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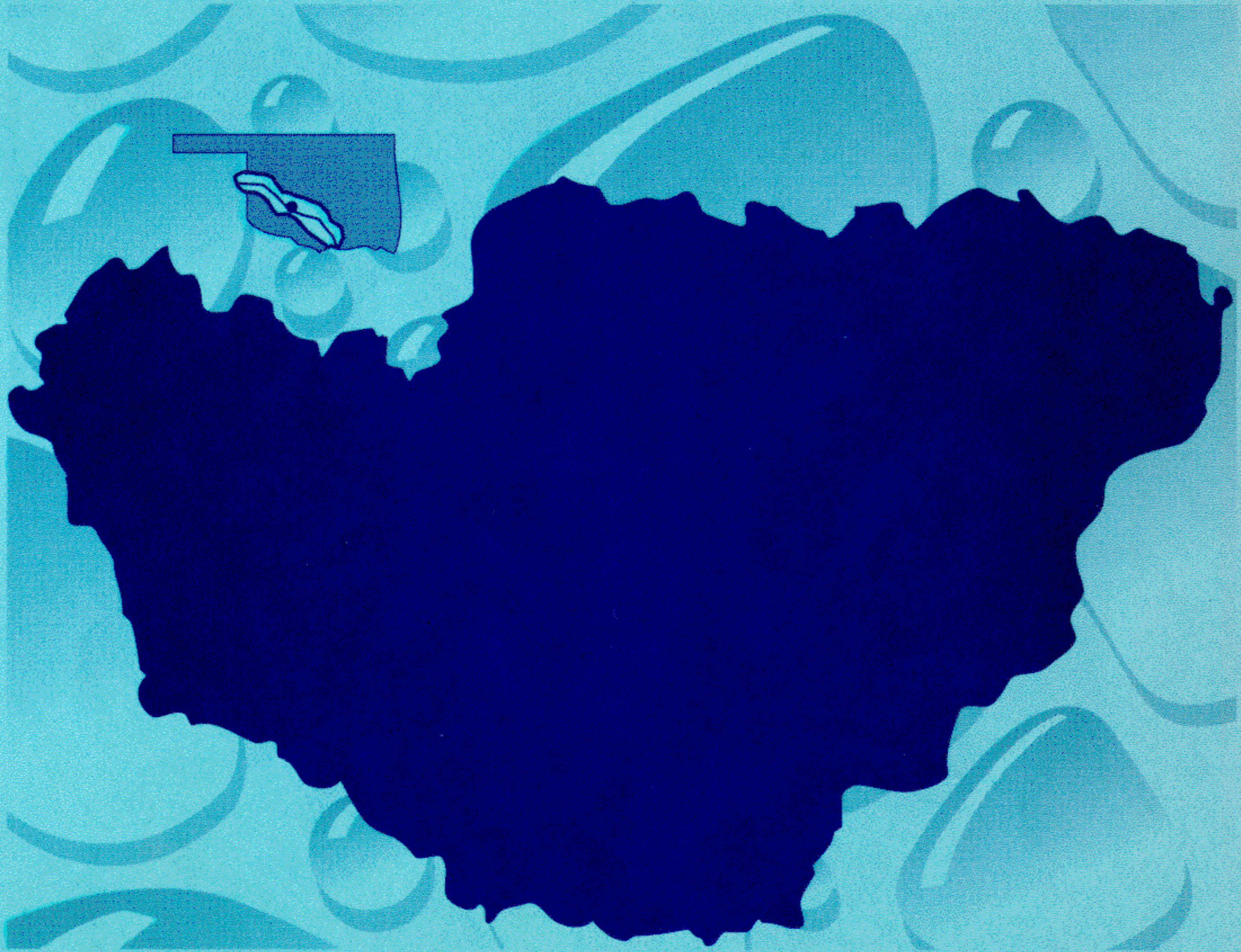
ARS-90

December 1991

Hydrology of the Little Washita River Watershed, Oklahoma

Data and Analyses



Abstract

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The Little Washita River Watershed in southwest Oklahoma is unique in that over a period of more than fifty years, it has had an unusually large amount of research on climate, erosion, hydrology, and the environmental impacts of soil-and-water-conservation practices. The large volume of data available for this watershed, the past numerous significant findings, and the potential uses of the data base have been compiled in this document. This report serves as a guide for retrieval of the data, stored on magnetic tape. Future studies involving field data collection and developing and testing mathematical models of watershed processes may be planned and conducted more economically by building upon this data base.

KEYWORDS: basic, computer, conservation, data, floodwater, groundwater, hydrology, model, precipitation, reservoir, river, runoff, sediment, water quality, watershed.

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by

Paul B. Allen
and
James W. Naney

National Agricultural Water
Quality Laboratory,
Durant, Oklahoma 74702

Acknowledgments

Since this hydrologic data collection program had a broad scope and spanned a long period, it naturally involved a large number of scientists and engineers. The following people in the Agricultural Research Service contributed significantly to the collection program through planning, supervising the development, acquiring, and installing of instrumentation; stream gauging and water sample collection; sample analysis; or data reduction: Bruce Blanchard, Gerald Coleman, Donn DeCoursey, Maurice Frere, Don Goss, Monroe Hartman, J.R. McHenry, Ronald Menzel, Arlin Nicks, Harry Pionke, Edd Rhoades, Frank R. Schiebe, Russel Schoof, S.J. Smith, Norman Welch, and Coyd Yost, Jr. Other professionals who contributed, principally in computer related work, include Bill Barnes, Gene Gander, John D. Ross, and Edward H. Seely. Numerous technicians and aides contributed to the data collection program. We thank Janice A. Story and Lora E. Mead for preparing this manuscript on the word processor, and Bill Barnes for developing the computer data base from a variety of historical data ranging from raw field notes to various computer formats.

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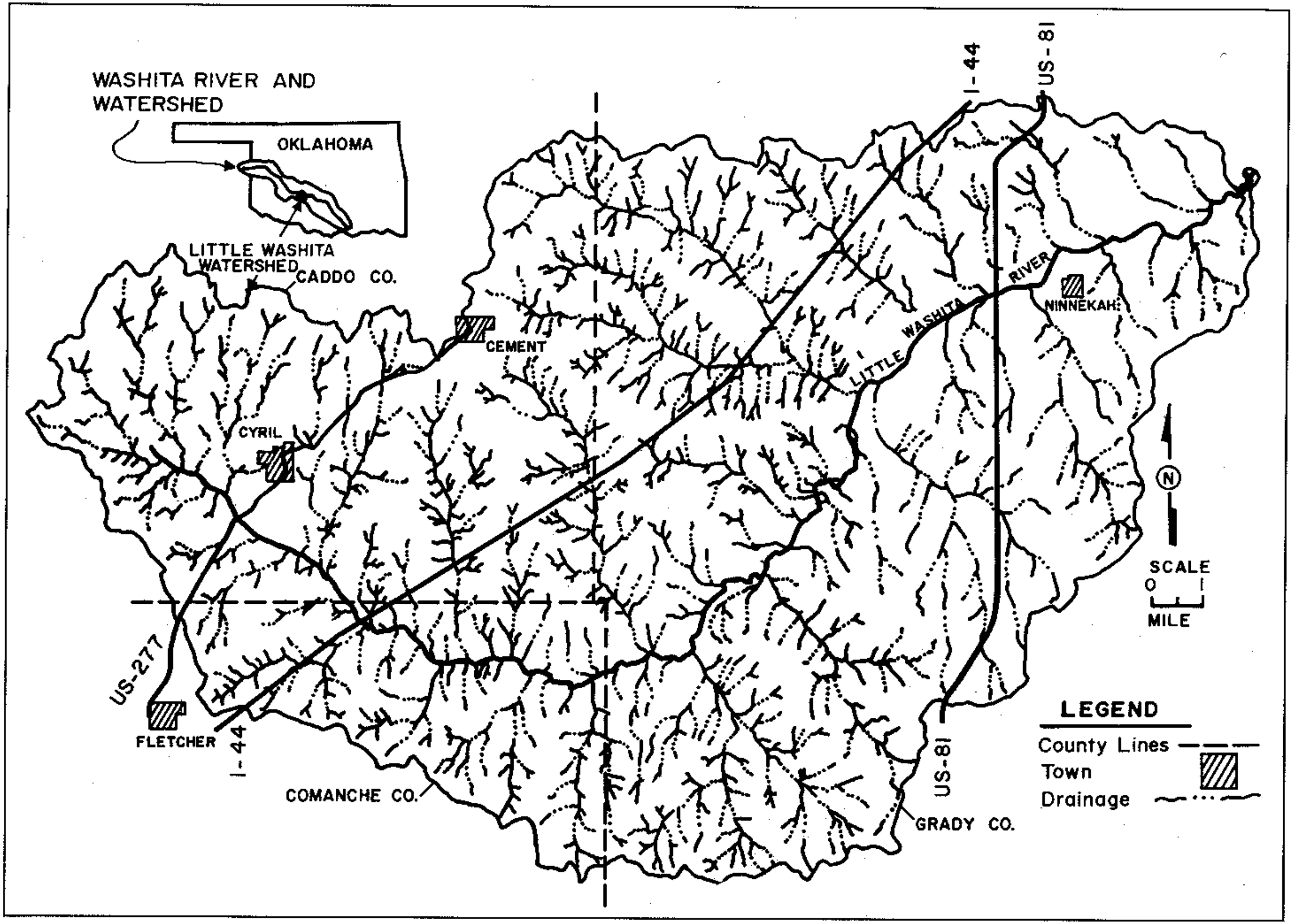

Figure 1. Location and map of the watershed.

Hydrology of the Little Washita River Watershed, Oklahoma

Data and Analyses

P.B. Allen and J.W. Naney

Purpose of the Report

The Little Washita River Watershed in southwest Oklahoma (fig. 1) is unique in that over a period of several years it has had an unusually large amount of soil and water conservation treatments and research. In 1936 the eastern portion of the watershed was chosen as part of a national demonstration project for soil erosion control. In the late 1930's the Civilian Conservation Corps (CCC) did extensive erosion control work, such as terracing, drop-structure building, gully plugging, and tree planting. Since establishing county offices in the 1940's, the U.S. Department of Agriculture's (USDA) Soil Conservation Service (SCS) has applied extensive soil and water conservation structures and measures, including terraces, diversions, farm ponds, floodwater-retarding reservoirs, gully plugging and smoothing, scrub timber removal, and land use planning.

In 1961 the USDA's Agricultural Research Service (ARS), in compliance with U.S. Senate Document 59 (1959), began collecting hydrologic data on the Little Washita River Watershed and other watersheds in the vicinity to determine the downstream hydrologic impacts of the SCS floodwater-retarding reservoirs. This data collection process involved an intensive rain gauge network and a stream gauging station near the watershed outlet that provided data on continuous flow, suspended sediment transport, and, for a few years, water quality. Data on groundwater levels and channel geometry were also collected to determine possible effects of the treatment program.

In 1978 this watershed was one of seven watersheds chosen across the Nation for the Model Implementation Project (MIP), which was jointly sponsored and administrated by the USDA and the U.S. Environmental Protection Agency (EPA). The main objective of the MIP was to demonstrate the effects of intensive land conservation treatments on water quality in watersheds that are larger than about 25 square miles.

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Because the hydrologic and meteorologic data from the Little Washita River Watershed were made available, several agencies and institutions have used this watershed and its data to research the potential of obtaining this type of data from a satellite. These agencies and institutions include the National Aeronautical and Space Administration (NASA); Agricultural Research Service, Durant, OK; Oklahoma State University Center for Application of Remote Sensing (CARS); and the University of Oklahoma Geography Department.

The large volume of data available for this watershed, the past numerous research findings, and the potential uses of the data base prompted the compilation of this comprehensive summary of data and reports. We believe that assembling the data into one document will facilitate the use of the data, make potential users aware of the data's existence, and preserve the data for future users. Future studies involving watershed data collection may build upon this data base. Since most uses of these data will probably involve electronic computer applications, most of the data have been stored on magnetic tape. This report serves as a guide for retrieval of these data. The significant research findings to date are presented along with a bibliography of pertinent reports.

Watershed

Location and Climate

The Little Washita River Watershed covers 235.6 square miles and is a tributary of the Washita River in southwest Oklahoma (fig. 1). The watershed is in the southern part of the Great Plains of the United States. The climate is classified as moist and subhumid, and the average annual rainfall was 29.42 inches for the 24 years of data collection by the ARS.

Summers are typically long, hot, and relatively dry. The average daily high temperature for July is 94 degrees Fahrenheit, and the average accumulative rainfall for July is 2.22 inches. Winters are typically short, temperate, and dry but are usually very cold for a few weeks. The average daily low temperature for January is 24 degrees Fahrenheit, and the average accumulative precipitation for January is 1.07 inches. Much of the annual precipitation and most of the large floods occur in the spring and fall. A more detailed review of the climate and its variability for this watershed and the surrounding area is presented by the Staff, Water Quality and Watershed Research Laboratory (1983).

Geology

The bedrock exposed in the watershed consists of Permian age sedimentary rocks. The formations, as reported by Davis (1955), dip gently to the southwest, but the surface drainage is generally to the east. The oldest formation in the watershed, the Chickasha formation, outcrops in the eastern or outlet side of the watershed and comprises 4.6 percent of the total watershed area (fig. 2). As reported by Davis (1955), the Chickasha formation is several hundred feet thick, is relatively impermeable, and consists of a heterogeneous mixture of sandstones, shales, and siltstones. The Dog Creek and Blaine formations, which are undifferentiated and overlie the Chickasha formation (fig. 2), outcrop in 8.0 percent of the watershed and consist of dark red even-bedded shales interbedded with fine-grained gypsiferous sandstones that locally grade into pure gypsum. The Marlow formation overlies the Dog Creek and Blaine formations, comprises 14.2 percent of the watershed, and consists mostly of even-bedded, brick-red sandy shale that is gypsiferous. Near the middle of the Marlow formation lies the Verden sandstone member, which consists of cross-bedded dolomitic sandstone that is about 10 feet thick and one-quarter mile wide. The Rush Springs formation overlies the Marlow formation, outcrops in a central portion of the watershed, and comprises 45.6 percent of the watershed area. The Rush Springs formation consists of fine-grained sandstone and siltstone strata that are even to highly crossbedded. The Cloud Chief formation, comprising 16.6 percent of the watershed, overlies the Rush Springs formation and consists of irregular, impure gypsum beds interbedded with gypsiferous shales. The Cloud Chief formation outcrops in this watershed as outliers, so only its lower parts can be seen. Alluvial deposits generally cover the bedrock valleys throughout the watershed. The alluvium covers approximately 11 percent of the total area of the watershed.

Soils

Surveys of the soils in the watershed have been made by the SCS and published (Bogard et al. 1978, Moffatt 1973, Mobley et al. 1967). In these surveys 64 different soil series were defined for the watershed, and 162 soil phases were mapped within these soil series to reflect differences in surface soil textures, slopes, stoniness, degree of erosion, and other characteristics that affect land use. These survey publications also provide information associated with each soil series, such as depth to bedrock, typical texture found at each depth, permeability, available water capacity, pH, shrink-swell potential, corrosivity, and suitability for use in construction projects, such as road fill, pond embankments, building foundations, and septic tank filter fields. Hydrologic soil groups are also listed along with estimated average crop yields for each series under irrigated and nonirrigated conditions.

In large watersheds the large number and areal distribution of individual soil types often hinders gaining an understanding of the general nature of soils present. Therefore, similar soils are often grouped into associations. Figure 3 shows the watershed soils grouped into the following nine associations:

1. Grant-Pond Creek-Lucien-Minco soils are deep and shallow, loamy; slope ranges from nearly level to steep on uplands.

2. Port-Pulaski-Gracemont soils are deep, loamy and sandy; slope is nearly level on flood plains.

3. Konawa-Dougherty-Eufala soils are deep, sandy, well drained to some what excessively drained in upland; slope ranges from nearly level to rolling.

4. Cobb soils are prairie soils that are moderately deep, loamy; slope ranges from nearly level to greatly sloping.

5. Renfrow-Kirkland-Bethany soils are well drained, loamy; slope ranges from nearly level to gently sloping.

6. Dale-Reinach-McLain soils are well drained or moderately well drained, loamy; slope nearly level.

7. Stephenville-Eufala soils are well drained or somewhat excessively drained, loamy or sandy; slope ranges from gently sloping to moderately steep.

8. Stephenville-Noble-Darnell-Windthorst soils are deep or shallow, moderately well drained to well drained, loamy or sandy on uplands; slope ranges from very gently sloping to hilly.

9. Nash-Lucien-Stephenville soils are well drained, loamy or sandy; slope ranges from very gently sloping to moderately steep.

To facilitate information retrieval, the watershed was divided into 40-acre cells, and data on the soil types and characteristics for each cell were entered into computer files by the SCS at Lincoln, NE. These files are in a data system called MIADS and can be accessed from most computers in the United States. The State office of the SCS in Oklahoma in conjunction with CARS at Oklahoma State University has a similar file system except that the files are for 10-acre cells.

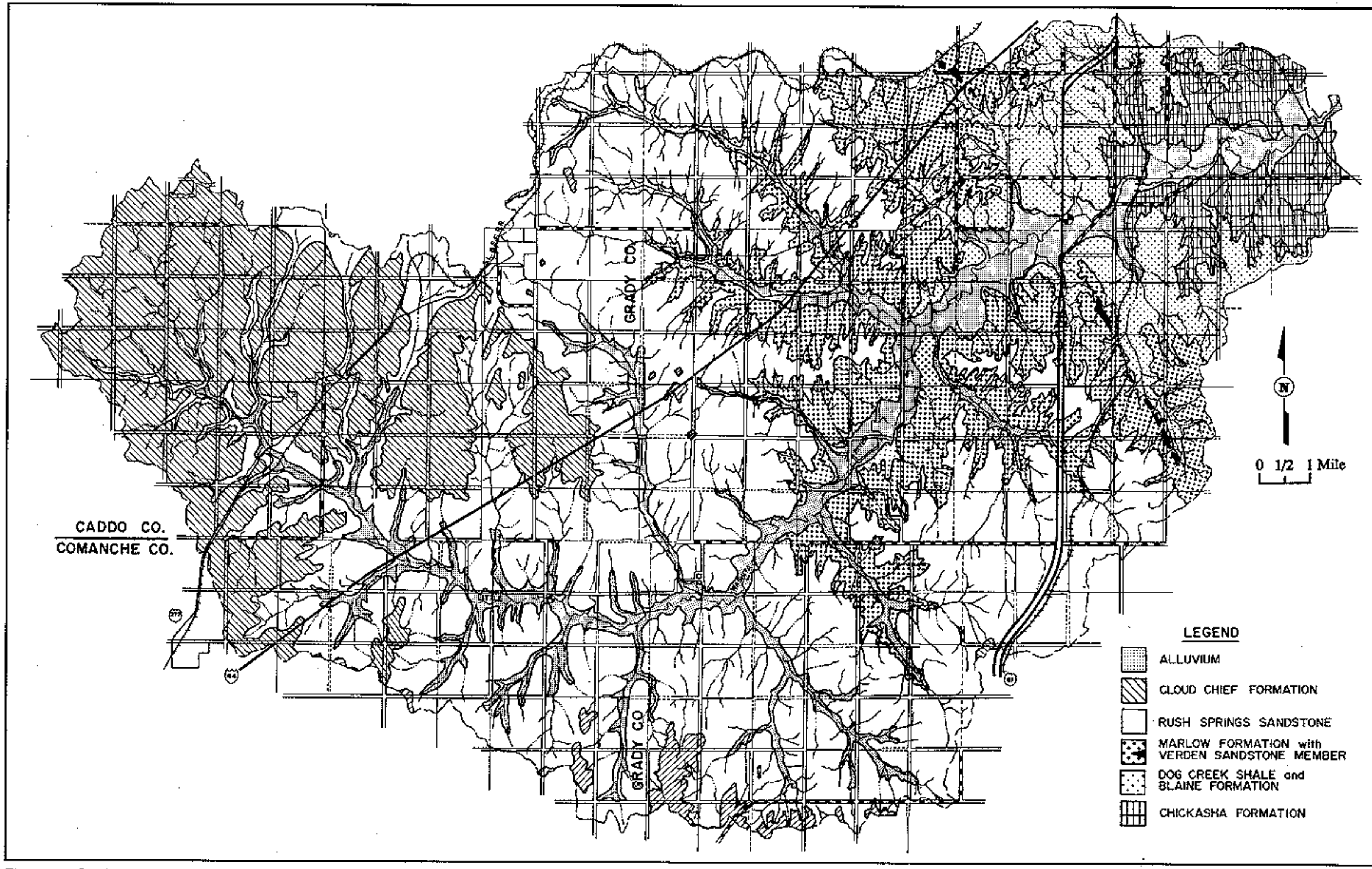

Figure 2. Geology of the watershed.

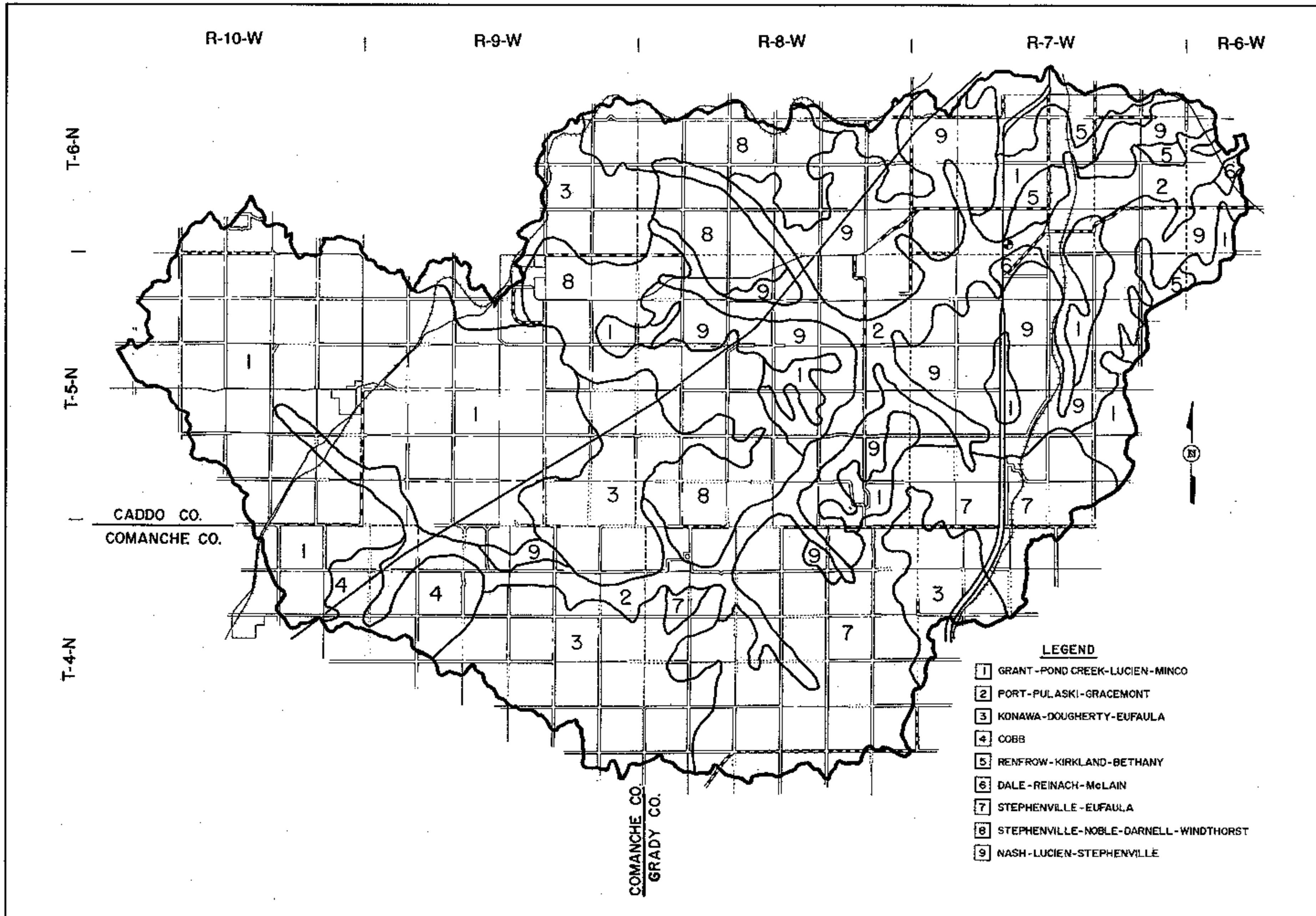

Figure 3. Soil association groups in the watershed.

Some soil characteristics pertinent to this watershed's hydrologic response are illustrated in figures 4-8, which were produced by CARS. Figure 4 shows the areal distribution of five surface soil textures. By comparing figures 4 and 2, it is apparent that the soil is closely related to the composition of the underlying bedrock from which it was developed. In roughly the central half of the watershed, where the Rush Springs sandstone outcrops, the soils have a coarser texture and consist of fine sand and loamy fine sand. In the remainder of the watershed area, where the bedrock is either shale or various mixtures of shale, siltstone, and sandstone, the soils are finer and consist of fine sandy loams, loams, or silty loams.

Soil permeabilities under saturated conditions are shown in figure 5. By comparing figures 4 and 5 it is apparent that soil texture and soil permeability are related. In the central portion of the watershed, soils are sandier and permeabilities are 2 inches per hour or greater. In other areas of the watershed, soils are finer and permeabilities generally are less than 2 inches per hour.

The watershed's deepest soils (greater than 5 feet deep) are generally found in the northeastern section, where alluvial soils are found; the southern section, where the land is flatter and, thus, less prone to erosion; and in the upstream western section, where soils formed from the Cloud Chief formation (fig. 6). The scarps around the Cloud Chief outliners in the western section of the watershed contain the shallowest soils (less than 20 inches deep). Thus, the western area has the greatest range of soil depths. Similar soil depths, ranging from 20 to 60 inches, are present over most of the Chickasha, Marlow, and Rush Springs formations.

The total water holding capacity (in inches of water per inch of soil depth) of each soil in the watershed was computed from the available water holding capacity and the soil's depth to bedrock (fig. 7). Available water holding capacity was calculated as the difference between the amount of soil water at field capacity and the amount at wilting point. Soils with the highest total water holding capacity are found in the western side (upstream) of the watershed (fig. 7). Scattered throughout this western area, however, are the shallowest soils (fig. 6) with the lowest water holding capacity. The alluvial soils in the northeastern area have the second highest waterholding capacity (9 to 12 inches); and soils in the remaining area, representing most of the watershed area, the next highest (between 3 and 9 inches).

Soils in the watershed were grouped into one of four hydrologic groups, groups A through D (fig. 8), on the basis of their soil properties that are known to influence runoff. These soil properties included depth to the water table, infiltration rate, and low permeability of subsurface soil layers. Hydrologic group A has the lowest amount of runoff and group D, the highest. Hydrologic group B is predominant, covering 72.3 percent of the watershed. Scattered areas of shallow soil in the western end of the watershed have high runoff potential. There are also a few areas with high runoff potential in the eastern end of the watershed because the soils have very low permeability. Scattered throughout the central portion of the watershed are areas with very low runoff potential because the soils are predominantly sandy and, thus, have a high infiltration rate and are flatter.

Land Use and Cover

Watershed areas were grouped into categories according to land use and cover: timber, crops, range, or water (fig. 9). Loesch (1988) related the distribution pattern of these categories to remotely sensed reflectance data collected by satellite. He used an unsupervised classification approach and then gathered field "truth" data and assigned the data to appropriate land use categories.

Topography and Stream Channels

Except for a few rocky, steep hills near Cement, OK, the upland topography is gently to moderately rolling. Maximum relief in the watershed is only about 600 feet. A topographic map of the watershed with contour intervals of 20 feet is shown in figure 10. This map was traced from U.S. Geological Survey (USGS) 7.5-minute quadrangle maps, but every other contour line was deleted for the sake of legibility. The flatter upland soils are those developed from the finer textured Dog Creek Shale and Blaine Formations near the eastern end of the watershed and those developed from the Cloud Chief Formation in the western portion of the watershed. The alluvial areas have the flattest slopes, usually 1 percent or less. The channel system is well developed throughout the watershed and extends practically to the drainage divide in most areas, so the watershed is well drained except for a few alluvial areas. Although the channel system has been deleted for legibility reasons from figure 10, it is shown in figure 2 essentially as it appears in the USGS quadrangle maps. Very small drainageways, which are not included in figure 2, would add about 30 to 35 percent to total channel length. Drainageways in the western third of the watershed have eroded through the Cloud Chief Formation into the less erosion resistant, underlying Rush Springs Sandstone. Incised channels in the Rush Springs Sandstone are up to 60 to 70 feet deep (fig. 10). Much channel surveying has been done by the SCS and ARS in this watershed. Results are included in the data section of this report.

