when only a small portion of a watershed is harvested, or (2) when adequate buffer strips are left along streams, the potential adverse effects of harvesting on stream temperatures are minimized.

Organics

Discussed within the section on harvesting.

Introduced Chemicals

Forest cutting has no direct impacts in terms of introduced chemicals.

Harvesting Operations

Descriptions of Practices

There are three basic types of timber harvesting operations: (1) shortwood pulp, (2) product length, and (3) tree length. As the names imply, the distinction between them is based on the length of the material removed. Each type of operation has essentially six procedural steps: (1) felling, (2) limbing, (3) bucking, (4) skidding, (5) loading, and (6) hauling. Each of these steps in the harvesting process are briefly defined below.

Felling: This step involves severing the tree trunk at just above ground level so that the tree will fall in a pre-planned location

Limbing: This step involves removing all limbs from the bole of the tree.

Bucking: This step involves cutting the felled trees into the desired lengths. In the case of a tree length harvesting operation, no bucking would be done except to cut the top off the tree at some specified minimum diameter.

Skidding: This step involves moving the tree or log length material from the site of felling to a centrally located area called a "landing". This movement can be accomplished in either of two ways. The first method entails dragging the material across the soil surface using a mobile skidding device. The second method, called "cable yarding", entails the use of a fixed power source and cables. In recent years, modified skidding operations using balloons and helicopters have been tried on a very limited scale.

Loading: This step involves the placement of the tree or log length material onto trucks or railroad cars.

Hauling: This step involves transporting the raw wood products from the harvest area to some manufacturing facility.

State-of-the-Arts in Texas

Throughout the South, including East Texas, tree length logging has been very popular in recent years. Accordingly, it will be taken as the harvesting method characteristic of the East Texas area. Using this method, trees are normally felled and limbed with chain saws or hydraulic shears -- and then dragged to a central landing by means of wheeled skidders. Cable yarding systems, and systems using balloons or helicopters, are not used in East Texas. These techniques were developed for use in steep, mountainous areas. Indeed, cable yarding loses its log lifting capacity on flat or moderately sloping ground. Furthermore, these systems usually involve a very large capital investment, and thus to be economically feasible must be used on large tracts with extremely high timber volumes per acre.

Once the tree length material has been moved to a central landing, it is loaded on to diesel or gasoline trucks by means of a knuckle-boom loader. At this point the material is transported from the woods to a diversified manufacturing facility where it is processed into products.

During the harvesting operation itself, and following its completion, certain precautions are frequently taken to minimize the likelihood of any adverse impacts on water quality. To illustrate, streamside buffer strips are often left uncut to help protect streamwater quality during and after harvesting. Secondly, an attempt is made to fell trees away from streams whenever possible. Thirdly, skidder activity in streams is minimized to protect water quality. Finally, logging operations are usually delayed during wet weather when soils are subject to serious compaction.

Potential Environmental Impacts

Sediment

Dissmeyer (unpublished manuscript) has estimated that in the Coastal Plain and Piedmont areas of the South, the relative sediment contribution of various logging activities is as shown in Table 16.

Table 16. Sediment production from various logging practices by land resource area in Southeastern United States (Dissmeyer, 1976).

Land Resource Area	Logging Practice	Estimated Sediment Production (tons/acre/year)
Southern Coastal Plain	Felling	.32
	Landings	3.08
	Skidtrails	6.27
Southern Piedmont	Felling	.76
	Landings	N.A.
	Skidtrails	15.92

As can be seen, the act of felling trees, by itself, does not appear to produce significant changes in sediment concentrations. The conclusion is supported by the results of numerous studies (Garrison and Rummel, 1951; Brown and Krygier, 1971; Swanston, 1971; Douglass, 1974). Felling, after all, does not appreciably disturb the forest floor. If the litter layer remains intact, and if soils are not compacted, infiltration rates will remain high and overland flow will not occur unless the soil becomes saturated or the storm event is of a particularly high intensity. About the only other type of situation in which felling could lead to a significant increase in sediment production would be on steep slopes with fragile soils. Under these circumstances, felling, by causing the decay of existing root systems, can trigger problems of mass soil movement. Clearly, however, the potential danger is of no concern in East Texas.

Much of the increased sediment that can result from harvesting operations appears to originate from landings and skidtrails. On both of these areas the mineral soil is typically exposed. Depending on the type of soil, the direct impact of raindrops can reduce infiltration rates and thus increase overland flow. In addition, the soils on such areas are subject to compaction due to repeated trafficing by heavy equipment. To illustrate, in northern Mississippi, rubber-tired skidders loaded with three hardwood logs made seven runs along sample trails located on different type soils. The results showed that on loamy sand and silty clay loam, bulk density was increased by 20 percent (Dickerson, 1976). Such compaction can accentuate the potential dangers of erosion (Dunford, 1960; Swanston and Dryness, 1973).

Weather has a bearing on the soil compaction caused by skidders. In the Douglas-fir region of Washington, it took four trips with a 2-ton crawler tractor to create the same effect on soil infiltration rate as one trip when the site was wet (Steinbrenner and Gessel, 1956). This is significant when viewed in light of the findings of a study conducted in the Atlantic Coastal Plain. This investigation found that on severely eroded and compacted soils, created by log landings and skidtrails, the average time required for bulk density to return to the density of undisturbed soils was about 18 years (Hatchell, Ralston and Foil, 1970).

The differential impacts of landings and skidtrails, as noted by Dissmeyer in Table 16, is probably attributable to the fact that skidtrails normally represent a considerably larger area of disturbance than do landings. Dickerson (1968) estimated that only 1 percent of a logged area is typically disturbed by landings; others have estimated 1.5 percent (Hatchell, Ralston and Foil, 1970). Still, by comparison to the area normally occupied by skidtrails, the percentage is small. Dunford (1960) has stated that skidtrails normally cover at least 20 percent of a logged area. His findings are consistent with those of an earlier study conducted in the West which found that crawler tractors disturbed an average 20.9 percent of logged areas (Garrison and Rummell, 1951). More recently, research results have not been as consistent. Campbell, et al., (1973), have estimated the disturbance at 23 percent in the Piedmont, but studies conducted in the Atlantic Coastal Plain indicate primary skid trails occupy 12.4 percent of the forested area and secondary skid trails another 19.9 percent (Hatchell, Ralston and Foil, 1970). At the opposite extreme, in Mississippi skidtrails were found to occupy only 9 percent of the logged area. As one can see, while there is no agreement on the exact amount of soil disturbance resulting from skidding activities, all estimates are in excess of that attributable to landings.

In terms of the actual amount of sediment originating from skidtrails, different studies, as one would expect, have produced results somewhat different from those reported by Dissmeyer. On the Mississippi Coastal Plain, erosion from trails created by uphill skidding on a variety of soils, slopes and slope lengths, produced an average of .84 tons of sediment per acre of trail during the first year after logging. This was by far the major contributor to erosion activity. In a similar study at the Fernow Experimental Watershed in West Virginia, first-year soil erosion averaged 0.4 inches on gradients of 0-20 percent, and 75 percent higher on grades 21-40 percent (Trimble and Weitzman, 1953). This was the direct result of skidder activity.

The objective of non-point pollution control strategies related to skid trails should be to disperse surface water from them thus reducing soil movement. Kidd (1963) stated that structures that divert water from trails are superior to those that only retard water movement and filter out sediment along the way. As for the best spacing between such structures, it depends on the percent slope, the location of the trails (sidehill or ravine) and the soil parent material. In moderately sloped areas, short trails placed along the contour can reduce the amount of runoff channeled down the skidtrail thereby limiting erosion (Dickerson, 1968). This is not always easy to accomplish, however, as skidding direction, grade and location are usually functions of the main haul road location (Kochenderfer, 1970). This points out the need for careful advance planning. In a 1958 logging study on the Fernow Experimental Forest, careful planning of the skidding system could have reduced the area in skidtrails by 40 percent (Lull and Reinhart, 1963).

In planning, any area on the harvest site whose potential runoff may drain down a skidtrail should be examined carefully. A ravine skidtrail that drains several acres needs more diversion control structures than a sidehill skidtrail that drains a small area. The control structures that might be used include log water bars or slash dams (Kidd and Kochenderfer, 1973). Heavily compacted trails may require special drainage features to divert surface runoff. In addition, they should be treated so as to establish a vegetative cover (Swanston and Dyrness, 1973).

Logging debris left following a harvesting operation can also lead to sediment problems. The literature seems to indicate that the major danger from debris is that it will accumulate in stream channels thereby diverting stormflow from the channel or into channel banks (Lull and Reinhart, 1963).

Channel scouring can result when debris accumulations are carried by stormflow (Dunford, 1960). This problem is aggravated by roadways which place restrictions on the movement of debris and by culverts which constrict channel flow (Froehlich, 1970).

Prevention of debris accumulations and the possible problems they can create requires reducing the amount of such material entering into streams (Froehlich, 1970).

Nutrients

The potential impacts of forest cutting on stream nutrient concentrations were discussed in the section on regeneration systems.

Temperature

The potential effects of forest cutting on streamwater temperatures were also discussed in the section on regeneration systems.

Organics

As a consequence of logging, debris, which includes bark scraped off by skidding and hauling activities, can accumulate on the site until it either decomposes naturally, is disposed of during site preparation, or finds its way into streams. Even though very little research has been done concerning the water quality impact of logging debris, it is recognized that debris which actually reaches streams may have a significant impact in terms of clogging channels and possibly altering oxygen levels (Narver, 1970). This in turn can be detrimental to fish and plant life in streams.

The introduction of solid organic debris into streams during harvesting operations can be prevented by directional felling and/or leaving an adequate buffer strip. Froehlich (1970) found accelerated debris loading to be strongly related to the timber felling process. Conventional felling increased organic loading five times above pretreatment levels whereas directional felling only doubled the load. Buffer strips were found to provide a debris barrier which limited organic loading increases.

Introduced Chemicals

Timber harvesting has no direct impacts in terms of introduced chemicals.

Intensive Site Preparation and Planting

Description of Practices

Intensive mechanical site preparation practices are applied in East Texas to prepare sites for regeneration of commercial timber. These practices are performed after clearcut harvesting of commercial species to: 1) reduce competing woody and herbaceous vegetation, and 2) prepare the soil for mechanical planting of pines.

Mechanical site preparation may consist of one or more of the following techniques: 1) roller chopping; 2) shearing by KG or V-blade; 3) raking into windrows; 4) disking; 5) burning; and 6) bedding. Cutover areas containing a residual of large cull hardwoods (greater than 10 inches in diameter) and with no drainage limitations are usually site prepared by shearing the standing vegetation at ground level with a KG blade; piling or windrowing debris; and burning. By comparison areas with a residual of small cull hardwoods (smaller than 10 inches in diameter) and no drainage limitations are usually site prepared by roller chopping. Sites with drainage limitations are usually prepared in a similar manner, with the possible addition of bedding. In stands with little residual hardwood composition, burning may be the only site preparation technique applied.

Some mechanical site preparation techniques can drastically disturb the area leaving the soil open to erosion. However, a site usually will revegetate within one year (up to 80 percent of the ground covered)[1/] in forestlands of East Texas. Although rapid natural revegetation occurs,

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1/ E. V. Hunt, Jr. 1978. Erosion after intensive site preparation and regeneration of a sandy pine site in East Texas. School of Forestry, Stephen F. Austin University, Nacogdoches, Texas. Unpublished Manuscript.

site preparation activities are often performed in a way to further protect the site. For example, streamside buffer strips are used most of the time when streams border areas which are to be mechanically site prepared. Also site preparation activities, such as windrowing, are usually oriented along the contours in order to minimize soil movement. Lastly, many activities are not used when site conditions such as steep slopes or unstable soils prohibit their use.

Following site preparation, the sites are usually planted with improved pine species. This is generally accomplished by machine; although some hand planting and direct seeding does occur.

State-of-the-Art in Texas

Regarding those forestlands that receive a final harvest cut each year, about 142,820 acres receive some form of site preparation prior to reestablishment of a new forest (Table 17). Mechanical means, prescribed burning and herbicides are used to annually site-prepare 100,428 acres, 33,163 acres and 9,229 acres, respectively. The majority of this site preparation occurs on industry managed forestlands.

The following site preparation activities are employed on East Texas industrially managed forest lands: 1) bedding, 2) chopping, 3) disking, 4) raking, 5) shearing, 6) windrowing, and 7) burning the windows. These activities may be employed singly or in various combinations. Shearing has been found to be the most commonly used site preparation technique. On the other hand, bedding and disking are only employed on poorly drained soils of southeast Texas. Generally, mechanical site preparation proceeds in the following order of events: 1) shear, 2) rake, 3) windrow, and 4) burn the windrows.

Table 17. Estimated acres of industrially, private, non-industrially and publicly managed forestland receiving a site-preparation treatment annually.

Site-preparation Technique	Industrial	Private Non-Industrial	Public	Total
Herbicides	2,970	4,259	2,000	9,229
Prescribed Burning	26,500	3,463	3,200	33,163
Mechanical Means	89,050	7,878	3,500	100,428
Total	118,520 1/	15,600 1/	8,700 1/	142,820 1/

1/ Actual area treated is less do to overlapping activities.

Care is taken to protect the harvest site during site preparation activities. Streamside buffer strips are usually employed when streams border cutting units. Activities such as piling of windrows are generally performed on the contour to minimize soil loss downslope. Grass is not usually seeded on site-prepared areas because of the rapid revegetation which occurs in East Texas.

Approximately 51,100 acres are allowed to regenerate naturally on industrial forestlands. The approximate acreages which annually receive some form of artificial regeneration are shown in the following table. As the table indicates, machine planting of seedlings is the predominant artifical method of stand reestablishment in East Texas. About 26,000 acres are annually planted with improved seedlings on industrially-managed forestlands. Hand planting is used in small amounts because of the expense involved in this labor-intensive activity. Direct seeding is also used in limited amounts because of: 1) the expense involved in the application of seed, and 2) the unpredictable survival and germination rate of pine seeds.

Table 18. Approximate acres of industrially managed cut-over forestland which annually receive some form of artifical regeneration.

Artificial Regeneration Practice	Land in Fee Simple	Land Under Lease	Land Under Mgmt. Agreement
Direct Seeding (ground)	300	0	0
Direct Seeding (air)	900	0	0
Planting (hand)	3,872	0	0
Planting (machine)	73,367	300	100

Of the 101,000 acres of private non-industrial forest land in East Texas that receive a final harvest cut each year, only about 14 percent receive some type of site preparation. Mechanical site preparation is the predominant method used. Generally, shearing, raking, and windrowing are the mechanical activities involved in site preparation. These operations may be employed singly or in various combinations, however, site preparation is usually accomplished in the following order of operations: 1) shearing, 2) raking, 3) windrowing, and 4) burning of windrows.

Following the final harvest cut, most private non-industrial forest land is left to revegetate naturally. In other words, no effort is made to plant either seed or seedlings to aid in re-establishing the new forest. However, there is a trend toward conversion of forestland to uses other than forestry.

Regarding those public forestlands that receive a final harvest cut each year, about 5,500 acres receive some form of site preparation to ready them for establishment of a new forest crop. The method of site preparation used is dependent on: 1) soils, 2) slope, 3) location and visual sensitivity, 4) species being regenerated and 5) competing vegetation. Soil and slope limitations for various types of mechanical work have been established, and soil scientists and hydrologists assist in selecting site preparation methods. The mechanical methods used, in order of preference are: 1) brush chopping, 2) shear, with no windrows, and 3) shear and windrow. KG blades are not generally used on National Forest lands and windrows are burned only when the area is one of high visual sensitivity.

Care is taken to protect the harvest site during site preparation. Streamside buffer strips are employed when streams border the harvest unit and activities are performed on the contour to minimize soil loss. Grass is not usually seeded on site-prepared areas because of the rapid revegetation which occurs in East Texas.

Considering those lands receiving a final harvest cut each year, about 1,600 acres are allowed to regenerate naturally. About 500 acres are hand planted and 3,000 acres are machine planted with pine seedlings. There has been an effort to replace harvested trees with improved seedlings. About 3,000 acres are planted using improved seedlings each year.

Potential Environmental Impacts

Sediment

Research data on the impact of site preparation procedures are sparse. However, there are a few studies being conducted in the Southeast and some inferences can be drawn. Site preparation increases the potential for sediment production by disturbing the soils and the protective forest floor. Compaction and destruction of surface soil structure and macropore space cause an increase in surface runoff, thus increasing the sediment production potential (Dixon, 1975; Lull, 1959; Moehring and Rawls, 1970; and Campbell, et al., 1973; Dickerson, 1968; Hatchel et al., 1970). Disturbing the protective vegetation and litter opens the soil up to rain drop impact, which breaks soil aggregates into their component particles or smaller aggregates. These smaller particles are more easily detached and may leave the site in runoff water and/or be carried into larger soil pores thus increasing surface runoff and erosion (Edwards and Larson, 1969). Disturbing the forest floor also reduces the resistance to overland flow offered by litter and vegetation and increases the velocity of water which may fail to infiltrate. Because the velocity is increased, the kinetic energy and carrying-power of runoff are increased (Douglass, 1975).

Beasley (1977) studied the impact of three intensive site preparation treatments on highly erodible loess soils in the upper Coastal Plain of northern Mississippi. The treatments studied were: 1) roller chopping and burning; 2) shearing, windrowing and burning; 3) bedding on the contour after shearing, windrowing and burning; and 4) control, no logging, site preparation or other disturbance. After site preparation the treated watersheds were fertilized, limed, sown with Mississippi Subterranean Clover and planted with loblolly pine seedlings.

The bedding treatment exposed the largest amount of mineral soil (Table 19). Stormflow was about the same for the three treated watersheds (17.8 to 20 acre inches); likewise, discharge weighed sediment yield was similar (0.28 to 0.32 tons/acre-inch stormflow). Beasley found most of the sediment yield occurred during November, January, February and March. Channel scouring attributable to the increased stormflow produced by vegetation removal had more influence on sediment production than the relative degree of surface disturbance on the site.

Table 19. Hydrologic and site data for three sites prepared and one control watershed in northern Mississippi (Beasley, 1977).

Treatment	Exposed Mineral (Soil (%))	Storm-flow (Area Inch)	Sediment Yield (Tons/Acre)	Discharge-Weighted Sediment Yield (Tons/Acre-inch of Stormflow)
Control	--	0.4	0.02	0.06
Chopped	37	20.0	5.60	0.28
Sheared and windrowed	57	17.8	6.36	0.32
Bedded	69	20.0	5.71	0.32

Compared to other forest regions, the Southeast is unique because of previous cultivation and widespread erosion of forestlands. Sediment from eroding lands while under row-crop agriculture built up on minor flood plains and created sand-filled channels which are important sources of sediment today. Sediment concentrations from small watersheds in the Ouachita Mountains of central Arkansas were lower than those in Mississippi. Sediment yields were only 2.3 pounds per acre-inch of stormflow during an 8-year period. The difference is attributed to the greater resistance of the Arkansas channels to erosion (Rogerson, 1971; Ursic, 1975).

Douglass (1977) evaluated three intensive site preparation treatments: 1) shearing with a KG blade; 2) shearing and disking; 3) shearing, disking, fertilization and grass seeding, in the North Carolina Piedmont.

All treatments except the control, were windrowed, burned and planted to loblolly pine. He found that one year after treatment, the shearing and disking treatments produced the largest sediment yield (0.30 and 0.34 tons/acre-inch stormflow, respectively) (Table 20). The shearing, disk, fertilize and grass seeding treatment reduced sediment by one-third (0.10 tons/acre-inch stormflow) but produced five times more sediment than the control (0.02 tons/acre-inch stormflow).

Table 20. Stormflow and sediment yield from site prepared watersheds, North Carolina Piedmont (Douglass, 1977).

Treatment	Stormflow (Area Inch)	Sediment Yield (Ton/Acre)	Discharge-Weighted Sediment Yield (Ton/Acre-inch Stormflow)
Control	1.82	0.04	0.02
Shear and Disk	7.58	2.24	0.30
Shear	3.16	1.06	0.34
Shear, Disk, Fertilizer, Plant Grass	2.45	0.26	0.10

Eighteen months after a site in northern Mississippi was prepared by tree-crushing and planted with loblolly pine, Ursic (1977) found the treated site produced about 2 times more sediment than the control. A major 5.5-inch rainstorm, four years after treatment, produced four times more sediment from the treatment site than the control. The values were low (crushed, 1.6 pound/acre-inch stormflow; control 0.4 pounds/acre-inch stormflow) as compared to previous observed data, but indicate increased sediment production still occurring after four years.

A paired watershed experiment on the southern piedmont of Georgia has shown relatively low levels of sediment from clearcutting followed by double site preparation with roller-choppers (Hewlett, 1977). Harvesting increased sediment production by 16 lbs./acre-inch of stormflow over the control watershed, while roller-chopping increased sediment production by 94 lbs./acre-inch of stormflow.

Hunt and Miller (1976) studied soil erosion following site preparation and planting in East Texas. During the first year after treatment they observed no excessive erosion and concluded that some erosion and deposition occur within this disturbed area, but little sediment is moved off the watershed.

Nutter (1975) states that planting activities, when conducted sensibly using conservation practices similar to those used in agriculture, will not cause an increase in erosion. However, when planting is done in a way to cause severe disturbance, e.g., planting up and down slopes, soil scalping with a V-blade on the planter, etc., sediment problems can result. Hewlett (1977) found planting to produce about 3.5 times more sediment than double site preparation with roller choppers (315 lbs./acre-inch stormflow vs. 94 lbs./acre-inch stormflow, respectively).

Nutrients

Sediment is the primary potential pollutant of concern to Texas forest managers; however, chemical water quality is also important but not expected to be a problem. Information on the impact of site preparation on chemical water quality is generally lacking.

A preliminary study (Hewlett, 1977) on Georgia's southern piedmont found no evidence of large increases in dissolved mineral concentrations in a stream due to clearcutting and site preparation (Table 21). However, annual water yield from the treated basin increased by about 60 percent. The total watershed export of dissolved minerals increased by 60 percent for calcium, potassium, sodium and magnesium and by 100 percent for nitrate-nitrogen and phosphate. These increases are in line with similar studies conducted elsewhere (Corbett, Lynch and Sopper, 1975).

Table 21. Dissolved mineral concentrations (as percent of control) in streamwater following clearcutting and site preparation in the southern piedmont of Georgia (Hewlett, 1977).

Ions in Stream Water	Before cutting 12/12/73 to 10/30/74	During Harvest and Roller-chopping 1/1/75 to 12/16/75
Nitrate Nitrogen	35%	52%
Total Phosphorus	29	89
Potassium	107	120
Sodium	88	73
Calcium	49	49
Magnesium	46	51

Organics

Logging slash and debris are potential sources of organic pollution and care must be taken to prevent their entry into the stream channel. Transport of organic material into the stream course increases when site preparation activities are performed in or near streamside buffer zones. Discussed in more detail under harvesting operations on page 72 .

Temperature

Discussed under regeneration systems on page 64 .

Introduced Chemicals

Discussed under herbicides on page 91 and fertilization on page 88 .

Intermediate Cultural Practices

Prescribed Fire

Description of Practices

The largest use of prescribed fire in southern forests is for wildfire hazard reduction (Hough, 1973). Fire is also used to: 1) manipulate vegetation, e.g., kill selected species and/or size classes while stimulating others, 2) enhance production and palatability of forage for wildlife and livestock, 3) expose a mineral seedbed prior to stand establishment, 4) return nutrients to the soil where they can again be utilized for tree growth, and 5) improve forest accessibility. Properly executed burns yield other benefits such as: 1) creating vegetation mosaics, 2) opening up vistas, and 3) increasing the amount and diversity of herbaceous vegetation (Wade and Ward, 1974).

State-of-the-Art in Texas

On publicly-held forestlands, about 41,900 acres are prescribed burned annually. On private non-industrial ownerships, prescribed burning is employed to a very limited extent. However, on industrially-managed forestlands, about 110,000 acres are prescribed burned annually.

Potential Environmental Impacts

Sediment - Prescribed fire, if applied properly, does not seem to be a threat to soil or water quality. Ralston and Hatchell (1971) concluded that drastic changes in soil properties and removal of forest floor materials sufficient to cause a significant increase in erosion can only be expected from severe fires or sites where particular combinations of soil, topography, and rainfall confer high risk of damage.

One or two prescribed burns in loblolly pine stands in the lower piedmont of Georgia and South Carolina did not increase soil movement under the canopy (Brender and Cooper, 1968). Cushwa et al., (1971) demonstrated that a spring or summer prescribed burn in loblolly pine stands of the South Carolina Piedmont did not increase soil erosion in established gullies. They did observe soil erosion on poorly constructed firelines.

Ursic (1970) found in the Upper Coastal Plain of northern Mississippi, sediment production from light, winter prescribed burning of ungullied, poor quality upland hardwoods, followed by the subsequent deadening of the hardwoods, was not alarming. During the first year after treatment, comparison with the control showed that sediment production increased 50 percent on the watershed with sandy soil and more than 100 percent on the loess watershed. Sediment production continued high from the watershed with loess soils during the second and third years. However, on the sandy watershed the sediment increase was largely confined to the first year.

Moehring (1971) states that physical soil properties in the Coastal Plain are not noticeably damaged by repeated prescribed fires; however, wildfires may consume the entire litter mat and expose the mineral soil to erosion. On the other hand, in the Upper Coastal Plain, with its increased relief and stormflow, erosion of exposed soil may occur causing severe and sometimes permanent reduction in site productivity. Prescribed burning should be cautiously applied or avoided on soils with a history of erosion.

Use of prescribed fires in the predominately sandy soils and level terrain of East Texas, appears to have minimal effects on soil movement.

Most prescribed fires are conducted in the winter and at an intensity not expected to cause drastic changes in the soils physical properties. Topography, soil type, vegetation, moisture content of fuel, and weather conditions must all be carefully taken into consideration when applying a prescribed burn.

Nutrients, Organics, and Temperature - After prescribed burning of southern pine stands, even when annual burns (which are seldom used in East Texas) are applied, some of the forest floor is left. Generally, these fires result in small shifts in soil pH, organic matter and nutrients. Only incorrectly applied prescribed burns and severe wildfires can be expected to increase sediment production, build up certain nutrients, increase organic loading and cause water temperature to rise significantly (Wells, 1971; Moehring, 1971; Ralston and Hatchell, 1971; Anderson, 1976; Fredriksen, 1971; and Leuno' and Rothacher, 1969).

Introduced Chemcials - No fire retardants are used in East Texas. Other introduced chemicals are not applicable.

Fertilization

Description of Practice

Few forest soils provide an optimum supply of the nutrient elements essential for the growth of trees. Sometimes marked deficiencies exist because of improper land management in the past or inherently low natural fertility. Most fertilization has been done in connection with planting, especially that done for erosion control or similar special purposes on depleted soils (Smith, 1962). On the basis of knowledge of the forest ecosystem we can hypothesize that fertilizing forestlands should have little or no effect on water quality. In contrast to cultivated lands, the forest soil generally has an organic layer over its surface. Organic matter content of the first few inches of mineral soil is almost always much greater than that in cultivated soils. This substantial amount of organic matter provides a large number of adsorption sites for applied chemicals. Further, most well-established forest stands, including understory vegetation, have a massive root system that offers great opportunity for interception and rapid uptake of chemical nutrients (Moore, 1971).

Operational forest fertilization is not currently practiced on hardwood areas. Instead, it has been mainly confined to the phosphorus deficient, poorly drained soils of the pine flatwoods of the Gulf Coastal Plains. Usually phosphorus and nitrogen are applied at the same time in order to get better growth responses from the pines.

Up to 1969, available data for the Southern region indicates that approximately one-half of the fertilization was accomplished with ground equipment, and that 79 percent of the fertilizers were applied to young stands. The proportions of various types of fertilizers applied were 82 percent super-phosphate, 7 percent urea only, and the remainder were nitrogen-phosphorus combinations.

State-of-the-Art in Texas

At the present time, it is estimated that there is little or no use of fertilizers in connection with forestry operations in East Texas (Tables 22, 23 and 24). This is due primarily to their high cost and relatively small benefit of use. Use of fertilizers has been limited to isolated areas, seedling nurseries, seed orchards, and experimental plots. In the future as more intensive management of the southern pines takes place, there may be greater use of chemical fertilizers.

Potential Environmental Impacts

Fertilizers used with common sense should have no significant impact on sediment, nutrients, organics and stream temperature.

Introduced Chemicals - Increased nitrogen concentrations in water have been recorded following fertilization. The general pattern indicates that peak concentrations of the various forms occur sequentially. Immediately following an application of urea (24-72 hours), a short lived peak may be detected resulting from its direct application to the water surface and adjacent riparian zone of streams flowing through the treated area. The maximum reported urea concentrations following forest fertilization are 27 and 44 mg/l of nitrogen (Burroughs and Froehlich, 1972). In both instances, small streams were not protected by untreated buffer strips, and in the latter case, all of the watershed was treated. Where only a fraction of a watershed was fertilized and streamside buffer strips were used, the maximum urea-nitrogen value was commonly less than 1 mg/l (Moore, 1975).

Ammonia concentrations may also be increased shortly following fertilization. The peak is of short duration and occurs during approximately the same time as the urea. The ammonia concentration is due to direct application of the fertilizer to the water surface. Some of the urea entering the water is converted to the ammonium form. Peak ammonia-nitrogen concentrations for watersheds that were fully treated and had no streamside buffer strips ranged between 0.35 and 1.4 mg/l. Properly treated watersheds and those with streamside buffer strips had concentrations between 0.01 to 0.16 mg/l well below the 0.5 mg/l standard recommended by the U. S. Environmental Protection Agency (1976).

Nitrate concentration peaks followed any initial urea and/or ammonium peaks. The influx of nitrate-nitrogen is caused by the conversion of urea to nitrate which is controlled by the physical, chemical, and biochemical conditions present on and in the forest soil. The lag observed between fertilization and nitrate peak and the longer duration of the peak is due to the time required to convert urea to nitrate and to transport it via subsurface flow to the watercourse. The increased concentrations are generally present for several weeks before returning to approximately pretreatment levels. It has been noted in every study where sampling has continued long enough after fertilization that a second peak of nitrate-nitrogen associated with a nutrient flush during periods of peak runoff has been detected. However, the level of $NO_3^{-}N$ returns to background concentrations within three to six weeks. Peak values for nitrate-nitrogen in streams with no buffer strips ranged from 1.8 to 2.1 mg/l while streams having buffer strips had concentrations between 0.04 to 2.1 mg/l. These values too are well below the U. S. Environmental Protection Agency (1976) recommended standard of 10 mg/l of nitrate-nitrogen (USDA, Forest Service, 1977).

Increased phosphorus concentrations following application of phosphate fertilizers have not normally been observed. Phosphorus added to the forest is readily utilized by forest organisms or is absorbed by soil materials. Most forest soils have the capacity to tie up many times the quantity of phosphate which foresters are likely to apply. (USDA, Forest Service, 1977).

Data varies according to stream surface area, rate and consistency of application, and other factors unique to each study, but approximately one-third to one-half of the total nitrogen loss may be associated with direct application to the surface water and immediate riparian zone. If the direct application of the fertilizer can be prevented (by buffer strips, marked watercourses, etc.), the impact on the stream can be minimized. Fertilizers applied properly will not result in degradation of water quality to the detriment of other resources. There is no data to indicate the use of fertilizers in East Texas would be a problem.

Pesticides

Herbicides

Description of Practices - Herbicides that are often used in the forest to control unwanted vegetation include 2,4,D; 2,4,5-T; and Tordan. These herbicides are applied either by ground or aerial methods.

