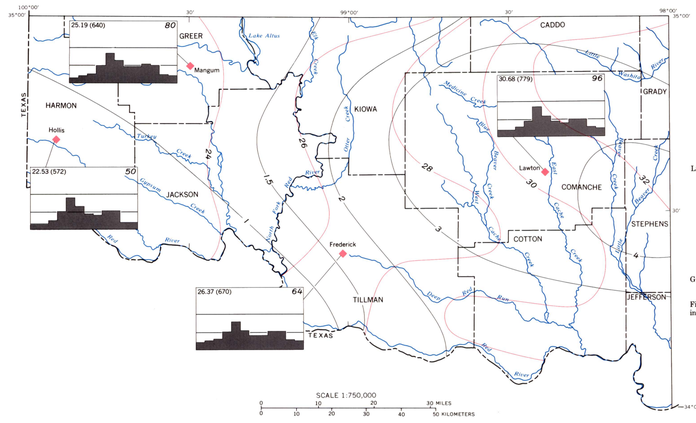
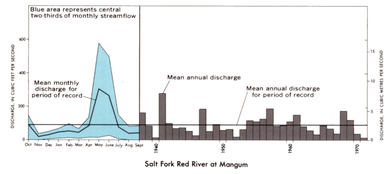
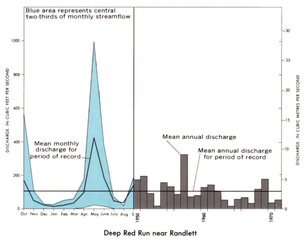


Figure 8. Map showing distribution of precipitation and runoff.





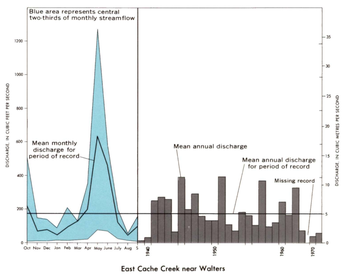


Figure 9. Monthly and yearly discharge at selected gaging stations.

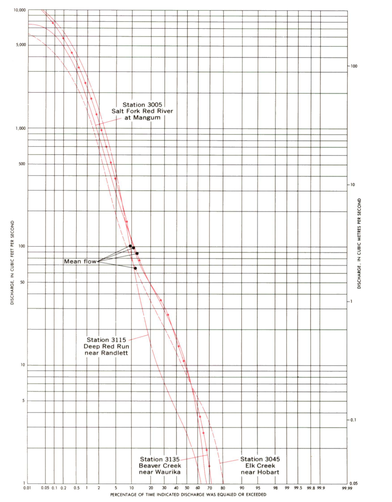


Figure 10. Flow-duration curves for selected streams.

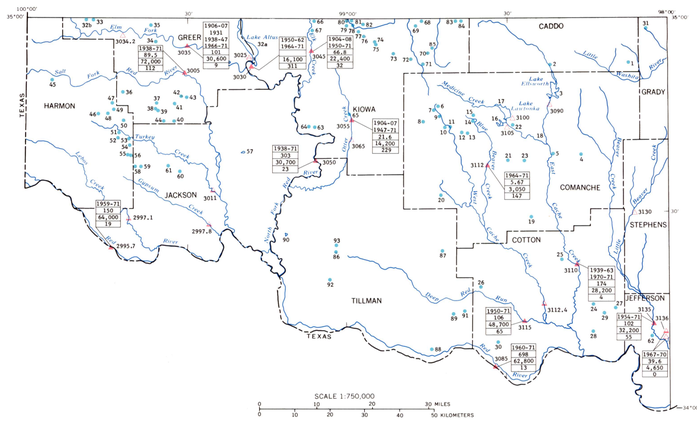


Figure 11. Map showing location of lakes and surface-water stations and citing selected streamflow data.

Table 1.—Surface-Water Stations in the Lawton Quadrangle.