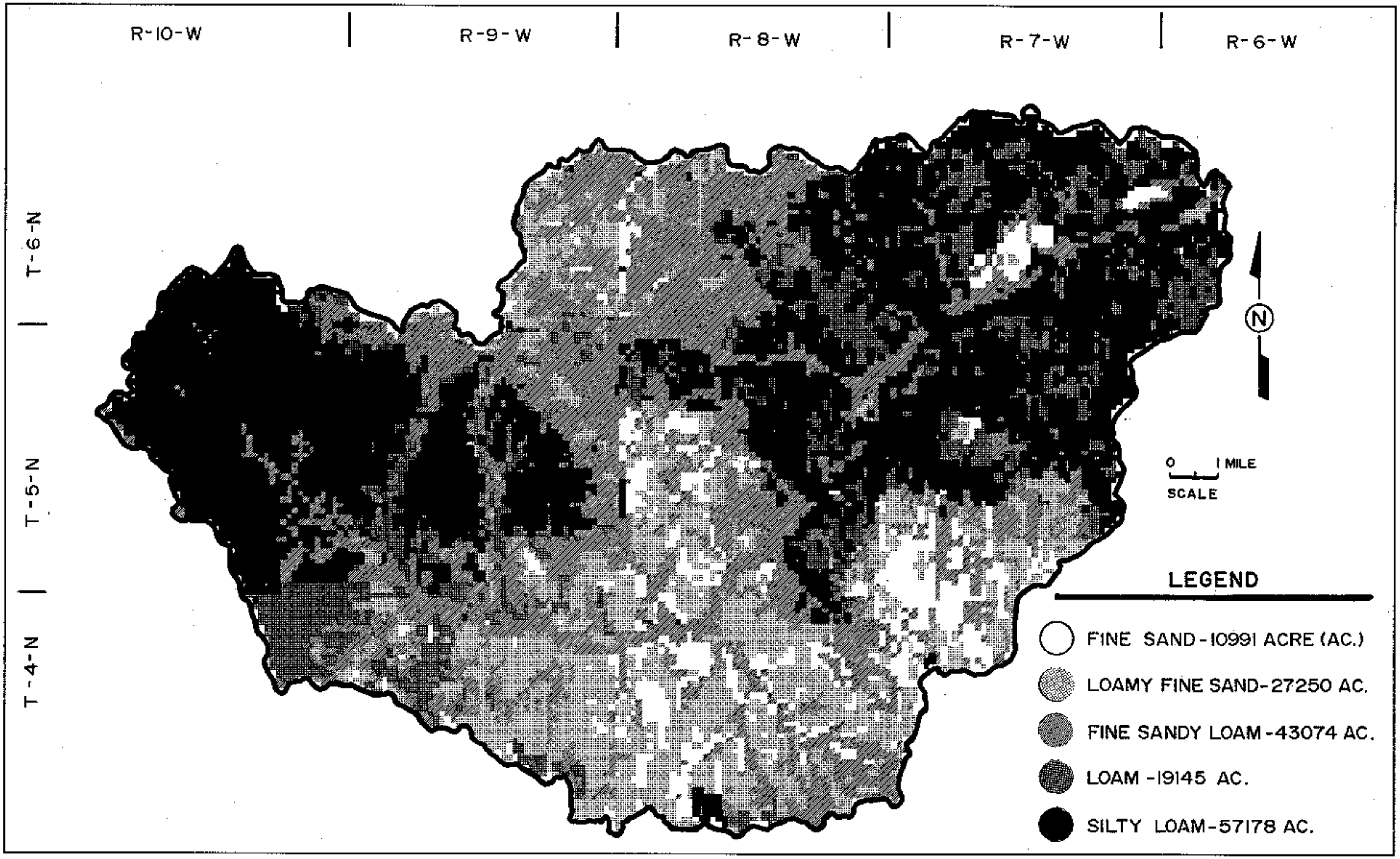

Figure 4. Areal distribution of soil textures for the watershed.

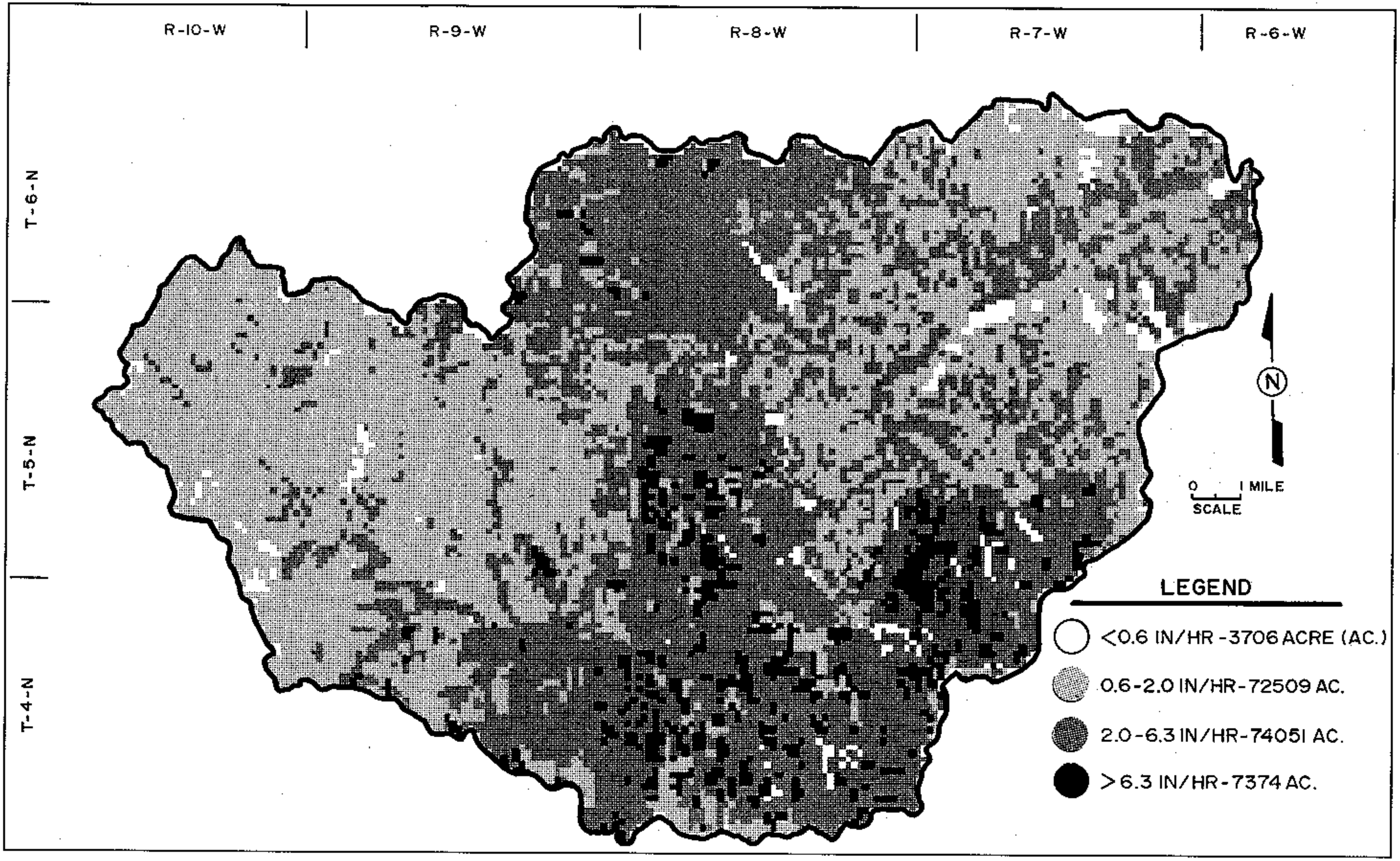

Figure 5. Permeability of the surface soils under saturated conditions in the watershed.

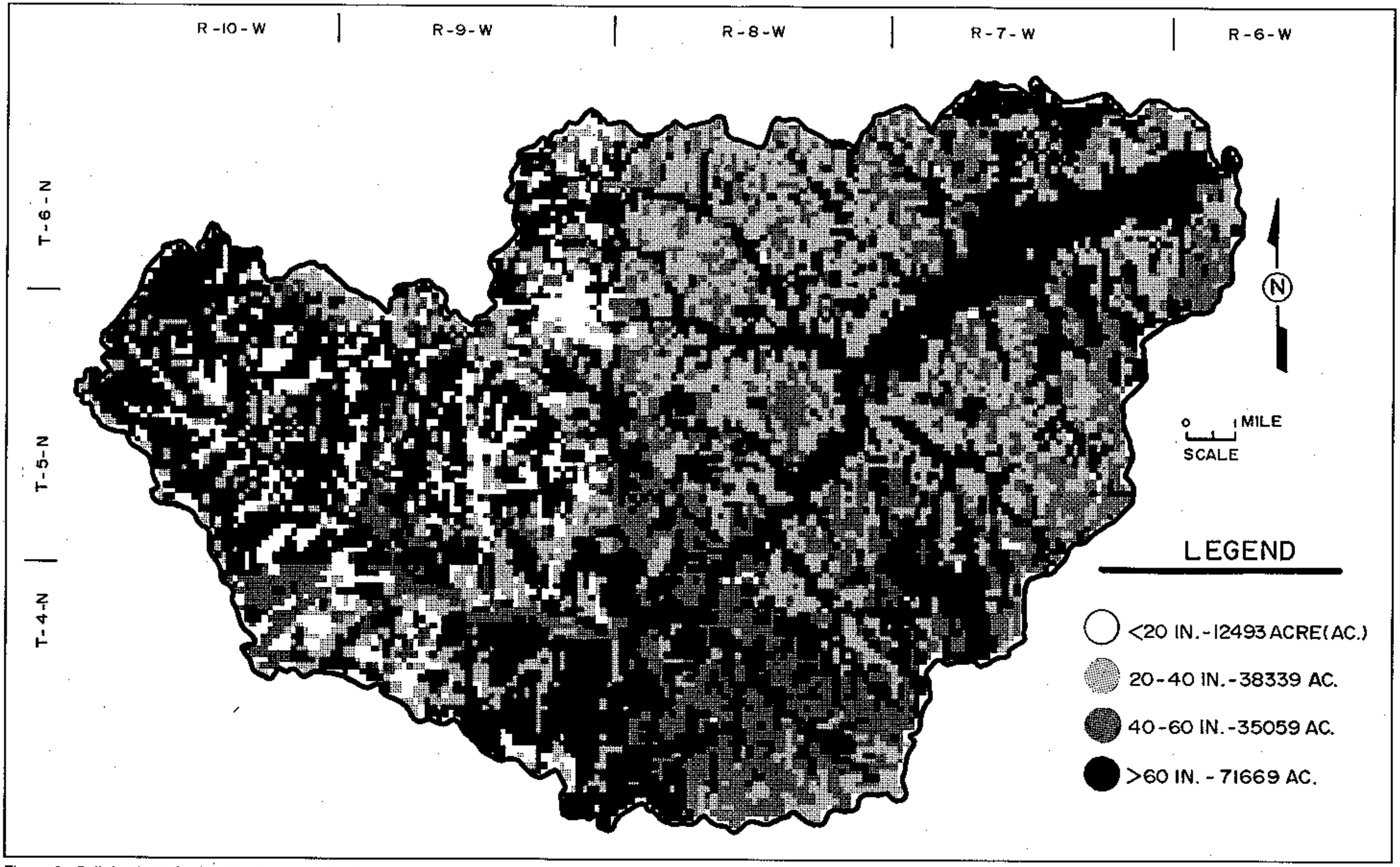

Figure 6. Soil depths to bedrock in the watershed.

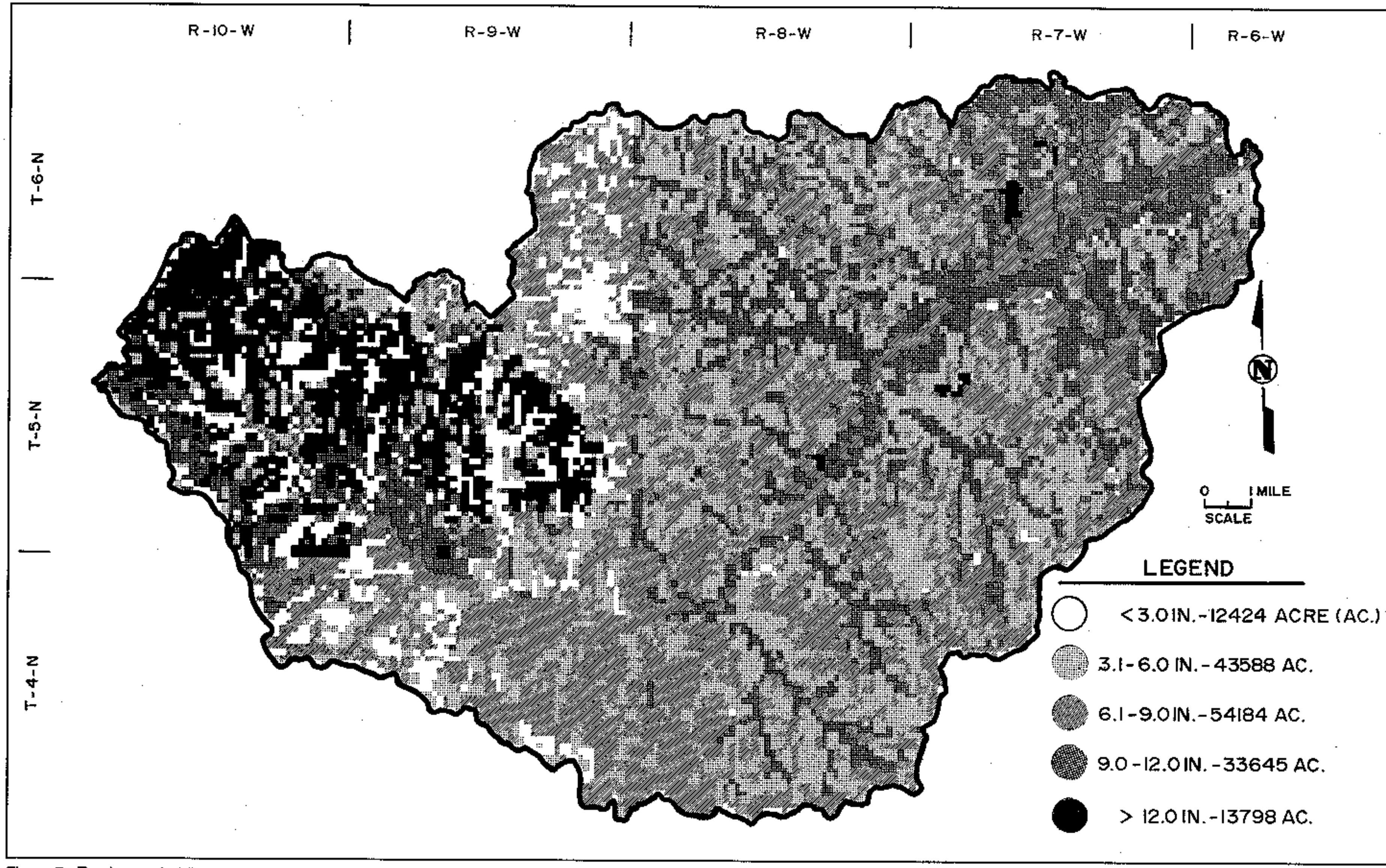

Figure 7. Total water holding capacity of the soils in the watershed.

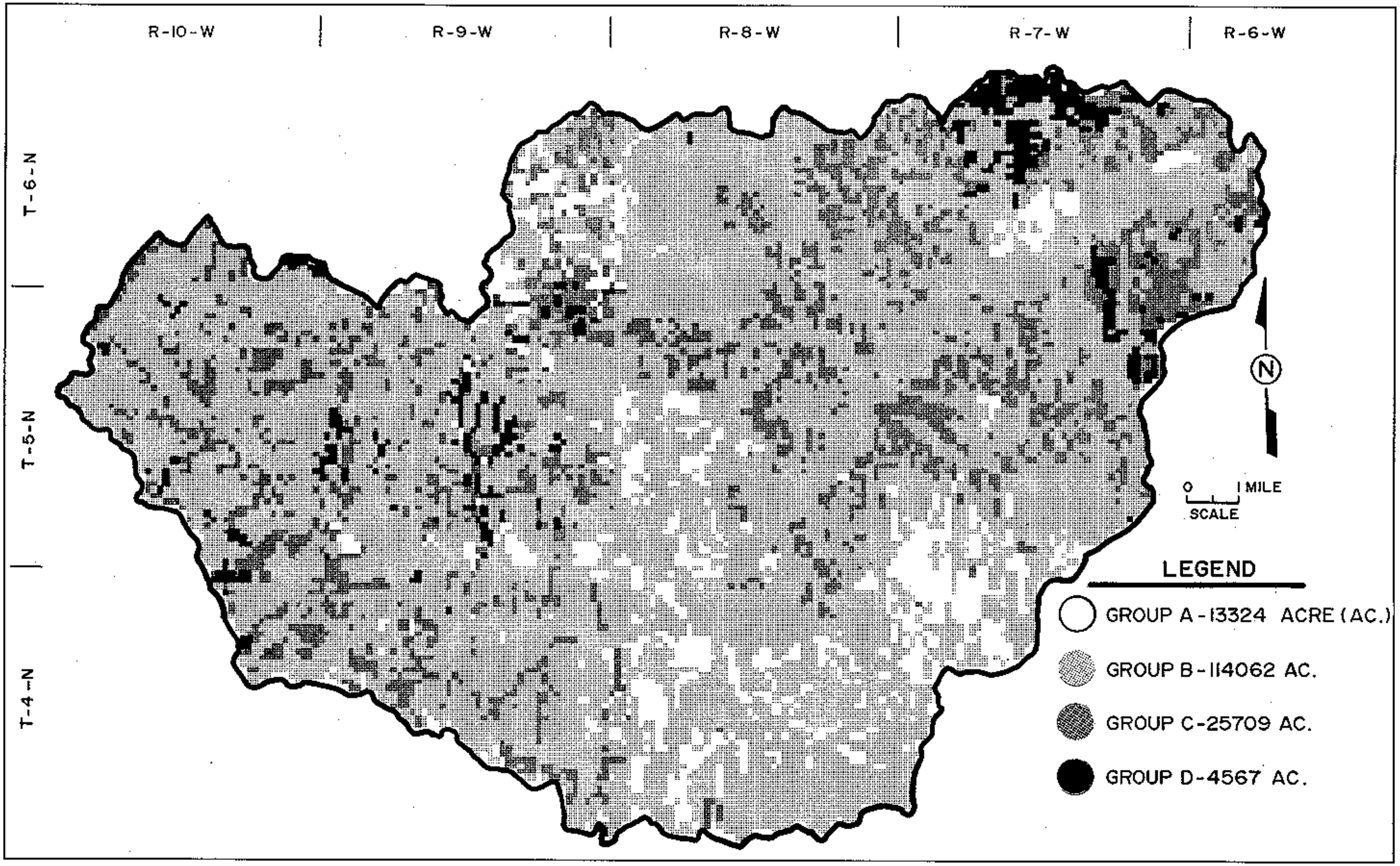

Figure 8. Hydrologic groups of the soils in the watershed.

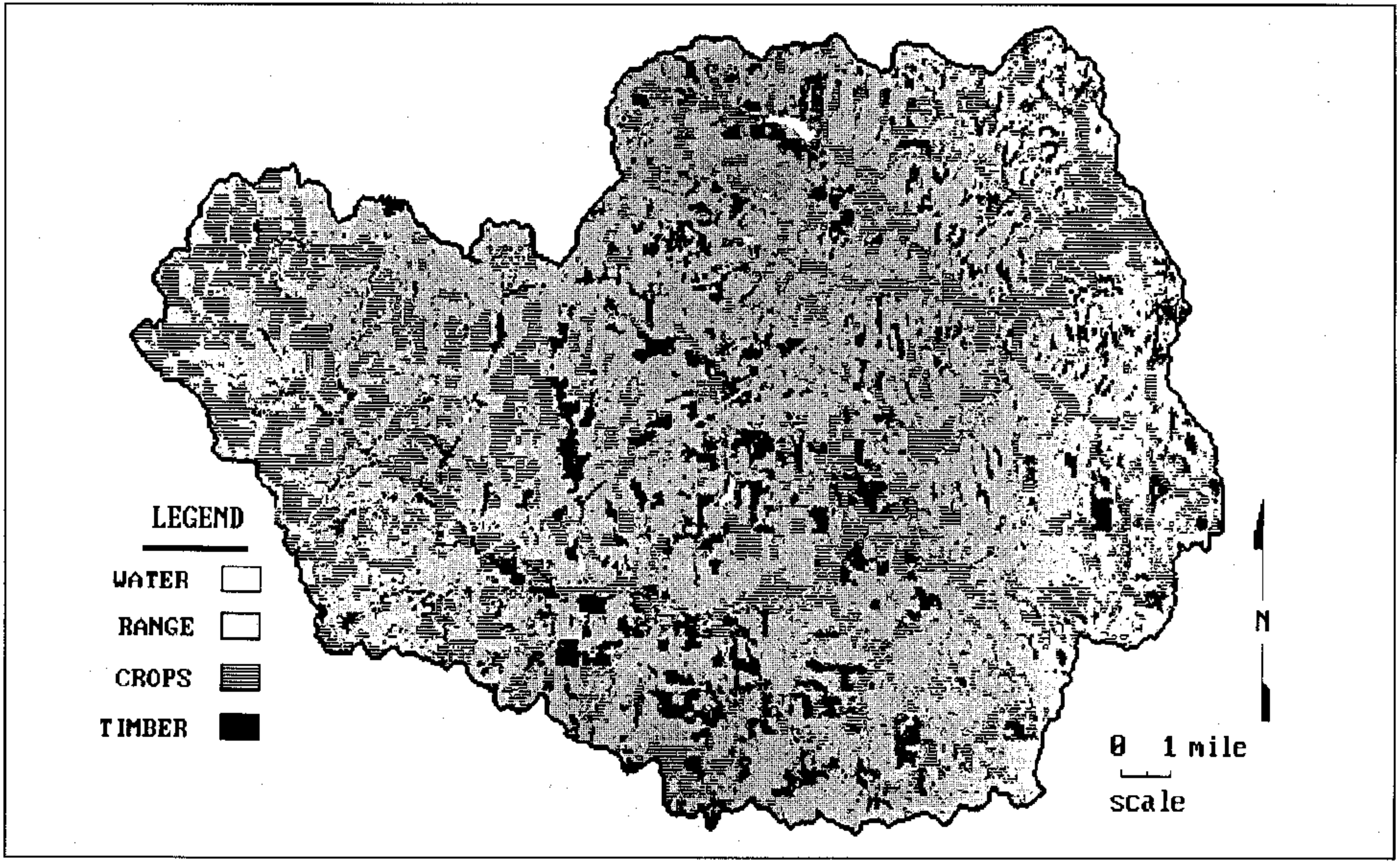

Figure 9. Land use and cover of the watershed in 1984.

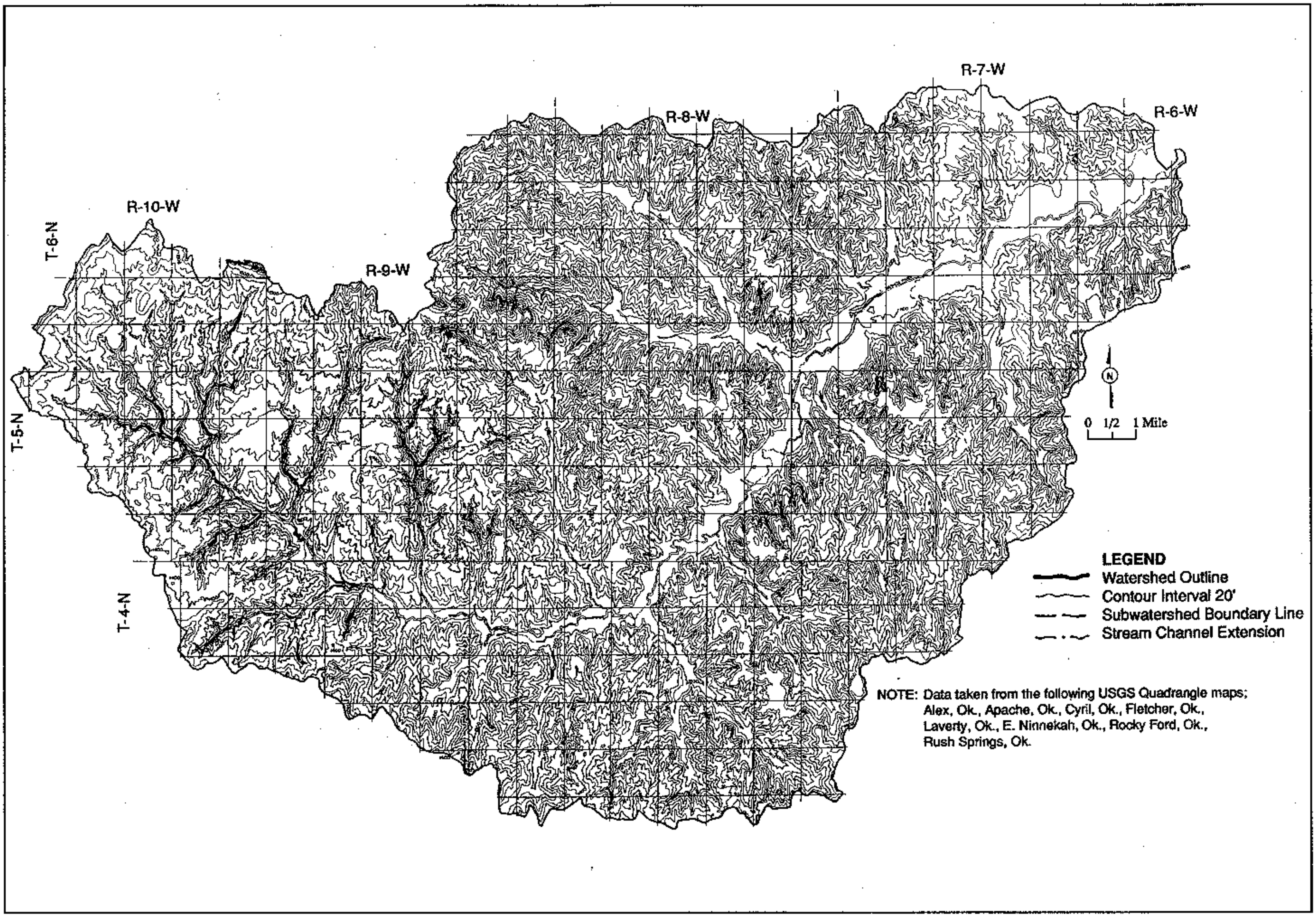

Figure 10. Topographic map of the watershed with 20-feet contour intervals.

Land Use and Erosional History

Prior to white settlement, which began around 1900 (and even earlier, by farmers in the area east of the 98th meridian), timber and range grasses covered the watershed. The Cross Timbers area, which approximates the area where soils were formed from the Rush Springs Sandstone (fig. 2), was timber covered. Most of the remaining areas consisting of the Rolling Red Plains (west of the Cross Timbers) and Reddish Prairies (northeast of the Cross Timbers) areas, were covered with grass. Timber also covered the alluvial areas and sharp drainage draws of the plains and prairies. Timber species in the Cross Timbers area probably consisted almost entirely of post oak and blackjack oak. Timber in the alluvial areas was probably a mixture of cottonwood, elm, and hackberry. Range grasses probably included climax grasses such as big and little bluestem, indian, and switch grasses. From a hydrologic standpoint this 19th century cover was excellent.

Timber in the Cross Timbers area was reportedly so dense that it was very difficult to ride through on horseback. Early explorers often commented on the appearance of the range grasses. Foreman (1937) quoted from the notes of U.S. Army explorer Captain Randolph B. Marcy about a site on Cache Creek about 15 miles south of the watershed: "The grass is very dense, of a good quality and from 2 to 3 feet high." Marcy was also impressed with the fertility of the soils in this area. He noted that weeds in abandoned Indian gardens were taller than the head of a man on horseback.

After the land was settled by farmers, the native vegetation was progressively destroyed by plowing. According to an unpublished report by the U.S. Bureau of Reclamation, good prices for wheat and cotton during World War I (1914-18) caused a great increase in the amount of cropped land. The amount of land in cultivation probably increased until the mid-thirties, when the depression and dust bowl conditions caused an exodus of farmers from Oklahoma.

As the amount of upland cultivation increased, so did soil erosion rates. Although no measurements were made, annual upland erosion rates and basin sediment yield rates probably increased from a small fraction of a ton per acre before settlement to 15 to 20 tons per acre in the uplands and 5 or 6 tons per acre at the basin outlet during the peak cultivation period. Although upland erosion rates in general may have peaked in the 1920's or 1930's, peak sediment yields at the basin outlet probably did not occur until the 1940's, a lag caused by the slow downstream movement of channel and alluvial deposition.

During the 1940's and especially during the 1950's, much of the upland cultivation was discontinued, and most of this land was retired and allowed to naturally restore itself to rangeland. The first ARS land use survey for this watershed was made in 1962. Subsequent surveys were made in 1967, 1971, and 1974. Land use changed little during this period; approximately 66 percent was rangeland, 18 percent was cultivated, and 16 percent was used for miscellaneous purposes. Dense timber land was included in this miscellaneous group and amounted to only about 5 percent of the total watershed area. Timber-pasture was included under rangeland and amounted to about 8 percent of the total watershed area in 1967 but dwindled to about 3 percent in 1974. Although not documented by measurements, range cover progressively improved (visually) during the 1970's. Range cover continued to improve through the 1980's, probably due to less intensive grazing and to accelerated grass growth that occurs later in the restoration cycle. The land use data are included in the data section of this report.

Watershed Treatments

Conventional Soil-and-Water-Conservation Practices

Terracing and contour plowing have been very widely used soil-and-water-conservation practices in the watershed since the USDA demonstration work in 1935. The programs of the CCC a few years later, followed by SCS engineering and USDA's Agricultural Stabilization and Conservation Service (ASCS) payment programs, have resulted in virtually all upland cropland being controlled by terraces. Presently, cropland terraces are usually maintained at a functional height, but terraces in retired cropland are in various stages of disrepair. On some long-abandoned fields, old terrace remnants can hardly be detected.

Diversions are commonly used at the base of hill slopes throughout the watershed to protect alluvial areas from unwanted runoff and sediment. Diversions are also occasionally employed to divert additional runoff into stockwater ponds. No quantitative terrace-diversion survey is available for the watershed. A modeler needing this survey could obtain it from the ASCS by mono- or stereo-optically viewing ASCS black-and-white aerial photos. For data from more recent years, 35-mm aerial color slides are available from the ASCS. Additionally, modern digitized systems for developing maps and photos into computerized data sets are available from the ASCS.