Ground application methods include the following: 1) broadcast foliar applications for general or selective control of susceptible brush species under 20 feet high; 2) direct basal-cut application of herbicides in concentrated form to cut surfaces of stems which are created by girdling or trunk injection; 3) direct basal application to the trunk of individual trees of a herbicide in oil solution; 4) broadcast soil application of herbicides (U.S. Environmental Protection Agency, No Date).

Aerially applied chemicals may be distributed to four components of the environment: air, vegetation, forest floor, and water. The amount of chemical entering each portion of the environment will be determined by the chemical used and the conditions which prevail at the time of application (Norris, 1967).

State-of-the-Art in Texas - Herbicides are used on a limited basis to control the competition of weed species with commercially important species. This may occur at the time of planting to reduce competition from herbaceous weeds, or as an intermediate cultural practice to release pine species from competing hardwoods or as a final treatment to release pine seedlings from non-commercial hardwoods.

Because herbicides are relatively expensive their use is limited on private non-industrial forestlands. It is estimated that about 12,000 acres are treated annually in this ownership class. On industrially managed forestlands the use of herbicides is more extensive (27,330 acres). Publicly-held forests receive little herbicide treatment. Only about 4,500 acres are treated annually. For a more detailed summary of herbicide use in East Texas see Tables 22, 23, and 24.

Potential Environmental Impacts - Herbicides that are used as prescribed by law and common sense should have no significant impact on sediment, nutrients, organics and stream temperature.

Introduced Chemicals - Losses of herbicides to the air may be appreciable, but there is little quantitative data available. During one test in western Oregon, from 20 to 75 percent of certain herbicides did not reach the ground (Newton et al., unpublished data). Norris and Moore (1976) reported that 70 to 90 percent of 2,4-D and picloram were recovered, respectively, at first intercepting surfaces after helicopter applications in southern Oregon. Chemicals dispersed in the air can be moved to other locations where they may settle to the earth, be washed out with rain, or be taken up by plants and other organisms. Degradation in the air is also possible (Moilanen et al., 1975).

Studies with herbicides have shown the highest concentrations occurring in foliage shortly after application (Morton et al., 1967; Getzendaner et al., 1969) with concentrations decreasing rapidly with time.

Adsorption and leaching are processes which work in opposition to one another. Adsorbed molecules are not available for leaching, but adsorption is not permanent. The amount of herbicide which is adsorbed is in equilibrium with the amount of chemical in the soil solution. As the concentration of chemical in the solution decreases, more pesticide will be released from adsorption sites. Thus, adsorption provides only temporary storage, and the soil is in effect, a reservoir of chemicals which will eventually be released. Leaching is a slow process capable of moving chemicals only short distances (Harris, 1967, 1968).

Herbicides move very little in forest soils. They are broken down in place by microorganisms, sunlight and chemical reactions. A compound that has an effective life of several months will usually move less than a foot or two from the site of application. Therefore, herbicides are not a serious threat to water supplies or fish unless they are placed directly (especially by spillage) into forest streams which will become waterways during storm periods.

Herbicides may enter streams by several processes. The direct application of drift to surface waters will occur for only a short period of time but may cause high concentrations of pollutant. Herbicides may also enter streams in rainfall which washes particulate and vapor forms from the air or from leaves. Herbicides may enter streams by leaching through the soil profile or in mass overland flow during periods of intense precipitation (Norris and Moore, 1976).

A point that needs to be emphasized is that the magnitude of contamination is closely related to the manner in which the treatment area is laid out with respect to live streams. Norris (1967) reports that peak concentrations seldom exceed 0.01 ppm in streams which run adjacent to, but do not actually enter, spray units. Herbicide residues persist for only short periods in these streams. Short-term, high level contamination results from direct application of herbicide to the water surface. This can be reduced markedly by excluding streams from treatment areas (Norris and Moore, 1976).

Insecticides

Description of Practices - The number of chemicals available for insect control runs into the hundreds, and each year many new materials are placed on the market. However, Federal and State laws prohibit the use of many in forest operations. These chemicals are extremely important as a means of controlling emergency situations, but they should not be used unless needed. When they are needed, they should be utilized wisely.

The ideal forest insecticide has never been developed. In fact, development of this ideal product can never be expected. Different situations require different insecticides with different characteristics. They must, of course, be highly toxic to the pests against which they are directed. Beyond this, some insecticides decompose slowly or not at all after application, while others decompose or volatilize in a few minutes or hours. If the insecticide is placed in a location where the insects will eat or contact it later, enough stability to permit this contact is essential. If, on the other hand, the insecticide is applied directly upon the insect, stability after treatment may not be of any consequence.

Many different types of equipment and techniques are available for applying insecticides. Aerial applications over large areas can be made by fixed-wing aircraft or helicopters. Individual trees, small groups of trees, and seed orchards may be treated by ground equipment such as mist blowers, knapsack sprayers, and hydraulic sprayers (Potts and Friend, 1946). Logs are treated by power sprayers. Systemic insecticides may be applied by trunk implantation or injection, by banking or spraying of the circumference of the trunk, by spraying the foliage, by treating the soil around the base of the trees, or by dipping cuttings prior to planting (Barras et al., 1967; Donley, 1964; Kulman and Dorsey, 1962; Merkel, 1969; Morris, 1960; Norris, 1967).

State-of-the-Art in Texas - Use of insecticides in East Texas forest areas is limited to small "spot" applications. It is estimated that about 600 acres of forestland are treated annually. For more detailed information concerning use of insecticides, see Tables 22, 23, and 24.

Potential Environmental Impacts - Insecticides that are used as prescribed by law and common sense should have no significant impact on sediment, nutrients, organics and stream temperature.

Introduced Chemicals - After an insecticide has done its work in the forest, the quicker it disappears from the environment the better. Unfortunately, many otherwise excellent insecticides have a high degree of stability. Insoluble arsenical salts of lead, copper, and calcium decompose slowly or not at all after they are applied. Some organic insecticides may remain active in the soil for indefinite periods. Repeated heavy application of these substances can result in undesirable accumulations. Therefore, they should never be used more often than is absolutely necessary or in heavier dosages than the minimum required to accomplish control.

No insecticide can be applied in the forest so that its effects will be entirely restricted to the pest against which it is directed. Inevitably, some associated organisms will be injured. When we use poisons against noxious insects, our objective should be to minimize, as far as possible, injury to desirable forms of life.

The movement of insecticides includes movement within a given part of the environment, such as leaching in the soil profile, or movement from one part of the environment to another (e.g. rain washing of insecticide residues from leaf surfaces to the forest floor). Losses of insecticides to the air may be appreciable, but there is little quantitative data. Chemicals dispersed in the air may be moved to other locations where they may settle to the earth, be washed out with rain, or be taken up by plants and other organisms. Degradation in the air is also possible (Moilanen et al., 1975).

The amount of insecticides intercepted by vegetation depends on the rate of application and the density of vegetation. There is limited absorption and very little translocation of many insecticides intercepted by foliage. Through the action of rain, much of the unabsorbed insecticide will be washed from the surface of the leaf. Insecticide remaining on the leaf surface and any insecticide not translocated to other plant parts, will also enter the environment of the forest floor due to leaf fall.

Insecticides retained by the plant may be excreted back into the environment through the roots or they may end up in some plant storage tissue to be released at a later time. Through metabolic activities, plants may degrade an insecticide to nonbiologically active substances.

The forest floor is a major receptor of aerially applied spray materials. Insecticides in the forest floor may be volatilized and reenter the air, absorbed on soil mineral or organic matter, leached through the soil profile by water, or degraded by chemical or biological means.

As the concentration of insecticide in the soil solution decreases, more insecticide will be released from the adsorption sites. Thus adsorption provides only temporary storage and the soil is in effect a reservoir of chemicals which will eventually be released. Leaching is a slow process, capable of moving chemicals only short distances (Harris, 1967, 1968).

Insecticides may enter streams by several processes. The direct application or drift to surface waters will occur for only a short period of time but may cause high concentrations of pollutants. Insecticides may also enter streams in rainfall which washes particulate and vapor forms from the air or from leaves. Insecticides also may enter streams by leaching through the soil profile or in mass overland flow during periods of high precipitation.

Fungicides, Rodenticides, Fire Retardants, and Other Chemicals

Chemical use other than herbicides and insecticides is almost non-existent. There were 200 acres treated with a rodenticide to control gophers and another 20 acres treated with Methyl Bromide to control ants (Tables 22, 23, and 24).

Chemicals that are registered for use in forested areas have been evaluated by private organizations, state and federal agencies prior to being accepted by the U.S. Environmental Protection Agency. Chemicals that are registered and used as prescribed by federal and state law should result in no significant impact to the aquatic environment.

Table 22. Chemical use on private non-industrial land in East Texas.

Category of Chemical Agent	Types Used	Total Quantity Used or Number of Acres Treated	Application Rate	Methods of Application	Reasons for Application
Insecticides	Lindane	150 acres	Label Recommendations	Spray	Southern Pine Beetle Control
	Myrex	500 acres	2 lbs./acre	Broadcast on soil	Leaf Cutting Ant Control
	Furadan	30 acres	Label Recommendations	Foliar Spray	Control Tip Moth in Christmas Trees
	Guthion	50 acres	Label Recommendations	Spray	Control of Pecan Worms
	Dysiston		Label Recommendations	Foliar Spray	Control Tip Moth in Christmas Trees
	Cygon		Label Recommendations	Foliar Spray	Control Tip Moth in Christmas Trees
Herbicides	Tordon	5,175 acres	1 gal./acre	Basal Injection	Control of Undesireable Trees
	2,4-D amine	2,055 acres	3 qts./acre	Basal Injection	Control of Undesireable Trees
	2,4,5-T	5,100 acres	Label Recommendations	Foliar Spray	Control of Undesireable Trees
Fungicides	None in use				
Rodenticides	None in use				
Fertilizers	None in use				
Fire Retardants	None in use				
Other Chemical Agents (e.g., soil stabilizers, soil fumigants, etc.)	Methyl Bromide	20 acres	Label Recommendations	Soil Fumigation	Control of Town Ant

Table 23. Chemical use on industrial land in East Texas.

Category of Chemical Agent	Types Used	Total Quantity Used or Number of Acres Treated	Application Rate	Methods of Application	Reasons for Application
Insecticides	Myrex	650 lbs.	one lb./med. size mound	Broadcast on towns	Control of Texas leaf cutting ant
	Methyl Bromide	12 pints	1 pint/mound	Injected into sealed mound	Control of Texas leaf cutting ant
	Guthion	70 acres		Spray	Control seed and cone insects in seed orchard
	Furadan	70 acres		Spray	Control seed and cone insects in seed orchard
	B.H.C.	10 gal.		Spray	Southern Pine Beetle Treatment in seed orchard
Herbicides	2,4,5-T	900 acres	1/2 gal./acre	Mist blower	Control of undesirable vegetation
	Tordon 101	3,220 acres	1/2 gal./acre	Tree injection	Control of undesirable vegetation
	2,4-D	23,210 acres	1/2 gal./acre	Mist blower	Control of undesirable vegetation
Fungicides	None used				
Rodenticides	Poison Maize	200 lbs.	one lb./acre	Drill machine	Gopher Eradication
Fertilizers	None used				
Fire Retardants	None used				
Other Chemical Agents (e.g. soil stabilizers, soil fumigants, etc.)	None used				

Table 24 . Chemical use on public land in East Texas.

Category of Chemical Agent	Types Used	Total Quantity Used or Number of Acres Treated	Application Rate	Methods of Application	Reasons for Application
Insecticides	Lindane	50 acres	1% Solution	Hand Sprayer	Control of Southern Pine Beetle
	Mirex	50 acres	1 oz./mound	Broadcast on Individual Mounds	Control of Fire Ant
Herbicides	Tordon	2,500 acres	1-1/2 - 2 lb. A.I./acre	Basal Injection into trees	Control of Undesirable trees
	2,4-D	2,000 acres	Label Recommendations	Basal Injection into trees	Control of Undesirable trees
Fungicides	None used				
Rodenticides	None used				
Fertilizers	None used				
Fire Retardants	None used				
Other Chemical Agents (e.g. soil stabilizers, soil fumigants, etc.)	None used				

CONTROL STRATEGIES

This section of the report presents alternative strategies for controlling the extent of silviculturally related nonpoint source pollution. In addition, within the constraints imposed by existing data limitations, an attempt has been made to characterize these strategies in terms of what it would cost to implement them and their probable effectiveness.

Costs of Implementation

Data pertaining to the cost of applying various forestry practices under typical East Texas conditions is generally unavailable from public sources. Accordingly, a questionnaire was developed and distributed to members of the forest industry and U.S. Forest Service. The questionnaire had a twofold objective: 1) to collect baseline data about the per unit costs of various forestry activities, and 2) to collect information about the probable cost impacts of imposing control strategies on forestry activities. With regard to this last objective, the word "probable" should be emphasized.[1/] Forest practice costs can be influenced by a great many factors, and in the case of several of the suggested control strategies there was no real experience upon which to formulate estimates of cost impact.

Table 25 provides current unit cost data for a broad range of silvicultural practices utilized in East Texas. Because of the tremendous differential, separate road cost figures have been reported for industry and the U.S. Forest Service. This difference is attributable to the exceptionally high engineering standards employed in constructing National

[1/] Copies of the cost questionnaire are included in Appendix III.

Forest roads. If an average cost were to be taken for both ownership classes, it would not really be reflective of the actual costs incurred by either.

Table 25. Range of Unit Costs for Various Silvicultural Practices Utilized in East Texas (1977).[1/]

Silvicultural Practices	Low	Average	High
Permanent Road System:			
Forest Industry	$5,700/mi.	$6,000/mi.	$6,300/mi.
U.S. Forest Service	$35,000/mi.	$40,000/mi.	$45,000/mi.
Maintenance (Industry)	$280/mi.	$400/mi.	$520/mi.
Harvesting Operations:			
Sawlogs	$42/MBF	$49.50/MBF	$57/MBF
Pulpwood	$20/cord	$22.50/cord	$25/cord
Site Preparation:			
Chemical herbicides	$12/ac.	$13.50/ac.	$15/ac
Prescribed burning	$2.50/ac.	$3.25/ac.	$4/ac.
Mechanical	$33/ac.	$50/ac.	$67/ac.
Planting:			
Direct Seeding (ground)	$22/ac.	$22/ac.	$22/ac.
Direct Seeding (air)	$15/ac.	$15/ac.	$15/ac.
Planting (hand)	$32/ac.	$32/ac.	$32/ac.
Planting (machine)	$20/ac.	$27.50/ac.	$35/ac.
Intermediate Cultural Practices:			
Cultivation	$100/ac.	$100/ac.	$100/ac.
Prescribed burning	$.75/ac.	$.88/ac.	$1/ac.
Salvage or Sanitation Cutting	$2/tree	$2/tree	$2/tree
Thinning (precommercial)	$16/ac.	$19/ac.	$22/ac.
Thinning (commercial)	$1.50/MBF	$1.50/MBF	$1.50/MBF
Chemical Use Practices:			
Insecticides	$25/ac.	$25/ac.	$25/ac.
Herbicides	$9/ac.	$19.50/ac.	$30/ac.
Others		Not used	

[1/] The reported figures are indicative of the costs experienced by forest industry. In the case of the non-industrial private woodland owner, the unit costs would typically be higher. This is due to the fact that within this latter ownership class, forestry operations are normally conducted on a much smaller scale.

Table 26 summarizes the available information pertaining to the probable impacts of the control strategies on the costs of the various silvicultural practices. A number of things should be kept in mind when interpreting this table. These include:

1.) The table was designed to indicate the probable maximum increase in cost that would result from always applying a particular control strategy.

2.) The table indicates probable cost increases in both percentage and dollar terms. These increases were calculated using the average cost figures given in Table 26

3.) Some silvicultural practices, because they are closely interrelated, have been grouped together and their costs have been combined. This is true of harvesting operations and regeneration systems -- and mechanical site preparation and machine planting. In these instances, the cost increases shown in the table have been calculated on the basis of these combined costs (e.g. $77.50/acre for mechanical site preparation and machine planting).

4.) In terms of site preparation and planting techniques, the table only estimates the impact of control strategies on the costs of mechanical site preparation and machine planting.

5.) In terms of chemical use practices, the table only estimates the impact of the control strategies on the costs of using herbicides.

6.) The estimated impacts of the control strategies on road construction costs are based on the cost per mile figure provided by forest industry (e.g. $6,000/mile).

7.) In terms of intermediate cultural practices, the table only estimates the impact of the control strategies on the cost of precommercial thinning.

Table 26 Probable Maximum Increase in the Average Unit Costs of Selected Silvicultural Activities Attributable to Always Applying the Specified Control Strategies.

Control Strategy by Silvicultural Activity	Silvicultural Activity										
	Access Systems		Harvesting and Regeneration			Mechanical Site Prep. and Planting		Intermediate Cultural Practices		Chemical Use Practices	
	%	$/Mi.	%	$/MBF[1/]	$/Cd.[2/]	%	$/Ac.	%	$/Ac.	%	$/Ac.
General											
1. Proper planning throughout all phases of silvicultural activities will help to minimize the potential for unfavorable impacts on water quality.	0 [3/]		0								
2. When planning to conduct silvicultural activities, particularly road and harvesting operations, utilize topographic maps, aerial photographs, soil surveys and combine these with local knowledge or field reconnaissance to ascertain on-the-ground conditions. (EPA, 1975; Waelti, 1970; Beasley, 1976).	0		0								
3. Road planning should be coordinated with logging planning to insure the requirements of the planned logging system are satisfied. (Larse, 1970).	0		0								
4. For all silvicultural activities, particularly access systems, harvesting, and site preparation; provide streamside buffer strips where only selective cutting is allowed. A brush cover may be sufficient on narrow streams; whereas, on wider streams, a buffer strip of trees may be required. (Beasley, 1977, Dunford, 1960; EPA, 1973; Rothacher, 1970; Ursic, 1974; Corbett, Lynch and Sopper, 1975).	0		0								
5. On wet soils with seasonal water problems, schedule the timing of silvicultural operations to minimize adverse impact on water quality.	40	2,400	40	20.00	9.00	40	20.00	25	5.00	25	6.25
6. Where possible roads, skid trails, windrowed slash, firelines, and planting should all be conducted on the contours (FWPCA, 1970).	25	1,500	15	7.50	3.50	15	7.50	90	17.00		
7. Where disturbances remove all vegetation, such as road building, embankments, cut-over and site prepared areas, seeding and mulching may be necessary to mitigate excessive erosion.	25	1,500	33	16.50	7.50	15	7.50				

Control Strategy by Silvicultural Activity	Access Systems		Harvesting and Regeneration			Mechanical Site Prep. and Planting		Intermediate Cultural Practices		Chemical Use Practices	
	%	$/Mi.	%	$/MBF	$/Cd.	%	$/Ac.	%	$/Ac.	%	$/Ac.
Access Systems											
1. To the extent possible, locate roads on areas with stable soils and away from streams. (FWPCA, 1970).	40	2,400									
2. Where topography permits, and if feasible, locate roads on the crests of ridges. (FWPCA, 1970; Rothwell, 1971; Larse, 1970).	25	1,500									
3. Minimize the location roads and skid trails in marshes, wet fields and natural drainage channels. (FWPCA, 1970).	40	2,400	40	20.00	9.00						
4. Use at least the minimum design standard that produces a road sufficient to carry the anticipated traffic load with reasonable safety, and with minimum environmental impact.		4/									
5. Construct roads well in advance of harvesting to assure adequate roadbed stabilization.	0										
6. Right-of-way timber should be removed or decked in suitable locations to insure it will not be incorporated into roadbeds or fills, or act as support for fills or embankments. (California State Water Res. Control Board, 1973).	0										
7. Road design should provide for the prevention of high surface water velocities through the use of rolling grades, dips and wing ditches (Rothacher, 1970).	33	1,500									
8. Ditches, culverts, drainage dips, water bars, cross drains, should be installed concurrent with construction.	0										
9. Where stream crossings are necessary, roads and skidtrails should climb away from both sides of the stream at right angles to the channel to prevent high water from running down road surfaces. (EPA, 1975; Kochenderfer, 1970; Satterlund, 1972).	25	1,500									
10. At stream crossings, fill material should be built with adequate base and toe support and the sidecast material should not be placed below the ordinary high water mark of a stream. (Bullard, 1972; Rothacher, 1970).	0										

Control Strategy by Silvicultural Activity	Access Systems		Harvesting and Regeneration			Mechanical Site Prep. and Planting		Intermediate Cultural Practices		Chemical Use Practices	
	%	$/Mi.	%	$/MBF	$/Cd.	%	$/Ac.	%	$/Ac.	%	$/Ac.
11. Dirt fills for bridge approaches should be protected from erosion. Methods include seeding, riprap, concrete surfacing, retaining walls and bulkheads.	N.A. 6/										
12. Low-water bridges and overflow culverts should be constructed to minimize changes in natural streambeds during high water. (EPA, 1975).	0										
13. Bridges should not constrict clearly defined stream channels. Permanent bridges should be designed to pass the normal flood level, or the road approach should be constructed to provide erosion protection from overflow flood waters.	0										
14. All drainage work should start at the downstream end and progress upward. (EPA, 1975).	N.A.										
15. Use large aggregate road surfacing material to stabilize road surface. (Packer 1967).	100+	6,000									
16. Install wing ditches or cross drainage culverts immediately upgrade of live stream crossings to prevent ditch sediment from entering the stream course, (Bullard, 1972).	90	5,400									
17. Culvert size should be adequate to carry the anticipated water flow unless soil and stream conditions require culvert sizing for maximum flow conditions. (Dunford, 1960; and Rothacher, 1970).	0										
18. Inspection should be started immediately after construction and should be continued to periodically determine maintenance requirements.	5	20.00 7/									
19. The road should be kept free of ruts, curbs and logging debris that prevents water from entering the drainage system. (Kochenderfer, 1970). Roads in a non-use category should be thoroughly drained, revegetated and physically closed to vehicle traffic where situations permit. (Rothacher, 1970 and Larse, 1970).	30	120 7/									
20. Roads which have a high potential for erosion should be closed to non-essential traffic in wet weather, particularly immediately following construction.	70	280 7/									

Control Strategy by Silvicultural Activity	Access Systems		Harvesting and Regeneration			Mechanical Site Prep. and Planting		Intermediate Cultural Practices		Chemical Use Practices	
	%	S/Mi.	%	S/MBF	S/Cd.	%	S/Ac.	%	S/Ac.	%	S/Ac.
Harvesting Operations											
1. To control erosion, identify potentially erodible or unstable soils and minimize logging disturbances on these areas. (Fredriksen, 1972).			N.A.								
2. Whenever practical, utilize topographic features, streams, roads and forest type changes in setting harvest area boundaries.			N.A.								
3. Where possible, trees should be felled parallel to the skidding direction with log butts toward the landing. This practice can facilitate skidding and minimize soil disturbance.			25	12.50	5.50 5/						
4. Trees should not be felled into streams, except where no safe alternative exists. In the latter case, such trees should be removed promptly before limbing or bucking.			25	12.50	5.50 5/						
5. Directional felling should be practiced near perennial streams to minimize debris entering the stream and to facilitate disposal of logging debris.			25	12.50	5.50 5/						
6. Logging debris which has accumulated in or has been deposited in streams or drainage systems should be removed during the harvesting operation.			25	12.50	5.50 5/						
7. Timber cut within buffer strip should be removed by the method which causes the least damage, consistent with the equipment reasonably available to the logger.			0								
8. Stream channels should not be used as skidtrails. (Patric and Aubertin, 1977).			0								
9. Temporary stream crossings utilizing culverts may be required. These culverts should be removed promptly upon completion of use.			33	16.50	7.50						
10. Skid trails on steep slopes should have occasional breaks in grade, and upon completion of use, should be water-barred, seeded or mulched with logging debris. (Patric and Aubertin, 1977).			33	16.50	7.50						

Control Strategy by Silvicultural Activity	Access Systems		Harvesting and Regeneration			Mechanical Site Prep. and Planting		Intermediate Cultural Practices		Chemical Use Practices	
	%	$/Mi.	%	$/MBF	$/Cd.	%	$/Ac.	%	$/Ac.	%	$/Ac.
11. Skid trails should be laid out to take advantage of topography, to minimize steep gradients, and to keep soil displacement to a minimum.			25	12.50	5.50 5/						
12. Servicing of equipment should be carried out away from streams, and fuel and lubricant storage tanks or containers should be located where an accidental spill would not result in stream contamination.			0								
Regeneration Systems											
1. To the extent feasible, clearcut areas, especially on long slopes, should take into consideration the size and shape of the cut to allow blending with the topography and breaks in slope for preventing erosion build up.			N.A.								
2. Assure prompt reforestation. (Rothacher, 1970).			0								
Site Preparation and Planting											
1. Select a technique that: (a) is compatible with the site; (b) leaves as much organic matter intact over mineral soil as possible; and (c) is restricted in the sensitive source areas. (Nutter, 1975).						N.A.					
2. Minimize the plowing effect of V-blade in conjunction with the planting machine, thus, reducing soil scalping.						50	25.00				
3. Once sites have pine species established, intensive mechanical site preparation may be minimized by: (a) a prescribed burning program throughout the life of the stand to minimize competition and as the final seedbed preparation (Wade and Ward, 1974); (b) herbicide control of hardwoods.						N.A.					
Intermediate Cultural Practices											
<u>Prescribed Fire</u>											
1. Burning should be attempted only by well trained personnel wupplied with adequate equipment for suppression.						N.A.		N.A.			
2. Weather conditions and fuel moisture should be such that only the top portion of the organic layer is burned away.								100+	19.00		

Control Strategy by Silvicultural Activity	Access Systems		Harvesting and Regeneration			Mechanical Site Prep. and Planting		Intermediate Cultural Practices		Chemical Use Practices	
	%	$/Mi.	%	$/MBF	$/Cd.	%	$/Ac.	%	$/Ac.	%	$/Ac.
3. To contain the fire, firelines or other barriers are needed. As much as possible, use existing barriers such as roads and streams. Where fireline construction is necessary, the line should be waterbroken at the time of construction or if the line will be used for mobile equipment during the burning, construction of waterbreaks should be done as soon as the burning operation is complete.								70	13.30		
Chemical Use Practices											
1. Follow state and federal requirements for registration and regulation of chemicals use. Use chemicals according to tested procedures and not for any purposes other than those for which it is registered. (Montgomery and Norris, 1970).										0	
2. When applying chemicals, follow the timing recommendations and exercise care not to exceed intended or allowable dosages.										0	
3. Fertilize at rates which do not exceed the utilization capacity of the timber stand. Frequent fertilization at low rates is environmentally safer than infrequent applications at higher rates. (EPA, 1973).										0	
4. To the extent that rainfall can be predicted, avoid fertilization in periods of heavy rainfall. (EPA, 1973).										0	
5. Use indirect controls in place of insecticides wherever possible. Types of indirect controls include: (a) prevention of spread; (b) modification of nutritional and physical conditions; e.g. food supply, moisture, temperature; (c) use of parasites and predators; and (d) application of silvicultural practices. (Graham and Knight, 1965).										100+	19.50
6. Utilize injection or stump treatment herbicide methods, where feasible, in areas immediately adjacent to streams.										N.A.	
7. When applying herbicides and insecticides, lay out spray boundaries to exclude streams from treatment areas and avoid application in flat, poorly drained areas. (Norris and Moore, 1976).										50	9.75

Control Strategy by Silvicultural Activity	Access Systems		Harvesting and Regeneration			Mechanical Site Prep. and Planting		Intermediate Cultural Practices		Chemical Use Practices	
	%	$/Mi.	%	$/MBF	$/Cd.	%	$/Ac.	%	$/Ac.	%	$/Ac.
S. To prevent drift, aerial spraying of chemicals should be done only when the wind is calm. (Arend, 1959 and Burns, 1961).										0	

1/Refers to sawlog harvesting operation.

2/Refers to pulpwood harvesting operation.

3/A zero indicates that the specified strategy is already in common usage and that consequently its adoption as a control would not increase costs. Generally speaking, however, this is only true for lands in public or industrial ownership.

4/Implied cost increase can perhaps be inferred from difference between U.S. Forest Service and industry road construction costs -- i.e. $34,000/Mi.

5/Due to increased supervisory cost.

6/Unable to estimate cost impact.

7/Represent increases in road maintenance costs.

Performance

Data does not exist that will enable a quantitative evaluation of the suggested control strategies by forest practice e.g. windrow slash on the contour rather than up and down slope; use of streamside buffer strips. However, control strategies for each practice can be qualitatively discussed as to their effectiveness in controlling nonpoint pollution. Generally, this amounts to performing forest practices in a manner that will minimize: 1) on site soil disturbance, 2) stream channel disturbance, and 3) direct application of chemicals and fertilizers into stream channels. For example, research from agricultural land has shown contour tillage to be effective in controlling sediment loss. Likewise, most watershed studies, where streamside buffer strips were used have been effective in controlling sediment, nutrient, organic matter and introduced chemical loss, and have prevented water temperature increases. Control strategies that should be the most effective in controlling nonpoint pollution from forest practices in East Texas are presented in Table 27. For each control strategy the table indicates the type of potential pollutant which the strategy should control and also its effectiveness i.e. not, slightly, moderately or highly. The use of a strategy may not be as successful as predicted because of changes in water yields and carrying capacity of the water. In some situations increased water yields may actually dilute concentrations of pollutants. More importantly, the effectiveness of the control strategies in controlling nonpoint pollution from silvicultural activities on more gentle slopes with stable soils may be reduced to zero.

Current intensive forest management practices can be ranked as to their sediment production potential and evaluated quantitatively. The intensive forest management practive ranked highest in sediment production.

potential is access systems followed in order by mechanical site preparation, harvesting, planting and intermediate culture practices such as prescribed fire, herbicides, insecticides and fertilizers. Dissmeyer and Stump (1977) using the Universal Soil Loss Equation (USLE) and Erosion Data Bank of the Southeast Area have estimated average, minimum and maximum soil loss by forest practice for the Southern Coastal Plains (Tex., La., Ark.) (Table 28). Soil loss as presented in this table represents the amount of soil predicted to reach the bottom of a slope, or where disposition occurs by the USLE. The bottom of the slope could be a stream, terrace, or undisturbed vegetation. Thus, the rates given in Table 28 do not necessarily represent the volume of sediment that enters a stream. It must be stressed that these are predicted values and should be used as indexes. The USLE predicts long-term (22 year) average erosion rates with an accuracy of plus or minus 100 percent. The erosion rates presented should be viewed as ballpark figures; however, they do show the magnitude of difference between forest practices and conditions, and that excessive erosion rates can occur if a poorly executed activity is applied to a hazardous area. As indicated the practices having the most impact on erosion are roads and skid trails with prescribed burning and clearcut harvesting having the least impact. The most effective practice in reducing soil loss is the one that will perform the desired task with minimum soil disturbance.

