To the Graduate Council:

I am submitting herewith a thesis written by Edward Allen Bright entitled "An Evaluation of Levee Protection of Agricultural Land in West Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geography.

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AN EVALUATION OF LEVEE PROTECTION OF AGRICULTURAL LAND IN WEST TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Edward Allen Bright

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ABSTRACT

The economic benefits occurring to production of crop have been used as a justification for construction of levees on the lower Mississippi floodplain. The purpose of this thesis is to determine if levee protection of agricultural land does in fact prevent severe crop reduction or loss in west Tennessee. The timing of the Mississippi floods is examined to evaluate the extent to which major floods, because of their seasonality, interfere with crop production. A water budget analysis is used to establish the field moisture condition of land protected by levees when floods occur during the crop growing season. The benefit-cost basis by which a levee in west Tennessee was justified is reviewed and an attempt made to evaluate the economic validity of the levee argument. It is concluded that most of the Mississippi floods occur before the normal growing season of the major crop. Tributary floods or standing water from excess local precipitation generally make cultivation of the levee-protected lands impossible when the Mississippi is in flood during the growing season. During recent years, flood related crop loss has been averted by delaying planting or replanting the crop. The benefits afforded to agriculture by the levee are overestimated, and if all of the costs of levee protection are considered levee protection of agricultural land is not cost effective. Levee

protection of agricultural land in west Tennessee is neither necessary nor can it be economically justified for that purpose.

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CHAPTER I

THE PROBLEM

Introduction and Statement of Problem

Since the 1700's, levees have been constructed along the Mississippi River for flood protection. In 1879, the Mississippi River Commission was formed to improve the river for navigation and flood control. The Commission planned an extensive levee system as the primary method of flood control and justified levees and flood protection using estimates of benefits to the agricultural use of land. A resolution passed in 1845 at the Memphis Convention of Southern and Western states proclaimed:

> . . . that millions of acres of public domain lying on the Mississippi River and its tributaries, now worthless for purposes of cultivation, might be reclaimed by throwing up embankments, so as to prevent overflow.[1]

As the floodplain was settled, levees were constructed in an attempt to protect not only the agricultural lands from floods, but also a great number of farmers, buildings, and livestock on the floodplain. With the development of large scale, mechanized agriculture over the past forty years many farmers have left these lands so that today there are many fewer farms and their facilities to protect.

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[1]Benjamin Humphreys, Floods and Levees on the Mississippi River (Memphis: Mississippi River Levee Association, 1914) p. 29.

Ideally, a levee is envisioned as providing protection which permits the continuation of normal farming practices on the protected land while the river is in floodstage and prevents flood related crop damage. Actually, however, agricultural land behind levees may experience standing water from local rainfall and upland run-off at times of river flooding. Thus levees may not provide protected land a large advantage over unprotected land. Water saturated soils are detrimental to cropping regardless of the origin of the surplus water. The purpose of this study is to evaluate the actual protection of agricultural lands in west Tennessee by the levees along the Mississippi River.

Literature Review

Research on levees in the lower Mississippi bottomlands has focused primarily upon the history of levee development in the area and proposals for new levee projects. In Floods and Levees of the Mississippi River, Benjamin Humphreys described the history of the levee system and comments on its general inadequacies during large flood events prior to 1914.[2] Humphreys criticized the early levee system for insufficient height or strength, lack of continuity, and poor maintenance. He, along with many others, proposed that levees were the only solution to the flood

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[2]Ibid., pp. 16-24.

control problem in the lower Mississippi Valley.[3] Robert Harrison provides the most notable history of levee development for a particular region of the floodplain in Levee Districts and Levee Building in Mississippi.[4]

Kemper's Rebellious River describes the flood control projects proposed by the Mississippi River Commission and the Army Corps of Engineers as authorized in the Flood Control Acts of 1928 and 1936.[5] These Acts produced a comprehensive flood control plan for the lower Mississippi River, including an extensive main-stem levee system designed and constructed by the Corps of Engineers.

Moore's Improvement of the Lower Mississippi River and Tributaries, 1931-1972 provides a comprehensive review of the levee systems development and the role of levees in the Mississippi River flood control plan.[6]

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[3]Ibid., p. 1.

[4]Robert W. Harrison, Levee Districts and Levee Building in Mississippi, Mississippi Agricultural Experiment Station, 1951.

[5]J.P. Kemper, Rebellious River (Boston: Bruce Hemphries, Inc., 1949).

[6]N.R. Moore, Improvements of the Lower Mississippi River and Tributaries 1931-1972 (Vicksburg: Mississippi River Commission, 1972).

All of these sources note several problems associated with levees, such as insufficient height and strength, seepage, backwater flooding, and maintenance. They concur, nevertheless, that levees were needed to protect the highly productive agricultural land. These sources often use flood protection of agricultural land as a justification for the development of the levee system even though no evidence is presented to substantiate the claim.

This study will attempt to determine whether levees have, in fact, prevented severe crop reductions or losses during major flooding events of the past.

Objectives of the Study

A majority of the most intensively cultivated area of the Mississippi floodplain in west Tennessee is protected from floodflows of the Mississippi River by a levee.[7] Specified objectives of the study are:

1. To investigate the extent to which major flood events, because of their seasonality, are likely to interfere with annual crop production under natural conditions.

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[7]M.E. Springer and J.A. Elder, Soils of Tennessee, Tennessee Agricultural Experiment Station Bulletin 596, 1980, p. 12.

2. To establish, by water balance analysis, the field moisture condition of land protected by levees when floods occur during the crop growing season.
3. To review the benefit-cost basis by which the levees were justified and evaluate the economic validity of the levee argument.

To determine the protection afforded agricultural land by levees in west Tennessee, several questions must be answered:

1. What farming practices are used on the unprotected land and the levee-protected land? This question includes such factors as the major crops grown in the area, their normal and extended planting dates, and the farming strategy used during years of floods.
2. At what time of the year does the Mississippi River reach floodstage? Floods occurring before the normal growing season of the major crops would not severely reduce crop production, because planting would not have started.
3. Do farms on unprotected land regularly produce a crop? If farms on the unprotected land produce a crop during the years of a major flood,

the levee would prove to be less than essential for agriculture in the area.

Flood dates and heights on tributary streams are examined to determine the frequency and extent of tributary flooding of levee-protected agricultural land.

Procedures

Interviews with informed sources in the study area were used to gain information on the normal planting dates of the major crops and on crop yields. Additional crop production data was taken from the U.S. Census of Agriculture and Tennessee Agricultural Statistics. Interviews with local agricultural officials and farmers were used to compare crop production on levee-protected land and unprotected land.

Mississippi River floods occurring during the years 1950-1981 are examined using data from the gage at Caruthersville, Missouri. Flood dates and heights are published in Climatological Data, Daily River Stages, and the Memphis Commercial Appeal. For the periods when floods occurred during the growing season, a water balance analysis was made to determine field moisture conditions of protected areas. The water budget analysis was calculated from data averaged from three nearby weather stations; Dyersburg, Tennessee; Blytheville, Arkansas; and New Madrid, Missouri. Monthly water balances were calculated to determine the

general soil moisture condition before the flooding event. Daily water balances were calculated at least three weeks prior to and during the flood event. These daily calculations are considered a reliable estimate of soil moisture conditions on protected lands during the period of floodflows.[8]

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[8]C.W. Thornthwaite and J.R. Mather, The Water Balance. Drexel Institute of Technology Laboratory of Climatology Publications in Climatology Series, vol. 8, no. 1., 3rd. ed. Centerton, New Jersey, 1955.

CHAPTER II

DESCRIPTION OF THE STUDY AREA

Physical Setting

The study area is the Mississippi River floodplain located in the western one-third of Dyer County and all of Lake County, Tennessee. This area is bounded by the Mississippi River on the north and west, the Forked Deer River on the south, and 150-200 foot bluffs on the east (See Figure 1). The floodplain surface is composed of alluvium ranging in size from gravels and sands to clays. Generally, the coarser surface soils are on the natural levee crests nearest the river, whereas, elsewhere finer textures prevail. The floodplain is characterized by near-level topography with slight swells and swales, especially in the natural levee zone. Under natural conditions the low local gradients and slowly permeable soils away from the natural levees, particularly, result in poor surface drainage during periods of persistent precipitation.[9]

The climate of the region is characterized by mild winters, hot summers, and abundant rainfall. The area has

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[9]W.T. Brown, W.F. Moffitt, C.L. Moore, and W.C. Jackson, Soil Survey of Dyer County, United States Department of Agriculture, Soil Conservation Service and Tennessee Agricultural Experiment Station, (Washington, D.C.: Government Printing Office 1965), p. 1.

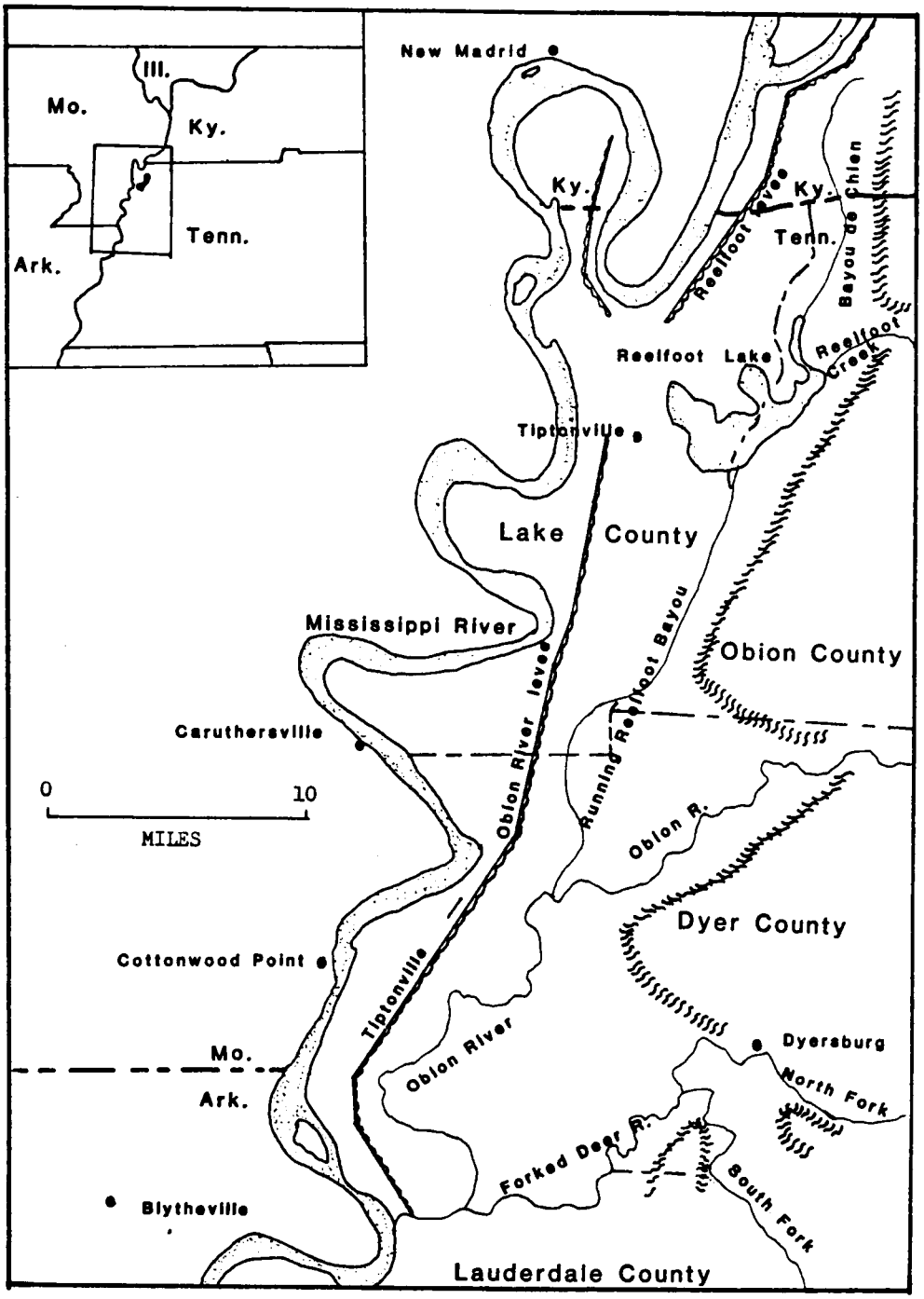


FIGURE 1. MISSISSIPPI RIVER FLOODPLAIN - DYER AND LAKE COUNTY, TENNESSEE.

a growing season of approximately 220 days. The average dates of the last freezing temperature in spring and of the first in fall are March 27 and October 31, respectively.

Average annual rainfall is approximately 48 inches, with the seasonal maximum occurring in the winter and early spring and the minimum in late summer and early fall.[10] This regime can cause excessive soils moisture in the spring and some moisture deficit in late summer, but usually soil moisture is adequate for the field crops grown.

The most significant topographic features in the study area are attributed to the New Madrid earthquake of 1811-1812, which consisted of a series of tremors starting in December 1811 and lasting throughout much of 1812. The main earthquake created Reelfoot Lake in Lake County, forming it by a combination of subsidence at the lake site and uplift of land to the west and south of the lake (Tiptonville Dome).[11] The basin quickly filled with water from Reelfoot Creek and Bayou de Chien. The Tiptonville Dome, which is an almost imperceptible surface water divide in the north-central part of Lake County, is an uplift of approximately ten feet.

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[10]National Oceanic and Atmospheric Administration, Environmental Data Service, Climatological Data - Tennessee, Annual Summaries 1950-1980.

[11]S.C. Glenn, "Geology and Geography of the Reelfoot Lake Region," Journal of the Tennessee Academy of Science, vol. 8, 1933, p. 27.

The floodplain surface of the rest of the study area slopes very gently eastward or away from the river and southward with the gradient of the river. Microrelief is extremely important to local drainage conditions on the Mississippi floodplain. Even slightly higher lands are generally better drained and often have coarser soil textures, whereas, basins usually have fine textured soils which in combination with their depression setting results in poor drainage.[12]

Soils

Four major soil associations are found in the study area (See Figure 2). Commerce-Robinsville-Crevassee association extends roughly one mile inland from the Mississippi in Dyer County and two to eight miles inland in Lake County. These loamy soils lie mainly between the river and the main levee. Coarser textures and better drainage are found on the higher areas next to the river. As the distance from the river increases, textures become finer and drainage poorer. Generally, soils of this association have moderate internal drainage and are considered the most fertile in the state.[13]

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[12]Ibid., p. 29.

[13]W.T. Brown, W.C. Jackson, G.L. Keathley, and C.L. Moore, Soil Survey of Lake County, United States Department of Agriculture, Soil Conservation Service and Tennessee Agricultural Experiment Station, (Washington, D.C.: Government Printing Office, 1969). pp. 6-8.

