POPLAR BLUFF, MISSOURI
Water Supply Study
Black River

INTRODUCTION:

This analysis was made to assess the availability of Poplar Bluff's water supply. Poplar Bluff obtains their water supply from The Black River. In 2001 there was an average of 3.075 million gallons per day (4.76 cfs) pumped from Black River, which is fed by numerous springs throughout its drainage area and a continuous release from Clearwater Reservoir.

DISCUSSION:

Poplar Bluff obtains their municipal water from Black River. There is no off channel storage to draw upon during periods of low flow. The drainage area at the intake for Poplar Bluff is 1245 square miles. There are two stream gages on Black River, one at Poplar Bluff with a drainage area of 1245 square miles and the other at Annapolis, drainage area is 484 square miles. Upstream of Poplar Bluff is Clearwater Lake at drainage area 898 square miles. Completion of the lake was in 1948. A minimum continuous release rate from the lake of 150 cfs is maintained at the dam. This was the estimated minimum continuous flow at the dam site prior to construction. Below the dam, Piedmont and Poplar Bluff use stream flow for their municipal water supplies. Clearwater dam was designed for flood control and has no storage for municipal supplies. In the year 2001 Poplar Bluff used 1,123 million gallons of water, or 3.075 MGD. In addition, Piedmont uses water from Black River and takes 164.25 million gallons or 0.45 MGD. Their intake is about 1 mile below Clearwater Dam.

Clearwater Reservoir is owned and operated by the Corps of Engineers and is managed for Flood Control. The most severe drought that has been recorded in the Black River Basin was for the period 1952 through 1956. Clearwater Lake was able to maintain normal Minimum releases during all drought periods.

Figure 60.1 shows the annual rainfall at Poplar Bluff for the period 1920 through 2001. This indicates the precipitation trend to be nearly uniform for the period of record.

Figure 60.2.a shows the annual runoff fin watershed inches for Black River at Poplar Bluff. The trend indicates an increase in total annual runoff from 7.5 inches to 10 inches or approximately 33% from 1955 to year 2000. **Figure 60.2.b** shows the runoff in terms of mean annual cubic feet per second.

Stream gage records on Black River at Poplar Bluff show the drought of record to be in the 1950's. The following **figures 60.3.a, 60.3.b, 60.3.c, and 60.3.d** compare the 1-%, 2% and 4% chance mean monthly non-exceedence flows (low flow) to measured flows for 1953, 1954, 1955 and 1956. All frequencies exceeded the adjusted 7-day Q-10 discharges at Poplar Bluff. In 1953, October had the lowest mean discharge of 268 cfs, which exceeded the 7-day Q-10 discharge by 52 cfs. Low flows for 1954, 1955 and 1956 exceeded 7-day Q-10 by 84, 60 and 43 cfs respectively.

Clearwater Reservoir controls all storm runoff from its drainage area of 898 square miles and releases the runoff at a minimum rate of 150 cubic feet per second. When droughts occur, low flows will be effected by releases from Clearwater to greater extent than high flows. Therefore it is necessary to make adjustments to account for controlled and uncontrolled drainage area contribution to base flow. The total drainage area at Poplar Bluff is 1245 square miles. The uncontrolled area is 347 square miles. By determining the base flow for the uncontrolled area and adding the minimum release of 150 cubic feet per second from the reservoir we were able to determine the expected base flow for dry periods.

Base flow separation was made using the USGS computer program, HYSEP. HYSEP separates the base flow hydrograph from the total hydrograph. This analysis was made to estimate

sustained flow for meeting water supply needs during a drought. **Figure 60.4.a** is the base flow index defined as the ratio of base flow to total stream flow. This chart shows the yearly fluctuation in base flow indexes and indicates the trend. The trend shows a constant base flow index of approximately 67% during the period of 1950 through 2000. Base flow was calculated and is shown in **figure 60.4.b** in terms of cfs for the period of 1950 through 2000. Trend shows that mean base flow has increased from about 850 cfs to approximately 1050 cfs for that period. Total flow was also calculated and is shown in **figure 60.4.c**. The trend for total flow shows an increase from 1300 cfs to 1600 cfs for the 50-year period.

To make the base flow analysis it was necessary to adjust the flow at Poplar Bluff for the uncontrolled area nad release from Clearwater Reservoir. A correlation between base flow and also total flow at Annapolis and Poplar Bluff gages for the period of 1940 through 1948 was determined. The gates on Clearwater Reservoir were closed in 1948. **Figure 60.4.d** is the base flow correlation and **figure 60.4.e** is the total flow correlation. Following are the steps to determine minimum base flow index.

Steps to adjust base flow are:

Step 1. Determine base flow and total stream flow for the Annapolis and Poplar Bluff Gages for years 1940 through 1948 using "HYSEP".

Step 2. Plot the annual total flow and annual base flow discharges to determine the relationship of the two gages. The resulting equations are:
Base Flow at Poplar Bluff = 2.4858 x flow at Annapolis – 5.8173 (Figure 4d)
Total Flow at Poplar Bluff = 2.066 x flow at Annapolis + 55.909. Figure 4e)

Step 3 Use the above equations to determine the mean annual base flow and total flow at Poplar Bluff for the intervening drainage area between the lake and Poplar Bluff for the period 1950 through 2000.

Step 4 Add the minimum release of 150 cfs from Clearwater Reservoir to each yearly mean discharge value from step 3.

Step 5 Plot adjusted mean annual base flow in cfs vs. year. (Figure 4b)

Step 6 Plot adjusted mean total annual flow in cfs vs. year. (Figure 4c)

Step 7 Plot ratio of base flow to total flow for the base flow index. (Figure 4a)

To determine the rate of flow needed to maintain in-stream flow requirements, the 7-day Q-10 low flow was determined using the period of record, 1950 through 2000. The 7-day Q-10 frequency discharge is used to establish standards for water quality issues. A computer program named 'DURFREK' (a duration frequency computer program developed by Hydrosphere) was used to make a frequency analysis of 7-day duration discharges. **Figure 60.5.a** shows the plot of the values for a frequency analysis. The 7-day Q-10 frequency analysis was determined to be 66 cfs for the intervening area below the Clearwater dam. 150 cfs was added for the minimum continuous release from Clearwater Lake and the minimum value for 7-day Q-10 low flow is 216 cfs.

Steps taken to make the adjustment for effects of Clearwater Reservoir on the minimum in-stream flow requirements are:

Step 1 Determine frequency of 7-day duration mean flow for Annapolis and Poplar Bluff Gages for years 1940 through 1948, which is the period when data was available for both gages and before Clearwater Reservoir was constructed. Run Durfrek on Annapolis and Poplar Bluff gages for that time period.

Step 2 Convert the 7-day duration discharges in step 1 to a per square mile of drainage area for each gage.

Step 3 Plot data in step 2, Poplar Bluff data vs. Annapolis data for 1940 through 1948, as shown in figure 60.5.b.

Step 4 Determine equation for relationship between the two gages from step 3. The following equation for the 7-day duration 10-year frequency low flow discharge was determined to be:

7-day duration low flow frequency =
1.6982 x (Discharge at Annapolis gage per square mile)^2 +
0.5885* (Discharge at Annapolis gage per square mile) + 0.597.

Step 5 Run duration frequency analysis, using Durfrek computer program, On Black River at Annapolis stream gage data for years 1950 through 2000 for 7-day duration.

Step 6 Convert results in step 5 to a per square mile basis by dividing by drainage area at the Annapolis gage.

Step 7 Multiply results in step 6 by the 346 square miles drainage area below Clearwater Reservoir.

Step 8 Add 150 cfs to each frequency value in step 7 to account for minimum release from Clearwater Reservoir.

Step 9 Plot results of 7-day Q-10 discharge in step 7 for the intervening area. Also plot step 8 results for the total 7-day Q-10 total discharge with constant release from Clearwater Reservoir.

Step 10 Minimum 7-day Q-10 discharge was determined to be 66 cfs from the intervening area plus 150 cfs constant release from Clearwater Reservoir established flow requirement for in-stream needs of 216 cfs.

Seven-day annual low flows for 1941 through 2000 were calculated and are shown **figure 60.6**. Visual observation shows that the trend for 7-day annual low flows has increased during the 60 years of record by about 40 percent.

Monthly non-excedence probabilities (low flows) for 1% chance of occurrence (1 time in 100 years), 2% chance (1 time in 50 years) and 4% chance (1 time in 25 years) were established from stream flow data for the years 1950 through 2000. **Figure 60.7** displays these results. Mean monthly low flow probabilities exceed the 7-day Q-10 discharge of 216 cfs for all frequencies. For this report, all statistical determinations were made using the Log Pearson Type 3 method as described in Water Resource Council bulletin 17B.

Because all mean monthly flows exceed the 7-day Q-10 in-stream flow requirements plus withdrawal rates by the city, it is not necessary to show shortages of water for Poplar Bluff. Any deficits that may occur would be of very short duration.

Figure 60.9 is the daily demand by Poplar Bluff, in million gallons per year. During the period of 1985 through 2001 their demand has increased from 1.937 MGD in 1985 to 3.075 MGD in 2001. The trend is increasing at the rate of 75,000 gallon per year.

Additional comparisons for the 1950's drought were made using the mean 7-day low flow for examining a shorter duration. These comparisons are shown in **figures 60.10.a, 60.10.b, 60.10.c and 60.10.d**. These figures compare mean seven-day low flows to 7 day Q10 flow, and indicate short-term critical periods. In the 4 years period of 1953 through 1956 there were 12 months that had mean seven-day flows below 7 day Q10 discharge.

They were:
1953 – 2 months October (255 cfs), November (245 cfs).
1954 - 2 months September (250cfs), October (259 cfs).
1955 - 2 months September (254 cfs), October (253 cfs).

1956 - 2 months September (253cfs), October (259 cfs).

Clearwater Lake is a Corps of Engineers project and was constructed in 1948 to provide flood control for the downstream drainage districts. Water supply was not included in the design of this lake. During planning, it was determined that base flow at the dam site was 150 cfs. The operating plan for the lake requires a minimum of 150-cfs continuous release. Their water control plan requires alerting the residents of Poplar Bluff if the stage drops below 0.3 feet. To date this has never happened and is not likely to occur. During the 1950's, the drought of record occurred from 1952 through 1956, release of 150 cfs from Clearwater Lake was maintained through the drought. There are several springs between the lake and Poplar Bluff that have continuous flow. **Figure 60.11** shows the storage in Clearwater Reservoir from its closure to year 2000.