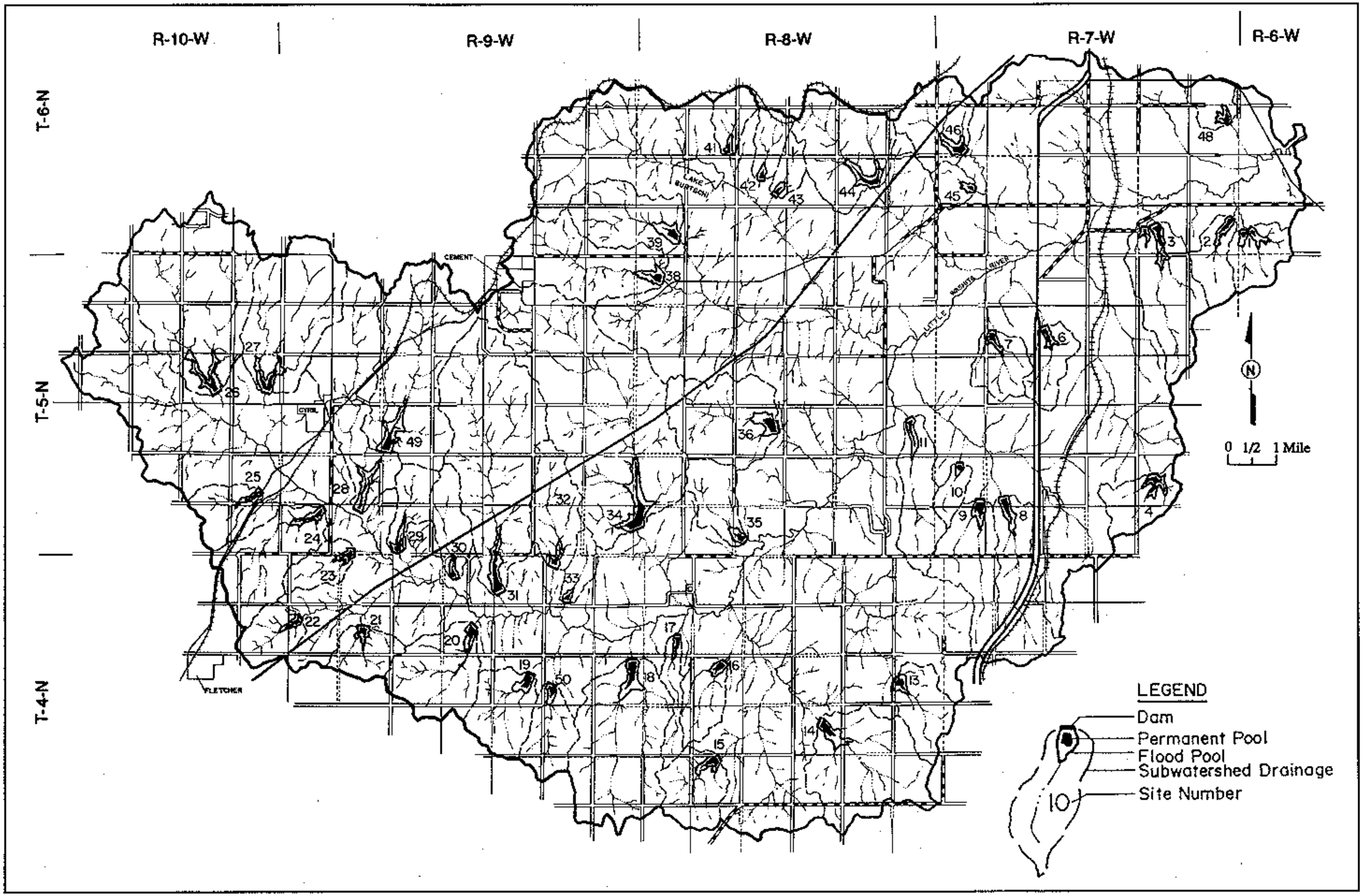

Figure 11. Locations of the floodwater-retarding reservoirs in the watershed.

A few stone masonry drop structures built by the CCC in steep terrace-outlet channels are still functioning. Because of the construction costs, however, present use of stone structures is rare. Instead, a small earthen dam with a metal pipe drop is used.

Although this watershed was east of both severe dust bowls that occurred in the United States during the 1930's, some wind erosion occurred, prompting some tree planting for windbreaks. Since the planting, changes in cultivation methods have allowed mulch, stubble, and soil clods to remain and have mostly eliminated the need for windbreaks. Older windbreaks have gradually been removed as the tree growth became detrimental to nearby crops. Today, black locust trees are usually planted to control erosion in gullies and other critical areas. On many steep, erodible, sandy hillsides, lovegrass plantings have been highly successful for controlling erosion.

There are numerous farm ponds on the watershed's eastern portion, where soils are moderately and very slowly permeable. Ponds are less numerous on the watershed's western portion, where soils are moderately permeable, and few ponds exist in the central area, where deep sandy soils are highly or moderately permeable. According to the Staff, Water Quality and Watershed Research Laboratory (1983), runoff from 40.5 square miles, or 19.5 percent of the watershed, is controlled by farm ponds. The stage on about 5 percent of the total number of ponds in the watershed was the basis for estimating the watershed land area not contributing to runoff. These noncontributing area estimates were abstracted from unpublished reports of the Southern Great Plains Research Watershed at Chickasha, OK, and are presented in table 1.

Floodwater-Retarding Reservoirs

U.S. public law 566 authorized the SCS to install floodwater-retarding reservoirs. The purpose of the reservoirs was to control flooding in alluvial areas by temporarily storing floodwater in a system of small upstream reservoirs. Of the 50 reservoirs originally planned for the Little Washita River Watershed, only 45 had been installed by the end of 1985. The locations of these 45 reservoirs are shown in figure 11.

Table 2 lists the completion dates for the construction of the reservoirs. Dam closure dates were roughly 30 days prior to these completion dates. The drainage areas, surface areas, storage capacities, crest elevations, and spillway dimensions vary widely among the reservoirs and are also listed in the table. The drain valves on the principal spillways were generally left open for 1 year after construction to allow time for vegetation to establish in the emergency spillways.

Runoff routes through reservoirs in the watershed can be determined from the water storage volume in each reservoir and the water discharge from each reservoir. Table 3 contains storage volume and storage area data for each of the reservoirs. Table 4 contains water discharge data for the principal spillways, and table 5 contains water discharge data for the grassy emergency spillways of each reservoir. All discharge data were calculated with equations, procedures, and a computer program provided by the staff, USDA-ARS, Water Conservation Structures Laboratory, Stillwater, OK.

Table 1.—Percentage of watershed area not contributing to runoff from the Little Washita River Watershed above stream gauge 522 due to storage in farm ponds

Date	Area[1] (%)	Date	Area (%)
2-7-66	20	3-10-69	15
3-9-66	19	5-6-69	10
3-29-66	20	6-4-69	18
4-20-66	19	6-14-69	11
5-1-66	20	6-24-69	18
9-11-66	19	7-15-69	19
10-1-66	20	9-16-69	17
4-8-67	17	10-22-69	19
4-25-67	18	6-8-70	18
5-7-67	16	7-7-70	19
6-4-67	18	8-17-71	17
7-7-67	20	9-14-71	19
1-1-68	19	9-20-71	18
5-1-68	17	9-28-71	12
5-28-68	19	10-15-71	4
6-4-68	18	10-30-71	18
6-18-68	17	5-2-72	14
7-16-68	18	5-9-72	16
7-31-68	19	5-31-72	18
11-6-68	18	7-12-72	19
11-20-68	17	11-14-72	14
1-29-69	16	11-28-72	16
2-17-69	17	12-20-72	19

[1]Percentages apply until next date.

Table 2.—Construction completion dates, drainage areas, storage capacities, surface areas, crest elevations, and spillway dimensions for floodwater-retarding reservoirs on the Little Washita River Watershed

	Units	Reservoir number 1	2	3	4	6	7	8
Date Construction Completed		7-17-80	12(—)69	2-26-76	2-26-76	12(—)69	6-11-73	3-5-80
Drainage Area	AC	830	704	1939	826	691	778	1786
Storage Capacity								
Sediment Pool	AC FT	84	67	186	80	53	69	148
Floodwater Pool	AC FT	348	238	566	250	294	253	491
Total	AC FT	432	305	752	330	347	322	639
Surface Area								
Sediment Pool	AC	13	11	26	11	7	16	20
Floodwater Pool	AC	44	36	88	32	37	57	64
Crest Elevations								
Dam (after settling)	FT	1107.2	1095.4	1104.5	1127.4	1169.1	1152.3	1221.1
Emergency Spillway	FT	1104.2	1093.4	1102.3	1125.4	1166.2	1150.3	1218.1
Principal Spillway	FT	1094.2	1082.3	1091.7	1113	1151	1138.5	1205
Sediment Pool Ports	FT	—	—	1086.0	—	—	—	—
Drain Value Elev. (Cen.)	FT	1081.0	1074.3	1078.2	1103.8	1143.8	1127.3	1192.0
Emergency Spillway								
Crest Width	FT	50	80	150	130	120	100	120
Crest Run	FT	50	50	50	50	50	50	50
Side Slope 1	RUN:RISE	2.5:1	2:1	2:1	2:1	2:1	2:1	3:1
Side Slope 2	RUN:RISE	2.5:1	3:1	2:1	3:1	3:1	3:1	3:1
Approach Slope	%	1.0	1.0	1.0	1.0	1.0	1.0	0.4
Back Slope	%	6.0	4.4	4.9	4.4	3.7	3.1	6.8
Principal Spillway								
Riser								
Material		CONCRETE	COR. STEEL	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE
Inside Dimen. or Dia.	FT	3 X 3	2	2 X 6	3 X 3	3 X 3	3 X 2	2 X 6
Inlet Type	FT	1 PORT	VERT. PIPE	2 WEIRS	1 PORT	1 PORT	1 PORT	2 WEIRS
Inlet Size (WXH/Dia.)	FT OR IN	13" X 10"	2'	6' X *	11" X 10"	13" X 10"	12" X 10"	6' X *
Ports, No./Size (In.)		—	—	1.16 X 10	—	—	—	—
Pipe								
Material		CONCRETE	COR. STEEL	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE
Diameter	IN	18	18	18	18	30	18	18
Length	FT	224	200	224	200	220	216	248
Elev. Inlet	FT	1080.2	1073.6	1077.7	1103.0	1143.0	1126.5	1191.0
Elev. Outlet	FT	1076.0	1063.5	1074.2	1097.7	1139.5	1120.0	1184.0
Other Features								
Vent Pipe		X	X		X	X	X	
Constric. Plate				X			X	

* Open top.
** Open top with grate.
*** Reservoir 28 has 2 identical emergency spillways. Dimensions for one is shown.
— Data unavailable.

Reservoir number							
9	10	11	13	14	15	16	17
11-12-69	11-12-69	6-11-73	4-14-78	4-14-78	4-14-78	7-21-71	5(—)70
1638	339	1322	966	2752	1101	943	502
124	27	89	78	197	88	76	44
476	101	396	282	688	295	275	134
600	128	485	360	885	383	351	178
27	5	11	15	11	17	14	5
98	17	49	43	100	48	40	18
1220.5	1212.4	1165.5	1285.2	1263.2	1304.7	1229.4	1226.7
1218.4	1209.7	1163.3	1283.2	1260.6	1302.2	1227.4	1224.7
1204.7	1199	1147.6	1272.5	1247.2	1292.3	1216.6	1211.5
—	—	—	—	1242.2	—	—	—
1194.5	1193.1	1136.4	1260.2	1230.7	1281.1	1210.4	1204.6
170	50	120	120	160	60	100	50
50	50	50	50	50	50	50	50
2:1	2:1	2:1	3:1	2:1	2:1	2:1	2:1
3:1	3:1	3:1	3:1	3:1	3:1	3:1	3:1
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4.6	5.0	5.8	5.4	7.7	5.7	5.2	7.3
CONCRETE	COR. STEEL	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	COR. STEEL
3 X 3	2	2 X 4	3 X 3	2 X 6	3 X 3	2 X 4	2
1 PORT	VERT. PIPE	2 WEIRS	1 PORT	2 WEIRS	1 PORT	2 WEIRS	VERT. PIPE
22" X 10"	2'	4" X **	14" X 10"	6' X *	17" X 10"	4' X **	2'
—	—	—	—	4.16 X 10	—	—	—
CONCRETE	COR. STEEL	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	COR. STEEL
30	^18	18	18	20	18	18	18
216	200	248	216	264	216	200	180
1193.7	1192.3	135.6	1259.5	1230.2	1280.3	1209.6	1203.8
1189.6	1186.3	1124.0	1252.8	1226.1	1270.1	1204.0	1197.0
X	X	X	X		X		X
		X				X	

Table 2—Continued. Construction completion dates, drainage areas, storage capacities, surface areas, crest elevations, and spillway dimensions for floodwater-retarding reservoirs on the Little Washita River Watershed

	Units	Reservoir Number 18	19	20	21	22	23	24
Date Construction Completed		2-7-72	4-8-77	10-27-82	5(—)70	4-8-77	7-27-71	11-8-76
Drainage Area	AC	3233	1229	1683	748	786	614	1888
Storage Capacity								
Sediment Pool	AC FT	216	108	175	60	94	61	135
Floodwater Pool	AC FT	942	305	337	206	204	164	590
Total	AC FT	1158	413	512	266	298	225	771
Surface Area								
Sediment Pool	AC	29	16	19	6	7	9	12
Floodwater Pool	AC	111	52	55	32	26	26	62
Crest Elevations								
Dam (after settling)	FT	1230.8	1260.5	1248.6	1298.7	1344.4	1303.7	1294.5
Emergency Spillway	FT	1228.1	1258.5	1245.6	1296.7	1342.0	1301.7	1292.3
Principal Spillway	FT	1214.0	1248.5	1234.7	1284.3	1327.3	1291.7	1273.1
Sediment Pool Ports	FT	—	—	—	—	—	—	—
Drain Value Elev. (Cen.)	FT	1201.0	1237.3	1221.5	1278.1	1310.1	1279.5	1249.9
Emergency Spillway								
Crest Width	FT	150	100	100	110	60	80	120
Crest Run	FT	50	50	50	50	50	50	50
Side Slope 1	RUN:RISE	2:1	2:1	3:1	2:1	3:1	3:1	2:1
Side Slope 2	RUN:RISE	3:1	3:1	3:1	3:1	3:1	3:1	3:1
Approach Slope	%	1.0	1.0	0.4	1.0	1.0	1.0	1.0
Back Slope	%	6.1	5.6	6.2	3.9	3.0	3.6	6.9
Principal Spillway								
Riser								
Material		CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE
Inside Dimen. or Dia.	FT	2 X 6	3 X 4	2.5 X 7.5	2 X 4	3 X 3	2 X 4	2 X 6
Inlet Type	FT	2 WEIRS	1 PORT	2 WEIRS	2 WEIRS	1 PORT	2 WEIRS	2 WEIRS
Inlet Size (WXH/Dia.)	FT OR IN	6' X *	18" X 10"	7.5' X *	4' X **	12" X 10"	4' X **	6' X *
Ports, No./Size (In.)		—	—	—	—	—	—	—
Pipe								
Material		CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE
Diameter	IN	20	18	30	18	18	18	18
Length	FT	304	200	248	224	304	208	344
Elev. Inlet	FT	1200.0	1236.5	1220.7	1277.3	1309.3	1278.7	1249.1
Elev. Outlet	FT	1187.5	1232.0	1209.2	1267.0	1300.3	1269.0	1243.5
Other Features								
Vent Pipe		X	X		X	X	X	
Constric. Plate				X			X	

* Open top.
** Open top with grate.
*** Reservoir 28 has 2 identical emergency spillways. Dimensions for one is shown.
— Data unavailable.

Reservoir Number							
25	**26**	**27**	**28**	**29**	**30**	**31**	**32**
11-8-76	12(—)71	11-8-76	5-16-80	11-8-76	4-16-81	9-14-78	6(—)70
672	4250	2944	2694	896	691	4877	1216
59	417	302	226	93	66	426	97
202	1310	921	871	329	160	1237	359
261	1727	1223	1097	422	226	1663	456
5	27	35	6	13	6	42	12
20	119	94	96	44	23	129	45
1335.4	1353.7	1349.0	1288.3	1284.9	1257.4	1256.7	1264.5
1332.7	1347.8	1344.2	1282.3	1282.9	1253.6	1253.2	1262.1
1316.0	1325.2	1329.0	1285.5	1270.0	1249.8	1237.3	1247.7
—	1315.0	—	1254.0	—	1242.8	—	—
1296.8	1291.5	1315.6	1244.0	1258.8	1224.6	1220.8	1238.5
40	270	240	150***	180	100	180	50
50	50	50	50	50	50	50	50
2:1	2:1	2:1	3:1	2:1	3:1	3:1	3:1
3:1	3:1	3:1	3:1	3:1	3:1	3:1	2.5:1
1.0	1.0	1.0	1.0	1.0	0.4	0.7	1.0
9.5	4.3	5.5	3.8	5.1	4.5	4.3	5.1
CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE
2 X 6	2.5 X 7.5	2 X 6	3 X 9	3 X 3	2 X 6	3 X 9	3 X 3
2 WEIRS	2 WEIRS	2 WEIRS	2 WEIRS	1 PORT	2 PORTS	4 WEIRS	1 PORT
6' X **	7.5' X **	6' X **	9' X **	12" X 10"	6' X 1.25'	4.08' X **	16" X 10"
—	4.24 X 12	—	4.30 X 12	—	1.14 X 10	—	—
CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE
18	27	24	36	18	18	36	24
328	456	336	368	264	216	288	240
1296.0	1290.2	1309.5	1243.5	1258.0	1231.6	1219.3	1237.7
1279.5	1279.8	1293.0	1239.0	1250.0	1218.5	1212.0	1227.0
X	X	X	X		X		X
		X				X	

Table 2—Continued. Construction completion dates, drainage areas, storage capacities, surface areas, crest elevations, and spillway dimensions for floodwater-retarding reservoirs on the Little Washita River Watershed

		Reservoir Number						
	Units	33	34	35	36	38	39	41
Date Construction Completed		5(—)70	3-22-73	9-28-72	9-29-72	3-29-72	6-26-78	10(—)69
Drainage Area	AC	384	7059	952	2104	2285	1565	512
Storage Capacity								
Sediment Pool	AC FT	25	412	77	132	197	115	42
Floodwater Pool	AC FT	110	2000	278	614	762	650	131
Total	AC FT	135	2412	355	746	959	765	173
Surface Area								
Sediment Pool	AC	6	53	10	26	21	20	5
Floodwater Pool	AC	19	201	39	80	73	84	19
Crest Elevations								
Dam (after settling)	FT	1238.2	1250.1	1197.2	1207.7	1255.6	1251.9	1243.8
Emergency Spillway	FT	1236.2	1247.2	1195.2	1205.6	1250.2	1248.2	1241.8
Principal Spillway	FT	1226.3	123.0	1182.5	1193.0	1231.7	1234.1	1229.7
Sediment Pool Ports	FT	—	—	—	—	—	—	—
Drain Value Elev. (Cen.)	FT	1222.4	1213.1	1171.3	1185.8	1214.7	1224.9	1223.8
Emergency Spillway								
Crest Width	FT	80	150	200	190	150	150	50
Crest Run	FT	50	50	50	50	50	50	50
Side Slope 1	RUN:RISE	2:1	2:1	2:1	2:1	2:1	2:1	2:1
Side Slope 2	RUN:RISE	3:1	3:1	2:1	3:1	3:1	3:1	3:1
Approach Slope	%	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Back Slope	%	7.2	4.9	3.0	6.2	6.8	5.4	5.7
Principal Spillway								
Riser								
Material		CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	COR. STEEL
Inside Dimen. or Dia.	FT	2	2.5 X 7.5	2 X 4	2 X 6	2.5 X 8.3	3 X	2
Inlet Type	FT	VERT. PIPE	2 WEIRS	2 WEIRS	2 WEIRS	4 WEIRS	1 PORT	VERT. PIPE
Inlet Size (WXH/Dia.)	FT OR IN	2'	7.5' X **	4' X **	6' X **	3.75' X **	20" X 10"	2'
Ports, No./Size (In.)		—	—	—	—	—	—	—
Pipe								
Material		COR. STEEL	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	COR. STEEL
Diameter	IN	18	30	18	1.8	30	24	18
Length	FT	160	312	232	184	320	224	160
Elev. Inlet	FT	1221.6	1212.0	1268.0	1185.0	1213.8	1224.1	1223.0
Elev. Outlet	FT	1219.5	1206.3	1161.0	1183.3	1204.8	1218.8	1220.0
Other Features								
Vent Pipe		X		X		X	X	X
Constric. Plate						X		

* Open top.
** Open top with grate.
*** Reservoir 28 has 2 identical emergency spillways. Dimensions for one is shown.
— Data unavailable.

Reservoir Number							
42	43	44	45	46	48	49	50
10(—)69	3-29-72	6-25-80	10(—)69	3-29-72	6-26-78	6-26-78	4-8-77
480	374	2048	373	1222	454	3283	909
46	39	183	37	114	52	284	71
132	109	648	112	357	141	1083	242
178	148	831	149	471	193	1367	313
7	4	25	6	19	9	29	12
21	19	88	20	56	28	115	34
1220.3	—	1177.7	1152.1	1169.5	1099.5	1321.1	1267.2
1218.3	1214.6	1172.6	1150.1	1167.3	1097.5	1317.2	1265.2
1207.8	1204.3	1159.5	1140.6	1157.1	1089.2	1300.4	1254.2
—	—	—	1254.0	—	—	—	—
1198.9	1199.1	1148.3	1134.7	1149.9	1080.0	1284.4	1243.0
50	50	190	45	100	50	200	70
50	50	50	50	50	50	50	50
2:1	2:1	2:1	2:1	2:1	3:1	2:1	2:1
3:1	3:1	2:1	3:1	3:1	3:1	3:1	3:1
1.0	1.0	0.4	1.0	1.0	3.0	1.0	1.0
3.7	6.3	4.2	4.2	3.5	4.0	5.0	6.5
COR. STEEL	CONCRETE	CONCRETE	COR. STEEL	CONCRETE	CONCRETE	CONCRETE	CONCRETE
2	2 X 4	2 X 6	2	2 X 6	3 X 3	2.5 X 7.5	3 X 3
VERT. PIPE	VERT. PIPE	2 WEIRS	VERT. PIPE	2 WEIRS	1 PORT	2 WEIRS	1 PORT
2'	4' X **	6' X **	2'	6' X **	10" X 8"	7.5' X **	15" X 10"
—	—	—	—	—	—	—	—
COR. STEEL	CONCRETE	CONCRETE	COR. STEEL	CONCRETE	CONCRETE	CONCRETE	CONCRETE
18	18	24	18	18	18	27	18
180	160	280	160	180	184	304	216
1198.1	1198.3	1147.5	1133.9	1149.1	1079.2	1283.4	1242.2
1195.6	1190.3	1142.5	1129.0	1145.0	1072.2	1274.1	1237.0
X	X		X		X		X
	X						

Table 3.—Water storage volume and surface area for the reservoirs of the Little Washita River Watershed

DISTANCE ABOVE DATUM (FT)	Reservoir number 1		2		3		4		6		7		8		9	
	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)
54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36	-	-	-	-	-	-	-	-	-	-	75	455	-	-	-	-
34	-	-	-	-	-	-	37	415	-	-	64	380	-	-	-	-
32	-	-	42	400	100	900	33	345	-	-	56	310	73	750	-	-
30	-	-	37	320	86	730	29	285	45	500	50	250	63	615	118	820
28	60	540	32	250	72	570	26	225	41	403	44	206	55	510	107	710
26	52	430	27	200	60	420	22	180	36	332	36	165	47	405	96	580
24	43	330	22	150	50	310	19	143	31	272	28	123	40	315	87	485
22	35	260	18	110	40	230	15	107	26	218	20	76	34	250	78	380
20	28	195	14	73	31	160	12	80	22	170	14	50	27	172	68	300
18	22	140	11	52	24	110	10.0	57	18	135	8.8	35	22	122	57	230
16	17	100	7.5	34	17	70	7.5	43	15	102	5.6	25	17	89	45	168
14	13	70	5.0	19	12	43	5.5	27	12	74	3.9	17	14	63	33	123
12	9.7	46	3.0	10	7.0	24	4.0	18	8.7	54	2.8	11	1.05	47	24	83
10	6.5	28	1.6	5	3.3	14	2.7	11	6.1	38	2.0	7	7.0	28	17	56
8	4.3	16	1.0	4	1.6	9	1.9	6	4.0	25	1.5	4	4.0	18	11	32
DATUM (FT)	**1080**		**1056**		**1068**		**1094**		**1140**		**1118**		**1188**		**1192**	

- Data unavailable.

Reservoir number													
10		11		13		14		15		16		17	
AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	137	1240	-	-	-	-	-	-
-	-	-	-	-	-	122	1020	-	-	-	-	-	-
-	-	51	523	-	-	90	825	-	-	-	-	-	-
-	-	44	435	-	-	76	660	-	-	-	-	-	-
-	-	37	349	-	-	64	520	-	-	-	-	-	-
-	-	30	282	45	405	54	400	-	-	-	-	-	-
-	-	26	226	39	320	44	315	54	480	-	-	22	240
-	-	21	179	34	242	36	228	47	385	-	-	19	200
19	164	17	141	28	185	26	166	39	290	46	452	17	165
17	129	14	110	24	130	20	120	32	205	41	375	15	133
15	101	11	84	19	86	20	120	27	155	37	290	12	107
12	75	9.5	64	13	55	15	81	22	107	32	215	10.5	83
8.7	75	8.2	46	9.0	31	11	58	16	72	26	158	5.7	64
7.4	38	6.8	31	4.8	16	7.1	31	11	43	21	110	6.8	45
6.0	26	5.7	18	2.5	8	4.8	19	7.0	21	17	72	5.0	35
4.1	16	4.2	9	1.1	3	2.8	12	4.0	10	13	46	3.3	27
1190		**1130**		**1256**		**1228**		**1278**		**1208**		**1202**	

Table 3—Continued. Water storage volume and surface area for the reservoirs of the Little River Watershed

DISTANCE ABOVE DATUM (FT)	Reservoir number 18		19		20		21		22		23		24		25	
	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)
54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52	-	-	-	-	-	-	-	-	-	-	-	-	69	880	-	-
50	-	-	-	-	-	-	-	-	33	420	-	-	61	750	-	-
48	-	-	-	-	-	-	-	-	30	355	-	-	53	630	-	-
46	-	-	-	-	-	-	-	-	26	300	-	-	47	530	-	-
44	-	-	-	-	-	-	-	-	23	250	-	-	40	440	-	-
42	-	-	-	-	-	-	-	-	20	205	-	-	33	370	22	290
40	-	-	-	-	-	-	-	-	17	170	-	-	28	308	19	240
38	-	-	-	-	-	-	-	-	14	140	-	-	24	252	17	204
36	-	-	-	-	-	-	-	-	11	110	-	-	19	206	16	170
34	-	-	-	-	75	735	-	-	9.2	80	36	368	16	175	13	135
32	137	1620	64	610	66	605	43	385	7.5	62	31	301	13	145	10.7	116
30	123	1380	58	500	57	495	37	305	6.1	50	27	243	11	120	9.0	95
28	110	1110	50	400	48	395	30	240	5.2	41	23	193	9.2	98	7.5	77
26	98	900	42	300	40	305	24	180	4.5	33	19	150	8.0	81	6.2	66
24	86	730	34	220	33	235	19	140	3.8	26	15	116	7.0	68	5.0	57
22	73	565	27	157	27	169	15	105	3.2	21	12	88	6.0	52	3.8	45
20	62	430	20	108	22	120	11	80	2.7	17	9.7	66	5.1	39	2.8	23
18	52	320	14	76	17	83	8.0	60	2.3	13	7.1	50	4.3	30	1.8	12
16	42	230	10.1	50	12	54	3.7	38	2.0	10	5.7	37	3.6	23	1.3	8
14	30	160	7.1	30	6.8	34	3.7	38	1.7	8	4.7	26	3.1	20	.8	7
12	21	110	5.0	20	4.2	21	2.4	29	1.4	6	3.9	18	2.6	17	.7	5
10	16	71	3.2	11	2.6	13	1.7	14	1.2	4	3.1	11	2.1	12	.6	4
8	12	65	1.8	6	1.6	8	1.2	5	1.0	3	2.4	6	1.8	10	.5	3
DATUM (FT)	1200		1230		1216		1268		1296		1272		1242		1292	

- Data unavailable.