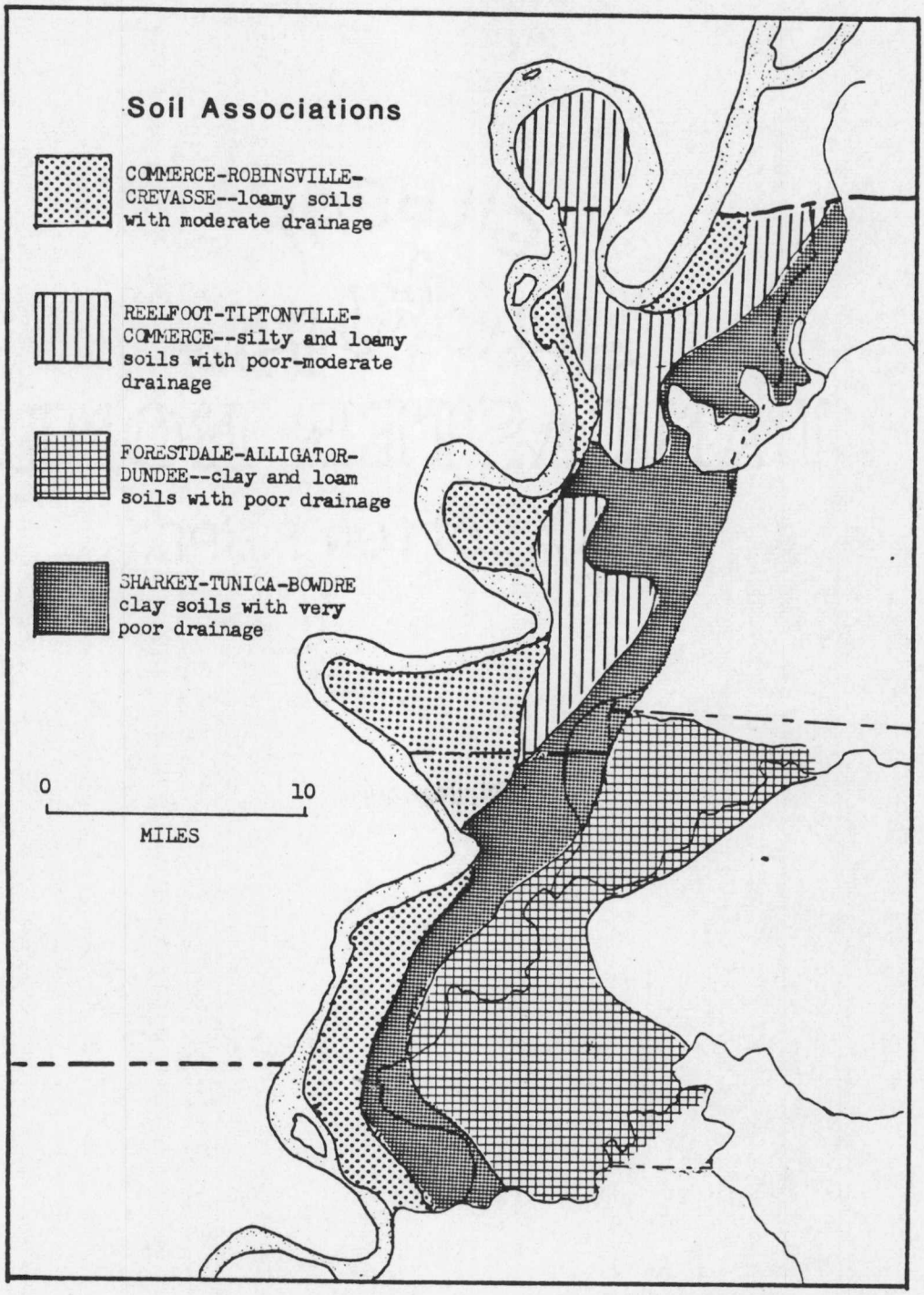


FIGURE 2. SOIL ASSOCIATIONS.

The Reelfoot-Tiptonville-Commerce association is mostly in north-central Lake County on the Tiptonville Dome. Soils are mostly silty and loamy in texture. For the most part, these soils are moderately well drained, but have pockets of poor drainage in lower areas. Practically all of the land in this association is cultivated. The main levee is along the western edge of this soil association.

South and east of the Tiptonville Dome lies the Sharkey-Tunica-Bowdre association, which are poorly drained clays occupying the lowest parts of the Mississippi River bottoms. The area of this soil association is behind the main levee along the Mississippi, but is subject to overflow from the Obion River and other local sources of run-off. Clays in this association are montmorillonitic and therefore have high shrink-swell properties. Internal drainage is very poor and water stands throughout the winter and spring and for some time after heavy rains. Nevertheless, most of this association is cultivated except for the lowest lying parts which are wooded and remain too wet for crops in most years.[14]

The Forestdale-Alligator-Dundee association lies east of the Sharkey-Tunica-Bowdre association in Dyer County. This association is comprised of poorly drained and somewhat

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[14]Brown et. al., Soil Survey Lake County, pp. 6-8.

poorly drained, clay and loamy soils. These soils have characteristics similar to those in the Sharkey-Tunica-Bowdre association but are slightly coarser textured. They too, retain standing water in the winter and spring and for a period of time after any heavy rain.[15]

Drainage

Major creeks in the area are Bayou de Chien and Reelfoot Creek, which drain into Reelfoot Lake. Running Reelfoot Bayou runs south from Reelfoot Lake into the Obion River. The Obion River flows southwest across the floodplain where it is joined by the Forked Deer River near the confluence of the Mississippi. Poor drainage is a major problem for agriculture because of the early level topography and fine textured soils create both poor surface and internal drainage. Ditches dug along some fields and roads have helped reduce surface drainage problems, but all ditches, sloughs, and creeks have very gentle gradients and are subject to frequent overflow.

When the Mississippi floods, the levee floodgates are closed and the streams have no outlet.[16] A damming effect from Mississippi River floodwater is created on the Obion and

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[15]Brown et. al., Soil Survey Dyer County, p. 6.

[16]John Bradley, Lake County SCS Chairman, Agricultural Extension Leader, Tiptonville, personal interview, February 5, 1982.

Forked Deer rivers, which enforce backwater flooding over much of the study area in Dyer County, because a levee to control backwater floods from the Obion and Forked Deer Rivers was never built. Flooding is also common place from smaller streams, especially those having outlets through levee floodgates.

Levee Developments

The bottomland in west Tennessee was settled relatively late compared to the adjacent uplands. The first inhabitants settled on the higher, better drained land. In 1857, a settlement was started at Tiptonville, and Lake County became established in 1870. The floodplain in Dyer County has remained very sparsely populated throughout the years because of the poor drainage. From the beginning levees were constructed to protect land from Mississippi River floodflows. Most levees were low and short.[17] In 1909, the Lake County levee district started construction of a levee from Hickman, Kentucky, to the high land north of Tiptonville. The purpose of this levee was, in part, to prevent floods from destroying Reelfoot Lake by sedimentation or scouring.[18]

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[17]Brown et. al., Soil Survey Dyer County, p. 1.

[18]C.C. Humphries, "History of the Reelfoot Lake Region," University of Tennessee, unpublished Masters Thesis, 1938, p. 75.

These levees only protected the land from minor flooding; during major floods they were readily overtopped or crevassed.

In 1927, the greatest flood of record occurred in the lower Mississippi Valley. It was described by Secretary of Commerce Hoover (later President Hoover) as " . . . the greatest disaster of peace times in our history".[19] The flood was a castastrophe because several hundred thousand tenant farmers living on the floodplain were left homeless. Much livestock was lost, and farm buildings, churches, schools, cotton gins, and sawmills were either greatly damaged or destroyed.

The great flood of 1927 was immediately followed by an extensive campaign for full Federal support for flood control in the lower Mississippi Valley. The Flood Control Act of 15 May 1928 contained a comprehensive flood control plan for the lower Mississippi Valley. It provided for raising and strengthening the levees between Cape Girardeau, Missouri and the Head of Passes, Louisiana. In addition to the levee work, the plan provided for the construction of floodways, spillways, cutoffs, bank revetments, and resevoirs for flood control.[20]

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[19]Robert W. Harrison, Alluvial Empire (Little Rock, Arkansas: Pioneer Press, 1961) p. 135.

[20]Kemper, pp. 135-179.

Funds under the Act became available to the Lake County district to complete the Reelfoot levee to the recommended grade standard. To qualify for funds, however, the necessary rights of way for the protective works must be provided without cost to the Federal Government. The Tennessee legislature appropriated the money to the district to secure the necessary rights of way for the levee.[21]

Although the Flood Control Act of 1928 was a catalyst for much of the structural flood control measured along the lower Mississippi Valley, most of the federally funded levee construction in west Tennessee was not authorized until later. The main levee in the study area, constructed by the Army Corps of Engineers, was not started until the late 1930's. It stretches from a point west of Tiptonville to the southern border of Dyer County at the Obion River. The levee is 15-30 feet high, roughly 15 feet wide at the top, and ranges from 200-300 feet wide at the base. In Dyer County, the distance from the river to the levee is approximately a mile and one-half. In Lake County, the distance from the river to the levee ranges from 8 miles in the southwestern part of the county to only a few feet at several places in the county.

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[21]C.C. Humphries, p. 89.

The Tiptonville-Obion River levee was constructed in two major stages. The Flood Control Act of 22 June 1936 authorized construction from Tiptonville to a point one-half south of the Lake and Dyer County boundary. The work involved moving 4,000,000 cubic yards of earth and constructing four drainage outlet structures through the levee. The grade of the levee was three feet below that of the opposite bank levee protecting the lower St. Francis basin. Actual work did not start until 1939 (two years passed before the necessary rights of way were obtained) and was completed in 1941.[22]

In 1946, the Flood Control Act authorized the construction of the levee extension to the Obion River. The original plan called for an extension of the levee across the Obion River and diversion of the river to empty into the Mississippi downstream from the levee extension.[23] The river diversion has not been constructed because of legal disputes. In 1946, the Tiptonville-Obion River levee was incorporated into the Mississippi River and Tributaries Project.[24]

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[22]United States Department of the Army, Corps of Engineers, Annual Report of the Chief of Engineers, Washington, U.S. Government Printing Office, 1941.

[23]United States Congress, House of Representatives, Mississippi River Western Tennessee Tributaries (Backwater Area) House Document 757, 79th Congress, 2nd Session, 1946, p. 11.

[24]Moore, p. 22.

Agriculture

Early settlers on the bottomlands of Dyer and Lake County located on the slightly higher lands with better drained soils. In 1870 only 16% of Lake County was in cultivation or pasture.[25] As time passed, much of the woodland in the area was cleared for agriculture and by 1925, 65% of the county was cultivated.[26]

During the 1920's, farms on the floodplain were small in size, usually only forty acres or less, and tenant operated.[27] In the 1940's, tenant farming began to decline and rapid mechanization and enlargement of farm operating units in the 1950's brought about a drastic reduction in the total number of farms and farmers, and a great increase in the average size of farms. For example, the average farm size in Lake County was 68 acres in 1954 compared to 647 acres in 1978.[28] Agriculture in the area changed from

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[25]United States Census Office, Ninth Census 1870 Statistics of Agriculture, Tennessee, Washington, D.C.: Government Printing Office, 1872.

[26]United States Department of Commerce, Bureau of the Census, Census of Agriculture, 1925, Part II The Southern States, Washington, D.C.: Government Printing Office.

[27]Ibid.

[28]United States Department of Commerce, Bureau of the Census, Census of Agriculture, 1954 and 1978, Washington, D.C.: Government Printing Office.

one in which many farmers lived on the floodplain and operated small farms to one of much larger farms with many fewer farmers living on the floodplain.

During the 1950's and 1960's, additional woodland in the study area was cleared for agriculture. Today, all but the wettest land is cultivated. For years cotton was the dominant cash crop in the Mississippi bottomlands of Dyer and Lake County, although corn and a variety of other crops were also produced. In the mid-1930's soybeans were introduced into the area, and by 1954 soybeans had surpassed cotton in total acreage harvested (See Figure 3). For the eleven year period, 1968-1978, soybean acreage harvested in Lake County increased from 44,504 acres to 73,058 acres, representing by 1978 over 75% of the total farmland in Lake County.[29]

Several factors were responsible for the great increase in soybean production in the study area. One reason was the increase in demand for soybeans and soybean by-products. Thus an improved market combined with rising prices for the crop stimulated production. Other factors responsible for the increase are associated with characteristics of soybeans that make them especially

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[29]United States Department of Agriculture and Tennessee Department of Agriculture, Tennessee Agricultural Statistics, Annual Bulletins 1968-1978.

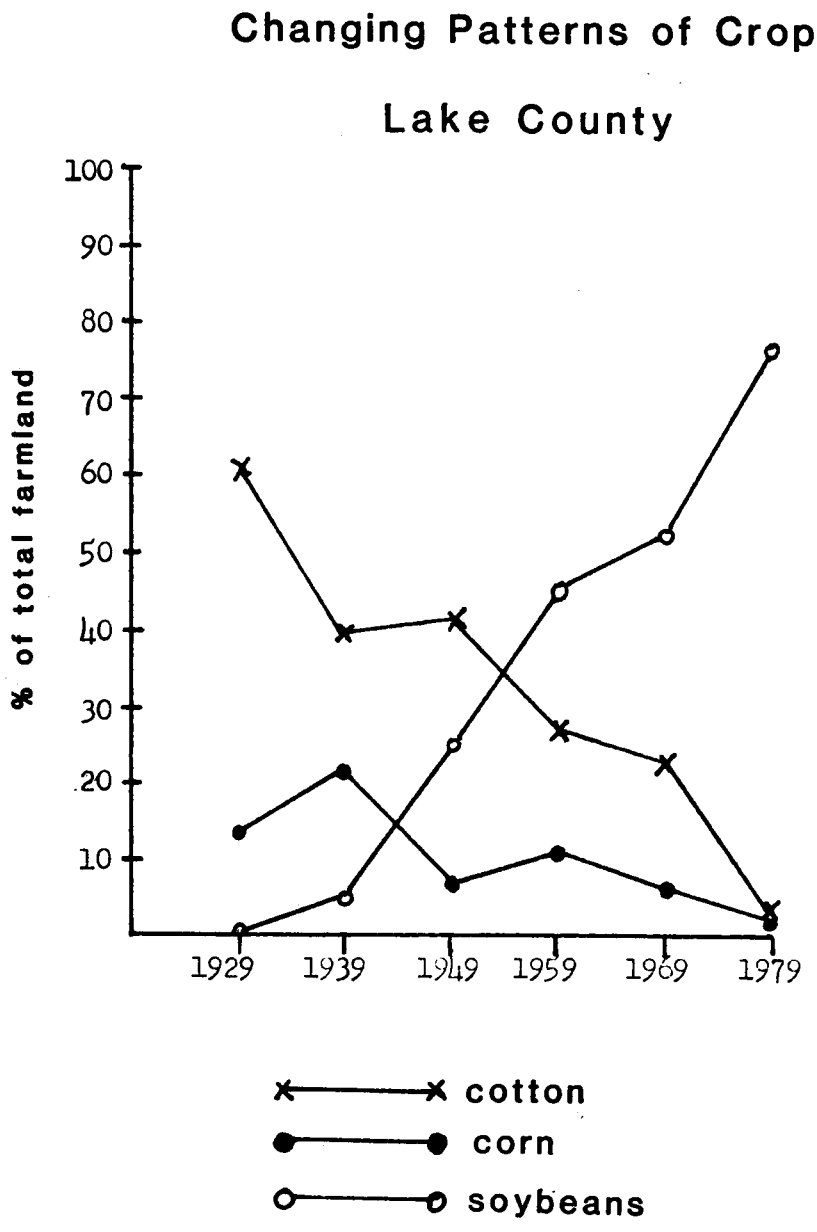


FIGURE 3. CHANGING PATTERNS OF CROPS, LAKE COUNTY.

adaptable to the floodplain environment. Soybeans are better adapted to the poorly drained soils, require less cultivation, and have a shorter growing season than cotton. On some of the better drained soils in the area, soybeans can be doublecropped with wheat.