Poplar Bluff, Missouri

Water Supply Study

Annual Rainfall

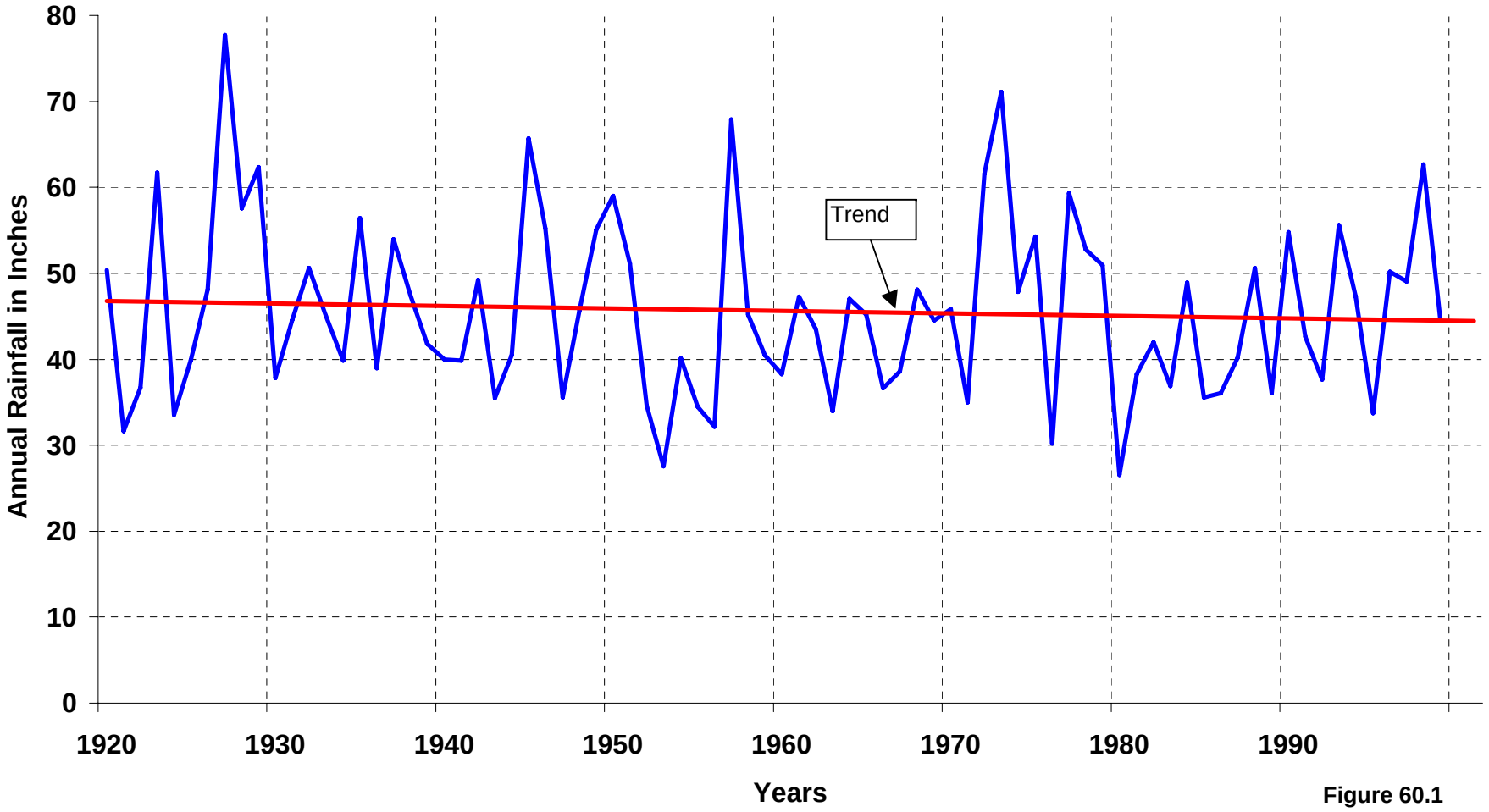

Figure 60.1

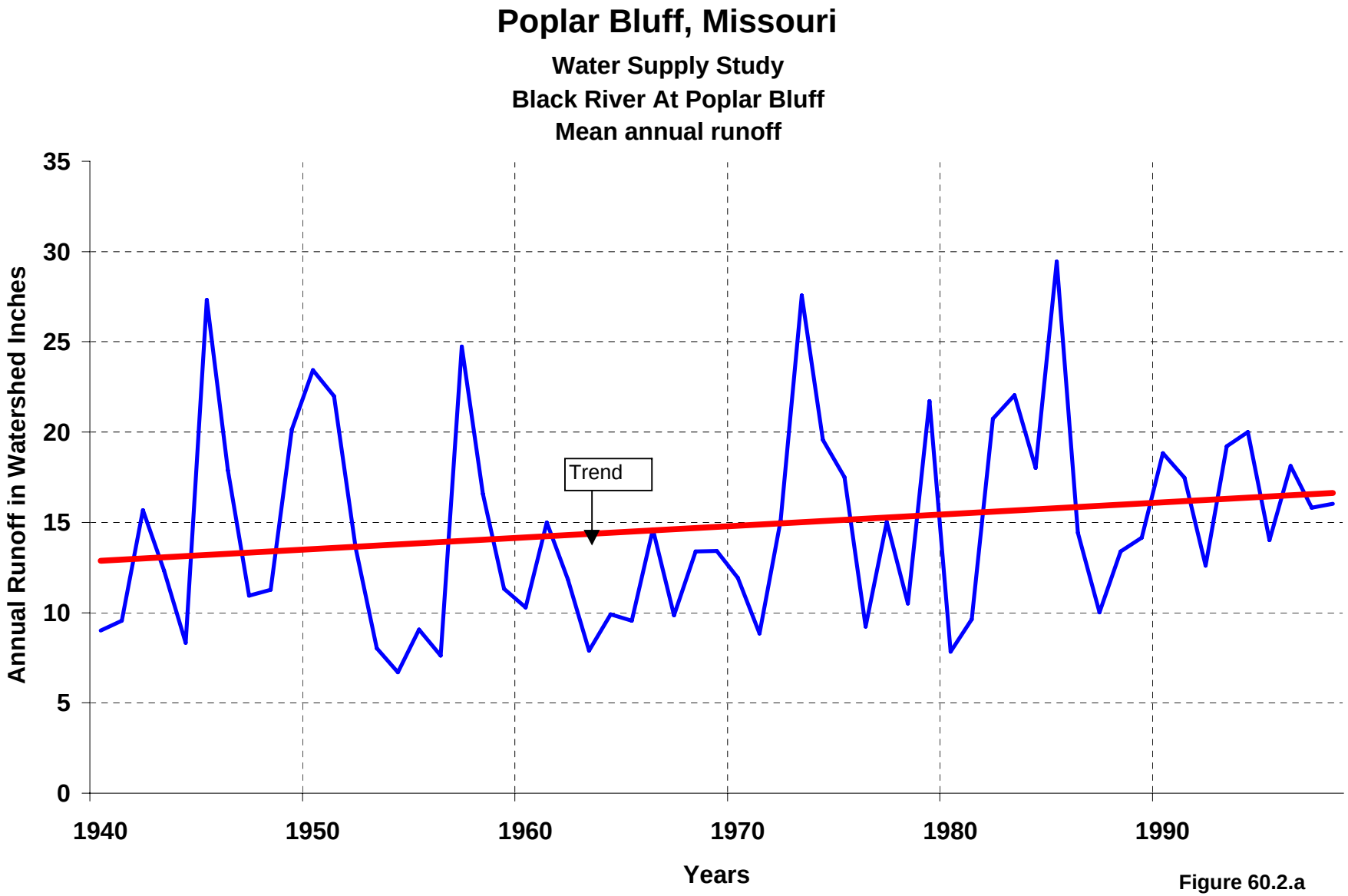
Poplar Bluff, Missouri
Water Supply Study
Black River At Poplar Bluff
Mean annual runoff
Annual Runoff in Watershed Inches
35
30
25
20
15
10
5
0
1940
1950
1960
1970
1980
1990
Years
Trend

Figure 60.2.a

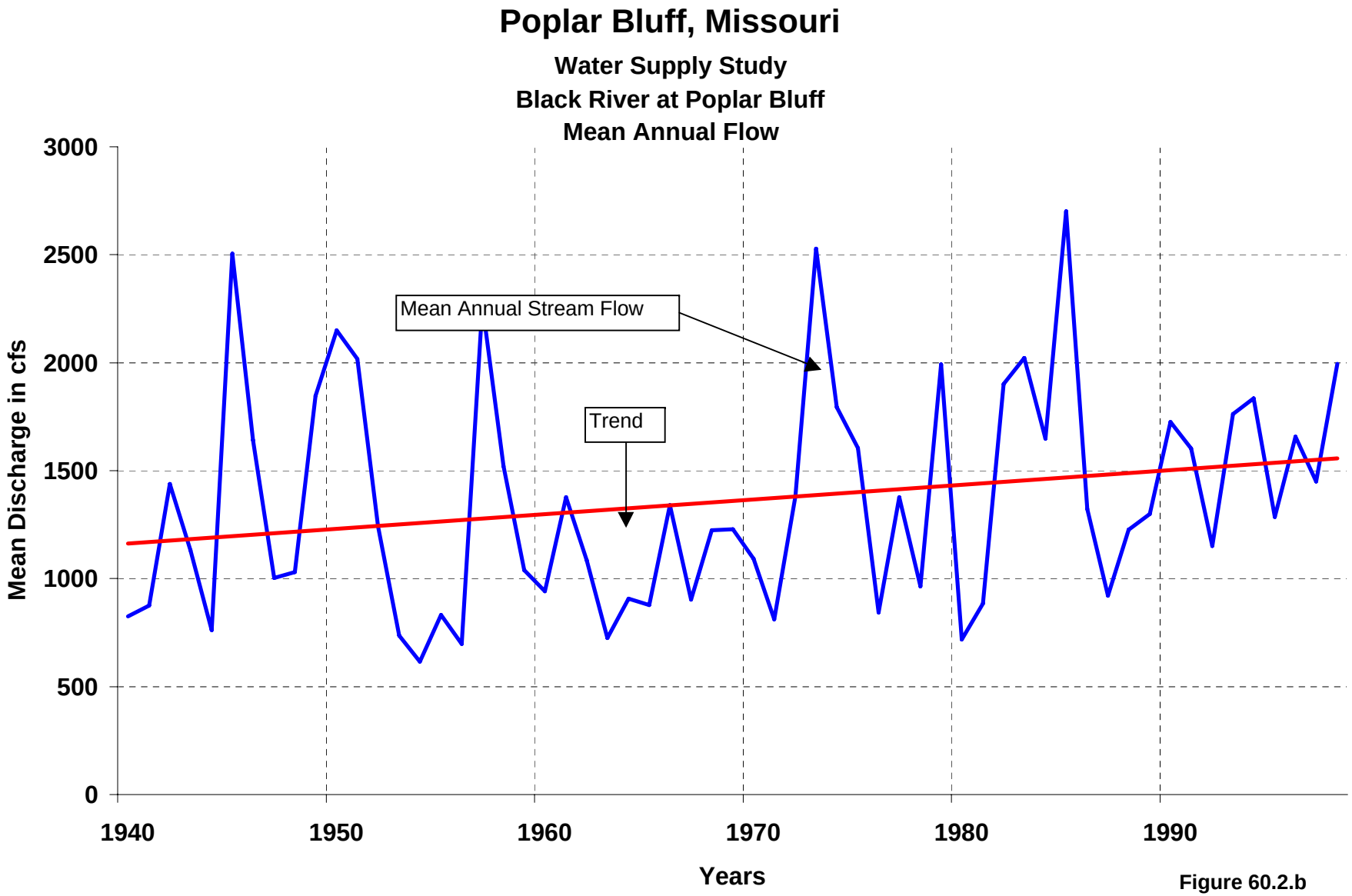
Poplar Bluff, Missouri
Water Supply Study
Black River at Poplar Bluff
Mean Annual Flow
Mean Annual Stream Flow
Trend
Mean Discharge in cfs
3000
2500
2000
1500
1000
500
0
1940
1950
1960
1970
1980
1990
Years

Figure 60.2.b

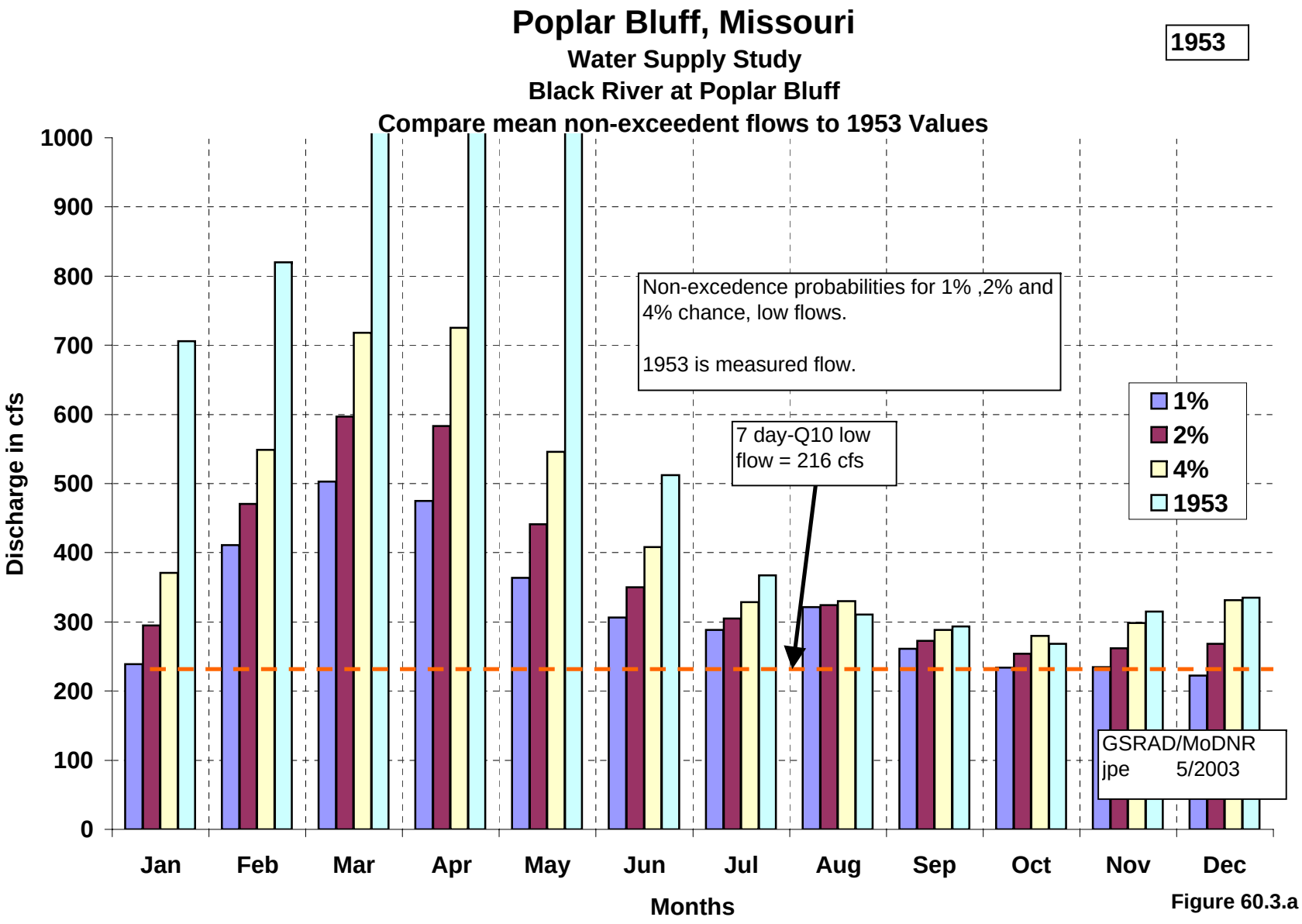
Poplar Bluff, Missouri
Water Supply Study
Black River at Poplar Bluff
Compare mean non-exceedent flows to 1953 Values
1953
Non-excedence probabilities for 1% ,2% and 4% chance, low flows.
1953 is measured flow.
7 day-Q10 low flow = 216 cfs
1%
2%
4%
1953
GSRAD/MoDNR
jpe 5/2003
Discharge in cfs
0
100
200
300
400
500
600
700
800
900
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 60.3.a