STATION NUMBER[1]	STREAM OR LAKE NAME AND GAGE LOCATION[2]	DRAINAGE AREA (SQUARE MILES)	PERIOD OF RECORD (CALENDAR YEARS)
	DAILY GAGING STATIONS		
7-2995.7	Red River near Quanah, Tex.	8,321	1959-
3005	Salt Fork Red River at Mangum	1,566	1905-06; 1937-
3025	Lake Altus at Lugert	2,515	1943-
3030	North Fork Red River below Altus Dam, near Lugert	2,515	1930-32; 1943-50; 1950-62; 1964-
3034.2	Elm Fork of North Fork Red River near Reed	579	1965-67
3035	Elm Fork of North Fork Red River near Mangum	838	1905-08; 1930-31; 1937-47; 1965-67; 1968-
3045	Elk Creek near Hobart	549	1904-08; 1949-
3050	North Fork Red River near Headrick (Snyder)	4,244	1905-08; 1937-
3055	West Otter Creek at Snyder Lake, near Mountain Park	132	1903-08; 1951-71; 1972-
3065	West Otter Creek at Mountain Park	164	1946-51
3085	Red River near Burkburnet, Tex.	20,570	1924-25;1959-
3090	East Cache Creek near Elgin	248	1955-58
3100	Little Medicine Bluff Creek near Lawton	7.0	1912-19
3105	Medicine Bluff Creek near Lawton	101	1912-19
3110	East Cache Creek near Walters	675	1938-63; 1969-
3112	Blue Beaver Creek near Cache	24.6	1964-
3115	Deep Red Run near Randlett	617	1949-
3130	Little Beaver Creek near Duncan	158	1948-63
3135	Beaver Creek near Waurika	563	1963-
3136	Cow Creek at Waurika	193	1966-70
	LOW-FLOW PARTIAL-RECORD STATIONS		
7-2997.1	Lebos Creek near Eldorado	280	1951-55; 1960-63
2997.8	Gypsum Creek near Olustee	107	1954-57; 1965-72
3011	Turkey Creek at Olustee	293	1951-57; 1960-63
3112.4	West Cache Creek near Cookietown	1,112	1951-55; 1965-72
3136	Cow Creek at Waurika	193	1971-

[1]From USGS national system of downstream order numbers.
[2]Slight changes in location may have occurred during period of record; listing is by most recent designation.

Table 2.—Lakes of 10 Acres or More in the Lawton Quadrangle.