Table 27. Effectiveness of the alternative control strategies in controlling nonpoint sources of pollution from Silvicultural activities on the most sensitive sites.[1/]

Control Strategy by Silvicultural Activity	Effectiveness			
	None	Slight	Moderate	High
General				
1. Proper planning throughout all phases of silvicultural activities will help to minimize the potential for unfavorable impacts on water quality.				TONSC[1/]
2. When planning to conduct silvicultural activities, particularly road and harvesting operations, utilize topographic maps, aerial photographs, soil surveys and combine these with local knowledge or field reconnaissance to ascertain on-the-ground conditions. (EPA, 1975; Waelti, 1970; Beasley, 1976).				TONSC
3. Road planning should be coordinated with logging planning to insure the requirements of the planned logging system are satisfied. (Larse, 1970).	C			TONS
4. For all silvicultural activities, particularly access systems, harvesting, and site preparation; provide streamside buffer strips where only selective cutting is allowed. A brush cover may be sufficient on narrow streams; whereas, on wider streams, a buffer strip of trees may be required. (Beasley, 1977, Dunford, 1960; EPA, 1973; Rothacher, 1970; Ursic, 1974; Corbett, Lynch and Sopper, 1975).				TONSC
5. On wet soils with seasonal water problems, schedule the timing of silvicultural operations to minimize adverse impact on water quality.				TONSC
6. Where possible, roads, skid trails, windrowed slash, firelines and planting should all be conducted on the contours (FWPCA, 1970).	C			TONS
7. Where disturbances remove all vegetation, such as road building, embankments, cut-over and site prepared areas, seeding and mulching may be necessary to mitigate excessive erosion.	C			TONS

Control Strategy by Silvicultural Activity	Effectiveness			
	None	Slight	Moderate	High
Access Systems				
1. To the extent possible, locate roads on areas with stable soils and away from streams. (FWPCA, 1970).	C			TONS
2. Where topography permits, and if feasible, locate roads on the crests of ridges. (FWPCA, 1970; Rothwell, 1971; Larse, 1970).	CTO			NS
3. Minimize the location roads and skid trails in marshes, wet fields and natural drainage channels. (FWPCA, 1970).	C	O		TNS
4. Use, at least, the minimum design standard that produces a road sufficient to carry the anticipated traffic load with reasonable safety, and with minimum environmental impact.	CTO			NS
5. Construct roads well in advance of harvesting to assure adequate roadbed stabilization.	CT	O		NS
6. Right-of-way timber should be removed or decked in suitable locations to insure it will not be incorporated into road-beds or fills, or act as support for fills or embankments. (California State Water Res. Control Board, 1973).	CT	O	NS	
7. Road design should provide for the prevention of high surface water velocities through the use of rolling grades, dips, and wing ditches. (Rothacher, 1970)	CT	O		NS
8. Ditches, culverts, drainage dips, water bars, cross drains, should be installed concurrent with construction.	CT		ONS	
9. Where stream crossings are necessary, roads and skidtrails should climb away from both sides of the stream at right angles to the channel to prevent high water from running down road surfaces. (EPA, 1975; Kochenderfer, 1970; Satterlund, 1972).	CTO			NS
10. At stream crossings, fill material should be built with adequate base and toe support and the sidecast material should not be placed below the ordinary high water mark of a stream. (Bullard, 1972; Rothacher, 1970).	CTO			NS

Control Strategy by Silvicultural Activity	Effectiveness			
	None	Slight	Moderate	High
11. Dirt fills for bridge approaches should be protected from erosion. Methods include seeding, riprap, concrete surfacing, retaining walls and bulkheads.	CTO			NS
12. Low-water bridges and overflow culverts should be constructed to minimize changes in natural streambeds during high water. (EPA, 1975).	CTO		NS	
13. Bridges should not constrict clearly defined stream channels. Permanent bridges should be designed to pass the normal flood level, or the road approach should be constructed to provide erosion protection from overflow flood waters.	CTO			NS
14. All drainage work should start at the downstream end and progress upward. (EPA, 1975).	CTO		NS	
15. Use large aggregate road surfacing material to stabilize road surface. (Packer 1967).	CTO			NS
16. Install wing ditches or cross drainage culverts immediately upgrade of live stream crossings to prevent ditch sediment from entering the stream course, (Bullard, 1972).	CT			ONS
17. Culvert size should be adequate to carry the anticipated water flow unless soil and stream conditions require culvert sizing for maximum flow conditions. (Dunford, 1960; and Rothacher, 1970).	CT	O	NS	
18. Inspection should be started immediately after construction and should be continued to periodically determine maintenance requirements.	CT	O		NS
19. The road should be kept free of ruts, curbs and logging debris that prevents water from entering the drainage system. (Kochenderfer, 1970). Roads in a non-use category should be thoroughly drained, revegetated and physically closed to vehicle traffic where situations permit. (Rothacher, 1970 and Larse, 1970).	CT	O		NS
20. Roads which have a high potential for erosion should be closed to non-essential traffic in wet weather, particularly immediately following construction.	CT	O		NS

Control Strategy by Silvicultural Activity	Effectiveness			
	None	Slight	Moderate	High
Harvesting Operations				
1. To control erosion, identify potentially erodible or unstable soils and minimize logging disturbances on these areas. (Fredriksen, 1972).	CT			ONS
2. Whenever practical, utilize topographic features, streams, roads and forest type changes in setting harvest area boundaries.	CT		ONS	
3. Where possible, trees should be felled parallel to the skidding direction with log butts toward the landing. This practice can facilitate skidding and minimize soil disturbance.	CT		ONS	
4. Trees should not be felled into streams, except where no safe alternative exists. In the latter case, such trees should be removed promptly before limbing or bucking.	C	T		ONS
5. Directional felling should be practiced near perennial streams to minimize debris entering the stream and to facilitate disposal of logging debris.	CT		NS	O
6. Logging debris which has accumulated in or has been deposited in streams or drainage systems should be removed during the harvesting operation.	CT		ONS	
7. Timber cut within buffer strip should be removed by the method which causes the least damage, consistent with the equipment reasonably available to the logger.	CT			ONS
8. Stream channels should not be used as skidtrails. (Patric and Aubertin, 1977).	C			TONS
9. Temporary stream crossings utilizing culverts may be required. These culverts should be removed promptly upon completion of use.	C	T		ONS
10. Skid trails on steep slopes should have occasional breaks in grade, and upon completion of use, should be water-barred, seeded or mulched with logging debris. (Patric and Aubertin, 1977).	CT			ONS

Control Strategy by Silvicultural Activity	Effectiveness			
	None	Slight	Moderate	High
11. Skid trails should be laid out to take advantage of topography, to minimize steep gradients, and to keep soil displacement to a minimum.	CT			ONS
12. Servicing of equipment should be carried out away from streams, and fuel and lubricant storage tanks or containers should be located where an accidental spill would not result in stream contamination.	TONS			C
Regeneration Systems				
1. To the extent feasible, clearcut areas, especially on long slopes, should take into consideration the size and shape of the cut to allow blending with the topography and breaks in slope for preventing erosion build up.	CT			ONS
2. Assure prompt reforestation. (Rothacher, 1970).	CT			ONS
Site Preparation and Planting				
1. Select a technique that: (a) is compatible with the site; (b) leaves as much organic matter intact over mineral soil as possible; and (c) is restricted in the sensitive source areas. (Nutter, 1975).	CT			ONS
2. Minimize the plowing effect of V-blade in conjunction with the planting machine, thus, reducing soil scalping.	CT			ONS
3. Once sites have pine species established, intensive mechanical site preparation may be minimized by: (a) a prescribed burning program throughout the life of the stand to minimize competition and as the final seedbed preparation (Wade and Ward, 1974); (b) herbicide control of hardwoods.	CT			ONS
Intermediate Cultural Practices				
Prescribed Fire				
1. Burning should be attempted only by well trained personnel wupplied with adequate equipment for suppression.	C			TONS
2. Weather conditions and fuel moisture should be such that only the top portion of the organic layer is burned away.	CT			ONS

Control Strategy by Silvicultural Activity	Effectiveness			
	None	Slight	Moderate	High
3. To contain the fire, firelines or other barriers are needed. As much as possible, use existing barriers such as roads and streams. Where fireline construction is necessary, the line should be waterbroken at the time of construction or if the line will be used for mobile equipment during the burning, construction of waterbreaks should be done as soon as the burning operation is complete.	CT		ONS	
Chemical Use Practices				
1. Follow state and federal requirements for registration and regulation of chemicals use. Use chemicals according to tested procedures and not for any purposes other than those for which it is registered. (Montgomery and Norris, 1970).	TONS			C
2. When applying chemicals, follow the timing recommendations and exercise care not to exceed intended or allowable dosages.	TONS			C
3. Fertilize at rates which do not exceed the utilization capacity of the timber stand. Frequent fertilization at low rates is environmentally safer than infrequent applications at higher rates. (EPA, 1973).	TONS		C	
4. To the extent that rainfall can be predicted, avoid fertilization in periods of heavy rainfall. (EPA, 1973).	TONS			C
5. Use indirect controls in place of insecticides wherever possible. Types of indirect controls include: (a) prevention of spread; (b) modification of nutritional and physical conditions; e.g. food supply, moisture, temperature; (c) use of parasites and predators; and (d) application of silvicultural practices. (Graham and Knight, 1965).	TONS		C	
6. Utilize injection or stump treatment herbicide methods, where feasible, in areas immediately adjacent to streams.	TONS			C
7. When applying herbicides and insecticides, lay out spray boundaries to exclude streams from treatment areas and avoid application in flat, poorly drained areas. (Norris and Moore, 1976).	TONS			C

Control Strategy by Silvicultural Activity	Effectiveness			
	None	Slight	Moderate	High
8. To prevent drift, aerial spraying of chemicals should be done only when the wind is calm. (Arend, 1959 and Burns, 1961).	TONS			C

1/ Effectiveness of the control strategies in controlling nonpoint sources of pollution from silvicultural activities on gentle slopes with stable soils may be reduced to zero.

2/ T = Stream temperature
O = Organic matter
N = Nutrients
S = Sediment
C = Introduced chemicals

Table 28. Erosion rates (tons/acre/year) by major forest practices for Southern Coastal Plains (Tex., La., Ark.) as determined by the Universal Soil Loss Equation, USLE[1].

Forest Practice	Recovery[2] Period-yrs	Average[3]	Minimum	Maximum
Undisturbed Forest	-	0.03	0.001	5.1
Prescribed Burning	2	0.18	0.002	12.7
Clearcut Harvesting	3	0.52	0.21	21.5
Grazed Forest	-	0.20	0.004	18.3
Chopping	3	0.26	0.004	32.3
Chopping plus burning	3	0.44	0.01	77.0
Shearing, K-G	4	0.70	0.03	41.2
Bedding	4	0.71	0.04	100.0+
Dozing	4	0.96	0.21	49.8+
Disking (4 yr. average)	4	2.66	0.18	100.0+
Skid Trails (3% of harvested area)		5.00	-	-
Roads (3% of harvested area)		6.50	-	-

[1]Dissmeyer, G. E. and R. F. Stump. 1977. Predicted Erosion Rates for Forest Management Activities and Conditions Sampled in the Southeast. Unpublished Manuscript. 9 pages. Authors are: Area Hydrologist Southeastern Area, U.S. Forest Service, Atlanta, Georgia, and 208 coordinator, Southeastern Area, U.S. Forest Service, Atlanta, Georgia, respectively.

[2]Time generally required for the condition to heal

[3]Representative erosion rate for the average conditions found in the field. The latter two (minimum and maximum) define the probable range of rates - low to high.

A METHODOLOGY FOR SELECTING ALTERNATIVE STRATEGIES TO CONTROL NONPOINT SOURCE POLLUTION FROM FOREST LANDS[1/]

Introduction

The purpose of this portion of the report is to outline a methodology which may be used to select alternative strategies for controlling silvicultural nonpoint source pollution. To clarify the terminology, control strategies refer to specific on site means of reducing the nonpoint source pollution of waterways. Generally, this will entail modifying forest management practices in a manner that will reduce sheet and rill erosion from forested watersheds.

In the Scope of Services issued by the Texas Department of Water Resources, we were charged with the responsibility for developing, "a step-by-step methodology . . . so that for any potential silviculturally related problem situation, alternative control strategies can be developed and the effects of applying the control strategies can be assessed." Furthermore, verbal directives from TDWR personnel indicated that this methodology should meet the following two criteria:

(1) Compatibility with the overall methodology for assessment of nonpoint source pollution as developed by Espey, Huston and Associates, Inc.

(2) Eliminate the need for collection of field data.

Thus, the methodology developed by Espey, Huston and Associates is the framework within which the silvicultural methodology has been developed. The next section of the paper is a discussion of methodological limita-

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[1/] Caution - An attempt to select and/or apply control strategies to forested watersheds based on USLE or MUSLE data should not occur without the verification by additional studies that a nonpoint pollution problem does exist.

tions, this will be followed by a review of Espey, Huston's work and the methodology for selecting silvicultural nonpoint source pollution control strategies. The last section of this portion of the report will illustrate the application of the silvicultural methodology to a hypothetical problem situation.

Limitations of the Methodology and USLE

The methodology is based on the USLE which was developed to predict soil erosion (tons/acre) on an average annual basis from agricultural land. It does not predict the amount of sediment reaching a stream channel, this has to be accomplished through the use of sediment transport equations. Pollutants, other than sediment, have to be estimated by loading functions. The method does not estimate soluble pollutants and the control strategies may not reduce soluble pollutants.

The USLE, transport equations and loading functions which have been developed for agricultural land are not directly applicable to East Texas forestlands without modifications. Such modifications should only be attempted after extensive research. The present reliability of the K, C, and P factors, transport equations and loading functions to East Texas is suspected to be poor.

The USLE transport equations and loading functions are believed to be useful in making relative comparisons between forest practices and some control strategies; however, the accuracy is not good. Most control strategies suggested in this report e.g. buffer strips, contour planting, etc. cannot be evaluated to any degree of accuracy with the present state-of-the-art USLE, transport equations and loading functions.

Gully or channel erosion cannot be accounted for by the USLE. Use of the USLE is confined to rill and interrill erosion.

Williams (1972) modification of the USLE (replacing the rainfall energy factor with a runoff energy factor) as used in this report and in Espey, Huston's methodology was deveolped especially for predicting sediment yield produced by individual storms and, supposedly, increases the accuracy of the USLE. Nevertheless, the same cautions and maybe more should be used with the MUSLE when it is applied to a forestry situation. Wischmeier (1976) states that neither the gross soil loss nor the delivery ratio can presently be predicted on an individual runoff-event basis. For a further discussion on the use and misuse of the USLE see Wischmeier, 1976.

The USLE or MUSLE when used to predict average erosion rates from forest practices do it with an accuracy of plus or minus 100 percent (Dissmeyer, G. E. and R. F. Stump. 1977. Predicted Erosion Rates for Forest Management Activities and Conditions Sampled in the Southeast. Unpublished manuscript. 9 pages.).

Review of the Espey, Huston and Associates, Inc. Methodology for Assessment of Nonpoint Sources of Pollution

Overview

The stated purposes of the methodology developed by Espey, Huston are as follows (Espey, Huston and Wells, 1976):

1) to project the quality and quantity of agricultural and silvicultural pollution in the state's waters
2) to provide procedures to assess the impact of nonpoint source pollution.

A master flow chart of the methodology is depicted in Figure 5. The procedure begins by considering a major river basin located within the state. A level I analysis is then conducted for all areas (counties) within the river basin. The level I analysis serves as a coarse screening process to identify those counties which contain agricultural and silvicultural lands that are probable contributors to nonpoint source pollution. These potential problem areas then undergo a level II analysis which identifies the quality, quantity and environmental impact of pollutants from all watersheds within these designated counties. The Espey, Huston methodology, however, stops short of recommending specific strategies to control nonpoint source pollution.

Level I Analysis

The level I analysis is depicted by a flow chart in Figure 6. The data required to conduct the level I analysis is obtained entirely from secondary sources which have been compiled by various government agencies such as the Texas Department of Water Resources and the Agricultural Research Service. From these secondary data sources, counties are

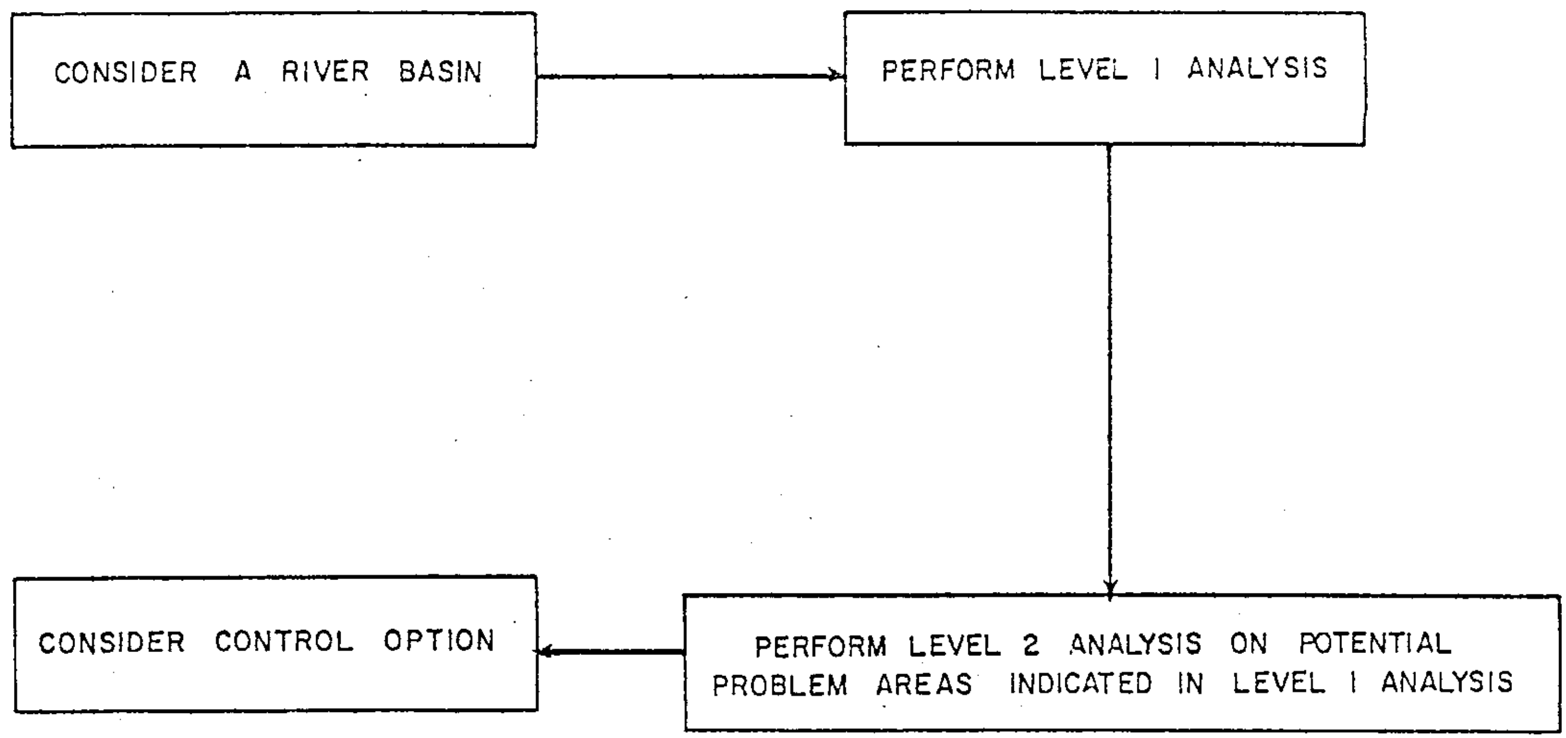

Figure 5 . Master Flow Chart of Methodology.

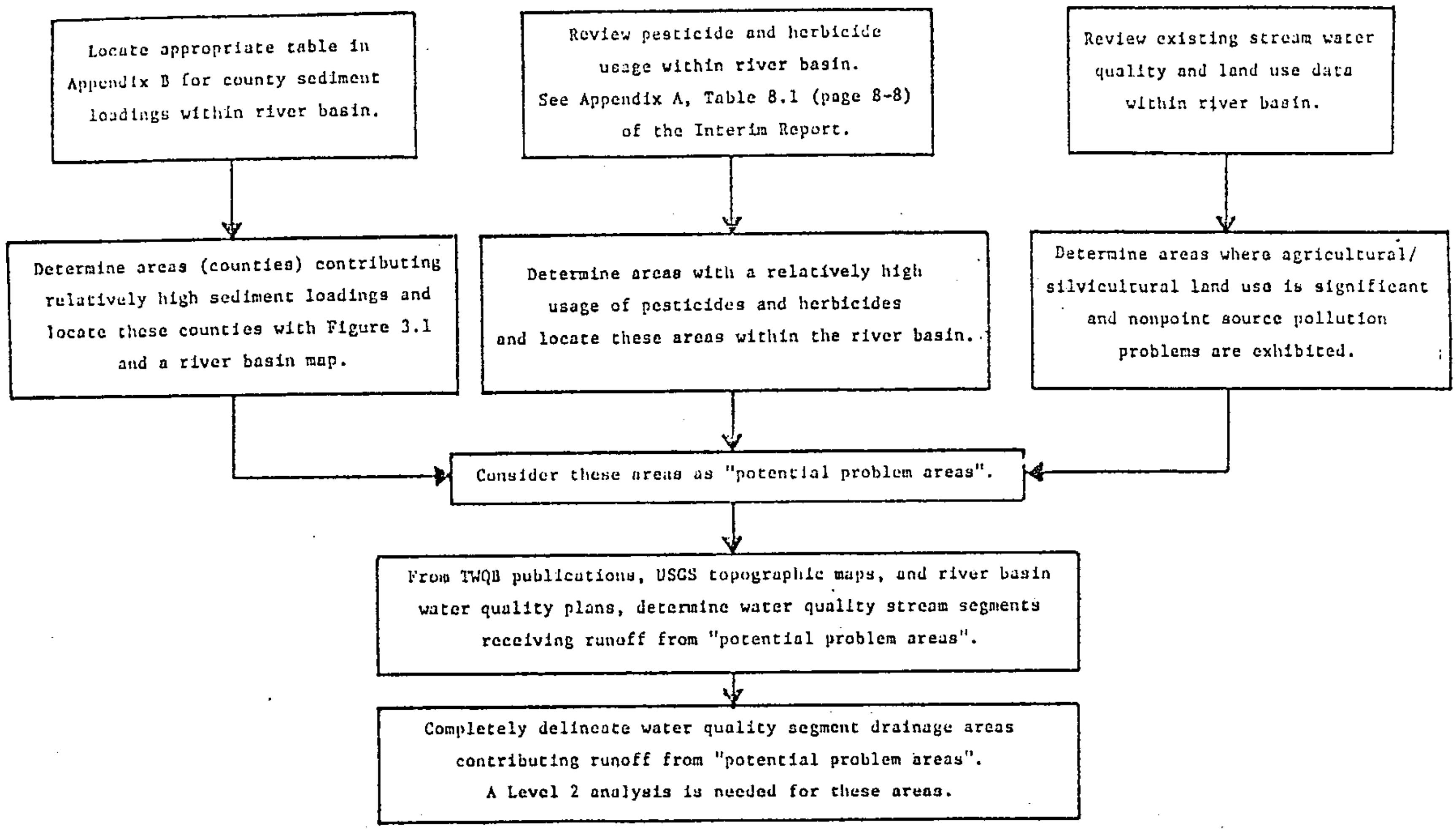

Figure 6 . Flow Chart for Level 1 Analysis.

selected which have: 1) relatively high sediment loadings, 2) relatively high usage of pesticides and herbicides, and 3) agricultural and/or silvicultural activity. Those counties which meet these criteria are identified as potential problem areas. Finally, in the level I analysis, the stream segments which receive runoff from these counties are identified and their respective watersheds are located and delineated on base maps prior to a level II analysis. It is important to note that at this juncture of the methodology, nonpoint source pollution problems have not been identified. Instead, only those watersheds which are the most likely contributors to nonpoint source pollution have been isolated.

Level II Analysis

The level II analysis, depicted by a flow chart in Figure 7, is used to determine the quality, quantity and environmental impact of pollutants from the watersheds which were designated as potential problem areas during the level I analysis.

Determination of Erosion

At the heart of the level II analysis is the modified universal soil loss equation (MUSLE). The equation which Espey, Huston has suggested for use is as follows:

$$Y = 95(Qxq_p)^{0.56} K \cdot LS \cdot CP$$

Where: Y = erosion in tons

(Qxq_p) = runoff energy factor

K = soil erodibility factor

LS = length slope factor

C = cropping management factor

P = erosion control practice factor

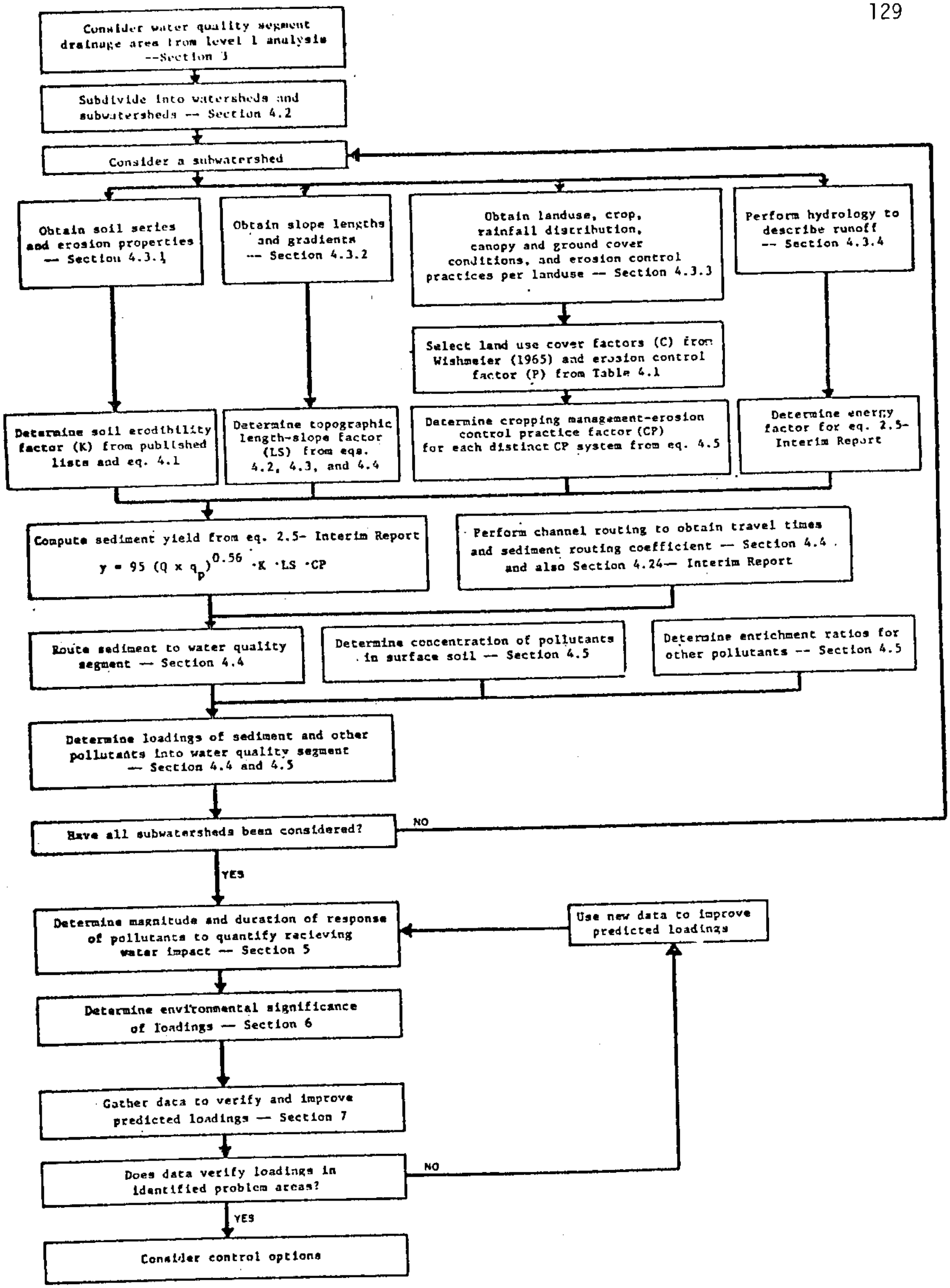

Figure 7 . Flow Chart for Level 2 Analysis.

The dependent variable of this equation (Y) indicates the gross erosion, for a given area, measured in tons. The independent variables, which are located on the right hand side of the equation, are based upond data obtained from a mixture of primary and secondary data sources. The runoff energy factor (Q) is derived from an analysis of hydrologic data obtained from government agencies, the soil erodibility factor (K) is derived from Soil Conservation Service reports, and the length-slope factor (LS) is derived from U.S. Geological Survey topographic maps. Together, these three independent variables represent factors which for all practical purposes cannot be readily manipulated by man. One can scarcely imagine economically feasible means of altering the precipitation, soil characteristics, or topography to a degree that would significantly alter rates of erosion from a watershed.

The two remaining independent variables in the MUSLE are subject to a great deal of manipulation by man and here, we can imagine, is the most feasible means of reducing erosion from watersheds. The cropping management factor (C) is based upon canopy, ground cover and disturbances which occur on the forested watersheds. In the Espey, Huston methodology, it has been suggested that cropping management conditions as they exist, can be obtained from aerial photographs, state and local expertise, Forest Survey reports and land use maps. While it is highly questionable whether cropping management conditions can actually be ascertained from these data sources, for the purpose of this example it is assumed that it is possible. The next step is to assign a numerical value to a given cropping management condition (i.e., develop a C-factor).

The erosion control practice factor (P) refers to various management practices which are instituted in order to reduce erosion from watersheds. Specifically in the case of forestry, this refers to a variety of practices such as buffer strips, contour planting, wing ditches and road surfacing that are used to reduce sediment which may be caused by silvicultural activities.

Presently the common practice is to use only the C factor or a CP factor. A list of CP factors for various woodland conditions are presented in Table 29. While not exhuastive in terms of the range of practices considered, this listing and a listing developed by the Soil Conservation Service (Appendix IV) does represent what appears to be the most complete set of data available.

Routing of Sediment

The MUSLE, as proposed by Espey, Huston indicates the gross erosion or soil movement on a watershed. A second equation is then used to route sediment to a stream segment. In effect, this second equation determines the portion of gross erosion which enters the stream. This equation is as follows:

$$RY = \sum_{i=1}^{n} Yi \cdot e^{-BTi(D50_1)^{0.5}}$$

RY = sediment yield for a large watershed, in tons

Yi = erosion for subwatershed (i), in tons

B = routing coefficient

Ti = travel time from subwatershed (i) to watershed outlet in hours

$D50_i$ = median particle size for subwatershed (i) in millimeters

TABLE 29. CP factors for selected forest practices in the Southern Coastal Plains (Texas, Louisiana, Arkansas)[1].

Forest Practices	CP Factors (1 to 4 years after treatment) 1	2	3	4
Undisturbed Forest	0.0007	-	-	-
Grazed Forest	0.004	-	-	-
Clearcut harvesting (3 yr. av.)	0.0046	0.0048	0.001	-
Chopping	0.0092	0.005	0.0003	-
Chop and burn	0.015	0.008	0.002	-
Burning (Prescribed)	0.006	0.005	-	-
Shearing, K-G	0.031	0.013	0.007	0.004
Disk	0.06	0.095	0.04	0.01
Bedding	0.039	0.002	0.001	-
Dozing	0.032	0.034	0.007	0.002

[1]Unpublished data furnished by George E. Dissmeyer, Forest Hydrologist, USFS, Atlanta, Georgia 30309.

Note: CP factors for forest practices in the Southern Coastal Plains are just now being developed. This table and the tables listed in Appendix IV represent the present state-of-the-art. This table was chosen to be used in the methodology example because it is a better representative of current forest practices in East Texas; however, more research is needed before these values receive broad use.

η = number of subwatersheds

In this equation the independent variable, Yi, is the dependent variable from the MUSLE. Thus, the amount of sediment which reaches the stream is a function of the gross erosion summed for all subwatersheds of various land use types and disturbance conditions.