Poplar Bluff, Missouri

Water Supply Study

Black River at Poplar Bluff, Missouri

Compare mean non-exceedent flows to 1954 Values

1954

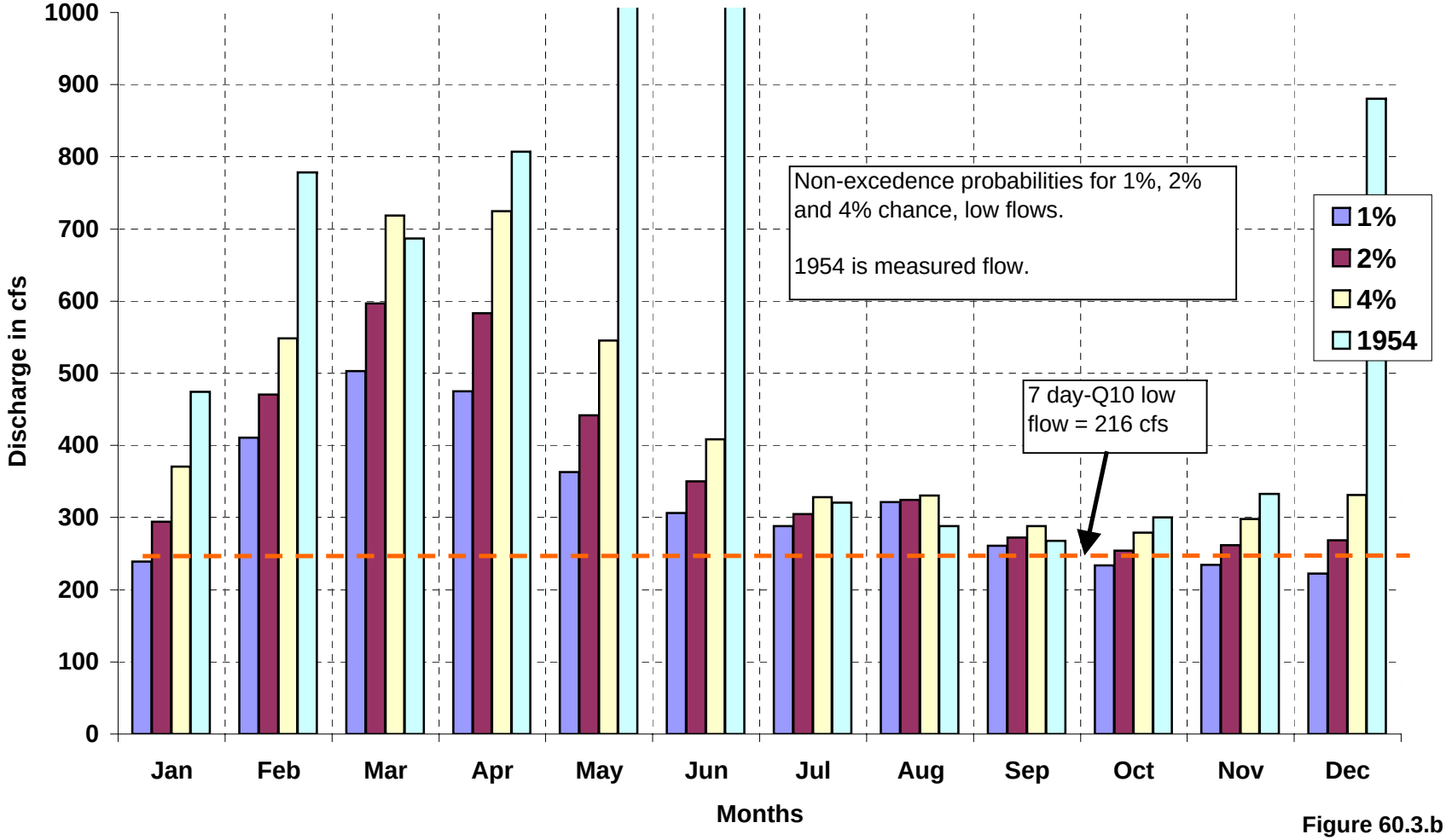

Figure 60.3.b

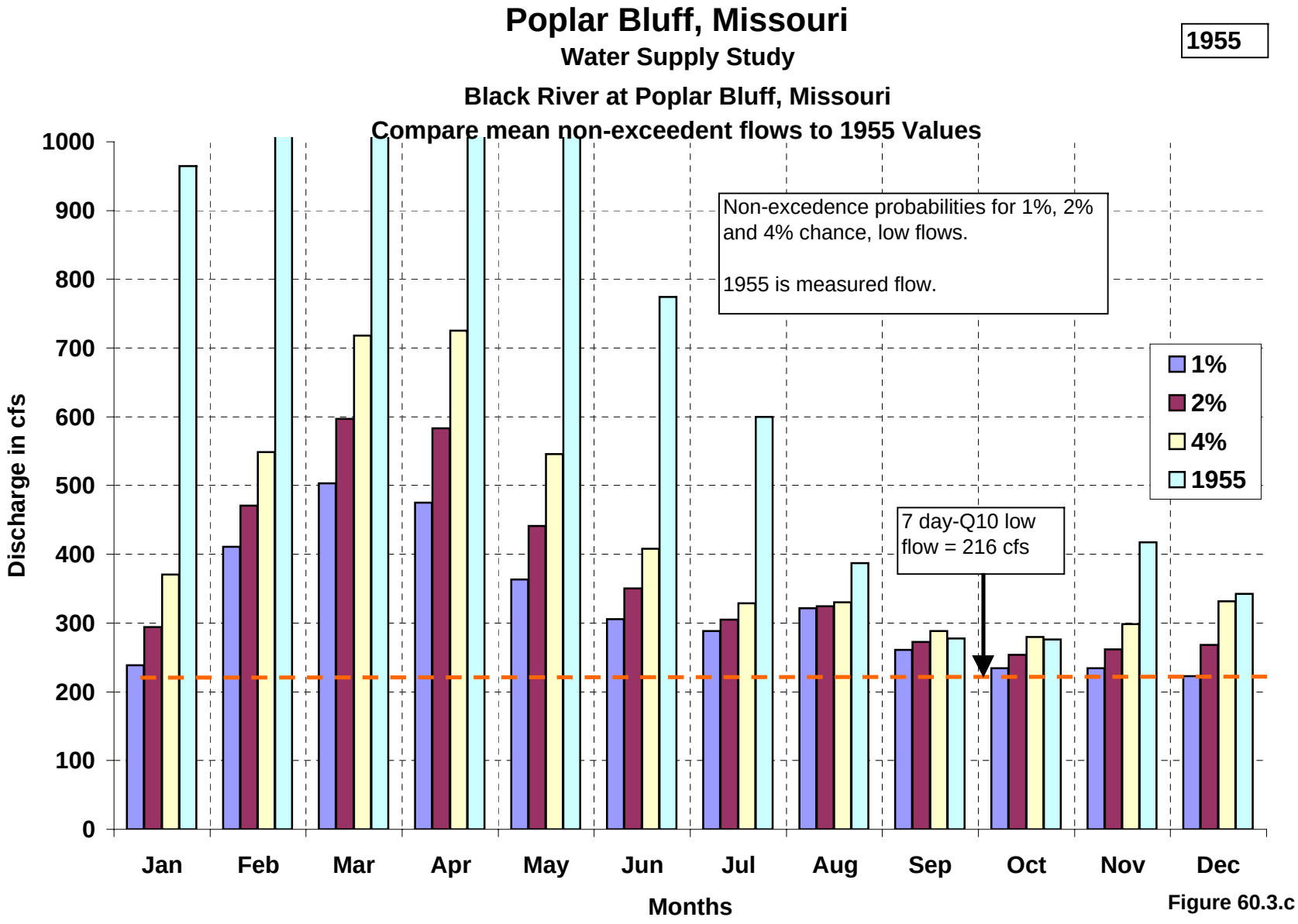
Poplar Bluff, Missouri
Water Supply Study
Black River at Poplar Bluff, Missouri
Compare mean non-exceedent flows to 1955 Values
1955
Non-excedence probabilities for 1%, 2% and 4% chance, low flows.
1955 is measured flow.
7 day-Q10 low flow = 216 cfs
1%
2%
4%
1955
Discharge in cfs
0
100
200
300
400
500
600
700
800
900
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 60.3.c

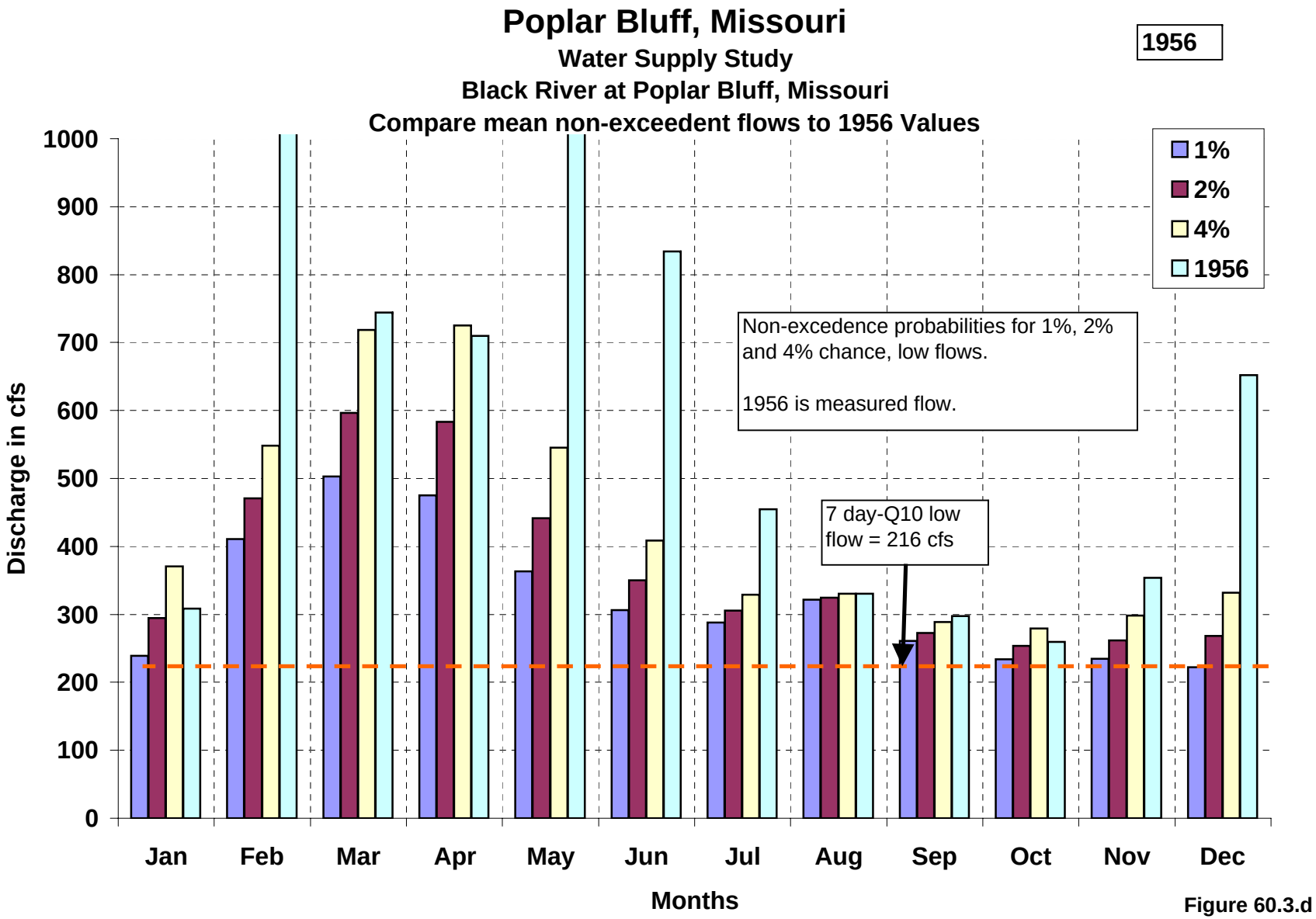
Poplar Bluff, Missouri
Water Supply Study
Black River at Poplar Bluff, Missouri
Compare mean non-exceedent flows to 1956 Values
1956
1%
2%
4%
1956
Non-excedence probabilities for 1%, 2% and 4% chance, low flows.
1956 is measured flow.
7 day-Q10 low flow = 216 cfs
Discharge in cfs
0
100
200
300
400
500
600
700
800
900
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 60.3.d