MAP NUMBER	DESIGNATION	AREA (ACRES)	CAPACITY (ACRE-FEET)
	CADDO COUNTY		
1	W. N. Rackley	20	160
2	Louis Hrbacek	13	60
	COMANCHE COUNTY		
3	Lake Ellsworth	5,600	94,475
4	J. O. Bailey	10	48
5	U.S. Army Lake	300	4,500
6	Granna Lake	114	3,450
7	Comanche Lake	54	900
8	Caddo Lake	11	135
9	Kiowa Lake	11	150
10	French Lake	30	420
11	Lost Lake	10	80
12	Quanah Parker Lake	96	960
13	Crater Lake	11	88
14	Jed Johnson Lake	58	1,350
15	Rush Lake	54	540
16	Elmer Thomas Lake	472	7,080
17	Lake Lawtonka	1,868	42,000
18	City of Lawton	14	112
19	Hatchery	58	264
20	Leo Lewis Lake	11	88
21	Fort Sill Indian School	10	80
22	Gondola Lake	10	80
23	Herring Lake	10	80
	COTTON COUNTY		
24	Mooney Lake	32	225
25	Boyer Lake	156	2,620
26	White Lake	112	560
27	Jones Lake	20	100
28	Keeter Lake	10	50
29	Newsom Lake	10	50
30	Inman Lake	20	100
	GRADY COUNTY		
31	L. Purtschi	180	1,800
	GREER COUNTY		
32a	Lake Altus	6,260	134,500
32b	Pevey Lake	10	40
33	Dr. Hollis	70	150
34	Purtsen Lake	15	60
35	Hughes Lake	10	70
36	Tri-County Turkey Creek Watershed site 14A	12	48
37	Tri-County Turkey Creek Watershed site 16A	11	66
38	Tri-County Turkey Creek Watershed site 17	16	104
39	Tri-County Turkey Creek Watershed site 18	10	37
40	Tri-County Turkey Creek Watershed site 28A	16	57
41	Tri-County Turkey Creek Watershed site 28B	28	128
42	Tri-County Turkey Creek Watershed site 28C	23	69
43	Tri-County Turkey Creek Watershed site 28D	12	45
44	Tri-County Turkey Creek Watershed site 29A	14	48
	HARMON COUNTY		
45	Lake Hall	40	300
46	Tom Motley Lake	20	120
47	Tri-County Turkey Creek Watershed site 2A	20	110
48	Tri-County Turkey Creek Watershed site 3	34	147
49	Tri-County Turkey Creek Watershed site 4	17	65
50	Tri-County Turkey Creek Watershed site 7	33	132
51	Tri-County Turkey Creek Watershed site 9	27	95
52	Tri-County Turkey Creek Watershed site 10	113	640
53	Tri-County Turkey Creek Watershed site 11	20	82
54	Tri-County Turkey Creek Watershed site 19	16	48
55	Tri-County Turkey Creek Watershed site 20	20	71
56	Tri-County Turkey Creek Watershed site 21	30	110
	JACKSON COUNTY		
57	Altus City Reservoir	183	2,745
58	Tri-County Turkey Creek Watershed site 23	23	71
59	Tri-County Turkey Creek Watershed site 24	24	69
60	Tri-County Turkey Creek Watershed site 27	24	95
61	Tri-County Turkey Creek Watershed site 29B	29	94
	JEFFERSON COUNTY		
62	Waurika Lake	65	800
	KIOWA COUNTY		
63	M. L. Messick	25	150
64	M. L. Messick	12	102
65	Snyder Lake	130	1,355
66	Perdomic Lake	23	184
67	Tally-Ho Lake	30	240
68	Rainy Mountain Creek Watershed site 4	55	311
69	Rainy Mountain Creek Watershed site 6	26	120
70	Rainy Mountain Creek Watershed site 8A	29	117
71	Rainy Mountain Creek Watershed site 10	25	187
72	Rainy Mountain Creek Watershed site 11	26	128
73	Rainy Mountain Creek Watershed site 13	29	118
74	Rainy Mountain Creek Watershed site 16	11	32
75	Rainy Mountain Creek Watershed site 17	15	54
76	Rainy Mountain Creek Watershed site 19	74	278
77	Rainy Mountain Creek Watershed site 20	23	85
78	Rainy Mountain Creek Watershed site 21	21	68
79	Rainy Mountain Creek Watershed site 22	57	224
80	Rainy Mountain Creek Watershed site 23	150	813
81	Rainy Mountain Creek Watershed site 24	18	74
82	Rainy Mountain Creek Watershed site 25	24	93
83	Saddle Mountain Creek Watershed site 4	11	36
84	Saddle Mountain Creek Watershed site 5	15	141
85	Saddle Mountain Creek Watershed site 6	58	340
	TILLMAN COUNTY		
86	Frederick Lake	45	360
87	Patton Lake	10	80
88	Martins Lake	10	80
89	Lake Jean Murray	25	200
90	White Lake	90	225
91	Huffington Lake	11	42
92	Crawford Lake	10	38
93	Burt's Lake	12	40

AVAILABILITY OF SURFACE WATER

The Red River and its tributaries are the main sources of surface water within the Lawton quadrangle. The Red River forms the boundary between Oklahoma and Texas, and its tributaries include the Salt Fork of the Red River, the North Fork of the Red River, East Cache Creek, and Beaver Creek, plus their tributaries. These streams form the drainage network of the study area, and they all generally have no-flow periods each year.

Streamflow is directly controlled by precipitation in the area. The average annual precipitation ranges from about 22 inches (560 mm) in the southwestern part of the quadrangle to about 33 inches (840 mm) in the northeastern part (fig. 8). Precipitation graphs show that spring is the wettest season, receiving about 32 percent of the total precipitation; winter is the driest season, receiving about 12 percent of the total.

In the Lawton quadrangle, evaporation from surface water (generally lake evaporation) can return 60 to 65 inches (1,520 to 1,650 mm) of water per year to the atmosphere; this represents more than twice the annual rainfall. Most runoff to streams occurs during short, intense storms when the precipitation rate exceeds the evaporation rate.

Variations in Streamflow

The bar graphs in figure 9 illustrate the variations in streamflow that are caused primarily by fluctuations in annual precipitation, using the Salt Fork of the Red River at Mangum, Deep Red Run near Randlett, and East Cache Creek near Walters as examples. The left side of the graph shows the monthly streamflow expected about two-thirds of the time and the mean (or average) monthly discharge for the period of record (table 1). The right side of the graph shows the mean discharge for each year that records are available and the mean annual discharge for the entire period of record.

