Illinois State Water Survey
HYDROLOGY DIVISION

SWS Contract Report 502

SEDIMENTATION SURVEY OF PINCKNEYVILLE CITY LAKE, PERRY COUNTY, ILLINOIS

by
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Prepared for the City of Pinckneyville

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INTRODUCTION

The Illinois State Water Survey, in cooperation with the city of Pinckneyville, conducted a sedimentation survey of Pinckneyville City Lake during 1990. This report presents the results of this sedimentation survey, including the current lake volume, the volume loss rate, and the sedimentation rate.

Reservoir and Watershed Description

Pinckneyville City Lake lies in Perry County, approximately 2 miles north-northwest of the city of Pinckneyville (figure 1). The dam, located in Section 14, Township 5S, Range 3W, impounds Opossum Creek, a tributary to Beaucoup Creek in the Big Muddy drainage basin. The lake occupies 192 acres in Sections 10, 11, and 14 of Township 5S, Range 3W.

The Pinckneyville City Lake watershed area contains 3,385 acres (5.29 sq mi) in the Southern Till Plains Division of the Mt. Vernon Hill Country Section of the Central Lowland Physiographic Province. This region is characterized by flat and rolling uplands dissected by tributary streams with steep slopes and varied relief. The soils are glacial till with an average thickness of approximately 20 feet, overlaid by windblown loess. The average annual precipitation (1951-1980) is approximately 39.60 inches (at DuQuoin).

Background

The earliest public water supply for the city of Pinckneyville was installed in 1894. This water supply was used only for fire protection and the electric plant. Water was taken from Beaucoup Creek during low flows, or from Breese Lake (a natural oxbow lake formed adjacent to the creek) during periods when the creek had high turbidity levels. Water for personal consumption came primarily from shallow private wells.

In 1925, a new treatment plant was constructed and Breese Lake was no longer used as a water source. Water in the system was used for personal consumption but

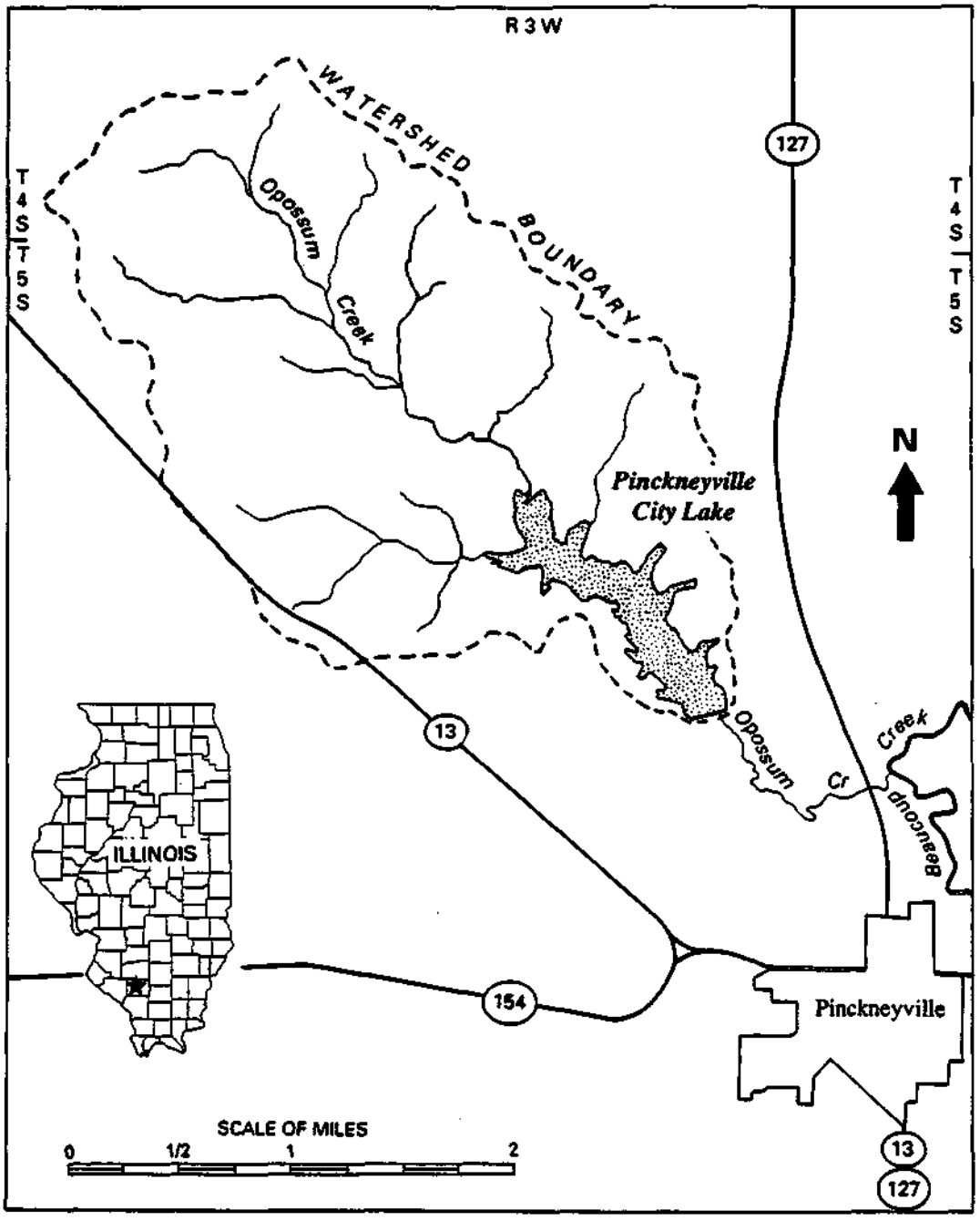

Figure 1. Location of Pinckneyville City Lake and its watershed

was not chlorinated. A 1932 evaluation of potential ground-water sources concluded that no viable sources existed that could provide sufficient water supply.

The present lake was built in 1944-1945 from plans prepared in 1941 by the Department of Conservation and the Division of Waterways for the Statewide Works Progress Administration Conservation Dam Program. Initiation of the project was delayed by wartime shortages of reinforcing steel. Through at least 1953, the lake was used to supplement the flows of Beaucoup Creek by releasing water into the channel. Water is now taken directly from the reservoir. The lake was seriously drawn down in 1953 (6.5 feet), 1970, 1976, and 1988-1989. The 1970 and 1976 drawdowns were the result of leaks in the intake tower. The 1953 and 1988-1989 drawdowns resulted from prolonged droughts.

LAKE SEDIMENTATION SURVEY

Surveying Techniques

The lake sedimentation survey was accomplished by creating 15 lake segments separated by 14 permanent range lines, as shown in figure 2. All range lines were marked at each end with a concrete survey monument to facilitate relocation for future surveys.

A marked polypropylene cable was stretched between the monument locations to provide horizontal control when positioning the sounding boat. The water depth relative to the spillway crest elevation was measured at 25-foot intervals along the range lines by using a 2-inch-diameter aluminum sounding pole with markings every 0.1 foot. An 8-inch diameter, free-sliding sounding shoe is used with the pole to increase the operator's sensitivity to the soft surface of the lakebed. This shoe floats on the sediment/water interface as the sounding pole is slowly worked up and down, to aid in determining a more precise depth. The sediment thickness is then measured by driving the sounding pole through the softer accumulated sediment to the firmer original lakebed sediments.

In addition to the range line soundings, 25 sonar transects were run by using a Lowrance sonar depth finder. The sonar transects were run as a control check between discrete sounding pole locations and to assist in contouring the lakebed between the surveyed range lines.