Reservoir number													
26		27		28		29		30		31		32	
AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)
150	2300	-	-	-	-	-	-	-	-	-	-	-	-
134	2000	-	-	-	-	-	-	-	-	-	-	-	-
120	1760	116	1600	-	-	-	-	-	-	-	-	-	-
106	1540	104	1390	-	-	-	-	-	-	-	-	-	-
92	1340	93	1190	123	1420	-	-	-	-	-	-	-	-
81	1170	83	1020	108	1240	-	-	-	-	-	-	-	-
71	1030	75	860	94	970	-	-	-	-	152	2080	-	-
62	890	67	710	83	870	-	-	-	-	135	1790	-	-
56	770	59	590	71	740	-	-	-	-	121	1520	-	-
47	660	51	475	60	605	48	480	-	-	109	1260	-	-
41	570	44	380	52	490	41	380	30	325	96	1060	-	-
36	490	38	292	44	400	34	310	24	275	85	865	53	532
31	420	32	320	35	310	29	240	19	225	75	720	45	450
27	370	26	168	26	245	24	190	15	180	64	595	39	368
23	320	19	122	22	192	20	150	11	144	55	475	33	298
20	280	13	87	19	150	16	114	7.8	110	45	375	27	232
17	240	9.0	60	15	119	13	87	6.5	79	36	295	22	185
15	210	6.2	41	11	91	10.5	62	5.5	53	26	225	19	142
14	185	4.5	32	9.0	72	8.4	42	4.4	53	20	170	15	11
12	155	3.8	27	7.4	58	6.0	28	3.6	26	14	125	12	83
11	130	2.8	22	6.0	40	4.1	17	3.1	21	9.2	80	9.7	60
9.0	100	2.0	19	4.8	30	2.5	10	2.6	16	6.7	60	7.0	49
7.0	80	1.8	15	3.9	20	1.5	7	2.0	12	4.6	45	5.0	22
6.0	70	4.2	9	2.8	14	1.0	5	1.5	9	3.3	30	3.5	12
1300		**1300**		**1240**		**1248**		**1222**		**1214**		**1232**	

Table 3—Continued. Water storage volume and surface area for the reservoirs of the Little Washita River Watershed

	Reservoir number															
DISTANCE ABOVE DATUM (FT)	33		34		35		36		38		39		41		42	
	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)
54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46	-	-	-	-	-	-	-	-	85	-	-	-	-	-	-	-
44	-	-	-	-	-	-	-	-	78	1070	-	-	-	-	-	-
42	-	-	-	-	-	-	-	-	71	942	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	64	810	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	58	687	-	-	-	-	-	-
36	-	-	-	-	-	-	-	-	51	576	-	-	-	-	-	-
34	-	-	231	3040	-	-	-	-	45	472	-	-	-	-	-	-
32	-	-	209	2630	-	-	-	-	39	394	-	-	-	-	-	-
30	-	-	188	2200	-	-	-	-	34	322	-	-	-	-	-	-
28	39	470	166	1830	41	389	-	-	30	267	107	950	-	-	-	-
26	35	400	147	1530	36	311	-	-	25	204	81	740	-	-	-	-
24	31	332	127	1220	31	245	92	915	21	153	69	580	23	217	24	208
22	28	268	110	900	26	186	82	760	18	114	59	450	19	175	20	170
20	25	218	96	770	26	141	72	618	15	82	50	340	16	137	17	135
18	22	170	82	590	16	103	62	490	11	59	41	260	13	107	14	101
16	19	130	67	430	12	74	52	362	7.0	40	32	187	11	84	12	72
14	15	95	53	320	9.3	53	43	262	4.5	28	26	130	8.9	63	9.5	54
12	12	70	40	230	7.0	35	36	195	3.1	19	19	84	6.9	47	7.0	39
10	9.2	48	29	160	5.2	24	29	120	2.1	12	14	50	5.2	33	4.0	24
8	7.2	30	21	110	3.8	14	22	69	1.6	10	8.5	27	3.6	22	2.7	13
DATUM (FT)	**1220**		**1216**		**1168**		**1184**		**1208**		**1222**		**1220**		**1196**	

- Data unavailable.

Reservoir number													
43		44		45		46		47		49		50	
AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)	AREA (AC)	VOL. (AF)
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	134	1640	-	-
-	-	-	-	-	-	-	-	-	-	120	1430	-	-
-	-	-	-	-	-	-	-	-	-	108	1220	-	-
-	-	110	-	-	-	-	-	-	-	97	1020	-	-
-	-	96	970	-	-	-	-	-	-	86	830	-	-
-	-	85	800	-	-	-	-	-	-	75	680	-	-
-	-	72	640	-	-	-	-	-	-	65	545	-	-
-	-	60	500	-	-	-	-	-	-	56	430	44	420
-	-	49	375	-	-	-	-	-	-	44	340	37	335
18	138	40	290	-	-	-	-	-	-	34	260	30	263
15	103	33	210	23	190	59	485	35	270	28	200	25	200
11	74	26	143	20	144	49	385	29	205	22	143	21	151
8.3	55	20	102	16	110	40	297	24	155	17	103	18	115
6.0	40	15	68	12	80	33	220	19	110	12	70	14	84
4.2	26	10.0	42	9.5	57	27	159	14	77	8.5	44	11	58
2.9	16	6.2	25	7.6	40	21	112	10.0	77	6.5	30	8.3	39
1.8	8	3.8	14	5.1	25	16	74	6.9	34	4.9	20	6.0	22
1.1	4	2.4	14	3.1	16	12	42	4.6	23	3.2	12	4.0	13
1190		**1140**		**1130**		**1146**		**1078**		**1278**		**1240**	

Table 4.—Water discharge data for principal spillways

HEAD ABOVE CREST (ft)	Water Discharge (ft³/s) Reservoir number							
	1	2	3	4	6	7	8	9
38.0	-	-	-	-	-	-	-	-
36.0	-	-	-	-	-	-	-	-
34.0	-	-	-	-	-	-	-	-
32.0	-	-	-	-	-	-	-	-
30.0	-	-	-	-	-	-	-	-
28.0	-	-	-	-	-	-	-	-
26.0	-	-	-	-	-	-	-	-
24.0	-	-	42.31	-	-	-	-	-
22.0	-	-	41.07	-	-	-	-	-
20.0	-	-	39.80	-	-	-	-	-
18.0	-	-	38.48	-	-	-	-	-
16.0	-	-	37.12	-	18.29	-	-	-
14.0	-	-	35.70	14.45	17.08	15.76	40.50	28.90
12.0	15.77	19.75	34.23	13.34	15.77	14.56	39.38	26.68
10.0	14.34	19.08	32.69	12.14	14.34	13.24	38.02	24.27
9.0	13.57	18.74	31.89	11.49	13.57	12.53	37.38	22.97
8.0	12.76	18.39	31.08	10.80	12.76	11.78	36.72	21.59
7.0	11.89	18.03	30.24	10.06	11.89	10.97	36.06	21.12
6.0	10.95	17.67	18.91	9.26	10.95	10.11	35.37	18.53
5.0	9.92	17.30	12.21	8.39	9.92	9.16	34.68	16.79
4.5	9.36	17.11	11.52	7.92	9.36	8.64	34.32	15.84
4.0	8.77	16.92	10.79	7.42	8.77	8.10	33.97	14.84
3.5	8.14	16.73	10.01	6.88	8.14	7.51	33.60	13.77
3.0	7.45	16.53	9.17	6.30	7.45	6.87	33.24	12.60
2.5	6.69	16.33	8.23	5.66	6.69	6.17	32.86	11.32
2.0	5.83	16.13	7.18	4.93	5.83	5.38	32.48	9.87
1.5	4.82	15.93	5.94	4.08	4.82	4.45	32.10	8.16
1.0	3.54	15.73	4.36	2.99	3.54	3.27	31.70	5.99
0.8	3.18	15.64	3.91	2.69	3.18	2.94	31.53	5.38
0.6	1.88	10.96	2.32	1.59	1.88	1.74	19.67	3.19
0.4	0.89	5.29	1.09	0.75	0.89	0.82	9.18	1.50
0.2	0.25	1.87	0.31	0.21	0.25	0.23	2.78	0.43
SPILLWAY CREST (ft)	**1094.2**	**1082.3**	**1086.0**	**1113.0**	**1151.0**	**1138.5**	**1205.0**	**1204.7**

- Data unavailable.
* Flow rates prior to 2-18-82, when constriction plate was in place.
**Flow rates after 2-18-82, when constriction plate was removed.

Water Discharge (ft³/s)							
Reservoir number							
10	11*	11**	13	14	15	16	17
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	51.82	-	-	-
-	-	-	-	50.31	-	-	-
-	18.82	44.99	-	48.76	-	-	-
-	18.13	43.80	-	47.15	-	-	19.87
17.63	17.41	42.58	16.98	45.49	20.62	15.47	19.14
16.88	16.66	41.32	15.45	43.77	18.76	14.61	18.38
16.49	16.27	40.67	14.62	42.88	17.75	14.17	17.99
16.09	15.87	39.80	13.74	41.97	16.68	13.71	17.59
15.69	15.47	38.75	12.80	41.04	15.55	13.24	17.18
15.27	15.05	37.67	11.79	40.09	14.32	12.74	16.76
14.83	14.61	36.56	10.68	39.21	12.97	12.23	16.33
14.61	14.39	36.00	10.08	38.62	12.24	11.97	16.11
14.39	14.17	35.42	9.44	38.12	11.47	11.70	15.89
14.16	13.94	34.84	8.76	37.61	10.64	11.42	15.66
13.93	13.71	34.24	8.02	36.66	9.74	11.14	15.43
13.70	13.48	33.63	7.20	32.92	8.74	10.84	15.20
13.46	13.24	29.72	6.28	38.70	7.62	10.54	14.97
13.21	12.99	14.84	5.19	23.74	6.31	10.24	14.73
12.97	12.74	4.50	3.81	17.42	4.63	9.92	14.48
12.87	12.67	2.25	3.43	15.67	4.16	9.79	14.38
10.96	12.54	0.86	2.03	9.30	2.47	9.66	10.96
5.29	6.12	0.17	0.95	4.38	1.16	6.12	5.29
1.87	1.85	0.00	0.27	1.27	0.33	1.85	1.87
1199.0	**1147.6**	**1147.6**	**1272.5**	**1242.2**	**1292.3**	**1216.6**	**1211.5**

Table 4—Continued. Water discharge data for principal spillways

HEAD ABOVE CREST (ft)	Water Discharge (ft³/s) Reservoir number							
	18	19	20	21	22	23	24	25
38.0	-	-	-	-	-	-	-	-
36.0	-	-	-	-	-	-	-	-
34.0	-	-	-	-	-	-	-	-
32.0	-	-	-	-	-	-	-	-
30.0	-	-	-	-	-	-	-	-
28.0	-	-	-	-	-	-	-	-
26.0	-	-	-	-	-	-	-	-
24.0	-	-	-	-	-	-	-	-
22.0	-	-	-	-	-	-	-	-
20.0	-	-	-	-	-	-	43.49	-
18.0	-	-	-	-	-	-	42.57	46.37
16.0	53.90	-	-	-	16.88	-	41.64	45.49
14.0	52.57	-	-	16.27	15.76	-	40.69	44.59
12.0	51.21	-	125.35	15.47	14.56	-	39.72	43.67
10.0	49.81	19.86	120.18	14.61	13.24	17.04	38.72	42.72
9.0	40.09	18.79	117.50	14.17	12.53	16.66	38.21	42.25
8.0	48.36	17.67	114.77	13.71	11.78	16.27	37.69	41.76
7.0	47.63	16.46	111.97	13.24	10.97	15.87	37.16	41.27
6.0	46.87	15.16	109.10	12.74	10.11	15.47	36.63	40.77
5.0	46.11	13.73	106.15	12.23	9.16	15.05	36.09	40.27
4.5	45.72	12.96	104.65	11.97	8.64	14.83	35.81	40.01
4.0	45.33	12.14	103.12	11.70	8.10	14.61	35.53	39.75
3.5	44.93	11.26	101.57	11.42	7.51	14.39	35.25	39.49
3.0	44.53	10.31	99.99	11.14	6.87	14.17	34.97	39.23
2.5	44.12	9.26	98.39	10.84	6.17	13.94	34.68	38.96
2.0	43.63	8.07	96.77	10.54	5.38	13.71	34.39	38.69
1.5	42.90	6.68	95.11	10.24	4.45	13.48	34.09	38.41
1.0	42.16	4.90	62.40	9.92	3.27	13.24	33.79	38.13
0.8	33.34	4.41	41.68	9.79	2.94	13.14	33.34	33.34
0.6	19.76	2.61	24.59	9.66	1.74	13.04	19.67	19.67
0.4	9.18	1.23	11.48	6.12	0.82	6.12	9.18	9.18
0.2	2.78	0.35	3.48	1.85	0.23	1.85	2.78	2.78
SPILLWAY CREST (ft)	**1214.0**	**1248.5**	**1234.7**	**1284.3**	**1327.3**	**1291.7**	**1273.1**	**1316.0**

- Data unavailable.
* Flow rates prior to 2-18-82, when constriction plate was in place.
**Flow rates after 2-18-82, when constriction plate was removed.

Water Discharge (ft³/s)						
Reservoir number						
26	27	28	29	30	31	32
127.65	-	-	-	-	-	-
125.85	-	-	-	-	-	-
124.02	-	-	-	-	-	-
122.17	-	211.81	-	-	-	-
120.38	-	207.06	-	-	-	-
118.37	-	202.19	-	-	-	-
116.42	-	197.21	-	-	-	-
114.45	-	192.10	-	-	-	-
112.43	-	186.85	-	-	-	-
110.38	-	181.45	-	-	-	-
108.29	90.88	175.89	-	-	213.11	-
106.16	89.12	170.14	-	-	206.84	22.51
103.99	87.33	164.20	15.76	44.22	200.37	21.02
101.76	85.49	158.03	14.56	42.98	193.69	19.41
99.49	83.62	151.62	13.24	41.02	186.77	17.65
98.33	82.66	148.30	12.53	40.00	183.21	16.71
97.16	81.69	144.92	11.78	38.96	179.59	15.70
95.97	80.71	141.45	10.97	12.80	175.88	14.63
94.76	79.72	137.88	10.11	11.79	172.10	13.47
87.09	78.17	127.55	9.16	10.68	168.23	12.21
82.11	77.33	102.64	8.64	10.08	166.26	11.52
76.81	76.49	96.01	8.10	9.44	164.27	10.79
71.11	75.63	88.89	7.51	8.76	162.26	10.01
64.92	74.77	81.14	6.87	8.02	160.22	9.17
58.06	73.89	72.58	6.17	7.20	158.15	8.23
50.28	73.01	62.85	5.38	6.28	156.05	7.18
41.06	72.11	51.32	4.45	5.19	139.88	5.94
29.03	49.92	36.29	3.27	3.81	67.94	4.36
23.52	33.34	29.40	2.94	3.43	45.39	3.91
13.95	19.67	17.44	1.74	2.03	26.77	2.32
6.58	9.18	8.22	0.82	0.96	12.50	1.09
1.91	2.78	2.38	0.23	0.27	3.79	0.31
1315.0	**1329.0**	**1254.0**	**1270.0**	**1242.8**	**1237.3**	**1247.7**

Table 4—Continued. Water discharge data for principal spillways

HEAD ABOVE CREST (ft)	Water Discharge (ft³/s) Reservoir number							
	33	34	35	36	38	39	41	42
38.0	-	-	-	-	-	-	-	-
36.0	-	-	-	-	-	-	-	-
34.0	-	-	-	-	-	-	-	-
32.0	-	-	-	-	-	-	-	-
30.0	-	-	-	-	-	-	-	-
28.0	-	-	-	-	-	-	-	-
26.0	-	-	-	-	-	-	-	-
24.0	-	-	-	-	-	-	-	-
22.0	-	-	-	-	56.62	-	-	-
20.0	-	-	-	-	55.17	-	-	-
18.0	-	136.60	-	-	53.68	-	-	-
16.0	-	133.13	-	-	52.14	28.14	-	-
14.0	-	129.57	41.64	36.14	50.57	26.27	-	-
12.0	-	125.91	40.40	34.51	48.94	24.26	18.15	18.26
10.0	15.88	122.13	39.13	32.80	47.25	22.07	17.26	17.47
9.0	15.38	120.20	38.48	31.92	46.39	20.88	16.80	17.05
8.0	14.86	118.23	37.81	31.00	45.50	19.63	16.32	16.63
7.0	14.32	116.23	37.14	30.06	44.60	18.29	15.83	16.20
6.0	13.67	114.19	36.45	29.09	43.69	16.84	15.33	15.75
5.0	13.18	112.10	35.74	28.08	42.75	15.26	14.81	15.29
4.5	12.88	111.05	35.38	27.56	42.27	14.40	14.54	15.06
4.0	12.57	109.97	35.02	27.04	41.79	13.49	14.27	14.82
3.5	12.25	108.89	34.66	26.50	41.30	12.52	13.99	14.58
3.0	11.93	107.79	34.28	25.95	40.81	11.46	13.71	14.33
2.5	11.59	106.68	33.91	25.38	40.31	10.29	13.42	14.08
2.0	11.25	105.54	33.52	24.81	39.80	8.97	13.12	13.83
1.5	10.89	104.38	33.13	24.22	39.29	7.42	12.82	13.57
1.0	10.53	62.40	32.73	23.60	38.77	5.44	12.51	13.31
0.8	10.38	41.68	22.23	23.35	38.56	4.90	12.38	13.20
0.6	10.22	24.59	13.11	19.67	24.59	2.90	10.96	10.96
0.4	5.29	11.48	6.12	9.18	11.48	1.37	5.29	5.29
0.2	1.87	3.48	1.85	2.78	3.48	0.39	1.87	1.87
SPILLWAY CREST (ft)	**1226.3**	**1230.0**	**1182.5**	**1193.0**	**1231.7**	**1234.1**	**1229.7**	**1207.8**

- Data unavailable.
* Flow rates prior to 2-18-82, when constriction plate was in place.
**Flow rates after 2-18-82, when constriction plate was removed.

Water Discharge (ft³/s)						
Reservoir number						
43	44	45	46	48	49	50
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	113.88	-
-	76.16	-	-	-	111.30	-
-	73.82	-	-	-	108.65	-
15.87	72.02	-	-	-	105.94	-
15.05	69.54	-	36.67	-	103.15	18.19
14.17	66.98	18.10	35.04	8.86	100.29	16.55
13.71	65.66	17.66	34.20	8.39	98.82	15.66
13.24	64.31	17.21	33.33	7.89	97.33	14.72
12.74	62.93	16.75	32.45	7.36	95.82	13.72
12.23	61.52	16.28	31.53	6.79	94.28	12.63
11.70	60.07	15.78	30.59	6.16	92.71	11.44
11.42	59.34	15.53	30.11	5.82	91.91	10.80
11.41	58.59	15.28	29.62	5.46	90.98	10.12
10.84	57.83	15.02	29.13	5.07	89.83	9.39
10.54	57.06	14.76	28.62	4.66	88.67	8.59
10.24	56.28	14.49	28.10	4.20	87.48	7.72
9.92	55.48	14.21	27.57	3.68	86.28	6.73
9.59	54.67	13.93	26.83	3.08	85.07	5.56
9.25	49.92	13.65	26.05	2.33	62.40	4.08
9.11	33.34	13.53	25.74	1.95	41.68	3.67
8.97	19.67	10.96	19.67	1.45	24.59	2.18
6.12	9.18	5.29	9.18	0.68	11.48	1.02
1.85	2.78	1.87	2.78	0.19	3.48	0.29
1204.3	**1159.5**	**1140.6**	**1157.1**	**1089.2**	**1300.4**	**1254.2**

Table 5.—Water discharge for the grassy emergency spillways

HEAD ABOVE CREST (ft)	Water Discharge (ft³/s) Reservoir number							
	1	2	3	4	6	7	8	9
5.4	-	-	-	-	-	-	-	-
5.2	-	-	-	-	-	-	-	-
5.0	-	-	-	-	-	-	-	-
4.8	-	-	-	-	-	-	-	-
4.6	-	-	-	-	-	-	-	-
4.4	-	-	-	-	-	-	-	-
4.2	-	-	-	-	-	-	-	-
4.0	-	-	-	-	-	-	-	-
3.8	-	-	-	-	-	-	-	-
3.6	-	-	-	-	-	-	-	-
3.4	-	-	-	-	-	-	-	-
3.2	-	-	-	-	-	-	-	-
3.0	-	-	-	-	-	-	-	-
2.8	-	-	-	-	-	-	-	-
2.6	535.00	-	-	-	-	-	1280.00	-
2.4	461.00	-	-	-	1110.00	-	1110.00	-
2.2	393.00	-	-	-	944.00	-	944.00	-
2.0	329.00	-	-	-	790.00	-	790.00	-
1.8	268.00	-	803.00	-	642.00	-	642.00	-
1.6	210.00	335.00	629.00	525.00	503.00	419.00	503.00	713.00
1.4	155.00	248.00	464.00	402.00	371.00	310.00	371.00	526.00
1.2	104.00	166.00	312.00	270.00	250.00	208.00	250.00	354.00
1.0	60.00	96.00	180.00	156.00	144.00	120.00	144.00	204.00
.8	23.20	37.00	69.50	60.20	55.60	46.30	55.60	78.70
.6	6.63	10.60	19.90	17.20	15.90	13.30	15.90	22.50
.4	2.75	4.40	8.25	7.15	6.60	5.50	6.60	9.35
.2	0.66	1.06	1.99	1.72	1.59	1.33	1.59	2.25
.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SPILLWAY CREST (ft)	**1104.20**	**1093.40**	**1102.30**	**1125.40**	**1166.20**	**1150.30**	**1218.10**	**1218.40**

- Data unavailable.

Water Discharge (ft³/s)						
Reservoir number						
10	11	13	14	15	16	17
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
393.00	-	-	1260.00	-	-	-
329.00	-	-	1050.00	395.00	-	-
268.00	642.00	-	856.00	321.00	-	-
210.00	503.00	503.00	671.00	252.00	419.00	210.00
155.00	371.00	371.00	495.00	186.00	310.00	155.00
104.00	250.00	250.00	333.00	125.00	208.00	104.00
60.00	144.00	144.00	192.00	72.00	120.00	60.00
23.20	55.60	55.60	74.10	27.80	46.30	23.20
6.63	15.90	15.90	21.20	7.95	13.30	6.63
2.75	6.60	6.60	8.80	3.30	5.50	2.75
0.66	1.59	1.59	2.12	0.80	1.33	0.66
0.00	0.00	0.00	0.00	0.00	0.00	0.00
1209.70	**1163.30**	**1283.20**	**1260.60**	**1302.20**	**1227.40**	**1224.70**

Table 5—Continued. Water discharge for the grassy emergency spillways

HEAD ABOVE CREST (ft)	Water Discharge (ft³/s) Reservoir number							
	18	19	20	21	22	23	24	25
5.4	-	-	-	-	-	-	-	-
5.2	-	-	-	-	-	-	-	-
5.0	-	-	-	-	-	-	-	-
4.8	-	-	-	-	-	-	-	-
4.6	-	-	-	-	-	-	-	-
4.4	-	-	-	-	-	-	-	-
4.2	-	-	-	-	-	-	-	-
4.0	-	-	-	-	-	-	-	-
3.8	-	-	-	-	-	-	-	-
3.6	-	-	-	-	-	-	-	-
3.4	-	-	-	-	-	-	-	-
3.2	-	-	-	-	-	-	-	-
3.0	-	-	-	-	-	-	-	-
2.8	-	-	-	-	-	-	-	-
2.6	-	-	1070.00	-	-	-	-	-
2.4	-	-	922.00	-	-	-	-	-
2.2	1180.00	-	787.00	-	-	-	-	315.00
2.0	987.00	-	658.00	-	395.00	-	-	41.27
1.8	803.00	-	535.00	-	10.11	-	642.00	40.77
1.6	629.00	419.00	419.00	461.00	9.16	335.00	36.09	40.27
1.4	464.00	310.00	310.00	340.00	8.64	14.83	35.81	40.01
1.2	312.00	208.00	208.00	229.00	8.10	14.61	35.53	39.75
1.0	180.00	120.00	120.00	132.00	7.51	14.39	35.25	39.49
.8	69.50	46.30	46.30	50.90	6.87	14.17	34.97	39.23
.6	19.90	13.30	13.30	10.84	6.17	13.94	34.68	38.96
.4	8.25	5.50	5.50	10.54	5.38	13.71	34.39	38.69
.2	1.90	1.33	1.33	10.24	4.45	13.48	34.09	38.41
.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SPILLWAY CREST (ft)	**1228.10**	**1258.50**	**1245.60**	**1296.70**	**1342.00**	**1301.70**	**1292.30**	**1332.70**

- Data unavailable.

Water Discharge (ft³/s)						
Reservoir number						
26	27	28	29	30	31	32
9670.00	-	10700.00	-	-	-	-
9120.00	-	10100.00	-	-	-	-
8560.00	-	9510.00	-	-	-	-
8040.00	-	8930.00	-	-	-	-
7490.00	-	8330.00	-	-	-	-
6980.00	6200.00	7760.00	-	-	-	-
6480.00	5760.00	7200.00	-	-	-	-
5970.00	5300.00	6630.00	-	-	-	-
5500.00	4890.00	6110.00	-	-	-	-
5020.00	4460.00	5570.00	-	-	-	-
4570.00	4060.00	5080.00	-	1690.00	-	-
106.16	3670.00	4590.00	-	1530.00	-	-
103.99	3280.00	4100.00	-	1370.00	2460.00	-
101.76	2910.00	3640.00	-	1210.00	2180.00	-
99.49	2570.00	3210.00	-	1070.00	1930.00	-
98.33	2210.00	2770.00	-	922.00	1660.00	-
97.16	1890.00	2360.00	-	787.00	1420.00	-
95.97	1580.00	1970.00	-	658.00	1180.00	329.00
94.76	1290.00	1610.00	-	535.00	963.00	268.00
87.09	1010.00	1260.00	755.00	419.00	755.00	210.00
82.11	743.00	929.00	557.00	310.00	557.00	155.00
76.81	499.00	624.00	374.00	208.00	374.00	104.00
71.11	288.00	360.00	216.00	120.00	216.00	60.00
64.92	111.00	139.00	83.30	46.30	83.30	23.20
58.06	31.80	39.80	23.90	13.30	23.90	6.63
50.28	13.20	16.50	9.90	5.50	9.90	2.75
41.06	3.18	3.98	2.39	1.33	2.39	0.66
0.00	0.00	0.00	0.00	0.00	0.00	0.00
1347.80	**1344.20**	**1282.30**	**1282.90**	**1253.60**	**1253.20**	**1262.10**

Table 5—Continued. Water discharge for the grassy emergency spillways

HEAD ABOVE CREST (ft)	Water Discharge (ft³/s) Reservoir number							
	33	34	35	36	38	39	41	42
5.4	-	-	-	-	-	-	-	-
5.2	-	-	-	-	-	-	-	-
5.0	-	-	-	-	-	-	-	-
4.8	-	-	-	-	4470.00	-	-	-
4.6	-	-	-	-	4160.00	-	-	-
4.4	-	-	-	-	3880.00	-	-	-
4.2	-	-	-	-	3600.00	-	-	-
4.0	-	-	-	-	3320.00	-	-	-
3.8	-	-	-	-	3050.00	-	-	-
3.6	-	-	-	-	2790.00	-	-	-
3.4	-	-	-	-	2540.00	-	-	-
3.2	-	-	-	-	2290.00	2290.00	-	-
3.0	-	-	-	-	2050.00	2050.00	-	-
2.8	-	-	-	-	1820.00	1820.00	-	-
2.6	-	-	-	-	1600.00	1600.00	-	-
2.4	-	1380.00	-	-	1380.00	1380.00	-	-
2.2	-	1180.00	-	-	1180.00	1180.00	-	-
2.0	-	987.00	-	-	987.00	987.00	-	-
1.8	-	803.00	-	-	803.00	803.00	-	-
1.6	335.00	629.00	839.00	797.00	629.00	629.00	210.00	210.00
1.4	248.00	464.00	619.00	588.00	464.00	464.00	155.00	155.00
1.2	166.00	312.00	416.00	395.00	312.00	312.00	104.00	104.00
1.0	96.00	180.00	240.00	228.00	180.00	180.00	60.00	60.00
.8	37.00	69.50	92.60	88.00	69.50	69.50	23.20	23.20
.6	10.60	19.90	26.50	25.20	19.90	19.90	6.63	6.63
.4	4.40	8.25	11.00	10.50	8.25	8.25	2.75	2.75
.2	1.06	1.99	2.65	2.52	1.99	1.99	0.66	0.66
.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SPILLWAY CREST (ft)	**1236.20**	**1247.20**	**1195.20**	**1205.60**	**1250.20**	**1248.20**	**1241.80**	**1218.30**

- Data unavailable.

Water Discharge (ft³/s)						
Reservoir number						
43	44	45	46	48	49	50
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	5270.00	-	-	-	-	-
-	4910.00	-	-	-	-	-
-	4560.00	-	-	-	-	-
-	4200.00	-	-	-	-	-
-	3870.00	-	-	-	-	-
-	3530.00	-	-	-	-	-
-	3220.00	-	-	-	3390.00	-
-	2910.00	-	-	-	3060.00	-
-	2600.00	-	-	-	2740.00	-
-	2300.00	-	-	-	2430.00	-
-	2030.00	-	-	-	2140.00	-
-	1750.00	-	-	-	1850.00	-
-	1500.00	-	-	-	1570.00	-
-	1250.00	-	-	-	1320.00	-
-	1020.00	-	535.00	-	1070.00	-
210.00	797.00	189.00	419.00	210.00	839.00	293.00
155.00	588.00	139.00	310.00	155.00	619.00	217.00
104.00	395.00	93.60	208.00	104.00	416.00	146.00
60.00	228.00	54.00	120.00	60.00	240.00	84.00
23.20	88.00	28.80	46.30	23.20	92.60	32.40
6.63	25.20	5.96	13.30	6.63	26.50	9.28
2.75	10.50	2.48	5.50	2.75	11.00	3.85
0.66	2.52	0.60	1.33	0.66	2.65	0.93
0.00	0.00	0.00	0.00	0.00	0.00	0.00
1214.60	**1172.60**	**1150.10**	**1167.30**	**1097.50**	**1317.20**	**1265.20**

Model Implementation Project (MIP)

During 1978 through 1980 the SCS reported the following totals of MIP watershed treatments:

Treatment	Amount
Grade stabilization structures[1]	325
Critical area treatment[2]	592 acres
Diversions	233,036 feet
Grassed waterways and terrace outlets	71 acres
Pasture revegetation	3,750 acres
Terraces	28,777 feet
Animal waste lagoons	6

[1]Structures usually have a metal pipe spill drop and include ponds, erosion control dams, and road fills.
[2]Includes smoothing and vegetation of gullies and containment of runoff from oil field waste areas and salted soil areas.

Because of the work involved, we did not attempt to determine the areal locations of all of the MIP treatments. To do so would involve searching the records of the sponsoring agencies, principally the ASCS.