Loading Functions

At this point, the Espey, Huston methodology utilizes loading functions to determine the amount of pollutants, other than sediment, which are associated with the soil which is routed to the stream. The pollutants considered by the methodology are nitrogen, phosphorus, organic matter and pesticides, and their loading functions are as follows:

Nitrogen

$$NT_e = a \cdot Y(s) \cdot Cs(NT) \cdot r_n$$

Where: NT_e = loading of total nitrogen from erosion, in lbs.

a = dimensional constant

$Y(s)$ = sediment loading, tons

$Cs(NT)$ = total nitrogen in soil, in grams/100 grams

r_n = nitrogen enrichment ratio

Phosphorus

$$PT_e = a \cdot Y(s) \cdot Cs(PT) \cdot r_p$$

Where: PT_e = loading of phosphorus from erosion in lbs.

Organic Matter

$$OM_e = a \cdot Y(s) \cdot Cs(OM) \cdot r_{om}$$

Where: OM_e = organic loading, lbs.

Pesticide

$$P_e = Y(s) \cdot Cs(P) \cdot r_p \cdot 10^{-6}$$

Where: P_e = pesticide yield, in lbs./day

$Y(s)$ = sediment yield, lbs./day

$Cs(P)$ = pesticide in soil, ppm

r_p = enrichment ratio

Determination of Environmental Impact

Thus far, the Espey, Huston methodology, through the MUSLE, routing and loading functions, has theoretically estimated the amount of sediment, nitrogen, phosphorus, organic matter and pesticides which are present within a stream. Therefore, the objective relating to the quality and quantity of pollutants has been achieved. The environmental impact of these pollutants is then assessed by an examination of stream standards or bioassay data for Texas organisms. If one or more of the potential pollutants exceeds stream standards or levels which are tolerable to an organism, then the organism, the type of pollutant and the level of excess are known. It is at this point, following the determination of the environmental impact of pollutants, that the methodology is implemented to select and assess alternative strategies to control nonpoint source pollution from forest lands.

Outline of Methodology[1]

Introduction

The following methodology is intended to guide the selection of alternative control strategies for reducing the extent of silviculturally related nonpoint source water pollution. Two things are presumed:

(1) That the existence or non-existence of a nonpoint source pollution problem has been demonstrated by application of the methodology developed by Espey, Huston, and Associates.

(2) That the nonpoint source pollution problem may be potentially attributable, at least in part, to silvicultural activities. This implies that the major watershed under consideration, and the smaller watersheds where the problem exists, must be located within the thirty-seven county East Texas area depicted in Figure 1.

The methodology incorporates a manipulation of C- and P-factors as the means by which alternative control strategies are selected and, thus, pollution is reduced. At present, CP-factors are only available for a limited number of forest management activities and they are often based on scant research data. The general feeling is that they tend to over estimate the amount of sheet and rill erosion.

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[1]Caution - An attempt to select and/or apply control strategies to forested watersheds based on USLE or MUSLE data should not occur without the verification by additional studies that a nonpoint pollution problem does exist.

Sequence of Steps

Step 1. Consider a major river basin to which the Espey, Huston and Associates, methodology has been applied and a pollution problem is said to exist.

Step 2. Proceed if the river basin under consideration is among the following:

Red River	Neches-Trinity
Sulphur	Trinity
Cypress	Trinity-San Jacinto
Sabine	San Jacinto
Neches	San Jacinto-Brazos

Step 3. Proceed if the Espey, Huston and Associates level I analysis has designated one or more of the following counties as potential problem areas:

Anderson	Nacogdoches
Angelina	Newton
Bowie	Orange
Camp	Panola
Cass	Polk
Chambers	Red River
Cherokee	Rusk
Franklin	Sabine
Gregg	San Augustine
Hardin	San Jacinto
Harris	Shelby

Harrison	Smith
Houston	Titus
Jasper	Trinity
Jefferson	Tyler
Liberty	Upshur
Marion	Walker
Montgomery	Wood
Morris	

Step 4. Within the designated counties, obtain from the Espey, Huston analysis, the computation of erosion, routed sediment and pollutants. By examination of the CP-factors, separate the total erosion, routed sediment and pollution in an amount proportional to the contribution of these activities to total pollution.

Step 5. Examine the stream standard or when appropriate Espey, Huston environmental impact analysis and determine the amount by which specific potential pollutants (sediment, nitrogen, phosphorus, organic matter and pesticides) are in excess. These are the amounts by which each pollutant should be reduced.

Step 6. For each of the pollutants (sediment, nitrogen, phosphorus, organic matter and pesticides), deduct the amount by which the pollutant is to be reduced from the total amount of the pollutant. This yields an acceptable level of silvicultural pollution for each of the pollutants.

Step 7. Place the acceptable level of pollution for each pollutant into the appropriate loading function equations and solve to determine the acceptable levels of routed sediment.

Nitrogen: $Y(s) = \frac{NT_e}{a \cdot C(s)\,NT \cdot r_n}$

Phosphorus: $Y(s) = \frac{PT_e}{a \cdot C(s)PT \cdot r_p}$

Organic Matter: $Y(s) = \frac{OM_e}{a \cdot C(s)OM \cdot r_{om}}$

Pesticides: $Y(s) = \frac{P_e}{C(s)P \cdot r_p \cdot 10^{-6}}$

Step 8. From Step 7, select the smallest Y(s) value (i.e. smallest acceptable level of routed sediment) and place this into the sediment routing equation and solve the equation to determine the maximum level of sheet and rill erosion that will still be acceptable in the sense that it won't result in pollutant levels in excess of established standard or those which can be tolerated by the organisms of concern.

$$Y(i) = \frac{RY}{e^{-BTI(D50i)^{0.5}}}$$

Step 9. From Step 8, take the maximum acceptable level of sheet and rill erosion (YCi) and place this value into the MUSLE solve for the cropping management erosion control practice (CP-factor).

$$CP = \frac{Y}{95(Qxq_p)^{0.56} \cdot K \cdot LS}$$

Step 10. Use the calculated value of CP, in conjunction with the data provided in Table 29, to select an alternative procedure for accomplishing the same management objective while simultaneously reducing the extent of silvicultural nonpoint source pollution to an acceptable level. Where several alternatives exist, the relative cost of each should also be considered.

Application of the Methodology

The purpose of this section is to demonstrate the application of the methodology for selecting alternative strategies to control non-point source pollution. For the demonstration, an imaginary watershed located within one of the 37 East Texas counties will be considered. The watershed is 300 acres in size, and is devoted entirely to silvicultural activities. Recently, the entire watershed was harvested, and then sheared with a K-G blade in preparation for planting of pine seedlings. The soils are fine sandy loam with 4 percent organic matter and belong to the C hydrologic group. Antecedent moisture condition is II and the time of concentration for the watershed is 0.18 hr. The slopes are about 1,000 feet in length with a 10 percent gradient. Runoff energy factor was determined for a 30 minute ten year frequency storm. Following is a step-by-step demonstration of the methodology:

Step 1. The Espey, Huston and Associates, Inc. methodology was applied to the watershed with the following results:

I. MUSLE:

$$Y = 95\ (Q \times q_p)^{0.56}\ .\ K\ .\ LS\ .\ CP$$

where: Q = 17 acre-feet

q_p = 433 cubic feet per second

K = 0.24 (fine sandy loam with 4% organic matter)

LS = 4.3 (1,000 feet with 10% slope)

Cp = 0.031 (shearing, K-G from Table 29)

Thus: $$Y = 95(17 \cdot 433)^{0.56}\ (0.24)\ (4.3)\ (0.031)$$

$$Y = 445 \text{ tons}$$

II. Sediment routing:

$$RY = Yi \cdot e^{-BT\ (D50)^{0.5}}$$

where: Yi = 445 tons (from Y in MUSLE)

$$e^{-BT\ (D50)^{0.5}} = .28 \text{ (from Renfro 1975)}$$

thus: RY = (445) (.28)

RY = 125 tons

III. Nutrient loading:

For the purpose of this example nitrogen was the only water quality parameter found to be in excess of tolerable limits. Loading of nitrogen was computed as follows:

$$NTe = a \cdot Y(s) \cdot Cs\ (NT) \cdot r_n$$

where: a = 20 (a dimensional constant for English units, from McElroy, et. al. 1976)

Y(s) = 125 tons

Cs(NT) = .05 g/100 g (from McElroy, et. al. 1976)

r_n = 4 (estimates from McElroy, et. al. 1976)

thus: NTe = (20) (125) (.05) (4)

NTe = 500 lbs.

Step 2 and 3. These steps are satisfied because the watershed is located in East Texas.

Step 4. The watershed is entirely forested, thus silvicultural activity is the sole source of nonpoint source pollution.

Step 5. Nitrogen was the only pollutant found to be in excess of tolerable limits.

Step 6. The tolerable limit of nitrogen pollution for this example is estimated to be 244 lbs.

Step 7. $Y(s) = \frac{244}{(20)\ (.05)\ (4)}$

$Y(s) = 61$ tons

Step 8. $Yi = \frac{61}{.28}$

$Yi = 218$ tons

Step 9. $CP = \frac{218}{(13{,}906)\ (.24)\ (4.3)}$

Step 10. From Step 9, the value of CP must be approximately 0.015 to attain the acceptable level of nitrogen. Table 29, indicates that the site preparation practice of roller chopping and burn has a CP value of 0.015, therefore, this practice should have been implemented rather than shearing with K-G blade to maintain a tolerable level of nitrogen.

INSTITUTIONAL ASPECTS OF CONTROLLING SILVICULTURAL NON-POINT SOURCE POLLUTION

Introduction

Any measures which might be deemed necessary in Texas to moderate the impacts of silvicultural practices on water quality will have to be applied within a somewhat unique institutional framework. The basic purpose of this chapter is to briefly describe the nature of this institutional framework. In addition, an effort will be made to suggest new institutional arrangements which could conceivably facilitate implementation of chosen control measures.

The chapter has been organized into three parts. These are as follows:

1) A discussion of the existing organizations which could influence the implementation of control measures.
2) A discussion of the existing programs which could influence the implementation of control measures.
3) A discussion of possible new programs which might facilitate implementation of control measures.

Existing Organizations

For purposes of this report, the existing organizations which could conceivably influence the implementation of silvicultural control measures can be classified into four groups: (1) federal, (2) state, (3) industrial, and (4) miscellaneous. The more important organizations within each of these groups are discussed below.

Federal Organizations

U.S. Forest Service

The U.S. Forest Service (USFS), within the Department of Agriculture, is the federal agency which has been mandated to provide for protection and utilization of the Nation's forest resources. To accomplish this broad mission the agency has been organized into three branches: (1) National Forest System, (2) Forestry Research, and (3) State and Private Forestry.

The National Forest System is responsible for managing the timber, forage, recreation, wildlife, and water resources of the national forests and national grasslands. Nationwide there are 155 national forests representing a combined acreage of approximately 183 million acres, and 19 national grasslands representing a combined acreage of approximately 4 million acres (Robinson, 1975). Here in Texas there are 4 national forests representing a combined acreage of 661,280 acres, and 5 national grasslands representing a combined acreage of 117,288 acres (Robinson, 1975). By law, the various resources of these lands must be managed so as to provide a "sustained yield" of each. In addition, management practices are to be selected so as to minimize potential adverse environmental impacts.

The Forestry Research branch, through a nationwide system of experiment stations, conducts a comprehensive program of basic and applied research in all phases of forestry and forest management. A substantial amount of the existing research on the relationship between various forest practices and water quantity and quality has been performed by Forest Service scientists. In the southeastern U.S. there are two hydrologic laboratories -- one at Oxford, Mississippi and one at Franklin, North Carolina -- that are specifically concerned with studying water quality from forested watersheds.

The State and Private Forestry branch is involved in providing a variety of different types of assistance to state and private forest owners. To illustrate, in cooperation with the states, fire protection and control is provided for all forest lands. The state is responsible for providing the necessary organization, manpower and equipment, while the Forest Service provides financial and technical aid. Similar types of programs exist to provide for the growing and distribution of planting stock, insect and disease control, watershed development and flood prevention, technical assistance on multi-purpose management, and technical assistance on product utilization and marketing.

Further information about Forest Service activities and programs in Texas can be obtained by writing to the Supervisor of the National Forests in Texas whose office is located in Lufkin.

Agricultural Stabilization and Conservation Service

The Agricultural Stabilization and Conservation Service (ASCS) was established in 1961 as an agency of the U.S. Department of Agriculture. Its function is to administer specified commodity and related land use programs designed for voluntary production adjustment; resource protection; and price, market, and farm income stabilization.

In each State, operations are supervised by a state committee appointed by the Secretary of Agriculture. The State Director of the Agricultural Extension Service is an ex-officio member of the State committee. In each agricultural county, a county committee of three farm members is responsible for local administration. The County Agricultural Extension Agent is an ex-officio member of the county committee.

The ASCS administers commodity stabilization programs for specified agricultural crops. Commodity stabilization is achieved through loans, purchases and payments at announced levels. Cropland set-asides, acreage allotments, and marketing quotas, are used whenever applicable in an effort to keep the production of legally designated commodities in line with demand.

Two resource Conservation programs are also administered: the Agricultural Conservation Program (ACP) and the Forestry Incentives Program (FIP). The ACP provides federal cost sharing money to help farmers carry out needed conservation and environmental measures. The FIP is also a federal cost sharing program, but is designed to increase timber production and protect the environment on private forest land. Further details on both of these programs will be provided later in this section of the report.

Soil Conservation Service

The Soil Conservation Service (SCS) was established under the U.S. Department of Agriculture in 1935 to plan and carry-out a national program for conserving and developing our soil and water resources. Among the agencies specific responsibilities are the following:

1) To provide assistance in developing and implementing watershed protection and flood prevention programs.
2) To provide technical assistance to farmers and ranchers in the development of long-range conservation plans.
3) To provide leadership in conducting the national cooperative soil survey and land inventory.
4) To provide technical assistance to state, county and municipal governments on land-use planning.
5) To provide appraisals of the potential for outdoor recreation development.

The services provided by SCS are coordinated largely through a system of conservation districts, with an SCS office located in each district. In the case of forest lands, SCS professional conservationists and foresters will make on-site inspections and will formulate management recommendations as part of an overall conservation plan. Soil interpretations for woodland use are also provided. These include an assessment of potential site quality and of soil related hazards and limitations. Finally, assistance with such activities as ordering tree seedlings, tree planting, and timber stand improvement measures is also provided.

Virtually all of Texas is covered by a conservation district.

Environmental Protection Agency

The Environmental Protection Agency (EPA) was created because of increasing governmental concern about the effects of various types of pollution on the health and welfare of U.S. citizens. Its basic purpose is to permit coordinated and effective governmental action on behalf of the environment. The EPA endeavors to abate and control pollution through integration of a variety of standard setting, monitoring, and enforcement activities. The Agency is also responsible for supporting and coordinating the research and other antipollution activities initiated by state and local governments, private groups and individuals, educational institutions, and other federal agencies. Specific agency programs deal with air and water pollution, solid waste management, toxic substances and hazardous materials.

From an administrative standpoint, the EPA is organized into 10 regional offices. Each regional office is responsible for essentially all phases of the agencies activities within a particular region. The regional office for the region which includes Texas is located in Dallas.

Farmers Home Administration

The Farmers Home Administration (FHA) makes loans available to private landowners for a variety of forestry purposes such as land clearing, stand improvement and drainage. The loans are basically of three types: Farm Ownership, Soil and Water, and Operating. Farm Ownership and Soil and Water loans, in any combination, may not exceed $100,000. However, if such loans are used in combination with funds obtained from other sources, total indebtedness may reach $225,000. Interest on these two types of FHA loans is set at five percent, and the maximum length of loan is 40 years. Operating loans may be made for up to $50,000 and for as long as seven years. Interest rates for this latter type of loan are set once a year (R. L. Sherman, 1977).

Eligibility for FHA loans is determined on the basis of the landowners needs, financial situation, ability to secure credit, and the importance of his woodland to his total income.

Federal Land Banks

The Federal Land Banks are empowered to make long term loans to timberland owners. These are offered to qualified tree farmers, including partnerships and corporations. A first mortgage is required on the property and the banks may lend for periods ranging from 5 to 40 years. Land Bank Loans are usually made through the local Federal Land Bank Association serving the county in which the property is located. The interest rate charged is variable, but before a loan will be made the borrower must be able to demonstrate: (1) that he is in a sound financial position and has a good credit rating; (2) that he has the ability to manage his forest property satisfactorily -- either himself or through the services of a professional consultant; and (3) that he has a sound management and development plan.

Cooperative State Research Service

The Cooperative State Research Service (CSRS) administers Federal grant funds for research in agriculture, agricultural marketing, rural development and forestry. Funds are made available to the State Agricultural Experiment Stations and other designated State institutions.

The scientific staff of the Service reviews research proposals, gives leadership in planning and coordinating research, conducts on-site reviews of research in progress, and encourages cooperation between the experiment stations and the Department of Agriculture.

State Organizations

Texas Forest Service

The Texas Forest Service (TFS) was established to assure Texas an adequate supply of timber, to provide fire protection, to control insect and disease pests, to provide management assistance, and to educate and inform the public on forestry programs and the ecological and economic conditions of Texas forests.

The Texas Forest Service has jurisdiction covering 53 counties in East Texas. These counties are divided into 5 areas, each under the control of an area office. These offices are located in the following cities: Linden, Henderson, Lufkin, Woodville, and Conroe. The counties are further organized into 14 districts, with offices located in the following cities: Gilmer, Marshall, Jacksonville, Carthage, Crockett, Nacogdoches, Center, Livingston, Kirbyville, Kountze, Conroe, Brenham, LaGrange, and Linden.

As noted, one of the major services provided is fire protection. TFS is responsible for developing plans for the control of wildfires in Texas. They administer the Rural Fire Defense Program which provides fire trucks to over 100 communities at minimal cost. Work is done with community groups and individual landowners in plowing firebreaks and initiating other measures to reduce the danger from fire. Prescribed burning and fire plowing are available to landowners on a cost per acre and a cost per hour basis, respectively.

The Forest Environment Department is concerned with the production of forest tree seedlings for wood fiber production, windbreaks, watersheds, and green belts. Tree seedlings can be obtained at cost from the seedling nursery near Alto. Work is done in cooperation with other government agencies and private organizations in natural resource planning and environmental impact statements related to forestry.

The TFS Information and Education Department conducts statewide programs to inform and educate the general public about the acitivites of the TFS and about the trees and forest resources of Texas. They also cooperate with other state and federal agencies which educate the public in the use and protection of forest resources.

Pest control is provided through aerial surveillance for southern pine beetle infestations. TFS will report any infestations to landowners and will take the necessary control measures on request. TFS supports the cut and leave policy where prompt salvage or other control alternatives are not feasible.

The Forest Management Department, besides maintaining a statewide inventory of timber growth and removals, also provides technical management assistance to private non-industrial woodland owners. Among the specific management services provided at no cost to the landowner are: (1) site inspections and evaluations, and (2) development of long-range management plans. Other specialized services are provided on a fee basis. These include: (1) site preparation, (2) timber stand improvement, and (3) timber marking. TFS foresters will not make pre-sale timber appraisals, but they will help with locating potential buyers and with the preparation of an appropriate timber sale contract. To minimize conflicts with private forestry consultants, TFS foresters will not provide management assistance to large landowners.

Texas State Soil and Water Conservation Board.

The Texas State Soil and Water Conservation Board is an independent governmental agency which was created in 1939 and which is headquartered in Temple, Texas. The Board is composed of 5 members, each elected from one of the conservation district zones in the State. Board members are non-salaried but are supported by a staff of 21 persons. The Board is responsible for helping to organize the conservation districts, to coordinate their activities, to provide them with financial and other aid, and to inform the public about conservation programs. In addition to these responsibilities, the Board has been assigned the responsibility for non-point source planning for agricultural and silvicultural activities.

Texas Department of Water Resources

The Texas Department of Water Resources is the governmental agency with primary responsibilities for the development, administration, and regulation of the State's water resources. To carry out these broad responsibilities it is organized into three administrative subdivisions: one concerned with water development, one concerned with water rights, and one concerned with water quality.

That subdivision concerned with water development has been charged with several specific responsibilities. One involves the creation and periodic updating of a comprehensive State Water Plan. The plan serves as the official policy guide for water development in Texas; it provides the conceptual framework for meeting water supply problems and managing the use of the available resource. Other functions include: (1) serving as the state cooperator in water development planning with the Bureau of Reclamation and the Corps of Engineers; (2) collecting basic data on the occurrence, quantity, and quality of surface and groundwater resources; and (3) determining statewide water requirements both in terms of quantity and quality.

That subdivision concerned with water rights is charged with regulating the use of Texas' public water resources to insure that they will be conserved and used for the greatest long-run public benefit. To carry out this charge it is empowered, within certain statutory limits, to grant or deny water permit applications, to adjudicate claims of water rights, to supervise various water districts and review their engineering projects, and to perform other regulatory activities.

That subdivision concerned with water quality is charged with several responsibilities. It is responsible for establishing criteria governing the discharge of wastes into State waters, and for maintaining a water quality sampling and monitoring program. It is responsible for conducting necessary research and planning, both independently and in cooperation with outside sources, toward the goal of developing comprehensive water quality management programs. It is responsible for administering grants allocated to the State by the Environmental Protection Agency, and also funds appropriated by the legislature for the planning and construction of sewage treatment facilities. Finally, it is responsible for providing primary leadership in the coordination, development, and implementation of Section 208 plans. The only qualifier to this, as noted earlier, is the role of the State Soil and Water Conservation Board in 208 planning for agriculture and silviculture.

To carry out these responsibilities, the subdivision concerned with water quality is empowered with certain regulatory capabilities. To illustrate, it issues waste discharge permits, regulates the subsurface injection of wastes, controls collection and disposal of industrial solid wastes, and has certain inspection and investigative powers.

Texas River Authorities

Geographically, Texas is divided into 15 major river basins, with a River Authority managing each one. The River Authorities are responsible for water supply and distribution, flood control, and water quality. Included within these responsibilities are activities in soil conservation, irrigation, water treatment, and water quality studies. They also have authority to develop navigation and generate hydroelectric poser. River Authorities provide park and recreational facilities, general river basin improvements, and technical assistance to local governments in water resource development and flood control.

Each Authority is unique in its organization. Some Authorities have a manager, while others are managed through board committees. All are served by a board of directors, of which some are elected and some are appointed.

The River Authorities and river basins are the basic planning organiations and planning units, respectively, for the non-designated areas as defined in Section 208 of the Federal Water Pollution Control Act Amendments of 1972. There are 7 river basins that at least partially encompass forested watersheds. These are the Red, Cypress, Sulphur, Neches, Sabine, Trinity, and San Jacinto river basins. Each basin has a 208 Advisory Committee on which there are 3 to 4 forestry representatives.

Texas Parks and Wildlife Department

The basic objective of the Texas Parks and Wildlife Department is to manage the game and fish resources of the State. With both these resources a wide variety of research projects concerning such thins as life histories, population dynamics, and stocking programs are conducted.

The Parks Division operates almost 100 parks throughout the State, with the basic objective of providing a place for citizens to come in contact with the out-of-doors. The Department also has the responsibility for enforcing pollution laws affecting aquatic life or wildlife.

Most activities relating to forestry are indirect, with the one important exception being the responsibility for management of the State parks and wildlife management areas. On the wildlife management areas, the wooded acreage is generally managed in accordance with some research project. In the State Parks, all forest management practices are predicated on camping, hiking and other non-consumptive uses as being of predominant importance.

Texas Agricultural Extension Service

The Texas Agricultural Extension Service is a integral part of the Texas A&M University System and functions as a communication and education organization for Texas citizens. County agents serve each county and comprise the basic educational unit of the system. Their technical knowledge and skills are reinforced by specialist in forestry, agriculture, family living, 4-H and youth, community resource development, and related areas. Many specialists are headquartered at College Station while others are located at one of 14 district headquarters. There ate two area forestry specialists located in Overton, one in Houston and one at College Station.

County agents provide many services to forest landowners to help them increase their returns from timber growing. Advice is provided to timber growers on such important matters as fire, insect, and disease protection; planting; and needed timber stand improvement measures. In addition, agents will advise landowners as to sources of financial assistance and what precautions they should take in marketing their timber. For technical problems, agents refer timber growers to extension specialists or consulting foresters.

Texas Agricultural Experiment Station

The Texas Agricultural Experiment Station is the agricultural research agency for the State of Texas. Organizational structure places it under the direction of the Texas A&M University System and the Board of Regents. The Experiment Station consists of the Main State Experiment Station located at College Station and 36 other research sites located throughout the State. Of the 36 units, 14 are designated as regional Research Centers or Research and Extension Centers. The remaining units are designated as research stations.

The regional research centers are assigned specific missions, with each center serving as a site for major multidisciplinary efforts. Scientists are specifically selected and assigned to research the most important problems and/or to develop opportunities for agricultural and human resource development within the regions they serve.

The research stations have more limited roles. Missions may range from demonstrations - to veterinary diagnostic services - to comprehensive research programs.

Forestry research is closely coordinated with the Texas Forest Service through joint planning and joint staffing with the Forest Science Department at Texas A&M University. Research at the Main Station concentrates on woodland productivity, protection from insects and disease, tree improvement, and woodland planning.

Industrial Organizations

National Forest Products Association

The National Forest Products Association (NFPA) is an industrially sponsored organization, located in Washington, D.C., that represents the wood using industry on national matters affecting the use and management of timberlands, the growth and harvest of timber, and the manufacture and utilization of wood products. NFPA provides a forum through which common industry objectives can be achieved. NFPA's goals are extremely broad and include the following: to achieve a healthy atmosphere within which the forest industry can operate profitably; to encourage and promote policies and programs that will assure a continuous supply of timber and forest products to meet the public demand; to provide and maintain the broadest regulatory acceptance for wood products; and to advance the interests of wood products manufacturers and their customers and users.

These objectives are achieved through two major programs, the Product Acceptance Program and the Resource and Environment Program. The Resource and Environment Program is responsible for dealing with issues involving forest land management and timber supply on public, industrial, and private forest lands. It also deals with issues relating to regulation of forest practices and land use; timber growing; solid wood manufacturing; water and air quality; endangered species; and forest chemicals. Support is received from more than 30 committees, sub-committees and task groups which deal with specific issues affecting forest management, wood supply, and the environment. Through this program, NFPA and the American Paper Institute have joined forces to deal with common environmental issues. With regard to non-point sources of water pollution, the goals of the joint environmental action committee include: 1) securing recognition of forestry activities as a minimal contributor to non-point source water pollution problems, and 2) securing industry participation in shaping federal and state water quality programs so they will not prove overly restrictive to timber growing and harvesting on commercial forest lands.

Even though NFPA does not concede to the necessity of statewide 208 planning, it feels industry efforts must be undertaken to monitor and provide input to the 208 process as it develops. NFPA's activities on Section 208 will include: 1) litigation involving the implementation of Section 208; 2) review and comment on national 208 guidelines and informational material developed by EPA; and 3) monitoring the implementation of Section 208 in those states of interest to the forest industry.

Southern Forest Products Association

The Southern Forest Products Association (SFPA) is a trade organization representing the southern pine lumber industry throughout the southern states. The objectives of SFPA are far-reaching in scope and include the following:

(1) Provide assistance in finding solutions to major forest resource and environmental problems confronting Association members.

(2) Communicate to teachers, students, conservationists and the general public the benefits to be derived from forest management.

(3) Encourage private non-industrial woodland owners throughout the South to practice better forest management.

(4) Resist the imposition of unnecessary or overly stringent restrictions on the use of accepted forest practices.

SFPA monitors the progress of Section 208 planning in each of the southern states in order to be able to keep Association members informed on current developments.

American Forest Institute

The American Forest Institute (AFI) is a professional communications organization supported by the wood-using industry. AFI members include producers of pulp, paper, and paper products; logs; lumber; plywood; and other forest-based products.

Some of the objectives of the AFI include: 1) to develop public understanding and support for the conservation of forest resources; 2) to further practical policies in the areas of land use, forest practices, air and water pollution abatement, and solid waste management; and 3) to create public understanding of industry policies and practices. The AFI is also responsible for administering the American Tree Farm System on a national basis.

Southern Forest Institute

The Southern Forest Institute (SFI) is a communications organization involved in compiling forest resource facts and data; preparing appropriate printed and audio-visual materials; and distributing these materials to the news media, teachers, legislators, and the general public. It is supported by the southern forest products industry and is administratively a regional subdivision of the American Forest Institute. Its basic mission is to develop public understanding and support for conservation, management, and use of the southern forest resource. More specifically, it has responsibility for managing the Tree Farm System in the South and for providing regional support for the national programs of AFI. The organization includes professionals trained in the fields of forestry, communications, and conservation education.

Miscellaneous Organizations

Included in this category are a variety of conservation and professional organizations.

Texas Forestry Association

The Texas Forestry Association (TFA) is a private, non-profit, non-governmental organization dedicated to promoting and further developing Texas forests and related resources. Members include individuals, corporations and organizations interested in the ownership, production, consumption or conservation of forests and forest products in Texas.

As a service organization, TFA's objectives are far-reaching in scope: to advance the cause of forestry; to develop public appreciation for the value of Texas forests; to assist in determining and securing the adoption of the most beneficial forest policy within Texas; to aid and assist in the growing, production, processing, storage, transportation and use of forest products; to promote ethical practices and high standards in the forest products industry; to promote air and water pollution research; to encourage multiple use, expansion, protection and proper management of all forest and related resources of Texas.

A number of programs and services are provided by TFA to help promote and achieve these objectives. TFA encourages adherence to the Texas Voluntary Forest Practice Guidelines. These guidelines cover proper methods of harvesting and regeneration, protection of soil and water, wildlife conservation, and preservation of aesthetic values.

TFA assists with statements and testimony on state and federal legislation and regulations concerning forest management and the forest products industry. TFA serves as the state's industry sponsor for the Texas Tree Farm Program. Other projects include distribution of pine seedlings to youth groups, promotion of the Texas Forestry museum, sponsorship of environmental conservation workshops and tours, and support for Timber Harvesting instruction in East Texas high schools. TFA also publishes a bi-monthly newspaper, Texas Forestry, dealing with current forestry topics and issues of concern in this state.

Soil and Water Conservation Districts

The Soil and Water Conservation Districts in Texas were created in 1939 to provide a source of conservation assistance to landowners. These districts are organized under state law by local citizens and are managed by an elected and unsalaried board of five district directors made up of local citizens. Each district is responsible for soil and water conservation work within its boundaries. The purpose of the districts is to focus attention on land, water and related resource problems; to develop programs to solve them; and to enlist and coordinate assistance from all public and private sources that can contribute toward accomplishing the district's goals. Organization and financial assistance is provided to the conservation districts by the Texas State Soil and Water Conservation Board.

Within the State, the conservation districts are organized into a Texas Association of Soil and Water Conservation Districts, which is in turn a member of the National Association of Conservation Districts. The Texas Association of Conservation Districts is a non-governmental association representing all the conservation districts in Texas. The

Association works with the individual districts in solving common problems and sponsors an annual meeting of district directors to discuss current issues. The National Association of Conservation Districts is a non-profit organization which represents the 3000 soil and water conservation districts in the 50 states on matters of national concern.

American Forestry Association

The American Forestry Association (AFA) is a national, independent, non-political conservation organization. Its primary goal has been to conserve and develop America's forests and related resources of soil, water and wildlife for the good of all Americans. AFA's policies are directed toward stimulating public action and support for protection against forest fires and floods, for the prevention and control of soil erosion, for the development of conservation policies in forest and range management, for the control of forest insects and diseases, for the preservation of wildlife, and for the establishment and maintenance of outdoor recreation areas. It seeks through its magazine (American Forests) and by other means to increase public appreciation for natural resources and the part they play in the social, recreational, and economic life of the nation. AFA serves as sponsor for the periodic World Forestry Congresses. In addition, specifically regarding forestry in relation to water quality, AFA sponsored a series of workshops throughout the country to increase the level of understanding of PL 92-500 and to provide for an exchange of ideas and information on the relationship of forestry activities to water quality.