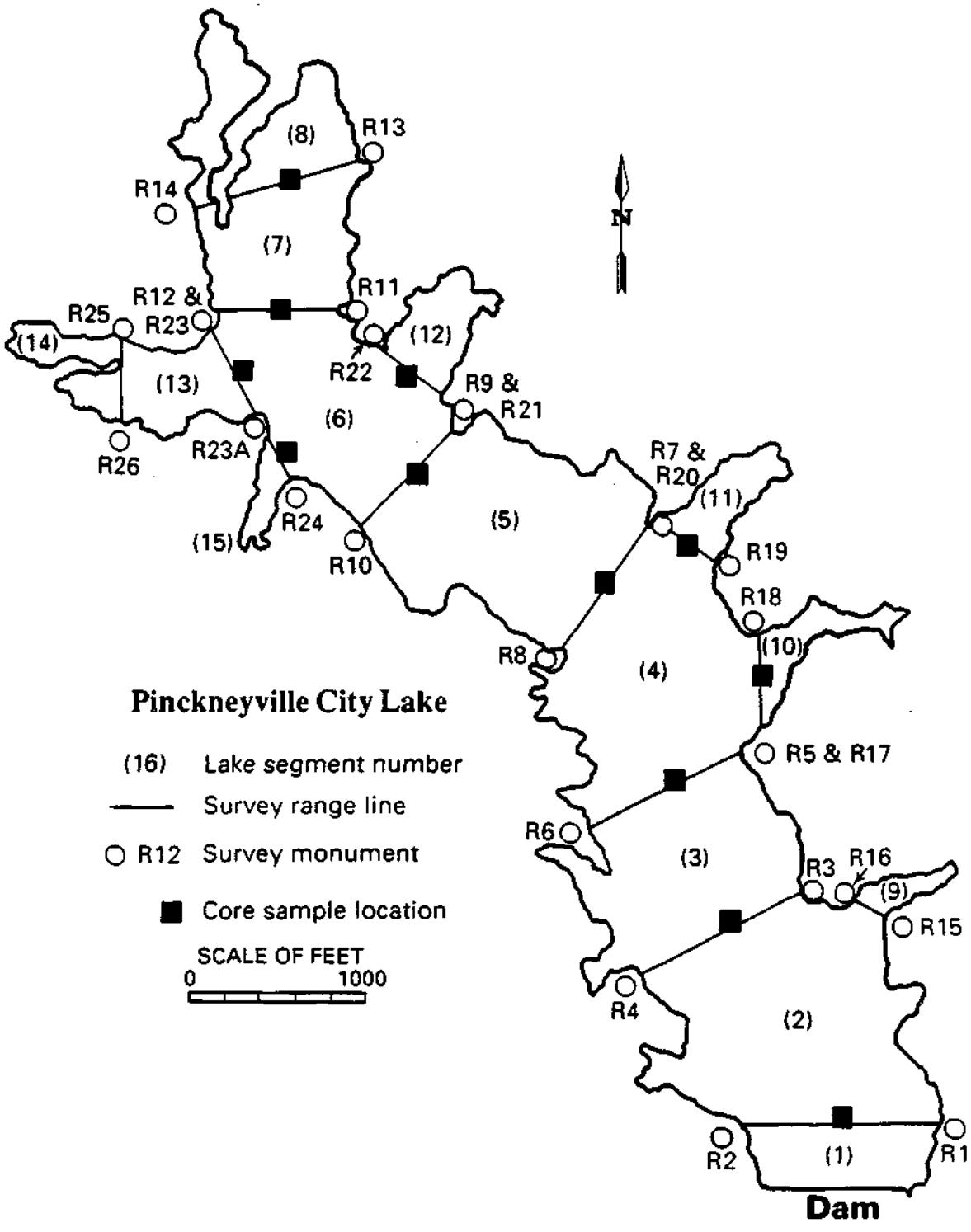

Figure 2. Pinckneyville City Lake survey range lines, lake segments, and core sample locations

Sediment Sampling

Lakebed samples were collected at 12 locations in the lake as shown in figure 2. The samples were analyzed for particle size distribution and unit weight. Two types of samplers were used: a 3-foot-long, 2-inch-diameter piston-type core sampler and an Ekman dredge surface sampler. The core sampler will produce a core up to 3 feet long, while the Ekman dredge samples the top 2 to 4 inches of the lakebed. The core samples were placed on a sample board for the recording of sample length and physical description. Subsamples were then measured and cut **from** the cores for laboratory analysis of unit weight and particle size distribution. Samples of the lakebed surface were taken **for** particle size analysis by using the Ekman dredge.

LAKE SEDIMENTATION ANALYSES

Range-Line Profiles

The range-line survey data were used to generate range-line plots comparing the original lakebed and the current lakebed profiles. This information was analyzed to:

1) Determine the volume loss rate and sedimentation rate.
2) Create a bathymetric map.
3) Develop the stage-volume-area relationship.

Figure 3 is a plot of the survey data from range line R9-R10 located in the upper one-third of the reservoir (see figure 2). As can be seen in this figure, the trend is for the lakebed topography to smooth out over time as the inflow of sediment accumulates fastest in the deeper portions of the cross section such as the original creek channel. The average depth along this survey line relative to the spillway crest at the time of the lake construction was 13.2 feet compared to the current average depth of 9.7 feet, for a 3.5-foot loss of average depth.

Figure 4 is a plot of the survey data from range line R3-R4 located at the lower end of the lake. A similar smoothing out of the lakebed is seen. The average original depth at construction was 20.8 feet compared to the current average depth of 17.4 feet, for a 3.4-foot loss of average depth. The other range-line plots are presented in the appendix.

Range-Volume Calculations

To determine the lake volume and the volume of the accumulated sediments, the depth data from the range-line profiles were combined with surface-area data