The average annual runoff ranges from less than 1 inch (25 mm) in the southwestern part of the quadrangle, which is less than 5 percent of the total annual precipitation, to about 4 inches (100 mm), or about 12 percent of the annual precipitation, in the eastern part (fig. 8). At Mangum, discharge of the Salt Fork of the Red River reflects both the average annual rainfall of about 25 inches (635 mm) and the runoff of only about 1.25 inches (32 mm). Annual precipitation at Deep Red Run near Randlett is about 31 inches (787 mm), and runoff is about 2.5 inches (64 mm). Around East Cache Creek near Walters, annual precipitation is about 29 inches (737 mm), and runoff is about 3.5 inches (89 mm). A comparison of the 3 graphs in figure 9 shows that as precipitation and runoff increase from southwest to northeast, the discharge at gaging stations increases. The drainage area of the Salt Fork of the Red River at Mangum is about twice that of either Deep Red Run near Randlett or East Cache Creek near Walters.

During periods of no rainfall, streamflow is maintained by ground-water discharge from rocks underlying the stream basins. Water from the aquifers drains into adjacent streams to provide base flow. When water levels in the aquifer fall below the stream channel and no more water enters the stream, the stream ceases to flow. Also, when water levels in an aquifer fall below stream level, storm runoff results in flow from the stream into the aquifer. Streams flowing through shaly or clayey areas generally receive little ground-water inflow and are dry most of the year.

Flow-duration curves for 4 selected streams in the Lawton quadrangle show the variability of streamflow (fig. 10). These curves show the percentage of time a given flow can be expected to be equaled or exceeded at the selected gaging sites. For example, the flow of the Salt Fork of the Red River at Mangum equaled or exceeded 10 ft^3/s (cubic feet per second), which is 28 m^3/s (cubic metres per second), 50 percent of the time. The curve also shows that the flow for that station is less than 1.0 ft^3/s (0.03 m^3/s) about 32 percent of the time. The mean, or average, flows plotted on figure 10 show that the mean flow is equaled or exceeded only about 9 to 13 percent of the time in these streams.

These curves should not be interpreted as frequency curves. The shape of the curve indicates the geologic and hydrologic characteristics of a drainage basin. A curve with a moderate slope indicates the presence of ground-water or surface-water storage, tending to equalize flow. All 4 curves in figure 10 have a steep slope, which indicates that streamflow results largely from direct runoff. Such streams have low base flows, with periods of no flow, and tend to be "flashy," with rapid rises and recessions following precipitation.

Availability of Streamflow Records

Streamflow data are available for 19 daily gaging stations and 4 low-flow partial-record stations in the Lawton quadrangle. Table 1 gives the station numbers, names, size of drainage areas, and periods of published record; the locations of these stations are shown in figure 11.

Prior to 1961, records of streamflow and major-reservoir contents were published in an annual series of U.S. Geological Survey Water-Supply Papers, *Surface Water Supply of the United States*. Records for the 5-year period 1961-65 are contained in a 2-volume publication of the same series.

Beginning with the 1961 water year, the U.S. Geological Survey has also published streamflow records separately for each state and released them through their district offices, primarily for local use.

Additional streamflow data may be obtained by contacting the District Office, U.S. Geological Survey, Oklahoma City, Oklahoma.

Lakes

Surface storage has been developed in much of the Lawton quadrangle because of the limited availability of potable ground water, the high variability of streamflow, and the lack of sustained low flow in streams. Man-made ponds and small lakes provide water for stock and other farm uses and for individual domestic supplies. Lakes 10 acres (4.05 ha) or more in surface area are listed in table 2 and shown in figure 11.

Three major reservoirs have been constructed within the Lawton quadrangle: Ellsworth and Lawtonka Lakes, which supply water for municipal and industrial use in Lawton and Fort Sill, and Lake Altus, which provides a municipal and industrial water supply for Altus and is used to irrigate about 48,000 acres (19,400 ha). Although these lakes are primarily intended for water supply, recreation is an important secondary benefit.