The normal planting date for soybeans in the study area ranges from May 1 to June 21. On the poorer-drained soils, soybeans are rarely planted before May 15 and can be planted as late as mid-July without suffering a large decrease in yield. Such flexibility in planting dates can be crucial, because excessive soil moisture on the poorer-drained soils can frequently occur well into the summer. When this occurs, farmers must delay planting, but this also permits soybeans to be planted or replanted after spring floods on any of the floodplain. As long as the farmers can plant or replant their soybeans by late July, no severe reduction in crop production will occur.

CHAPTER III

FLOODS AND CROP PRODUCTION

Historic Major Floods

Great floods are known to occur with some regularity in the lower Mississippi Valley. The first recorded flood, reported by De Soto, stated that the Mississippi River overflowed its banks in March of 1543, crested forty days later and remained out of its banks about eighty days. Over the past century and a half, great floods have occurred in 1849, 1912, 1913, 1927, 1937, 1945, 1950, and 1973. The 1927 and 1937 floods were of record proportions and were devastating to human settlements.[30]

The 1927 flood was the flood of record for the entire lower Mississippi Valley (See Figure 4). Unusually heavy rainfall from January to April fell upon soils already saturated. There were three flood waves, one in each January, February, and April, the last having the greatest magnitude. The estimated crest height at Arkansas City was twenty feet above floodstage.[31] The existing system of levees was not capable of withstanding a flood of this magnitude,

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[30]Lower Mississippi Region Comprehensive Study, Flood Problems, Lower Mississippi Region Comprehensive Study Coordinating Committee, vol. 6, 1974, p. 8.

[31]Harrison, Alluvial Empire, p. 159.

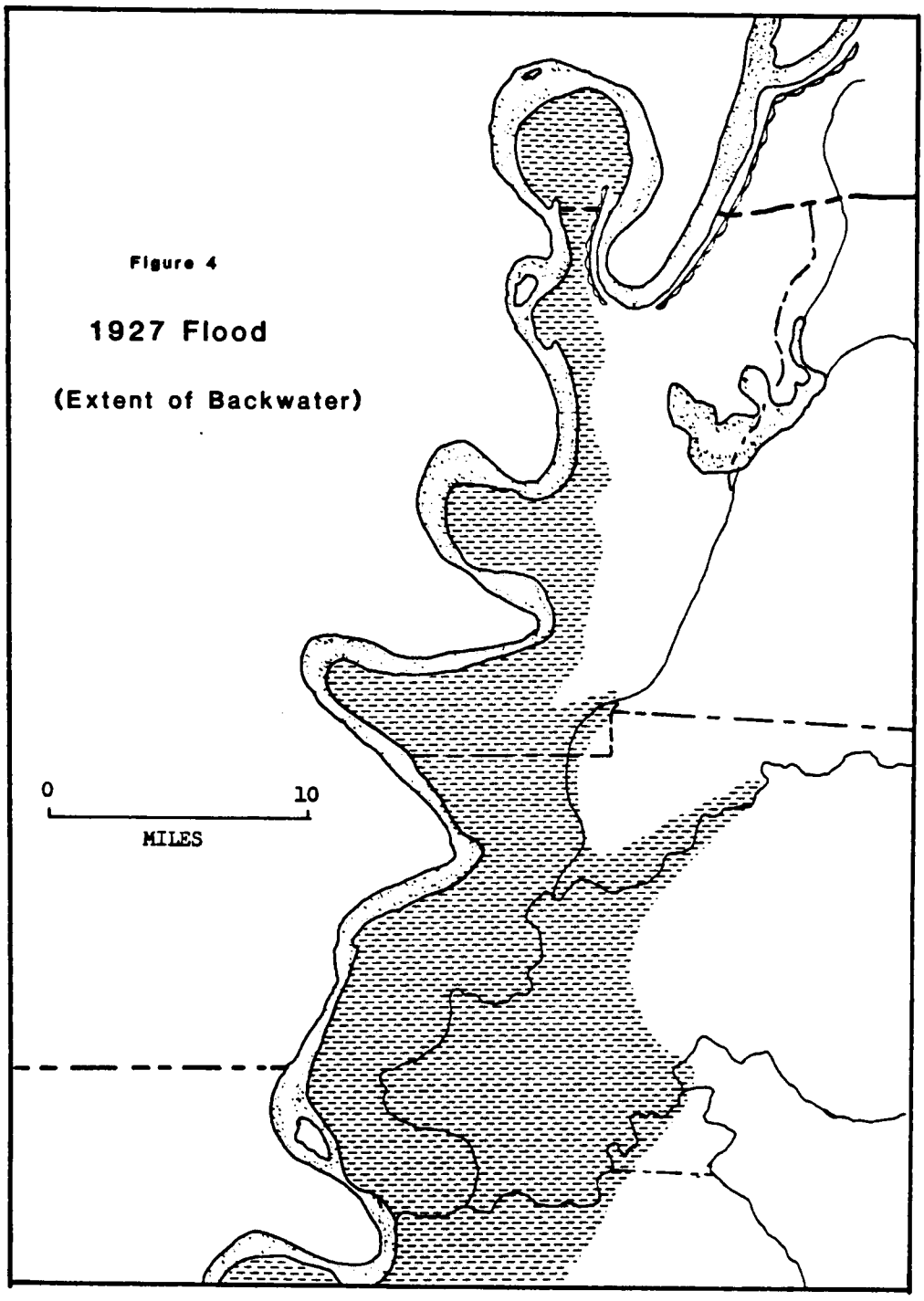


FIGURE 4. 1927 FLOOD EXTENT OF BACKWATER.

and forty major breaks occurred in the levee lines. Approximately 700,000 people were forced to abandon their homes, 300,000 of those were rescued from rooftops or trees.[32] Approximately 200 deaths were attributed to the flood, and damages were reported to be over $200,000,000.[33]

Although the 1927 flood is the flood of record, the 1937 flood actually produced a higher stage in west Tennessee. From December, 1936, through January, 1937, the Ohio and Mississippi Valleys experiences extremely heavy rainfall. Precipitation in west Tennessee for the month of January averaged 19 inches, with 14 inches of precipitation occurring during a nine day period. It was estimated that 340,000 acres of land in west Tennessee were inundated by backwater flooding of the Mississippi and headwater flooding from tributary streams.[34] On February 6, the gauge at Cottonwood Point, Missouri, reported a stage of 44.4 feet which is 14.4 feet above floodstage.[35]

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[32]Ibid.

[33]Lamar Beman "Flood Control" The Reference Shelf, vol. 5, No. 7, pp. 54-56.

[34]Lower Mississippi Region Study, Flood Problems, p. 63.

[35]U.S. Army Corps of Engineers and Mississippi River Commission, Annual Highest and Lowest Stages of the Mississippi River and its Tributaries, (Vicksburg: Mississippi River Commission, 1960) p. 48.

Timing of Floods 1926-1981

To determine if levee protection reduced crop losses from flooding in west Tennessee, flood events during the years 1926-1981 were examined. Data on floodstages were those from the gauges at Caruthersville and Cottonwood Point, Missouri.[36] For a period of 56 years the Mississippi River reached floodstage a total of 83 times (See Table 1) and all occurred during the months of December through July (See Figure 5). The month of most frequent floods was April, with 35 of the 56 year of record having a flood during that month. Only four floods occurred in July and three floods in December. During the years 1931, 1934, 1941, 1953, 1954, 1959, 1966, 1976, 1977, and 1981 the Mississippi River did not reach floodstage in the study area.

The floods that occurred during the 1926-1981 period varied greatly in magnitude. The heights of flood crests ranged from 0.1 feet above floodstage in May 1928 to 14.4 feet above floodstage in February 1937. Most of the floods with high crests came in winter or early spring.

It is quite evident that floods occurring prior to planting would not cause severe crop reduction. In the study area, floods occurring before May are not much of a threat to

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[36] From 1926 to 1945, the flood data was derived from the gage at Cottonwood Point, Missouri. Flood data from 1945 to 1981 was derived from the gage at Caruthersville, Missouri.

TABLE 1

DURATION AND PEAK STAGES OF
MISSISSIPPI RIVER FLOODS IN WEST TENNESSEE*

Year	Duration Above Floodstage	Crest Above Floodstage (feet)	Date of Crest
1926	Dec. 30 - Dec. 31	1.4	Dec. 31
1927	Jan. 1 - Jan. 15	5.2	Jan. 9
	Jan. 30 - Feb. 20	5.1	Feb. 10
	Mar. 15 - May 20	10.1	Apr. 22
	May 30 - June 22	6.5	June 11
1928	Apr. 27 - May 4	1.3	Apr. 30
	June 14 - July 14	4.0	July 7
1929	Mar. 5 - June 6	7.6	May 20
1930	Jan. 15 - Jan. 27	3.2	Jan. 20
1931	No Flood		
1932	Jan. 17 - Feb. 27	6.2	Feb. 17
1933	Feb. 1 - Feb. 3	0.2	Feb. 2
	Mar. 26 - Apr. 28	6.8	Apr. 7
	May 16 - Jun3 7	6.8	May 25
1934	No Flood		
1935	Mar. 14 - Apr. 24	5.8	Mar. 25
	May 18 - June 4	3.5	May 28
	June 28 - July 1	0.7	June 30
1936	Mar. 28 - Apr. 29	7.0	Apr. 14
1937	Jan. 13 - Mar. 1	14.4	Feb. 6
1938	Apr. 2 - Apr. 25	2.8	Apr. 18
1939	Feb. 10 - Mar. 30	6.4	Mar. 21
	Apr. 16 - May 17	5.9	Apr. 27
1940	Apr. 28 - May 8	2.0	May 5

TABLE 1 (Continued)

Year	Duration Above Floodstage	Crest Above Floodstage (feet)	Date of Crest
1941	No Flood		
1942	Mar. 23 - Mar. 30	1.4	Mar. 27
1943	Jan. 3 - Jan. 18	4.8	Jan. 12
	Mar. 23 - Apr. 8	5.7	Apr. 2
	May 21 - June 10	7.3	June 1
1944	Mar. 26 - Apr. 10	2.5	Apr. 7
	Apr. 16 - May 19	6.8	Apr. 30
1945	Feb. 28 - Apr. 30	8.1	Mar. 23
	May 26 - May 30	1.0	May 28
1946	Jan. 12 - Jan. 27	7.4	Jan. 19
	Feb. 18 - Feb. 25	1.7	Feb. 22
1947	Apr. 14 - May 9	3.8	Apr. 21
	June 18 - June 25	1.8	June 21
	July 7 - July 10	0.6	July 8
1948	Feb. 22 - Mar. 14	2.7	Feb. 26
	Mar. 26 - Apr. 29	7.3	Apr. 4
1949	Jan. 15 - Mar. 8	6.4	Feb. 2
	Mar. 31 - Apr. 9	3.4	Apr. 5
1950	Jan. 8 - Mar. 7	9.7	Jan. 18
	Apr. 7 - Apr. 8	2.6	Apr. 12
1951	Feb. 22 - Mar. 15	4.7	Feb. 28
	Apr. 2 - Apr. 30	3.6	Apr. 6
1952	Feb. 4 - Feb. 20	3.9	Feb. 11
	Mar. 15 - Apr. 13	6.8	Mar. 29
1953	No Flood		
1954	No Flood		
1955	Mar. 16 - Apr. 6	5.8	Mar. 30

TABLE 1 (Continued)

Year	Duration Above Floodstage	Crest Above Floodstage (feet)	Date of Crest
1956	Feb. 28 - Feb. 29	0.1	Feb. 28
1957	Feb. 8 - Feb. 20	4.0	Feb. 14
	Apr. 13 - Apr. 24	0.4	Apr. 20
	May 27 - May 31	0.5	May 30
1958	May 12 - May 14	0.1	May 12
	July 26 - July 31	0.7	July 28
1959	No Flood		
1960	Apr. 6 - Apr. 21	3.9	Apr. 14
1961	Mar. 9 - Mar. 31	5.9	Mar. 20
	May 9 - May 27	9.3	May 18
1962	Mar. 1 - Apr. 26	6.0	Mar. 17
1963	Mar. 14 - Apr. 8	7.0	Mar. 26
1964	Mar. 14 - Apr. 2	3.9	Mar. 25
1965	Apr. 3 - Apr. 26	3.5	Apr. 11
1966	No Flood		
1967	May 17 - May 27	1.0	May 22
1968	June 4 - June 10	0.4	June 8
1969	Feb. 2 - Feb. 19	3.9	Feb. 13
	Apr. 22 - Apr. 30	1.7	Apr. 27
1970	Apr. 28 - May 15	5.2	May 8
1971	Feb. 25 - Mar. 14	4.5	Mar. 6
1972	Apr. 22 - May 12	4.5	Apr. 29
1972/73	Dec. 16 - Jan. 11	2.9	Dec. 24

TABLE 1 (Continued)

Year	Duration Above Floodstage	Crest Above Floodstage (feet)	Date of Crest
1973	Mar. 13 - May 25	10.4	Apr. 3
	May 31 - June 14	1.4	June 7
	Dec. 4 - Dec. 12	1.5	Dec. 9
1974	Jan. 10 - Feb. 15	7.3	Feb. 3
	Mar. 19 - Mar. 28	1.1	Mar. 22
	Apr. 14 - Apr. 19	0.5	Apr. 17
	June 5 - June 18	2.4	June 13
1975	Feb. - Mar. 12	1.7	Mar. 4
	Mar. 15 - Apr. 16	10.4	Apr. 4
	Apr. 29 - May 16	3.0	May 4
1976	No Flood		
1977	No Flood		
1978	Mar. 20 - Apr. 10	6.5	Mar. 31
	May 17 - May 22	0.7	May 19
1979	Mar. 2 - Apr. 30	9.3	Apr. 21
	May 9 - 14	0.5	May 11
1980	Mar. 26 - Apr. 14	4.3	Apr. 5
	Apr. 20 - Apr. 24	0.4	Apr. 22
1981	No Flood		

*From 1926 - 1945, the flood data was taken from the Cottonwood Point Gage. Flood data was taken from the gage at Caruthersville from 1946 - 1981.