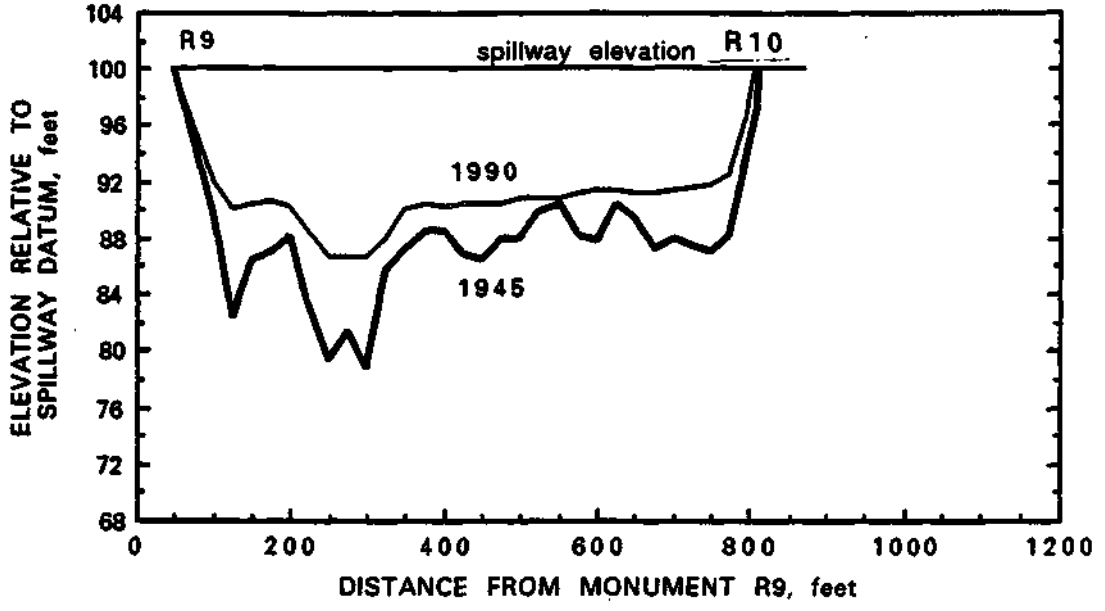

Figure 3. Typical cross section of the upper end of Pinckneyville City Lake

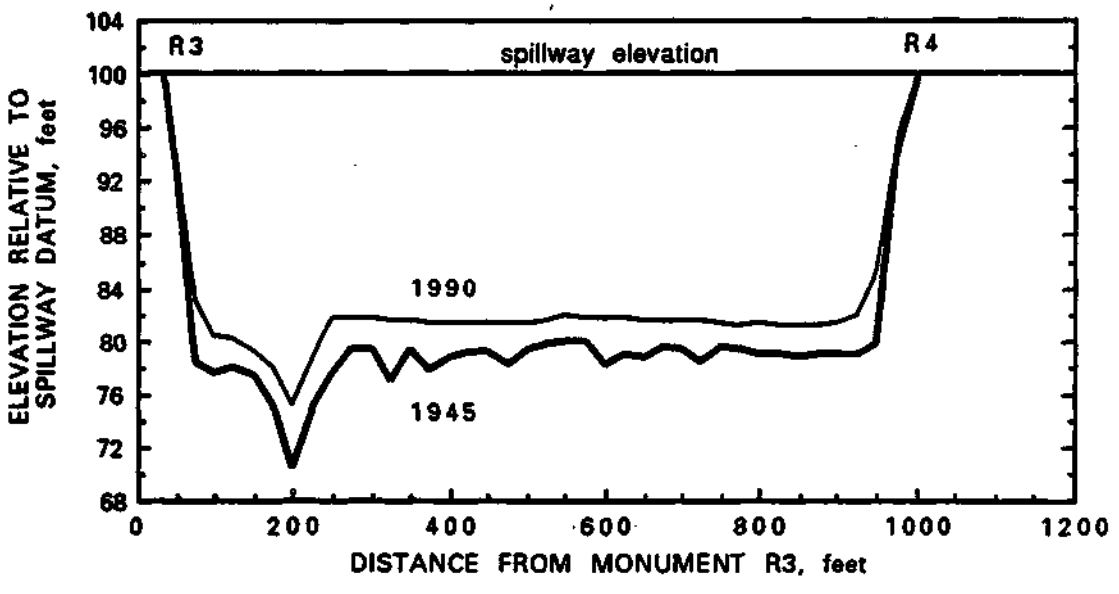

Figure 4. Typical cross section of Pinckneyville City Lake near the dam

determined from aerial photography. The methods used were developed by the U.S. Soil Conservation Service, as described in their National Engineering Handbook (U.S. Department of Agriculture, Soil Conservation Service, 1968).

Table 1 shows the lake volume at the time of construction of the lake in 1945 and at the time of the lake survey in 1990. Table 2 lists the individual segmental volumes for each lake segment indicated in figure 2.

Table 1. Volume of Pinckneyville City Lake
and Volume of the Accumulated Sediment

Watershed area - 5.29 square miles
Reservoir area -192 acres

Year of survey	*Interval since last survey (years)*	*Lake volume (acre-feet)*	*(MG)**	*Lake volume per square mile of watershed (acre-feet)*	*Sediment volume (acre-feet)*
1945		2510	818	475	
1990	45	2020	658	382	490

*Million gallons

Lake and sediment volumes are given in units of acre-feet in this report because of the common usage of these units in water resources analyses. In text or tables where units of million gallons might be most useful for water supply analysis, the volume is also noted in this form. The conversion from acre-feet to million gallons (MG) is:

Volume (MG) = 0.3258 x Volume (acre-feet)

Stage-Volume-Area

Data collected for the cross-sectional survey were used in conjunction with supplemental depth sounder transects to develop the bathymetric map presented in figure 5. This map is a plot of depth contours below the spillway crest elevation.

The bathymetric map was used to develop the stage-volume-area relationship presented in figure 6. This relationship can be used to determine the volume of water remaining in the reservoir for any drawdown below the spillway crest elevation.

Table 2. Original Lake Volume, Current Lake and Sediment Volumes, and Percent Volume Loss by Lake Segment

Lake segment	*Original lake volume (acre-ft)*	*Current lake volume (acre-ft)*	*Sediment volume (acre-ft)*	*Percent volume loss*
1	159.3	135.1	24.2	15.2
2	681.5	585.7	95.8	14.1
3	423.2	360.0	63.2	14.9
4	424.4	351.0	73.4	17.3
5	343.3	268.8	74.5	21.7
6	216.8	153.6	63.2	29.2
7	58.0	34.8	23.2	40.0
8	45.1	23.5	21.6	47.8
9	10.6	7.6	3.0	28.2
10	34.4	28.1	6.3	18.3
11	28.0	21.5	6.6	23.3
12	27.3	19.8	7.5	27.6
13	37.5	19.4	18.1	48.3
14	14.5	7.5	7.0	48.5
15	7.5	5.7	1.8	23.5
TOTAL	2510	2020	490	20*