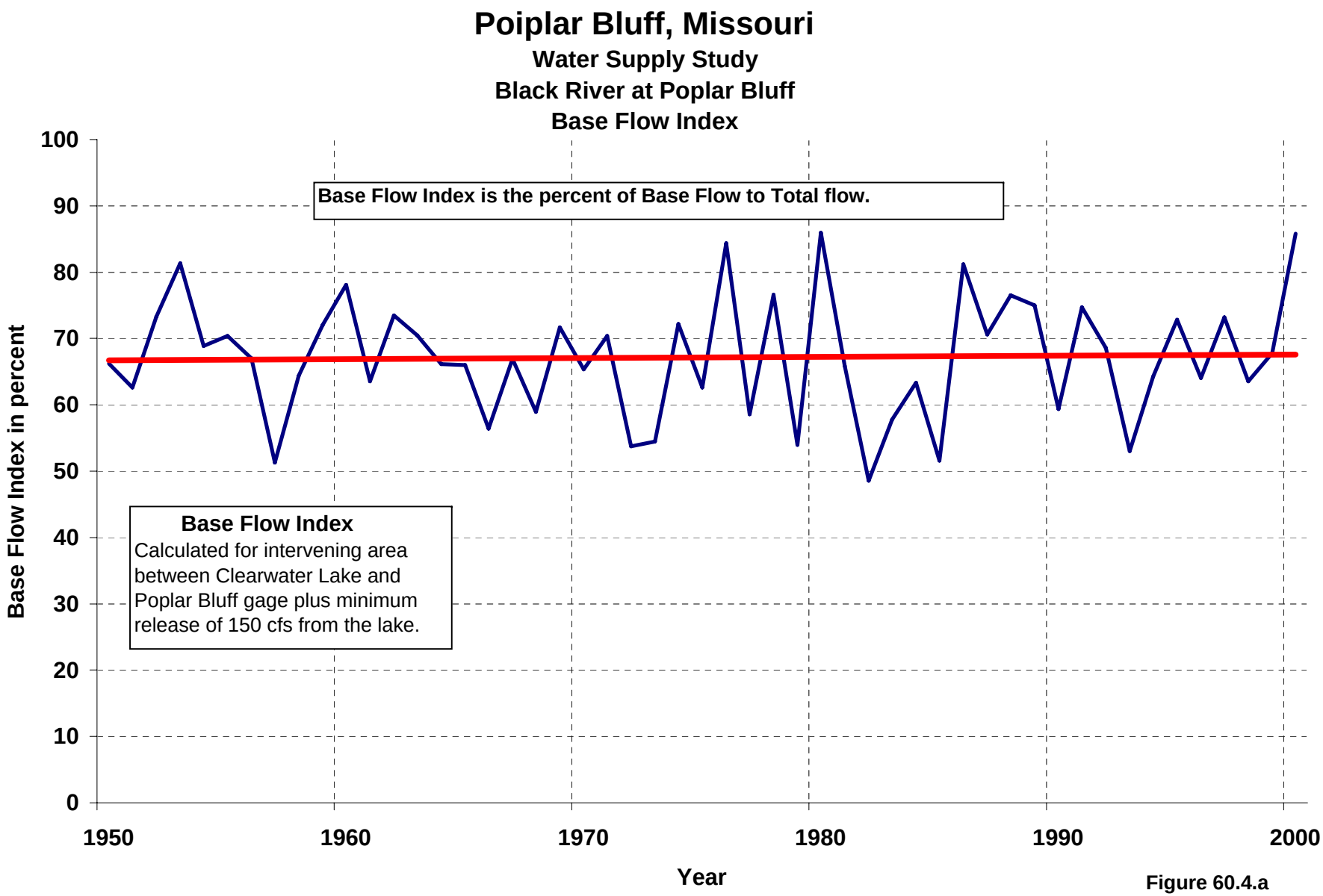
Poiplar Bluff, Missouri
Water Supply Study
Black River at Poplar Bluff
Base Flow Index
Base Flow Index is the percent of Base Flow to Total flow.
Base Flow Index
Calculated for intervening area between Clearwater Lake and Poplar Bluff gage plus minimum release of 150 cfs from the lake.
Base Flow Index in percent
100
90
80
70
60
50
40
30
20
10
0
1950
1960
1970
1980
1990
2000
Year

Figure 60.4.a

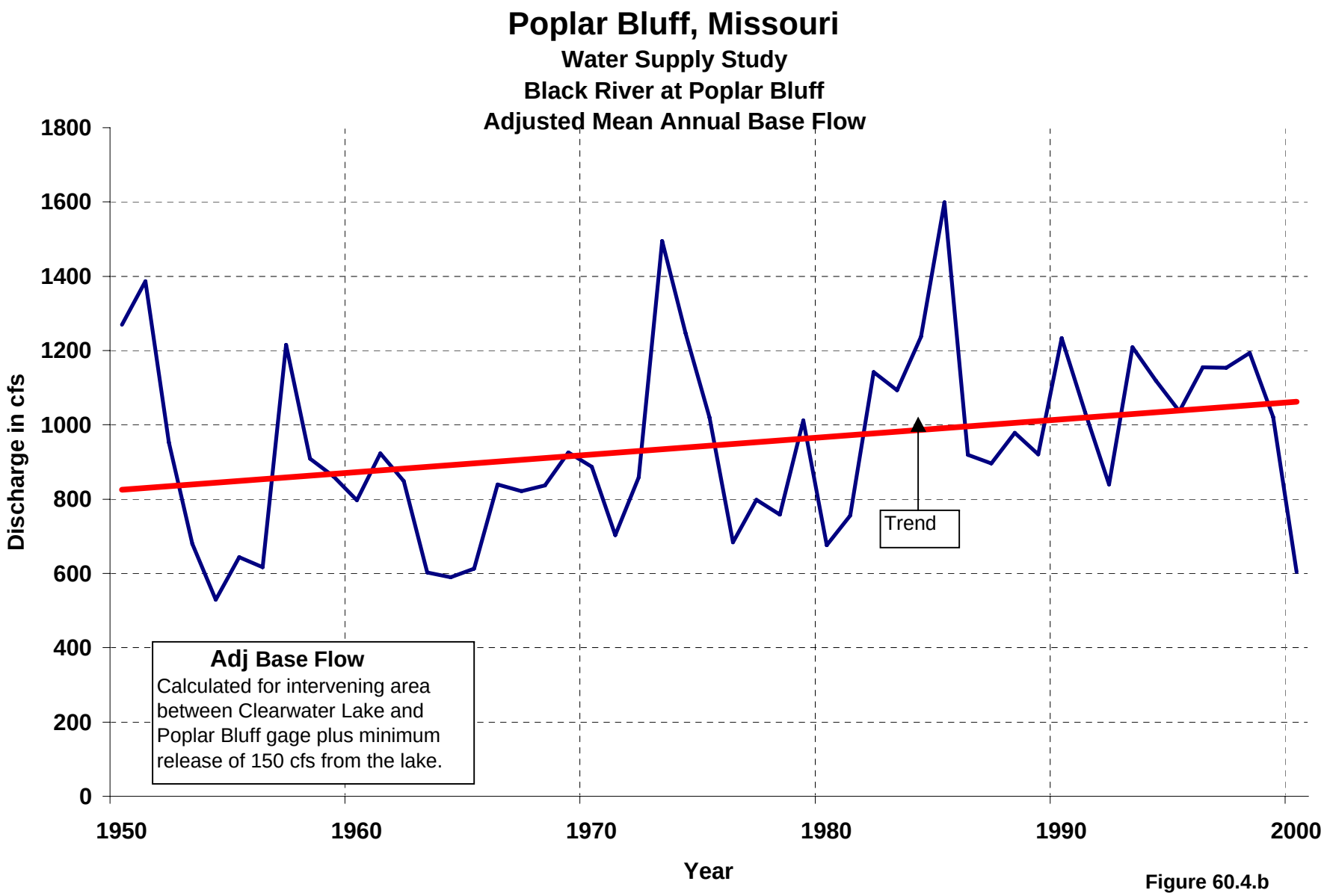
Poplar Bluff, Missouri
Water Supply Study
Black River at Poplar Bluff
Adjusted Mean Annual Base Flow
Discharge in cfs
1800
1600
1400
1200
1000
800
600
400
200
0
1950
1960
1970
1980
1990
2000
Year
Trend
Adj Base Flow
Calculated for intervening area between Clearwater Lake and Poplar Bluff gage plus minimum release of 150 cfs from the lake.

Figure 60.4.b

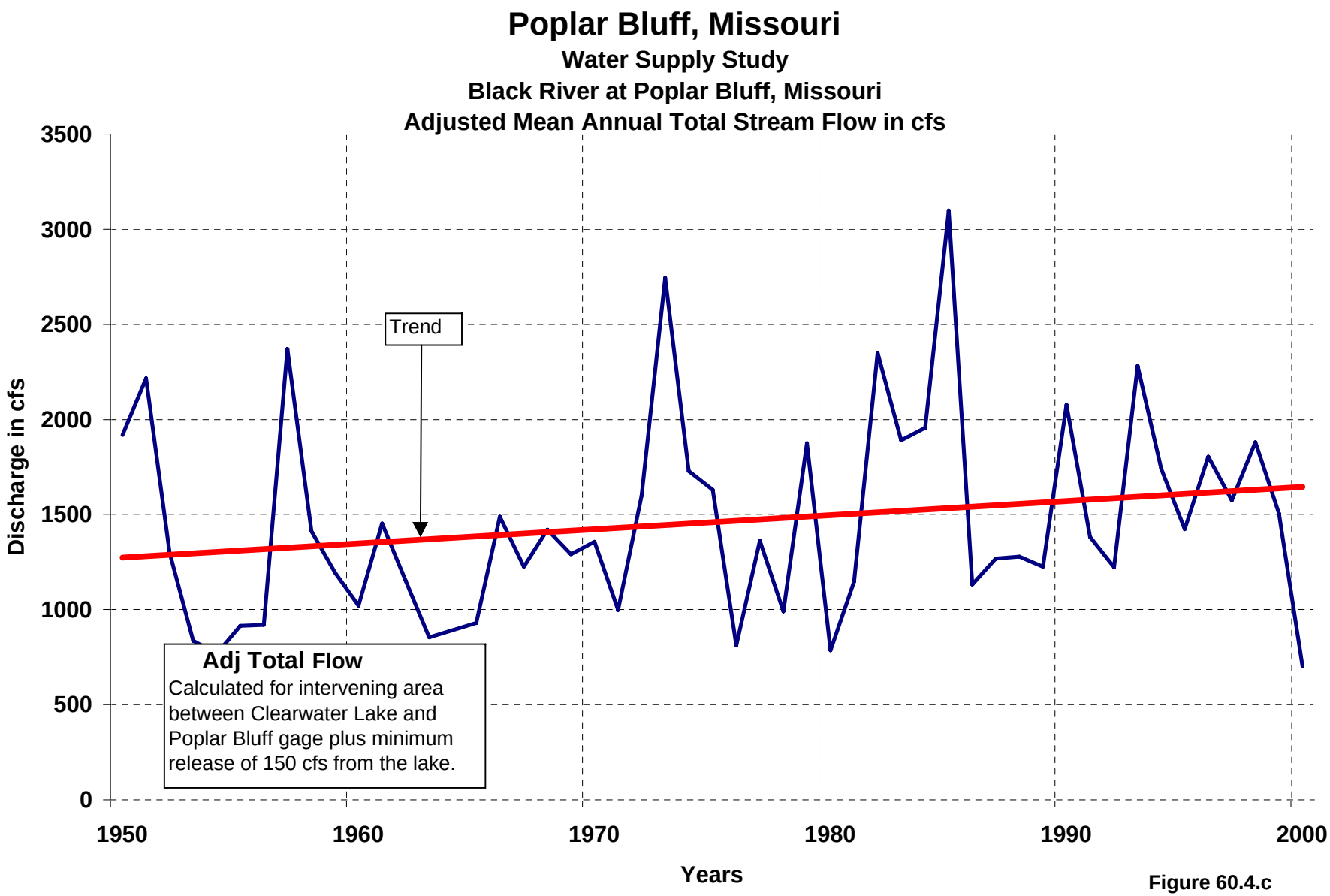
Poplar Bluff, Missouri
Water Supply Study
Black River at Poplar Bluff, Missouri
Adjusted Mean Annual Total Stream Flow in cfs
Discharge in cfs
3500
3000
2500
2000
1500
1000
500
0
1950
1960
1970
1980
1990
2000
Years
Trend
Adj Total Flow
Calculated for intervening area between Clearwater Lake and Poplar Bluff gage plus minimum release of 150 cfs from the lake.