Other Practices

In the late 1960's and early 1970's upland-scrub-timber removal was an approved ASCS cost-sharing practice. ARS land use surveys showed that timber-pasture area decreased 5 percent from 1967 to 1974 (Staff, Water Quality and Watershed Research Laboratory 1983). Assuming half of this area was covered by trees, the cleared area totaled roughly 3,300 acres.

Although 5.9 miles of channel dredging and a concrete drop structure were in the original SCS flood control plan for East and West Bills Creeks (tributary streams), these works were not included in the final plan. Much piecemeal channel-realignment dredging has been done on the Little Washita River Channel and its tributaries, presumably by individual landowners or groups of landowners. Many of these short dredgings can be identified from the ground or from aerial photos by their straight and uniform appearance.

Data Collection

Climatologic Data

Precipitation

Figure 12 shows the locations of 36 continuous recording rain gauges on the watershed. All gauges have 24-hour charts which provide continuous records for each day until removed, except gauges 145 and 164, which have 8-day (192-hour) continuous recording charts. Since all charts were removed approximately weekly, the 8-day chart gauges were needed to determine the exact day when some rainfall events occurred at the 24-hour chart gauges.

Computer tape files LW1 through LW36 contain daily rainfall data for all 36 gauges for 1962-85. The computer tape file for data from each rain gauge is listed in table 6. A sample page of data from the files is shown in figure 13. Header information, in figure 13 and in all files, is found at the beginning of each file. Occasional missing data due to stoppages of spring-wound chart drives are denoted with a dash in the file.

Table 6.—Computer tape files containing daily rainfall data from respective rain gauges in the Little Washita River Watershed

Computer file	Rain gauge	Computer file	Rain gauge	Computer file	Rain gauge
LW1	121	LW13	137	LW25	155
LW2	122	LW14	144	LW26	156
LW3	123	LW15	145	LW27	157
LW4	124	LW16	146	LW28	159
LW5	125	LW17	147	LW29	160
LW6	130	LW18	148	LW30	161
LW7	131	LW19	149	LW31	162
LW8	132	LW20	150	LW32	163
LW9	133	LW21	151	LW33	164
LW10	134	LW22	152	LW34	165
LW11	135	LW23	153	LW35	167
LW12	136	LW24	154	LW36	182

At 11 of the above 36 rain gauges, the rainfall records were digitized with an electronic chart reader. Data points were incrementally recorded when slope breaks occurred in the accumulated rainfall record. Time intervals between data points varied from 2 minutes to over 2 hours. The rainfall data from the 11 rain gauges are contained in computer files LW37 through LW47 (table 7). Figure 14 shows a sample page of this rainfall.

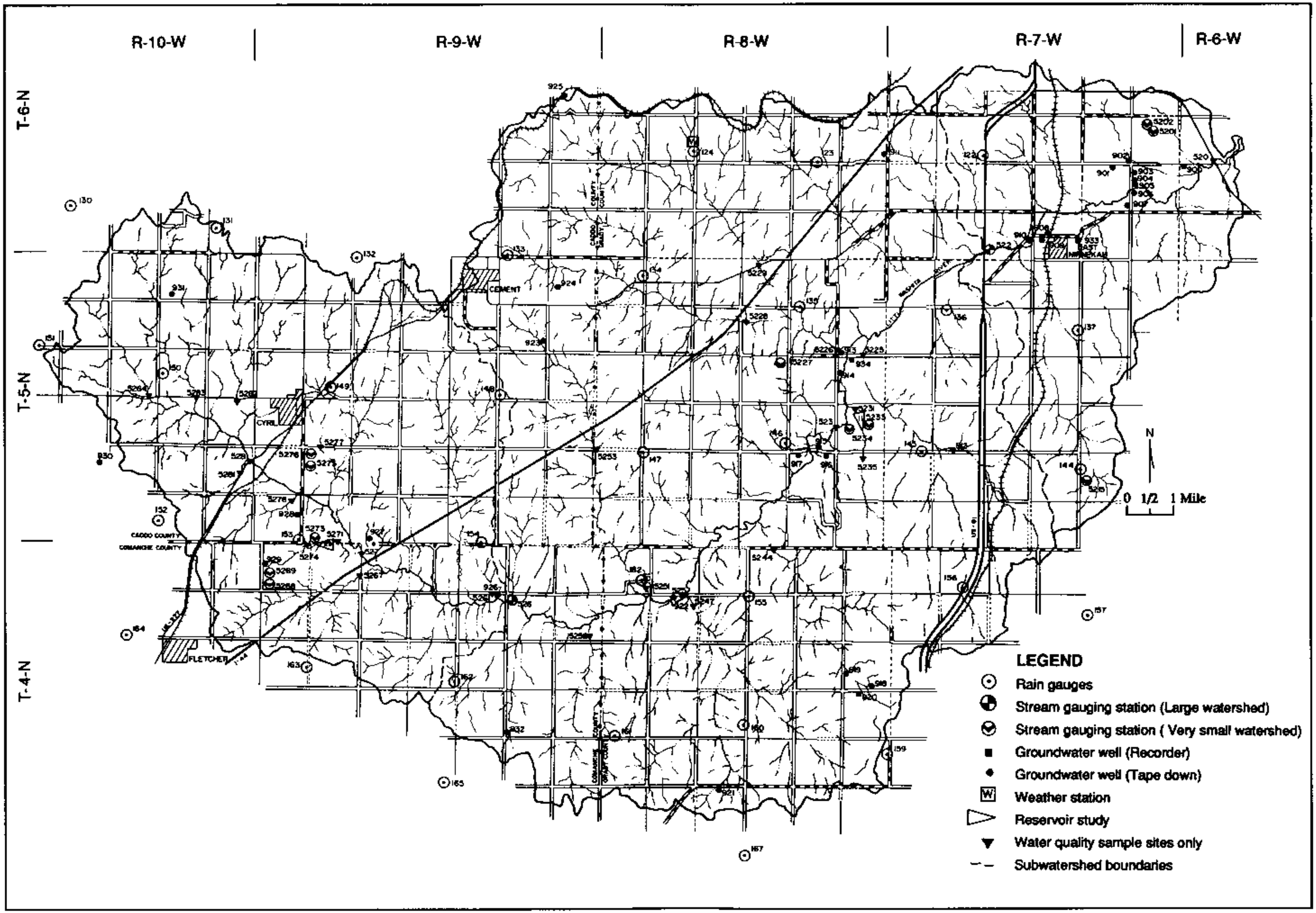

Figure 12. Locations of climatologic and hydrologic instruments and gauges in the watershed.

GAUGE	MO	DY	YR	DAILY PRECIP. (IN)
182	10	2	61	.24
182	10	9	61	1.15
182	10	10	61	.50
182	10	13	61	.11
182	10	29	61	.04
182	10	30	61	.05
182	10	31	61	.16
182	11	1	61	1.09
182	11	2	61	1.01
182	11	14	61	.02
182	11	15	61	.71
182	11	21	61	.50
182	11	22	61	.28
182	12	4	61	.08
182	12	8	61	.36
182	12	16	61	.55
182	12	17	61	.05
182	1	4	62	.10
182	1	14	62	.12
182	1	21	62	.07
182	1	25	62	.08
182	2	14	62	.20
182	2	15	62	.15
182	2	27	62	.58
182	3	13	62	.07
182	3	20	62	1.06
182	3	24	62	.04
182	3	25	62	.05
182	4	4	62	.08
182	4	5	62	.13
182	4	23	62	.57
182	4	24	62	.00
182	4	26	62	.10
182	4	27	62	.81
182	5	4	62	.09
182	5	20	62	.20
182	5	24	62	.09
182	5	25	62	.00
182	5	26	62	1.97
182	5	27	62	.10
182	5	28	62	.30
182	6	1	62	1.05
182	6	5	62	.97
182	6	6	62	.01
182	6	7	62	1.57
182	6	8	62	.07
182	6	9	62	1.25

Figure 13. Sample of daily precipitation data in files LW1 to LW36.

					ACCUM. PRECIP.	
GAUGE	MO	DY	YR	TIME (MCST)	STORM (IN)	DAILY (IN)
122	6	7	61	440	0.00	0.00
122	6	7	61	453	0.07	0.07
122	6	7	61	458	0.24	0.24
122	6	7	61	510	0.37	0.37
122	6	7	61	528	0.45	0.45
122	6	7	61	541	0.50	0.50
122	6	7	61	646	0.50	0.50
122	6	7	61	703	0.54	0.54
122	6	7	61	712	0.60	0.60
122	6	7	61	714	0.60	0.60
122	6	7	61	758	0.65	0.65
122	6	7	61	833	0.68	0.68
122	6	7	61	901	0.69	0.69
122	6	7	61	927	0.70	0.70
122	6	7	61	950	0.71	0.71
122	6	7	61	1040	0.71	0.71
122	10	2	61	15	0.00	0.00
122	10	2	61	29	0.01	0.01
122	10	2	61	46	0.02	0.02
122	10	2	61	54	0.09	0.09
122	10	2	61	56	0.10	0.10
122	10	2	61	139	0.10	0.10
122	10	2	61	153	0.12	0.12
122	10	2	61	211	0.14	0.14
122	10	2	61	242	0.14	0.14
122	10	2	61	301	0.16	0.16
122	10	2	61	313	0.17	0.17
122	10	2	61	330	0.18	0.18
122	10	2	61	357	0.18	0.18
122	10	9	61	1045	0.00	0.00
122	10	9	61	1051	0.15	0.15
122	10	9	61	1117	0.23	0.23
122	10	9	61	1157	0.37	0.37
122	10	9	61	1207	0.43	0.43
122	10	9	61	1213	0.51	0.51
122	10	9	61	1234	0.54	0.54
122	10	9	61	1256	0.61	0.61
122	10	9	61	1307	0.65	0.65
122	10	9	61	1323	0.67	0.67
122	10	9	61	1340	0.67	0.67
122	10	9	61	1350	0.71	0.71
122	10	9	61	1414	0.78	0.78
122	10	9	61	1416	0.81	0.81
122	10	9	61	1742	0.83	0.83
122	10	9	61	1801	0.84	0.84
122	10	9	61	1813	0.85	0.85

Figure 14. Sample of data in files LW37 to LW47 showing increments of precipitation accumulated by storm and by day: MCST, military central standard time.

Table 7.—Computer tape files containing incremental rainfall data from rain gauges

Computer file	Rain gauge	Computer file	Rain gauge
LW37	122	LW43	149
LW38	124	LW44	152
LW39	131	LW45	155
LW40	132	LW46	156
LW41	133	LW47	162
LW42	148		

In addition to the above 36-gauge network, the U.S. Weather Bureau has a rain gauge located at Chickasha, OK, about 4 miles north of the watershed. Record collecting began at this gauge before 1900 and continued until 1966. Other rainfall gauges were initially placed in the vicinity of Chickasha, at Anadarko, Apache, and Marlow, OK. The gauges at Apache and Marlow have since been removed.

Air Temperature

Air temperatures were monitored with a continuous temperature recorder at the ARS weather station near rain gauge 124 (see fig. 12 for gauge location) from September 1965 through 1985. Daily maximum and minimum temperatures were extracted from these records and are stored in computer file LW48. A sample page of the maximum and minimum temperature data is shown in figure 15. Maximum and minimum daily temperatures in the area from 1931 to the present can be obtained from the U.S. Weather Bureau Station at Chickasha, OK (location changed to Chickasha Experiment Station in 1966).

(AT RAIN GAUGE 124)

MO	DY	YR	AIR TEMP. MAX (°F)	AIR TEMP. MIN (°F)
8	24	65	87	66
8	25	65	96	67
8	26	65	97	72
8	27	65	98	72
8	28	65	82	63
8	29	65	86	66
8	30	65	88	71
8	31	65	87	66
9	1	65	77	55
9	2	65	79	53
9	3	65	88	64
9	4	65	91	71
9	5	65	88	73
9	6	65	87	68
9	7	65	88	68
9	8	65	89	67
9	9	65	89	67
9	10	65	88	65
9	11	65	88	64
9	12	65	91	65
9	13	65	98	69
9	14	65	97	69
9	15	65	94	70
9	16	65	91	72
9	17	65	70	50
9	18	65	83	56
9	19	65	75	62
9	20	65	82	62
9	21	65	74	51
9	22	65	75	47
9	23	65	70	53
9	24	65	58	46
9	25	65	55	43
9	26	65	77	55
9	27	65	74	53
9	28	65	78	53
9	29	65	80	61
9	30	65	62	46
10	1	65	68	43
10	2	65	72	39
10	3	65	70	53
10	4	65	59	52
10	5	65	62	52
10	6	65	67	51
10	7	65	84	51

Figure 15. Sample of data in file LW48 showing maximum and minimum daily air temperatures at rain gauge 124.

Pan Evaporation

Computer tape file LW49 contains water evaporation data collected with a Young's screen pan at the ARS weather station near rain gauge 124 from 1967 through 1985. The elevation of the water surface within the screen pan was measured approximately weekly during most of the recording period. Each elevation reading reflects water additions or abstractions from rainfall or evaporation since the previous reading. Notations are included in the file when a water surface reading was not possible because the pan water was frozen. A different notation was made if ice was known to have formed in the pan between readings. Occasionally, a series of rains or one large rainfall during a week overflowed the pan. Such periods are noted as "overflow" periods, and no water surface elevation readings are given. Figure 16 shows a sample of data from file LW49.

(AT RAIN GAUGE 124)

YR	MO	DY	PAN EVAP (IN)
67	1	4	.20
67	1	6	.18
67	1	9	.29
67	1	11	.06
67	1	16	.39
67	1	18	.30
67	1	23	.34
67	1	25	.22
67	1	27	.18
67	1	30	.20
67	1	31	.09
67	2	8	.70
67	2	10	.17
67	2	12	.32
67	2	15	.49
67	2	17	.28
67	2	20	.53
67	2	21	.15
67	2	24	.38
67	2	27	.32
67	2	28	.16
67	3	1	.16
67	3	3	.44
67	3	6	.49
67	3	8	.29
67	3	10	.21
67	3	13	.49
67	3	15	.51
67	3	17	.24
67	3	20	.42
67	3	22	.27
67	3	24	.17
67	3	27	.33
67	3	31	.31
67	4	3	.28
67	4	5	.47
67	4	7	.43
67	4	10	.26
67	4	12	.05
67	4	13	.02
67	4	17	.70
67	4	20	.30
67	4	24	.59
67	4	26	.35
67	4	30	.63
67	5	1	.16

Figure 16. Sample of data in file LW49 showing evaporation between pan readings at rain gauge 124.

Table 8.—Total evaporation per month obtained using a Young's screen pan at the ARS weather station

Year	Evaporation from screen pan (in)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1967	2.45	3.50	4.33	4.08	4.79	5.04	4.78	7.27	4.25	5.18	2.69	2.24	50.60
1968	0.54	2.37	2.37	4.81	3.50	3.30	6.47	7.21	5.23	4.01	3.57	1.85	45.23
1969	1.49	2.01	2.10	3.63	4.39	6.20	7.14	6.95	4.28	3.94	2.81	1.78	46.72
1970	1.16	2.35	2.72	4.08	5.83	6.19	7.94	8.40	6.10	3.59	3.28	2.03	53.67
1971	1.87	2.33	4.69	6.05	6.08	4.59	7.18	5.40	3.77	2.35	2.40	1.41	47.76
1972	1.31	1.53	4.23	4.67	4.18	5.57	7.11	6.24	5.17	4.36	1.94	1.08	47.39
1973	1.34	1.40	2.74	2.95	5.47	4.27	4.39	4.83	3.17	3.11	2.38	2.12	38.15
1974	1.24	2.70	3.60	4.52	4.62	5.61	6.89	5.86	3.92	3.32	2.06	1.74	46.08
1975	1.58	1.65	3.17	3.78	3.48	3.72	3.47	4.64	4.09	3.73	2.85	1.94	38.10
1976	2.01	3.05	3.79	3.50	3.73	4.81	5.53	5.50	4.48	2.78	2.62	1.79	43.59
1977	1.15	2.37	4.42	4.10	4.11	5.01	4.74	4.51	4.99	4.51	2.87	2.74	45.34
1978	-	-	2.93	4.58	4.71	-	8.20	7.02	5.72	5.16	3.58	2.32	-
1979	-	1.74	2.89	4.78	5.09	6.60	5.28	6.14	5.49	5.15	2.62	-	-
1980	-	0.87	2.95	4.40	4.90	6.58	8.26	7.78	5.68	3.90	2.16	1.36	-
1981	1.50	1.42	2.94	3.60	-	-	6.82	6.33	5.11	-	2.60	2.02	-
1982	-	-	3.25	4.33	-	4.03	6.01	6.21	5.61	4.10	2.76	1.81	-
1983	1.25	1.23	2.40	3.47	4.60	5.43	5.64	5.76	5.15	-	2.27	1.95	-
1984	1.68	2.35	2.63	3.97	5.72	5.70	6.69	5.81	5.74	3.90	2.36	-	-
1985	-	1.98	-	-	-	-	6.34	6.33	6.01	-	4.04	1.53	-

- Data unavailable.

The total evaporation for each month was calculated from file LW49 data (table 8). In early years of the data collection program, water elevation readings were also taken on the last day of each month, so the monthly totals for evaporation were based on measured data. For most of the recording period, however, the weekly readings did not fall on the last day of the month; thus, a linear interpolation was used to obtain the monthly totals.

(AT RAIN GAUGE 124)

YR	MO	DY	WIND VEL. (MPH)
65	11	5	3.0
65	11	8	1.2
65	11	12	4.1
65	11	15	4.6
65	11	22	3.3
65	11	26	4.3
65	11	29	4.9
65	12	3	3.9
65	12	6	4.1
65	12	9	5.9
65	12	13	5.9
65	12	17	4.1
65	12	20	3.4
65	12	27	5.5
65	12	30	9.3
66	1	3	4.0
66	1	7	3.3
66	1	10	5.5
66	1	14	8.5
66	1	17	5.7
66	1	24	3.7
66	1	31	5.5
66	2	7	3.9
66	2	11	6.5
66	2	15	3.9
66	2	23	6.2
66	2	28	4.2
66	3	2	7.1
66	3	4	7.7
66	3	7	6.3
66	3	9	8.2
66	3	14	7.8
66	3	15	5.1
66	3	17	7.7
66	3	21	7.7
66	3	22	8.2
66	3	24	8.8
66	3	28	5.2
66	3	30	3.7
66	4	1	4.6
66	4	4	8.7
66	4	5	5.5
66	4	8	4.5
66	4	11	7.7
66	4	13	7.0
66	4	15	5.8
66	4	18	6.3

Figure 17. Sample of data in file LW50 showing average wind velocities for the period elapsed since the previous reading at rain gauge 124.

Wind Velocities

Wind velocities were monitored from November 1965 through 1985 at the ARS weather station near rain gauge 124 with a standard three-cone anemometer, located 18 inches above the ground. The data were collected approximately weekly and average wind speed was calculated for the period elapsed since the previous reading. Computer file LW50 contains these average wind velocities. Figure 17 shows a sample page from file LW50. On four occasions the anemometer malfunctioned and had to be replaced, and on two occasions freezing rain prevented the cones from turning. Consequently, data for some periods are missing in the file.

Humidity

A continuous record of relative humidity was obtained with a hygrograph from 1965 through 1985 at the ARS weather station near rain gauge 124. Instrumentation problems prevented the inclusion of humidity data after late 1983. Daily maximum and minimum humidity data are stored in computer file LW51, and figure 18 is a sample page from the file.

Runoff, Sediment Yield, Water Quality, and Other Data

Measurement Procedures

Various standard procedures and instruments were used to obtain the data in this section. Stream stage data for the two large stream gauging sites, sites 522 and 526 (see fig. 12 for location of sites), were obtained with a mercury manometer bubble gauge and a continuous stage recorder. Since both gauging sites had channel control, periodic stream discharge measurements were made during surface runoff events and low flow periods to define the relationship between flow discharge and stage. Discharge measurements were made using reported procedures (Corbett 1943, Brackensiek et al. 1979). Discharge data by time increments were computed from the stage charts by the stage shift method (Corbett 1943, Brackensiek et al. 1979).

Sediment transport data for the two large stream gauging sites were obtained by taking several suspended sediment samples during each runoff event with a U.S. D-49 suspended sediment sampler, which was cable suspended from a stream-gauging reel and bridge crane. During low flow periods similar samples were taken weekly with a hand-held U.S. D-48 suspended sediment sampler.

Also at sites 522 and 526, samples were collected at both of these sites with a U.S. PS-66A automatic, pumping-type suspended sediment sampler. Pumped samples were obtained at 30-minute intervals prior to flow peaks and at 1- to 5-hour intervals after flow peaks, depending upon the servicing technician's selection.

(AT RAIN GAUGE 124)

			REL. HUM.	
YR	MO	DY	MAX (%)	MIN (%)
65	8	24	94	47
65	8	25	90	27
65	8	26	80	29
65	8	27	77	28
65	8	28	98	29
65	8	29	95	50
65	8	30	77	39
65	8	31	92	48
65	9	1	95	35
65	9	2	96	45
65	9	3	96	43
65	9	4	81	36
65	9	5	76	42
65	9	6	90	45
65	9	7	93	44
65	9	8	92	38
65	9	9	88	38
65	9	10	87	42
65	9	11	92	48
65	9	12	80	37
65	9	13	86	28
65	9	14	73	23
65	9	15	64	28
65	9	16	67	38
65	9	17	96	40
65	9	18	95	50
65	9	19	95	63
65	9	20	94	42
65	9	21	94	47
65	9	22	96	38
65	9	23	95	52
65	9	24	90	42
65	9	25	97	44
65	9	26	94	41
65	9	27	94	42
65	9	28	89	36
65	9	29	90	44
65	9	30	92	41
65	10	1	97	29
65	10	2	97	30
65	10	3	93	35
65	10	4	97	66
65	10	5	95	43
65	10	6	92	49

Figure 18. Sample of data in file LW51 showing daily maximum and minimum relative humidities at rain gauge 124.

These pumped samples were obtained with a fixed pipe intake near a streambank, where the flow rate is slower. Therefore, they did not represent the coarser load as did the above hand-collected, depth-integrated, equal-transit-rate (ETR) samples.

Site 526 had lower suspended sand concentrations and higher flow turbulence than site 522, which is wider and shallower. As a result of the higher flow turbulence at site 526, pumped-type samples from site 526 were generally well mixed and more representative than samples at site 522, and the concentration data for site 526 were more useful for determining sediment transport rates. Since most pumped-type samples from site 522 were not representative of the flow at site 522, concentration data from this site were used only to establish sediment concentration trends between ETR samples.

For the 11 very small (unit source) watersheds shown in figure 12, flow and sediment yield data were obtained with precalibrated flow measuring devices and automatic, pumping-type suspended-sediment samplers. These completely automated data collection devices were necessitated by the remoteness of the watersheds and by the streams' small size, which resulted in runoff peaks occurring during or soon after rainfall events. The two gully sites (gauges 5201 and 5202) and the two road erosion sites (gauges 5215 and 5227) had high sediment loads. Santa Rosa flumes were used to measure the flows of the gully and erosion sites; two-foot H-flumes were used at all other sites. Chickasha automatic, pumping-type suspended sediment samplers were used to obtain the sediment concentration records at all gauging sites. Samples were extracted at 90 degrees to the flow through a small hole near the bottom of the flume wall.

Sediment yield and transport data for all gauging sites were computed from sediment concentration and flow data as described in a manual by Brackensiek et al. (1979). This manual also describes the flow measuring devices, sediment samplers, and laboratory sediment analysis procedures.

Little Washita River Gauging Station 522

Figure 12 shows the location of stream gauging station 522 on the Little Washita River. The watershed area upstream of this gauge is 207.7 square miles. Files LW52 through LW74 contain incrementally recorded water discharge rates and measured and total sediment transport rates from 1963 through 1985. Table 9 shows the file number for data from each year. Figure 19 shows the format of data in these data files with column headings and units. File LW75 contains daily means for water discharge rate and for measured and total sediment transport rates for gauge 522 throughout the 23-year recording period. Figure 20 is a sample page of data from file LW75. Although the water discharge data in files LW52 through LW75 were first collected on April 13, 1963, sediment transport data were not collected until January 1, 1964. In addition to the 22 years of water discharge rates recorded by the ARS, the USGS has collected and published in the Water Supply Papers the water discharge data for water years (October 1 - September 30) 1952 through 1963 from a gauging site on the Little Washita River about 2 miles downstream from gauge 522.

Table 9.—Computer files by respective year for incremental discharge

Computer file	Year	Computer file	Year	Computer file	Year
LW52	1963	LW60	1971	LW68	1979
LW53	1964	LW61	1972	LW69	1980
LW54	1965	LW62	1973	LW70	1981
LW55	1966	LW63	1974	LW71	1982
LW56	1967	LW64	1975	LW72	1983
LW57	1968	LW65	1976	LW73	1984
LW58	1969	LW66	1977	LW74	1985
LW59	1970	LW67	1978	-	-

GAUGING STATION 522

YR	MO	DY	TIME (MCST)	DISCH (CFS)	SEDIMENT MEASURED (TONS/DY)	TRANSPORT TOTAL (TONS/DY)
63	4	14	12.0	20.2	21.7	74.4
63	4	15	12.0	20.2	21.7	74.4
63	4	16	12.0	19.5	21.0	71.5
63	4	17	12.0	22.3	30.1	89.3
63	4	18	12.0	34.4	55.6	154.8
63	4	19	12.0	25.3	34.1	102.8
63	4	20	12.0	19.5	21.0	71.5
63	4	21	12.0	18.1	19.6	66.0
63	4	22	12.0	17.5	18.8	63.1
63	4	23	12.0	16.2	15.3	55.5
63	4	24	12.0	16.8	20.4	62.8
63	4	25	12.0	20.9	27.0	81.8
63	4	26	0.0	21.6	29.1	86.1
63	4	26	12.2	23.0	43.5	105.1
63	4	26	14.5	28.5	138.3	217.3
63	4	26	15.0	41.0	332.0	454.9
63	4	26	16.1	40.8	253.1	375.0
63	4	26	17.1	47.8	1172.9	1319.8
63	4	26	17.8	69.3	2522.1	2751.3
63	4	26	18.0	129.5	4818.4	5307.4
63	4	26	18.1	190.7	7352.2	8128.5
63	4	26	18.5	320.6	14861.2	16305.1
63	4	26	18.9	336.9	18344.5	19877.2
63	4	26	19.0	451.5	24823.6	27012.1
63	4	26	19.4	516.7	26044.4	28616.2
63	4	26	19.6	611.8	28032.7	31186.5
63	4	26	19.9	609.8	26461.2	29602.7
63	4	26	20.6	529.5	20408.1	23058.6
63	4	26	21.2	470.9	17007.6	19306.6
63	4	26	21.5	433.5	14840.3	16924.9
63	4	26	22.1	420.0	13811.1	15815.3
63	4	26	23.1	369.1	11639.4	13352.6
63	4	26	24.0	339.3	10059.4	11603.3
63	4	27	2.9	275.8	7359.2	8562.2
63	4	27	6.9	200.5	4594.7	5419.6
63	4	27	12.2	129.4	2267.3	2751.9
63	4	27	17.2	90.8	1052.5	1371.0
63	4	27	24.0	66.5	484.2	702.9
63	4	28	12.9	49.8	214.8	369.1
63	4	28	22.5	38.9	125.9	241.4
63	4	28	24.0	33.5	90.3	186.3
63	4	29	12.0	41.8	135.1	260.6
63	4	30	12.0	37.1	110.0	218.7
63	5	1	12.0	34.4	92.7	191.9
63	5	2	12.0	37.1	90.0	198.7
63	5	3	12.0	37.1	90.0	198.7

Figure 19. Sample of data in files LW52 through LW74. Total sediment transport rates at gauging station 522 were calculated from measured sediment transport data and from estimated unmeasured bed load data: MCST, military central standard time; CFS, cubic feet per second.

GAUGING STATION 522

YR	MO	DY	DISCH (CFS)	SEDIMENT MEASURED (TONS/DY)	TRANSPORT TOTAL (TONS/DY)
63	4	14	20.0	21.7	74.4
63	4	15	20.0	21.7	74.4
63	4	16	20.0	21.0	71.5
63	4	17	22.0	30.1	89.3
63	4	18	34.0	55.6	154.8
63	4	19	25.0	34.1	102.8
63	4	20	20.0	21.0	71.5
63	4	21	18.0	19.6	66.0
63	4	22	18.0	18.8	63.1
63	4	23	16.0	15.3	55.5
63	4	24	17.0	20.4	62.8
63	4	25	21.0	27.0	81.8
63	4	26	128.0	4359.9	4936.5
63	4	27	159.0	3311.7	3951.0
63	4	28	51.0	254.9	415.7
63	4	29	42.0	135.1	260.6
63	4	30	37.0	110.0	218.7
63	5	1	34.0	92.7	191.9
63	5	2	37.0	90.0	198.7
63	5	3	37.0	90.0	198.7
63	5	4	34.0	76.8	172.8
63	5	5	32.0	72.8	163.0
63	5	6	34.0	78.8	178.0
63	5	7	34.0	74.2	173.4
63	5	8	32.0	68.6	158.7
63	5	9	28.0	61.4	140.5
63	5	10	28.0	59.7	136.1
63	5	11	26.0	56.2	127.5
63	5	12	25.0	46.3	112.8
63	5	13	25.0	46.3	112.8
63	5	14	23.0	43.5	105.2
63	5	15	20.0	31.5	82.0
63	5	16	18.0	28.3	72.6
63	5	17	14.0	19.4	54.1
63	5	18	14.0	17.4	52.1
63	5	19	14.0	15.5	50.2
63	5	20	16.0	14.7	53.1
63	5	21	13.0	10.2	39.9
63	5	22	12.0	19.5	47.5
63	5	23	14.0	9.3	42.2
63	5	24	13.0	8.9	40.0
63	5	25	12.0	7.7	34.3
63	5	26	8.5	4.6	22.9
63	5	27	7.6	4.1	20.0
63	5	28	7.1	3.8	18.7
63	5	29	6.3	3.4	16.0

Figure 20. Sample of data in file LW75, which contains daily means for water discharge rates and for measured and total sediment transport rates at gauging station 522: CFS, cubic feet per second. Total sediment transport rates were calculated from measured sediment transport data and from estimated unmeasured bed load data.