*Average for entire lake

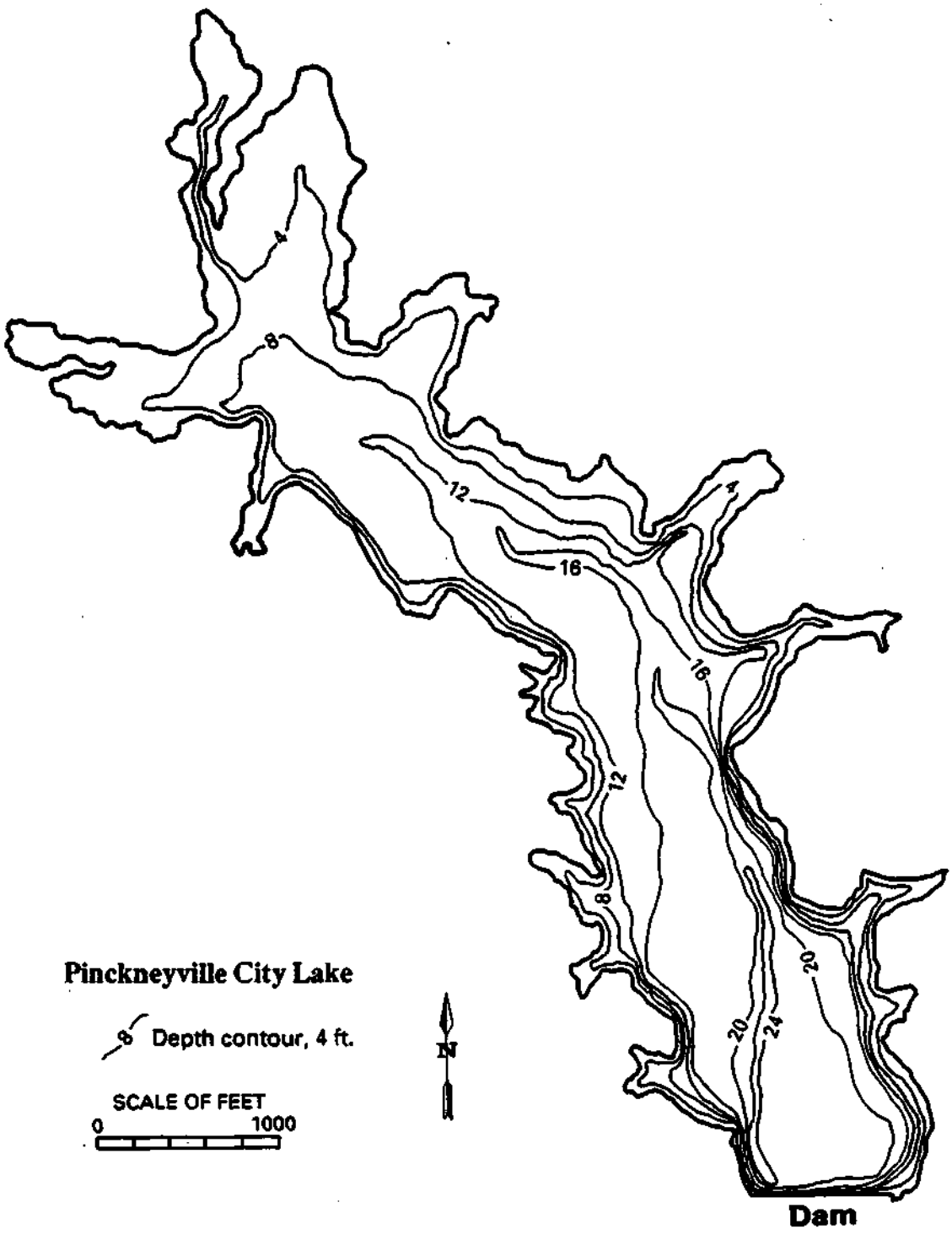

Figure 5. Bathymetric map of Pinckneyville City Lake

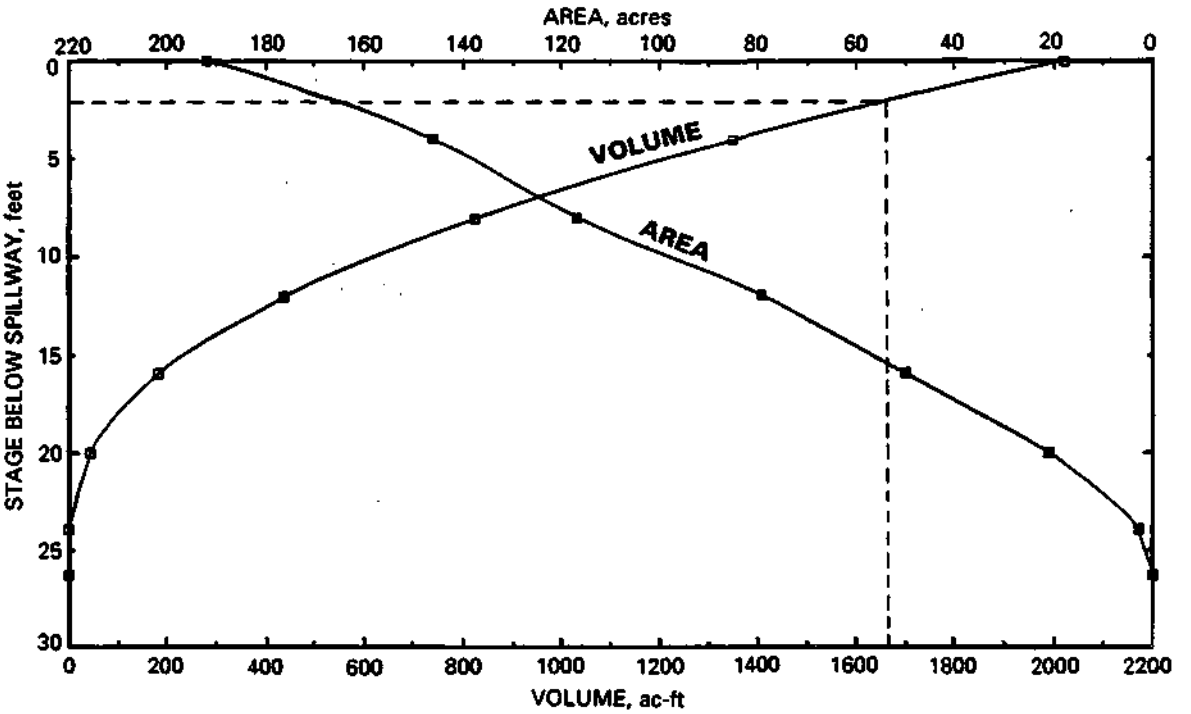

Figure 6. Stage-volume-area relationship for Pinckneyville City Lake, 1990

In figure 6, lines have been drawn to indicate the use of the graph. For a water level in the lake which is 2 feet below the spillway level, follow the line across from 2 feet on the vertical scale and then look directly down to observe the volume at that lake level of 1,670 acre-feet.

Lake Sediment Characteristics

The sediments in Pinckneyville City Lake are typical of Illinois lake sediments. The particles are typically fine-grained with very little sand and no gravels. The weighted averages for all sediments in Pinckneyville City Lake are 6% sand, 36% silt, and 58% clay.

Twenty-five unit weight samples were taken throughout the lake for analysis. Figure 2 shows the locations of these samples. The objective is to collect representative sediment samples from various locations in the lake to determine the average unit weight in each lake segment.

Table 3 lists the unit weight and accumulated tonnage of sediment for each lake segment. The average unit weight of the sediment is 43 pounds per cubic foot. A total of 461,000 tons of sediment has accumulated since the lake was constructed in 1945.

Sedimentation Rate

Lake sedimentation rates can be expressed in terms of reservoir volume loss or sediment accumulation. Reservoir volume loss, which is the actual amount of lake storage that has been displaced by the accumulated sediments, is the most significant factor in water supply analysis. Lake sediment accumulation rates, on the other hand, are most useful in comparing the differential sedimentation patterns between lake systems, determining differences in sedimentation rates for lakes that have had multiple surveys, and analyzing sediment input from the watershed area. Sediment accumulation is expressed by the weight of sediment in the lake; this measurement is not affected by physical compaction of the sediments.

The 490 acre-feet (160 MG) of sediment that have accumulated in Pinckneyville City Lake (table 1) represent a loss of 20 percent of the original volume of the lake. Table 2 and figure 7 show the percent loss of volume for each lake segment. Overall, the average annual volume loss rate has been 0.44 percent.

There has been an average accumulation of 2.6 feet of sediment on the lakebed, which amounts to an annual accumulation of 0.06 foot. The accumulation of 461,000 tons of sediment in Pinckneyville City Lake amounts to an average annual accumulation of 10,200 tons.

Table 3. Lake Sediment Volume, Average Sediment Density, and Sediment Tonnage by Lake Segments

Lake segment number	*Sediment volume (acre-feet)*	*Average density (lbs. per cubic foot)*	*Sediment (kilotons)*
1	24.2	19.4	10.2
2	95.8	22.0	45.9
3	63.2	25.3	34.9
4	73.4	29.1	46.5
5	74.5	56.0	91.0
6	63.2	75.5	103.9
7	23.2	71.1	35.9
8	21.6	71.3	36.0
9	3.0	24.6	1.6
10	6.3	63.9	8.8
11	6.5	58.7	8.3
12	7.5	28.7	4.7
13	18.1	58.0	22.9
14	7.0	44.1	8.9
15	1.8		1.7
TOTAL	490		461