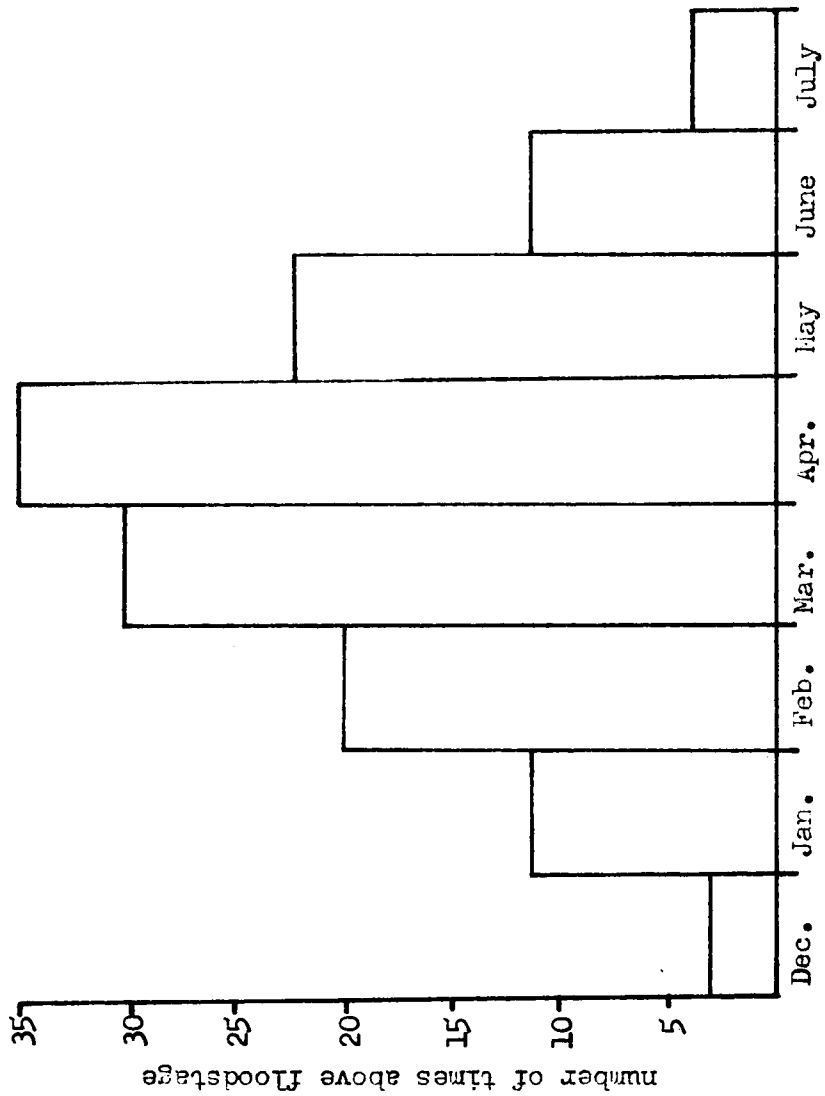


FIGURE 5. MISSISSIPPI RIVER AT FLOODSTAGE, 1926 - 1981, MONTHLY TOTALS.

crop production, because planting would not have started. Of the 83 floods that occurred during the 56 years, 61 crested before May 1, and 53 of the floods had totally receded before May 1. Therefore, approximately 64% of the Mississippi River floods in west Tennessee would not be expected to cause serious reduction to crops because they occurred before the normal growing season. These floods cannot be used to justify flood protection of agricultural land.

Floods occurring after May 1 have the potential to reduce crop production in the area. Ideally, a levee should keep surplus water off the agricultural land and permit the continuation of normal farming practices when the river is at or above floodstage. Land behind the levee does flood, however, when the Mississippi floods. The levee cannot deter water from accumulating on the land from excessive local precipitation or from overflow of the Obion and Forked Deer Rivers, which often occurs during times of floods on the Mississippi.

To determine the soil moisture condition of the lands protected by the levee while the Mississippi was above floodstage after May 1, a water budget analysis was used.

The Water Budget Analysis

C.E. Thornthwaite devised a procedure, known as the water balance or water budget, to estimate the moisture

condition of the soil. The water budget is an accounting procedure in which the water income (via precipitation) is compared to water loss from evapotranspiration and run-off. Information needed for a water budget includes precipitation and temperature data, soil moisture storage capacity, and tables for computing potential evapotranspiration.[37]

When precipitation in an area is greater than the potential evapotranspiration the actual evapotranspiration equals the potential. Excess water is stored in the soil until the storage is full, additional water is surplus and either runs off or stands as free water on the land surface. When the potential evaportranspiration is greater than the amount of precipitation, the actual evapotranspiration may equal the total precipitation plus any available water stored in the soil. A soil moisture deficit occurs when potential evapotranspiration is greater than precipitation and any available water from soil storage.

An example of a yearly water budget for Dyersburg, Tennessee, is given in Table 2. From this water budget, it is seen that precipitation is greater than potential evapotranspiration in the winter and early spring, and 4 inches of surplus water per month must run off or stand on the land.

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[37]C.W. Thornthwaite and J.R. Mather, The Water Balance. Drexel Institute of Technology Laboratory of Climatology Publications in Climatology Series, vol. 8, no. 1, 3rd ed. Centerton, New Jersey, 1955.

TABLE 2

WATER BUDGET DYERSBURG, TENNESSEE

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Temp °F	40.1	42.2	50.2	60.1	69.3	77.9	80.3	79.5	72.5	62.7	49.5	41.6	60.4
Heat Index (I)	.85	1.21	2.91	5.61	8.61	11.76	12.73	12.41	9.75	6.41	2.74	1.10	76.09
Unadj. P.E.	.01	..01	.04	.07	.12	.17	.18	.18	.14	.08	.03	.01	
Potential Evapotranspiration (PE)	.26	.25	1.23	2.31	4.35	6.22	6.69	6.26	4.32	2.32	.77	.25	35.23
Precipitation	5.40	4.41	5.24	4.13	4.13	4.02	3.95	2.95	3.15	2.93	4.13	4.33	48.78
Prec - P.E.	+5.14	+4.16	+4.01	+1.82	-.22	-2.19	-2.74	-3.31	-1.17	+.61	+3.36	+4.08	+13.55
Soil Storage*	4.00	4.00	4.00	4.00	3.78	1.59	0	0	0	.61	3.97	4.00	
Change - Storage	0	0	0	0	-.22	-2.19	-1.59	0	0	+.61	+3.36	+.03	
Actual Evapotranspiration	.26	.25	1.23	2.31	4.35	6.22	5.54	2.95	3.15	2.32	.77	.25	
Deficit	0	0	0	0	0	0	1.15	3.31	1.17	0	0	0	5.63
Surplus	5.14	4.16	4.01	1.82	0	0	0	0	0	0	0	4.05	19.18

* Assumed capacity = 4 inches

In the late spring and early summer, potential evapotranspiration exceeds precipitation, and water is withdrawn from soil storage. In the late fall, precipitation again exceeds potential evapotranspiration and the soil storage is recharged. Run-off potential would therefore, be the greatest in winter and spring, and least in the late summer.

Daily water budgets were calculated for all flood days after May 1 for the years 1950 to 1981. The daily water budgets were calculated for at least three weeks prior to and during each flood event. From these daily water budget calculations it can be determined whether the agricultural land, even though protected by the levee, experienced surplus moisture and hence waterlogged conditions assuming there is no place for it to drain. Climatic information used in the water budget calculations were averaged from nearby weather stations: Dyersburg, Tennessee; Blytheville, Arkansas; and New Madrid, Missouri.

Monthly water budgets were first calculated to determine the general soil moisture condition before the flooding event. In each case, surplus conditions were present in the months preceeding the flood event (See Appendix A) so it was assumed that the soil moisture storage was full at the beginning of the daily water budget calculations.

Precipitation occurring on an already saturated soil becomes surplus. When the river is at floodstage, run-off from the fields cannot occur; it has nowhere to go unless it is pumped out. Drainage ditching is not well developed, and there are only a few small pumping stations; hence the surplus water remains on the soil. The daily water budget calculations are listed in Appendix B and summarized in Table 3. Table 3 shows the estimated amount of standing water (above field capacity) accumulated on the levee protected land during the first and last day of Mississippi River floods occurring after May 1. These figures are the average amounts of water standing on the surface (surplus water must stand on the land because it has no place to drain). Slightly higher areas may have been less surplus and lower areas may have considerably greater depths of surplus water than indicated. Such standing water effectively inhibits any cultivation and crop damage or loss will result when depths are more than a few inches.

The daily water budget calculations show that surplus moisture was present on the protected lands during thirteen of the fourteen flood events occurring after May 1. For the remaining flood, occurring in July 1958, surplus moisture was present for a period of nine days shortly before the Mississippi River reached floodstage. Seven floods, including the flood of July 1958, had a crest of less than

TABLE 3

CALCULATED DEPTH OF WATER ON LAND PROTECTED BY LEVEES DURING FLOODS IN THE PERIOD 1950-1981*

	Duration over the Growing Season**	First Day Of Flood	Last Day Of Flood
1957	May 27 - May 31	7.0"	6.4"
1958	May 12 - May 14	4.3"	4.0"
	July 26 - July 31	-	-
1961	May 9 - May 27	4.3"	3.4"
1967	May 17 - May 27	5.8"	4.5"
1968	June 4 - June 10	1.3"	.3"
1970	May 1 - May 15	4.7"	5.2"
1972	May 1 - May 12	3.2"	3.1"
1973	May 1 - May 25	8.2"	11.9"
	May 31 - June 14	12.6"	11.7"
1974	June 5 - June 18	3.0"	4.2"
1975	May 1 - May 16	1.5"	1.4"
1978	May 17 - May 22	2.9"	2.9"
1979	May 9 - May 14	10.8"	11.1"

*As estimated by the water budget analysis and does not include backwater on tributary flooding.

**May 1 is used as the beginning of the growing season. Depths of floods that originated before that date are not shown.

one foot above floodstage. These floods inundated only a small portion of the unprotected land. During three flood events, the water budget analysis indicates that the depth of water stored on the surface of the protected lands was greater than the depth of floodwater on the unprotected land at the flood crest.

The great flood of 1973 was accompanied by heavy rains over the Mississippi Valley, and the Mississippi rose to 10.4 feet above floodstage at Caruthersville, Missouri (See Figure 6). The flood had begun to recede slowly when the region was again struck by heavy precipitation in late April and early May. The second crest peaked at 9.5 feet above floodstage before it began to recede. The 1973 flood's magnitude and great duration has caused it to be described as one of the worst floods of the century.[38] The daily water budget calculations for that flood indicate that at least 13 inches of water were present on the surface of the protected land while the river was at floodstage. A local agricultural official felt that 13 inches was a relatively conservative estimate of the standing water on the so-called protected land.[39] Farming of these ponded fields was

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[38]Lower Mississippi Region Comprehensive Study, Flood Problems, vol. 6, 1974, pp. 63-64.

[39]John Bradley, Lake County SCS Chairman, Agricultural Extension Leader, Tiptonville, personal interview, February 5, 1982.

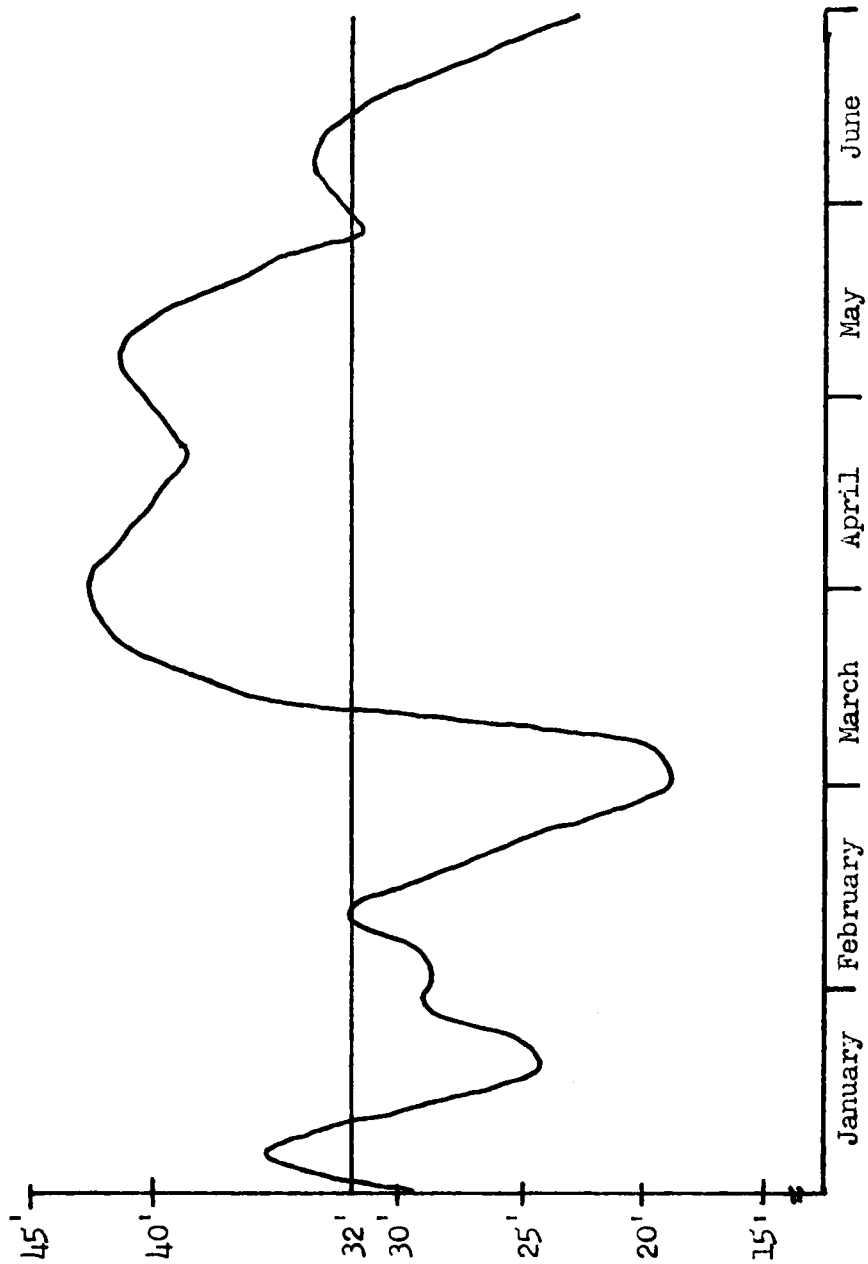


FIGURE 6. MISSISSIPPI RIVER AT CARUTHERSVILLE, MISSOURI, 1973.

impossible. The levee did not give the protected farms a great advantage over those farms not protected from the flood flows.

The water budget analysis indicates that surplus moisture is present on the land when the Mississippi is at floodstage, whether the land is protected by the levee or not. Since saturated ponded soils are present when the river is at floodstage, the farmers must delay planting or replanting their crop until the fields dry. The excess water on the fields quickly evaporates after the flood recedes, because of the high potential evapotranspiration that coincides with the growing season. The coarser textured soils dry more rapidly than the fine textured soils. In the study area the coarser textured soils are located near the river, unprotected from the flood flows, while most of the finer textured soils are protected by the levee. In west Tennessee, farmers are able to return to the fields faster on the better drained soils near the river than on the poorly drained soils protected by the levee.[40] If replanting is necessary on both sides of the levee after a major flood, the levee does not materially aid in the reduction of the crop losses, thereby providing few benefits to the agricultural land.

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[40]James Lloyd, Dyer County Agricultural Extension Leader, Dyersburg, personal interview, February 5, 1982.

Tributary Floods

In addition to the problem of excess precipitation, shown in the water budget analysis, headwater and backwater flooding on the major tributaries is common on the levee-protected agricultural land. Floods and standing water are a major problem for agriculture in the Obion and Forked Deer floodplains despite channel modification. Little data are available on tributary floods on the Mississippi River floodplain upstream from the bottomlands. Floodstage information from gauges on the North Fork and South Fork Forked Deer River near Dyersburg were examined for the period 1937-1967. These gauges are located just upstream from where the rivers join to form the Forked Deer River on the Mississippi River floodplain. Major floods on the Forked Deer River occur with the same frequency as floods on either or both the North Fork and South Fork. The timing and frequency of headwater flooding on the Obion River is similar to that of the Forked Deer River.[41]

Table 4 shows the frequency of flood crests and the average crest height in feet above floodstage by month. The main flood season for the tributary streams, like the Mississippi, is in the winter and spring. Most of the higher floods are the result of heavy rains over the entire

[41]Richard Swain, Obion-Forked Deer Basin Authority, telephone interview, May 7, 1982.