In files LW52 through LW75 the measured sediment transport rate was determined by multiplying the sediment concentration data derived from the sediment sample measurements, by the associated discharge rate data, and by an appropriate units-conversion constant. Since the nozzle for obtaining sediment samples was located a few inches above the sampler bottom, the water immediately above the stream bed was not sampled. The water at this depth contains some of the suspended load and the bed load, which is the unsuspended material that is transported across the bed surface by sliding, rolling, or saltation (a movement via a series of intermittent jumps). This unmeasured load, which was used to calculate total sediment transport, was predicted by the modified Einstein procedure. The computations for the procedure were made by using data sets collected over a period that encompassed the full flow range. Estimates of unmeasured loads were plotted on log-log paper, and a curve representing the mean unmeasured load was drawn. The curve is defined by the equation

$$S = 1.41Q^{1.2022}$$

where

S = unmeasured sediment transport rate (tons/day), and

Q = discharge rate (ft^3/s).

Table 10.—Particle-size distribution and D values for the bed material at stream gauge 522

Date collected	Discharge (ft^3/s)	Particle sizes - mm <0.062	.062-.124	.125-.249	.250-.499	.500-1.000	>1.000	D values[1] D_{35}	D_{50}	D_{65}
		(Percent of total by weight)						particle size (mm)		
6-17-63	8.5	7.9	43.7	45.6	1.8	1.0	0.0	.112	.124	.136
9-16-64	177	4.6	16.8	73.9	2.9	1.3	.5	.143	.155	.164
11-5-74	38	.5	32.3	64.2	2.4	.6	.0	.127	.137	.146
12-19-79	16	1.8	10.2	77.0	11.0	.0	.0	.147	.168	.178
5-29-80	3380	2.7	25.6	66.8	4.9	.0	.0	.128	.138	.151

[1]Subscript of D values denotes percentage of particles equal to or finer than the indicated particle size.

A variable common to all but one of the many bedload and total load procedures or equations is the size gradation of the stream bed material. Table 10 lists composited data for five sampling dates at gauge 522. Concerning the D values, the notation "D35," for example, means that 35 percent (by weight) of the particles in the sample had a diameter equal to or less than that indicated in the table.

Between 1963 and 1985 several thousand pairs of suspended sediment samples were collected and then analyzed in a laboratory for total sediment concentration. Stream temperatures were recorded at each sampling. The water discharge rate at the time of sample collection was estimated by interpolation between the pair of incremental water discharge rates (see files LW52 through LW74) for the periods most closely preceding and following the time of sample collection. Each sample collected after June 1964 was brought into the laboratory shortly after sampling and analyzed for conductivity, expressed in units of micromhos adjusted to the standard 25°C. Conductivity measurements were used to estimate a correction weight for dissolved solids. The equation for estimating dissolved solids is

$$DS = 0.742EC + 406$$

where

DS = dissolved solids in the stream ($mg\ L^{-1}$), and

EC = electrical conductivity (μmhos @ 25°C).

Each sample's calculated dissolved solid weight was subtracted from the sample's dried sediment weight to obtain its corrected sediment weight.

Data on water temperature and suspended sediment are included in the report, since they affect the microbiological aquatic environment and may, therefore, be useful to others. These data are stored as tape file LW76. Because a fairly long 22-year record exists, statistical methods can be used to detect trends in the various data over time. Figure 21 is a sample page from file LW76. A few of the sediment samples were sieved with a 62-micron wire mesh sieve to determine the percentage of sand. The sand fraction was run through a particle-size analyzer, and the data obtained were used in modified Einstein computations. Because particle-size distribution data have many uses, they are included as file LW77. Figure 22 is a sample page of data from file LW77.

GAUGE 522 YR MO DY	TIME (MCST)	INSTANTANEOUS DISCHARGE (CFS)	SEDIMENT CONCENTRATION (MG/L)	CONDUCTIVITY (MICROMHOS)	TEMPERATURE (°F)	SAND ANALYSIS
64 08 17	0850	0.3	162	1950	75	
64 08 18	0755	171.0	8080	847	73	*
64 08 18	1040	238.0	10400	1480	76	*
64 08 18	1520	212.0	8430	1260	82	*
64 08 19	0945	16.0	858	1300	77	*
64 08 25	1420	0.1	96	1420	91	
64 09 16	0930	138.0	8980	1120	65	*
64 09 16	1220	123.0	6410	1120	65	*
64 09 17	1510	15.0	1200	1120	78	*
64 09 18	1200	7.7	238	1390	78	
64 09 20	1040	1090.0	20900	1030	–	*
64 09 20	1220	868.0	19100	1210		*
64 09 21	1220	26.0	1530	1120	72	*
64 09 22	1600	44.0	1720	1250	73	*
64 09 23	0915	27.0	850	853	70	*
64 09 27	1210	71.0	3160	1650	64	*
64 09 28	1215	16.0	864	1190	68	*
64 09 29	1620	5.7	452	1650	78	
64 10 01	1425	5.6	165	1660	78	*
64 10 15	1445	5.9	164	·	65	*
64 10 22	1335	5.2	150	–	70	
64 10 28	1030	6.7	200	--	64	
64 11 02	1600	6.9	72	704	78	
64 11 03	1830	52.0	8700	812	61	*
64 11 03	1900	172.0	8920	1010	59	*
64 11 03	1935	293.0	8700	792	60	*
64 11 03	1945	372.0	12400	792	60	
64 11 03	2025	360.0	13100	678	59	*
64 11 03	2110	238.0	10700	678	59	*
64 11 03	2150	556.0	14800	1250	59	*
64 11 03	2310	970.0	23800	1000	59	*
64 11 04	0020	985.0	20000	947	59	*
64 11 04	0225	595.0	29900	920	59	*
64 11 04	0930	96.0	8310	841	60	*
64 11 04	1020	85.0	8170	895	60	*
64 11 04	1500	48.0	3080	923	60	*
64 11 05	1105	39.0	2670	1070	60	*
64 11 06	1400	31.0	1670	1150	65	
64 11 06	1805	58.0	3060	1070	60	*
64 11 07	1135	23.0	1430	1370	58	
64 11 09	1405	14.0	944	1710	70	
64 11 17	0105	510.0	20300	--	49	*
64 11 17	0200	450.0	18700	–	49	*
64 11 17	0245	969.0	28400	570	49	
64 11 17	0310	1340.0	37900	932	49	*
64 11 17	0345	1720.0	41500	932	49	*

Figure 21. Sample of data in file LW76 data from gauging station 522. Includes discharge, suspended sediment concentration, electrical conductivity, water temperature, and whether or not sand analysis was performed on samples: MCST, military central standard time; CFS, cubic feet per second; *, sand analysis was performed (results shown in fig. 22).

GAUGE 522		SIZE RANGES (MM)			
YR MO DY	TIME (MCST)	< .062	.062 .124	.125 .249	.250-.500
		PERCENT IN SIZE RANGE			
63 04 27	0820	62	20	18	0
63 07 11	1505	90	7	3	0
64 02 04	1655	55	27	18	0
64 02 05	1040	54	26	20	0
64 04 23	2320	81	15	4	0
64 04 23	2330	83	13	4	0
64 04 23	2340	81	17	2	0
64 05 06	0730	74	17	9	0
64 05 06	1125	83	11	6	0
64 05 06	1250	82	13	5	0
64 05 06	1535	85	11	4	0
64 05 08	0835	86	12	2	0
64 05 10	0105	56	26	18	0
64 05 10	0305	44	28	28	0
64 05 10	0535	58	25	17	0
64 05 11	0100	68	20	12	0
64 05 11	1550	79	9	12	0
64 05 30	0745	73	18	9	0
64 05 30	2115	72	19	9	0
64 05 31	0010	66	19	15	0
64 08 18	0755	89	6	5	0
64 08 18	1520	85	8	7	0
64 08 19	0945	67	18	15	0
64 09 16	0930	82	9	9	0
64 09 17	1510	27	20	53	0
64 09 20	1220	74	16	10	0
64 09 21	1220	83	8	9	0
64 09 27	1210	75	15	10	0
64 11 04	0225	51	28	20	1
64 11 17	0105	59	28	13	0
64 11 17	0310	48	35	17	0
64 11 17	0445	49	23	28	0
64 11 17	0720	53	23	24	0
64 11 17	0825	44	33	23	0
64 11 17	1300	60	22	18	0
64 11 17	1450	57	27	16	0
64 11 17	1655	64	19	17	0
64 11 18	1600	59	15	26	0
64 11 19	0505	47	33	20	0
64 11 19	0940	39	34	27	0
64 11 19	1510	44	28	28	0
64 11 20	1305	73	11	16	0
65 04 14	1850	90	8	2	0
65 04 14	2015	81	12	7	0
65 04 15	0035	65	23	12	0
65 04 15	0325	79	8	13	0
65 04 15	0905	78	13	9	0
65 05 09	1745	59	28	13	0
65 05 09	1835	78	12	10	0
65 05 09	2135	63	18	19	0
65 05 09	2320	59	15	26	0
65 05 14	1100	81	14	5	0
65 05 26	0900	78	13	9	0
65 05 26	1205	56	21	23	0
65 05 26	1515	63	22	15	0
65 05 26	1750	77	13	10	0
65 05 27	1250	67	17	16	0
65 06 02	1120	70	16	14	0

Figure 22. Sample of data in file LW77 showing particle-size distribution of sand in suspended sediment samples at gauging station 522: MCST, military central standard time.

Water temperature data at stream gauge 522 in addition to those in file LW76 were collected from August 8, 1969, through May 10, 1971, with an automatic continuous recorder. Daily maximum and minimum water temperatures were extracted from the recorder charts and stored as file LW78. Figure 23 is a sample page of data from file LW78.

In water year 1952 USGS collected water temperature data on the Little Washita River at a gauging site located at the railroad bridge 1/2 mile north of East Ninnekah, OK. These data were published as average daily temperatures by Dover (1954).

From October 1, 1967, through September 30, 1971, the ARS collected daily water samples at gauge 522 for water quality analyses. At each sampling, the date, time, gauge height, and stream temperature were recorded. Each sample was tested for electrical conductivity in µmhos, and adjusted to the standard 25°C. These data were stored as file LW79, and figure 24 is a sample page of the data. Discharge was determined from gauge height data. Missing data in file LW79 resulted from various problems, e.g., the stream was dry or frozen, the observer failed to obtain a sample, or the sample bottle was broken.

The samples listed in file LW79 were analyzed for water quality in a USGS laboratory either as single samples (usually for higher flows) or as 3- to 7-day composite samples for periods with base flow. Table 11 shows the types of analyses performed on these and other samples collected in 1948-71 at stream gauge 522 and the publications in which the analyses were reported. Samples collected in water year 1956 (October 1, 1955 - September 30, 1956) and prior water years probably came from the old U.S. Highway 81 bridge, 2/3 mile downstream from the present gauge 522. Samples collected in water years 1956 through 1963 were taken at the railroad bridge that crosses the Little Washita River about 2 miles downstream from the present gauge 522. From October 1, 1967, through September 30, 1971, samples were taken at the present stream gauge 522 located at the newer U.S. Highway 81 bridge (fig. 12).

From October 1, 1971, through June 24, 1976, collection of water samples at gauge 522 was continued on almost a daily schedule by ARS. As was done in previous collections, time, stream temperature, and gauge height were recorded for each sample, and the electrical conductivity was determined in the laboratory. File LW80 includes these data, and its format is the same as that of file LW79, shown in figure 24.

(AT GAUGE 522)

YR	MO	DY	WATER TEMP. MAX (°F)	WATER TEMP. MIN (°F)
69	08	25	-	80
69	08	26	72	90
69	08	27	74	94
69	08	28	74	92
69	08	29	73	95
69	08	30	74	95
69	08	31	73	97
69	09	01	69	95
69	09	02	72	90
69	09	03	71	90
69	09	04	71	94
69	09	05	71	94
69	09	06	72	96
69	09	07	73	96
69	09	08	73	89
69	09	09	72	85
69	09	10	69	80
69	09	11	69	81
69	09	12	62	87
69	09	13	66	85
69	09	14	66	79
69	09	15	70	90
69	09	16	70	80
69	09	17	70	86
69	09	18	70	82
69	09	19	67	89
69	09	20	66	89
69	09	21	71	79
69	09	22	70	80
69	09	23	69	75
69	09	24	63	78
69	09	25	66	84
69	09	26	71	87
69	09	27	71	90
69	09	28	71	90
69	09	29	72	87
69	09	30	70	85
69	10	01	66	81
69	10	02	64	85
69	10	03	64	83
69	10	04	67	79
69	10	05	70	74
69	10	06	60	66
69	10	07	54	74
69	10	08	57	76

Figure 23. Sample of data in file LW78 showing daily maximum and minimum water temperatures at gauging station 522.

Table 11.—Summary of water quality analyses at or near stream gauge 522

Water year	Number samples	Analysis Performed[1] Common constituents	Diss. solids	Trace elements	Nutrients	Publication
1948	1	x	x	-	-	Walling, 1949
1949	3	x	x	-	-	Walling, 1951
1950	2	x	x	-	-	Walling, 1951
1951	3	x	x	-	-	Dover, 1953
1952	54	x	x	x	-	Dover, 1954
1953	8	x	-	-	-	Murphy, 1955
1954	5	x	-	-	-	Dover, 1956
1955	6	x	-	-	-	Dover, 1958
1956	2	x	-	-	-	Dover, 1959
1958	33[3]	x	-	-	-	Cummings, 1963
1959	9	x	x	-	-	Cummings, 1964
1961	4	x	x	-	-	Cummings, 1965a
1962	5	x	x	-	-	Cummings, 1965b
1963	8	x	-	-	-	Cummings, 1966
1968	54	x	x	x	x	USGS, 1968
1969	75	x	x	x	x	USGS, 1969
1970	49	x	x	x	x	USGS, 1970

[1]X indicates the analysis was performed.
[2]An additional 31 samples were taken from the Little Washita River downstream at Oklahoma State Highway 19.

STATION 522

YR	MO	DY	TIME (MCST)	GAUGE HEIGHT (FT)	TEMP (°C)	ELEC COND (µMHOS)
67	10	01	0948	08.92	19	2190
67	10	02	0852	08.86	18	2380
67	10	03	0750	08.65	18	2290
67	10	04	1345	09.06	29	2330
67	10	05	0752	09.08	19	2400
67	10	06	0745	09.08	19	7510
67	10	07	0837	08.97	18	5070
67	10	08	1032	09.27	17	2230
67	10	09	1400	09.26	–	2360
67	10	10	0825	09.16	12	2080
67	10	11	1022	09.03	16	2290
67	10	12	0755	09.12	16	2290
67	10	13	1007	09.12	20	2380
67	10	14	0730	09.11	17	2310
67	10	15	1315	10.40	17	0627
67	10	16	–	09.02	19	0742
67	10	17	0830	08.90	16	1140
67	10	18	1200	08.83	18	1650
67	10	19	0740	08.81	16	2060
67	10	20	1500	08.78	22	2310
67	10	21	0950	08.78	14	2430
67	10	22	0745	08.78	13	2490
67	10	23	1230	08.78	–	2490
67	10	24	0927	08.78	14	2510
67	10	25	1410	08.77	20	0540
67	10	26	1630	08.77	20	2550
67	10	27	0725	08.80	8	2360
67	10	28	1008	08.89	11	2420
67	10	29	1028	08.82	19	2550
67	10	30	1250	08.88	07	2370
67	10	31	1335	09.45	08	1510
67	11	01	1640	09.14	13	1910
67	11	02	1635	08.99	15	2000
67	11	03	1630	08.98	13	2260
67	11	04	1630	08.99	13	2510
67	11	05	1635	08.95	09	2340
67	11	06	1630	08.90	14	2380
67	11	07	1635	08.91	14	2300
67	11	08	1630	08.88	11	2380
67	11	09	1630	09.92	14	2370
67	11	10	1630	08.89	18	2400
67	11	11	1635	08.89	18	2370
67	11	12	1630	08.93	18	2360
67	11	13	1630	08.93	20	2360
67	11	14	1635	08.92	16	2360
67	11	15	1635	08.93	18	2360
67	11	16	1630	08.93	19	2340

Figure 24. Sample of data in file LW79 showing gauge height, water temperature, and electrical conductivity data from gauging station 522. Data in file LW79 was collected in water years 1967 through 1971: MCST, military central standard time.

The water quality analyses procedures of the samples collected in 1971-76 differed from those of samples collected prior to 1971. The analyses of 1971-76 samples were performed by the ARS on roughly one individual sample per week, rather than a composite of several samples. Also, the number of analyses was decreased to include only pH, carbonate, bicarbonate, calcium, magnesium, chloride, sodium, and sulfate analyses. File LW81 includes data from the analyses, and figure 25 shows a sample page of data from the file.

More samples were collected at gauge 522 in 1979-82 during the MIP study and were analyzed for various chemical constituents. These analyses are reported later in this report in the MIP section. Table 12 shows the land use data collected in 1962, 1967, 1971, and 1974 for the Little Washita River Watershed upstream of gauge 522 (from Staff, Water Quality and Watershed Research Laboratory 1983). The 1962 data are from an aerial survey. An aerial point sampling procedure was used in other surveys.

Little Washita River Gauging Station 526

The location of stream gauging station 526 is shown in figure 12. The watershed area upstream of this gauge is 61.9 square miles. Flow and sediment transport data were collected at this gauging station from April 25, 1979, through 1985. Water quality samples were taken as part of the MIP study from February 26, 1979, through June 27, 1983. Files LW82 through LW88 contain incrementally recorded discharge rates and corresponding measured and total sediment transport rates. The data from each year are stored in a separate file. The file names for the corresponding years of data are tabulated below:

Computer file	Year
LW82	1979
LW83	1980
LW84	1981
LW85	1982
LW86	1983
LW87	1984

STATION 522

DATE			TIME	DISCH	TEMP	COND	pH	CA	MG	NA	HCO3	CO3	SO4	CL
MO	DY	YR	(MCST)	(CFS)	(⁰F)	(µMHOS)		(MG/L)						
10	1	71	1810	5.0	79	2538	7.9	420	29	62	173	4	1449	115
10	3	71	0422	3880.0	70	888	7.9	173	10	17	89	0	549	14
10	11	71	1615	15.0	75	2459	7.8	412	43	59	250	8	1449	230
10	20	71	1645	17.0	62	2089	8.2	349	29	47	206	11	713	205
10	25	71	1610	9.7	71	2649	8.1	430	40	71	233	10	937	283
11	1	71	1555	12.0	39	2466	8.1	414	38	59	211	6	960	224
11	21	71	1621	9.7	68	2653	8.0	436	47	57	252	9	1020	264
12	5	71	1555	15.0	–	2382	8.0	418	37	65	285	10	749	116
1	2	72	1615	15.0	49	2496	8.0	412	44	66	266	10	659	253
1	9	72	1231	15.0	50	2439	8.0	402	47	86	79	0	863	232
1	17	72	1635	19.0	38	2454	7.7	373	46	125	287	0	834	228
1	24	72	1710	14.0	–	2453	7.9	372	61	75	272	7	863	245
2	4	72	1610	4.2	–	2170	7.9	436	52	135	129	5	960	232
2	21	72	1616	10.8	67	2475	7.9	416	39	130	219	4	900	243
3	5	72	1635	11.0	54	2468	7.9	424	41	130	222	11	887	240
3	12	72	1835	6.5	70	2390	8.0	400	65	109	220	7	852	229
3	26	72	1830	10.2	68	2512	8.2	409	44	125	170	7	887	233
4	2	72	1645	9.2	68	2453	8.3	392	41	125	202	12	827	244
4	8	72	1508	9.2	72	2605	8.3	401	48	130	228	11	863	252
4	14	72	1910	6.8	76	2762	8.3	434	48	101	244	19	867	321
4	15	72	0925	19.0	62	1995	8.1	292	37	–	190	14	594	215
4	20	72	1640	31.0	70	1723	7.7	206	24	81	158	8	426	226
4	23	72	1800	9.7	73	2584	8.1	432	46	107	241	11	999	236
4	27	72	0535	852.0	57	849	7.8	121	15	22	110	6	286	54
4	27	72	0710	1440.0	57	1187	7.8	205	19	23	123	5	504	59
4	27	72	0853	1010.0	50	1061	7.9	184	18	17	105	5	420	37
4	27	72	1141	506.0	56	1052	7.7	197	14	11	108	0	475	28
4	27	72	1437	286.0	59	1288	7.6	244	18	12	103	3	588	31
4	28	72	1715	46.0	73	1690	8.1	275	24	37	161	10	800	86
4	30	72	1400	382.0	68	1073	7.9	189	14	12	102	5	504	30
5	7	72	1950	25.0	–	2210	8.2	364	43	75	236	12	887	204
5	12	72	1820	197.0	70	1076	7.6	177	18	20	137	0	407	42
5	13	72	1900	47.0	75	1529	7.8	257	32	40	176	8	588	102
5	15	72	1125	20.0	80	2341	8.1	396	40	75	265	0	840	201
5	21	72	1000	11.0	–	2750	8.0	404	64	106	228	3	960	287
5	26	72	1030	9.7	–	2725	8.1	442	77	160	141	6	995	296
6	1	72	1745	10.2	–	2405	8.4	408	38	97	205	11	883	192
6	10	72	1737	3.8		3040	8.2	456	51	97	205	6	931	405
6	18	72	1855	5.4	–	2596	7.9	408	46	113	171	5	860	317
6	25	72	1955	4.6	–	3087	8.0	414	62	136	156	7	944	493
7	9	72	1625	2.8	89	2761	8.3	450	61	130	158	11	999	367
7	16	72	1115	0.1	82	3352	8.2	549	93	148	169	2	999	437
7	20	72	1910	0.3	84	3472	7.2	627	96	97	143	0	1692	345
7	21	72	1815	0.4	86	2758	7.3	538	77	57	159	0	999	176
9	5	72	1445	1.8	91	2580	7.4	516	58	60	173	0	1410	126
10	31	72	1120	507.0	45	672	7.9	127	19	7	131	0	-	32
11	1	72	1445	118.0	52	1146	8.1	231	26	11	154	0	514	53

Figure 25. Sample of data in file LW81 showing results from analyses of water samples at gauging station 522. Data in file LW81 was collected in water years 1972 through 1976 at gauging station 522: MCST, military central standard time; CFS, cubic feet per second.

Table 12.—Land use survey of the Little Washita River Watershed above gauge 522

	Year			
	1962[1]	1967	1971	1974
	— — — — — (Percent) — — — —			
Cultivation				
Sowed crop	11.49	9.47	12.12	12.85
Summer sowed crop	-	2.33	3.13	1.74
Alfalfa	1.96	2.85	2.74	1.47
Row crop	3.78	2.20	.78	1.74
No crop	.52	.39	.39	.40
Subtotal	17.75	17.24	19.16	18.20
Range				
Timber pasture	-	7.78	6.13	2.81
Pasture	-	52.43	52.57	61.38
Gullied pasture	-	5.70	6.52	1.61
Subtotal	-	65.91	65.22	65.80
Miscellaneous				
Timber[2]	-	5.32	4.69	5.62
Farmstead	-	1.43	1.30	1.24
Stomp lot	-	.52	.39	.80
Farm pond	-	.65	.65	1.61
Detention reservoir	-	.13	.39	.13
Creek	-	3.74	2.73	1.24
Farm road	-	1.30	.91	.94
Private road	-	.26	.26	.00
Highway (paved)	-	1.30	1.82	1.34
Urban	-	.13	.26	.27
Rock	-	2.07	2.22	2.81
Subtotal	-	16.85	15.62	16.00

[1]Hyphen indicates no measurement was taken. Range and miscellaneous land uses comprised 82.25 percent of the watershed.
[2]Dense timber with little or no forage growth.
Source: Staff, Water Quality and Watershed Research Laboratory, 1983.

The data in these files are in the same format as the incrementally recorded data for stream gauge 522. Therefore, the format of the data in files LW82 through LW88 can be seen in figure 19.

File LW89 contains daily means for water discharge rate and for measured and total sediment transport rates for 1979-85. The format of file LW89 is identical to that shown in figure 20.

Total sediment load at gauge 526 was calculated using the same modified Einstein procedure that was used for calculating total sediment load at stream gauge 522. Total sediment load data from site 526 were used to develop a relationship between unmeasured load and discharge rate. The relationship curve is represented by the equation

$$S = 0.109\, Q^{1.775}\, Q^{-0.0066 \ln Q} \qquad [3]$$

for discharge rates below 45 ft^3/s

or

$$S = 0.276\, Q^{1.607}\, Q^{-0.0338 \ln Q} \qquad [4]$$

for discharge rates above 45 ft^3/s

where

S = unmeasured sediment transport rate (tons/day), and

Q = discharge rate (ft^3/s).

Table 13 gives the particle-size distribution of the bed material and suspended sediment in the analyzed samples. File LW90 contains data from the suspended sediment samples, including the date and time of collection, discharge rate, suspended sediment concentration, electrical conductivity, and stream temperature. Since the storage format for stream gauge 526 data is the same as that used for sample data from stream gauge 522, figure 21 serves as an example of the format in file LW90. The chemical constituent data from the water quality samples collected at gauge 526 are included later in the MIP section of this report.

Model Implementation Project (MIP)

Hydrologic data collection for the MIP on the Little Washita River Watershed commenced in mid-1979 to study the effects of intensive land treatment on the quality of water in the basin. The previously described rain gauge network, which was already in place, was sufficient and was not altered. Stream gauge 526 was used to monitor flow discharge, sediment transport, stream temperature, water quality, and particle-size distribution. Eleven unit source watersheds were instrumented to monitor smaller streams that flowed into the main channel. A groundwater study that was already in place was expanded (see groundwater well section). A 24-stream-site water quality study was begun, and 2 reservoirs were selected for a water quality study (see reservoir section).

Table 14 lists the 11 unit source watersheds and their respective drainage areas and land uses. Figure 12 shows the locations of the watershed gauges. Files LW91 through LW101 contain the data incrementally measured throughout each runoff event, and table 15 indexes the file numbers to the data from the respective watersheds. Figure 26 shows data in files LW91 through LW101. Annual summaries of runoff and sediment yield for the watersheds are shown in table 16.

Table 13.—Particle-size distribution and D values for the bed material and suspended sediment at stream gauge 526

Date collected	Discharge (ft^3/s)	Particle sizes - mm: <0.062	.062-.124	.125-.249	.250-.500	D values[1]: D_{35}	D_{50}	D_{65}
		(Percent of total by weight)				particle size (mm)		
		Bed Material						
12-19-79	7.0	1.7	54.3	44.0	0.0	.113	.121	.130
5-29-80	797.0	1.9	42.7	51.9	3.5	.121	.128	.134
		Suspended Sediment						
5-29-80	1070.0	47.3	39.1	12.9	.7	-	-	-
5-29-80	2160.0	55.0	29.4	15.6	.0	-	-	-
5-29-80	1430.0	52.8	33.1	13.1	1.0	-	-	-
5-29-80	847.0	87.1	8.2	4.5	.2	-	-	-

[1]Subscript of D values denotes percentage of particles equal to or finer than the indicated particle size.

Table 14.—Drainage areas and land uses for the 11 unit source watersheds

Watershed No.	Drainage area (Acres)	Land use
5201	9.39 9.22 after 6-83	Native grass pasture with large gully; formerly cultivated.
5202	14.06 14.23 after 6-83	Native grass pasture with large gully; formerly cultivated.
5215	1.17 .85 after 9-84	Road ditch gully.
5227	7.83	Road ditch gully.
5233	5.71	Good native grass pasture.
5234	2.87	Poor native grass pasture; formerly cultivated.
5268	7.69	Idle land. Now improved pasture.
5269	10.30	Wheat. Now improved pasture.
5273	3.50	Bermudagrass pasture.
5275	1.49 1.46 after 1-82	Conventional till wheat.
5276	1.37 1.28 after 1-82	Low till wheat.