Conservation Organizations

There are several private, non-profit organizations which have been active in conservation activities in Texas. These include: the Sierra Club, Audubon Society, Nature Conservancy, and the Texas Conservation Council. The basic concern of these organizations is the protection of our natural resources and the quality of our environment. Accordingly, they would generally support any measures to control nonpoint sources of pollution. Local chapters have also been involved in such activities as constructing nature trails, distributing educational materials on the conservation ethic, and attempting to generate support for the preservation of unique and undeveloped areas.

Society of American Foresters

The Society of American Foresters (SAF) is the official organization representing the profession of forestry in the United States. Its purpose is to advance the science, education, and practice of forestry in America so that our forest resources will make their maximum contribution to our economic and social well-being. The SAF formulates forest policies which recognize the multiple use and sustained yield aspects of forestland management, and yet which reflect its belief that the skills and judgement of the professional forest manager are the best means of implementing these principles. The Society publishes several technical journals including the Journal of Forestry, Forest Science, and the Southern Journal of Applied Forestry.

The SAF is organized, on a geographical basis, into 24 Sections. Each Section is in turn subdivided into Chapters and Groups. The Texas Chapter is part of the Gulf States Section and consists of four local

Groups: the Brazos-Trinity, the Lufkin-Nacogdoches, the Northeast Texas, and the Southeast Texas. In total there are about 700 members in the Texas Chapter. These are all professional foresters who work in federal service, state service, with industry, or as private consultants. Chapter activities include providing testimony on forestry issues; development of a speakers bureau; and conducting occasional educational tours and programs to explain current forest practices to teachers, newspaper people, and others.

Forestry Consultants

Forestry consultants are playing a growing role in the management of private forestlands in East Texas -- particularly on those lands not in industrial ownership. Among the services provided by such consultants are: development of forest management plans; timber cruising; appraisals of land and timber; marketing assistance; regeneration work (i.e. site preparation and planting); timber stand improvement work; and land acquisition and disposal. The Texas Forest Service's referral list of consulting foresters includes 18 Texas based firms and 5 large national firms.

Existing Programs

In the preceding section, those existing organizations which could conceivably have an impact -- direct or indirect -- on the implementation of measures to reduce silvicultural nonpoint source pollution, were identified and discussed. In this section, the objective is a parallel one -- namely, to identify and discuss those existing programs which could conceivably impact on the implementation of measures to reduce silvicultural nonpoint source pollution. The programs that will be explicitly considered can be classified into two categories: (1) public programs, and (2) industrial programs.

Public Programs

Forestry Incentives Program.

The Forestry Incentives Program (FIP) was created by the Agriculture and Consumer Protection Act of 1973, to share the cost of tree planting and forest management with small private landowners. The program may provide up to 75 percent of the cost of applying approved forest management practices.

The Texas Forest Service, in conjunction with the Agricultural Stabilization and Conservation Service, helps to coordinate the Forestry Incentives Program. The county ASCS office administers the contracts for cost sharing assistance and certifies payments for practices satisfactorily completed. The function of the TFS is to approve the forest management plan required under FIP.

Private landowners are eligible if they own less than 500 acres of timberland (in designated counties); have land capable of growing at least 50 cubic feet of wood per year; are not in the wood processing business nor a public utility; and have made no commercial harvest on the land within the past 5 years (Does not apply if harvest was made by a previous owner or if it was a salvage cut).

The forest management plan, that the TFS must approve, should include the following: 1) an adequate description of the property, so that it can be relocated; 2) a photo or sketch showing the location of the work area; 3) a description of the practice, with all its components and goals; and 4) a schedule of when activities will be completed.

There are two general types of forestry practices that qualify for cost-sharing under FIP, planting and timberstand improvement.

Planting trees includes site preparation of understocked sites or sites with vegetation that will compete with planted seedlings. A TFS forester must inspect each site to decide if it is suitable for growing commercial wood crops; he will also determine if site preparation is needed. Clearings must not be made along creek banks, gullies, or slopes exceeding a 10% grade; or over more than 90% of the total area. Site preparation may be accomplished by prescribed burning, mechanical equipment, or chemicals.

Any species of tree seedling available from the TFS nursery for the specific area and site can be used. Direct seeding may be used where access, terrain or drainage will not allow planting of seedlings. Areas planted must be part of the approved management plan and have a site index of 60 or more. Planted trees should be protected from destructive grazing and wildfires.

Timber stand improvement involves removing competing vegetation which hinders the growth of reproduction of economically desirable tree species. Approved control methods include chemical injection, mechanical girdling, prescribed burning, broadcast chemicals, removal of "cull" trees and pruning of crop trees. Other measures that may be performed include: erosion control on fire lanes, logging roads and trails; building fences to protect the area from grazing; and construction of firebreaks for forest fire protection.

Site preparation, tree planting and timber stand improvement may be performed by the landowner himself, a private contractor, or the TFS. The TFS is responsible for certifying that the work has been completed according to the management plan.

Agricultural Conservation Program

The Agricultural Conservation Program (ACP) provides federal cost-sharing money for approved agricultural and forestry practices. The program is administered by the Agricultural Stabilization and Conservation Service, but the county ASCS committees normally seek the assistance of the state foresters and Soil Conservation Service in determining what practices will be approved within each county. The basic goal of the program is to promote soil and water conservation by encouraging the adoption of sound land management practices.

Typically, two forestry activities are approved for cost-sharing: 1) tree planting, and 2) timberstand improvement work. Other forestry practices that may be approved include fencing, firebreaks, and pruning. All cost shares are paid upon satisfactory completion of the work. Payments may cover anywhere from 50 to 80 percent of the total cost of the activities undertaken.

Industrial Programs

American Tree Farm Program.

The American Tree Farm System was established in 1941 to help private non-industrial woodland owners gain access to professional forestry advice. By pointing out the potential benefits in terms of added income, improved food and cover for wildlife, improved watershed protection, and improved recreational value; the program seeks to encourage such landowners to protect and manage their land for the sustained production of timber crops.

The program is sponsored by the forest products industry and is administered nationally by the American Forest Institute. In Texas it is sponsored by the Texas Forestry Association, which provides program direction at the state level. As of January 1, 1977, there were approximately 1700 Tree Farmers in the State with combined holdings of over 4 million acres.

A property will not be certified as a Tree Farm until it has been carefully inspected by a professional forester. Texas Forest Service and industry foresters will provide this service free of charge. To qualify for certification the woodland must be:

1) Privately owned.
2) Managed for the sustained growth and harvest of forest crops.
3) Adequately protected from fire, insects, disease, and destructive grazing.

Upon certification the landowner will be sent a certificate by AFI. Thereafter, his property will be periodically reinspected to insure that management standards are maintained.

Landowner Assistance Programs

A number of the forest-based firms in East Texas operate programs aimed at providing technical management assistance to private non-industrial woodland owners. Although these programs differ somewhat from company to company, services that might be provided include formulation of management plans, timber sale preparation (i.e. marking and volume estimation), timber sale administration (i.e. supervision of logging), and advice on planting and timber stand improvement work. While these services are normally provided without cost, the company may request first refusal rights on any timber which the landowner chooses to sell.

Possible New Programs

Those existing organizations and programs which could conceivably influence the implementation of silvicultural nonpoint source controls have been identified and discussed. At this juncture the relevant question becomes -- what new programs might prove to be necessary, or at least useful, in achieving implementation of 208 plans related to forestry? Before this question can be answered, those factors which might retard program acceptance must be identified. Once this has been done, potential problem areas can be compared to existing programs and inferences can be drawn concerning needed new programs.

Potential Problem Areas

It's difficult to envision exactly what factors might complicate the task of implementing measures to minimize the impacts of silvicultural practices on water quality. Nonetheless, four factors are sufficiently evident that they can be identified and discussed.

Landowner Resistance.

Many Americans still believe in the idea that a man's land is his to do with as he pleases. This attitude is particularly prevalent in rural East Texas. Gehlhausen (1976), in a regional study of small woodland owner attitudes, found that this group was highly suspicious of any program that hinted at federal or state involvement in influencing land use. Similarly, Dreesen (1977), in a study of attitudes regarding the need for a Texas forest practices act, observed that approximately 75 percent of the respondents felt that such a law was unnecessary at the present point in time. This is undoubtedly a conservative estimate of opposition, because the sample did not consist of rural landowners; it was composed of opinion leaders from federal and state agencies, conservation organizations, and the forest industries.

Number of Landowners

Current estimates of the number of forest landowners in East Texas are unavailable, but it's generally felt that the number is substantial -- perhaps on the order of 400,000 in just the private non-industrial ownership group. These ownerships are predominantly small and are scattered throughout the 37-county region. This situation will create some obvious problems from the standpoint of program implementation; particularly if a regulatory approach were to be taken.

Insufficient Capital.

Professional foresters have tried for many years, with only limited success, to get private non-industrial woodland owners to practice better forestry. One of the constraining factors has been insufficient investment capital. Many landowners are willing to harvest what nature provides, but then they are financially unable to undertake subsequent reforestation activities. If silvicultural nonpoint source controls add to forestry costs, capital insufficiencies may preclude their application.

Lack of Knowledge

Private non-industrial woodland owners, who control the bulk of the forest resource in East Texas, typically know little or nothing of forest management. They will have no conception of what precautions they might take to minimize the impacts of their forest practices on water quality. The same statement probably applies, although to a lesser degree, to many loggers. The point is that these people can't be expected to utilize what they don't know.

Problem Areas in Relation to Existing Institutions

The various types of assistance available in Texas from existing organizations and programs is summarized in Table 30 . As can be seen, there are many existing institutions, which with a slight redirection of emphasis, could be made to facilitate implementation of forestry 208 plans. Those involved in information and education could address the problem of landowner resistance. Similarly, those involved in providing technical assistance could help to overcome the lack of knowledge problem. Finally, those involved in providing financial support could deal with the capital insufficiency problem. About the only potential problem that appears to be beyond even partial resolution is the extremely large number of forest landowners.

Suggested New Programs

In spite of the fact that existing organizations and programs can probably be modified to deal with most of the problems that might arise in program implementation, a few suggestions regarding possible new programs will be made. For the most part, these ideas have been stimulated by some of the new institutional arrangements which have been adopted in other southern states.

Landowner Education Program

The greatest effort should be directed at informing and educating the public about improved forest practices. If a voluntary program is to be successful, private landowners, forest industry, logging contractors and other forestry involved parties, must be informed of the consequences of not following recommended practices. There are currently several organizations in the State which serve in an educational capacity (Table 30). The role of these organizations in communicating forestry

Table 30. Assistance Available from Existing Organizations and Programs in Texas.

X - Primary role
S - Supportive role

	Education & Information	Technical Assistance	Rules & Regulations	Research	Administration & Planning	Credit	Financial Support (Grants, Cost-sharing)	Conservation Incentive
Federal Organizations								
U.S. Forest Service	X	S		X	S			S
Agr. Stabilization & Consv. Serv.	S						X	S
Soil Conserv. Service	X	X		S	S			X
Environmental Protection Agency	X		X		X		X	S
Farmers Home Administration						X		
Federal Land Banks						X		
Cooperative State Research Serv.				X				
State Organizations								
Texas Forest Service	X	X			X			X
Soil & Water Conserv. Bd.	X	X			X			X
Tx. Dept. of Water Resources			X		X			
Texas River Authorities					X			
Texas Parks & Wildlife Dept.	X							X
Tx. Agr. Ext. Service	X	X						X
Tx. Agr. Exp. Station				X				
Industrial Organizations								
National Forest Products Assn.	X				S			S
Southern Forest Products Assn.	X				S			S
American Forest Institute	X				S			S
Southern Forest Institute	X				S			S
Miscellaneous Organizations								
Texas Forestry Assn.	X				X			X
Soil & Water Cons. Districts	X				X			X
American Forestry Assn.	X				S			S
Conservation Groups	X							X
Soc. of Amer. Foresters	X				S			S
Consulting Foresters	S	X						
Public Programs								
Forestry Incentives Prog.							X	S
Ag. Conservation Prog.							X	S
Industrial Programs								
Tree Farm System	S	X						S
Landowner Assistance	S	X						S

practices to desired parties can in most circumstances be expanded.

Since approximately 60 percent of the commercial forest land in East Texas is controlled by private non-industrial landowners, a major portion of the educational process should be directed toward them. For example, the Texas Forestry Associations' voluntary forest practice guidelines could be expanded to include the newly developed guidelines, along with other basic good management practices. Similar guidelines prepared in South Carolina, West Virginia, and Maryland have proved successful when distributed to woodland owners. The National Association of Conservation Districts (NSCD) has suggested a vigorous information and education program should be conducted through the Cooperative Extension Service. This along with help from the Conservation Districts and Texas Forest Service, would allow maximum contact with private woodland owners. Expansion of industry's cooperative management programs with small private landowners is another means for disseminating information on pollution controls. Forest landowner practices can also be improved by expanding the required conservation practices for participation in the Tree Farm Program.

Logger Education Program.

Training programs and certification of forest operators is another means by which to improve forest practices. Most harvesting operations and forest cultural work, such as mechanical site preparation, is largely conducted by independent private operators. This includes activities performed on Federal, State, private non-industrial and industrial lands. Operators are often small, family-owned businesses, and in some instances they only work part-time in forest operations. They are usually knowledgeable and skilled in their own trade but are often not cognizant of the relationship between their operations and environmental concerns.

Therefore, the initiation of a program directed at these potentially important disturbers of the forest, could be quite beneficial in terms of ameliorating their impact on water quality degradation.

The Mississippi Forestry Association has a program to recognize timber harvesters who do a good job in cutting and removing wood products from the forest. The Association has adopted a Code of Good Practices which set a standard for timber harvesters who are interested in performing their work with pride and efficiency. Included within these Practices are watershed management guidelines which are intended to minimize harvesting and road construction effects on water quality. Timber harvesters are certified upon application and approval of the Mississippi Forestry Association.

North Carolina foresters have determined that the first step toward solution of their water quality problems is a vigorous educational program directed toward forest practice operators. They have also realized that major site abuse often results from an unawareness on the part of equipment operators relative to the impact of their actions on water quality. Because of this, development of programs to train, control and reward forest operators are under consideration.

Virginia, which has aimed at voluntary compliance with Section 208 requirements, has held a series of meetings throughout the State to explain the law and its implications to loggers. The series was a joint effort involving forest industry, the State Foresters' office, the Extension Service and the Forest and Wood Products Associations in the State. The laws were explained and methods were presented to reduce siltation and other pollutants. In all, 75 percent of the loggers in the State attended this series of dinner meetings and were asked to voluntarily comply. A measurable response to this effort at siltation reduction was monitored by the State Forester (Pennock, 1977).

Oregon, which passed a Forest Practices Act in 1972, has worked through their Extension Service to provide educational programs for forest operators. Technical workshops, seminars and tours on logging and erosion control techniques have all been successfully used. Forest industry, represented by the Southern Forest Council has also recommended educational and training programs for timber operators to encourage forestry to be practiced in a manner which does not degrade water quality.

Similar forest operator training or certification programs could be desirable and feasible in Texas. The Texas Forest Service or U.S. Forest Service would be qualified to conduct any technical training programs. A certification program could be administrated by the TFS or Texas Forestry Association. However, several other organizations could be helpful in carrying out educational objectives. Suggested organizations include the Extension Service, Soil Conservation Service, and forest products industry representatives. A joint effort of these organizations can help to implement improved forest practices and reduce the harmful effects that this segment of the forest industry can have on water quality.

State Forestry Incentives Program

The possible cost increases associated with implementing silvicultural controls may be prohibitive to many private non-industrial landowners. In many cases, unless financial incentives are made available to these owners, the economical growing and harvesting of trees might not be possible. One possible solution, in addition to the Federal Forestry Incentives Program, is a State incentives program. The

National Association of Conservation Districts and the Southern Forestry Council have recommended increases in funding for state and federal incentive programs to provide technical and cost-share assistance to landowners.

North Carolina has recently passed a state forest incentives act to supplement FIP; so also have Virginia and Mississippi. Funding for the new Virginia program comes from two sources, the state's general fund, and a severance tax on pine timber. Mississippi's program is financed exclusively by income from a timber severance tax. (Forest Farmers Association, 1977).

Registration and/or Licensing of Foresters.

There are several other programs which have been adopted in other states in an effort to improve forest practices. One such program provides for the registration and/or licensing of forestry practitioners. Theoretically this program would provide a means of insuring that those people who desire to practice forestry as their vocation, and consequently whose decisions will have an impact on the quality of the forest environment, are well versed on the extent of our existing knowledge about the potential impacts of forest practices on water quality. At present several southern states including Georgia, Alabama, Florida, South Carolina, and Oklahoma have such laws. They are highly controversial, however, and before one could suggest that Texas adopt such a law -- the question would have to be studied in some depth.

ONGOING RESEARCH AND RESEARCH NEEDS

On-going Research

To date little research has been conducted on the identification of existing potential sources of silvicultural nonpoint source pollution or its control in Texas. This lack of data makes the planning process that much more difficult. Until more fundamental evidence determines that a water quality problem exists, implementation of applicable control measures will be difficult.

Currently, the only study being conducted, is at Stephen F. Austin State University (Chang, 1977)[1/]. The School of Forestry has been contracted by the Department of Water Resources to establish baseline water quality data for undisturbed forested watersheds in East Texas. The study is located on 10 forested watersheds in Nacogdoches, Cass, Marion and Harrison counties on streams of varying size. Data will be collected on precipitation, soil and vegetation type, topography, sedimentation, stream flow, nutrients, pesticides and biological properties of the water.

Following collection, the data will be submitted to the TDWR. The water quality data will then be correlated with meterological and site parameters to establish a method of predicting water quality by use of the modified universal soil loss equation. The results will be used by the TDWR for formulation of plans for water quality management for the forested areas of East Texas.

1/ Chang, M. 1977. Personal communication. Stephen F. Austin State University, Nacogdoches, Texas 75961.

Research Needs

In Texas, the impact of forest practices e.g. harvesting, site preparation, planting, etc. on water quality received little or no research attention. There is no research data for East Texas that indicates there is a water quality problem associated with forest practices and yet we are writing guidelines to control nonpoint sources of pollution. Most research regarding the impact of forest practices upon water quality has been conducted outside the Southern Region and, more importantly, outside the Gulf Coastal Plains. Forest practices in East Texas may be judged guilty of polluting streams without factual information to confirm that such is the case. Because geology, soils, topography, climate, etc. are somewhat unique in Texas, extension of research data from the mountainous Northwest and Northeast will be misleading.

Watershed research is needed in East Texas to:

1. Develop base line data on nonpoint source water pollution from stabilized undisturbed forest sites.
2. Assess the impact of forest practices on the quality of water of receiving streams.
3. Determine site recovery rates following disturbance.
4. Determine the impact of nonpoint source pollution on the aquatic environment.
5. Develop and test sediment yield models.
6. Determine the effectiveness of the different control strategies in controlling nonpoint source water pollution.

If the Universal Soil Loss Equation is going to be used to assess the impact of forest practices, the coefficients need to be adapted to East Texas forest conditions. The coefficients needing research attention are: K, C and P.

APPENDIX I.
HYDROLOGY OF EAST TEXAS

APPENDIX I. HYDROLOGY OF EAST TEXAS

About 70 percent of the land area of the United States is classified as forest and range land. These areas are major sources of fresh water. In fact, it is estimated that 90 percent of the usable water in the 11 conterminous western states originates from forest and range lands (Water Resources Council, 1968).

The major source of all our water in Texas is precipitation, which falls primarily as rain. The amount, kind, and seasonal distribution of precipitation is the dominant factor in the determination of water yields from any area. Part of the precipitation striking the ground and its vegetative cover is retained at the surface, to be evaporated back to the atmosphere. Part or all of the water entering the ground is held by capillary forces and may be evaporated directly or absorbed by plant roots and removed to the atmosphere by transpiration. If more water enters the ground than can be retained by capillary forces, the excess percolates through the soil, moving into a stream channel or into ground water, where it may appear in springs or wells or sustain the flow of streams during dry periods (Figure 8).

A description of several hydrologic processes as they are experienced on East Texas forestlands are presented in this section.

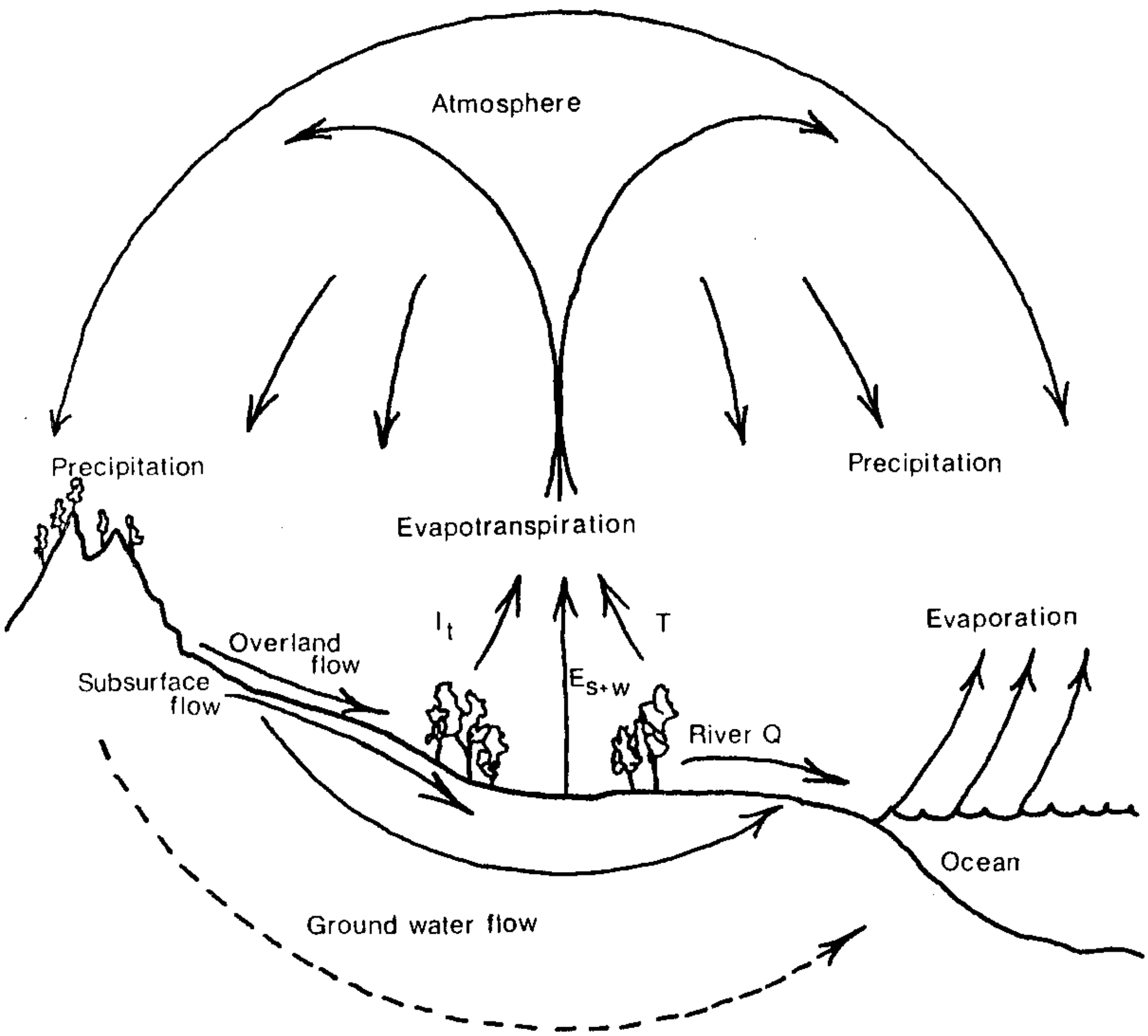

Figure 8.

The Hydrologic Cycle. Symbols are Q= streamflow; I_t= interception loss; E_{s+w} = evaporation from soil and water surfaces; T= transpiration loss. (Hewlett and Nutter, 1969).

Interception

Rain drops strike plant leaves and stems and are retained on these surfaces by the forces of adhesion and cohesion until a sufficiently thick film of water accumulates and gravity overcomes these forces. If rain continues, the storage on an individual leaf will become nearly constant, with as much water falling from the leaf as falls upon it. Water will also be lost from the film on vegetation by evaporation. Rain intercepted by the canopy may subsequently reach the ground by dripping from the leaves or as stemflow (Woolhiser, 1976).

Interception varies with species composition, age and density of stands, season of the year, and regional differences in rainfall patterns. Variations in crown density between crowns of different kinds of trees and even under different parts of the same trees are almost infinite and consequently the amount of precipitation that reaches the soil may be quite varied. In respect to single trees, interception is greatest close to the boles, becomes less under the central and other parts of the crown, and is still less under the edge of the crown where there is some concentration of dripping.

Coniferous trees intercept more rainfall than deciduous trees in full leaf. The deciduous canopy tends to be more dense but raindrops remain hanging on the separate conifer needles, whereas in hardwoods they flow together and drip off the leaves or run down the trunks.

A dense even-aged conifer stand will usually intercept about one-fourth to one-third of the precipitation that falls (Trimble, 1959). For any given depth of precipitation, winter and summer losses appear to be about the same for conifers, but for deciduous trees summer interception losses are two to three times greater than winter losses (Chow, 1964).

It's expected that thinning or regeneration (by natural means or by plantation) of forests in East Texas would lead to a decrease in total interception and an increase in water yield for a period after treatment; however, as the tree stand develops a gradual increase in interception would occur. This is particularly the case during the period of crown closure. Poorly stocked land and land being converted from low-grade hardwoods to pine will eventually increase the amount of water being intercepted.

Depression Storage

Depression storage is the water which collects into pools and depressions shortly after rainfall and either evaporates or infiltrates. Depression storage has an appreciable effect on stormflow in limestone sinkhole areas (Karst topography), where it can greatly reduce direct runoff by reserving overland flow for later infiltration. Another example of depression storage is often seen behind contour terraces following storms. Litter dams in the forest floor sometimes play the role of depression storage (Hewlett and Nutter, 1969).

Depression storage can be increased by agronomic and engineering practices and, therefore, can be important in reducing direct runoff. Doty and Wiersma (1969) found that the maximum potential depression storage capacity for conventional contouring and for bedding and listing practices ranged from approximately 1 inch for contouring to as much as 3 inches for listing and bedding. The potential surface water storage decreases as land slope increases, and is approximately half as great for a 7 percent slope as for a 1 percent slope (Woolhiser, 1976).

The amount of depression storage available on forestlands can appreciably affect streamflow, overland flow, and sediment production. The forest manager can do many things, again, to alter this valuable aspect of the forestland. Practices such as contour planting and windrowing can be used to increase the storage capacity of the land, thus decreasing the amount of overland flow and erosion.

Infiltration

Rainfall, stemflow, and drip from vegetation can either be stored in irregularities of the surface and be lost by evaporation, move over the surface as runoff, or infiltrate. Infiltration is the process by which water enters and moves through the soil surface. It is strictly a surface phenomenon.

Two groups of factors control the infiltration rate of a watershed: 1) those factors which determine how rapidly the surface can absorb water, and 2) rainfall intensity and duration. The first group alone determines infiltration capacity, or rate at which water can infiltrate, but does not necessarily determine how fast it will infiltrate. The infiltration rate is either less than or equal to the infiltration capacity, depending upon the rate at which water is applied. Thus, the infiltration capacity determines infiltration rates only when water is applied faster than it can be absorbed. This distinction is important in evaluating the significance of changes in infiltration capacity that may result from man's activities, for the rainfall intensity that may be expected varies greatly from place to place (Satterlund, 1972).

The rate at which water can enter the soil is dependent on many factors, among which may be vegetal cover, litter and rock cover, surface soil crusting, soil texture, bulk density, capillary force patterns, percent organic matter, degree of aggregation, microbial activity, macropores, shrinking and swelling colloids, moisture content of soil, and soil structure (Branson, Gifford, and Owen, 1972).

The infiltration rate of a give soil is not constant. Under most circumstances, the infiltration capacity of a dry soil is high at the beginning of a rainstorm, and diminishes with time until it approaches a constant rate.

The direct effects of disturbance on infiltration capacity are mostly changes in the amount and kind of vegetative and litter cover and the soil exposure and compaction associated with activities to obtain the products of the land. These activities modify the soil structure, bulk density, macropores, moisture content, and vegetative cover and biota above and within the soil.

The exposure of some soil to raindrop impact is a very important factor in compaction. Raindrops exert a considerable force when striking the earth, which moves the soil particles closer together, and more importantly, this force may break down aggregates, and carry small particles of clay and silt into larger pores as the water infiltrates. These small particles may fill and clog the pores until the amount and size of pores in the surface film is very seriously reduced (McIntyre, 1958). On soils covered with vegetation and litter, the force of rain is largely dissipated.

Infiltration capacity of an undisturbed forest soil in East Texas is generally high and very seldom exceeded. Thus, surface runoff is the exception (Hewlett and Troendle, 1975). However, when forest soils are disturbed the infiltration capacity is usually decreased for a period and surface runoff and erosion increases.

Evapotranspiration

Evapotranspiration is a major component of the hydrologic cycle. It transports about 70 percent of the water that falls on the conterminous United States back to the atmosphere. This percentage can vary from 100 in arid regions to about 50 or less in some mountainous regions (Woolhiser, 1976). Evapotranspiration is highest in summer and lowest in winter and the annual evapotranspiration decreases from the equator toward the poles (Hewlett and Nutter, 1969). Three physical factors must be met for evaporation from a surface to continue: 1) there must be a supply of heat to convert liquid water to vapor, 2) the vapor pressure of the air must be less than that of the evaporative surface, and 3) water must be continually available (Woolhiser, 1976).

There are many factors which effect evapotranspiration that have been identified and others that are not fully understood. Timber harvest usually reduces evapotranspiration, increases the amount of moisture in the mantle, length of time soils remain wet, and water yield. The amount of precipitation returned to the atmosphere as vapor depends upon the energy supply which can be applied to evaporate the water. The primary source is solar radiation and a secondary source is advected heat transferred from a warmer to a cooler region. If water were always available, then actual evapotranspiration would be the same as potential and dependent only upon energy supplies.

Forest density plays a role in the amount of evapotranspiration which occurs. Numerous studies have indicated that logging, thinning and understory removal reduces evapotranspiration (Barrett and Youngberg, 1965; Bay and Boelter, 1963; Koshi, 1959; Zahner, 1967). However, it is seldom possible to separate effects on transpiration from interception or soil evaporation. Probably the major effect results from the change in the root distribution which leaves the soil incompletely occupied by absorbing roots (Satterlund, 1972).

The traditional means of treating watershed vegetation to increase streamflow (decrease evapotranspiration) have depended upon removal of woody vegetation by cutting, chemicals, or fire, with subsequent regrowth or replacement by some other kind of vegetation. At the Coweeta Hydrologic Laboratory in western North Carolina, clearcutting on north slopes yielded a first-year streamflow increase from 11 to 16 inches (Figure 9). On south slopes, clearcutting resulted in a 5 to 7.3 inch increase, or about one-half of that obtained on the north slopes. Partial cutting on an individual tree basis yielded from 0 to 12 inches per equivalent basal area cut on north slopes, and 0 to 6.2 inches on south slopes (Hibbert, 1967). It appeared that all forms of selective cutting were less efficient than removal of the same amount of trees by clearcutting. At the Fernow Experimental Forest in West Virginia, where 15 to 86 percent of the tree volume remained after partial cutting, the first-year streamflow increase from north slope watersheds averaged 6 inches. As at Coweeta, the lightest cuts resulted in a statistically non-significant increase in streamflow (Reinhart, et al., 1963).