TABLE 4

FLOOD CRESTS NORTH AND SOUTH FORK FORKED DEER RIVER, 1937 - 1967

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
North Fork												
Number of Flood Crests	22	20	20	13	15	16	18	8	9	6	20	14
Average Crest Height Above Bankfull	5.8'	5.1'	7.0'	5.8'	4.7'	3.6'	2.4'	1.4'	2.1'	1.1'	3.3'	2.8'
South Fork												
Number of Flood Crests	15	17	25	19	19	8	8	3	0	0	11	8
Average Crest Height Above Bankfull	3.6'	4.5'	2.8'	2.8'	2.0'	1.9'	1.1'	1.5'	-	-	2.1'	3.6'

lower Mississippi Valley. Floods do, however, occur in the summer months in response to intense local thunderstorms.[42] During the 1937-1967 period, the North Fork of the Forked Deer River, exceeded bankfull an average of six times a year and the South Fork of the Forked Deer River exceeded bankfull an average of five times a year. Average flood crests on both rivers were highest in the winter and spring months, although some significant floods did occur in the summer months.

Headwater flooding often occurred on these tributary streams when the Mississippi River was not at floodstage, but each Mississippi River flood event during the 1937-1967 period was accompanied by a headwater flood on either or both the North Fork and South Fork Forked Deer River. No major levees have been constructed to protect the agricultural land from backwater flooding from these tributaries. When the Mississippi River reaches floodstage, backwater flooding occurs on both the Obion and Forked Deer Rivers. During extreme floods Mississippi River backwater covers all but the highest parts of the floodplain. The Mississippi River backwater creates a damming effect, and the tributary headwater floods, having no outlet, also back upstream.[43]

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[42]U.S. Army Corps of Engineers, Flood Plain Information, Forked Deer Rivers and Lewis Creek, Dyersburg, Tennessee, Washington: U.S. Government Printing Office, 1968.

[43]Richard Swain, Obion-Forked Deer Basin Authority, telephone interview, May 7, 1982.

Tributary floods clearly are a major problem for agriculture on the Mississippi floodplain in west Tennessee. Agricultural lands protected by the levee along the Mississippi are nevertheless inundated from Mississippi River backwater and tributary flooding. Cultivation of these lands is impossible during backwater flood conditions despite the main stem levee protection.

Several important points arose from the examination of Mississippi River floods in west Tennessee:

1. Over sixty percent of the Mississippi River floods occurred before the growing season.
2. Heavy rains that often accompany floods during the growing season created surplus moisture conditions on the agricultural land protected by the levee.
3. In addition to the excess precipitation, backwater flooding and flooding by tributaries make cultivation of the levee protected land impossible during the times the Mississippi River is at floodstage.

Crop Production

The purpose of this study is to determine whether levees are necessary to prevent a severe reduction in crop loss in the Mississippi River floodplain of west Tennessee. Because soybeans are by far the dominant crop in the area,

Table 5

SOYBEAN PRODUCTION

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Lake County										
Acres planted in thousands	50	52	64	86	72	92	84	81	84	88
Yield/Acre	24	27	23	28	20	28	24	28	28	31
Production in mils. bushels	1.2	1.3	1.4	2.4	1.4	2.5	1.9	2.3	2.3	2.6
Dyer County										
Acres planted in thousands	135	138	142	189	204	232	213	232	246	238
Yield/Acre	23	26	22	26	22	28	24	27	24	27
Production in mils. bushels	3.0	3.4	2.9	4.8	4.1	6.2	4.9	6.2	5.8	6.3
State Average										
Yield/Acre	23	26	22	23.5	21	22.5	23	23.5	23.5	27

soybean production was used to estimate the impact of flooding on crop production. To determine the extent of crop loss caused by Mississippi River flooding, soybean production during the 1970's was examined. During the 1970's several major floods occurred in the study area, both before and after May 1. Soybean production data for Dyer and Lake County is listed in Table 5 and represented graphically in Figure 7.

It has been shown, through the water budget analysis, that normal farming practices are impossible when the Mississippi River is at floodstage, and reduction of total crop production would be expected during years of major floods. However, from examining Figure 7 it is impossible to determine the years in which major floods occurred.

During the 1970's, a flood occurred in every year except 1976 and 1977. The largest floods occurred in 1973 and 1975, with the Mississippi cresting both years 10.4 feet above floodstage, and in 1979 the river crested 9.3 feet above floodstage. By comparing the years in which major floods occurred and total crop production (See Figure 7) it is seen that no severe reduction in crop production occurred during the major flood years. In fact, during the years of major floods, total soybean production in Dyer and Lake County was greater than in several years in which no flood occurred during the growing season.

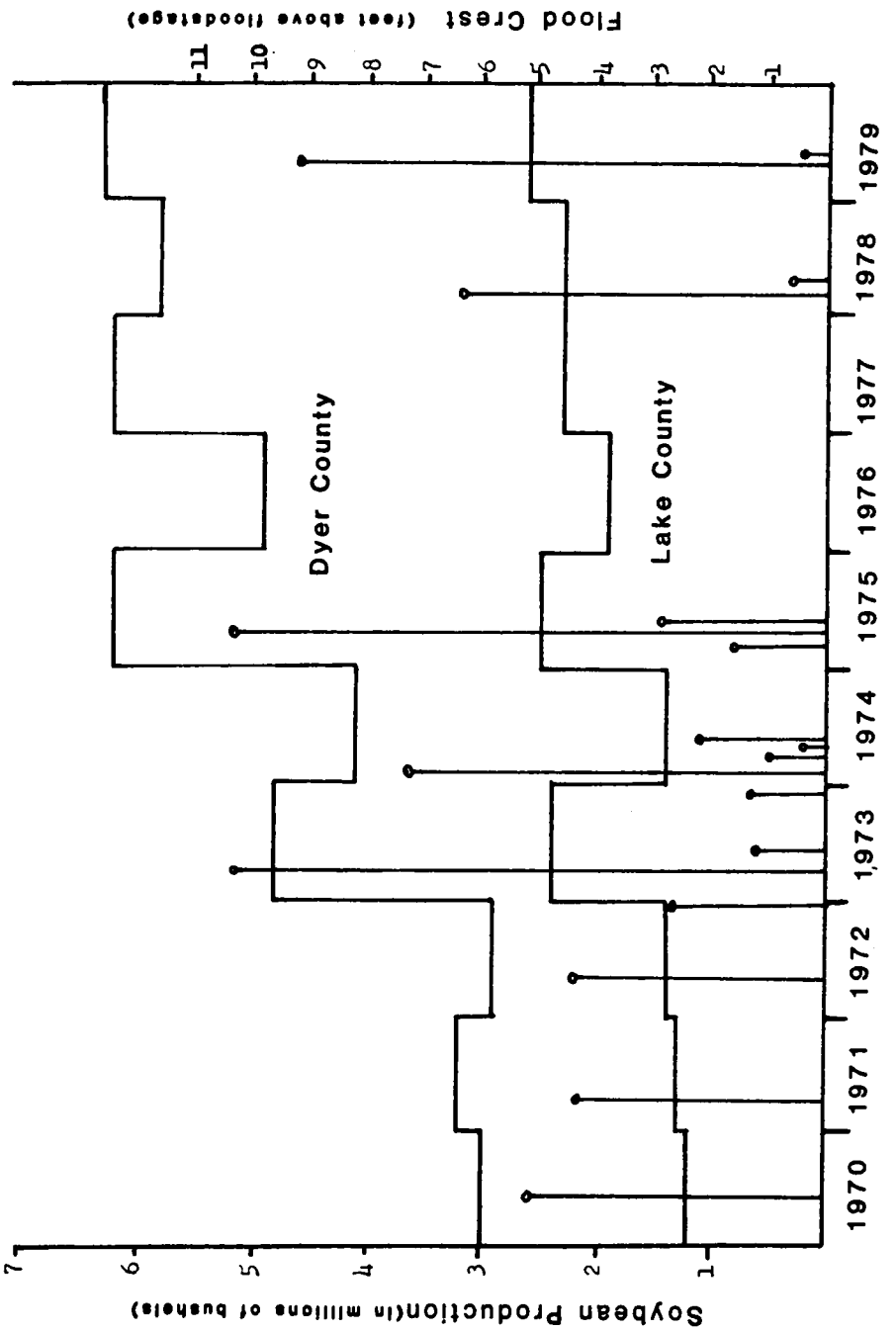


FIGURE 7. FLOODS AND SOYBEAN PRODUCTION IN THE 1970's

The main-stem levee should not be considered to be the factor responsible for preventing crop loss during years of major floods. Much of the agricultural land in the study area is located on the river side of the main levee, and as shown before, surplus moisture conditions exist on both sides of the levee when the Mississippi is at floodstage. No reduction in crop production occurred because the farmers simply delayed their planting or replanted their crops after the flood receded and the fields dried. The levee is not absolutely essential to crop production in the area. To illustrate this point, crop production and farming practices on lands protected by the main levee were compared to that of land on the river side of the levee. Many farmers in the Mississippi River floodplain in Dyer and Lake County farm on both sides of the main levee. These farmers are ideally suited to ascertain any benefits of levee protection agriculture during major flood years.

Mr. Jerry Hollingsworth of Dyer County is an example of a farmer who farms both sides of the main levee. Hollingsworth and his family farm over 3800 acres. Much of the land is located on the west or river side of the main levee, and east of a small levee near the river. Land is also farmed east of the main levee and west of the small levee on an island. During the major floods in 1973 and 1975, the small levee near the river could not hold back the

high floodstage and land behind the main levee was inundated by surface water. Yet instead of experiencing a decrease in crop production during these major flood years, yield per acre and total crop production were exceptionally high. Soybean production was especially high on the cropland on the river side of the main levee. Hollingsworth credited the high yields to the layer of rich sediment deposited on the land by the floodwaters. However, not all of the floodwater deposition was beneficial for much sand was deposited on the cropland on the island. The layer of sand had to be bulldozed before planting on the island could begin. A crop was still produced on the island, but yields were not as high as other parts of the floodplain.

Land west of the main levee is normally planted by the 10th of May, yet in 1973 Hollingsworth was not able to plant his crop until the first week of June. Land on the protected side of the main levee was not planted until late June and early July. A similar situation existed in 1975.[44]

Sandy subsoils on cropland west of the main levee permit the farmers to replant their crops sooner than on the poorly drained soils east of the levee. Backwater flooding and excess precipitation on the protected side of the levee do not readily percolate through the clay soils.

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[44]John Hollingsworth, telephone interview, May 22, 1981.

Thus planting was greatly delayed on the cropland protected by the main levee. Even though planting was delayed, total production was not reduced, but yields were generally not as great as the bumper yields produced on cropland west of the main levee.[45]

Cropland in the study area is not totally immune from flood damages. Any floods occurring late in the growing season would adversely affect total production. Floods could come at a time that would make even the replanting of soybeans impossible and would greatly reduce total crop production. However, the heavy precipitation associated with a late summer Mississippi flood would also cause surplus moisture conditions on the levee protected land and would probably cause tributary flooding. Therefore, a major flood, occurring at a time that would make replanting impossible would likely reduce crop production on either side of the levee.

Summary

From the flood analysis, it was determined that over sixty percent of the Mississippi River floods would not severely reduce soybean production because they occurred before the growing season. Floods occurring after May 1 have the potential to reduce crop production, but a water

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[45]Ibid.

budget analysis shows that when the Mississippi River is at floodstage, waterlogged soils exist on land behind the levee because of surplus precipitation. Also, backwater and headwater flooding on the tributaries contribute standing water to the protected side of the levee. Therefore, cultivation in the study area is virtually impossible when the Mississippi is at floodstage, regardless of which side of the levee the cropland is on. Interviews with area agricultural officials and farmers confirmed that the levee-protected soils are normally too wet to farm when the Mississippi is at floodstage.

CHAPTER IV

BENEFITS AND COSTS OF LEVEE PROTECTION OF AGRICULTURAL LAND

In the previous chapter it was shown that the levee provides few benefits to agriculture because it cannot prevent excessively wet fields and crop losses from surplus local precipitation during times of flood by the Mississippi. Yet one of the main purposes for the construction of the Tiptonville-Obion River levee was to protect agricultural lands. In 1936, when the levee was first proposed, protection of agricultural lands also included the protection of the many farmers living on the floodplain. Nevertheless, protection of crops was the primary economic factor used to justify levee construction. To determine whether levee protection of agricultural land in west Tennessee is economically justified, the Tiptonville-Obion River levee extension plan may be examined.

Examination of the Tiptonville-Obion River Levee Extension Benefit-Cost Analysis

The extension of the Tiptonville-Obion River levee, from just below the Lake County border to the Obion River, was proposed in 1946 under the Mississippi River, West Tennessee Tributaries (Backwater Area) Project. The main objective of this plan was the extension of about 28 miles of the Tiptonville-Obion River levee and a diversion of the

Obion River so that it would empty into the Mississippi below the levee extension. This plan also provided for channel improvements on the Obion and Forked Deer Rivers, and local drainage improvements in the vicinity of Tiptonville State Highway 79, and Lake No. 9.[46] The Obion River diversion part of the project was not completed for reasons stated in Chapter Two. Before the levee extension plan could be adopted, it had to pass the requirements and conditions stated in the June 22, 1936 Flood Control Act. This act is significant in the history of flood control legislation because it declared that flood control was a proper activity of the Federal Government if the benefits were greater than the estimated costs and if the lives and social security of people are otherwise affected.[47] Section 3 of this act gave the conditions of local cooperation for flood control works in the following terms:

> hereafter no money appropriated under authority of this act shall be expended on the construction of any project until States, political subdivisions thereof, or other responsible local agencies have given assurances satisfactory to the Secretary of War that they will (a) provide without cost to the United States all lands, easements, and rights of way necessary for the construction of the project, except as otherwise provided herein; (b) hold and save the United States free from damages due to the

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[46]United States, House of Representatives, Mississippi River Western Tennessee Tributaries (Backwater Area) House Document 757, 79th Congress, 2nd Session, 1946.

[47]Moore, p. 14.

> construction works; (c) maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of War.[48]

The estimated first costs and annual charges of the Tiptonville-Obion River levee extension and associated improvements are summarized in Table 6.[49] The total estimated Federal costs for all of the improvements was $6,000,000 of which $5,000,000 was for the construction of the levee extension and river diversion. Local and State costs for the levee rights of way and various bridges were estimated to be $350,000. The annual Federal charges or costs for the entire project was $264,000, paid over a twenty-five year period, and the annual non-federal cost was $57,000 for a ten-year period. Therefore, the total estimated annual costs of the improvements was $321,000.

It was estimated that 65,000 acres in the area would be completely protected from overflow and an additional 115,000 acres would be materially benefited. The estimated annual benefits from flood damage prevented was $305,000, which was less than the estimated annual cost of $321,000. However, added to the estimate of flood damage prevented was a 10% or $30,000 increase for "normal development" and an additional $95,000 for "enhancement". No explanation was

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[48]Ibid.

[49]House Document 757, pp. 15-16.

TABLE 6

ESTIMATED TOTAL COSTS AND ANNUAL COSTS SUMMARY

Improvement	Cost		Annual Cost	
	Federal	Non-Federal	Federal	Non-Federal
Levee and Obion Diversion	$5,000,000	$350,000	$220,000	$35,000
Obion and Forked Deer Improvement	$ 700,000	$ 55,000	$ 31,000	$11,000
Tiptonville-State Highway 79	$ 230,000	$ 92,000	$ 10,000	$ 7,000
Lake No. 9	$ 70,000	$ 52,000	$ 3,000	$ 4,000
TOTAL	$6,000,000	$549,000	$264,000	$57,000

Annual Federal and Non-Federal Cost - $321,000

Source: Taken directly from U.S. House Document 757, as prepared by the Corps of Engineers.

given for these terms or the means by which the values for these terms were calculated. These projected annual benefits brought the total annual benefits estimate to $430,000. Questions concerning the validity of this estimate arose for the reason that $125,000 or 30% of the total annual benefits was given without any documented evidence assuring that the projected amounts of normal development and enhancement would occur annually. Summarized calculations for the estimate of annual flood damage prevented was given, but their derivation were also somewhat questionable.