Table 15.—Computer file numbers for incremental runoff and sediment yield data for the 11 unit source watersheds

Computer file	Watershed No.	Computer file	Watershed No.
LW91	5201	LW97	5268
LW92	5202	LW98	5269
LW93	5215	LW99	5273
LW94	5227	LW100	5275
LW95	5233	LW101	5276
LW96	5234	—	—

GAUGING STA.	MO	DY	YR	CODE	TIME (MCST)	GHT (FT)	SED CONC (PPM)	DISCH. (CFS)	----RUNOFF---- (IN/HR)	(ACC IN)	SEDIMENT (LBS/HR)	TRANSPORT (ACC LBS)
5201	1	19	80	1	1210	.00	0.	.0000	.00000	.00000	.000	.000
5201	1	19	80	1	1212	.14	40000.	.1200	.01267	.00021	1078.272	17.971
5201	1	19	80	1	1214	.28	50000.	.6270	.06622	.00153	7042.464	153.317
5201	1	19	80	1	1216	.32	48000.	.8650	.09136	.00415	9327.053	426.142
5201	1	19	80	1	1218	.30	44100.	.7330	.07742	.00697	7261.556	702.619
5201	1	19	80	1	1222	.24	40000.	.4400	.04647	.01109	3953.664	1076.459
5201	1	19	80	1	1226	.19	34000.	.2140	.02260	.01340	1634.480	1262.730
5201	1	19	80	1	1232	.16	30000.	.1630	.01722	.01539	1098.489	1399.379
5201	1	19	80	1	1240	.20	22260.	.2750	.02904	.01847	1375.134	1564.287
5201	1	19	80	1	1250	.31	18000.	.7950	.08396	.02789	3214.598	1946.765
5201	1	19	80	1	1300	.25	17230.	.4800	.05070	.03911	1857.863	2369.469
5201	1	19	80	1	1310	.19	16000.	.2440	.02577	.04548	876.995	2597.374
5201	1	19	80	1	1320	.26	14000.	.5240	.05534	.05224	1647.959	2807.786
5201	1	19	80	1	1326	.20	11500.	.2750	.02904	.05646	710.424	2925.705
5201	1	19	80	1	1345	.15	7650.	.1380	.01458	.06337	237.152	3075.738
5201	1	19	80	1	1350	.19	7000.	.2440	.02577	.06505	383.685	3101.606
5201	1	19	80	1	1355	.20	6000.	.2750	.02904	.06733	370.656	3133.037
5201	1	19	80	1	1403	.14	5000.	.1200	.01267	.07011	134.784	3166.732
5201	1	19	80	1	1415	.09	4000.	.0420	.00444	.07183	37.740	3183.984
5201	1	19	80	1	1440	.07	3000.	.0240	.00253	.07328	16.174	3195.216
5201	1	19	80	1	1455	.04	2000.	.0060	.00063	.07367	2.696	3197.575
5201	1	19	80	2	1508	.00	1000.	.0000	.00000	.07374	.000	3197.867
5201	1	19	80	1	1718	.00	0.	.0000	.00000	.00000	.000	.000
5201	1	19	80	1	1723	.04	2000.	.0060	.00063	.00003	2.696	.112
5201	1	19	80	1	1728	.05	1800.	.0110	.00116	.00010	4.448	.410
5201	1	19	80	1	1748	.05	1500.	.0110	.00116	.00049	3.707	1.769
5201	1	19	80	1	1758	.03	1000.	.0030	.00032	.00061	.674	2.134
5201	1	19	80	1	1812	.01	1000.	.0000	.00000	.00065	.000	2.213
5201	1	19	80	1	1818	.03	1000.	.0030	.00032	.00066	.674	2.246
5201	1	19	80	1	1823	.11	2000.	.0670	.00708	.00097	30.102	3.529
5201	1	19	80	1	1834	.10	1800.	.0540	.00570	.00214	21.835	8.290
5201	1	19	80	1	1852	.06	1500.	.0160	.00169	.00325	5.391	12.374
5201	1	19	80	1	1904	.06	1200.	.0160	.00169	.00359	4.313	13.344
5201	1	19	80	1	1928	.03	1000.	.0030	.00032	.00399	.674	14.341
5201	1	19	80	1	1958	.01	800.	.0000	.00000	.00407	.000	14.510
5201	1	19	80	1	2018	.01	800.	.0000	.00000	.00407	.000	14.510
5201	1	19	80	1	2028	.02	800.	.0010	.00011	.00408	.180	14.525
5201	1	19	80	1	2050	.02	800.	.0010	.00011	.00412	.180	14.591
5201	1	19	80	2	2106	.00	800.	.0000	.00000	.00413	.000	14.618
5201	1	19	80	1	2354	.00	0.	.0000	.00000	.00000	.000	.000
5201	1	20	80	1	0	.05	2000.	.0110	.00116	.00006	4.942	.247
5201	1	20	80	1	10	.07	5000.	.0240	.00253	.00037	26.957	2.905
5201	1	20	80	1	19	.10	10000.	.0540	.00570	.00098	121.306	14.025
5201	1	20	80	1	27	.14	16000.	.1200	.01267	.00221	431.309	50.866
5201	1	20	80	1	36	.15	13000.	.1380	.01458	.00425	403.004	113.439

Figure 26. Sample of data in files LW91 through LW101, which contain incrementally measured data on gauge height (GHT), sediment concentration, discharge, runoff, and sediment transport for the 11 unit source watersheds: MCST, military central standard time.

Table 16.—Annual runoff and sediment yield for the 11 unit source watersheds

Watershed	Runoff volume (inches/acre)						Sediment yield (tons/acre)					
	1980	1981	1982	1983	1984	1985	1980	1981	1982	1983	1984	1985
5201 - Gully	1.58	1.89	1.78	4.07	3.22	2.47	30.84	10.03	7.84	20.79	14.77	10.33
5202 - Gully	2.50	2.83	3.73	4.30	3.93[1]	3.89[1]	51.49	46.79	40.68	28.10	30.28[1]	9.99[1]
					4.99[2]	4.04[2]					53.40[2]	10.28[2]
5215 - Roadside Erosion	3.12	8.1	13.47	9.47	4.32	5.40	80.97	131.58	271.59	172.14	44.93	80.38
5227 - Roadside Erosion	2.27	6.89	6.68	—	—	—	41.29	37.70	25.74	—	—	—
5233 - Native Range Virgin	0.12	0.39	0.14	—	—	—	0.03	0.03	0.00	—	—	—
5234 - Native Range Form. Cult.	0.35	1.02	0.67	—	—	—	0.11	0.18	0.02	—	—	—
5268 - Idle Land Form. Cult.	4.90	5.76	4.83	6.24	2.24	6.84	1.16	0.09	0.03	0.05	0.01	0.07
5269 - Wheat	7.22	8.15	6.58	10.53	8.70	10.10	10.55	3.41	1.62	3.25	1.13	3.69
5273 - Improved Pasture Bermuda	0.79	0.01	0.00	—	—	—	1.48	0.00	0.00	—	—	—
5275 - Wheat Conv. Till	5.59	6.02	4.63	5.31	2.85	7.08	1.70	1.43	0.11	0.63	0.63	1.03
5276 - Wheat Low Till	5.05	5.06	3.99	6.50	4.26	—	1.08	1.48	0.88	0.39	0.82	—

[1] From entire watershed.
[2] From area of watershed that contributes.

For each runoff event files LW102 through LW112 contain runoff and sediment yield data, and mean concentrations of chemical constituents in the runoff water. Table 17 indexes the computer file numbers to the data from the respective watersheds. Figure 27 shows a sample page of data in files LW102 through LW112.

The load (on a weight basis) of a chemical constituent in storm runoff can be obtained by multiplying the mean concentration of that constituent by the storm runoff volume and by the appropriate unit conversion constant.

Table 16.—Annual runoff and sediment yield for the 11 unit source watersheds

	Runoff volume (inches/acre)						Sediment yield (tons/acre)					
Watershed	1980	1981	1982	1983	1984	1985	1980	1981	1982	1983	1984	1985
5201 - Gully	1.58	1.89	1.78	4.07	3.22	2.47	30.84	10.03	7.84	20.79	14.77	10.33
5202 - Gully	2.50	2.83	3.73	4.30	3.93[1]	3.89[1]	51.49	46.79	40.68	28.10	30.28[1]	9.99[1]
					4.99[2]	4.04[2]					53.40[2]	10.28[2]
5215 - Roadside Erosion	3.12	8.1	13.47	9.47	4.32	5.40	80.97	131.58	271.59	172.14	44.93	80.38
5227 - Roadside Erosion	2.27	6.89	6.68	—	—	—	41.29	37.70	25.74	—	—	—
5233 - Native Range Virgin	0.12	0.39	0.14	—	—	—	0.03	0.03	0.00	—	—	—
5234 - Native Range Form. Cult.	0.35	1.02	0.67	—	—	—	0.11	0.18	0.02	—	—	—
5268 - Idle Land Form. Cult.	4.90	5.76	4.83	6.24	2.24	6.84	1.16	0.09	0.03	0.05	0.01	0.07
5269 - Wheat	7.22	8.15	6.58	10.53	8.70	10.10	10.55	3.41	1.62	3.25	1.13	3.69
5273 - Improved Pasture Bermuda	0.79	0.01	0.00	—	—	—	1.48	0.00	0.00	—	—	—
5275 - Wheat Conv. Till	5.59	6.02	4.63	5.31	2.85	7.08	1.70	1.43	0.11	0.63	0.63	1.03
5276 - Wheat Low Till	5.05	5.06	3.99	6.50	4.26	—	1.08	1.48	0.88	0.39	0.82	—

[1]From entire watershed.
[2]From area of watershed that contributes.

For each runoff event files LW102 through LW112 contain runoff and sediment yield data, and mean concentrations of chemical constituents in the runoff water. Table 17 indexes the computer file numbers to the data from the respective watersheds. Figure 27 shows a sample page of data in files LW102 through LW112.

The load (on a weight basis) of a chemical constituent in storm runoff can be obtained by multiplying the mean concentration of that constituent by the storm runoff volume and by the appropriate unit conversion constant.

WATERSHED 5201				----NITROGEN-----		--PHOSPHORUS--					ELEC				
MO DY YR	SEDIMENT	RUNOFF	NO3	NH4	TKN	REACTIVE	TOTAL	CL	SO4	pH	COND	NA	K	CA	MG
	(KG/HA)	(CM)	------ (PPM) ------			---- (PPB) ------		------- (PPM)		-----	(μMHOS)	-------- ---- (PPM) -----------			
1 19 80	469.00	.290	.500	.070	8.80	17.70	2691.00	2.10	5.50	8.03	120.00	.00	-	-	
5 15 80	6329.00	.590	.740	.060	70.62	17.20	14926.00	2.87	10.10	7.60	125.00	.01			-
5 18 80	1599.00	.150	.540	.110	21.68	17.80	6887.00	2.34	9.10	7.50	122.00	.01	-	-	-
6 22 80	3429.00	.470	1.080	.000	18.80	4.80	7010.00	4.14	9.30	8.00	173.00	.00	-	-	-
4 30 82	435.00	.152	.750	.140	10.90	20.40	5204.00	3.60	.00	7.30	128.00	.00	-	-	-
5 5 82	8543.00	1.210	.910	.000	14.00	11.10	5987.00	3.40	17.30	7.50	203.00	-	-	-	-
5 12 82	278.00	.114	.770	.000	7.55	20.00	4557.00	4.50	16.90	7.50	148.00	-	-	-	-
5 17 82	570.00	.371	.320	.000	1.26	16.00	2849.00	4.10	14.30	6.10	135.00	-	-	-	
5 19 82	83.00	.060	.240	.050	3.75	27.10	1562.00	4.60	18.70	6.40	95.00	-	-		-
5 24 82	2556.00	.779	.640	.000	7.78	10.60	4138.00	3.70	16.10	6.50	184.00		-	-	
5 24 82	356.00	.101	.250	.000	3.90	7.10	2692.00	2.10	20.90	5.90	118.00	-	-		-
5 26 82	196.00	.099	.240	.120	3.65	24.60	1762.00	2.30	34.30	6.00	117.00		-	-	-
5 27 82	172.00	.099	.710	.040	5.09	24.00	2209.00	3.60	12.40	6.50	203.00	-	-		-
6 17 82	13.00	.020	.320	.090	9.50	6.50	7618.00	3.50	32.80	5.90	156.00	.00	-	-	-
6 25 82	53.00	.030	.610	.070	5.60	8.20	3274.00	3.80	17.40	6.40	147.00	-	-	-	-
7 7 82	2435.00	.512	.360	.020	9.75	16.20	5085.00	3.60	12.30	6.70	174.00	-	-	-	-
9 14 82	735.00	.141	.370	.060	12.30	12.00	7545.00	3.70	15.50	6.10	136.00		-	-	-
5 23 83	167.61	.059	.420	.090	11.10	18.90	5773.00	3.60	21.60	6.62	109.00	-	-	-	-
6 13 83	1182.59	.287	.420	.000	12.87	12.10	6612.00	3.10	5.40	6.36	132.00	-		-	-
10 19 83	7929.65	2.292	.490	.040	11.20	16.60	6356.00	4.10	17.50	7.21	164.00	-	-	-	
10 19 83	703.67	.189	.240	.060	9.00	12.80	5094.00	3.80	27.00	7.11	133.00	-			-
10 19 83	11744.30	7.142	.250	.030	9.20	13.60	5253.00	2.20	12.60	7.11	106.00	-	-	-	
4 7 84	274.44	.074	.800	.050	11.20	-	5867.00	1.10	15.30	6.20	155.00	5.24	.54	18.40	11.00
10 26 84	13166.67	2.541	.850	.010	20.45	-	8854.00	2.50	16.60	7.99	159.00	4.09	1.61	20.50	7.30
12 13 84	810.31	.265	.490	.050	9.20	-	6201.00	2.70	12.70	8.01	144.00	4.64	1.82	14.40	6.60
12 15 84	470.18	.209	.320	.040	4.80	-	3150.00	4.10	20.00	7.70	121.00	4.28	1.99	13.50	5.50
12 31 84	4738.92	2.443	.290	.090	6.15	-	3943.00	4.00	18.20	7.83	101.00	3.67	1.57	11.70	4.40
3 3 85	1059.00	1.100	.550	.000	4.15	12.70	2627.00	3.00	22.40	7.83	136.00	6.12	2.01	15.10	5.72
3 19 85	401.00	.326	.470	.010	8.75	11.00	4380.00	2.00	20.40	7.89	125.00	6.57	1.67	12.60	5.67
3 26 85	197.00	.073	.520	.050	8.60	17.90	4748.00	3.40	21.10	8.01	168.00	7.31	1.91	21.20	7.03
3 30 85	1150.00	.217	.430	.030	12.00	10.00	6657.00	2.00	18.30	7.85	125.00	4.52	1.79	13.70	5.24
4 22 85	2187.00	.510	.630	.010	7.10	13.20	4019.00	1.80	15.60	7.91	134.00	4.82	1.88	15.30	6.44
4 29 85	50.90	.036	.500	.020	5.10	13.80	2486.00	2.60	23.00	7.91	156.00	7.40	1.94	16.90	7.00
6 5 85	25.80	.015	.450	.020	8.25	12.00	4372.00	4.10	22.20	8.09	174.00	9.76	1.98	18.80	9.40
8 7 85	1823.00	.368	1.390	.020	20.00	13.60	9341.00	2.80	17.20	8.21	239.00	9.37	1.90	24.50	11.30
8 23 85	1679.00	.216	1.000	.030	25.20	8.70	13845.00	5.70	23.60	8.10	245.00	11.30	1.98	28.40	13.40
9 22 85	4886.00	.664	.660	.020	10.30	10.70	5725.00	3.30	16.50	8.09	147.00	6.63	1.92	16.70	6.84
9 29 85	455.00	.129	.440	.050	8.89	25.60	5473.00	3.00	20.80	7.79	140.00	7.78	1.64	14.10	6.78
10 18 85	1299.00	.508	.530	.040	4.25	.00	2964.00	1.50	11.50	7.71	132.00	4.88	2.03	14.30	5.88
11 14 85	317.00	.255	.240	.030	4.38	.00	2917.00	2.00	11.60	7.90	107.00	3.08	1.96	12.40	4.37

Figure 27. Sample of data in files LW102 through LW112, which include data on sediment yields, runoff yields, and mean concentrations of chemical constituents in runoff water from each runoff event in the 11 unit source watersheds: TKN, total Kjeldahl nitrogen. Electrical conductivity data are also provided.

SITE 520 MO	DY	YR	NITROGEN NO3 (PPM)	NITROGEN NH4 (PPM)	NITROGEN TKN (PPM)	PHOSPHORUS REACTIVE (PPB)	PHOSPHORUS TOTAL (PPB)	CL (PPM)	SO4 (PPM)	PH	ELEC COND (µMHOS)	NA (PPM)	K (PPM)	CA (PPM)	MG (PPM)
2	26	79	.540	1.030	1.78	105.00	222.00	305.00	642.00	–	-	.01	.00	.00	.00
4	16	79	.390	.360	1.45	101.00	366.00	127.00	704.00	-	–	.04	.00	.00	.00
5	21	79	.470	.140	2.88	47.80	1601.00	172.00	510.00	–	–	.02	.00	.00	.00
6	9	79	.730	.000	11.03	89.70	4540.00	26.10	168.00	–	–	.00	.00	.00	.00
7	30	79	.100	.170	.76	53.50	97.30	105.00	916.00	–	1800.00	.00	.00	.00	.00
12	17	79	.450	2.900	4.02	49.00	220.00	240.80	624.00	7.55	2200.00	.01	.00	.00	.00
3	12	80	.290	.160	.57	52.00	111.00	200.00	734.00	8.00	1940.00	.01	.00	.00	.00
5	15	80	2.020	.080	6.17	50.90	1923.00	91.10	448.00	7.60	1430.00	.00	.00	.00	.00
5	21	80	–	.000	14.00	54.70	2359.00	114.50	576.00	7.60	1310.00	.00	.00	.00	.00
5	29	80	.430	.680	24.99	36.20	7817.00	21.90	220.00	7.70	775.00	.03	.00	.00	.00
7	14	80	.060	.220	.60	63.30	52.70	33.30	504.00	7.80	1470.00	.03	.00	.00	.00
8	21	80	.120	.000	.72	71.30	60.90	66.00	1196.00	7.30	2260.00	.00	.00	.00	.00
12	9	80	.330	.860	2.45	27.10	287.00	81.00	772.00	7.90	1810.00	.02	.00	.00	.00
2	19	81	.200	.480	1.18	49.00	164.00	190.00	1104.00	8.20	1930.00	–	.00	.00	.00
2	18	82	.570	.210	.80	58.10	161.00	123.00	796.00	6.60	1860.00	–	.00	.00	.00
5	6	82	.400	.280	8.73	49.30	4918.00	78.60	446.00	6.00	1210.00	–	.00	.00	.00
8	23	82	.000	.040	.98	8.10	72.00	72.00	1032.00	6.70	1910.00		.00	.00	.00

Figure 28. Sample of data in files LW113 through LW136, which contain analyses of water samples taken during the 24-stream-site sampling study: TKN, total Kjeldahl nitrogen.

WELL NO.	LOCATION LATITUDE (DEG	MIN	SEC)	LONGITUDE (DEG	MIN	SEC)	TOP OF PIPE (FT)	ELEVATIONS ABOVE MSL GROUND SURFACE (FT)	BEDROCK SURFACE (FT)	DEPTH OF WELL (FT)
900	34	59	08	97	51	50	1057.99	1057.99	972.97	85.00
901	34	58	18	97	52	40	1052.47	1052.47	1022.47	30.00
902	34	58	20	97	53	58	1065.95	1065.95	999.95	66.00
903	34	58	10	97	53	58	1062.86	1062.86	1015.86	47.00
904	34	58	02	97	53	58	1064.19	1064.19	1021.19	43.00
905	34	57	56	97	53	58	1065.40	1065.20	1024.90	40.00
906	34	57	47	97	53	58	1066.97	1066.77	1031.77	35.00
907	34	57	43	97	53	59	1070.31	1068.81	1031.81	37.00
908	34	57	00	97	55	48	1079.98	1077.98	1020.98	60.00
909	34	57	00	97	55	55	1081.27	1080.27	1018.27	63.00
910	34	56	59	97	56	34	1079.87	1079.87	1018.87	61.00
913	34	54	47	98	00	15	1120.62	1120.62	1051.62	69.00
914	34	53	37	98	00	18	1128.84	1128.84	1061.14	68.00
915	34	53	05	98	00	48	1137.39	1137.39	1071.39	66.00
916	34	53	00	98	01	02	1140.26	1140.26	1071.26	69.00
917	34	53	00	98	00	35	1136.62	1138.62	1072.62	66.00
934	34	54	45	97	59	59	1117.31	1117.31	1047.31	70.00

Figure 29. Sample of physical data in file LW137 showing locations; elevations of pipe top, ground surface, and bedrock surface; and well depths for each groundwater well: MSL, mean sea level.

WELL NO.	LAYER NO.	LAYER THICK (FT)	SOIL TEXTURE OR LITHOLOGY	LAYER COLOR
900	1	6	F.SAND	RED
900	2	2	SILT	GRAY
900	3	1	SILT-F.SAND	GRAY-RED
900	4	9	SILT-C.SAND	RED
900	5	5	F.SAND	RED
900	6	23	V.F.SAND-GYP	
900	7	12	V.F.SAND-M.SAND	–
900	8	11	SILT-V.F.SAND	GRAY-BROWN
900	9	11	SILT-C.SAND	–
900	10	5	C.SAND-GYP	–
900	11	0	UNDIF-BEDROCK	–
902	1	15	F.SAND	–
902	2	2	UNDIF-ALLUV	.
902	3	17	F.SAND	–
902	4	2	SANDSTONE	.
902	5	30	SILT	-
902	6	0	UNDIF-BEDROCK	–
903	1	47	F.SAND	TAN
903	2	0	UNDIF-BEDROCK	–
904	1	43	UNDIF-ALLUV	
905	1	28	V.F.SAND	–
905	2	2	SAND	–
905	3	41	SILT	
905	4	0	UNDIF-BEDROCK	–
906	1	16	CLAY	
906	2	–	-	..
906	3	14	SAND	–
906	4	5	SAND	
908	1	3	F.SAND	BLACK
908	2	4	GRAVEL	–
908	3	1	F.SAND	BLACK
908	4	5	V.F.SAND	TAN
908	5	5	F.SAND-SILT	RED
908	6	39	V.F.SAND	–
908	7	0	UNDIF-BEDROCK	–
909	1	16	F.SAND-GYP	TAN
909	2	8	F.SAND-SILT	TAN
909	3	8	SILT-F.SAND	RED
909	4	4	M.SAND-GYP	–
909	5	12	F.SAND	RED
909	6	15	F.SAND-LIME	RED
909	7	0	UNDIF-BEDROCK	–
912	1	12	F.SAND	TAN
912	2	18	CLAY	RED
912	3	5	F.SAND	ORANGE
912	4	5	SANDSTONE	RED
913	1	4	SAND	...

Figure 30. Sample of data in file LW138 showing driller's log of the wells.

WELL NO.	MO	DY	YR	TIME (MCST)	WATER ELEV (FT ABOVE MSL)
900	1	22	70	1102	1039.20
900	2	25	70	1353	1039.12
900	4	8	70	1331	1039.04
900	5	14	70	1200	1038.85
900	6	24	70	853	1038.69
900	8	11	70	1418	1038.48
900	10	6	70	1505	1039.42
900	2	25	71	1406	1038.75
900	4	30	71	1040	1038.44
900	6	1	71	1325	1038.40
900	7	19	71	1312	1037.99
900	8	26	71	1228	1039.48
900	10	4	71	900	1040.71
900	12	1	71	1205	1040.01
900	1	25	72	1104	1040.13
900	1	25	72	1104	1040.13
900	3	9	72	902	1039.98
900	5	2	72	1025	1040.44
900	6	9	72	1247	1040.22
900	8	1	72	1028	1039.80
900	9	14	72	954	1038.44
900	10	19	72	850	1037.66
900	12	7	72	1028	1039.83
900	1	24	73	955	1039.98
900	1	24	73	955	1039.98
900	3	19	73	1238	1041.31
900	4	25	73	954	1041.97
900	5	17	73	845	1041.92
900	6	27	73	754	1042.80
900	7	20	73	955	1042.30
900	9	21	73	1016	1042.69
900	12	6	73	1122	1043.61
900	2	27	74	1407	1042.86
900	2	27	74	1407	1042.86
900	6	19	74	1032	1042.96
900	10	7	74	1243	1043.77
900	1	22	75	1140	1043.37
900	1	22	75	1140	1043.37
900	4	28	75	937	1043.39
900	6	27	75	1249	1044.07
900	9	5	75	1405	1047.21
900	11	7	75	1035	1047.02
900	1	23	76	1427	1046.25
900	1	23	76	1427	1046.25
900	3	23	76	1507	1046.25
900	6	3	76	800	1045.77
900	8	13	76	1049	1045.35
900	10	19	76	1016	1045.17

Figure 31. Sample of data in files LW139 through LW163, which contain data on well water elevations above mean sea level (MSL): MCST, military central standard time.

During the MIP study, water levels in the 25 groundwater wells were measured, and water samples were collected 1 or more times per year and analyzed for content of chemical constituents as a determinant of water quality. An additional 10 wells, numbered 911, 920-22, 924-26, 930-31, and 933 (see fig. 12 for locations), were also sampled and tested for chemical constituents. File LW164 contains the chemical analyses for all 35 wells, and figure 32 shows a sample page of data from the file.

Well NO.	Date MO DY YR	Time (MCST)	TEMP (°F)	NO2-N (PPM)	NO3-N (PPM)	NH3-N (PPM)	pH	ELEC. COND. (µmhos/cm)	SO4= (PPM)	Cl- (PPM)	TKN (PPM)	TWS-P (PPB)	Boron (PPM)
900	11 20 79	1300	–	–	0.43	11.87	8.2	740.	34.8	40.1	–	1157.0	0.0
900	3 10 80	1048	55	–	.09	30.50	8.3	950.	133.0	48.4	–		–
900	6 25 80	1102	67	–	4.10	.00	7.6	643.	29.1	22.9	–	–	–
900	12 11 80	–	–	–	.15	119.00	7.0	2020.	16.9	46.0	–	6183.0	–
900	4 28 81	–	–	–	.09	–	8.2	1750.	12.2	23.9		–	–
900	6 25 81	–	–	–	3.90	63.70	7.5	1590.	14.8	32.8	–	64.8	
900	1 20 82	–			.68	.28		–	–	–		3.8	–
901	7 20 79	1217	–	–	2.20	.00	–	–	9.2	13.4	–	79.1	
901	11 20 79	1235	–		2.32	.00	6.1	570.	13.0	11.2	–	40.1	–
901	3 10 80	1537	64	–	1.17	.30	8.4	530.	12.5	4.5		–	–
901	6 26 80	1042	67	–	1.45	.00	7.6	562.	11.5	8.2	–	–	–
901	8 15 80	–	–	–	1.30	.00	7.6	695.	20.0	6.9	–	–	–
901	12 11 80	–	–	–	1.21	.00	8.0	609.	17.4	8.0	–	27.4	–
901	4 28 81	–	–		1.15	.07	8.2	613.	38.6	8.4	–	–	–
901	6 25 81		–	–	1.20	.40	7.9	616.	17.5	13.8	–	13.8	–
901	1 20 82	–	–	–	1.46	.13	–		–	–	–	15.3	–
902	11 20 79	1213		–	.17	91.10	7.2	840.	10.4	25.1	–	11263.0	–
902	2 19 80	1300	64	0.006	.07	3.30	8.2	820.	15.9	5.2	4.06	559.0	
902	2 19 80	1340	64	.000	.04	.26	8.3	790.	15.9	5.7	.44	184.0	–
902	2 19 80	1350	64	.085	.27	9.50	8.2	270.	7.9	7.6	19.97	668.0	–
902	4 22 80	–	–	–	.06	.17	7.5	813.	19.6	5.8	–	–	–
902	6 26 80	1024	70	–	.75	.00	7.7	727.	18.7	6.4	–	–	–
902	8 15 80	–	–	–	.28	.00	8.0	778.	28.7	7.6	–	–	–
902	12 11 80	–		–	.78	.00	8.4	775.	27.8	10.0	–	192.0	–
902	4 28 81	–	–	–	.49	.37	8.0	750.	29.8	9.2	–		
902	6 01 81	–	–		.26	.21	6.5	607.	147.0	20.8		115.0	–
902	6 25 81			–	.38	.17	7.9	614.	134.0	34.4	–	52.0	–
902	1 20 82	–	–	–	.86	.13	–		–	–	–	25.7	–
903	11 20 79	1205		–	.28	.20	7.9	940.	221.0	66.4	–	224.0	–
903	3 10 80	0937	54	–	.38	.00	8.2	1260.	240.0	82.0	–	–	–
903	6 25 80	1014	67	–	.10	.00	8.0	1210.	249.0	70.4	–	–	–
903	8 15 80	–	–	–	.00	.05	7.9	1240.	304.0	66.0	–	–	
903	12 11 80	–	–		.21	.11	8.1	1240.	340.0	59.0	–	296.0	–
903	4 28 81		–	–	.15	.20	8.1	1340.	305.0	52.0	–	–	–
903	6 01 81	–	–	–	.08	.09	6.6	705.	179.0	29.0	–	411.0	
903	6 25 81	–		–	.04	.19	8.0	708.	192.0	41.3	–	57.3	–
903	1 20 82	–	–	–	.31	.15	–	–		–	–	31.2	
904	7 20 79	1228	–		4.40	.00	–	–	42.4	134.0	–	4.5	–
904	11 20 79	1228	–	–	5.08	.00	8.0	860.	42.1	111.0	–	8.9	–
904	3 10 80	0919	63	–	4.13	.00	8.4	1040.	40.8	137.0	–	–	–
904	6 26 80	1035	70	–	5.10	.00	7.6	956.	34.0	120.0	–	–	–
904	8 15 80	–	–	–	5.60	.00	7.9	1040.	49.0	112.0	–	–	–
904	12 11 80	–		–	–	–		–	–		–	–	–
904	4 28 81		–	–	6.60	.16	8.0	1250.	56.7	113.0	–		
904	6 25 81	–	–		5.60	.06	7.9	1130.	48.7	163.0	–	35.5	–
904	1 20 82		–	–	6.50	.10	–	–	–	–	–	4.8	
905	11 20 79	1140	–	–	.16	.99	8.0	1500.	932.0	28.5	–	17.9	–

Figure 32. Sample of data in file LW164. Chemical analyses of water from groundwater wells as a determinant of water quality: MCST, military central standard time; EC, electrical conductivity; TKN, total Kjeldahl nitrogen; TWS-P, total water soluble phosphorus.