Figure 60.4.c

Poplar Bluff, Missouri

Water Supply Study

Black River

Comparison of Gages on Black River

Total Mean Base Flow

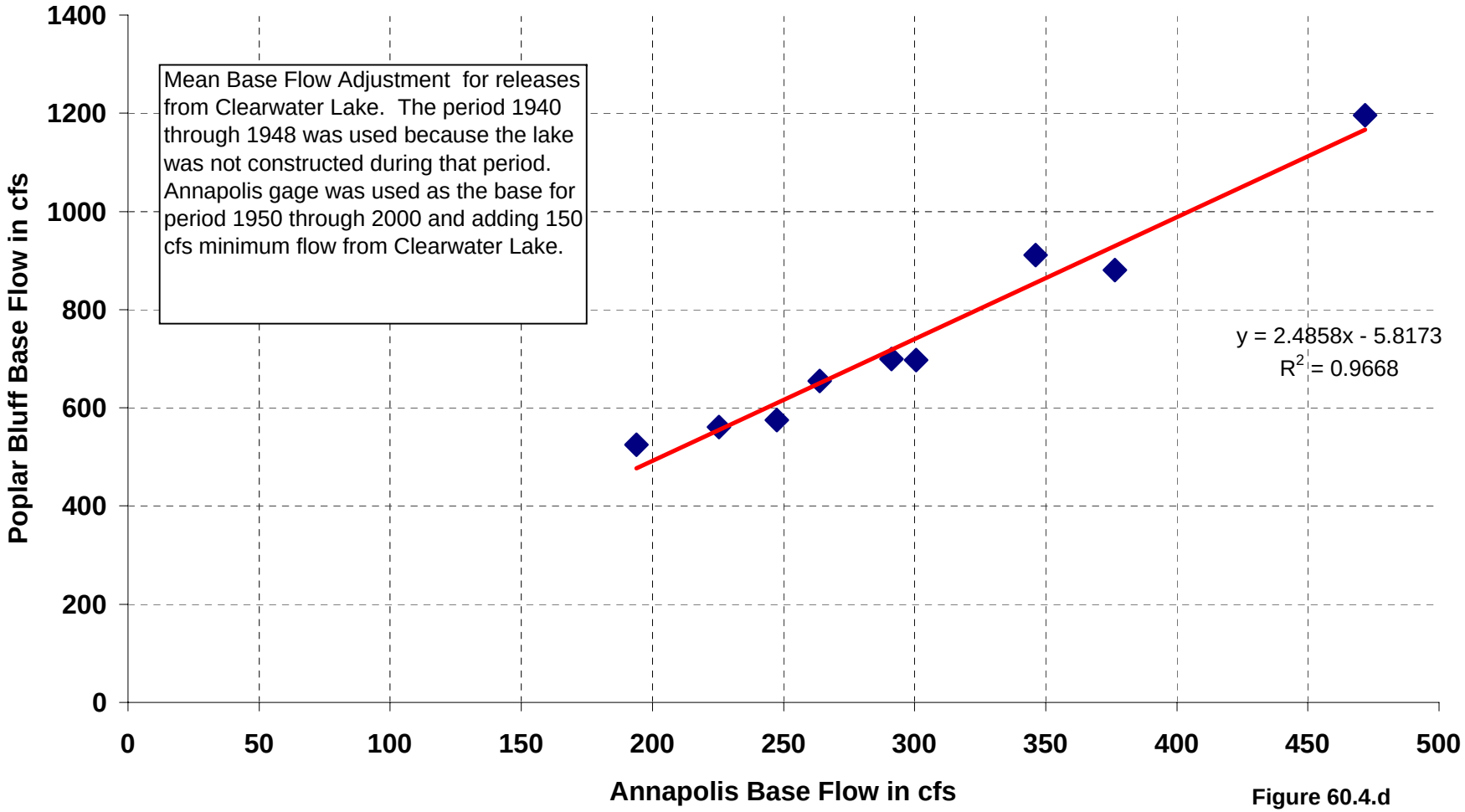

Figure 60.4.d

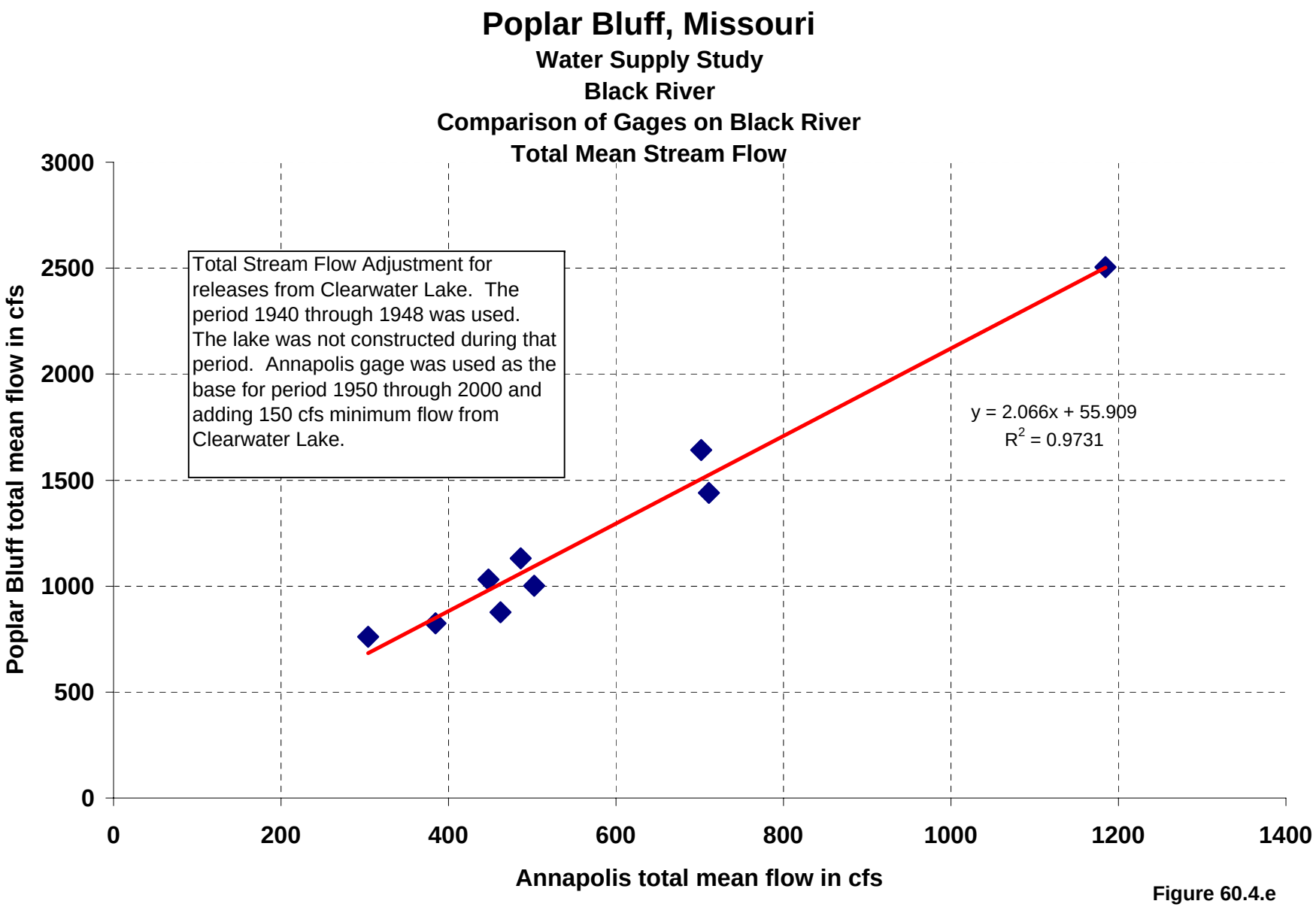
Poplar Bluff, Missouri
Water Supply Study
Black River
Comparison of Gages on Black River
Total Mean Stream Flow
Total Stream Flow Adjustment for releases from Clearwater Lake. The period 1940 through 1948 was used. The lake was not constructed during that period. Annapolis gage was used as the base for period 1950 through 2000 and adding 150 cfs minimum flow from Clearwater Lake.
y = 2.066x + 55.909
R2 = 0.9731
Poplar Bluff total mean flow in cfs
Annapolis total mean flow in cfs
0
500
1000
1500
2000
2500
3000
0
200
400
600
800
1000
1200
1400

Figure 60.4.e

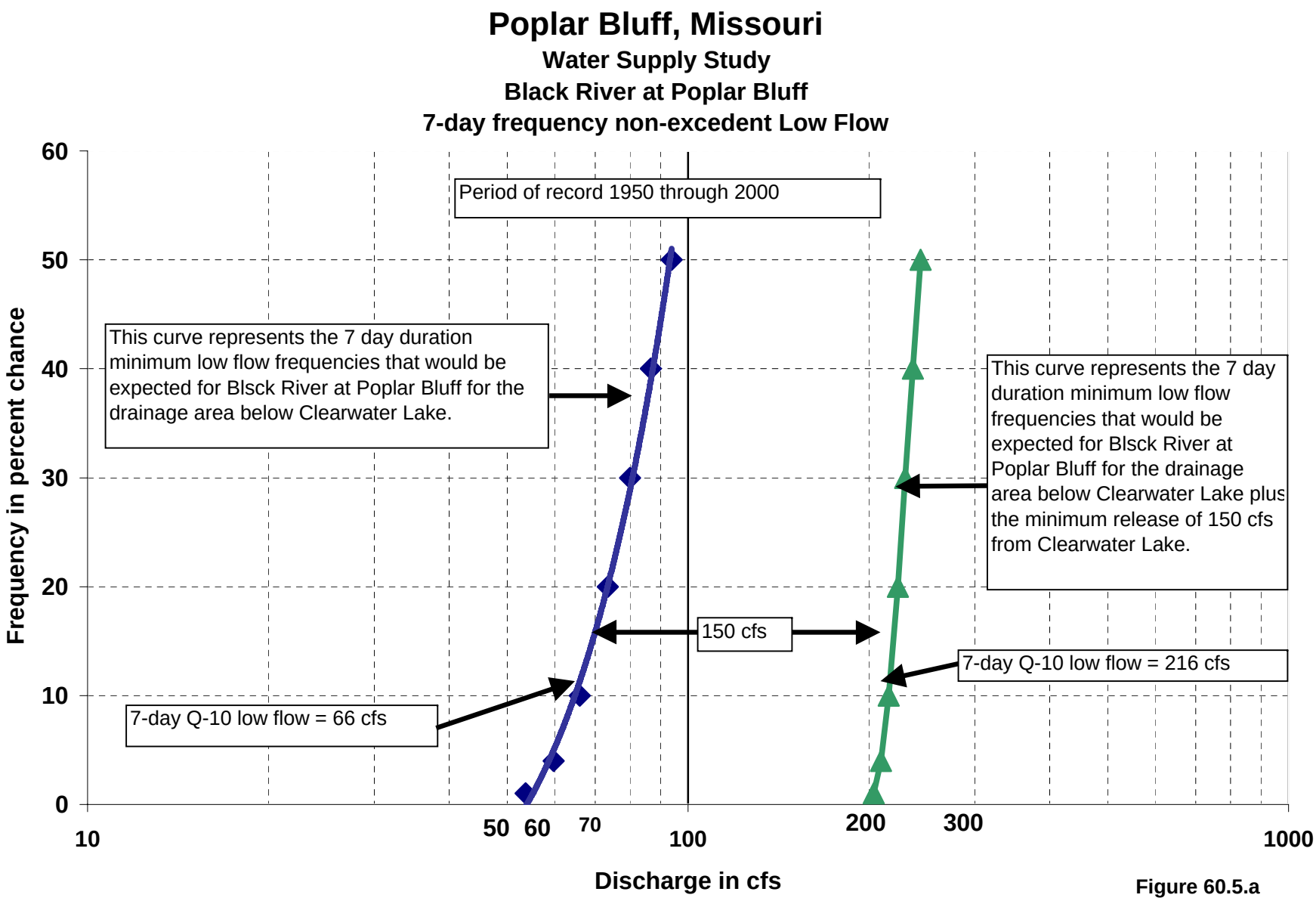
Poplar Bluff, Missouri
Water Supply Study
Black River at Poplar Bluff
7-day frequency non-excedent Low Flow
Frequency in percent chance
60
50
40
30
20
10
0
Period of record 1950 through 2000
This curve represents the 7 day duration minimum low flow frequencies that would be expected for Blsck River at Poplar Bluff for the drainage area below Clearwater Lake.
This curve represents the 7 day duration minimum low flow frequencies that would be expected for Blsck River at Poplar Bluff for the drainage area below Clearwater Lake plus the minimum release of 150 cfs from Clearwater Lake.
150 cfs
7-day Q-10 low flow = 216 cfs
7-day Q-10 low flow = 66 cfs
10
50
60
70
100
200
300
1000
Discharge in cfs