The estimate of annual flood damage prevented in the benefit-cost analysis was based upon the acreage flooded, crop damage, and total flood damage during the period 1933 - 1945. The damages reported from the floods of 1933-1945 (See Table 7) were adjusted to the conditions present on the floodplain in 1946 (See Table 8). Also calculated were the damages that would result from a recurrence of the 1933-1945 flood cycle if the levee extensions and other improvements were constructed (See Table 9). The estimated average annual damages under the improved conditions were subtracted from the estimated average annual damages under the 1946 floodplain conditions to determine the average annual flood damage prevention, if the 1933-1945 flood cycle recurred. In each case, the estimated damages were based upon the prevailing prices at the time of flood. With a recurrence of the 1933-

TABLE 7

FLOODED ACREAGES AND DAMAGES (Backwater Area)
OBSERVED CONDITIONS

Year	1933	1935	1936	1937	1938	1939	1940	1942	1943	1944	1945	Average Annual
Area Flooded (thousand acres)												
Cropland	75	80	85	97	34	87	16	19	76	60	95	55
TOTAL	267	254	248	291	156	242	95	97	248	203	248	181
Damage (thousand dollars)												
Crop	321	979	591	754	22	385	76	133	1520	600	950	487
TOTAL	365	1037	646	1555	26	397	76	133	1690	647	1236	600

Source: Taken directly from U.S. House Document 757, as prepared by the Corps of Engineers.

TABLE 8

FLOODED ACREAGES AND DAMAGES (Backwater Area)
RECURRENCE OF 1933 - 1945 FLOODCYCLE - 1946 CONDITIONS

Year	1933	1935	1936	1937	1938	1938	1940	1942	1943	1944	1945	Average Annual
Area Flooded (thousand acres)												
Cropland	96	62	90	123	49	90	30	30	95	70	95	64
TOTAL	250	197	240	286	151	240	95	97	248	203	248	173
Damage (thousand dollars)	410	770	630	960	30	400	140	210	1900	700	950	546
TOTAL	580	850	800	1990	70	440	140	210	2090	750	1240	705

Source: Taken directly from U.S. House Document 757, as prepared by the Corps of Engineers.

TABLE 9

FLOODED ACREAGES AND DAMAGES (Backwater Area)
RECURRENCE OF 1933 - 1945 FLOODCYCLE - IMPROVED CONDITIONS

Year	1933	1935	1936	1937	1938	1939	1940	1942	1943	1944	1945	Average Annual
Area Flooded (thousand acres)												
Cropland	58	49	51	79	33	52	14	19	56	57	55	40
TOTAL	186	171	180	235	115	175	53	66	184	176	196	134
Damages (thousand dollars)	250	610	360	620	20	230	70	130	1120	570	550	348
TOTAL	290	650	390	1060	30	240	70	130	1170	590	600	400

Source: Taken directly from U.S. House Document 757, as prepared by the Corps of Engineers.

1945 flood cycle, the average annual flood damage, based upon the condition of the floodplain in 1946 was estimated to be $705,000. The average annual damage from a recurrence of the 1933-1945 flood cycle, if the levee and other minor improvements were made, was estimated to be $400,000. Therefore, the estimate for the annual flood damage prevented was $305,000.

The manner in which the estimated average annual benefits from flood protection was derived is open to criticism. First, a relatively short period of record, 1933-1945, was used as the flood cycle in the area. The benefits from the levee may have been overestimated by basing the average annual damages upon a short period of time, especially a period containing several disastrous floods. Secondly, the damages to crops reported under "observed" conditions seem exaggerated. No explanation was given for the manner in which the data for the observed damage conditions (See Table 7) were obtained. An overestimation of the flood damage to crops is apparent in certain years. For example, in 1937 the observed damages to crops alone were $754,000 in the Dyer and Lake County bottomlands. The 1937 flood was the greatest flood recorded, yet its period above bankfull was from January 13 to March 1. The flood had completely receded by the first of March, well over a month before the planting of any crops would have started. If the

damage to crops reported during years in which the floods occurred before planting started (1936, 1937, 1938, and 1942) was subtracted from total crop damage during the 1933-1945 period, the estimate for the average annual damage to crops would be reduced by at least 25%. Undoubtedly, some overestimation of the flood damage to crops occurred in the other years. If the damages reported in the observed conditions were overestimated, the error became further magnified when adjusted to the conditions existing in 1946.

The most important criticism of the benefit-cost analysis concerns the great importance placed upon crop damage prevention. The estimated average annual total damage in the area without the levee was $705,000, of which $546,000 was damages to crops. The estimated average annual total damage in the area with the improvements was $400,000, of which $348,000 was damage to crops. Therefore, the estimate for the total flood damage prevented by levee was $305,000, of which $198,000 was crop damage prevented. Thus approximately 65% of the projected total flood damage prevented was derived from a reduction in crop damage. However, from the analysis of floods and crop production in Chapter Three, it was shown that the levee was not necessary to prevent a severe crop damage or loss, and that the levee afforded little, if any, benefits to agriculture. If the projected benefits to crops were considerably reduced or

removed from the benefit-cost analysis, the annual costs would exceed the estimated benefits, and the levee would become greatly cost ineffective.

Thus far, the examination of the economic justification for levee protection of agricultural lands has concentrated upon the benefit-cost analysis used to justify a portion of the Tiptonville-Obion River levee. From the benefit-cost analysis alone it has been shown that levee protection of agricultural lands was not cost-effective. However, the benefit-cost analysis did not include certain additional costs that are associated with levee protection of agricultural land.

Additional Costs of Levee Protection

Large levees, like the Tiptonville-Obion River levee, have a high initial construction costs and frequently require expensive maintenance work. The 1936 Flood Control Act stipulated that local agencies should maintain and operate all flood control work after completion. However, the Federal Government has, in the past, paid for emergency repair work on levees. In 1943, 1944, and 1945, for example, Congress appropriated $10,000,000, $12,000,000, and $12,000,000, respectively as emergency funds for the repair and strengthening of levees and other flood control works which had been damaged by floods. In 1945, less than half of the present Tiptonville-Obion River levee was completed,

yet after the 1945 flood, emergency repair work to levees in Dyer County and Lake County exceeded $140,000.[50] Although the Federal Government pays for major emergency repair work on the levees, the local government must pay for the minor repair work. These costs are not considered in the benefit-cost calculations.

An additional cost of levee protection is the prime agricultural land taken up by the levee. The 1946 benefit-cost analysis for the Tiptonville-Obion River levee included the levee right-of-way as a non-Federal cost. At that time, cropland was valued at $75 per acre.[51] Today the value of cropland near the levee ranges from $1,000 to $1,500 per acre.[52] The Tiptonville-Obion levee has a base width of roughly 300 feet and is joined by the borrow pit, also approximately 300 feet wide. Therefore, each mile of levee comprises approximately 2,760 acres of cropland that has been taken out of production. With today's value of agricultural land per acre, the land taken by the levee represents a price ranging from $2,500,000 to $4,000,000. If the 2,760 acres taken out of production by the levee were planted in soybeans, the resulting crop would be worth approximately

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[51]House Document 757, p. 10.

[52]Billy Rose, Dyer County Farmers Co-op, personal interview, February 5, 1982.

$500,000 per year (based upon a yield of 30 bushels/acre and price of $6/bushel).[53] By having the levee, $500,000 in crop production is lost annually. This additional cost must be considered another economic cost of levee protection. If the high maintenance cost, cost of land lost to the levee, and the annual cost of potential crops taken out of production by the levee were included in the benefit-cost analysis, the levee would become overwhelmingly cost-ineffective.

Summary and Alternatives to Levee Protection

The primary purpose for levee protection of agricultural land is the protection of crops. Before construction of any flood control project can begin, it must be shown that the benefits of the project exceed the costs. Benefits afforded to the prevention of crop damage appear to have been overestimated in the Tiptonville-Obion River levee benefit cost analysis. When all of the costs of levee protection of agricultural lands are considered, the levee becomes cost-ineffective.

Regardless of the structural flood control programs devised to prevent damage to crops in the Mississippi floodplain in west Tennessee, crop loss would occur if a major flood occurred late in the growing season. Surplus moisture

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[53]Ibid.

conditions from the excess precipitation and backwater flooding exist on both sides of the levee when a flood occurs. Crop loss suffered by area farmers from damaging floods might possibly be reduced more effectively at much lower costs through non-structural measures.

One alternative to levee protection would have been to invest an amount equal to one-half the cost of the levee construction into a local crop damage relief fund. One-half of the estimated construction cost of the main levee in Dyer County is $2,500,000. If this amount were invested into a fund earning 10% interst, $250,000 would be available each year for relief. The interest earning from the fund alone would probably cover any replanting costs incurred by the local farmers. In addition, no land would be taken out of production by the levee, and the high levee maintenance costs would alleviated.

Another non-structural flood damage reduction program that many agricultural areas are turning to is crop insurance. The Federal Crop Insurance Corporation has devised a program, where in the individual farmer decides the level of protection he wants for his crops. In the event a natural disaster reduces crop yields, the insurance curtails the farmers losses.[54]

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[54]United States Department of Agriculture, Federal Crop Insurance Corporation, "Crop Insurance Makes Good Sense," Washington: U.S. Government Printing Office, February, 1981.

Conclusions

Benefits to crops have been used as a justification for levee protection in the Mississippi River floodplain for years. A levee was constructed in west Tennessee primarily for the protection of crops. However, when the Mississippi River floods are examined, it may be determined that over sixty percent of the floods occurred before the growing season of the major crop. Floods occurring during the growing season are accompanied by surplus moisture on the levee-protected land from excess precipitation and flooding on the tributaries. When the Mississippi River is at flood-stage, cultivation is impossible on either side of the levee. The levee, therefore, does not afford protection from crop losses during floods that occur in the growing season. Moreover, crop production was not necessarily reduced during major flood years, because the farmers have delayed planting or have replanted their crops.

An examination of the benefit-cost analysis for the Tiptonville-Obion River levee extension shows that with modern agricultural practices, the benefits of the levee protection are greatly reduced, and the costs of the levee would be greatly increased. Thus levee protection of agricultural land becomes cost-ineffective. Losses from crop damage in the area might be more effectively reduced through some non-structural measures.

Levees have been constructed throughout the lower Mississippi floodplain and have undoubtedly prevented much damage and saved many lives. However, levee protection of agricultural land in west Tennessee is neither necessary for crop production nor can it be economically justified for that purpose. Flood protection of agricultural land should not be used as a justification for levee construction in west Tennessee.

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APPENDICES

APPENDIX
A

Monthly water budgets were calculated to determine the general soil moisture condition before a flooding event. Surplus conditions in the months preceeding the flood event lead to the assumption that the soil moisture storage was full at the beginning of the daily water budget calculations.

MONTHLY WATER BUDGET

	J	F	M	A
1957				
Temp.	36.5	46.9	49.4	63.1
Unadj. PE	.00	.02	.03	.09
PE	.00	.5	.9	2.47
Precip.	7.67	5.73	2.03	7.23
P - PE	+7.67	+5.53	+1.13	+4.26
1961				
Temp.	35.0	45.8	52.6	56.2
Unadj. PE	.00	.02	.04	.06
PE	.00	.5	1.2	2.0
Precip.	1.47	5.37	7.8	4.85
P - PE	1.47	5.37	6.6	2.85

	J	F	M	A
1958				
Temp.	35.9	31.8	43.6	59.3
Unadj. PE	.00	.00	.02	.07
PE	.00	.00	.6	2.3
Precip.	3.76	2.78	7.20	4.45
P - PE	3.76	2.78	6.60	2.15
1967				
Temp.	41.2	37.7	54.9	64.4
Unadj. PE	.01	.00	.05	.09
PE	.26	.00	1.54	2.97
Precip.	1.76	2.37	3.65	3.41
P - PE	1.50	2.37	2.11	.44

MONTHLY WATER BUDGET

	J	F	M	A
1968				
Temp.	34.0	35.6	48.7	60.2
Unadj. PE	.00	.00	.03	.07
PE	.00	.00	.02	2.31
Precip.	2.43	1.66	5.71	5.90
P - PE	2.43	1.66	.479	3.59
1972				
Temp.	39.1	42.1	50.9	
Unadj. PE	.01	.01	.04	
PE	.3	.3	1.2	
Precip.	3.3	2.6	4.7	
P - PE	3.0	2.3	3.5	

	J	F	M	A
1970				
Temp.	31.5	38.9	46.7	
Unadj. PE	.00	.01	.02	
PE	.00	.02	1.3	
Precip.	1.41	3.40	5.30	
P - PE	1.41	3.10	4.70	
1973				
Temp.	37.1	41.1	56.4	
Unadj. PE	.00	.01	.06	
PE	.00	.03	1.3	
Precip.	4.07	3.20	7.30	
P - PE	4.07	2.90	5.50	

MONTHLY WATER BUDGET

	J	F	M	A
1974				
Temp.	39.8	43.4	54.1	59.7
Unadj. PE	.01	.02	.05	.07
PE	.3	.6	1.54	2.3
Precip.	4.82	2.61	2.48	6.15
P - PE	4.52	2.01	.94	3.85
1978				
Temp.	22.9	26.7	45.6	
Unadj. PE	.00	.00	.02	
PE	.00	.00	.6	
Precip.	5.77	1.59	4.5	
P - PE	5.77	1.59	3.9	

	J	F	M	A
1975				
Temp.	42.3	41.5	47.0	
Unadj. PE	.01	.01	.02	
PE	.3	.3	.6	
Precip.	3.76	4.15	12.26	
P - PE	3.47	3.85	11.66	
1979				
Temp.	26.2	32.6	50.1	
Unadj. PE	.00	.00	.03	
PE	.00	.00	.9	
Precip.	3.61	5.74	4.53	
P - PE	3.61	5.74	3.63	

APPENDIX
B

DAILY WATER BALANCE
MAY 1957

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	73	.16	.04	-.12	-.12	-.12		
2	73	.16	.26	+.10	-.02	+.10		
3	64	.10	.03	-.07	-.09	-.07		
4	53	.05		-.05	-.14	-.05		
5	54	.06		-.06	-.20	-.06		
6	59	.08		-.08	-.28	-.08		
7	62	.09		-.09	-.37	-.09		
8	66	.11		-.11	-.48	-.11		
9	72	.16		-.16	-.64	-.16		
10	74	.17	.04	-.13	-.77	-.13		
11	73	.16	.60	+.44	-.33	+.44		
12	76	.17	.13	-.04	-.37	-.04		
13	74	.17	.87	+.70	Full	+.37	.33	.33
14	73	.16	2.27	+2.05	Full		2.05	2.38
15	77	.19	.08	-.11	Full			2.27
16	75	.18		-.18	Full			2.09
17	78	.20	.01	-.19	Full			1.90
18	77	.10	.42	+.23	Full		.23	2.13
19	68	.13	.57	+.44	Full		.44	2.57
20	66	.12	.09	-.03	Full			2.54
21	76	.18	.05	-.13	Full			2.41
22	70	.14	1.93	+1.79	Full		1.79	4.20
23	71	.15	2.64	+2.49	Full		2.49	6.69
24	74	.17	.35	+.18	Full		.18	6.87
25	77	.20	.23	+.03	Full		.03	6.90
26	72	.15	.41	+.26	Full		.26	7.16
27	67	.13	.01	-.12	Full			7.04
28	66	.12		-.12	Full			6.92
29	70	.14		-.14	Full			6.78
30	74	.17		-.17	Full			6.61
31	77	.19		-.19	Full			6.42