Timber harvesting in East Texas can be expected to decrease evapotranspiration and increase water yield for several years after treatment. This will be due mainly to the reduced transpiration of the low growing vegetation. To what extent this will occur is not known for East Texas conditions.

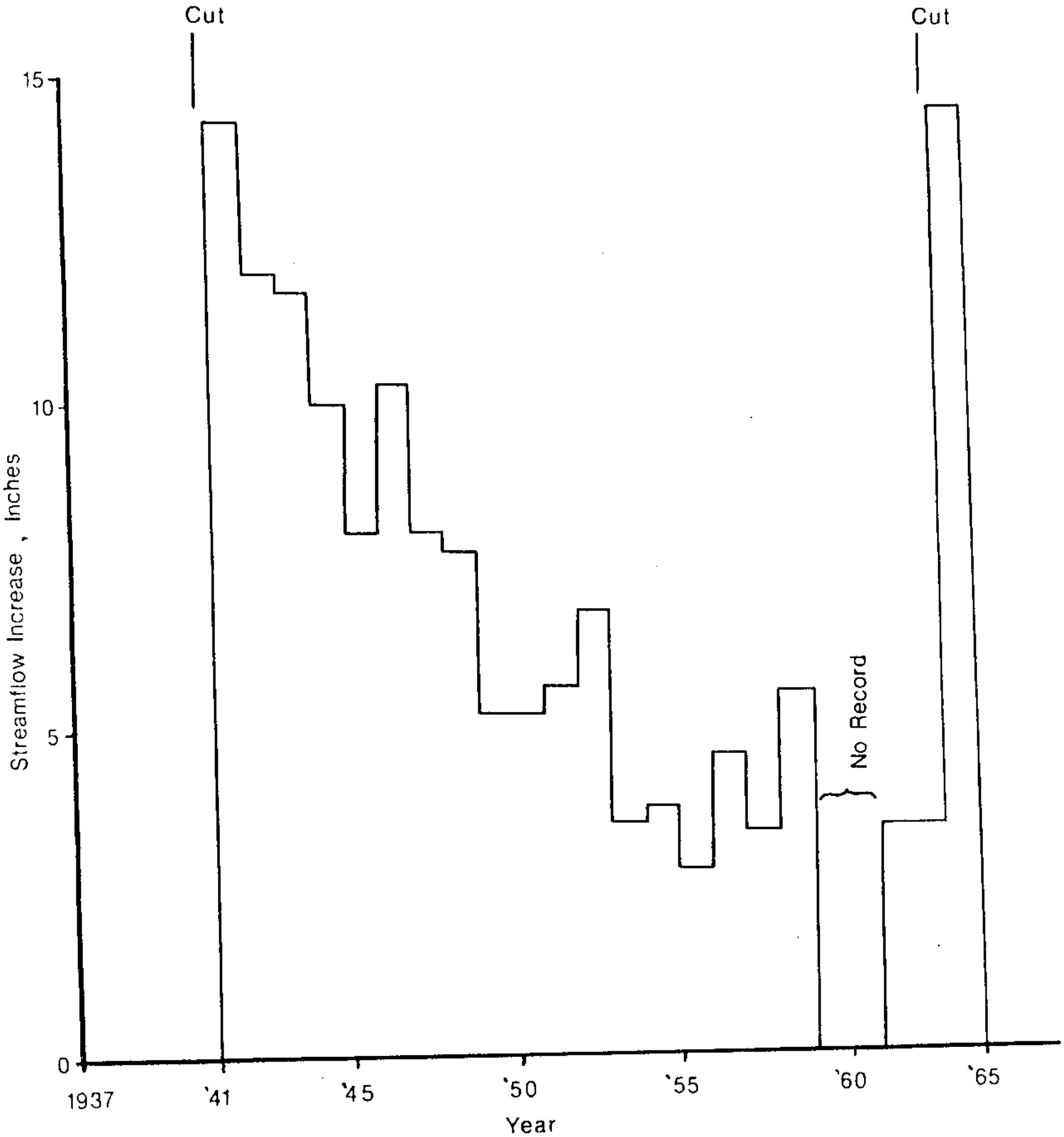

Figure 9.
Declining trend in annual streamflow following clear cutting and forest regrowth. (Hibbert, 1967)

Surface Runoff

Surface runoff is that part of the water which travels over the ground surface to reach a channel. After the flow enters a stream channel, it joins with subsurface flow to form total runoff (Figure 10).

Surface runoff is of hydrologic importance for several reasons: 1) it moves quickly to stream channels, thereby causing fast flood peaks; 2) it is only slightly subject to evaporation because of its short time in transit, and sometimes a greater proportion of surface flow than of subsurface flow contributes to streamflow; and 3) it has the capacity, by virtue of its velocity, to detach soil particles and is therefore an important agent in eroding soil and impairing water quality in streams (Chow, 1964).

Rarely does water move over land as a sheet. Because of surface irregularities, areas of even a few square feet exhibit micro-drainage patterns from which water flows downhill, merging with other micro-channels which merge into rills, gullies, or streams that provide drainage facilities for runoff water. The velocity of overland flow largely determines its flood-and-erosion potential.

In order to generate surface runoff, the precipitation intensity must exceed the infiltration rate and depression storage.

Surface runoff varies in quantity from watershed to watershed and storm to storm. From undisturbed forested watersheds in good condition, it is unusual for surface runoff to occur. However, surface flow is observed over matted leaves or needles, which can act as thatch or shingles under certain circumstances. It may also occur from areas of shallow soil, rock outcrops and moist swales. It can be very important from watersheds disturbed by logging, grazing, fire, and other activities.

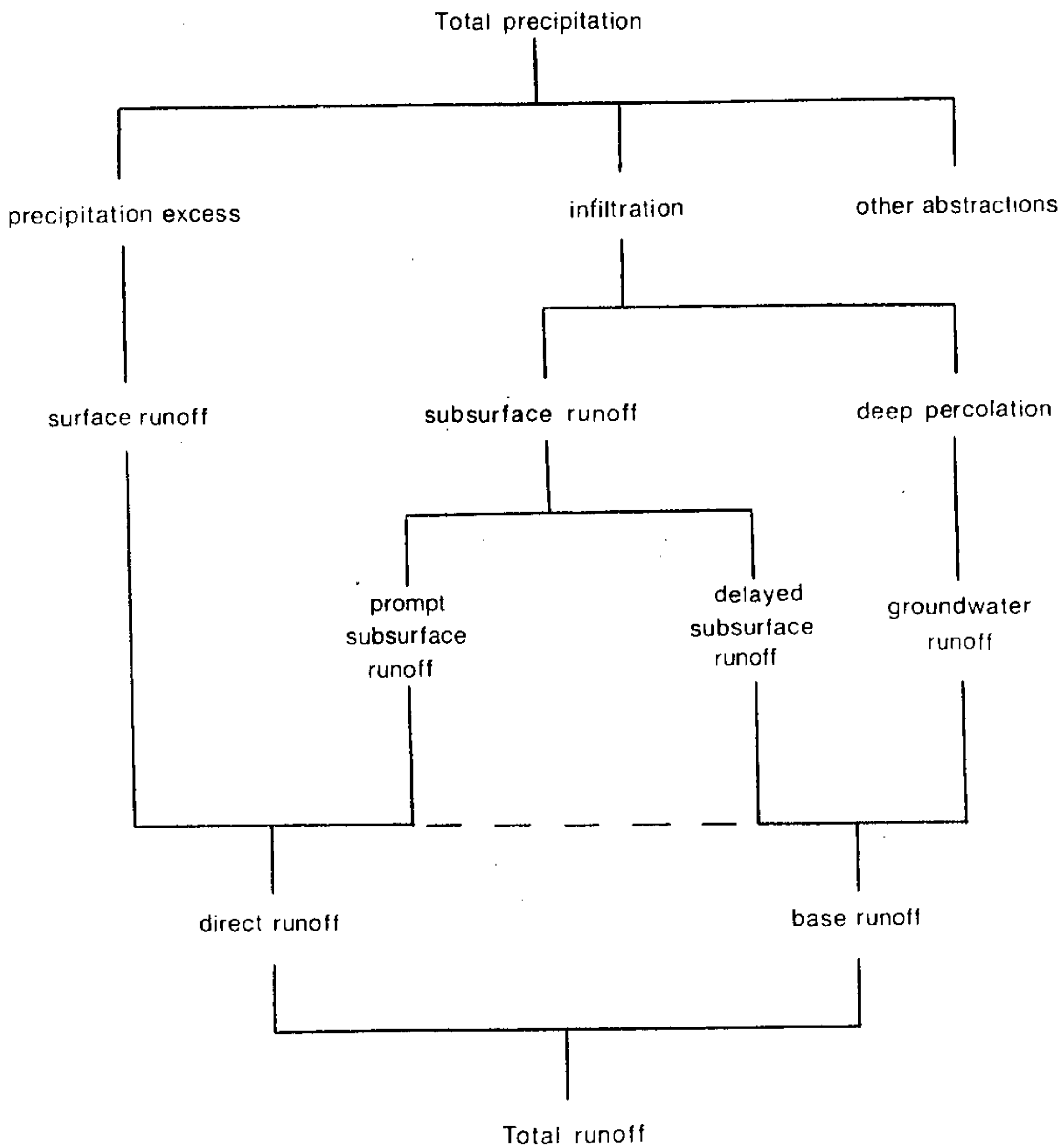

Figure10. Runoff Phenomena. (Chow, V.T., 1964)

The forest floor offers resistance to overland flow and reduces the velocity of any water which may fail to infiltrate. Decomposed litter is incorporated into surface layers of soil by earthworms and other soil fauna. Surface soils under forests characteristically differ from old fields by having: 1) lower bulk density; 2) greater organic matter content; 3) greater percentage of large pore space; 4) greater detention storage capacity; and 5) higher infiltration rates (Alderfer and Merkle, 1941; Hoover, 1944; Sartz, 1961; Trimble et al., 1951). Infiltration rates are typically 20 to 100 inches per hour in undisturbed upland forest soils. Because rainfall rarely exceeds 8 inches per hour anywhere in East Texas, little or no surface runoff occurs from undisturbed forests (Douglass, 1975).

Climate

Except for some small areas in the Trans Pecos, Texas lies in a Warm-Temperature Subtropical Zone. The proximity to the Gulf of Mexico, the persistant southerly and southeasterly flow of warm tropical maritime air into Texas from around the westward extension of the Azores High, and adequate rainfall, combine to produce a humid subtropical climate with hot summers across the eastern 1/3 of the state. While the changes in climate across Texas are considerable, they are nevertheless gradual. No natural boundary separates the moist east from the dry west or the cool north from the warm south.

Rainfall varies greatly from year-to-year. Average annual rainfall along the Louisiana border exceeds 56 inches (Figure 11). The number of days with measurable precipitation follows the general trend of rainfall totals so that seasonal frequencies are lowest where amounts are lowest.

Patterns of seasonal precipitation vary considerably for different areas of the State. Throughout most of East Texas (east of about 95° west longitude) rainfall is fairly evenly distributed throughout the year. East of about 96° west longitude annual rainfall exceeds average potential evapotranspiration.

In East Texas, where the average annual rate of rainfall is highest, there are broad flat valleys and large areas of brush and timberland. The natural drainage channels have gentle slopes, limited capacity, and follow meandering courses from their headwater areas to the Gulf. Runoff is comparatively slow. During periods of intense general rainfall, large volumes of water are temporarily stored in the valleys of the basins and then slowly released into the streams. This, produces a broad flat-

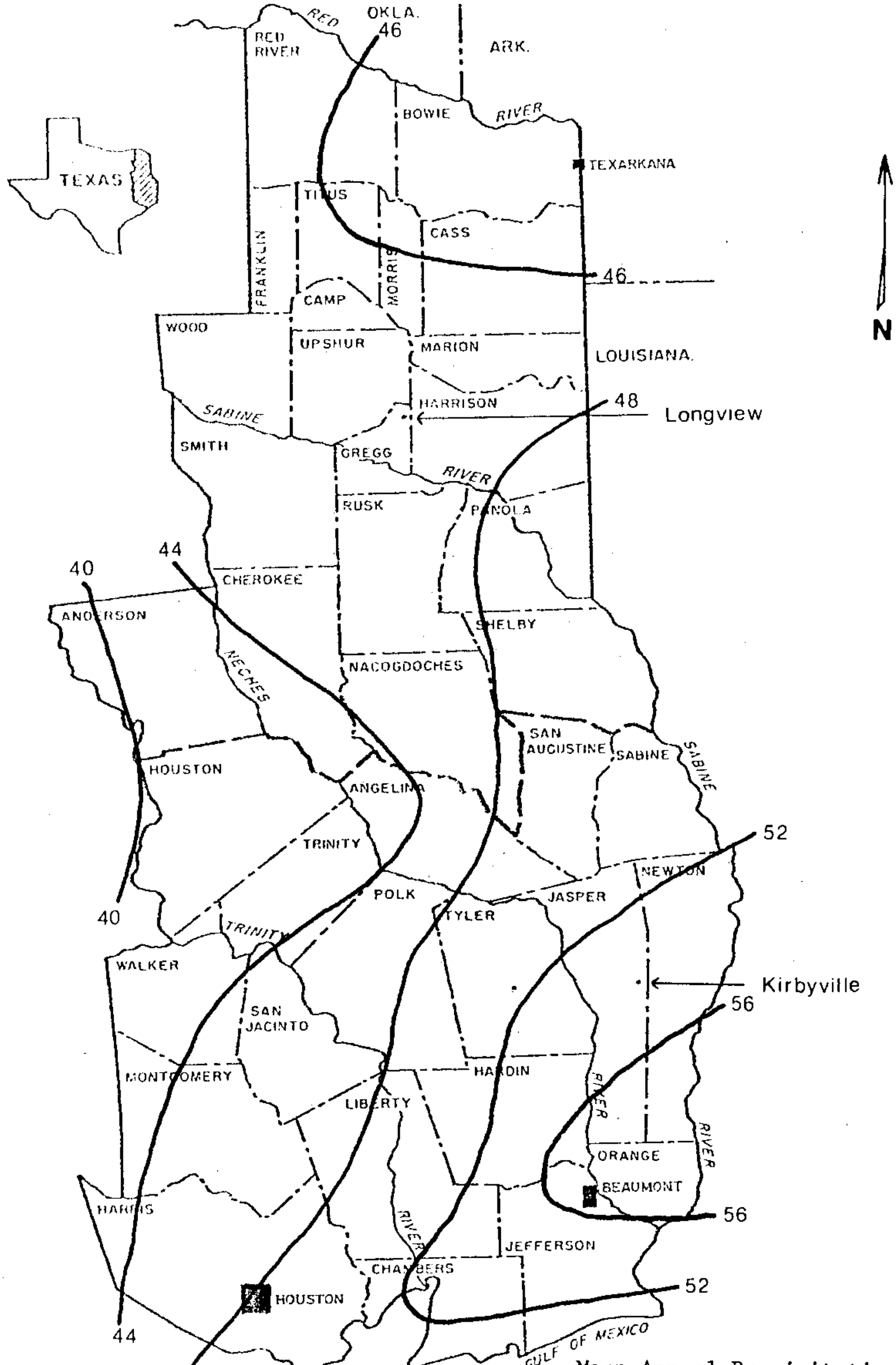

Figure 11. Mean Annual Precipitation (IN.)
Based on U.S. Department of Commerce, National Oceanic and Atmospheric Administration Environmental Data Service "Climatography of the United States No. 81 (Texas)" for the period 1941-1970.

crested slow-moving flood which in the lower basin regions results in protracted periods of inundation (U.S. Department of Commerce, 1974).

Precipitation is both a direct and indirect factor in erosion. Falling precipitation directly represents the greatest force impacting the surface on most watersheds. It is also the source of all overland flow, soil moisture, and channel runoff.

On cultivated soils, research studies show that when all factors other than rainfall are held constant, surface erosion losses are directly proportional to the product of two rainstorm characteristics: total kinetic energy of the storm times its maximum 30-minute intensity (Wischmeier and Smith, 1965). This factor is called "rainfall erosion index" (EI), and reflects the combined potential force of raindrop impact and surface runoff to detach and transport soil particles from the field (Satterlund, 1972). For the purposes of this report, EI has been shown graphically for a location in southeast Texas and a location in northeast Texas (Figure 12 and Figure 13) (U.S. Department of Commerce, 1974).

The Environmental Protection Agency is suggesting that logging activities be curtailed during months of high EI (U.S. Environmental Protection Agency, 1975). This concept may have some application for cropland and forest practices in other parts of the country but it is not practical for forestry as practiced in East Texas. The months of high EI are during late spring and early summer, the time of year that many areas can and should be logged. More damage to water quality can be done during the winter when EI values are low and soils are saturated than during the period when EI values are high and soils are relatively dry.

There is wide variation in temperatures in East Texas. From November through March, surges of cold air from the north are frequent. These

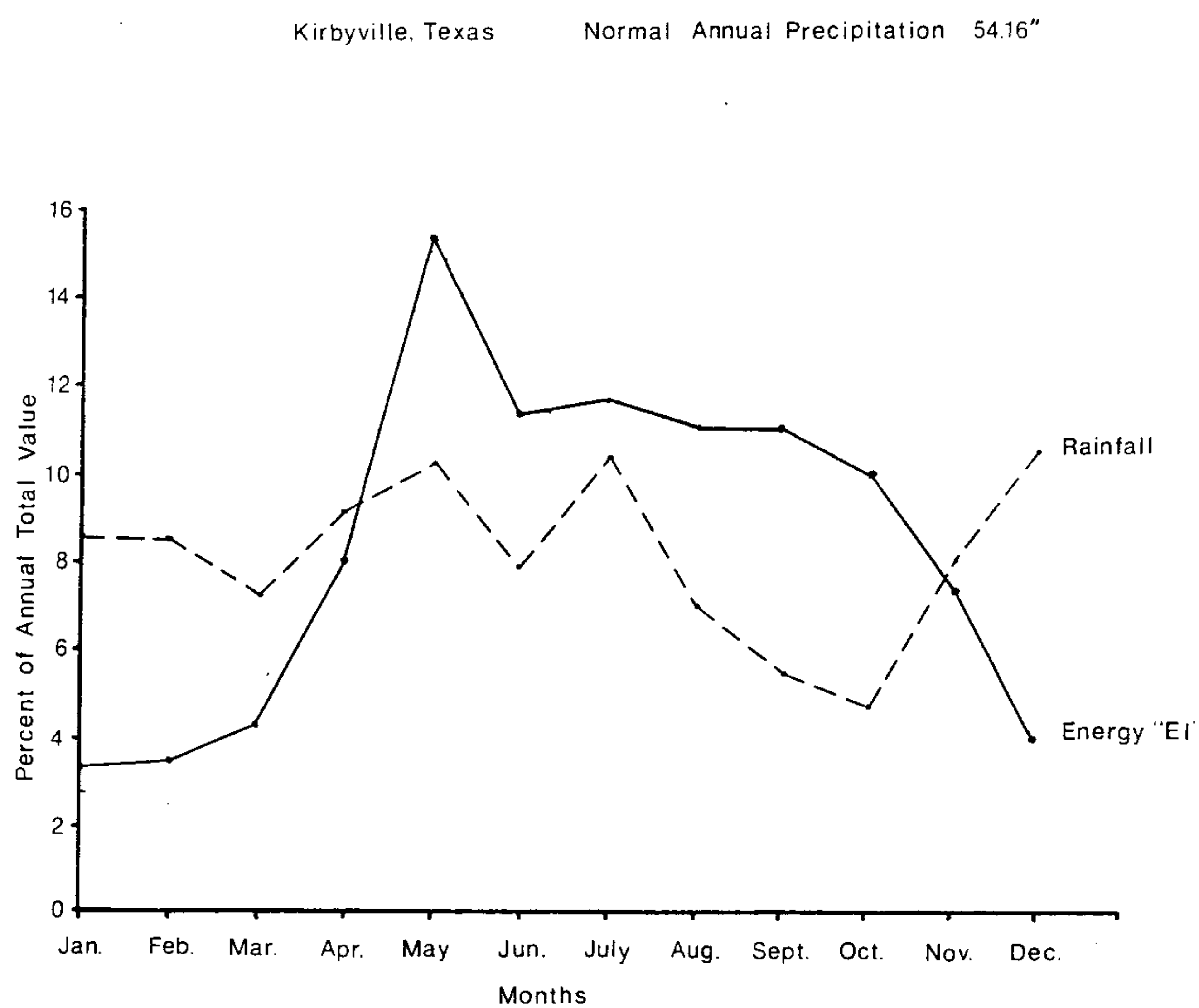

Figure12. **Frequency Distribution of Erosivity Index "EI"**

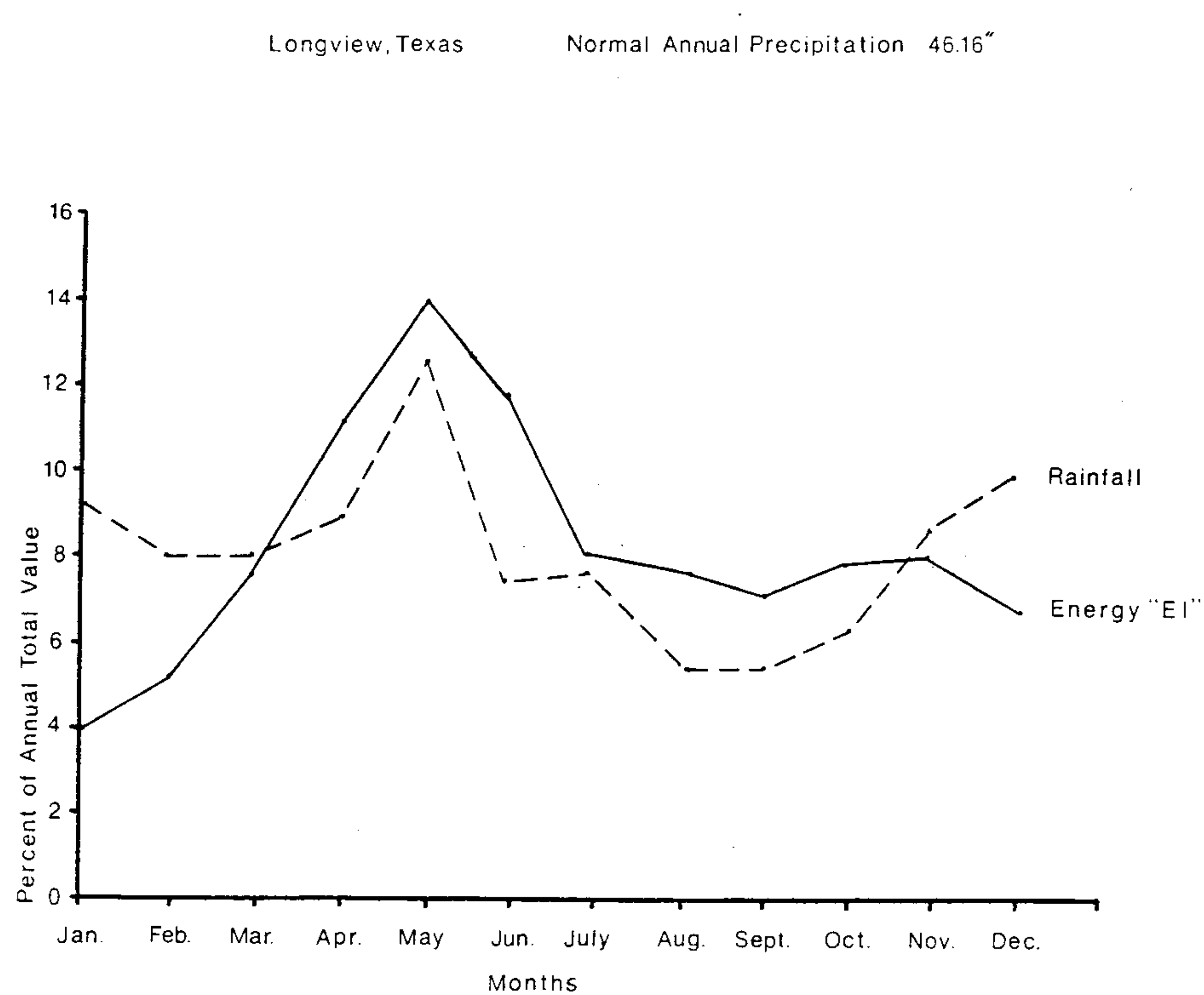

Figure 13. **Frequency Distribution of Erosivity Index "EI"**

cold fronts modify rapidly as they reach warmer latitudes. Fast moving cold fronts, followed by rapid warming, result in frequent and pronounced temperature changes from day to day, and sometimes from hour to hour, during the cold months of the year. Extended periods of sub-freezing temperatures are rare. Cold spells that seriously interfere with outdoor activities usually do not last more than 48 to 72 hours at the most. In summer, the temperature contrast is much less pronounced from north to south with daily highs in the 90's. August is the hottest month (Figure 14).

Relative humidity is highest in the coastal region, and decreases gradually inland, as the distance from the Gulf of Mexico increases. Mean annual relative humidity at noon, Central Standard Time, is about 60 percent near the coast. On the whole, there is a range of approximately 10 percent between the high summer and low winter averages. As temperature increases, relative humidity generally decreases, and when temperatures fall, the relative humidity tends to rise. The lowest relative humidities are found generally in the daytime, especially in the afternoon, while the highest values occur in the early morning (U.S. Department of Commerce, 1974).

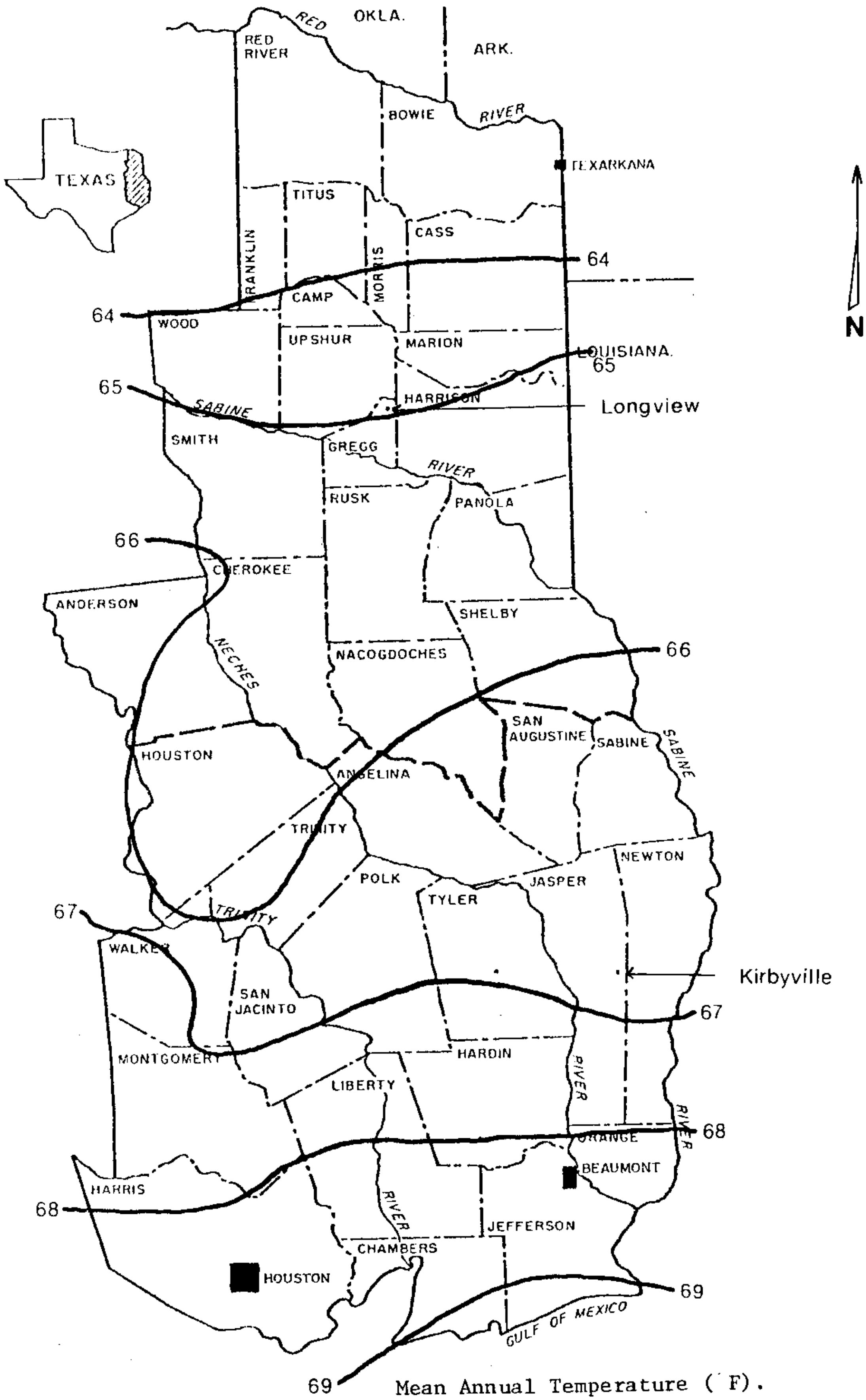

Figure 14. Mean Annual Temperature (°F).
Based on U.S. Department of Commerce, National Oceanic and Atmospheric Administration Environmental Data Service "Climatography of the United States No. 81 (Texas)" for the period 1941-1970.

APPENDIX II.
GLOSSARY

APPENDIX II. GLOSSARY

Adsorption: the adhesion of substances to the surfaces of soils. In soils it has to do with the attraction of ions and of water molecules to colloidal particles.

Balloon Logging: a method of removing felled trees from the harvest site with the use of balloons. Usually used in mountainous terrain.

Basal Sprouting: sprouts that appear at or near the base of a tree trunk.

Bedding: a method of site preparation in which raised beds are created in the soil for the pine seedlings to be planted on. This procedure is usually done in poorly drained areas to raise the seedlings further from the water level.

Borrow Pit: an excavation outside the limits of a construction to provide fill for earthworks.

Bucking: the process of cutting felled trees into the desired lengths.

Buffer Strip: a strip of varying size and shape preserving or enhancing aesthetic and environmental values along roads, streams, trails, and recreation sites, where selective harvesting may occur. Used in this report to be synonymous with stream side management zone.

Cable Yarding: a loose term for any system involving transport along, and/or by means of, steel cables, or, more primitively, single fixed wires, the load being lifted partly or wholly off the ground.

Cambium: the layer of cells that lies between, and gives rise by active division to, secondary xylem and secondary phloem.

Climax: the culminating stage in plant succession for a given environment, the vegetation being conceived as having reached a highly stable condition.

Commercial Thinning: any type of thinning producing merchantable material at least to the value of the direct costs of harvesting.

Crawler Tractor: any of several tractors which utilize tracks instead of wheels or ties (e.g. bulldozer).

Crop Tree: any tree forming or selected to form, a component of the final crop. Generally a tree selected in a young stand or plantation for carrying through to maturity.

Cull Hardwood: any hardwood tree picked out for rejection because it does not meet certain specifications, e.g. as regards usable content.

Culvert: a passage, sometimes merely a pipe, constructed beneath a road, railway or canal to lead the water from the upper side to the lower.

Deadening of Hardwoods: killing unwanted hardwoods through the use of chemicals.

Directional Felling: felling trees in such a way that the butt end will be toward the landing (parallel to the skidding direction).

Direct Seeding: dissemination of seed by hand, helicopter, or other method other than by natural seeding.

Disking: the use of a plough having one or more heavy, concave sharpened steel disks, angled to cut and turn furrow slices. Used in constructing fire lines and also in site preparation.

Double Site Preparation with Roller Choppers: repetition of roller chopping two times.