Figure 60.5.a

Poplar Bluff, Missouri

Water Supply Study

Black River

Compare 7-day frequency discharges
Annapolsis and Poplar Bluff before Clearwater Dam

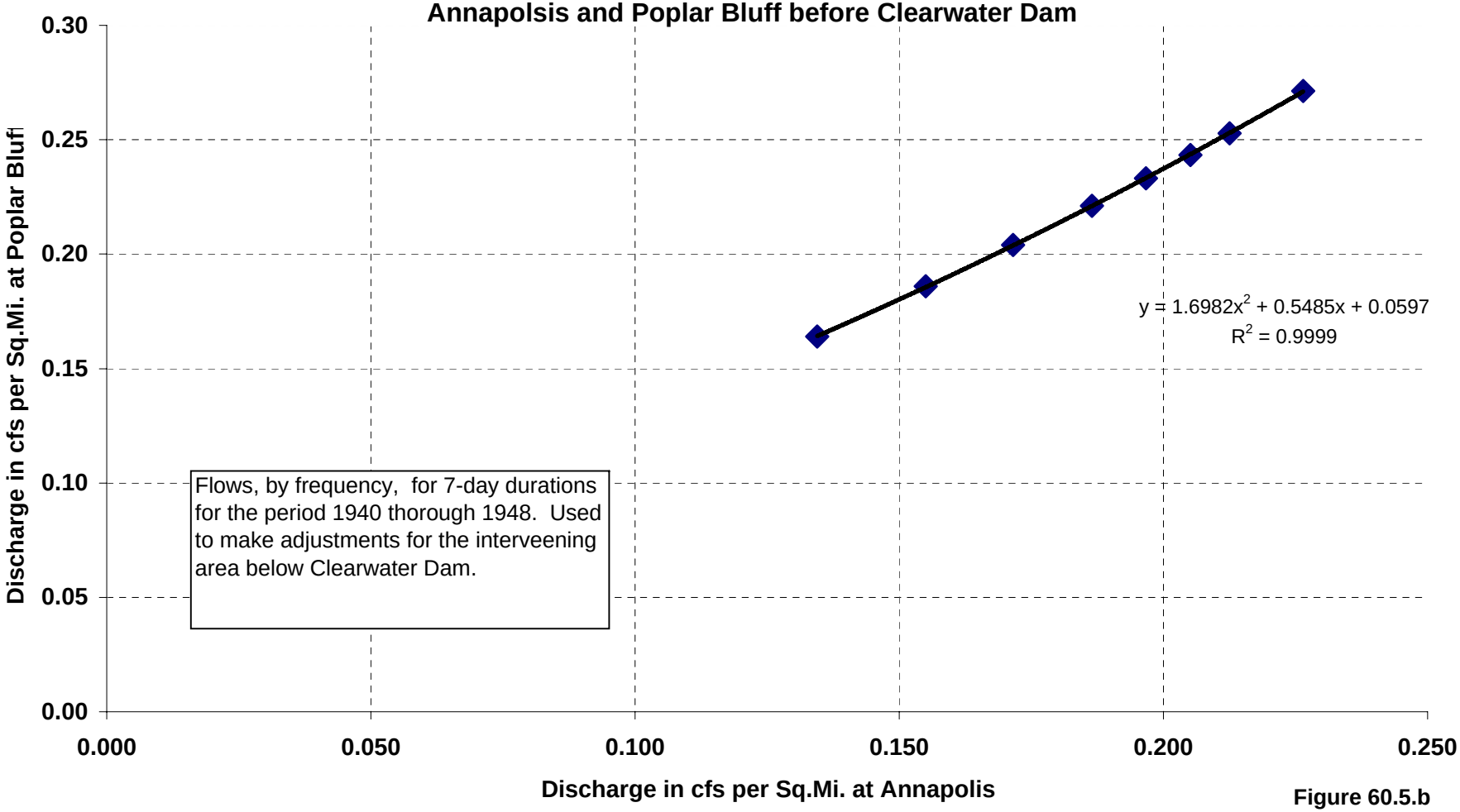

Figure 60.5.b

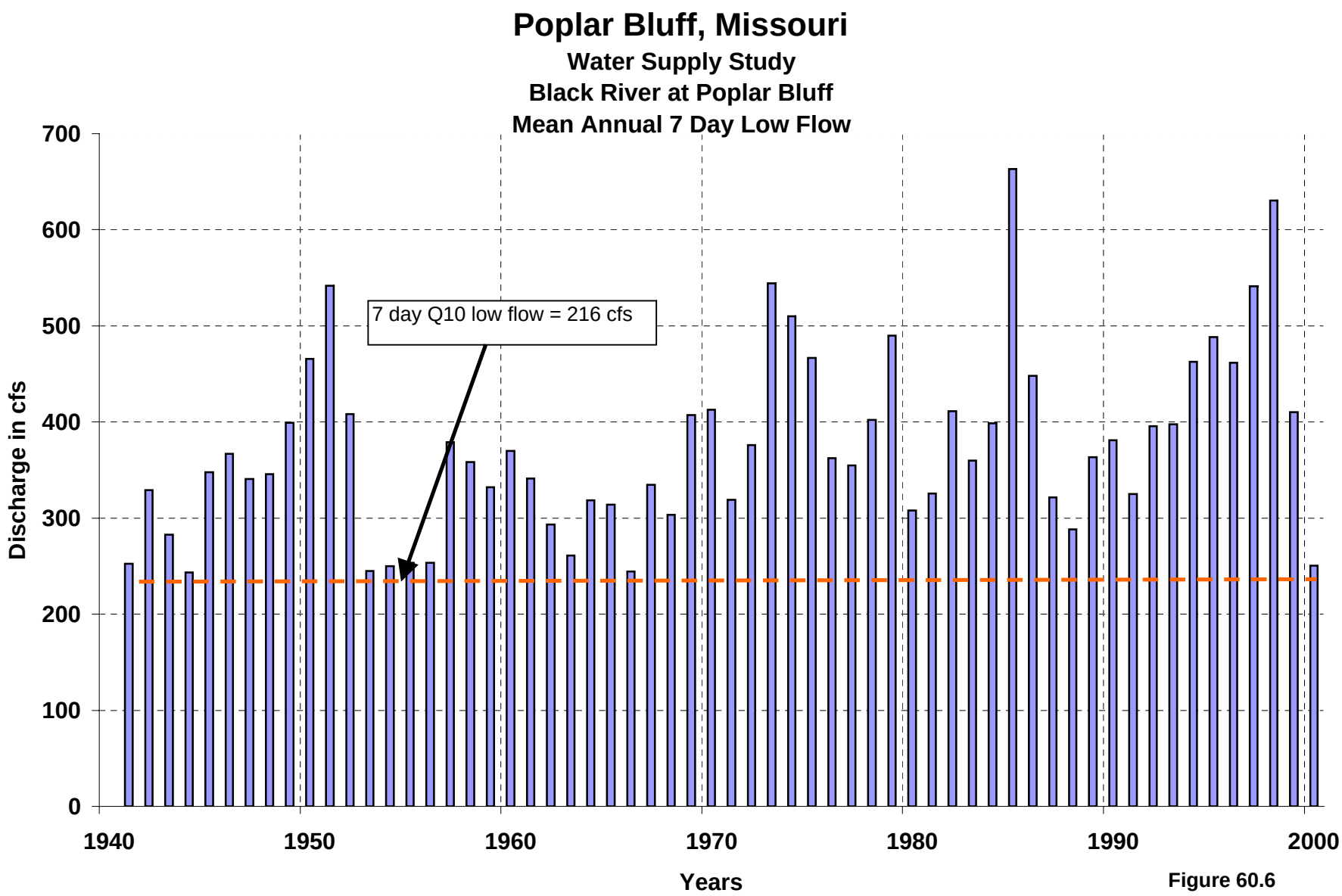
Poplar Bluff, Missouri
Water Supply Study
Black River at Poplar Bluff
Mean Annual 7 Day Low Flow
7 day Q10 low flow = 216 cfs
Discharge in cfs
0
100
200
300
400
500
600
700
1940
1950
1960
1970
1980
1990
2000
Years

Figure 60.6

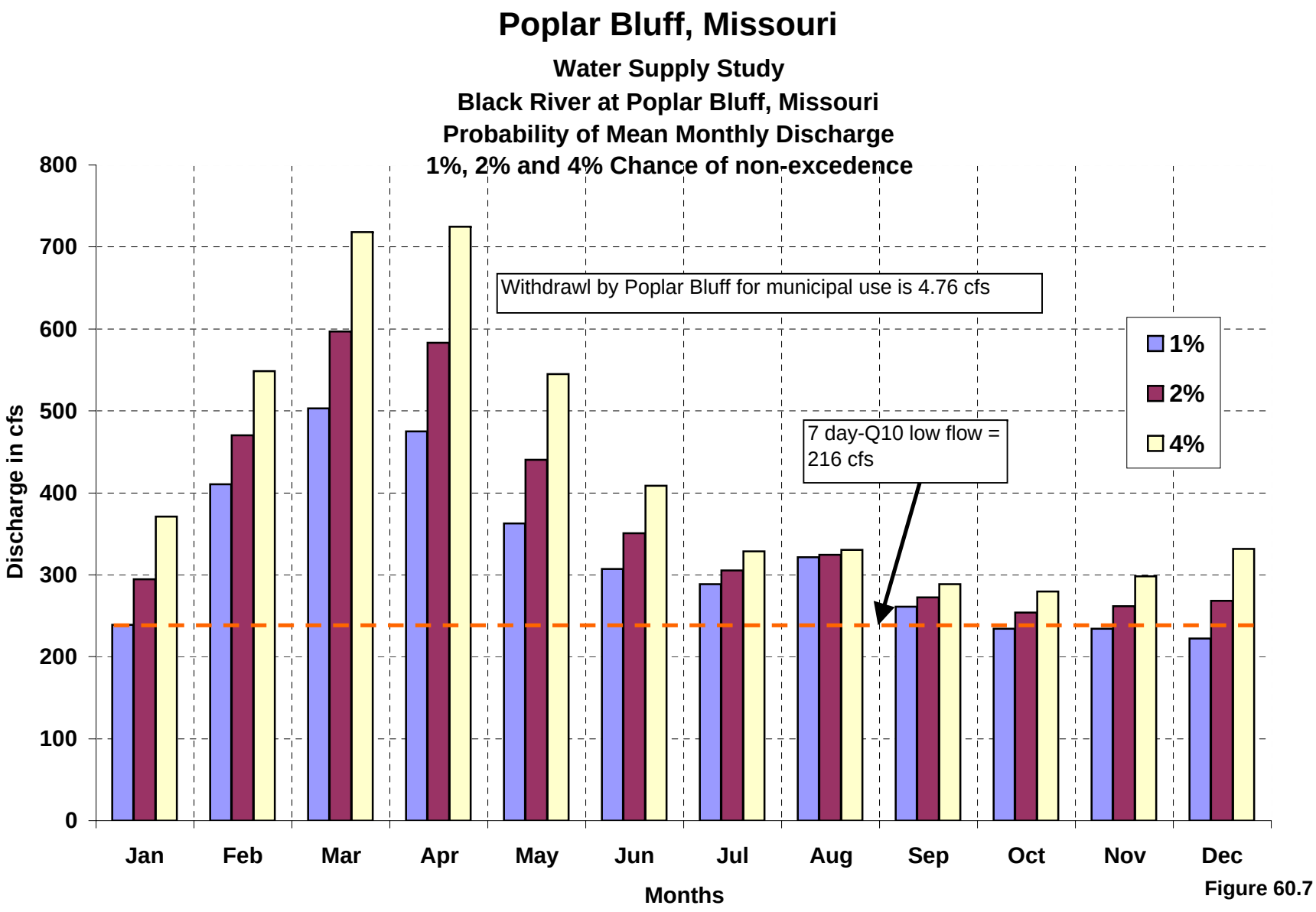
Poplar Bluff, Missouri
Water Supply Study
Black River at Poplar Bluff, Missouri
Probability of Mean Monthly Discharge
1%, 2% and 4% Chance of non-excedence
Withdrawl by Poplar Bluff for municipal use is 4.76 cfs
7 day-Q10 low flow = 216 cfs
1%
2%
4%
Discharge in cfs
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 60.7