DAILY WATER BALANCE
MAY 1958

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	59	.08	.13	+.05	Full		.05	.05
2	68	.12	.76	+.64	Full		.64	.69
3	73	.16	.99	+.83	Full		.83	1.52
4	71	.15	.99	+.84	Full		.84	2.36
5	60	.08	.64	+.56	Full		.56	2.92
6	53	.05	.53	+.48	Full		.48	3.40
7	55	.06		-.06	Full			3.34
8	58	.07	.19	+.12	Full		.12	3.46
9	56	.07	.57	+.50	Full		.50	3.96
10	64	.10	.61	+.51	Full		.51	4.47
11	67	.13	.08	-.05	Full			4.42
12	71	.15		-.15	Full			4.27
13	71	.15		-.15	Full			4.12
14	70	.14		-.14	Full			3.98
15	75	.18	.08	-.10	Full			3.88
16	77	.19	.03	-.16	Full			3.72
17	75	.18	.13	-.05	Full			3.67
18	75	.18		-.18	Full			3.49
19	71	.15	.22	+.07	Full		.07	3.56
20	71	.15	.01	-.14	Full			3.42
21	75	.18		-.18	Full			3.24
22	76	.19		-.19	Full			3.05
23	77	.19		-.19	Full			2.86
24	76	.19		-.19	Full			2.67
25	76	.19	.08	-.11	Full			2.56
26	73	.17		-.17	Full			2.39
27	75	.18		-.18	Full			2.21
28	74	.18	.19	+.01	Full			2.22
29	68	.13		-.13	Full			2.09
30	72	.16	.06	-.10	Full			1.99
31	76	.19		-.19	Full			1.80

DAILY WATER BALANCE
JUNE 1958

	Mean Temp.	Adj. PE	Prec.	Prec -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			1.80
1	84	.24		-.24	Full			1.56
2	75	.18		-.18	Full			1.38
3	72	.16		-.16	Full			1.22
4	77	.19		-.19	Full			1.03
5	86	.25	.05	-.20	Full			.83
6	80	.22	.13	-.09	Full			.74
7	76	.19		-.19	Full			.55
8	82	.23		-.23	Full			.32
9	83	.23	.31	+.07	Full		.07	.39
10	85	.25		-.25	Full			.14
11	76	.19	.89	+.89	Full		.89	1.03
12	82	.23		-.23	Full			.80
13	86	.25		-.25	Full			.55
14	86	.25		-.25	Full			.30
15	82	.23	.22	-.01	Full			.29
16	72	.16		-.16	Full			.13
17	75	.18		-.18	-.05	0.05		
18	78	.21	.01	-.20	-.25	-.20		
19	80	.22	.03	-.19	-.44	-.19		
20	81	.22	.14	-.08	-.52	-.08		
21	76	.20	.04	-.16	-.68	-.16		
22	67	.13	.03	-.10	-.78	-.10		
23	70	.15		-.15	-.93	-.15		
24	75	.18		-.18	-1.11	-.18		
25	77	.20	.10	-.10	-1.21	-.10		
26	66	.12	.48	+.36	-.85	+.36		
27	70	.15	.01	-.14	-.99	-.14		
28	73	.17		-.17	-1.16	-.17		
29	74	.18		-.18	-1.34	-.18		
30	77	.20		-.20	-1.54	-.20		

DAILY WATER BALANCE
JULY 1958

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					-1.54			0
1	78	.21		-.21	-1.75	-.21		
2	81	.22	-	-.22	-.197	-.22		
3	81	.22		-.22	-2.19	-.22		
4	81	.22	.20	-.02	-2.21	-.02		
5	79	.21	.02	-.19	-.240	-.19		
6	79	.21	.79	+.58	-1.82	+.58		
7	74	.18	1.01	+.83	-.99	+.83		
8	76	.19	1.97	+1.78	Full	+.99	.79	.79
9	80	.22	.02	-.20	Full			.59
10	80	.22		-.22	Full			.37
11	81	.22		-.22	Full			.15
12	77	.19	.49	+.30	Full		.30	.45
13	79	.21	.50	+.29	Full		.29	.74
14	81	.22		-.22	Full			.52
15	83	.24		-.24	Full			.28
16	82	.23	.02	-.21	Full			.07
17	84	.24		-.24	-.17	-.17		
18	86	.25		-.25	-.42	-.25		
19	87	.26		0.26	-.68	-.26		
20	86	.25	.05	-.20	-.88	-.20		
21	79	.21	.22	+.01	-.87	+.01		
22	78	.20	.80	+.60	-.27	+.60		
23	78	.20	.13	-.07	-.34	-.07		
24	80	.21		-.21	-.55	-.21		
25	79	.20	.15	-.04	-.59	-.04		
26	80	.21	.06	-.15	-.74	-.15		
27	82	.22		-.22	-.96	-.22		
28	84	.23		-.23	-1.19	-.23		
29	83	.23		-.23	-1.42	-.23		
30	83	.23		-.23	-1.65	-.23		
31	84	.23		-.23	-1.88	-.23		

DAILY WATER BALANCE
MAY 1961

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	62	.09	1.20	+1.11	Full		1.11	1.11
2	52	.05		-.05	Full			1.06
3	60	.08		-.08	Full			.98
4	57	.07	.06	-.01	Full			.97
5	63	.09	.18	+.09	Full		.09	1.06
6	67	.13	1.62	+1.49	Full		1.49	2.55
7	72	.15	.43	+.28	Full		.28	2.83
8	69	.14	.79	+.65	Full		.65	3.48
9	58	.07	.93	+.86	Full		.86	4.34
10	55	.06		-.06	Full			4.28
11	64	.10		-.10	Full			4.18
12	69	.13		-.13	Full			4.05
13	72	.15		-.15	Full			3.90
14	73	.16	.01	-.15	Full			3.75
15	69	.13		-.13	Full			3.62
16	62	.09		-.09	Full			3.53
17	68	.13	.01	-.12	Full			3.41
18	73	.16		-.16	Full			3.25
19	68	.13		-.13	Full			3.12
20	68	.13		-.13	Full			2.99
21	71	.15	.04	-.11	Full			2.88
22	65	.11	.61	+.50	Full		.50	3.38
23	64	.11	.22	+.11	Full			3.49
24	63	.11		-.11	Full			3.38
25	70	.15	.04	-.11	Full			3.27
26	58	.07	.24	+.17	Full		.17	3.44
27	54	.06		-.06	Full			3.38

DAILY WATER BALANCE
MAY 1967

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	72	.15	.72	+.57	Full		.57	.57
2	59	.07	.56	+.48	Full		.48	1.05
3	55	.07		-.07	Full			.98
4	60	.08		-.07	Full			.90
5	64	.10		-.10	Full			.80
6	65	.10	.07	-.03	Full			.77
7	61	.09	.73	+.64	Full		.64	1.41
8	63	.10		-.10	Full			1.31
9	63	.10		-.10	Full			1.21
10	64	.10	.01	-.09	Full			1.12
11	73	.16	.02	-.14	Full			.98
12	64	.10	.66	+.56	Full		.56	1.54
13	64	.10	2.26	+2.16	Full		2.16	3.70
14	63	.10	.68	+.58	Full		.58	4.28
15	59	.08	1.74	+1.66	Full		1.66	5.94
16	62	.09	.01	-.08	Full			5.86
17	66	.12	.08	-.04	Full			5.82
18	70	.14		-.14	Full			5.68
19	73	.17		-.17	Full			5.51
20	67	.13	.09	-.04	Full			5.47
21	60	.08	.01	-.07	Full			5.40
22	63	.10	.01	-.09	Full			5.31
23	64	.11		-.11	Full			5.20
24	71	.15		-.15	Full			5.05
25	76	.19		-.19	Full			4.86
26	75	.18		-.18	Full			4.68
27	78	.20		-.20	Full			4.48

DAILY WATER BALANCE
MAY 1968

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	70	.14		-.14	-.14	-.14		
2	72	.15		-.15	-.29	-.15		
3	73	.16		-.16	-.45	-.16		
4	70	.14		-.14	-.59	-.14		
5	62	.09		-.09	-.68	-.09		
6	58	.07		-.07	-.75	-.07		
7	63	.10		-.10	-.85	-.07		
8	69	.14	.01	-.13	-.98	-.13		
9	71	.15	.07	-.08	-1.06	-.08		
10	68	.13	.43	+.30	-.76	+.30		
11	65	.10	1.32	+1.22	Full	+.76	.46	.46
12	69	.11		-.14	Full			.32
13	69	.14	.50	+.36	Full		.36	.68
14	71	.15	1.33	+1.18	Full		1.18	1.86
15	75	.17	.03	-.14	Full			1.72
16	72	.15	1.73	+1.58	Full		1.58	2.30
17	69	.14	.07	-.07	Full			2.23
18	60	.08	.15	+.07	Full		.07	2.30
19	63	.10		-.10	Full			2.20
20	59	.08		-.08	Full			2.12
21	61	.09		-.09	Full			2.03
22	64	.10		-.10	Full			1.93
23	70	.14	.01	-.13	Full			1.80
24	78	.20		-.20	Full			1.60
25	75	.17	.46	+.29	Full		.29	1.89
26	73	.16	.25	+.09	Full		.09	1.98
27	66	.12		-.12	Full			1.86
28	68	.13		-.13	Full			1.73
29	70	.14	.01	-.13	Full			1.60
30	68	.13		-.13	Full			1.47
31	73	.16		-.16	Full			1.31

DAILY WATER BALANCE
JUNE 1968

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			1.31
1	78	.20		-.20	Full			1.11
2	77	.19	.54	+.35	Full		.35	1.46
3	76	.19	.25	+.06	Full		.06	1.52
4	79	.20		-.20	Full			1.32
5	79	.20		-.20	Full			1.12
6	81	.22		-.22	Full			.90
7	79	.20		-.20	Full			.70
8	81	.22		-.22	Full			.48
9	82	.23		-.23	Full			.25
10	85	.25		-.25	Full			

DAILY WATER BALANCE
APRIL 1970

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	60	.07	.20	+.13	Full		.13	.13
2	51	.04	1.10	+1.06	Full		1.06	1.19
3	51	.04		-.04	Full			1.15
4	53	.05		-.05	Full			1.10
5	51	.04		-.04	Full			1.06
6	56	.06		-.06	Full			1.00
7	59	.07		-.07	Full			.93
8	60	.07		-.07	Full			.86
9	66	.11		-.11	Full			.75
10	63	.09		-.09	Full			.66
11	64	.10		-.10	Full			.56
12	64	.10		-.10	Full			.46
13	63	.10	.29	+.19	Full		.19	.65
14	56	.07		-.07	Full			.58
15	57	.07		-.07	Full			.51
16	61	.09		-.09	Full			.42
17	68	.12	.36	+.24	Full		.24	.66
18	70	.13		-.13	Full			.53
19	70	.13	1.28	+1.15	Full		1.15	1.68
20	66	.11	.72	+.61	Full		.61	2.29
21	62	.09		-.09	Full			2.20
22	63	.10		-.10	Full			2.10
23	71	.13	.07	-.06	Full			2.04
24	71	.14	.79	+.65	Full		.65	2.69
25	66	.11	1.07	+.96	Full		.96	3.65
26	66	.11	.17	+.06	Full		.06	3.71
27	70	.13	.24	+.11	Full		.11	3.82
28	74	.16	.10	-.06	Full			3.76
29	76	.18		-.18	Full			3.58
30	77	.18		-.18	Full			3.40

DAILY WATER BALANCE
MAY 1970

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			3.40
1	69	.12	1.21	+1.29	Full		1.29	4.69
2	57	.07	.30	+.23	Full		.23	4.92
3	56	.07	.05	-.02	Full			4.90
4	61	.09		-.09	Full			4.81
5	66	.11	.06	-.05	Full			4.76
6	68	.13	.20	+.07	Full		.07	4.83
7	68	.13		-.13	Full			4.70
8	72	.15		-.15	Full			4.55
9	73	.16		-.16	Full			4.39
10	71	.14	.89	+.75	Full		.75	5.14
11	72	.16	.95	+.79	Full		.79	5.93
12	77	.19		-.19	Full			5.74
13	78	.20		-.20	Full			5.54
14	77	.19		-.19	Full			5.35
15	76	.18	.03	-.15	Full			5.20

DAILY WATER BALANCE
APRIL 1972

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	46	.02		-.02	-.02	-.02		
2	49	.03		-.03	-.05	-.03		
3	59	.07	.25	+.18	Full	+.05	.13	.13
4	46	.02	.63	+.61	Full		.61	.74
5	48	.03		-.03	Full			.71
6	63	.10		-.10	Full			.61
7	64	.10	.13	+.03	Full		.03	.64
8	40	.01	.30	+.29	Full		.29	.93
9	47	.02		-.02	Full			.91
10	60	.08		-.08	Full			.83
11	70	.13	.02	-.11	Full			.72
12	76	.16	.01	-.15	Full			.57
13	78	.18	.03	-.15	Full			.42
14	64	.10		-.10	Full			.32
15	61	.09	.02	-.07	Full			.25
16	61	.09	1.84	+1.73	Full		1.73	1.98
17	62	.09		-.09	Full			1.89
18	73	.15		-.15	Full			1.74
19	70	.12		-.12	Full			1.62
20	68	.12	.32	+.20	Full		.20	1.82
21	62	.09	.89	+.80	Full		.80	2.62
22	69	.12	.39	+.27	Full		.27	2.89
23	69	.12		-.12	Full			2.77
24	60	.08	.05	-.03	Full			2.74
25	53	.05		-.05	Full			2.69
26	54	.06		-.06	Full			2.63
27	60	.08		-.08	Full			2.55
28	67	.12		-.12	Full			2.43
29	63	.10	.61	+.51	Full		.51	2.94
30	66	.11		-.11	Full			2.83

DAILY WATER BALANCE
MAY 1972

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			2.83
1	65	.10	.46	+.36	Full		.36	3.19
2	65	.10	.46	+.39	Full		.39	3.58
3	61	.09		-.09	Full			3.49
4	63	.09		-.09	Full			3.40
5	68	.13		-.13	Full			3.27
6	70	.14		-.14	Full			3.13
7	70	.14	.05	-.09	Full			3.02
8	67	.13	.02	-.11	Full			2.91
9	60	.08	.03	-.05	Full			2.86
10	59	.08		-.08	Full			2.78
11	62	.09		-.09	Full			2.69
12	64	.10	.48	+.38	Full		.38	3.07

DAILY WATER BALANCE
APRIL 1973

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	59	.07		-.07	-.07	-.07		
2	57	.06		-.06	-.13	-.06		
3	57	.06	.10	+.04	-.09	+.04		
4	50	.03	.43	+.40	Full	+.09	.31	.31
5	49	.03	.01	-.02	Full			.29
6	53	.04		-.04	Full			.25
7	55	.05	.37	+.32	Full		.32	.57
8	53	.04	.38	+.34	Full		.34	.91
9	51	.04	.45	+.41	Full		.41	1.32
10	43	.02		-.02	Full			1.30
11	-4	.02		-.02	Full			1.28
12	54	.05		-.05	Full			1.23
13	48	.03		-.03	Full			1.20
14	53	.04		-.04	Full			1.16
15	59	.08		-.08	Full			1.08
16	60	.08	.34	+.26	Full		.26	1.34
17	64	.10	.19	+.09	Full		.09	1.43
18	64	.10	1.48	+1.38	Full		1.38	2.81
19	64	.10	.83	+.73	Full		.73	3.54
20	68	.12	2.31	+2.19	Full		2.19	5.73
21	70	.13	.04	-.09	Full			5.64
22	68	.12	.72	+.60	Full		.60	6.24
23	68	.12	1.78	+1.66	Full		1.66	7.90
24	68	.12	.16	+.04	Full		.04	7.94
25	64	.10	.28	+.18	Full		.18	8.12
26	56	.07	.31	+.24	Full		.24	8.36
27	54	.06	.11	+.05	Full		.05	8.41
28	54	.06	.01	-.05	Full			8.36
29	60	.08		-.08	Full			8.28
30	67	.11		-.11	Full			8.17

