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Technical Research Project Completion
and Termination Report

Water Yield as Influenced by Watershed Characteristics and Small Upstream Reservoirs

Submitted to

The Oklahoma Water Resources Research Institute
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Stillwater, Oklahoma

by

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COMPLETION REPORT

☐ Partial

☒ Complete
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Date August, 1968

State Oklahoma

Project No. A-005 Oklahoma
Agreement No. 14-01-0001-806
Date Started May, 1965
Date Terminated June, 1968

1. **Title of Project** : WATER YIELD AS INFLUENCED BY WATERSHED CHARACTERISTICS AND SMALL UPSTREAM RESERVOIRS

2. **Investigators** (List principal investigator first)

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3. **Principal Investigators Title**

   Professor of Agricultural Engineering

4. **Principal Investigators Department**

   Agricultural Engineering

5. **College or Major Subdivision**: College of Engineering, College of Agriculture

6. **Cooperating Agencies** (Other than OWRR and principal investigator's department)

   Oklahoma State University

7. **Project Objectives**

   (a) Original

   1. To measure the percent of total volume change in water yield caused by various sizes of upstream reservoirs.
   2. To relate the volume and peak rate of runoff to rainfall and watershed characteristics.

   (b) Any revised objectives

   1. To analyze the rainfall measurements to determine the effect of areal distribution, method of estimating averages, gage density, and precipitation ranges.
   2. Rainfall and soil moisture measurements were used to determine the soil moisture depletion rates or the consumptive use of native grass.

ABSTRACT

The original objectives could not be achieved as construction of the reservoirs was delayed. The objectives were revised. Hydrologic problems require the determination of average depth or volume of precipitation over a large range of areas. The accuracy of estimating the average depth of precipitation with a network of rain gages is dependent on the gage density. Most research in this area has been conducted on large watersheds with gage densities of two square miles or greater. Data were collected from 13 recording rain gages with a density of approximately 2 gages per square mile from April 1, 1967 to June 30, 1968. Gage densities were compared for 32 daily precipitation totals greater than 0.50 inches. Densities of 2.6 and 5.2 square miles per gage had errors greater than 5% over one-third of the time as compared to a gage density of 0.4 square miles per gage. Seventy-six percent of the total precipitation occurred from storms greater than 0.50 inches. No significant difference was noted between the arithmetic average and Thiessen polygon methods of estimating average precipitation as the network approximated a grid system. Daily soil moisture depletion rates ranged from 0.03 to 0.16 inches per day during the 1967 growing season.

KEYWORDS--neutron probe/ *soil moisture/ *volume of precipitation/ digital computer/ volume of runoff/ small watersheds/ manometer servo/ consumptive use/ *soil moisture depletion rate/ *gage density/ recording raingage/ areal distribution

Procedure

Three reservoirs were selected with watershed sizes of 432, 926 and 1963 acres. All are class "c" structures, having a capacity sufficient for a 100-year frequency storm. These watersheds are adjacent, similar in soil, cover, drainage area to storage capacity ratio, and configuration of the drainage area. The watersheds are located from 3.5 to 6.5 miles north of Stillwater, Oklahoma.

Verbal consent was received to install 13 recording rain gages and soil moisture sampling tubes from 13 land owners. The watersheds are divided into sections. The 3331 acres has 43 land owners. The installations were located near the unimproved roads and as near the one-half mile lines as land owners would permit. This would form a grid system with a network density of 2 gages per square mile. The maximum distance from the desired location was approximately 700 feet.

Soil moisture measurements were made by the neutron scattering method. Measurements were taken at six-inch increments to depths of 42 inches.

Soil moisture sampling tubes were installed at 10 of the sites. Rock formation near the surface prevented tube placement at the remaining 3 sites. The rain gage network and soil moisture tube placements were completed in March, 1967.

Controlled data points were collected to use to calibrate a standard neutron probe. A least squares regression program written for a digital computer was used to determine the best fit calibration curve for this standard probe. This program was also used to calibrate a second probe by comparison of the two probes. The calibration of the two probes was checked twice a year.

The recording rain gages were mounted on 16-inch square concrete slabs extending one foot above ground level and below the normal freeze depth. The enclosures are 10 feet square and 4 feet high with stiles for easy access. The rain gages were calibrated in place.

The rain gages were serviced weekly or after each storm. Daily precipitation totals were read from the charts and punched on computer cards. The IBM 7040 digital computer was used for analysis of the data.