QUALITY OF SURFACE WATER

The solubility of minerals within geologic formations traversed by a stream, the flow characteristics of a stream, and the addition of dissolved minerals from man's activities directly influence the quality of stream water. Minerals such as rock salt and gypsum dissolve easily and may contribute large quantities of dissolved solids to a stream. Maximum concentrations of dissolved solids occur during periods of low flow, when streamflow is maintained primarily by ground-water discharge. Minimum concentrations usually occur during periods of heavy precipitation and high runoff. Discharging sewage and industrial waste into streams contributes dissolved solids and organic matter downstream from treatment plants, but this problem is comparatively minor in the Lawton quadrangle.

Data collected and published by the U.S. Geological Survey provide general information on the chemical quality of surface water at selected sites in the Lawton quadrangle (table 3). From 1941 through 1965, data were published in an annual series of Water-Supply Papers entitled *Quality of Surface Waters in the United States*. Records for Oklahoma are in part 7 of this series. Beginning with the 1964 water year, water-quality data have also been published in a series of annual releases on a state-by-state basis. Chemical-quality data given in these reports include information about concentrations of certain dissolved constituents, such as sodium, calcium, sulfate, and chloride, and characteristics such as hardness, sodium-adsorption ratio, specific conductance, and pH. Data on fluvial sediment and water temperature are also included in these reports. Fluvial-sediment information is given for suspended-sediment discharges and for particle-size distribution of suspended sediment and bed material. Water temperature data are given only for daily observations.

Figure 12 indicates that most streams in the quadrangle contain 500 mg/l (milligrams per litre) or more of dissolved solids, and the majority contain 1,000 mg/l or more. Reservoirs generally are filled by flood flows, which tend to have less dissolved solids than low flows have.

About one-half of the streams have an SAR (sodium-adsorption ratio) of 4 or more and have specific conductances of more than 3,000 micromhos per centimetre at 25°C (fig. 13). The Red River and its tributaries in the western one-half of the area provide water for municipal use and for irrigation. Elm Fork of the Red River contains high-chloride water from salt deposits in the western part of the area. In the eastern part of the area, water from East Cache Creek, West Cache Creek, and Beaver Creek is used for domestic, municipal, and irrigation supply, but local brine pollution can make water unusable.

WATER USE

As shown in figure 14, 36 municipalities obtain their water supplies from ground-water sources; 2 municipalities from surface-water sources; and 3 municipalities from both ground-water and surface-water sources.

Ground water provides approximately two-thirds of the total water used in the Lawton quadrangle; surface water provides the remaining one-third for some municipal supply and some irrigation. The following table shows estimated water usage in the quadrangle for 1972.

Water Use in Lawton Quadrangle, 1972

(Amounts shown in acre-feet)

USE	Source of supply: GROUND WATER	SURFACE WATER	GROUND AND SURFACE WATER	PERCENTAGE OF TOTAL (ROUNDED)
Irrigation	95,140	27,020		78
Municipal	7,670	19,950		17
Farm animals			4,600	
Industrial	1,530			6
Rural domestic (not within water district)			1,530	
Rural water district			1,530	
TOTALS	104,340	47,570	7,660	

Because of the difficulty in obtaining potable water supplies throughout much of the rural area, rural water districts have been established; 10 were operating in 1973 (fig. 14). Comanche County Rural Water District No. 1 and Hillary's Water District purchase surface water from the City of Lawton; all other rural water districts use ground water. Both Hillary's Water District and Cotton County Rural Water District No. 1 supply water for only one town and are counted as municipal supplies. Many of these districts plan expansion, and other districts may be established to meet demands for additional service.

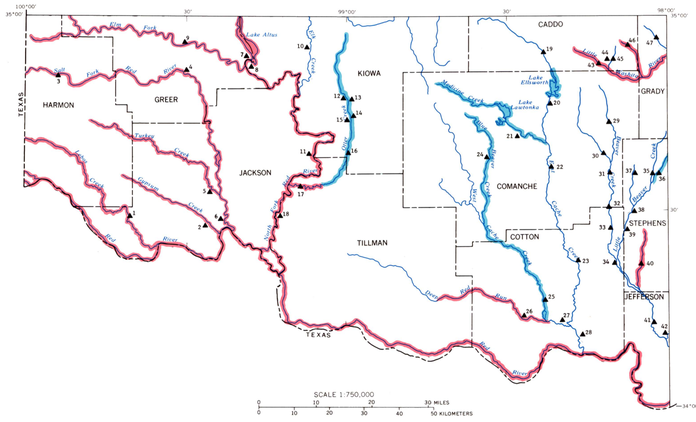


Figure 12. Map showing location of surface-water-quality sampling stations and dissolved-solids concentrations of streams during low-flow periods.