Drainage Dip: a channel cut through a road shoulder to lead off water, particularly storm water.

Ephemeral Stream: a stream in which flow occurs during and for short periods after an extreme storm; channels are not well defined.

Even-aged Stand: all the trees are the same age or at least of the same age class; a stand is considered even-aged if the difference in age between the oldest and youngest trees does not exceed 20 percent of the length of the rotation.

Fire Line: any cleared strip from which flammable materials have been removed by scraping or digging down to mineral soil. Used in fire control.

Forest Type: a system of classifying biotic community types in terms of the trees, those plants which give the community its characteristic physiogamy (e.g. beech-maple forest, spruce-fir forest).

Hardwood: a conventional term for the timber of broad leaved trees, and the trees themselves, belonging to the botanical group Angiospermae.

Harvest Cut: the felling of the final crop, either a single (i.e. clear) cutting or a series of regeneration cuttings.

Helicopter Logging: a method of removing felled trees from the harvest site with the use of balloons. Usually used in mountainous terrain.

Hydraulic Shear: a mechanical felling device which cuts the tree off at or near ground level.

Infiltration Capacity: the rate at which water can enter and move through the soil surface.

Landing: any place where round timber is assembled for further transport.

Leaching: the movement of materials in solution through the soil profile.

Limbing: the process of removing the limbs from the bole of the tree.

Loess: wind-bloom material deposited in the uplands, the thickest deposits being found where the valleys were widest. It is usually silty in nature. Quartz seems to predominate.

Lopping and Scattering: the process of cutting logging slash into relatively small pieces, then scattering it over the harvest site.

Macropore Space: characteristically allows the ready movement of air and percolating water through the soil.

Main Haul Road: roads used by all truck traffic into and out of the logging site.

Merchantable: of commercial, marketable, saleable quality. Of trees, crops or stands, of a size, quality, and condition suitable for marketing under given economic conditions even if so situated as not to be immediately accessible for logging.

Micropore Space: air movement is greatly impeded and water movement is restricted primarily to slow capillary movement.

Mulch: any loose covering on the surface of the soil, whether natural, like litter, or deliberately applied, like organic residues (e.g. cut grass, straw, foliage) or else artificial materials like cellophane, glass-wool, metal foil, and paper, as applied on nursery beds. Used mainly to conserve moisture and check weed growth, but also to protect from winter climate.

Overland Flow: that portion of precipitation which does not infiltrate into the soil, but flows over the surface until it reaches a channel.

Overstory Vegetation: that portion of the trees, in a forest of more than one level of vegetation, forming the uppermost canopy.

Perennial Stream: a stream which flows almost throughout the year (90 percent of the time or more) in a well defined channel.

Permanent Road: all-weather roads with some system of maintenance, designed according to engineering specifications encompassing drainage and surfacing characteristics.

Pre-commercial Thinning: any type of thinning not producing merchantable material at least to the value of the direct costs of harvesting.

Prescribed Burning: contorlled application fo fire to wildland fuels in either their natural or modified state, under such conditions of weather, fuel moisture, soil moisture, etc. as to allow the fire to be confined to a predetermined area and at the same time to produce the intensity of heat and rate of spread required to further certain planned

Prescribed Burning (con't.)
objectives of silviculture, wildlife management, grazing, fire hazard reduction, etc. It seeks to employ fire scientifically so as to realize maximum net benefits with minimum damage and at acceptable cost.

Product Length Sawlog Operation: a harvesting operation in whic the trees are cut (in the forest) into produce lengths before removal from the harvesting site (e.g. 8 foot plywood bolts, 20 foot dimension lumber logs, etc.).

Pulpwood: wood cut and prepared primarily for manufacture into wood pulp.

Raking: the process of removing all residual woody material from a harvest site and either pushing it into rows or piles with the use of a bulldozer fitted with a rake attachment on the bulldozer blade.

Release: freeing a tree, or groups of trees, from more immediate competition by cutting, or otherwise eliminating, growth that is overtopping or closely surrounding them.

Rill Erosion: concentrations of overland flow resulting in small channels.

Rip Rap: the use of rock, cement-filled sacks, etc. laid on the soil surface to protect it from erosion.

Roller Chopper (Tree-Crusher): an implement with blades mounted on a horizontal power-driven shaft, for reducing the bulk of slash after felling and so facilitating planting.

Root Collar: the transition zone between stem and root, sometimes recognizable in trees and seedlings by the presence of a slight swelling.

Rotation: the period of years required to grow a crop of timber to this specified condition of either economic or natural maturity.

Roundwood: of timber and fuelwood, prepared in the round state - from felled trees to material trimmed, barked and crossed-cut, e.g. logs, transmission poles, etc.

Salvage Cutting: the exploitation of trees, that are dead, dying, or deteriorating (e.g. because overmature or materially damaged by fire, wind, insects, fungi or other infurious agencies) before their timber becomes worthless.

Sanitation Cutting: the removal of dead, damaged, or susceptible trees, essentially to prevent the spread of pests or pathogens and to promote forest hygiene.

Sapwood: the outer layers of wood which, in the growing tree, contain living cells and reserve materials. May be lighter in color than heartwood but may not be clearly differentiated.

Saw Log: a log considered suitable in size and quality for producing sawn timber.

Shearing: the process of cutting off all residual vegetation at the ground line (after a harvest operation) with either a V-shaped bulldozer blade or a blade that is positioned diagonally in relation to the long axis of the bulldozer (called a KG blade). The process is accomplished through the use of a bulldozer.

Sheet Erosion: removal of a fairly uniform layer of soil or material from the land surface by the action of rainfall and runoff.

Shortwood Pulp Operation: a harvesting operation where 5 foot length pulpwood sticks are cut from the felled trees.

Skidtrail: any way, more or less prepared, over which logs are dragged from the stump to the landing.

Slash: the residues left on the ground after felling and tending and/or accumulating there as a result of storm, fire, girdling, or poisoning. It includes unutilized logs, uprooted stumps, broken or uprooted stems and the heavier branchwood.

Slash Dam: the piling of logging debris into a gully or ravine creating a dam.

Soil Scalping: removal of the surface soil as a result of intensive mechanical site preparation practices, mechanical planting, etc.

Soil Solution: soil water in which are dissolved the ionic forms of plant nutrients. Because of its segregation in the large and small pore spaces of the soil, the solution is not always continuous nor does it move freely in the soil.

Subclimax: the (seral) stage in plant succession immediately preceeding the climax.

Temporary Road: roads not intended for all-weather use, designed with minimum engineering specifications for drainage and surfacing and little or not provision for maintenance.

Thinnings: cuttings made in immature stands in order to stimulate the growth of the trees that remain and to increase the total yield of useful material from the stand.

Tolerance: the relative capacity of a forest plant to survive and thrive in the forest understory.

Tree Bole: the tree stem once it has grown to substantial thickness (tree trunk).

Tree Injector: a mechanical device used for injecting chemicals into a tree in order to kill it.

Tree-Length Harvesting Operations: a harvesting operation in which the trees are felled, limbed and topped on the harvesting site. Then the tree-length logs are removed.

Understory Vegetation: generally, trees and woody species, growing under an overstory.

Uneven-aged Stand: contains at least three age classes intermingled intimately on the same area.

Water Bar: a raised barrier, e.g. a ridge of packed earth or a thin pole laid diagonally across the surface of a road so as to lead water, particularly storm water, off it.

Wildfire Hazard Reduction: any treatment of fuels that reduces the threat of ignition and spread of fire.

Windrow: slash, brushwood, etc. concentrated along a line so as to clear the intervening ground.

Windthrow: the uprooting of a tree by the wind.

APPENDIX III.

QUESTIONNAIRES

INDUSTRIAL FOREST MANAGEMENT PRACTICES

QUESTIONNAIRE

(All information strictly CONFIDENTIAL)

Department of Forest Science
Texas A&M University

PART (I)

OWNERSHIP AND OTHER GENERAL DATA

This section is concerned with the amount of commercial forest land your company owns and/or manages in East Texas. It also seeks to determine what type of management assistance, if any, your company provides for private, non-industrial woodland owners.

(1) In East Texas, how many acres of commercial forest land does your company manage in each of the catagories listed below?

_______ acres of land in fee simple ownership

_______ acres of land under long-term lease

_______ acres of land under cooperative management agreement (i.e. landowner assistance programs)

NOTE: If your company has an active landowner assistance program, please answer questions (2) and (3) before proceeding to PART (II).

(2) How long has the company's landowner assistance program been in operation?

- [ ] less than 2 years
- [ ] 2 - 5 years
- [ ] 6 - 10 years
- [ ] over 10 years

(3) What types of assistance does your company's program provide for the landowner? (Check all services that apply.)

- [ ] management plans
- [ ] timber sale preparation (i.e. marking and volume estimation)
- [ ] timber sale administration (i.e. supervision of logging)
- [ ] site preparation
- [ ] planting
- [ ] other (SPECIFY: ______________________________.)

PART (II)

ROAD CONSTRUCTION AND MAINTENANCE PRACTICES

This section is concerned with the location, construction and maintenance of permanent access roads. (DEFINITION: All-weather roads with some system of of maintenance, designed according to engineering specifications encompassing specific drainage and surfacing characteristics.)

(1) Approximately how many miles of permanent access roads are constructed each year on the forest lands which your company manages in each of the catagories listed below? (NOTE: Take an average of the last 3 years.)

_______ miles/year on land in fee simple ownership

_______ miles/year on land under long-term lease

_______ miles/year on land under cooperative management agreement

(2) What is the average cost per mile for constructing permanent access roads?

_______ $/mile in the flatwoods

_______ $/mile in the uplands

(3) Rank the following road construction activities as to their relative costliness. (Indicate by 1 = most costly, 2 = next most costly, and so on.)

_______ engineering or location survey

_______ cuts and fills

_______ debris disposal

_______ drainage ditches

_______ surfacing

_______ water crossing (bridges)

_______ water crossing (culverts)

_______ water crossing (logs and fill dirt)

_______ other (SPECIFY: ________________________________.)

(4) What proportion of the total mileage of permanent access roads is typically built by private contractors?

_______ % on land in fee simple ownership

_______ % on land under long-term lease

_______ % on land under cooperative management agreement

(5) Who typically determines the route location and design specifications of permanent access roads? (Indicate your responses by placing an "X" in the cells of the table below.)

Decision-Maker	Land in Fee Simple		Land Under Lease		Land Under Mgmt. Agreement	
	Location	Design Specs.	Location	Design Specs.	Location	Design Specs.
Landowner or Representative	--	--				
Company Engineer or Forester						
Private Contractor						
Other (SPECIFY: ________________.)						

(6) Is an on-site engineering or location survey typically conducted prior to beginning construction of permanent access roads?

a.) On land in fee simple ownership?

☐ Yes ☐ No

b.) On land under long-term lease?

☐ Yes ☐ No

c.) On land under cooperative management agreement?

☐ Yes ☐ No

(7) In those instances where an engineering or location survey is conducted, which of the following factors are normally considered in the process? (Check all that apply.)

- [ ] drainage characteristics of the site
- [ ] soil structure and characteristics
- [ ] expected traffic
- [ ] other (SPECIFY: ______________________.)

(8) The table below lists several different design features and construction practices that might be used in building permanent access roads. How would you describe the frequency with which these various factors and practices are actually used? Indicate your answers by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Design Feature or Construction Practice	Land in Fee Simple	Land Under Lease	Land Under Mgmt. Agreement
Attempt to locate roads along ridges			
Follow contours in road construction			
Crown or outslope road surface			
Minimize activity in stream channels and wet areas			
Install culvert or bridge at water crossings			
Seed grass on cut and fill areas			
Use roadside buffers*			

(*DEFINITION: A perimeter of undisturbed vegetation along a roadway.)

(9) How frequently are permanent access roads inspected to determine the need for maintenance?

a.) On land in fee simple ownership?

- [ ] at least twice a year
- [ ] once a year
- [ ] less than once a year
- [ ] never

b.) On land under long-term lease?

- [ ] at least twice a year
- [ ] once a year
- [ ] less than once a year
- [ ] never

c.) On land under cooperative management agreement?

- [ ] at least twice a year
- [ ] once a year
- [ ] less than once a year
- [ ] never

(10) The table below lists several practices that might be used to maintain the integrity of permanent access roads. Indicate the frequency with which the practices are actually used by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Road Maintenance Practice	Land in Fee Simple	Land Under Lease	Land Under Mgmt. Agreement
Close roads when not in use			
Open drainage ditches			
Regrade road surfaces			
Reseed or fertilize cut and fill areas			
Restrict traffic during wet weather			

(11) What sorts of equipment -- both as to type and size -- are commonly used in constructing permanent access roads?

____

____

____

PART (III)

HARVESTING AND LOGGING PRACTICES

This section is concerned with the types of silvicultural systems being used, the acreages of timber being cut, and the entire range of logging activities associated with removing timber products from the forest.

(1) What proportion of your timber management effort is directed toward the following species groups?

_______ % pine

_______ % hardwood

(2) What proportion of your timber management effort is directed toward the following product groups?

_______ % pulpwood

_______ % sawtimber

(3) Approximately how many acres of sawtimber and pulpwood size material receive a final harvest cut each year using the various harvesting systems shown in the table below? (NOTE: Take an average for the last 3 years.)

Harvesting System	Land in Fee Simple		Land Under Lease		Land Under Mgmt. Agreement	
	Sawtimber	Pulpwood	Sawtimber	Pulpwood	Sawtimber	Pulpwood
		-- area cut in acres --				
Clearcut						
Seed Tree						
Shelterwood						
Selection						

NOTE: If the clearcut harvesting system is used, answer questions (4) and (5) before going on to question (6).

(4) What is the average size clearcut area for each of the land classifications listed below?

_______ acres on land in fee simple ownership

_______ acres on land under long-term lease

_______ acres on land under cooperative management agreement

(5) In East Texas, what is the average rotation length employed for each of the timber stand and land classification combinations identified in the table below?

Timber Stand Classification	Land in Fee Simple	Land Under Lease	Land Under Mgmt Agreement
	-- rotation in years --		
Pine Pulpwood			
Pine Sawtimber			
Hardwood Pulpwood			
Hardwood Sawtimber			

(6) Approximately what proportion of the total acreage harvested in a given year is logged by private contractors?

_______ % on land in fee simple ownership

_______ % on land under long term lease

_______ % on land under cooperative management agreement

(7) Approximately what proportion of the total timber harvest in a given year is logged under a "tree length" system?

_______ % of sawtimber harvested

_______ % of pulpwood harvested

(8) What is your best estimate of the total number of miles of <u>temporary access roads</u> being constructed in conjunction with timber harvesting operations in a typical year? (<u>DEFINITION</u>: Roads not intended for all-weather use, designed with minimum engineering specifications for drainage and surfacing and little or no provision for maintenance.)

_______ miles/year on land in fee simple ownership

_______ miles/year on land under long-term lease

_______ miles/year on land under cooperative management agreement

(9) Is an on-site engineering or location survey typically conducted prior to beginning construction of temporary access roads?

a.) On land in fee simple ownership?

☐ Yes ☐ No

b.) On land under long-term lease?

☐ Yes ☐ No

c.) On land under cooperative management agreement?

☐ Yes ☐ No

(10) In those instances where an engineering or location survey is conducted, which of the following factors are normally considered in the process? (Check all that apply.)

- [ ] drainage characteristics of the site
- [ ] soil structure and characteristics
- [ ] expected traffic
- [ ] other (SPECIFY: ________________________________.)

(11) How many landings are normally constructed within a 40 acre area?

_______ landings/40 acres

(12) Visualizing a circular landing, what would be a typical average diameter?

_______ feet

(13) What proportion of harvested timber is felled with chainsaws, and what proportion with shears?

_______ % felled with chainsaws

_______ % felled with shears

(14) What proportion of harvested timber is skidded with the following types of equipment?

_______ % with rubber-tired skidders

_______ % with tracked skidders

_______ % with cable systems (SPECIFY TYPE: ____________________.)

(15) Assuming skidding with rubber-tired or tracked skidders, approximately what proportion of the area around a typical landing would be disturbed by skid trails during a normal harvesting operation?

- [ ] 30% or more
- [ ] 20% - 29%
- [ ] 10% - 19%
- [ ] less than 10%

(16) What proportion of your harvesting operations are conducted during each of the following time periods?

_______ % during Dec. through Feb.

_______ % during Mar. through May

_______ % during Jun. through Aug.

_______ % during Sep. through Nov.

(17) The table below lists several practices that might be used during a logging operation. Indicate the frequency with which the practices are actually used by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

QUESTION (17) CONTINUED ON NEXT PAGE

Harvesting or Logging Practice	Land in Fee Simple	Land Under Lease	Land Under Mgmt. Agreement
Avoid felling trees into streams			
Fell trees parallel to skid direction			
Leave streamside buffers*			
Limit skidder activity in streams			
Skid uphill or along contours			
Delay logging due to wet site			

(*DEFINITION: A perimeter of undisturbed vegetation along a stream.)

NOTE: If logging is typically delayed on wet sites, answer question (18) before going on to question (19).

(18) What criteria is used to determine when a site is too wet to log?

- [ ] visual inspection of the site
- [ ] equipment becomes bogged down
- [ ] other (SPECIFY: ______________________________.)

(19) How frequently are the following actions taken to reduce soil loss from temporary access roads, landings and skid trails after completion of the timber harvesting operation? Indicate your answers by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Actions to Prevent Soil Loss	Land in Fee Simple	Land Under Lease	Land Under Mgmt. Agreement
Construct water bars			
Restrict traffic			
Scatter logging slash			
Seed grass on surfaces			

(20) On areas that are not subsequently site-prepared, what is typically done with the logging slash following a harvesting operation?

- [ ] left as is to decompose naturally
- [ ] lopped and scattered to facilitate decomposition
- [ ] piled and burned
- [ ] other (SPECIFY: ______________________________.)

(21) What sorts of equipment -- both as to type and size -- are commonly used in conjunction with logging activities?

____

____

____

PART (IV)

SITE PREPARATION PRACTICES

This section is concerned with the techniques used to prepare forest land for the production of new timber crops.

(1) Approximately how many acres are treated each year using each of the general catagories of site-preparation techniques listed in the table below? (NOTE: Take an approximate average for the last 3 years.)

Site-Preparation Techniques	Lands in Fee Simple	Land Under Lease	Land Under Mgmt. Agreement
	-- acres treated per year --		
By use of chemical herbicides			
By use of prescribed burning			
By use of mechanical means			

(2) In terms of acreage, what proportion of mechanical site-preparation work is done by private contractors?

_______ % on land in fee simple ownership

_______ % on land under lease

_______ % on land under cooperative management agreement

(3) Listed below are several mechanical site-preparation techniques. Which of these techniques are used in East Texas? (Check all that are used.)

- [ ] bedding
- [ ] chopping
- [ ] disking
- [ ] raking
- [ ] shearing
- [ ] windrowing
- [ ] other (SPECIFY: ________________________________.)

(4) Regarding question (3), which of the site-preparation techniques are most frequently used, and in what combinations are they commonly employed?

____

____

____

____

(5) Considering all land owned and/or managed by the company -- on the average, how many acres are fertilized each year in conjunction with site-preparation activities? (NOTE: Take an average for the last 3 years.)

_______ acres/year

(6) The table below lists several procedures which might be used during mechanical site-preparation activities. Indicate the frequency with which the procedures are actually used by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Mechanical Site-Preparation Procedures	Land in Fee Simple	Land Under Lease	Land Under Mgmt. Agreement
All activities (excluding chopping) performed on contour			
Leave streamside buffers*			
Use techniques which minimize disturbance on steep slopes			
Seed grass cover crop			
Windrow slash along contours			

(*DEFINITION: A perimeter of undisturbed vegetation along a stream.)

(7) What sorts of equipment -- both as to type and size -- are commonly used in mechanical site-preparation work?

____

____

____

PART (V)

STAND RE-ESTABLISHMENT PRACTICES

This section is concerned with the methods -- both natural and artificial -- used for reforestation and afforestation purposes.

(1) Approximately how many acres of forest land which receive a harvest cut each year are allowed to regenerate naturally? (NOTE: Take an approximate average for the last 3 years.)

_______ acres/year on land in fee simple ownership

_______ acres/year on land under long-term lease

_______ acres/year on land under cooperative management agreement

(2) The table below indicates some alternative artificial regeneration practices. In each cell of the table, indicate the approximate acreage of cut-over forest land which annually receives each type of treatment. (NOTE: Take an average for the last 3 years.)

Artificial Regeneration Practice	Land in Fee Simple	Land Under Lease	Land Under Mgmt. Agreement
	-- acres treated per year --		
Direct Seeding (ground)			
Direct Seeding (air)			
Planting (hand)			
Planting (machine)			

(3) What sorts of equipment -- both as to type and size -- are commonly used in stand re-establishment by artificial means?

____

____

____

(4) Approximately how many acres of land are annually converted from some other use (e.g. cropland, pasture, etc.) to forestry? (NOTE: Take an approximate average for the last 3 years.)

_______ acres/year on land in fee simple ownership

_______ acres/year on land under long-term lease

_______ acres/year on land under cooperative management agreement

(5) Of the total acreage which is artificially regenerated each year, approximately how many acres are regenerated using improved seed or planting stock? (NOTE: Take an average for the last 3 years.)

a.) On land in fee simple ownership?

_______ acres/year with improved seed

_______ acres/year with improved seedlings

b.) On land under long-term lease?

_______ acres/year with improved seed

_______ acres/year with improved seedlings

c.) On land under cooperative management agreement?

_______ acres/year with improved seed

_______ acres/year with improved seedlings

PART (VI)

INTERMEDIATE CULTURAL PRACTICES

This section is concerned with the nature and extent of the various cultural practices that may be employed during the period from stand establishment to final harvest cut.

(1) Listed below are several intermediate cultural practices. Complete the table by indicating in each cell the approximate acreage which receives each treatment in a typical year. (NOTE: Take an approximate average for the last 3 years.)

Intermediate Cultural Practices	Land in Fee Simple	Land Under Lease	Land Under Mgmt. Agreement
	-- acres treated per year --		
Cultivation			
Prescribed Burn (not site preparation)			
Salvage or Sanitation Cutting			
Thinning (precommercial)			
Thinning (commercial)			

(2) At what age is a developing stand normally given a precommercial thinning? (NOTE: Leave this question blank if precommercial thinnings are not performed.)

_______ years for pine stands

_______ years for hardwood stands

(3) At what age(s) is a developing stand normally given a commercial thinning(s)? (NOTE: Leave this question blank if commercial thinnings are not performed.)

_______ and _______ years for pine stands

_______ and _______ years for hardwood stands

PART (VII)

CHEMICAL USE PRACTICES

This section is concerned with the types, amounts, and methods of application for all chemical agents (i.e. pesticides, fertilizers, fire retardents, etc.) used in connection with your forest management activities.

(1) The table on p.(12) identifies the principal catagories of chemical agents used in forestry operations. Complete the table by providing all requested information. Usage figures should be reported for all forest land which is owned or managed. Furthermore, they should reflect the average annual usage for the period of the last 3 years. (NOTE: If insufficient space is available, please attach additional paper.)

CHEMICAL USE TABLE ON PAGE (12)

PART (VIII)

OTHER PRACTICES

This section is concerned with those forest practices which did not logically fit into any of the previously defined catagories.

(1) Approximately how many acres of forest land undergo species type conversion in a typical year? (NOTE: Take an average for the last 3 years.)

a.) On land in fee simple ownership?

_______ acres/year from hardwood to pine

_______ acres/year from pine to hardwood

b.) On land under long-term lease?

_______ acres/year from hardwood to pine

_______ acres/year from pine to hardwood

c.) On land under cooperative management agreement?

_______ acres/year from hardwood to pine

_______ acres/year from pine to hardwood

CHEMICAL USE TABLE

Catagory of Chemical Agent	Types Used	Total Quantity Used or Number of Acres Treated	Application Rate	Methods of Application	Reasons for Application
Insecticides					
Herbicides					
Fungicides					
Rodenticides					
Fertilizers					
Fire Retardents					
Other Chemical Agents (e.g. soil stabilizers, soil fumigants, etc.)					

PRIVATE NON-INDUSTRIAL

FOREST MANAGEMENT PRACTICES

QUESTIONNAIRE

(All information strictly CONFIDENTIAL)

Department of Forest Science

Texas A&M University

PART (I)

OWNERSHIP AND OTHER GENERAL DATA

> This section is concerned with the number of private non-industrial forest landowners who are assisted each year by personnel of the Texas Forest Service. It excludes land in this ownership class which is managed by forest industry under cooperative management agreements or long-term leases.

(1) In your district, how many private non-industrial landowners do you assist in a typical year? (NOTE: Take an average of the last 3 years.)

_______ landowners/year

(2) What is the average number of acres of forest land held by those private non-industrial owners who receive management assistance?

_______ acres/landowner

PART (II)

ROAD CONSTRUCTION AND MAINTENANCE PRACTICES

> This section is concerned with the location, construction and maintenance of permanent access roads which are built, at least in part, for forest management purposes. (DEFINITION: All-weather roads with some system of maintenance, designed according to engineering specifications encompassing specific drainage and surfacing characteristics.)

(1) What is your best estimate of the number of miles of permanent access roads being constructed annually on the private non-industrial forest lands in your district? (NOTE: Take an approximate average for the last 3 years.)

_______ miles/year

(2) What is the approximate average cost per mile for constructing such roads?

_______ $/mile in the flatwoods

_______ $/mile in the uplands

(3) Who typically supervises the construction of permanent access roads?

- [ ] landowner or representative
- [ ] Texas Forest Service
- [ ] private contractor

(4) Which of the following responses most accurately describes the degree of supervision over construction of such roads?

- [ ] close supervision of construction activities
- [ ] moderate supervision of construction activities
- [ ] very little supervision of construction activities
- [ ] no supervision of construction activities

(5) Is an on-site engineering or location survey typically conducted prior to beginning construction of permanent access roads?

- [ ] Yes
- [ ] No

QUESTION (5) CONTINUED ON NEXT PAGE

IF YES - Which of the following factors are normally considered in the process?

- [ ] drainage characteristics of the site
- [ ] soil structure and characteristics
- [ ] expected traffic
- [ ] other (SPECIFY: ______________________________.)

(6) The table below lists several design features and construction practices that might be used in building permanent access roads. How would you describe the frequency with which these various features and practices are actually used? Indicate your answers by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Design Feature or Construction Practice	Coded Responses
Attempt to locate roads along ridges	
Follow contours in road construction	
Crown or outslope road surface	
Minimize activity in stream channels and wet areas	
Install culvert or bridge at water crossings	
Seed grass on cut and fill areas	
Use roadside buffers*	

(*DEFINITION: A perimeter of undisturbed vegetation along a roadway.)

(7) How frequently are permanent access roads inspected to determine the need for maintenance?

- [ ] at least twice a year
- [ ] once a year
- [ ] less than once a year
- [ ] never

(8) The table below lists several practices that might be used to maintain the integrity of permanent access roads. Indicate the frequency with which the practices are actually used by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Road Maintenance Practice	Coded Responses
Close roads when not in use	
Open drainage ditches	
Regrade road surfaces	
Reseed or fertilize cut and fill areas	
Restrict traffic in wet weather	

(9) Who typically maintains permanent access roads?

- ☐ landowner or representative
- ☐ county
- ☐ other (SPECIFY: ______________________________.)

PART (III)

HARVESTING AND LOGGING PRACTICES

> This section is concerned with the types of silvicultural systems being used, the acreages of timber being cut, and the entire range of logging activities associated with removing timber products from the forest.

(1) Regarding the private non-industrial forest landowners in your district, approximately what proportion practice some type of timber management?

_______ % practice some form of continuing management

_______ % harvest mature timber but don't practice continuing management

_______ % don't practice any form of management

(2) Regarding those owners who do practice some form of timber management, approximately what proportion of their management effort is directed toward the following species groups?

_______ % pine

_______ % hardwood

(3) Again considering those owners who do practice some form of timber management, approximately what proportion of their management effort is directed toward the following product groups?

_______ % pulpwood

_______ % sawtimber

(4) In your district, approximately how many acres of private non-industrial forest land recieve a final harvest cut in a typical year? (NOTE: Your estimate as to the acreage involved will be very useful.)

_______ acres/year of sawtimber

_______ acres/year of pulpwood

(5) At approximately what age or DBH are trees when a final harvest cut is made?

_______ years or _______ inches DBH for pine

_______ years or _______ inches DBH for hardwood

(6) On the private non-industrial forest land in your district, approximately what percent of the total acreage of sawtimber and pulpwood sized material which receives a final harvest cut each year, is cut using the various harvesting systems shown in the table below?

Harvesting System	Percent of Total Acreage Cut	
	Sawtimber	Pulpwood
Clearcut		
Seed Tree		
Shelterwood		
Selection		

(7) Approximately what is the average size clearcut area?

_______ acres

(8) What is your best estimate of the total number of miles of temporary access roads being constructed annually in conjunction with timber harvesting operations on private non-industrial forest lands in your district? (DEFINITION: Roads not intended for all-weather use, designed with minimum engineering specifications for drainage and surfacing and little or no provision for maintenance.)

_______ miles/year

(9) Who typically supervises the construction of temporary access roads?

- ☐ landowner or representative
- ☐ Texas Forest Service
- ☐ private contractor

(10) Which of the following responses most accurately describes the degree of supervision over construction of such roads?

- ☐ close supervision of construction activities
- ☐ moderate supervision of construction activities
- ☐ very little supervision of construction activities
- ☐ no supervision of construction activities

(11) The table below lists several practices that might be used during a logging operation. Indicate the frequency with which the practices are actually used by entering the appropriate code numbers for the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Harvesting or Logging Practice	Coded Responses
Avoid felling trees into streams	
Fell trees parallel to skid direction	
Leave streamside buffers*	
Limit skidder activity in streams	
Skid uphill or along contours	
Delay logging due to wet site	

(*DEFINITION: A perimeter of undisturbed vegetation along a stream.)

(12) On areas that are not subsequently site-prepared, what is typically done with the logging slash following a harvesting operation?

- ☐ left as is to decompose naturally
- ☐ lopped and scattered to facilitate decomposition
- ☐ piled and burned
- ☐ other (SPECIFY: ________________________________.)

(13) How frequently are the following actions taken to reduce soil loss from temporary access roads, landings and skid trails after completion of a timber harvesting operation? Indicate your answers by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Actions to Prevent Soil Loss	Coded Responses
Construct water bars	
Restrict traffic	
Scatter logging slash	
Seed grass on surfaces	

PART (IV)

SITE PREPARATION PRACTICES

This section is concerned with the techniques used to prepare forest land for the production of new timber crops. (NOTE: This is still for private non-industrial land only.)

(1) Of the total acreage of private non-industrial forest land which receives a final cut each year on your district, what percentage would you estimate receives some type of site-preparation treatment?

_______ percent

(2) Considering that portion of the private non-industrial forest land which is site-prepared, what percentage would you estimate is site-prepared using the general types of techniques listed below?

_______ % by use of chemical herbicides

_______ % by use of prescribed burning

_______ % by use of mechanical means

(3) Who typically supervises site-preparation activities on these lands?

☐ landowner or representative

☐ Texas Forest Service

☐ private contractor

(4) Listed below are several mechanical site-preparation techniques. Which of these techniques are commonly used on forest land in private non-industrial ownership? (NOTE: Check all techniques that are used.)

☐ bedding

☐ chopping

☐ disking

☐ raking

☐ shearing

☐ windrowing

☐ other (SPECIFY: ________________________________.)