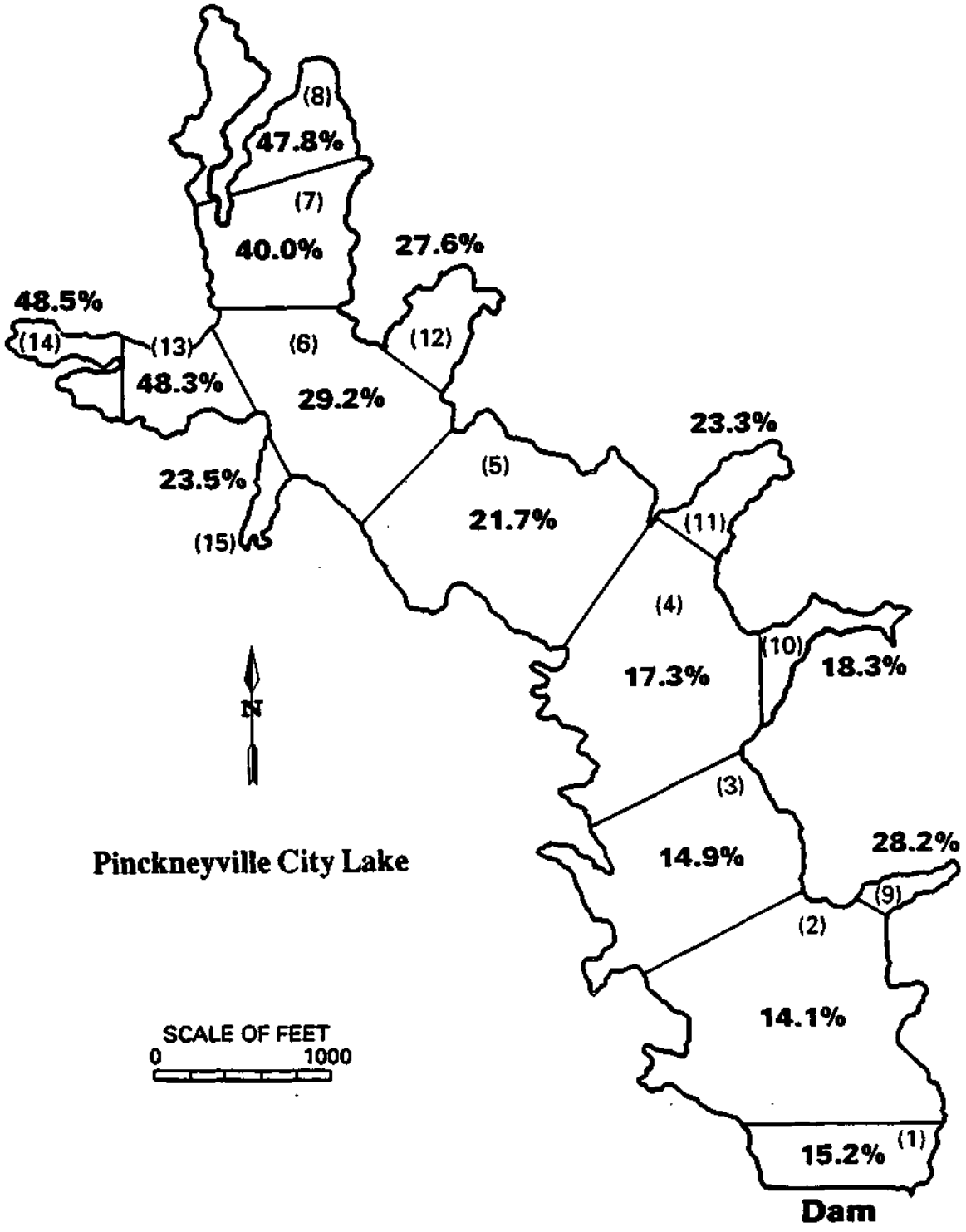

Figure 7. Percent loss of original lake volume by lake segment
(Lake segment numbers in parentheses)

Table 4 shows annual sediment accumulation rates per unit of watershed land, in terms of different units of measurement.

Table 4. Annual Sediment Accumulation Rates from the Pinckneyville City Lake Watershed

	Sediment deposited		*Sediment deposited per unit watershed area*		
			per square mile	*per acre*	*per acre*
Period	*(acre-feet)*	*(MG)*	*(acre-feet)*	*(cubic feet)*	*(tons)*
1945-1990	10.9	3.6	2.1	142	3.0

The sedimentation conditions at Pinckneyville City Lake are within a range which can be considered moderate when compared to those at other Illinois lakes and water supply lakes in the same area. Bhowmik et al. (1985) found that capacity loss rates in Illinois lakes were distributed as shown in figure 8. The 0.44 percent per year capacity loss for Pinkneyville City Lake falls below the 50th percentile for all Illinois lakes.

Table 5 compares the results of this survey of Pinkneyville City Lake to results of recent surveys of two nearby lakes: Ashley Lake in Washington County (Bogner, 1986) and Lake Carlinville in Macoupin County (Bogner, 1987). This comparison shows that the lower capacity loss rate in Pinckneyville City Lake is the result of the high capacity/watershed ratio. The delivery rate of sediment from the watershed of Pinckneyville City Lake is actually much higher than the rates of delivery to the other lakes. The most likely causes of this higher delivery rate are differences in watershed land use, slopes, cropping patterns, and cropping systems. Climatological factors such as periods of unusually high precipitation are another possible source of high sediment runoff rates.

SUMMARY

Pinckneyville City Lake was constructed in 1945. A lake sedimentation survey was conducted in 1990 to determine the lake volume, the lake volume loss, and the sedimentation rate since construction.

The lake has a surface area of 192 acres, and its original storage volume in 1945 was 2,510 acre-feet (818 MG). The 1990 lake survey determined a present storage volume of 2,020 acre-feet (658 MG) with an accumulation of 490 acre-feet (160 MG) of sediment over the past 45 years. This is a total volume loss of 20 percent, or a 0.44 percent volume loss per year.

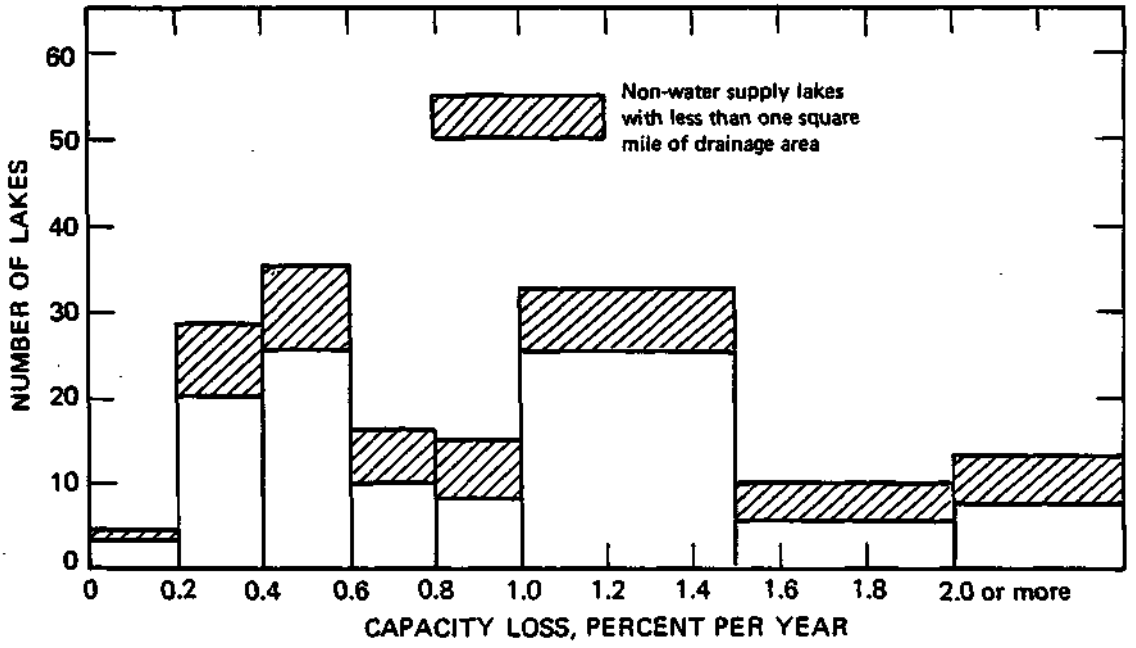

Figure 8. Capacity losses of Illinois lakes

Since construction of the lake in 1945, 461,000 tons of sediment have been deposited in the lake. This is an average of 10,200 tons per year, or 3.0 tons per acre of watershed per year.