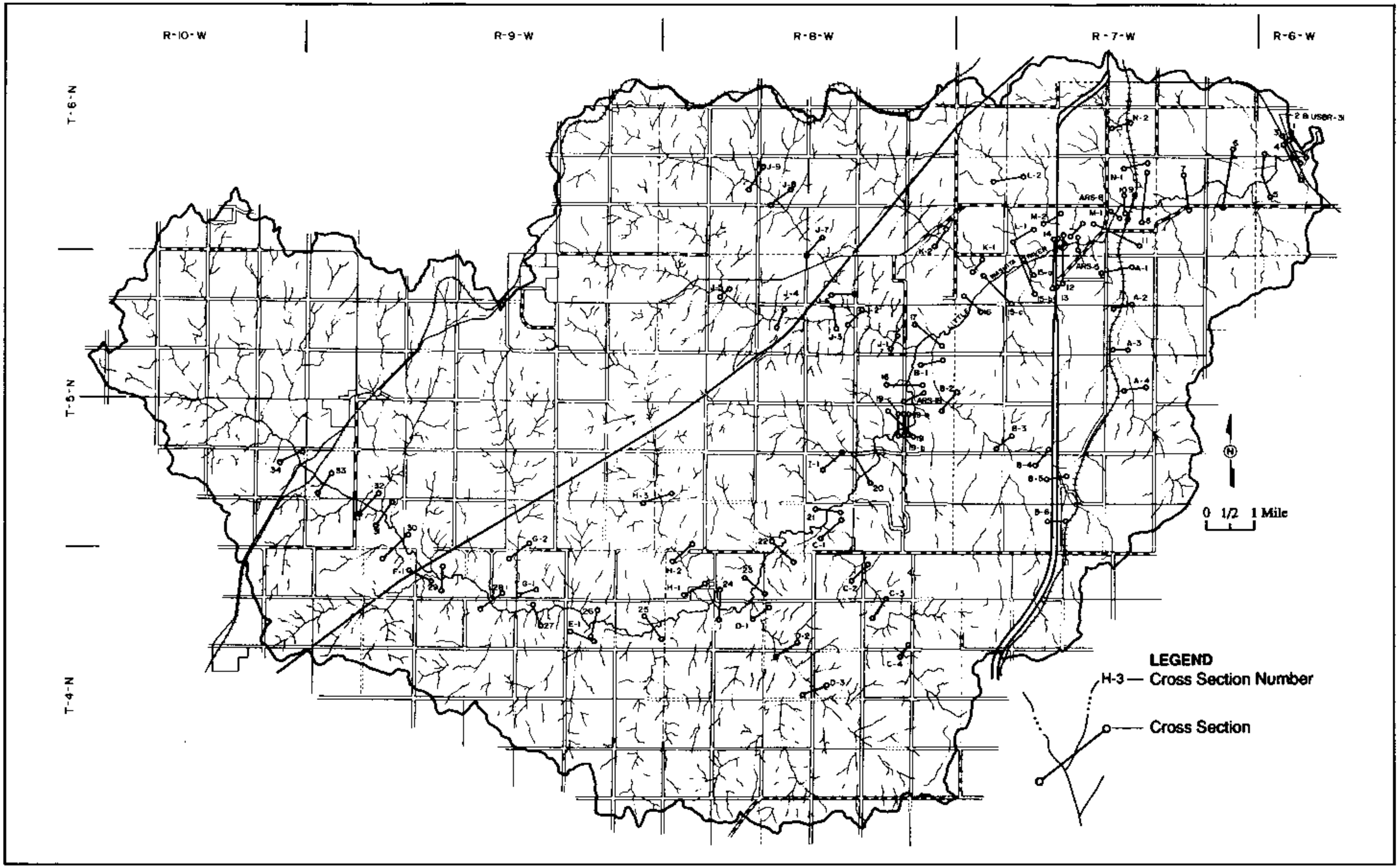

Figure 33. Locations of channel cross sections in the watershed.

Stream and Valley Cross Sections

In 1964, 81 stream and valley cross sections were surveyed in SCS studies on the Little Washita River and its tributaries in conjunction with planning the floodwater control program for the watershed. Although the SCS studies provided some information on flood plain vegetation as an indication of flow roughness and resistance, SCS' primary purpose was to study flood flow. The SCS cross sections, those not labeled "ARS" or "USBR" in figure 33, are located throughout most of the watershed and were surveyed only once by the SCS. The three cross sections labeled "ARS" were established in the late sixties in an ARS study to determine the hydrologic effects and changes in channel geometry attributable to the upstream

SCS floodwater-retarding program. Some of the SCS cross sections were resurveyed many times during the ARS study. Another cross section, USBR-31 (established by the U.S. Bureau of Reclamation in 1948) was also resurveyed several times in the ARS study. Elevation data and notes from all of the original cross section surveys and resurveys are in file LW165. Figure 34 is a sample page of data from file LW165.

CROSS SECTION	DATE MO DY YR	STATION (FEET)	ELEV (FEET)	********** REMARKS ***********
1	08 28 64	000.	1062.0	North End X-Sec
1	08 28 64	100.	1059.2	Cotton Field
1	08 28 64	200.	1058.6	
1	08 28 64	300.	1057.5	
1	08 28 64	400.	1057.2	
1	08 28 64	500.	1056.7	
1	08 28 64	600.	1057.0	
1	08 28 64	700.	1057.2	
1	08 28 64	800.	1056.9	Alfalfa Begins
1	08 28 64	900.	1054.1	
1	08 28 64	1000.	1051.8	
1	08 28 64	1100.	1051.5	
1	08 28 64	1161.	1052.4	
1	08 28 64	1200.	1050.3	
1	08 28 64	1300.	1045.8	
1	08 28 64	1400.	1044.7	
1	08 28 64	1500.	1044.6	
1	08 28 64	1527.	1044.6	Small Grain Begins
1	08 28 64	1600.	1044.8	
1	08 28 64	1700.	1045.1	
1	08 28 64	1800.	1045.3	
1	08 28 64	1900.	1045.2	
1	08 28 64	2000.	1044.8	
1	08 28 64	2100.	1044.8	
1	08 28 64	2200.	1046.0	
1	08 28 64	2280.	1045.9	Alfalfa Begins
1	08 28 64	2300.	1046.4	
1	08 28 64	2366.	1052.7	
1	08 28 64	2400.	1048.8	
1	08 28 64	2430.	1050.0	Cotton Begins
1	08 28 64	2500.	1056.2	
1	08 28 64	2600.	1056.2	
1	08 28 64	2670.	1056.8	Alfalfa Begins
1	08 28 64	2700.	1055.1	
1	08 28 64	2733.	1049.4	
1	08 28 64	2767.	1047.8	
1	08 28 64	2800.	1048.9	
1	08 28 64	2900.	1048.9	
1	08 28 64	2922.	1051.7	
1	08 28 64	2962.	1056.3	
1	08 28 64	2975.	1056.3	
1	08 28 64	3000.	1057.1	
1	08 28 64	3100.	1056.3	
1	08 28 64	3200.	1055.2	
1	08 28 64	3300.	1054.4	
1	08 28 64	3400.	1054.1	
1	08 28 64	3500.	1053.1	
1	08 28 64	3550.	1049.7	
1	08 28 64	3600.	1049.3	
1	08 28 64	3658.	1050.1	
1	08 28 64	3673.	1050.4	North Top Bank
1	08 28 64	3681.	1046.9	
1	08 28 64	3687.	1054.3	
1	08 28 64	3700.	1040.5	Bank Toe
1	08 28 64	3705.	1035.7	
1	08 28 64	3715.	1031.7	
1	08 28 64	3725.	1031.2	Dry Channel
1	08 28 64	3762.	1030.7	
1	08 28 64	3774.	1037.3	Bank Toe
1	08 28 64	3800.	1048.4	
1	08 28 64	3810.	1050.5	
1	08 28 64	3894.	1051.2	South Top Bank
1	08 28 64	3900.	1042.8	
1	08 28 64	3907.	1038.0	
1	08 28 64	3911.	1038.0	Drain
1	08 28 64	3918.	1045.4	
1	08 28 64	3936.	1051.4	
1	08 28 64	4000.	1049.9	Johnson Grass Pasture Begins
1	08 28 64	4070.	1051.1	
1	08 28 64	4100.	1053.6	
1	08 28 64	4130.	1055.2	
1	08 28 64	4200.	1056.7	South End X-Sec.

Figure 34. Sample of file LW165 showing data and notes from surveys of many stations located along cross section 1: ELEV, elevation in feet above mean sea level.

Converting cross section locations obtained from aerial photos and from field sketches and notes to digital data requires special software and consumes an exorbitant amount of storage. Therefore, surveyed location data in this report do not include latitude and longitude. Users needing to determine this information should seek copies of the original field notes and documented aerial photos from the SCS Floodwater Planning Office at Chickasha, OK, or the ARS National Agricultural Water Quality Laboratory at Durant, OK.

Floodwater-Retarding Reservoirs

Of the 45 floodwater-retarding reservoirs built in the Little Washita River basin, only three (reservoirs 11, 23, and 41) were selected for study. Reservoirs 11 and 23 (see figs. 11 and 12 for locations) were selected for water quality study during the MIP. At reservoir 11, continuous stage records were collected at an inflow weir and on the reservoir itself so that the rates of the inflow and outflow could be determined later if desired. At reservoirs 11 and 23, water samples were collected on a per storm basis for chemical analyses of the inflow, the reservoir itself, and the outflow. Chemical analyses data from reservoir 11 samples collected from inflow (site 5235), within reservoir, and outflow (site 5231) sites are stored in files LW166, LW167, and LW168, respectively (see fig. 12 for locations of numbered sites). Files LW169, LW170, and LW171 contain chemical analyses for inflow (gauge 5274), within reservoir, and outflow (gauge 5271) samples, respectively, from reservoir 23. Inflow gauge 5274 measured only a part of the total inflow. The data storage format for these files is identical to that for files LW166 through LW168. Figure 35 shows a sample of data in files LW166 through LW171.

Reservoirs 41, 11, and 23 were topographically surveyed along parallel ranges, generally 100 feet apart in the permanent pool area, and established from a base transect on one shore. A topographic map was constructed from these survey data with 2-foot contour intervals, and the map was used to estimate the stage-volume

SAMPLING SITE - 5235

				------PHOSPHORUS------						ELEC				
MO DY YR	NO3	NH4	TKN	SOLUBLE	REACTIVE	TOTAL	CL	SO4	PH	COND	NA	K	CA	MG
------(PPM)	-------	-------	(PPB)	-------	------	(PPM)----	(µMHOS)	-------(PPM)	--------					
4 10 79	.090	.000	.45	43.90	19.30	67.20	12.50	217.00	-	-	.00	-	-	-
5 22 79	.160	.120	.94	74.70	54.70	132.00	29.70	180.00			.01			
5 30 79	.650	.210	3.76	41.30	39.10	4863.00	12.20	290.00	-	-	.01	-	-	-
5 30 79	.190	.090	.76	80.50	61.20	146.00	14.90	150.00	.		.00			.
5 30 79	.170	.000	.64	68.40	46.50	111.00	14.60	142.00	.	-	.00	-	-	-
6 5 79	.200	.270	1.82	68.80	50.80	712.00	9.30	156.00	-	-	.00	-	-	-
6 7 79	.180	.320	1.31	77.80	49.60	308.00	4.60	82.00	.		.00	-	-	-
6 11 79	.540	.000	.80	86.10	59.90	127.00	11.30	144.00	-	715	.00	-	-	-
6 25 79	.070	.320	.92	97.20	65.20	124.00	17.20	136.00	-	..	.01	.	..	..
7 9 79	.090	.160	.60	88.90	76.70	101.00	11.70	163.00	-	-	.00	-	-	-
7 23 79	.100	.080	.47	49.00	45.80	55.00	12.40	142.00	-	680	.01	-	-	-
8 6 79	.080	.100	.36	174.00	53.80	62.40	15.60	122.00		540	.00		.	
9 10 79	.090	.070	.65	50.90	48.30	88.90	17.90	161.00	-	720	.00	-	-	-
10 9 79	.130	.150	.47	25.70	16.00	47.00	17.10	216.00		840	.00			
11 13 79	.120	.180	.47	59.70	51.70	73.50	17.70	158.00	8.15	700	.00	-	-	-
12 28 79	.200	.000	1.53	63.90	56.40	265.00	15.00	157.10	8.00	720	.00	-	-	-
1 19 80	.200	.050	1.10	59.70	47.50	287.00	14.40	181.90	7.95	757	.00	-	-	-
5 15 80	.130	.100	1.89	113.00	63.20	474.00	9.17	179.00	7.80	676	.00	-	-	-
5 20 80	.180	.270	1.86	132.00	88.90	488.00	3.53	196.50	8.00	709	.00	.	.	.
5 29 80	.500	.050	4.86	65.20	45.90	2265.00	1.99	-	7.60	499	.01	-	-	-
6 22 80	.870	.000	7.15	129.00	121.00	3127.00	10.20	225.00	8.40	752	.38	.		.
7 2 80	.080	.000	.47	75.90	51.00	80.50	20.00	116.00	9.20	641	.16	.	-	-
12 7 80	.220	.190	-	58.60	42.90	1550.00	-	460.00	7.90	-	-	-	-	-
4 30 81	.610	.240	4.91	76.70	68.60	1230.00	10.40	104.00	7.70	314	.02			.
5 9 81	.230	.210	22.20	50.60	43.90	816.00	14.60	226.00	7.40	653	.01	-	-	-
6 15 81	.220	.000	2.12	53.70	53.50	966.00	10.50	222.00	7.90	635	.00	-	-	-
7 28 81	.140	.060	1.08	76.00	70.00	649.00	16.10	223.00	6.40	550	.00	-	-	-
8 7 81	.210	.100	2.84	79.00	52.00	1558.00	11.70	196.00	6.60	420	.00	-	-	-
8 16 81	.150	.060	2.65	86.00	72.80	1468.00	7.20	84.70	7.00	30	.00			
10 15 81	.090	.230	1.63	96.60	91.20	344.00	10.30	188.00	6.50	430	-	-	-	-
6 1 81	.220	.150	1.54	63.80	70.20	583.00	16.10	138.00	6.80	632	-	-		
6 3 81	.220	.250	2.10	83.60	80.70	686.00	10.60	131.00	7.00	508	-	-	-	-
5 13 82	.100	.100	1.38	42.20	48.30	308.00	15.00	264.00	6.40	503	-	-	-	-
5 17 82	.140	.060	3.13	54.30	62.20	1021.00	10.20	270.00	6.70	469	.	-	-	-
5 24 82	.250	.200	1.86	98.80	116.00	435.00	18.50	390.00	6.40	913	-	-	-	-
5 27 82	.300	.060	1.24	82.40	89.00	892.00	17.00	348.00	6.40	772	-	..	..	.
5 31 82	.250	.000	1.55	107.00	103.00	1099.00	13.20	344.00	6.50	573	-	-	-	-
6 11 82	.310	.220	1.80	105.00	111.00	539.00	15.00	365.50	6.60	759	-	-	-	-
6 19 82	.450	.160	3.28	122.00	122.00	1040.00	20.20	374.00	6.40	782			.	
6 25 82	.170	.130	2.17	88.80	88.80	767.00	13.40	197.00	6.30	810	-	-	-	-
7 7 82	.140	.070	4.30	66.50	53.40	1797.00	13.80	366.00	6.70	615	.			

Figure 35. Format of data in files LW166 through LW171. Analyses of discharge-weighted storm event samples collected from inflow, within reservoir, and outflow sites at reservoirs 11 and 23: TKN, total Kjeldahl nitrogen.

and stage-area data. Stage-volume and stage-area data have various uses in hydrologic investigations and modeling. Stage-volume data can be used with spillway stage-discharge data to estimate reservoir inflow and outflow. Stage-volume and spillway stage-discharge data from two surveys a few years apart can be used to estimate the sedimentation rate during that period. Stage-volume data are needed to estimate flow routes through drainage basins. Stage-area data are useful inputs for watershed models that have water surface evaporation routines.

Stage-area and stage-volume data for all of the floodwater-retarding reservoirs are shown in table 3. Data for most of the reservoirs in table 3 were estimated before the reservoirs were constructed and were not obtained from surveys. Data from these unconstructed reservoirs originated from USGS 10-feet interval topographic maps and from design plans for borrow pit areas (sites where dam fill material would be obtained). Reservoirs 41, 11, and 23 were surveyed in August 1969, October 1979, and November 1979, respectively. Survey data in table 3 for reservoirs 11, 23, and 41 were obtained by actual measurement after reservoir construction and are therefore more accurate than data from nonsurveyed reservoirs. None of the surveyed reservoirs have been resurveyed.

Published Findings

Runoff

In the Little Washita River Watershed and several other watersheds in the Southern Great Plains Watershed area, where average annual runoff volumes were roughly 2 inches or more, no detectable changes in annual runoff volumes were seen after the Little Washita River Watershed was treated with floodwater-retarding reservoirs (Staff, Water Quality and Watershed Research Laboratory 1983).

Nicks et al. (1985a) applied the SWRRB hydrology model to the Little Washita River basin to predict runoff. The basin was divided into four subbasins representing different soils, plant covers, and topographies. Predicted runoffs in each basin compared well with observed runoffs in the basins. Nicks et al. stated that the model should have broad applications in estimating long term basinwide runoff effects from land treatments and structures. Subsequently, Nicks et al. (1986) used the SWRRB hydrology model and estimated that runoff volumes decreased about 3 percent after reservoirs were installed on the Little Washita River Watershed.

Hartman et al. (1967) and Schoof et al. (1980) reported that peak stream flow was reduced on other watersheds treated with floodwater-retarding reservoirs in the Southern Plains. The percent of reduction approximately equaled the percentage of the watershed controlled by reservoirs. The SCS had been using this relation between reservoirs and peak flow in watershed planning prior to the reports of Hartman et al. (1967) and Schoof et al. (1980). Although a peak flow reduction study has not been done on the Little Washita River data, we presume that the relation applies to this watershed as well.

Floodwater-retarding reservoirs in the Little Washita River Watershed may have beneficially reduced low-flow-rate periods in the Little Washita River. Before most of the reservoirs were built, the river usually went dry in late summer of most years, resulting in water supply problems for livestock and irrigators and probably in the demise of many beneficial stream biota. According to a table from the Staff, Water Quality and Watershed Research Laboratory (1983), the stream was dry for at least 1 week in 9 of 11 years prior to 1973, when only 20 reservoirs existed. After 12 additional reservoirs were built in 1973, the stream did not go dry from 1973 through 1977. During these 4 years the average annual 1-week low flow volume was 57 cubic feet per second-days. This finding is controversial, however, since the average annual rainfall was 19 percent less than normal for the period prior to 1973.

Data from the 11 unit source watersheds, although limited to a few years, provide considerable information on runoff, erosion, and water quality for water supply and watershed planning purposes. Large variations in runoff among these watersheds resulted from differences in land use, plant cover, and topography (table 16). Annual runoff data averaged for 1980-85 were high for roadside watersheds along unpaved roads and for wheat covered (conventional till) watersheds. Watersheds that did not have gulleys and were covered with range or pasture crops had lower runoffs during this period.

No change in runoff was detected when gully watershed 5202 was treated with erosion control practices, such as adding a pond, creating a diversion, and smoothing and seeding raw banks.

Allen (1986) used runoff and drainage density data from soils from the Little Washita River Watershed and 16 other watersheds to develop the following runoff prediction equation ($r^2 = 0.884$):

$$Q = 1.28D + 0.726$$

where

Q = average annual runoff (cm), and

D = drainage density (km/km^2)

Miller (1980) used runoff data from the Little Washita River and its tributaries to evaluate the accuracy of Pettyjohn and Henning's (1979) base-flow separation method to estimate base flow. He found that base-flow calculations were within 20 percent of measurements.

Loesch (1988) used plant cover information developed from satellite data for the Little Washita River basin, the SWRRB hydrology model, and runoff data from the Little Washita River gauging stations to determine which of his four hydrologic data sets best simulated the water balance.

Erosion, Sediment Yield, and Channels

Suspended sediment is considered the major pollutant in the Little Washita River basin (Naney et al. 1979). This highly visible pollutant, no doubt, influenced the selection of the Little Washita River Watershed for various conservation research projects and the resulting extensive data collection. For the pioneering soil conservation demonstration project in 1936, Drake et al. (1977) reported that N.E. Winters and other early workers believed that soil erosion could be controlled and that it did not have to be accepted passively with no alternative.

The Staff, Water Quality and Watershed Research Laboratory (1983) reported that some Southern Plains watersheds had very sizable sediment yield reductions when treated with floodwater-retarding reservoirs. However, they reported that no reduction in sediment yield occurred as of December 1982 at stream gauge 522 on the Little Washita River, since no breaks were seen in the trend line of a double-mass plot of sediment yield and runoff data. The double-mass plot method appears valid for determining sediment yield, since the floodwater-retarding reservoirs appeared to have had little if any effect on the volume of runoff in the watershed (Staff, Water Quality and Watershed Research Laboratory, 1983). At gauge 522 we did not detect reductions in sediment yield resulting from the reservoirs until 1984 and 1985, when a 30-percent reduction was measured.

At upstream gauge 526 sediment yield reduction occurred sooner. In 1980 there was a 43-percent reduction. From 1983 through 1985 there was an additional 44-percent reduction, resulting in an overall reduction of 67 percent. As in many watershed studies that often involve several treatments to reduce sediment yield, it is not clear which treatment caused the reduction in sediment yield. On the Little Washita River the reduction may have resulted from floodwater-retarding reservoirs, treatment of critical erosion areas in the MIP, natural improvement in the native range, or some combination of these factors. From a timing standpoint the MIP treatments in 1980 and 1981 seem to be the logical cause. However, these treatments only decreased erosion and involved only a small percentage of the watershed. Reservoir treatment, on the other hand, affected more of the watershed area (68 percent of the area upstream of gauge 526 and 50 percent of the area upstream of gauge 522), and reservoirs trap almost all suspended sediment (probably 93 to 100 percent in this watershed). Therefore, the reservoirs may be most responsible for the sediment yield decrease. The lag time for the reservoir treatment (1969-76) to make an impact at gauge 526 (1981) and at gauge 522 (1984) may represent the length of time necessary for channels to purge themselves of excess sediment, which acts as a sediment source during periods when the channel has a smaller sediment load. After a channel is purged, sediment transport at any point in the channel approximately equals the input load to the channel system above that point. A channel cleanout of suspended sediment within 0.3 feet of the perimeter of a major channel approximately equals the channel's average annual sediment load from the watershed.

Schoof et al. (1987) resurveyed 10 cross sections in 1985 on the Little Washita River. They compared channel dimensions to those from surveys made around 1969 prior to reservoir installation. The small number of cross sections limited quantitative conclusions. For example, only one cross section was located upstream from gauge 526. From 1969 to 1985 the river in this section had deepened 2.3 feet, but deposition on the banks resulted in a channel 6 percent narrower. Six cross sections were resurveyed between gauges 526 and 522. The channel deepened by an average of 2.3 feet, and the average channel cross-sectional area increased 11 percent. From this data we estimated that about 300,000 tons of sediment were removed from the area between gauges 526 and 522 during 1969-85. Lack of data prevented accounting for overbank floodplain deposits that occurred during flood periods.

A review of water yeild data from gauges 526 and 522 indicated water yield decreased at gauge 526 beginning in 1983, further complicating sediment yield analysis. This decrease was probably due to the MIP treatments, since a change in runoff at the source, unlike a change in sediment yield, is immediately reflected in runoff downstream. The ratio of runoff at gauge 526 to that at gauge 522 averaged 1.55 prior to 1983 and averaged 1.26 afterwards, a decrease of 19 percent.

Williams and Nicks (1985) used Little Washita River Watershed data in the development and testing of the SWRRB hydrology model. Nicks (1986) used the SWRRB hydrology model to estimate sediment yields at gauge 522 in 1984 and 1985 with and without reservoirs and predicted a 29-percent decrease with reservoirs. Since predicted sediment yields compared well with measured sediment yields (measured yeilds decreased 30 percent in 1984 and 1985), the model should be useful for predicting sediment yields resulting from major shifts in land use and treatment of large river basins.

Using data from the Little Washita River and other channels in the Southern Plains, the Staff of the Water Quality and Watershed Research Laboratory (1983) reported that the cross-sectional shape of channels is related to the texture of the sediment load as shown by the equation

$$w/d = 0.17s + 3.55 \qquad [6]$$

where

w = channel width,

d = channel depth (in the same units as w), and

s = percentage of sand in the suspended sediment load.

This equation indicates that an increase in the load's percentage of sand will increase the ratio of channel width to depth. The texture of a watershed's sediment load can vary according to climatic erosional cycles, agricultural land use changes, and physical watershed treatments, such as terraces, reservoirs, and gully plugs.

Sediment yields were obtained from 11 small unit source watersheds that had various land uses. Mean sediment yield (in tons/acre) averaged for the 1980-85 study period was highest for two road ditch watersheds on unpaved roads (69.67), followed by two gullied areas (25.17), two conventionally tilled wheat areas (2.43), a low tilled wheat area (0.93), a bermudagrass pasture area (0.49), a pasture crop area that was previously idle or cultivated (0.24), a native range area that was formerly cultivated (0.10), and a virgin native range area (0.02).

Allen (1986) used data from the Little Washita River Watershed and 16 other watersheds in the Southern Plains to develop an equation to predict sediment yield from a watershed based on its drainage density. Drainage density in this equation must be calculated from microchannel and macrochannel data. The equation (r^2 = 0.83) is

$$S = 0.747D - 0.164$$

where

S = sediment yield (t/ha), and

D = drainage density (km/km^2).

Quality of Groundwater and Surface Water

During the MIP study numerous samples of groundwater, surface water, and reservoir water were collected and analyzed for various chemical constituents. The water quality was generally good in all but a few samples that had unacceptably high levels of some chemicals. Naney et al. (1979) described the design of the groundwater network and presented some before-treatment concentrations of selected constituents. Naney et al. (1983) reported that local geology and certain existing oilfield activity may cause high levels of chloride and sulfate in groundwater and that levels of ammonium increased in groundwater at certain wells near cattle feedlots, pastures, and farmsteads. Naney and Smith (1983) reported that land use had no apparent significant impact on levels of P, SO_4^{-2}, or Cl^-. Naney et al. (1984) reported that water in the Little Washita River Watershed appeared suitable for irrigation based on accepted criteria for water quality. They also found little effect on groundwater quality as a result of expanded oilfield activity. However, some isolated high Cl^- concentrations have been observed in wells near a 50-year-old oilfield.

Smith et al. (1986) found that soil conservation treatments of the MIP decreased the rate of removal of plant nutrients and other chemicals from upland soils of the Little Washita River basin. They also stated that plant nutrients were generally lower in valley alluvial soils and that no problems with pesticide residues were evident.

Smith et al. (1987) reported that the amount of soluble N (nitrate and ammonium) in the Little Washita River groundwater was well within limits for human and livestock consumption. They cautioned that minimum till soil conditions could cause nitrate buildup below the root zone. Smith et al. (1985) stated that with few exceptions, farming and ranching activities have a limited impact on groundwater quality.

Menzel et al. (1986) determined that the concentrations of total nitrogen and phosphorus in SCS floodwater-retarding reservoirs 11 and 23 and their outflow were only about 20 and 5 percent, respectively, of the inflow concentrations. This reduction was largely due to sediment deposition. Nutrient concentrations 7.5 to 10 km downstream, however, were similar to the concentrations of the reservoir inflow. Even though runoff from 51 percent of the Little Washita River basin is controlled by reservoirs, there was no apparent reduction in stream nutrient concentrations.

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Appendix: Computer Files

LW1 - LW36	Daily precipitation recorded from 36 rain gauges in the Little Washita River Watershed.
LW37 - LW47	Increments of precipitation accumulated per storm and per day as recorded at rain gauges in the Little Washita River Watershed.
LW48	Daily maximum and minimum air temperatures recorded at rain gauge 124.
LW49	Pan evaporation recorded at rain gauge 124.
LW50	Average wind velocities recorded at rain gauge 124.
LW51	Daily maximum and minimum relative humidity recorded at rain gauge 124.
LW52 - LW74	Incremental discharge rates and incremental measured and total sediment transport rates recorded at gauging station 522 in 1963 through 1985.
LW75	Daily means for discharge rates and measured and total sediment transport rates at gauging station 522.
LW76	Discharge rate, sediment concentration, electrical conductivity, and water temperature at gauging station 522.
LW77	Particle-size distribution of sand in suspended sediment samples at gauging station 522.
LW78	Daily maximum and minimum water temperatures at gauging station 522.
LW79	Electrical conductivity, temperature, and stream stage for water quality samples taken during water years (October 1 - September 30) 1967 through 1971 at gauging station 522.
LW80	Electrical conductivity, water temperature, and stream stage data from water quality samples taken during water years 1972 through 1976 at gauging station 522.
LW81	Chemical analyses of water samples taken during water years 1972 through 1976 at gauging station 522.
LW82 - LW88	Incremental discharge rates and incremental measured and total sediment transport rates at gauging station 526 in 1979 through 1985.
LW89	Mean daily discharge rates and daily measured and total sediment transport rates at gauging station 526.
LW90	Suspended sediment sample data at gauging station 526: discharge rate, sediment concentration, electrical conductivity, and flow temperature.
LW91 - LW101	Incremental accumulated runoff and sediment yield for the 11 unit source watersheds in the Model Implementation Project.
LW102 - LW112	Flow volumes, sediment yields, and nutrient concentrations for each storm event at the 11 unit source watersheds in the Model Implementation Project.
LW113 - LW136	Chemical analyses of water samples from the MIP 24-stream-site study.
LW137	Physical data from each groundwater well: elevations (above mean sea level) of pipe top, ground surface, bedrock; locations; and depths.
LW138	Driller's log of depth, lithology, and color for each layer in groundwater wells.
LW139 - LW163	Elevation (above mean sea level) of groundwater in 25 wells.
LW164	Chemical analyses of water samples from groundwater wells.
LW165	Survey data for the stream and valley cross sections.
LW166	Chemical analyses of gauge 5235 samples, representing inflow to reservoir 11.
LW167	Chemical analyses of samples from reservoir 11.

LW168	Chemical analyses of gauge 5231 samples, representing outflow from reservoir 11.
LW169	Chemical analyses of gauge 5274 samples, representing inflow to reservoir 23.
LW170	Chemical analyses of samples from reservoir 23.
LW171	Chemical analyses of gauge 5271 samples, representing outflow from reservoir 23.