Soil moisture readings were used to determine the volume of water in 7 zones at each access tube. The 6-inch depth reading was used to determine the top 9-inch zone and the remaining readings were used for 6-inch zones. Total soil moisture was determined for the 45-inch depth at each access tube and the average of the 10 access tube totals was calculated.

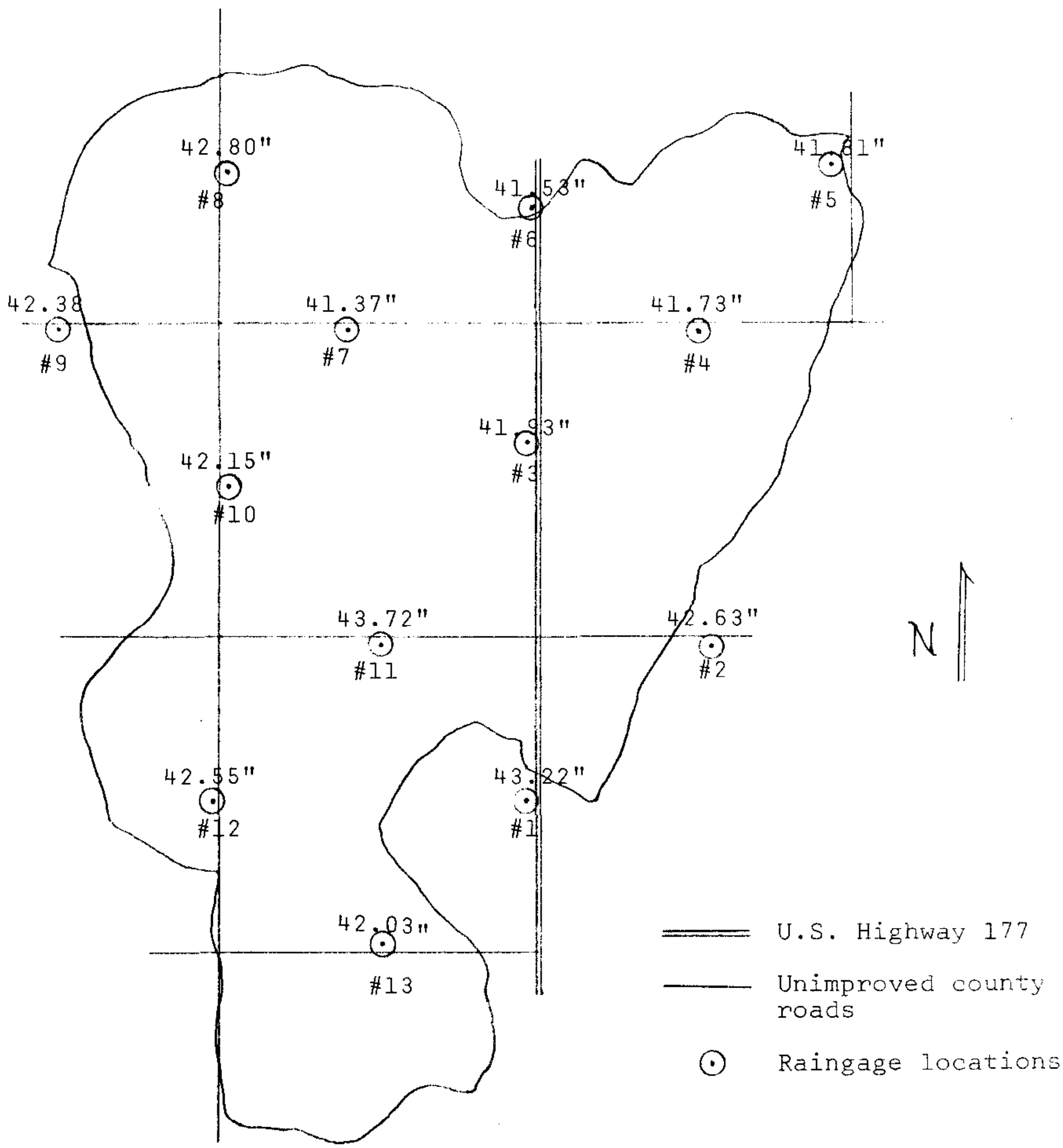
Three manometer servos and Steven A-35 Recorders were purchased to instrument the reservoirs. Original plans called for construction of the reservoirs in the fall of 1966 and spring of 1967. Necessary rights-of-way were not secured as planned causing a delay until 1968-1969. Construction is presently planned when funds become available. Design of structures is completed.