Table 5. Comparison of Survey Results to Results for Nearby Lakes

Lake name	*Most recent survey (year)*	*Reservoir storage capacity (ac-ft)*	*Capacity/ watershed ratio (ac-ft per sq mi)*	*Annual storage capacity loss (percent)*	*Annual sediment input per sq mi of watershed area (ac-ft)*	*(tons)*
Pinckneyville City Lake	1990	2020	382	0.44	2.1	1940
Lake Carlinville	1986	1650	65	0.73	0.68	780
Ashley Lake	1985	123	102	0.64	0.91	1090

ACKNOWLEDGMENTS

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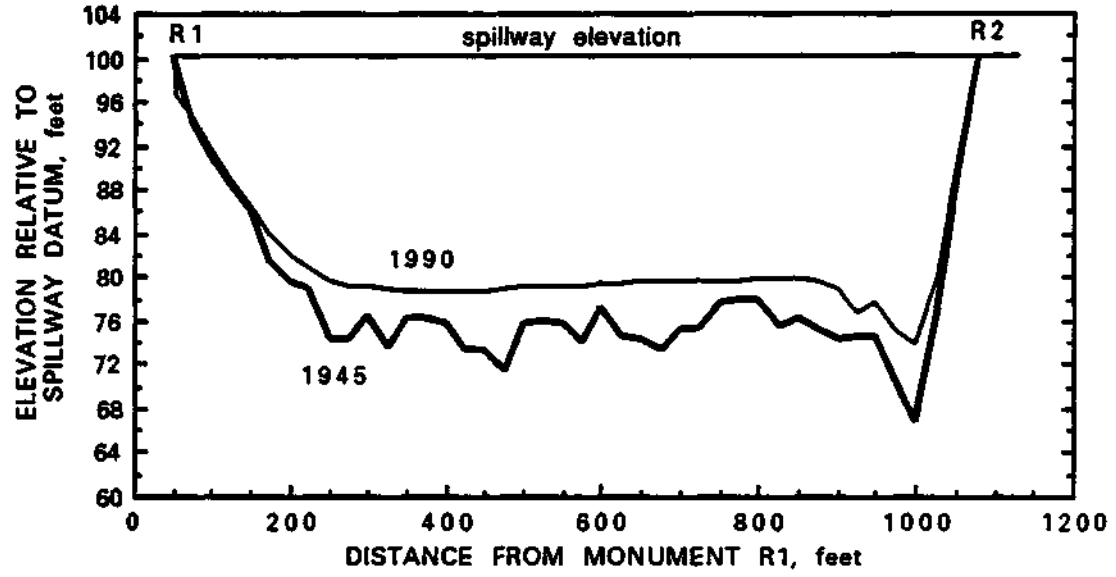
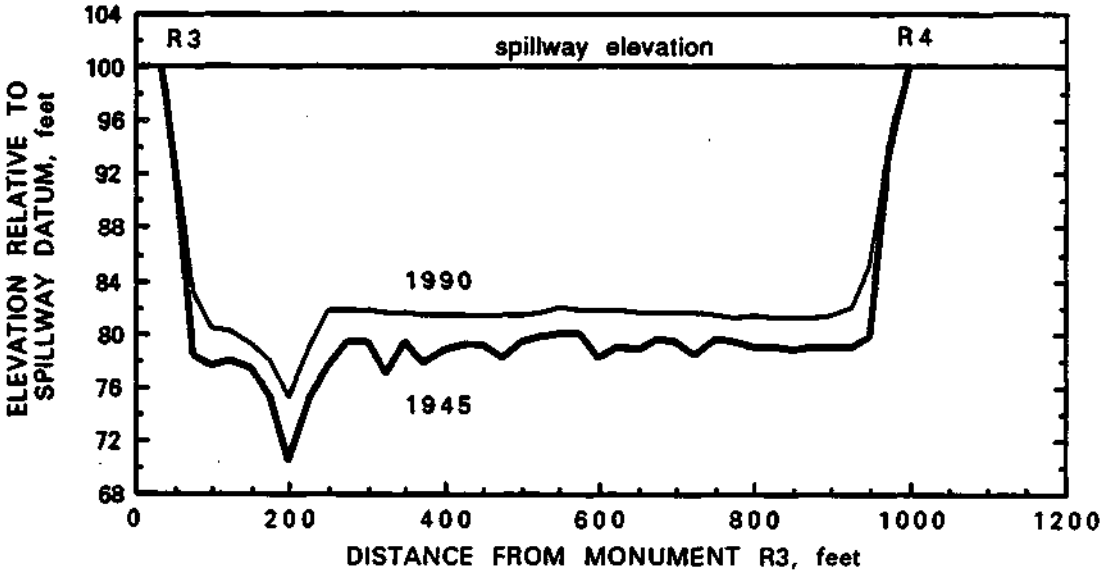
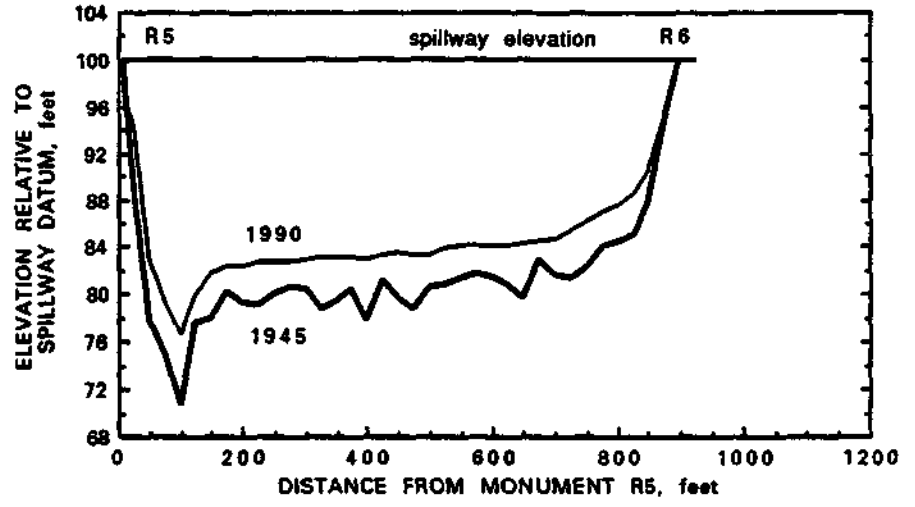
Appendix. Cross-Sectional Plots of Range Lines