(5) The table below lists several procedures that might be used during mechanical site-preparation activities. Indicate the frequency with which the procedures are actually used on private non-industrial lands by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Mechanical Site-Preparation Procedure	Coded Responses
All activities (excluding chopping) performed on contour	
Leave streamside buffers*	
Use techniques which minimize soil disturbance on steep slopes	
Seed grass cover crop	
Windrow slash along contours	

(*DEFINITION: A perimeter of undisturbed vegetation along a stream.)

PART (V)

STAND RE-ESTABLISHMENT PRACTICES

This section is concerned with the methods -- both natural and artificial -- used for reforestation and afforestation purposes on private non-industrial forest lands.

(1) In a typical year, approximately what percentage of the private non-industrial forest land which receives a harvest cut is allowed to regenerate by the methods listed below?

_______ % regenerated naturally

_______ % regenerated artificially

(2) Considering that portion which is artificially regenerated, what percentage would you estimate is regenerated using the specific techniques listed below?

_______ % regenerated by direct seeding (ground)

_______ % regenerated by direct seeding (air)

_______ % regenerated by planting (hand)

_______ % regenerated by planting (machine)

(3) Within the private non-industrial ownership class, approximately how many acres are annually converted from some other use (e.g. cropland, pasture, etc.) to forest land?

_______ acres/year

PART (VI)

INTERMEDIATE CULTURAL PRACTICES

This section is concerned with the nature and extent of the various cultural practices that may be employed during the period from stand establishment to final harvest cut.

(1) Listed below are several intermediate cultural practices. For those private non-industrial landowners who practice some form of timber management, how would you describe the frequency with which these various practices are actually used? Indicate your answers by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Intermediate Cultural Practice	Coded Responses
Cultivation	
Prescribed burn (not site-prep.)	
Salvage or sanitation cutting	
Thinning (pre-commercial)	
Thinning (commercial)	

(2) For those stands which are pre-commercially thinned, at what age is the thinning normally conducted?

_______ years for pine stands

_______ years for hardwood stands

(3) For those stands which are commercially thinned, at what age(s) is the thinning normally conducted?

_______ and _______ years for pine stands

_______ and _______ years for hardwood stands

PART (VII)

CHEMICAL USE PRACTICES

This section is concerned with the types, amounts, and methods of application for all chemical agents (i.e. pesticides, fertilizers, fire retardents, etc.) used in connection with forest management activities on land held by private non-industrial owners.

(1) The table on p.(8) identifies the principal catagories of chemical agents used in forestry operations. Complete the table by providing, as best you can, all requested information. Usage figures should reflect an approximate annual average for the period of the last 3 years. (NOTE: If insufficient space is available, please attach additional paper.)

CHEMICAL USE TABLE ON PAGE (8)

PART (VIII)

OTHER PRACTICES

This section is concerned with those forest practices which did not logically fit into any of the previously defined catagories.

(1) Approximately how many acres of private non-industrial forest land undergo species type conversion in a typical year?

_______ acres/year from hardwood to pine

_______ acres/year from pine to hardwood

CHEMICAL USE TABLE

Category of Chemical Agent	Types Used	Total Quantity Used or Number of Acres Treated	Application Rate	Methods of Application	Reasons for Application
Insecticides					
Herbicides					
Fungicides					
Rodenticides					
Fertilizers					
Fire Retardents					
Other Chemical Agents (e.g. soil stabilizers, soil fumigants, etc.)					

PUBLIC FOREST MANAGEMENT PRACTICES

QUESTIONNAIRE

(All information strictly CONFIDENTIAL)

Department of Forest Science

Texas A&M University

PART (I)

ROAD CONSTRUCTION AND MAINTENANCE PRACTICES

This section is concerned with procedures for the location, construction and maintenance of permanent access roads which are built on public (i.e. federal and state) forest lands in East Texas. (DEFINITION: All-weather roads with some system of maintenance, designed according to engineering specifications encompassing specific drainage and surfacing characteristics.)

(1) Approximately how many miles of permanent access roads are constructed annually on those public forest lands which you administer? (NOTE: Take an average for the last 3 years.)

_______ miles/year

(2) What is an approximate average cost per mile for constructing permanent access roads?

_______ $/mile in the flatwoods

_______ $/mile in the uplands

(3) Rank the following road construction activities as to their relative costliness. (Indicate by 1 = most costly, 2 = next most costly, and so on.)

_______ engineering or location survey

_______ cuts and fills

_______ debris disposal

_______ drainage ditches

_______ surfacing

_______ water crossing (bridge)

_______ water crossing (culvert)

_______ water crossing (logs and fill dirt)

_______ other (SPECIFY: ____.)

(4) What proportion of the total mileage of permanent access roads is typically built by private contractors?

_______ percent

(5) Is an on-site engineering or location survey typically conducted prior to beginning construction of permanent access roads?

☐ Yes ☐ No

IF YES - Which of the following factors are normally considered in the process?

☐ drainage characteristics of the site

☐ soil structure and characteristics

☐ expected traffic

☐ other (SPECIFY: ____.)

(6) The table below lists several design features and construction practices that might be used in building permanent access roads. How would you describe the frequency with which these various features and practices are actually used on those public forest lands which you administer? Indicate your answers by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

QUESTION (6) CONTINUED ON NEXT PAGE

Design Feature or Construction Practice	Coded Responses
Attempt to locate roads along ridges	
Follow contours in road construction	
Crown or outslope road surface	
Minimize activity in stream channels and wet areas	
Install culvert or bridge at water crossings	
Seed grass on cut and fill areas	
Use roadside buffers*	

(*DEFINITION: A perimeter of undisturbed vegetation along a roadway.)

(7) How frequently are permanent access roads inspected to determine the need for maintenance?

- [ ] at least twice a year
- [ ] once a year
- [ ] less than once a year
- [ ] never

(8) The table below lists several practices that might be used to maintain the integrity of permanent access roads. Indicate the frequency with which the practices are actually used by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Road Maintenance Practice	Coded Responses
Close roads when not in use	
Open drainage ditches	
Regrade road surfaces	
Reseed or fertilize cut and fill areas	
Restrict traffic in wet weather	

PART (II)

HARVESTING AND LOGGING PRACTICES

This section is concerned with the types of silvicultural systems being used, the acreages of timber being cut, and the entire range of logging activities associated with removing timber products form those public forest lands which you administer.

(1) What proportion of your timber management effort is directed toward the following species groups?

_______ % pine

_______ % hardwood

(2) What proportion of your timber management effort is directed toward the following product groups?

_______ % pulpwood

_______ % sawtimber

(3) Approximately how many acres of sawtimber and pulpwood sized material receive a final harvest cut each year using the various harvesting systems shown in the table below? (NOTE: Take an average for the last 3 years.)

Harvesting System	Total Acreage cut	
	Sawtimber	Pulpwood
Clearcut		
Seed Tree		
Shelterwood		
Selection		

NOTE: If the clearcut harvesting system is used, answer questions (4) and (5) before going on to question (6).

(4) What is the average size of clearcut area?

_______ acres

(5) What is the average length of rotation for each of the timber stand catagories listed below?

_______ years for pine pulpwood

_______ years for pine sawtimber

_______ years for hardwood pulpwood

_______ years for hardwood sawtimber

(6) Approximately what proportion of the total timber harvest in a given year is logged under a "tree length" system?

_______ % of sawtimber harvested

_______ % of pulpwood harvested

(7) What is your best estimate of the total number of miles of temporary access roads being constructed in conjunction with timber harvesting operations in a typical year? (DEFINITION: Roads not intended for all-weather use, designed with minimum engineering specifications for drainage and surfacing and little or no provision for maintenance.)

_______ miles/year

(8) Is an on-site engineering or location survey typically conducted prior to beginning construction of temporary access roads?

☐ Yes ☐ No

QUESTION (8) CONTINUED ON NEXT PAGE

IF YES - Which of the following factors are normally considered in the process? (Check all that apply.)

- [ ] drainage characteristics of the site
- [ ] soil structure and characteristics
- [ ] expected traffic
- [ ] other (SPECIFY: ______________________________.)

(9) How many landings are normally constructed within a forty acre area?

_______ landings/40 acres

(10) Visualizing a circular landing, what would be a typical average diameter?

_______ feet

(11) What proportion of harvested timber is felled with chainsaws, and what proportion with shears?

_______ % felled with chainsaws

_______ % felled with shears

(12) What proportion of harvested timber is skidded with the following types of equipment?

_______ % with rubber-tired skidders

_______ % with tracked skidders

_______ % with cable systems (SPECIFY TYPE: ______________________.)

(13) Assuming skidding is done with rubber-tired or tracked skidders, approximately what proportion of the area around a typical landing would be disturbed by skid trails during a normal harvesting operation?

- [ ] 30% or more
- [ ] 20% - 29%
- [ ] 10% - 19%
- [ ] less than 10%

(14) What proportion of your harvesting operations are conducted during each of the following time periods?

_______ % during Dec. through Feb.

_______ % during Mar. through May

_______ % during Jun. through Aug.

_______ % during Sep. through Nov.

(15) The table below lists several practices that might be used during a logging operation. Indicate the frequency with which the practices are actually used by entering the appropriate code numbers for the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

QUESTION (15) CONTINUED ON NEXT PAGE

Harvesting or Logging Practice	Coded Responses
Avoid felling trees into streams	
Fell trees parallel to skid direction	
Leave streamside buffers*	
Limit skidder activity in streams	
Skid uphill or along contours	
Delay logging due to wet site	

(*DEFINITION: A perimeter of undisturbed vegetation along a stream.)

NOTE: If logging is typically delayed on wet sites, answer question (16) before going on to question (17).

(16) What criteria is used to determine when a site is too wet to log?

- [ ] visual inspection of the site
- [ ] equipment becomes bogged down
- [ ] other (SPECIFY: ________________________________.)

(17) How frequently are the following actions taken to reduce soil loss from temporary access roads, landings and skid trails after completion of a timber harvesting operation? Indicate your answers by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Actions to Prevent Soil Loss	Coded Responses
Construct water bars	
Restrict traffic	
Scatter logging slash	
Seed grass on surfaces	

(18) On areas that are not subsequently site-prepared, what is typically done with the logging slash following a harvesting operation?

- [ ] left as is to decompose naturally
- [ ] lopped and scattered to facilitate decomposition
- [ ] piled and burned
- [ ] other (SPECIFY: ________________________________.)

PART (III)

SITE PREPARATION PRACTICES

This section is concerned with the techniques used to prepare forest land for the production of new timber crops.

(1) On those public forest lands which you administer, approximately how many acres are treated each year using each of the following general catagories of site preparation techniques? (<u>NOTE</u>: Take an approximate average for the last 3 years.)

_______ acres by use of chemical herbicides

_______ acres by use of prescribed burning

_______ acres by use of mechanical means

(2) In terms of acreage, what proportion of mechanical site-preparation work is done by private contractors?

_______ percent

(3) Listed below are a number of specific mechanical site-preparation techniques. Which of these techniques are used on the public forest land which you administer? (Check all techniques that are used.)

- [ ] bedding
- [ ] chopping
- [ ] disking
- [ ] raking
- [ ] shearing
- [ ] windrowing
- [ ] other (SPECIFY: ________________________________.)

(4) Regarding question (3), which of the site-preparation techniques are most frequently used, and in what combinations are they commonly employed?

____

____

____

(5) On the average, how many acres are fertilized each year in conjunction with site-preparation activities?

_______ acres/year

(6) The table below lists several procedures which might be used during mechanical site-preparation activities. Indicate the frequency with which the procedures are actually used by entering the appropriate code numbers from the following possible responses: (1) always, (2) most of the time, (3) sometimes, (4) seldom, (5) never.

Mechanical Site-Preparation Procedure	Coded Responses
All activities (excluding chopping) performed on contour	
Leave streamside buffers*	
Use techniques which minimize soil disturbance on steep slopes	
Seed grass cover crop	
Windrow slash along contours	

(*<u>DEFINITION</u>: A perimeter of undisturbed vegetation along a stream.)

PART (IV)

STAND RE-ESTABLISHMENT PRACTICES

This section is concerned with the methods -- both natural and artificial -- used for reforestation and afforestation purposes on public forest lands.

(1) Approximately how many acres which receive a final harvest cut each year are allowed to regenerate naturally? (NOTE: Take an average for the last 3 years.)

_______ acres/year

(2) Listed below are some alternative artificial regeneration practices. What is the approximate acreage of cut-over forest land which annually receives each type of treatment? (NOTE: Take an average for the last 3 years.)

_______ acres regenerated by direct seeding (ground)

_______ acres regenerated by direct seeding (air)

_______ acres regenerated by planting (hand)

_______ acres regenerated by planting (machine)

(3) Of the total acreage which is artificially regenerated each year, about how many acres are regenerated using improved seed or planting stock? (NOTE: Take an average for the last 3 years.)

_______ acres/ year with improved seed

_______ acres/year with improved seedlings

PART (V)

INTERMEDIATE CULTURAL PRACTICES

This section is concerned with the nature and extent of the various cultural practices that may be employed during the period from stand establishment to final harvest cut.

(1) Listed below are several intermediate cultural practices. Complete the table by indicating the approximate acreage which receives each type of treatment in a typical year. (NOTE: Take an average for the last 3 years.)

Intermediate Cultural Practice	Acres
Cultivation	
Prescribed Burn (not site-prep.)	
Salvage or Sanitation Cutting	
Thinning (pre-commercial)	
Thinning (commercial)	

(2) At what age is a developing stand normally given a pre-commercial thinning? (NOTE: Leave this question blank if pre-commercial thinnings are not made.)

_______ years for pine stands

_______ years for hardwood stands

(3) At what age(s) is a developing stand normally given a commercial thinning(s)? (NOTE: Leave this question blank if commercial thinnings are not made.)

_______ and _______ years for pine stands

_______ and _______ years for hardwood stands

PART (VI)

CHEMICAL USE PRACTICES

This section is concerned with the types, amounts, and methods of application for all chemical agents (i.e. pesticides, fertilizers, fire retardents, etc.) used in connection with your forest management activities.

(1) The table on p.(9) identifies the principal catagories of chemical agents used in forestry operations. Complete the table by providing all requested information. Usage figures should reflect an annual average for the period of the last 3 years. (NOTE: If insufficient space is available, please attach additional paper.)

CHEMICAL USE TABLE ON PAGE (9)

PART (VII)

OTHER PRACTICES

This section is concerned with those forest practices which did not logically fit into any of the previously defined catagories.

(1) Approximately how many acres of the forest land which you administer undergo species type conversion in a typical year? (NOTE: Take an average for the last 3 years.)

_______ acres/year from hardwood to pine

_______ acres/year from pine to hardwood

CHEMICAL USE TABLE

Category of Chemical Agent	Types Used	Total Quantity Used or Number of Acres Treated	Application Rate	Methods of Application	Reasons for Application
Insecticides					
Herbicides					
Fungicides					
Rodenticides					
Fertilizers					
Fire Retardents					
Other Chemical Agents (e.g. soil stabilizers, soil fumigants, etc.)					

FORFST MANAGEMENT PRACTICES

COST QUESTIONNAIRE

(All information strictly CONFIDENTIAL)

Department of Forest Science
Texas A&M University

PART (I)

SPECIAL NOTE TO RESPONDENTS

Many of the following questions attempt to relate cost to some unit of measure--such as cost per thousand board feet. If you feel the assigned unit of measurement is inappropriate for a particular item, feel free to use some other measurement unit, but please specify the alternate unit used.

PART (II)

ROAD CONSTRUCTION AND MAINTENANCE COSTS

This section is concerned with costs for the location, construction and maintenance of permanent access roads. (DEFINITION: All-weather roads with some system of maintenance, designed according to engineering specifications encompassing specific drainage and surfacing characteristics.)

1. What is your best estimate as to the percentage of total road construction costs that are accounted for by each of the following road construction activities? (NOTE: Values should total to 100 percent.)

Road Construction Activity	Percentage Estimate	
	Flatwoods	Uplands
a. Engineering of location survey		
b. Cuts and fills		
c. Debris disposal		
d. Drainage ditches		
e. Surfacing		
f. Water crossings (bridges)		
g. Water crossings (culverts)		
h. Water crossings (dirt fill)		
i. Other (Specify: ____________ ______________________.)		

2. In the flatwoods, what effect do you expect adoption of the following practices would have on total road construction costs? (NOTE: The possible responses are: 1 = none; 2 = 1 to 25%; 3 = 26 to 50%; 4 = 51 to 75%; 5 = 76 to 100%; 6 = over 100%.)

Practice	Cost Effect
a. Always locate roads on stable, well-drained soils	________
b. Locate roads away from natural drainage channels	________
c. Use roadside buffer strips	________
d. Use wing ditches to divert waterflow	________
e. Install cross drainages upgrade of live stream crossings	________
f. Surface roads with large aggregate material	________
g. Minimize crossings to two per mile	________

3. In the uplands, what effect do you expect adoption of the following practices would have on total road construction costs? (NOTE: Use same responses as for question 2.)

	Practice	Cost Effect
a.	Always locate roads on the ridges	________
b.	Always follow contours	________
c.	Always locate roads on stable, well-drained soils	________
d.	Use roadside buffer strips	________
e.	Use wing ditches to divert waterflow	________
f.	Install cross drainages upgrade of live stream crossings	________
g.	Surface roads with large aggregate material	________
h.	Locate roads away from natural drainage channels	________
i.	Use occasional grade breaks to facilitate drainage	________
j.	Minimize crossings to one per mile	________

4. Annually, what is the total cost per mile of maintaining permanent access roads?

$________ per mile in flatwoods

$________ per mile in uplands

5. What is your best estimate as to the percentage of total road maintenance costs that are accounted for by each of the following road maintenance activities? (NOTE: Values should total to 100 percent.)

Road Maintenance	Percentage Estimate	
	Flatwoods	Uplands
a. Clearing ditches		
b. Regrading		
c. Spot re-surfacing		
d. Repair of water crossings		
e. Inspection		
f. Seeding and/or mulching		
g. Other (Specify: ________ ________________.)		

6. How much would it cost--expressed as a percent of total maintenance cost--to close and enforce the closure of roads to non-essential traffic?

________% of total maintenance cost per mile

7. Provide a brief discussion about your policies concerning roadside buffer strips* Do you use such buffer strips? If so, how frequently - and what criteria determines their width?

____

____

____

____

____

____

*DEFINITION: A perimeter of undisturbed vegetation parallel to and on both sides of a roadway.

PART (III)

HARVESTING AND LOGGING COSTS

This section is concerned with the cost of using alternative silvicultural systems and of the logging activities associated with removing timber products.

1. What is the total logging cost for a final harvest cut of pulpwood or sawlogs using the clearcut harvesting system?

   a. For sawlog operations, total logging cuts per MBF typically fall somewhere within the ranges specified in the table below:

Location	Cost per MBF in Dollars	
	Low	High
Flatwoods		
Uplands		

   b. For pulpwood operations, total logging costs per cord typically fall somewhere within the ranges specified in the table below:

Location	Cost per Cord in Dollars	
	Low	High
Flatwoods		
Uplands		

2. In your judgment, what effect would adoption of the following practices have on total harvesting costs? (NOTE: The possible responses are, 1 = none; 2 = 1 to 25%; 3 = 26 to 50%; 4 = 51 to 75%; 5 = 76 to 100%; 6 = over 100%.)

Practice	Cost Effect
a. Mulching and/or seeding of erosion-prone areas (particularly skidtrails and landings) after logging	______
b. Skidding upward or along contours	______
c. Drain trails and close to vehicle traffic after logging	______

3. What is your best estimate of the percentage increase in logging costs that would result from the following activities? (NOTE: The possible responses are: 1 = none; 2 = 1 to 25%; 3 = 26 to 50%; 4 = 51 to 75%; 5 = 76 to 100%; 6 = over 100%.)

Logging Activities	Percentage Estimate	
	Flatwoods	Uplands
a. Supervision to assure trees will not be felled in streams		
b. Removal of all logging debris from streams		
c. Clearing all drainage systems of logging debris		
d. Crossing streams only at places with properly installed culverts, and drainage provisions		
e. Cross streams only at shallow banks and at right angles to stream		
f. Removal of temporary crossings after logging		

4. Provide a brief discussion about your policies concerning streamside buffer strips.* Do you use such buffer strips? If so, how frequently--and what criteria determines their width?

____

____

____

____

____

____

*DEFINITION: A perimeter of undisturbed vegetation parallel to and on both sides of a stream course.

5. Using the clearcut harvesting system as a basis for comparison, in your judgment, how would adoption of the alternative harvesting systems listed below influence each of the specified parameters?

   a. Selection System:

      i. Would (increase, decrease, not affect) total harvesting costs per MBF by _____ percent.

      ii. Would (increase, decrease, not affect) per acre volume yields (i.e. site productivity) by _____ percent.

      iii. Would (increase, decrease, not affect) per acre site preparation costs by _____ percent.

   b. Seed Tree System

      i. Would (increase, decrease, not affect) total harvesting costs per MBF by _____ percent.

      ii. Would (increase, decrease, not affect) per acre volume yields by _____ percent.

      iii. Would (increase, decrease, not affect) per acre site preparation costs by _____ percent.

   c. Shelterwood System:

      i. Would (increase, decrease, not affect) total harvesting costs per MBF by _____ percent.

      ii. Would (increase, decrease, not affect) per acre volume yields by _____ percent.

      iii. Would (increase, decrease, not affect) per acre site preparation costs by _____ percent.

PART (IV)

SITE PREPARATION COSTS

This section is concerned with the cost of the alternative techniques used to prepare forest land for the production of new timber crops.

1. Assuming an area has been clearcut, approximately what is the average total cost per acre of using each of the general categories of site-preparation techniques listed in the table on the following page. (NOTE: The question allows for both a high and low estimate for flatwoods and uplands.)

1. (continued)

Site Preparation Techniques	Flatwoods		Uplands	
	Low Estimate	High Estimate	Low Estimate	High Estimate
a. By use of chemical herbicides				
b. By use of prescribed burning				
c. By use of mechanical means				

2. What percent of the total mechanical site-preparation cost per acre is accounted for by each of the activities listed in the table below? (NOTE: The responses should add to 100 percent.)

Site-Preparation Activity	Percent of Total Cost per Acre
a. Bedding	
b. Chopping	
c. Disking	
d. Raking	
e. Shearing	
f. Windrowing	
g. Other (Specify: __________ ______________________.)	

3. In your judgment, what would be the percentage increase in the per acre costs of site preparation if the following practices were adopted? (NOTE: 1 = none; 2 = 1 to 25%; 3 = 26 to 50%; 4 = 51 to 75%; 5 = 76 to 100%; 6 = over 100%.)

Site Preparation Activities	Percentage Increase in Costs per Acre	
	Flatwoods	Uplands
a. Regularly use non-mechanical methods such as prescribed burning or herbicides.		
b. Regularly chopping instead of shearing and windrowing		
c. Schedule site preparation to reduce exposure during periods of high rainfall frequency		
d. Leave streamside buffer strips		
e. Seeding areas of high erosion potential		
f. Always windrow slash along contours		

4. How many years do you expect would be added to crop rotation if you did no site preparation?

__________ years

PART (V)

STAND RE-ESTABLISHMENT COSTS

This section is concerned with the cost of using both natural and artificial methods for reforestation and afforestation purposes.

1. The table below indicates some alternative artificial regeneration practices. In each cell of the table, indicate the approximate total cost per acre of implementing each type of treatment. (NOTE: The question is partitioned between the flatwoods and uplands.)

Artificial Regeneration Practice	Total Cost per Acre	
	Flatwoods	Uplands
a. Direct seeding (ground)		
b. Direct seeding (air)		
c. Planting (hand)		
d. Planting (machine)		

2. In your judgment, what would be the percentage increase in the per acre costs of machine planting if the following practices were adopted?

Practice	Percentage Increase in Cost per Acre
a. Always plant along countours	________
b. Do not use V-blade in conjunction with machine planting	________

PART (VI)

INTERMEDIATE CULTURAL PRACTICES

This section is concerned with the cost associated with the various cultural practices that may be employed during the period from stand establishment to final harvest cut.

1. Listed below are several intermediate cultural practices. Complete the table by indicating in each cell the average total cost per acre for each treatment.

Intermediate Cultural Practice	Average Total Cost per Acre	
	Flatwoods	Uplands
a. Cultivation		
b. Prescribed burn (not site prep.)		
c. Salvage or Sanitation cutting		
d. Thinning (precommercial)		
e. Thinning (commercial)		

2. What effect do you expect adoption of the following practices would have on costs of prescribed burns? (NOTE: The possible responses are: 1 = none; 2 = 1 to 25%; 3 = 26 to 50%; 4 = 51 to 75%; 5 = 76 to 100%; 6 = over 100%.)

Practice	Cost Effect
a. Weather conditions and fuel moisture should be such that only the top portion of the organic layer is burned	________
b. Always locate firelines on gentle slopes along the contour	________
c. In fireline construction, provide waterbreaks at time of construction	________

PART (VII)

CHEMICAL USE COSTS

> This section is concerned with the costs of all chemical agents applied in connection with forest management activities.

1. The following table lists several categories of chemical agents used in forest management. In each cell of the table, indicate the approximate total cost per acre of using the chemical agents.

Category of Chemical Agent	Total Cost Per Acre	
	Flatwoods	Uplands
a. Insecticides		
b. Herbicides		
c. Fungicides		
d. Rodenticides		
e. Fertilizers		
f. Fire Retardents		
g. Others: (Specify: ________ ________________.)		

2. In your judgment, what percentage effect would adoption of the following practices have on total costs per acre of herbicide, insecticide, and fertilizer application? (NOTE: The possible responses are: 1 = none; 2 = 1 to 25%; 3 = 26 to 50%; 4 = 51 to 75%; 5 = 76 to 100%; 6 = over 100%.)

Practice	Cost Effect		
	Herbicide	Insecticide	Fertilizer
a. Always leave untreated streamside buffer strips			
b. Avoid applying herbicides to flat, poorly drained areas containing live streams			
c. Aerial spraying should be done only when the wind is calm			
d. Use indirect controls in place of insecticides			
e. Avoid fertilization in periods on heavy rainfall			

Checklist of Roading Cost Questions for U. S. Forest Service

I. For specified roads, please indicate the average cost per mile and the average frequency per mile (where applicable) for the cost items listed below.

Cost Item	Cost/Mile		Frequency/Mile	
	Uplands	Flatwoods	Uplands	Flatwoods
1. Fill material at water crossings				
2. Water bars				
3. Cross drains				
4. Ditches				
5. Culverts				
6. Drainage dips				
7. Wing ditches				
8. Bridges (all weather)				
9. Low-water bridges				
10. Clearing right-of-way				
11. Erosion control (seeding and/or mulching)				
12. Road grade changes				
13. Clean-up				
14. Surfacing				
15. Cut and fill				

II. For skid trails or temporary roads, please indicate the average cost per mile and the average frequency per mile (where applicable) for the cost items listed below.*

Cost Item	Cost/Mile		Frequency/Mile	
	Uplands	Flatwoods	Uplands	Flatwoods
1. Water bars				
2. Erosion control (seeding and/or mulching)				
3. Clean-up				
4. Closure to traffic				

* If cost or frequency per mile is an inappropriate unit of measure please feel free to re-define to the correct unit of measure.

APPENDIX IV

SCS"C" FACTORS FOR WOODLAND

Table 31. "C" factors for undisturbed woodland

Effective Canopy[1] % of Area	Forest Litter[2] % of Area	"C"[3] Factor
100-75	100-90	.0001-.001
70-40	85-75	.002-.004
35-20	70-40	.003-.009

[1]When effective canopy is less than 20%, the area will be considered as grassland or idleland for estimating soil loss. Where woodlands are being harvested or grazed, use Table 31.

[2]Forest litter is assumed to be at least two inches deep over the percent ground surface area covered.

[3]The range in "C" values is due in part to the range in the percent area covered. In addition the percent of effective canopy and its height has an effect. Low canopy is effective in reducing raindrop impact and in lowering the "C" factor. High canopy, over 13 meters, is not effective in reducing raindrop impact and will have no effect on the "C" value.

From: USDA, Soil Conservation Service. 1977. Procedure for Computing Sheet and Rill Erosion on Project Areas. Engineering Division and Ecological Sciences and Technology Division. Technical Release No. 51 (Rev. 2) Geology.

Table 32. "C" factors for mechanically prepared woodland sites

Percent of soil covered with residue in contact with soil surface	Soil Condition and Weed Cover							
	Excellent		Good		Fair		Poor	
	NC	WC	NC	WC	NC	WC	NC	WC
None								
A. Disked, raked or bedded[1,2]	.52	.20	.72	.27	.85	.32	.94	.36
B. Burned[3]	.25	.10	.26	.10	.31	.12	.45	.17
C. Drum chopped[3]	.16	.07	.17	.07	.20	.08	.29	.11
10% Cover								
A. Disked, raked or bedded[1,2]	.33	.15	.46	.20	.54	.24	.60	.26
B. Burned[3]	.23	.10	.24	.10	.26	.11	.36	.16
C. Drum chopped[3]	.15	.07	.16	.07	.17	.08	.23	.10
20% Cover								
A. Disked, raked or bedded[1,2]	.24	.12	.34	.17	.40	.20	.44	.22
B. Burned	.19	.10	.19	.10	.21	.11	.27	.14
C. Drum chopped	.12	.06	.12	.06	.14	.07	.18	.09
40% Cover								
A. Disked, raked or bedded[1,2]	.17	.11	.23	.14	.27	.17	.30	.19
B. Burned[3]	.14	.09	.14	.09	.15	.09	.17	.11
C. Drum chopped[3]	.09	.06	.09	.06	.10	.06	.11	.07
60% Cover								
A. Disked, raked or bedded[1,2]	.11	.08	.15	.11	.18	.14	.20	.15
B. Burned[3]	.08	.06	.09	.07	.10	.08	.11	.08
C. Drum chopped[3]	.06	.05	.06	.05	.07	.05	.07	.05
80% Cover								
A. Disked, raked or bedded[1,2]	.05	.04	.07	.06	.09	.08	.10	.09
B. Burned[3]	.04	.04	.05	.04	.05	.04	.06	.05
C. Drum chopped[3]	.03	.03	.03	.03	.03	.03	.04	.04

[1]Multiply A. values by following values to account for surface roughness:

Very rough, major effect on runoff and sediment storage, depressions greater than 6"	.40
Moderate	.65
Smooth, minor surface sediment storage, depressions less than 2"	.90

[2]The "C" values for A. are for the first year following treatment. For A. type sites 1 to 4 years old multiply "C" value by .7 to account for aging. For sites 4 to 8 years old use Table 31. For sites more than 8 years old use Table 29.

[3]The "C" values for B. and C. areas are for the first 3 years following treatment. For sites treated 3 to 8 years ago use Table 31. For sites treated more than 8 years ago use

Table 33. "C" factors for permanent pasture, rangeland, idle land, and grazed woodland[1]

Vegetal Canopy		Cover That Contacts the Surface						
Type and Height of Raised Canopy[2]	Canopy Cover[3] %	Type[4]	Percent Ground Cover 0	20	40	60	80	95-100
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds or short brush (0.5 m fall ht.)	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.067	.038	.011
Appreciable brush or bushes (2 m fall ht.)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.040	.011
Trees but no appreciable low brush (4 m fall ht.)	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

[1]All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for at least a period of three consecutive years. Also to be used for burned forest land and forest land that has been harvested less than three years ago.

[2]Average fall height of waterdrops from canopy to soil surface: m - meters.

[3]Portion of total-area surface that would be hidden from view by canopy in a vertical projection, (a bird's-eye view).

[4]G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface), and/or undecayed residue.

From: USDA, Soil Conservation Service, 1977. Procedure for Computing Sheet and Rill Erosion on Project Areas. Engineering Division and Ecological Sciences and Technology Division. Technical Release No. 51 (Rev. 2) Geology.

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