Findings and Results

The 3331 acre watershed, 13 rain gage locations, and areal distribution of the 15-month total precipitation are presented in Figure 1. Rain gage No. 11 recorded the largest total precipitation which was 3.4% greater than the mean. Rain gage

Figure 1.

Watershed, raingage network, and fifteen month totals.



Scale: one inch equals one half mile

No. 7 recorded the smallest total precipitation which was 3.2% less than the mean. These two rain gages were near the center of the network and only 1 mile apart. No pattern of areal rainfall distribution was discernable.

The arithmetic average and Thiessen polygon methods are normally used to estimate average precipitation over a small area with relatively flat topography. The Theissen polygon method is best for randomly distributed gages. If the gages are placed in a grid network the two methods are identical. As the network approximated a grid system, no significant differences were detected using the two methods. The maximum difference was 0.03 inches for the 15-month total. No difference this great was detected for individual daily precipitation.

Use of 1, 2, 3, 4 and 5 gages were compared with the 13-gage network for each daily precipitation and the 15-month total. The 32 daily precipitation totals greater than 0.50 inches were used to obtain the number of times an error greater than 5% occurred, as compared to a 13-gage network. These results are presented in Table I.

Table I

Effect of Gage Density

No. of Gages in Network	Gage Density Acres/Gage	Gages Used	No. of Times Error Greater Than 5% from 32 Major Storms
1	3331	3	12
2	1665	6,13	11
3	1110	4,8,12	4
4	833	2,6,9,12	3
5	666	2,4,8,10,12	1
13	256	All	

Precipitation occurred 80 days in the 15-month period. The number of storm events and percent of the total precipitation are presented in Table II for 7 precipitation ranges. Seventy-six percent of the total precipitation measured was from the storms greater than 0.50 inches.

Table II

Number of Events and Percent of Total Precipitation for Seven Precipitation Ranges

Precipitation Range, Inches	Number of Storm Events in each Range	Percent of the Total Precipitation
0.00-0.09	12	1.73
0.10-0.19	15	4.92
0.20-0.29	7	4.07
0.30-0.39	5	4.05
0.40-0.49	9	9.18
0.50-0.99	22	36.08
Above 1.00	10	39.98

Soil moisture measurements were taken at the 10 access tube locations 20 times during the 14 month period. The rainfall and soil moisture data were used to determine the soil moisture depletion rates or the consumptive use of native grass.

The United States Department of Agriculture, Soil Conservation Service Method was used to estimate the runoff. The soil is predominately Renfrow-Kirkland Claypan Prairie. Range cover conditions were poor to fair in 1967, and fair in 1968. The annual rainfall for the four years prior to 1967 at the United States Weather Bureau Station, located approximately 5 miles south and 1 mile west of the watershed, was from 4.40 inches to 6.79 inches below the 71-year average. The total estimated runoff for the 14-month period was 2.53 inches.

Total soil moisture in the top 45-inch soil profile, rainfall minus estimated runoff, and daily soil moisture depletion rates are presented in Table III. Only random soil moisture changes were detected below the 3-foot depth prior to May, 1968. This would indicate the soil moisture depletion rates should approximate the consumptive use rates of native grass.

Table III

Daily Moisture Depletion Rates

Date	Soil Moisture in the Top 45 in. Profile (Inches)	Rainfall Minus Estimated Runoff (Inches)	Daily Soil Moisture Depletion Rates for the Period (Inches per day)
3-28-67	12.03		
		0.75	0.06
4-11-67	11.97		
		6.84	0.14
6- 2-67	11.76		
		0.50	0.07
6-13-67	11.53		
		3.73	0.16
7- 4-67	11.89		
		1.64	0.14
7-25-67	10.65		
		1.50	0.13
8- 8-67	10.39		
		0.00	0.09
8-15-67	9.74		
		0.38	0.08
8-31-67	8.86		
		2.47	0.03
9- 8-67	11.13		
		1.24	0.08
9-19-67	11.47		
		1.62	0.11
10- 3-67	11.51		
		1.84	0.10
10-19-67	11.83		
		0.95	0.05
11- 7-67	11.85		
		0.42	0.01
12- 6-67	11.89		
		0.43	0.00
12-20-67	12.36		
		1.06	0.03
1-24-68	12.52		
		2.98	0.02
3-27-68	14.05		
		6.65	0.13
5-16-68	14.19		
		3.00	0.18
5-30-68	14.63		