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spillway elevation
R6
1990
1945
ELEVATION RELATIVE TO SPILLWAY DATUM, feet
DISTANCE FROM MONUMENT R5, feet
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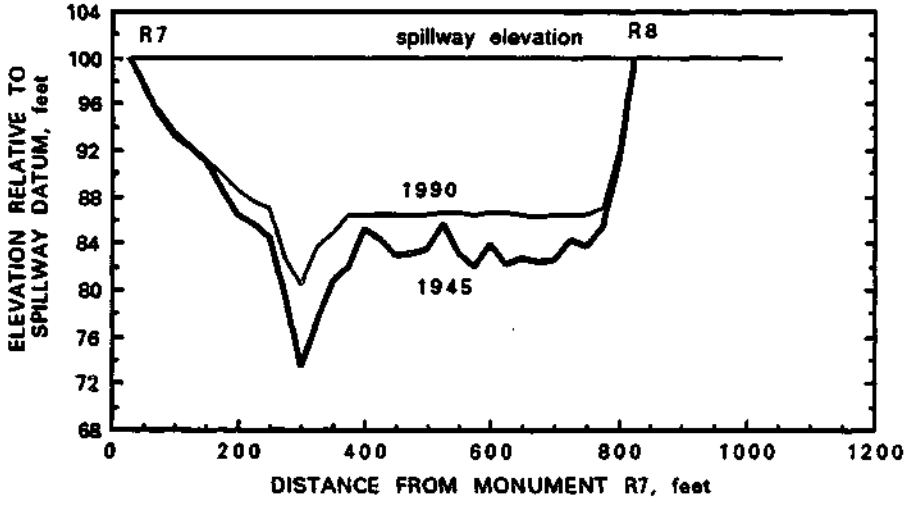
100
96
92
88
84
80
76
72
68
0
200
400
600
800
1000
1200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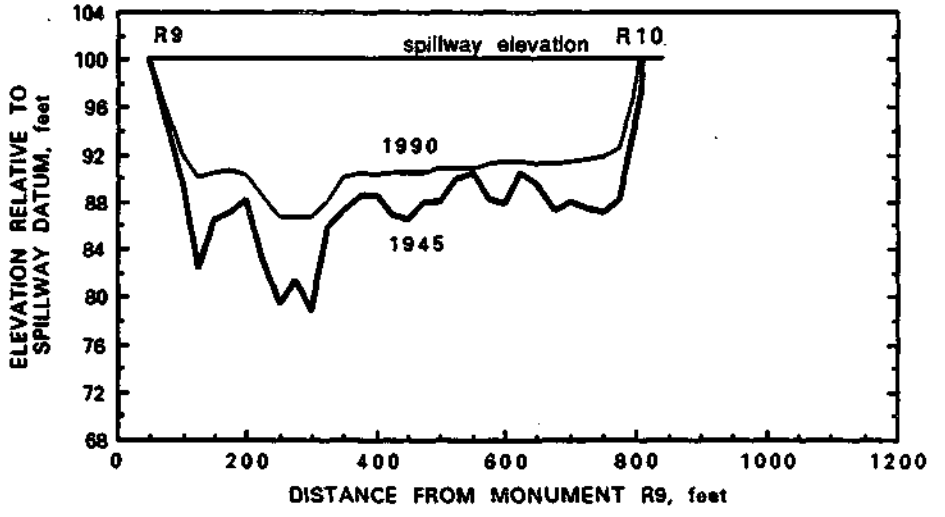
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R10
1990
1945
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DISTANCE FROM MONUMENT R9, feet
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80
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72
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0
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400
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800
1000
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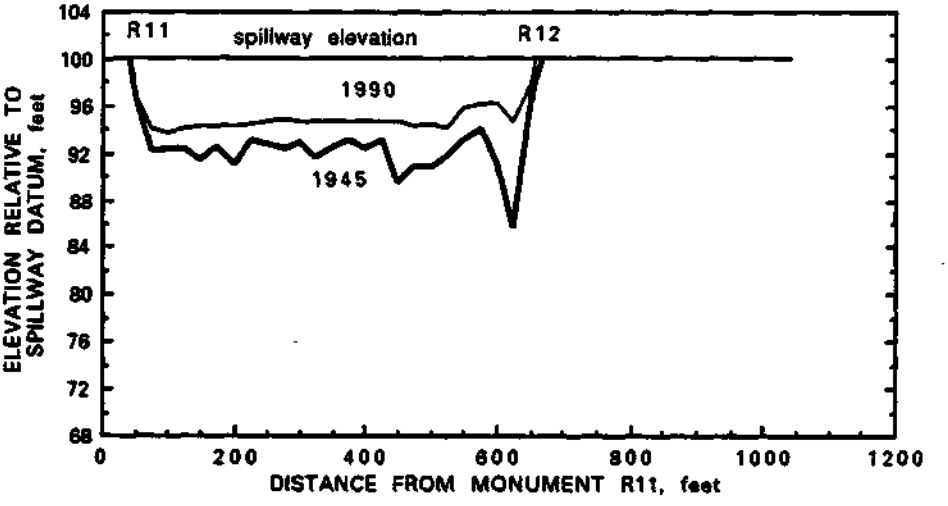
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R12
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76
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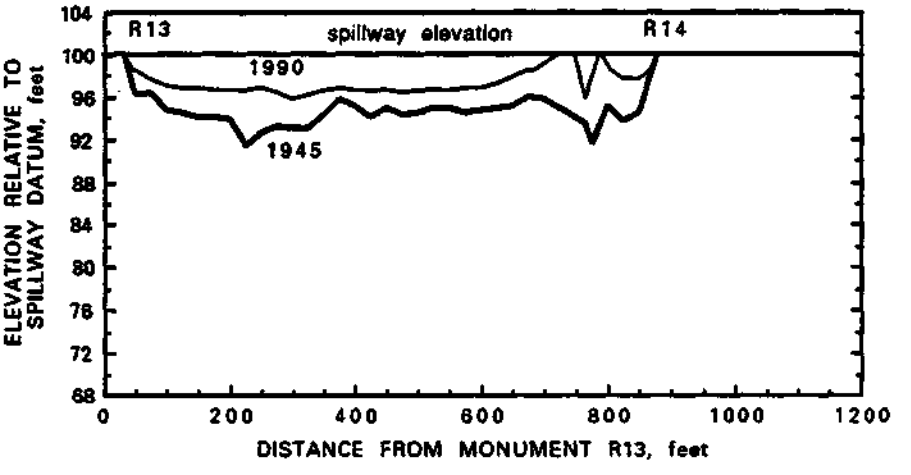
1200
DISTANCE FROM MONUMENT R11, feet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spillway elevation
R14
1990
1945
ELEVATION RELATIVE TO SPILLWAY DATUM, feet