Table 3.—Surface-Water Quality Sampling Stations in the Lawton Quadrangle

LOCATION NUMBER[1]	STREAM OR LAKE NAME AND STATION LOCATION	FREQUENCY OF SAMPLING: WATER YEAR: NUMBER OF PUBLISHED ANALYSES (IN PARENTHESES)
1	Lebos Creek near Eldorado	1952(5), 1953(11), 1954(2), 1955(4), 1953(2), 1961(3), 1962(9), 1963(10)
2	Gypsum Creek near Olustee	1955(4), 1956(7), 1957(7)
3	Salt Fork Red River near Vinson	1952(2), 1953(11), 1954(2), 1960(10), 1961(11), 1962(10), 1963(7)
4	Salt Fork Red River at Mangum	1947(41), 1948(29), 1949(1), 1950(1), 1951(4), 1952(11), 1954(1), 1955(2), 1956(1), 1960(11), 1961(12), 1962(9), 1963(5)
5	Turkey Creek at Olustee	1952(4), 1954(2), 1955(1), 1956(7), 1957(8), 1961(9), 1962(11), 1963(9)
6	Salt Fork Red River near Elmer	1960(9), 1961(12), 1962(11), 1963(9)
7	Lake Altus	1949(1), 1950(3), 1951(6), 1952(9), 1955(2), 1956(9), 1957(9)
8	N. Fork Red River below Altus Dam near Lugert	1963(4)
9	Elm Fork N. Fork Red River near Mangum	1951(3), 1952(1), 1958(2), 1960(2), 1962(10), 1963(9), 1968(14)
10	Elk Creek near Hobart	1949(1), 1950(62), 1951(56), 1952(3), 1954(6), 1955(5), 1956(7), 1957(3), 1958(2), 1959(57), 1960(59), 1961(58), 1962(85), 1963(48)
11	N. Fork Red River near Headrick	1951(3), 1952(2), 1954(4), 1955(10), 1956(5), 1957(11), 1958(5), 1959(7), 1960(66), 1961(102), 1962(108), 1963(74), 1968(14)
12	W. Otter Creek at Cold Springs	1961(2)
13	Glen Creek near Cold Springs	1961(2)
14	Snyder Lake on Otter Creek near Mt. Park	1948(1)
15	W. Otter Creek at Snyder Lake near Mt. Park	1952(1), 1960(2)
16	Otter Creek near Snyder	1951(2), 1960(9), 1961(13), 1962(10), 1963(2)
17	Otter Creek near Tipton	1960(9), 1961(15), 1962(11), 1963(10)
18	N. Fork Red River near Tipton	1960(2)
19	Cache Creek near Apache	1951(1)
20	East Cache Creek near Elgin	1956(36), 1958(82)
21	Medicine Creek near Fort Sill	1951(1)
22	Cache Creek near Lawton	1959(3)
23	E. Cache Creek near Walters	1947(1), 1948(2), 1951(1), 1952(54), 1953(51), 1954(3), 1955(3), 1958(3), 1959(2), 1960(6), 1961(9), 1962(7), 1963(17)
24	Blue Beaver Creek near Cache	1960(6), 1966(1), 1967(2), 1968(14)
25	W. Cache Creek near Cookietown	1952(3), 1953(1), 1954(2), 1955(1), 1960(5), 1961(6), 1962(7), 1963(6)
26	Deep Red Run near Randlett	1948(2), 1950(80), 1951(54), 1952(3), 1954(6), 1955(5), 1956(2), 1958(4), 1960(10), 1961(8), 1962(8), 1963(8)
27	Deep Red Run near Taylor	1959(2)
28	Cache Creek near Taylor	1959(2)
29	Beaver Creek near Sterling	1961(2)
30	Ninemile Beaver Creek near Letitia	1961(2)
31	Beaver Creek near Letitia	1961(2)
32	Beaver Creek near Hulen	1961(2)
33	Beaver Creek near Stringtown	1961(2)
34	Beaver Creek near Mills	1961(2)
35	Stage Stand Creek near Nellie	1961(2)
36	E. Stage Stand Creek near Nellie	1959(2)
37	Little Beaver Creek near Nellie	1961(2)
38	Little Beaver Creek near Duncan	1947(1), 1948(2), 1949(42), 1951(66), 1953(8), 1953(7), 1954(5), 1955(5), 1956(3), 1958(2), 1959(8), 1960(5), 1961(2), 1962(6), 1963(16)
39	Little Beaver Creek near Gas City	1961(2)
40	Walker Creek near Cornish	1961(2)
41	Beaver Creek near Waurika	1953(1), 1954(11), 1955(12), 1956(43), 1957(57), 1958(65), 1959(39), 1960(64), 1961(61), 1962(60), 1963(8), 1965(11)
42	Cow Creek at Waurika	1960(4), 1961(6), 1962(6), 1963(6), 1967(13), 1968(15)
43	Little Washita River near Cyril	1958(31)
44	West Chetonia Creek near Cyril	1958(3)
45	East Chetonia Creek near Cyril	1958(2)
46	McCardo Creek near Cement	1958(6), 1959(4), 1960(7)
47	Bills Creek near Cement	1958(3)