DAILY WATER BALANCE
MAY 1973

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			8.17
1	68	.12	.57	+.45	Full		.45	8.62
2	69	.13	2.56	+2.43	Full		2.43	11.05
3	61	.09		-.09	Full			10.96
4	59	.08		-.08	Full			10.88
5	62	.09		-.09	Full			10.79
6	65	.10	.09	-.01	Full			10.78
7	65	.12	1.52	+1.40	Full		1.40	12.18
8	66	.12	.03	-.09	Full			12.19
9	65	.12		-.12	Full			12.07
10	71	.15	.33	+.18	Full		.18	12.25
11	70	.14	.08	-.06	Full			12.19
12	64	.10	.12	+.02	Full		.02	12.21
13	61	.09		-.09	Full			12.12
14	61	.09		-.09	Full			12.03
15	60	.08		-.08	Full			11.95
16	61	.09		-.09	Full			11.86
17	64	.11	.08	-.03	Full			11.83
18	61	.09		-.09	Full			11.74
19	71	.15		-.15	Full			11.59
20	70	.14	.03	-.11	Full			11.48
21	70	.14		-.14	Full			11.34
22	74	.18	.11	-.07	Full			11.27
23	73	.17	.40	+.23	Full		.23	11.46
24	73	.17	.79	+.62	Full		.62	12.08
25	74	.18		-.18	Full			11.90
26	74	.18		-.18	Full			11.72
27	71	.14	1.41	+1.26	Full		1.26	12.98
28	67	.12	.01	-.11	Full			12.89
29	68	.13	.02	-.11	Full			12.78
30	69	.13	.08	-.05	Full			12.73
31	69	.13		-.13	Full			12.60

DAILY WATER BALANCE
JUNE 1973

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			12.60
1	72	.17		-.17	Full			12.43
2	74	.17		-.17	Full			12.26
3	80	.22	.01	-.21	Full			12.05
4	78	.20		-.20	Full			11.85
5	76	.19	.10	-.09	Full			11.76
6	76	.19	.15	-.04	Full			11.72
7	73	.17		-.17	Full			11.55
8	77	.19		-.19	Full			11.36
9	81	.22		-.22	Full			11.14
10	82	.23	.49	+.26	Full		.26	11.40
11	82	.23	.19	+.04	Full		.04	11.44
12	79	.21	.07	-.14	Full			11.30
13	80	.22	.15	-.07	Full			11.27
14	80	.22	.67	+.45	Full		.45	11.72

DAILY WATER BALANCE
MAY 1974

	Mean Temp.	Prec. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	66	.11	.01	-.10	-.10	-.10		
2	68	.12	.56	+.44	+.10	+.10	.34	.34
3	67	.12	.12	0	Full			.34
4	66	.11	.21	+.10	Full		.10	.44
5	61	.09	.18	-.09	Full		.09	.53
6	64	.10		-.10	Full			.43
7	61	.09		-.09	Full			.34
8	69	.13	.07	-.06	Full			.28
9	61	.09	.19	+.10	Full		.10	.38
10	67	.13	1.02	+.89	Full		.89	1.27
11	72	.15		-.15	Full			1.12
12	68	.13		-.13	Full			.99
13	70	.14		-.14	Full			.85
14	76	.19		-.19	Full			.66
15	70	.14	1.23	+1.09	Full		1.09	1.75
16	75	.18		-.18	Full			1.57
17	77	.19		-.19	Full			1.38
18	76	.19		-.19	Full			1.19
19	78	.20		-.20	Full			.99
20	78	.20		-.20	Full			.79
21	78	.20	.12	-.08	Full			.71
22	72	.15	.75	+.60	Full		.60	1.31
23	72	.15	.39	+.24	Full		.24	1.55
24	74	.18		-.18	Full			1.37
25	66	.12		-.12	Full			1.25
26	65	.11	.09	-.02	Full			1.23
27	67	.13		-.13	Full			1.10
28	71	.15		-.15	Full			.95
29	75	.18		-.18	Full			.77
30	79	.20		-.20	Full			.57
31	78	.20	1.49	+1.29	Full		1.29	1.86

DAILY WATER BALANCE
MAY 1974

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	66	.11	.01	-.10	-.10	-.10		
2	68	.12	.56	+.44	+.10	+.10	.34	.34
3	67	.12	.12	0	Full			.34
4	66	.11	.21	+.10	Full		.10	.44
5	61	.09	.18	+.09	Full		.09	.53
6	64	.10		-.10	Full			.43
7	61	.09		-.09	Full			.34
8	69	.13	.07	-.06	Full			.28
9	61	.09	.19	+.10	Full		.10	.38
10	67	.13	1.02	+.89	Full		.89	1.27
11	72	.15		-.15	Full			1.12
12	68	.13		-.13	Full			.99
13	70	.14		-.14	Full			.85
14	76	.19		-.19	Full			.66
15	70	.14	1.23	+1.09	Full		1.09	1.75
16	75	.18		-.18	Full			1.57
17	77	.19		-.19	Full			1.38
18	76	.19		-.19	Full			1.19
19	78	.20		-.20	Full			.99
20	78	.20		-.20	Full			.79
21	78	.20	.12	-.08	Full			.71
22	72	.15	.75	+.60	Full		.60	1.31
23	72	.15	.39	+.24	Full		.24	1.55
24	74	.18		-.18	Full			1.37
25	66	.12		-.12	Full			1.25
26	65	.11	.09	-.02	Full			1.23
27	67	.13		-.13	Full			1.10
28	71	.15		-.15	Full			.95
29	75	.18		-.18	Full			.77
30	79	.20		-.20	Full			.57
31	78	.20	1.49	+1.29	Full		1.29	1.86

DAILY WATER BALANCE
JUNE 1974

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			1.86
1	70	.14	1.47	+1.33	Full		1.33	3.19
2	71	.15	.01	-.14	Full			3.05
3	71	.15		-.15	Full			2.90
4	74	.18		-.18	Full			2.72
5	74	.18	.49	+.31	Full		.31	3.03
6	74	.18	.35	+.17	Full		.17	3.20
7	73	.17	1.95	+1.78	Full		1.78	4.98
8	76	.19	.21	+.02	Full		.02	5.00
9	74	.18		-.18	Full			4.82
10	70	.15		-.15	Full			4.67
11	72	.16		-.16	Full			4.51
12	72	.16	.02	-.14	Full			4.37
13	71	.16		-.16	Full			4.21
14	68	.10		-.13	Full			4.08
15	69	.14	.69	+.55	Full		.55	4.63
16	71	.16		-.16	Full			4.47
17	69	.14		-.14	Full			4.33
18	72	.16		-.16	Full			4.17

DAILY WATER BALANCE
APRIL 1975

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	50	.04		-.04	-.04	-.04		
2	59	.07		-.07	-.11	-.07		
3	46	.02		-.02	-.13	-.02		
4	44	.02		-.02	-.15	-.02		
5	45	.02		-.02	-.17	-.02		
6	49	.03		-.03	-.20	-.03		
7	51	.04		-.04	-.24	-.04		
8	54	.05	.07	+.02	-.22	+.02		
9	58	.07	.43	+.36	Full	+.22	.14	.14
10	57	.06	.20	+.14	Full		.14	.28
11	51	.04		-.04	Full			.24
12	48	.03		-.03	Full			.21
13	50	.04		-.04	Full			.17
14	51	.04	.27	+.23	Full		.23	.40
15	54	.05	.11	+.06	Full		.06	.46
16	59	.08		-.08	Full			.38
17	64	.10		-.10	Full			.28
18	71	.13		-.13	Full			.15
19	63	.10	.67	+.37	Full			.72
20	56	.07		-.07	Full			.65
21	59	.08		-.08	Full			.57
22	62	.09		-.09	Full			.48
23	70	.13	.02	-.11	Full			.37
24	71	.14	.11	-.03	Full			.34
25	70	.13	1.07	+.94	Full			1.28
26	72	.14		-.14	Full			1.14
27	74	.16		-.16	Full			.98
28	74	.16		-.16	Full			.82
29	68	.12	.02	-.19	Full			.72
30	47	.02	.17	+.15	Full			.87

DAILY WATER BALANCE
MAY 1975

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surface	Surface Storage
Prev. Day					Full			.87
1	67	.12	.79	+.67	Full		.67	1.54
2	60	.08		-.08	Full			1.46
3	66	.11	.17	+.06	Full		.06	1.52
4	65	.10		-.10	Full			1.42
5	67	.12		-.12	Full			1.30
6	71	.15		-.15	Full			1.15
7	70	.14	.72	+.58	Full		.58	1.73
8	71	.15	.31	+.16	Full		.16	1.89
9	68	.13	.04	-.09	Full			1.80
10	71	.15		-.15	Full			1.65
11	71	.15	.01	-.14	Full			1.51
12	69	.14	.46	+.32	Full		.32	1.83
13	63	.10		-.10	Full			1.73
14	66	.12		-.12	Full			1.61
15	70	.14	.08	-.06	Full			1.55
16	67	.13		-.13	Full			1.42

DAILY WATER BALANCE
APRIL 1978

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	72	.14		-.14	-.14	-.14		
2	72	.14		-.14	-.28	-.14		
3	73	.15	.01	-.14	-.42	-.14		
4	70	.13	.02	-.11	-.53	-.11		
5	66	.11	.02	-.09	-.64	-.09		
6	71	.14		-.14	-.78	-.14		
7	89	.13		-.13	-.91	-.13		
8	69	.13		-.13	-1.04	-.13		
9	73	.15		-.15	-1.19	-.15		
10	73	.15		-.15	-1.34	-.15		
11	60	.06	1.37	+1.29	-.05	+1.29		
12	56	.06		-.06	-.11	-.06		
13	59	.08		-.08	-.19	-.08		
14	59	.08		-.08	-.27	-.08		
15	61	.09		-.09	-.36	-.09		
16	61	.09		-.09	-.45	-.09		
17	61	.09		-.09	-.54	-.09		
18	67	.12	1.52	+1.40	Full	+.54	.86	.86
19	58	.08		-.08	Full			.78
20	48	.03		-.03	Full			.75
21	47	.02		-.02	Full			.73
22	50	.04		-.04	Full			.69
23	64	.10	.57	+.47	Full		.47	1.16
24	63	.10	.01	-.09	Full			1.07
25	60	.08	.05	-.03	Full			1.04
26	55	.06	.01	-.05	Full			.99
27	58	.08		-.08	Full			.91
28	58	.08		-.08	Full			.83
29	64	.10	.04	-.06	Full			.77
30	68	.12	.04	-.08	Full			.69

DAILY WATER BALANCE
MAY 1978

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			.69
1	59	.08	.53	+.45	Full		.45	1.14
2	49	.03	.11	+.08	Full		.08	1.22
3	53	.05	.30	+.25	Full		.25	1.47
4	53	.05	.23	+.18	Full		.18	1.65
5	55	.06		-.06	Full			1.59
6	60	.08		-.08	Full			1.51
7	65	.10	1.44	+1.34	Full		1.34	2.83
8	68	.13	.59	+.46	Full		.46	3.31
9	67	.12	.01	-.11	Full			3.20
10	64	.11		-.11	Full			3.09
11	69	.13		-.13	Full			2.96
12	71	.15	.36	+.21	Full		.21	3.17
13	66	.12	.21	+.09	Full		.09	3.26
14	63	.11		-.11	Full			3.15
15	62	.09		-.09	Full			3.06
16	59	.08		-.08	Full			2.98
17	61	.09		-.09	Full			2.89
18	65	.11	.08	-.03	Full			2.86
19	70	.14	.09	-.05	Full			2.81
20	74	.18	.44	+.26	Full		.26	3.07
21	70	.14	.15	+.01	Full		.01	3.08
22	73	.17	.01	-.16	Full			2.92

DAILY WATER BALANCE
APRIL 1979

	Mean Temp.	Adj. PE	Prec.	Prec. -PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			0
1	57	.05	1.89	+1.83	Full		1.83	1.83
2	55	.05	2.48	+2.43	Full		2.43	4.26
3	49	.03		-.03	Full			4.23
4	52	.04	.64	+.60	Full		.60	4.83
5	49	.93		-.03	Full			4.80
6	49	.03		-.03	Full			4.77
7	50	.04		-.04	Full			4.73
8	60	.07	.17	+.10	Full		.10	4.83
9	53	.04	1.16	+1.12	Full		1.12	5.95
10	46	.02	.04	+.02	Full		.02	5.97
11	58	.06	.03	-.03	Full			5.94
12	68	.12	.88	+.76	Full		.76	6.70
13	65	.10	.03	-.07	Full			6.63
14	58	.07	.01	-.06	Full			6.57
15	63	.10		-.10	Full			6.47
16	63	.10		-.10	Full			6.37
17	63	.10		-.19	Full			6.27
18	65	.10		-.10	Full			6.17
19	67	.12		-.12	Full			6.05
20	69	.13		-.13	Full			5.92
21	71	.14	.01	-.13	Full			5.79
22	65	.10	.09	-.01	Full			5.78
23	63	.10	1.04	+.94	Full			6.72
24	64	.10	1.25	+1.15	Full		1.15	7.87
25	66	.11	.19	+.08	Full		.08	7.95
26	63	.10	.16	+.06	Full		.06	8.01
27	55	.06	.01	-.05	Full			7.96
28	54	.06		-.06	Full			7.90
29	55	.06		-.06	Full			7.84
30	60	.08		-.08	Full			7.76

DAILY WATER BALANCE
MAY 1979

	Mean Temp.	Adj. PE	Prec.	Prec. PE	Soil Storage	Change Storage	Surplus	Surface Storage
Prev. Day					Full			7.76
1	60	.08		-.08	Full			7.68
2	60	.08	.08	0	Full			7.68
3	66	.11	2.08	+1.97	Full		1.97	9.65
4	61	.09	1.63	+1.54	Full		1.54	11.19
5	54	.06	.21	+.15	Full		.15	11.34
6	59	.08		-.08	Full			11.26
7	65	.10		-.10	Full			11.16
8	73	.16		-.16	Full			11.00
9	75	.17		-.17	Full			10.83
10	76	.18		-.18	Full			10.65
11	76	.18	.13	-.05	Full			10.60
12	76	.18	.88	+.70	Full		.70	11.30
13	56	.07		-.07	Full			11.23
14	63	.10		-.10	Full			11.13

VITA

Edward Allen Bright was born in Knoxville, Tennessee on September 28, 1959. He attended elementary and secondary schools in Knoxville and graduated from Halls High School in June, 1977. He entered the University of Tennessee - Knoxville in June, 1977, and received a Bachelor of Arts degree with a major in Geography in June of 1980. He accepted a teaching assistantship in September, 1980, and received a Master of Science degree with a major in Geography in August, 1982.

He is married to the former Kathy McCloud of Knoxville, Tennessee.