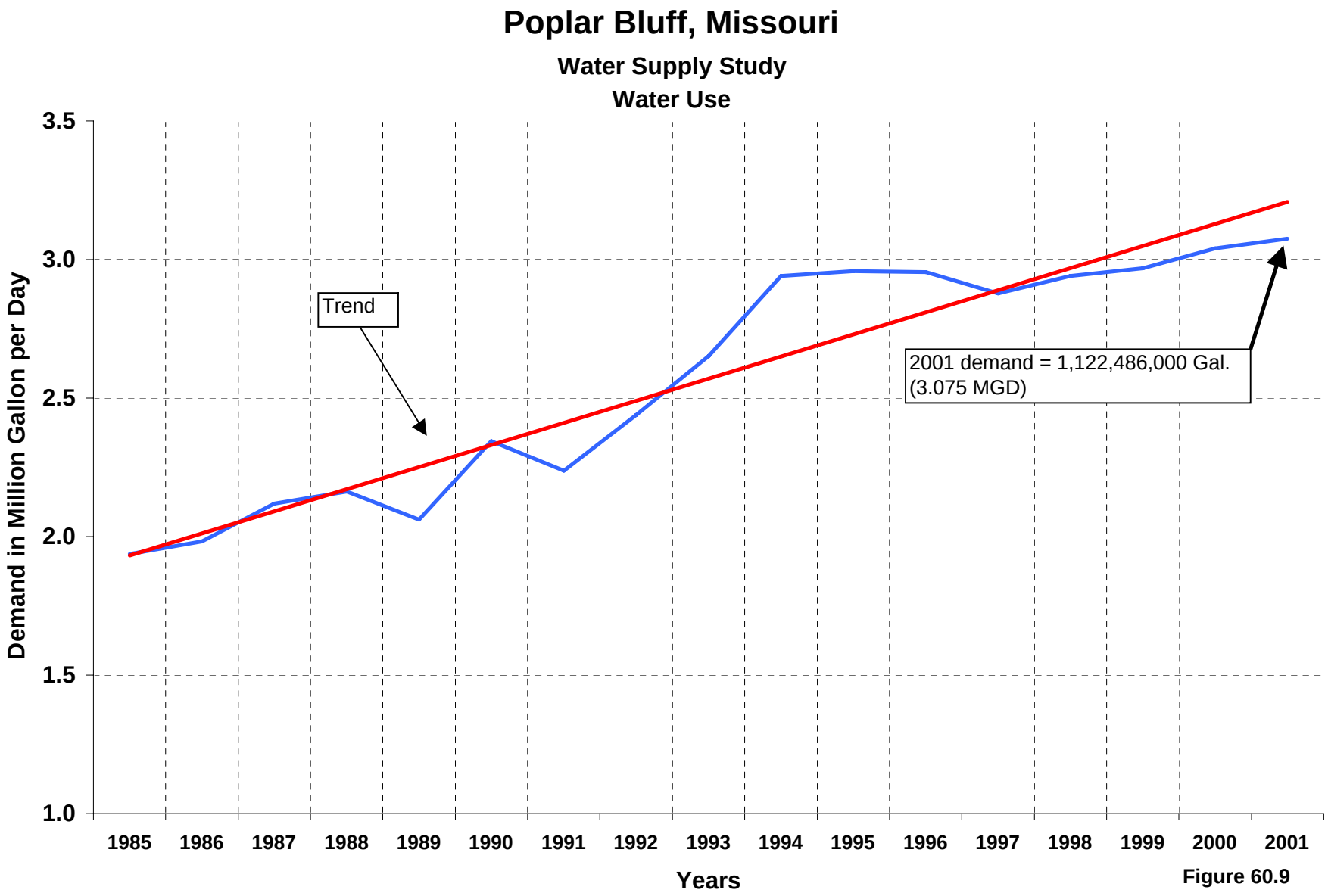
Poplar Bluff, Missouri
Water Supply Study
Water Use
Demand in Million Gallon per Day
3.5
3.0
2.5
2.0
1.5
1.0
Trend
2001 demand = 1,122,486,000 Gal.
(3.075 MGD)
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Years