[1]See figures 12 and 13.

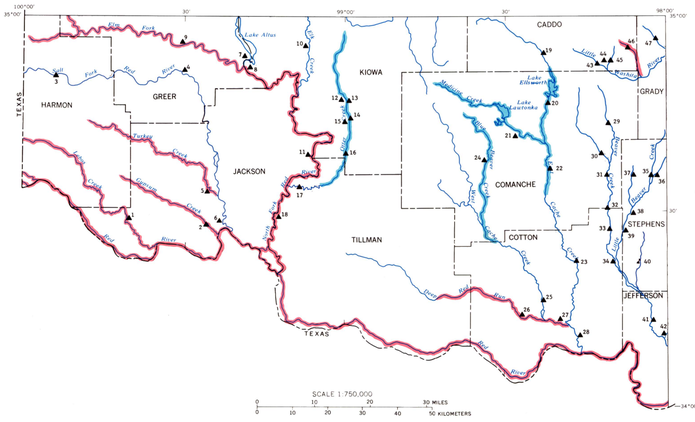


Figure 13. Map showing location of surface-water-quality sampling stations and indicating sodium-adsorption ratio and specific conductance of streams during low-flow periods.

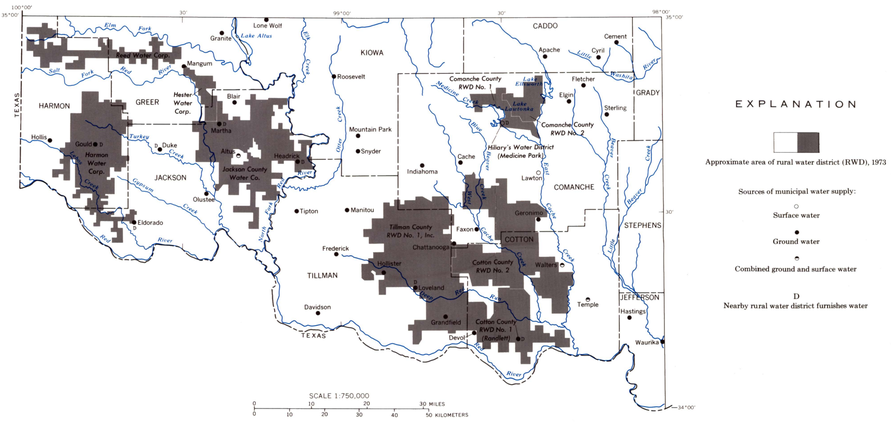


Figure 14. Map showing sources of municipal water supplies and approximate boundaries of rural water districts in 1973.

RECONNAISSANCE OF THE WATER RESOURCES OF THE LAWTON QUADRANGLE, SOUTHWESTERN OKLAHOMA

By
John S. Havens
U.S. Geological Survey

1976

Cartographic preparation by Oklahoma Geological Survey