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88
84
80
76
72
68
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1000
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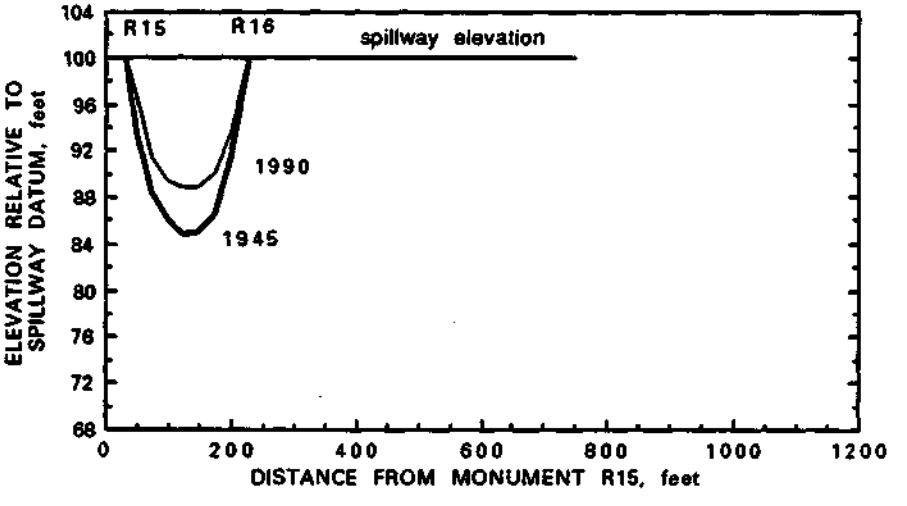
DISTANCE FROM MONUMENT R13, feet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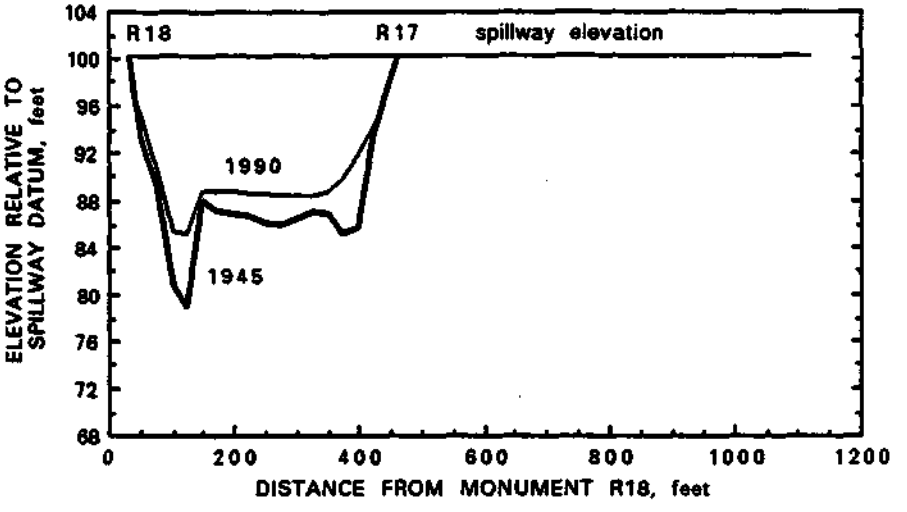
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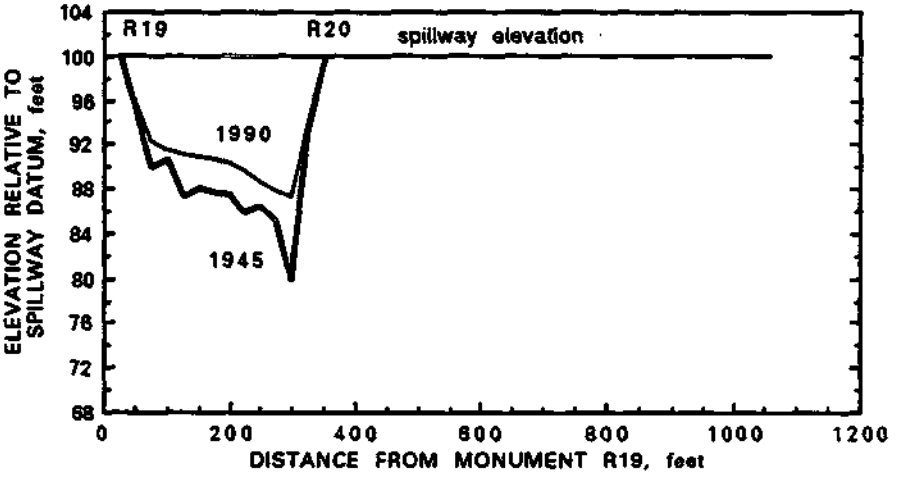
DISTANCE FROM MONUMENT R18, feet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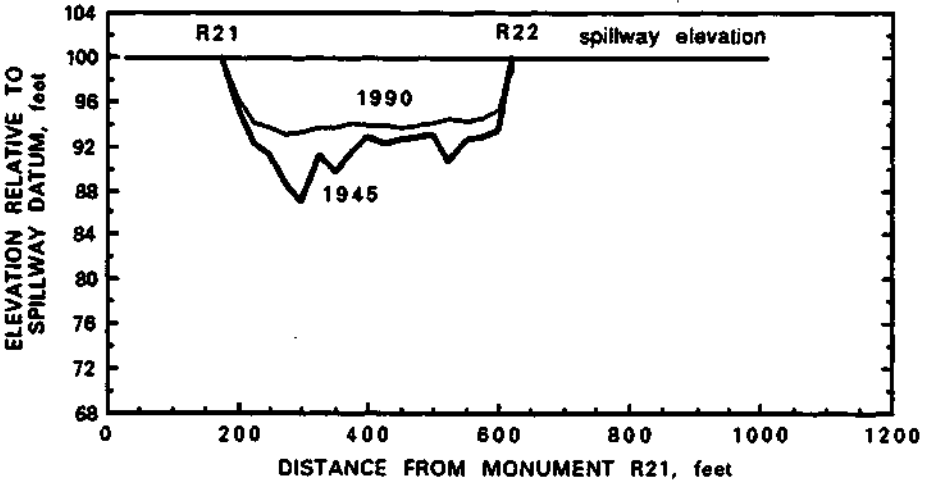
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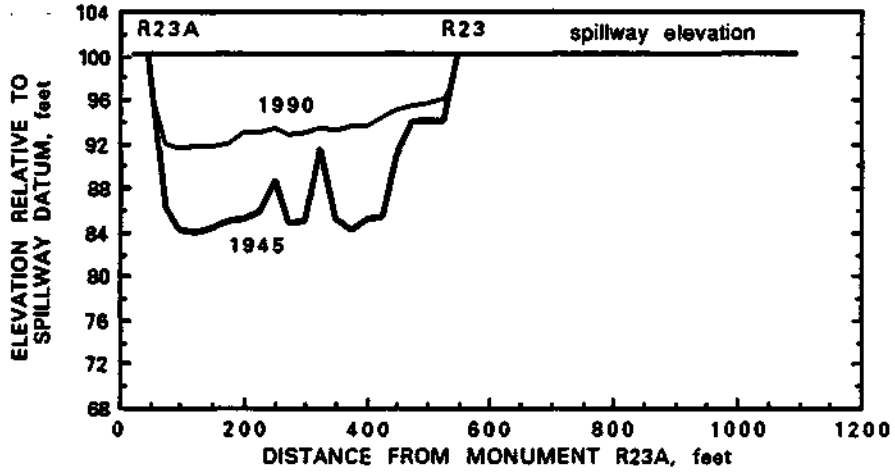
DISTANCE FROM MONUMENT R21, feet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R23
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1945
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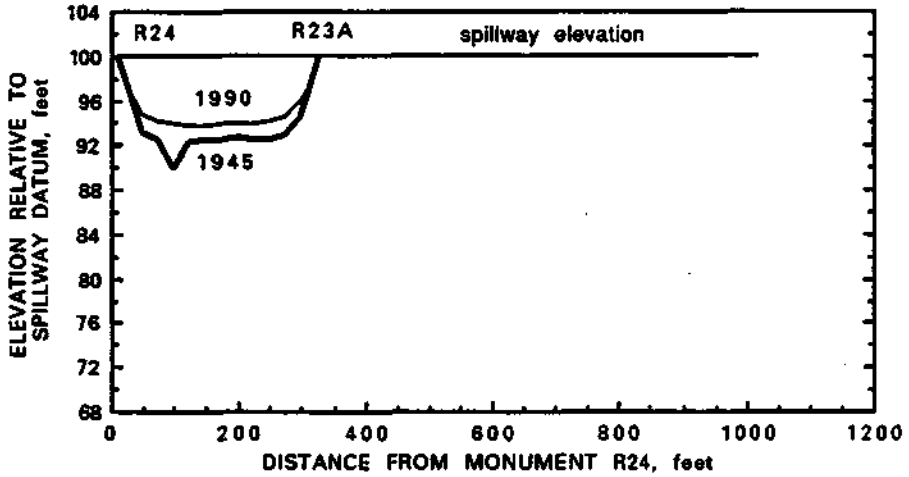
DISTANCE FROM MONUMENT R23A, feet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R23A
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1945
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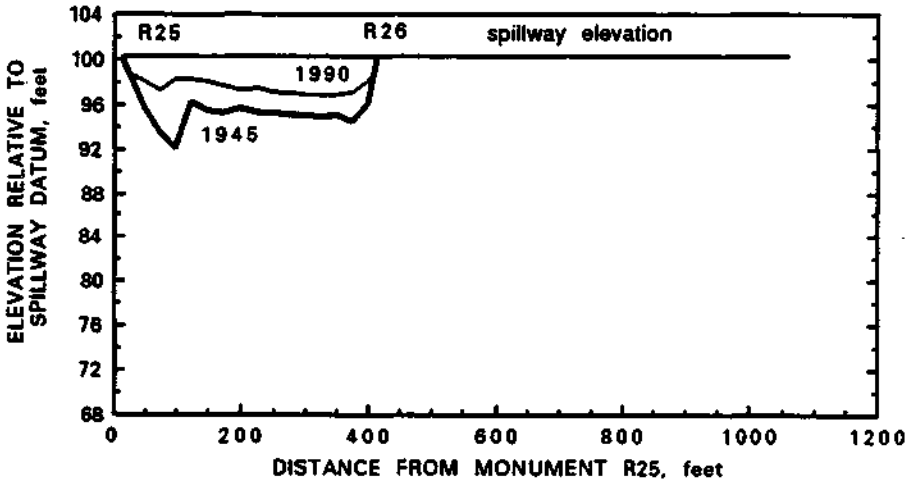
DISTANCE FROM MONUMENT R24, feet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R26
spillway elevation
1990
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