Figure 60.9

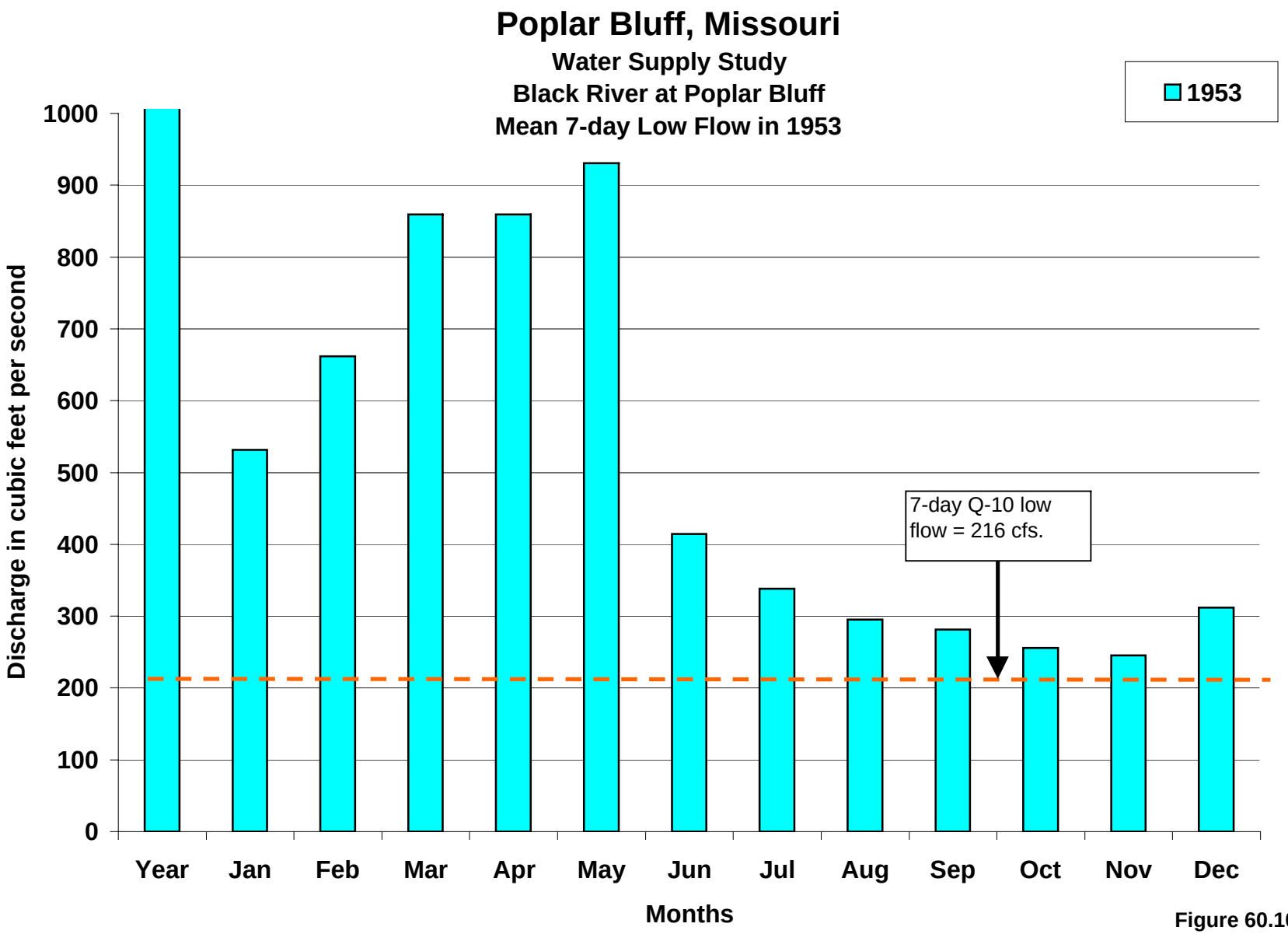

Figure 60.10.a

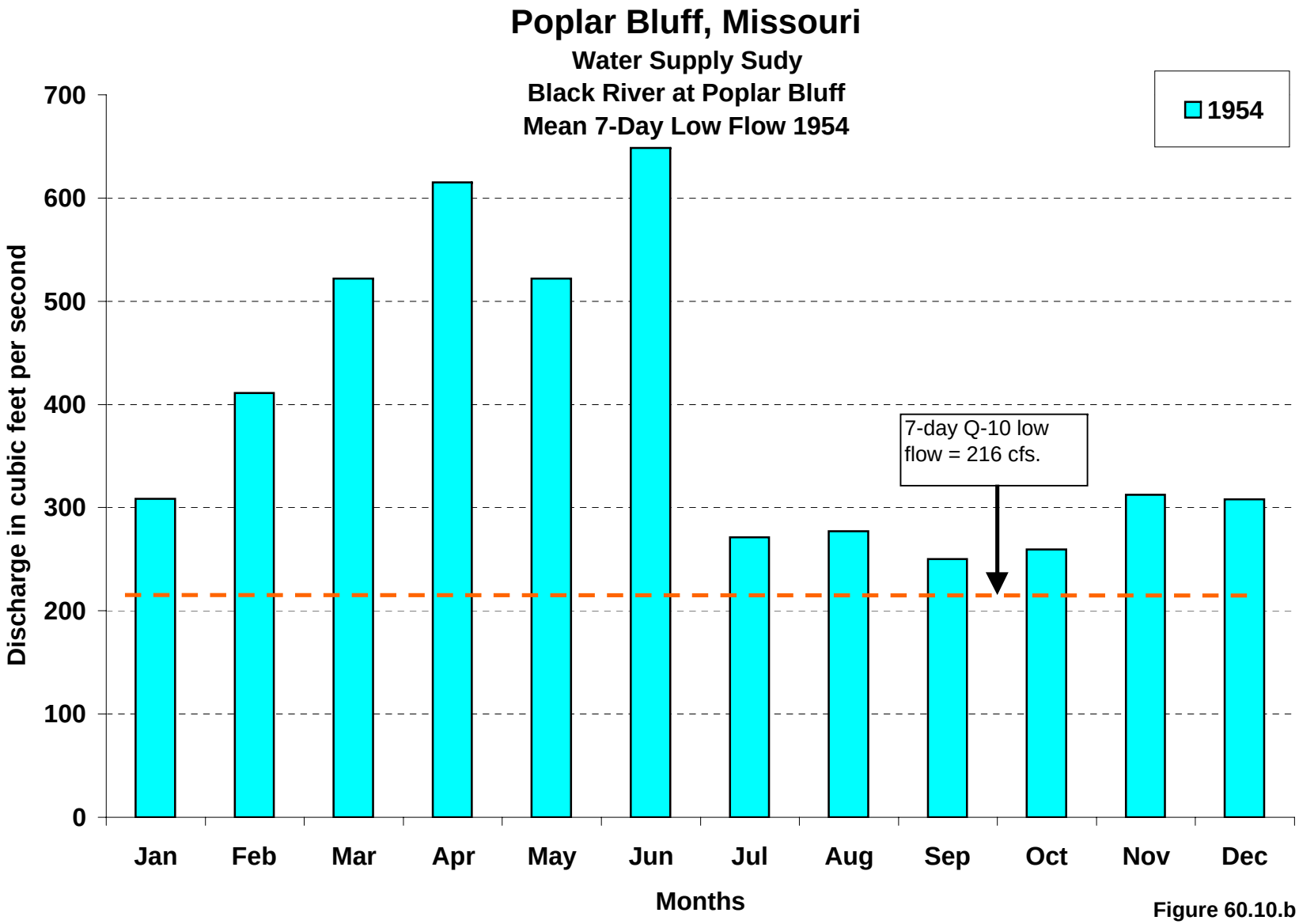

Figure 60.10.b

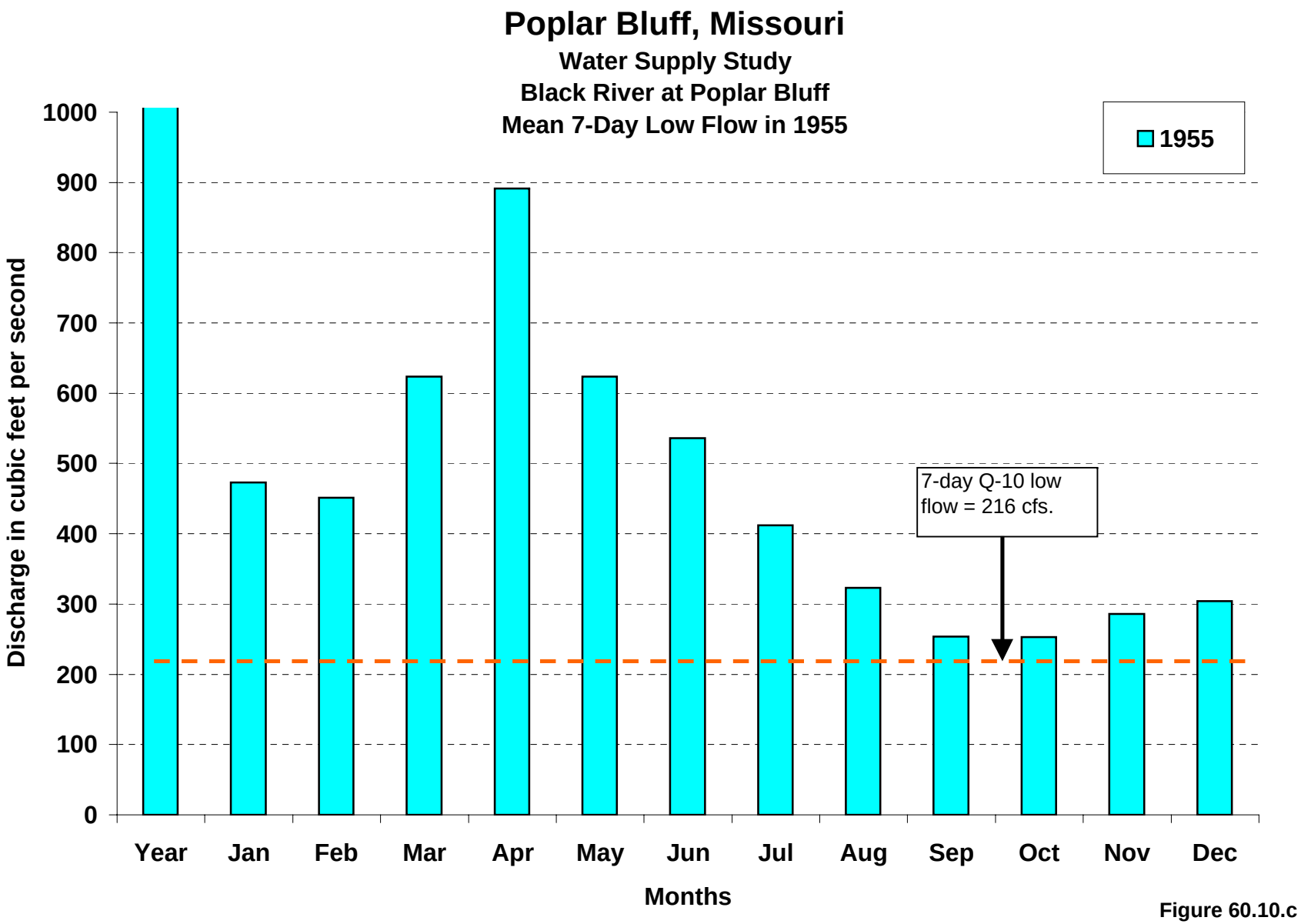

Figure 60.10.c

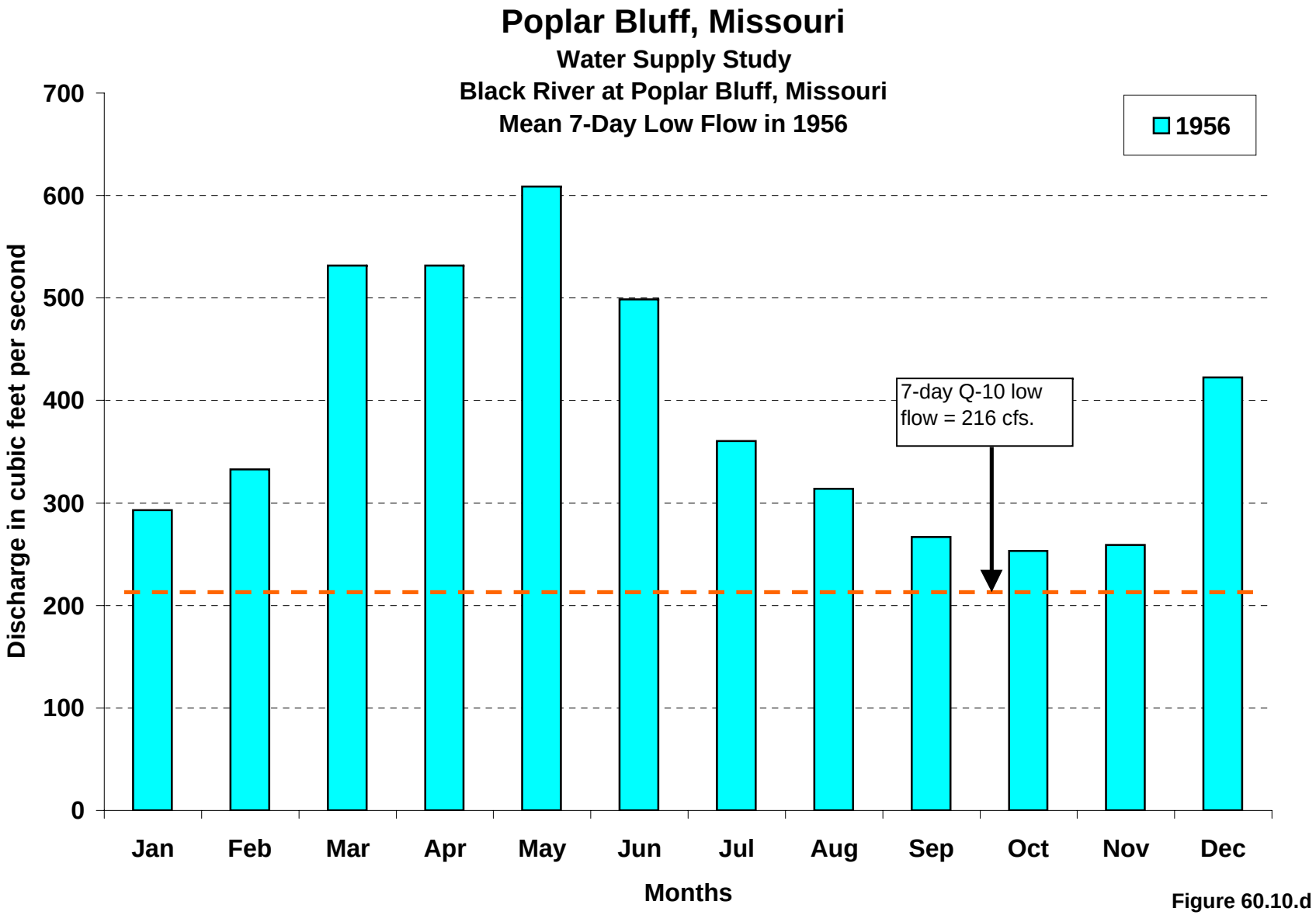

Figure 60.10.d

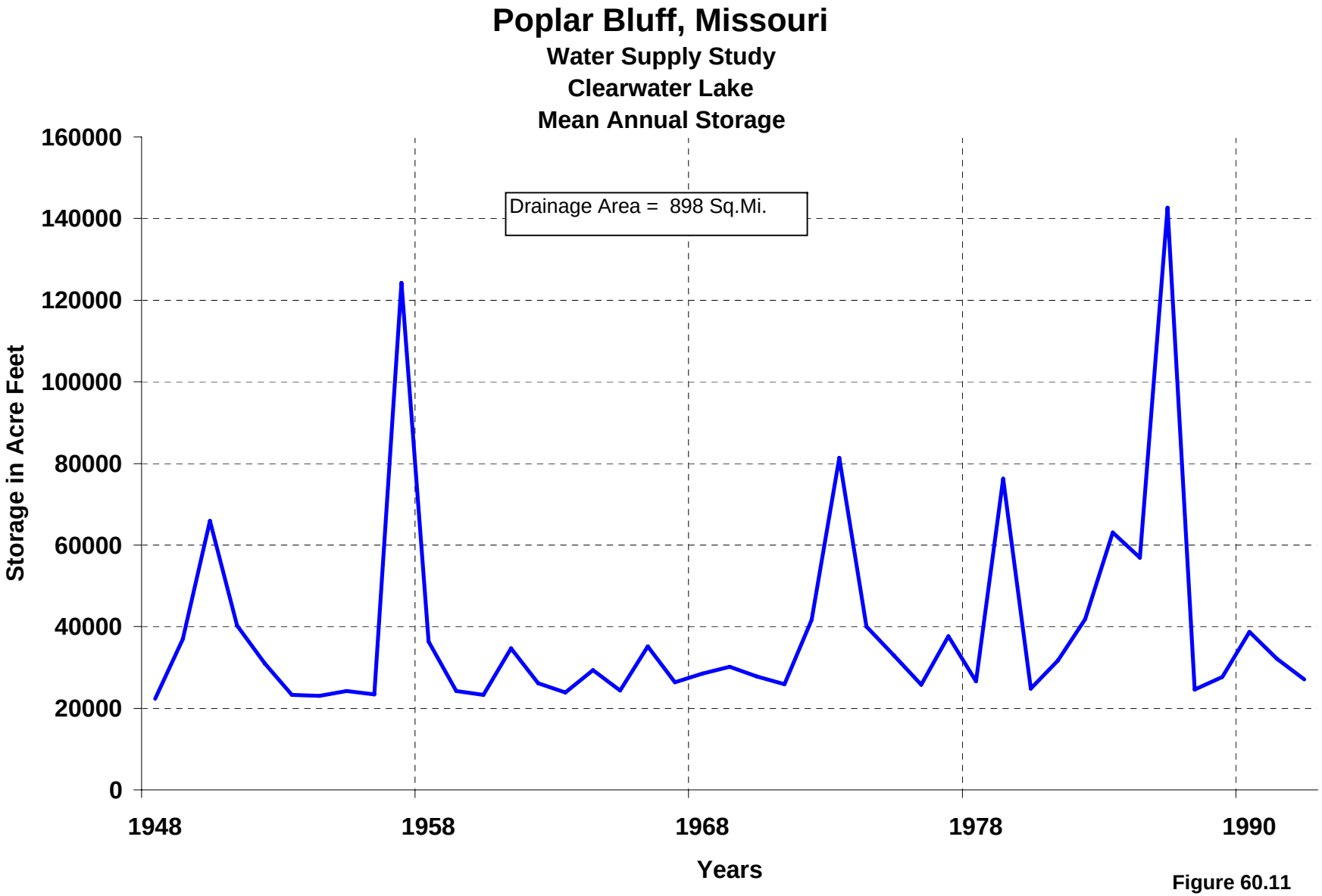
Poplar Bluff, Missouri
Water Supply Study
Clearwater Lake
Mean Annual Storage
Drainage Area = 898 Sq.Mi.
Storage in Acre Feet
160000
140000
120000
100000
80000
60000
40000
20000
0
1948
1958
1968
1978
1990
Years

Figure 60.11