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I 76-1(35) PE

# HYDROLOGY STUDY

OF
CLEAR CREEK

Between Wadsworth Boulevard

and Federal Boulevard

Colorado Division of Highways
By D. ROUPP
Hydraulic Engineer
April, 1977

CONTENTS

# LIST OF FIGURES

# HYDROLOGY

## Introduction

The peak flow prediction of Clear Creek is most critical! The vast amount of development within the natural flood plain must not be endangered by under design. However, the space limitations for interlacing the proposed highway through the established corridor and the high construction costs dictate that the luxury of overdesign cannot be tolerated.

This report considers applicable stream flow history and previous hydrologic studies to obtain the peak design flow along Clear Creek in the reach of the proposed I 76 highway encroachments.

The Clear Creek study is divided into two reaches as Ralston Creek is the only major tributary between the project limits. See Figure No. 1. The upper reach is above the Ralston Creek confluence and the lower reach is below the confluence.

## Design Frequency

Federal Administration Federal-Aid Program Manual[1] directs the following:

a. Where encroachment on a flood plain is necessary, an evaluation, using the basic (100 year) flood, shall be made of the flood hazard to the highway, and the effect of the proposed highway on the flood hazard to other property, stream stability, and the stream and flood plain environment.

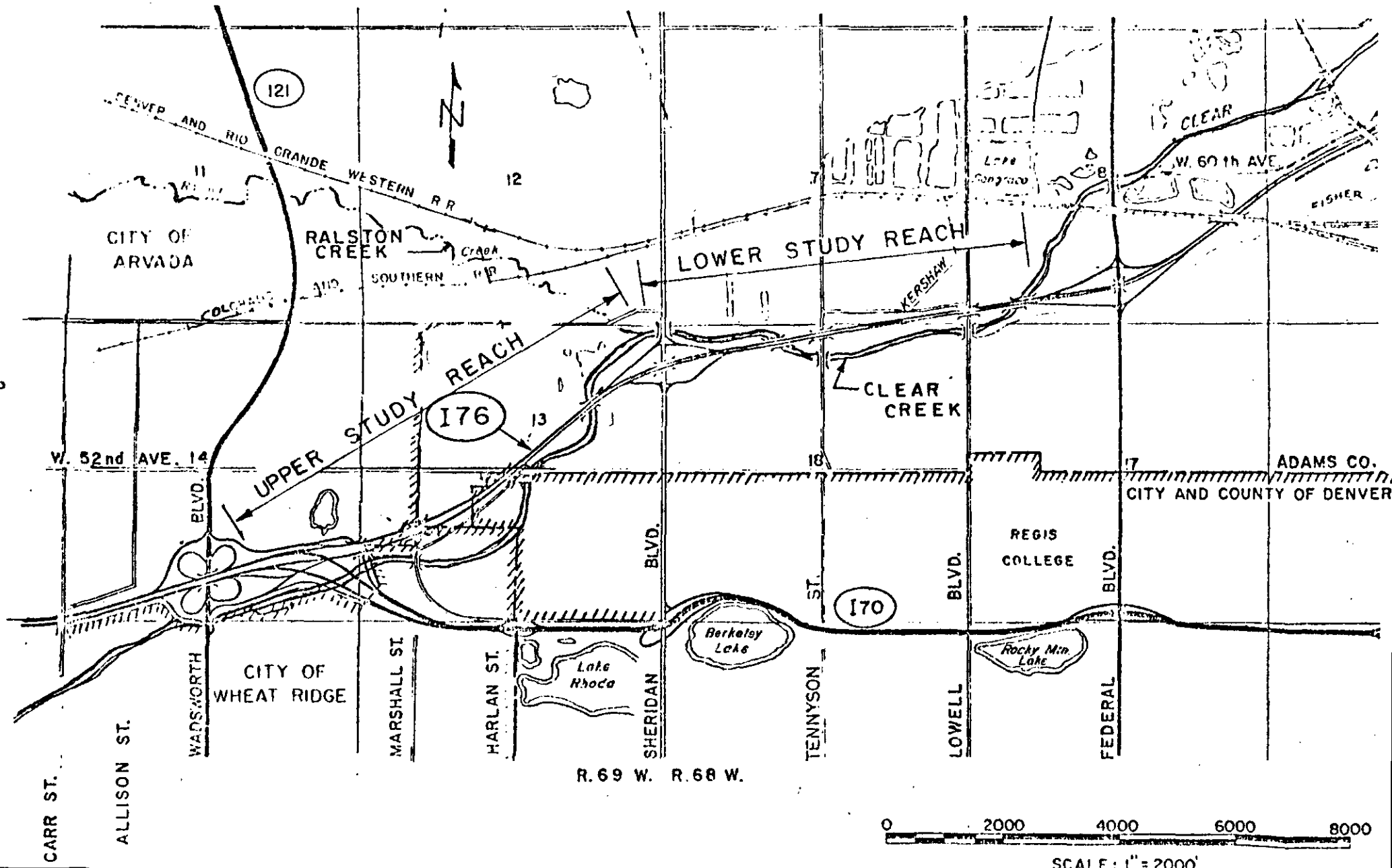
b. The design flood selected for each encroachment and the design for conveyance of the basic (100 year) flood should be supported by the following, where applicable: an incremental analysis of estimated construction costs; probable property damage including damage to the highway; the cost of traffic delays; the availability of alternate routes, emergency supply and evacuation routes; and with consideration of the potential for loss of life and of budgetary constraints.

f. All highways on the Interstate System that encroach on flood plains shall be designed to avoid inundation of the highway from floods at least as great at the 50-year flood.

1. Federal Highway Administration, Federal-Aid Highway Program Manual, Vol. 6, Chapter 7, Section 3, Subsection 2, May 29, 1974.

FIGURE NO. 1

# STUDY REACH OF CLEAR CREEK



This Manual directs that a 50-year to 100-year frequency flood will be the basis for design. Realizing the immense amount of property which is subject to flood damage, potential loss of life, cost of traffic delays and the established flood plain ordinances by the contiguous municipalities, the 100-year flood will be the basis for hydraulic design.

Method of Analysis

Stream Gages - Stream gages are basic in estimating peak stream flow. Preferably several of the gages are located on the stream to be studied. Fortunately two such gages exist on Clear Creek: gage 6-7195 near Golden, Colorado with 77 years of record, and gage 6-7200 near the mouth with 48 years of record. Two other gages 6-7165 and 7170 also on Clear Creek are too far upstream to be included in this study. See Figure No. 2.

While these gages have a long history, some hydrologists feel that these gages do not reflect the true flood potential of Clear Creek. (See U. S. Corps of Engineers letter of August 14, 1975 in Appendix.) Figure No. 3 is a plot of drainage area versus discharge for these two gages. Note that the discharge decreases with increasing drainage area. This anomaly is due to the irrigation diversions and excessive detention potential in the many sand and gravel pits along the broad flood plain. Since some of these pits are being reclaimed for land development, we can anticipate that some of the detention effects will be diminished.

The evaluation of other stream gages with similar basin characteristics and good records is essential to either check or support the Clear Creek gages. Gages meeting the following criteria were also studied:

a. The drainage basin originated in mountainous terrain.

b. The stream gage was located within 50 miles of this study reach.

c. The drainage area below elevation 7500 feet was between 10 and 200 square miles.

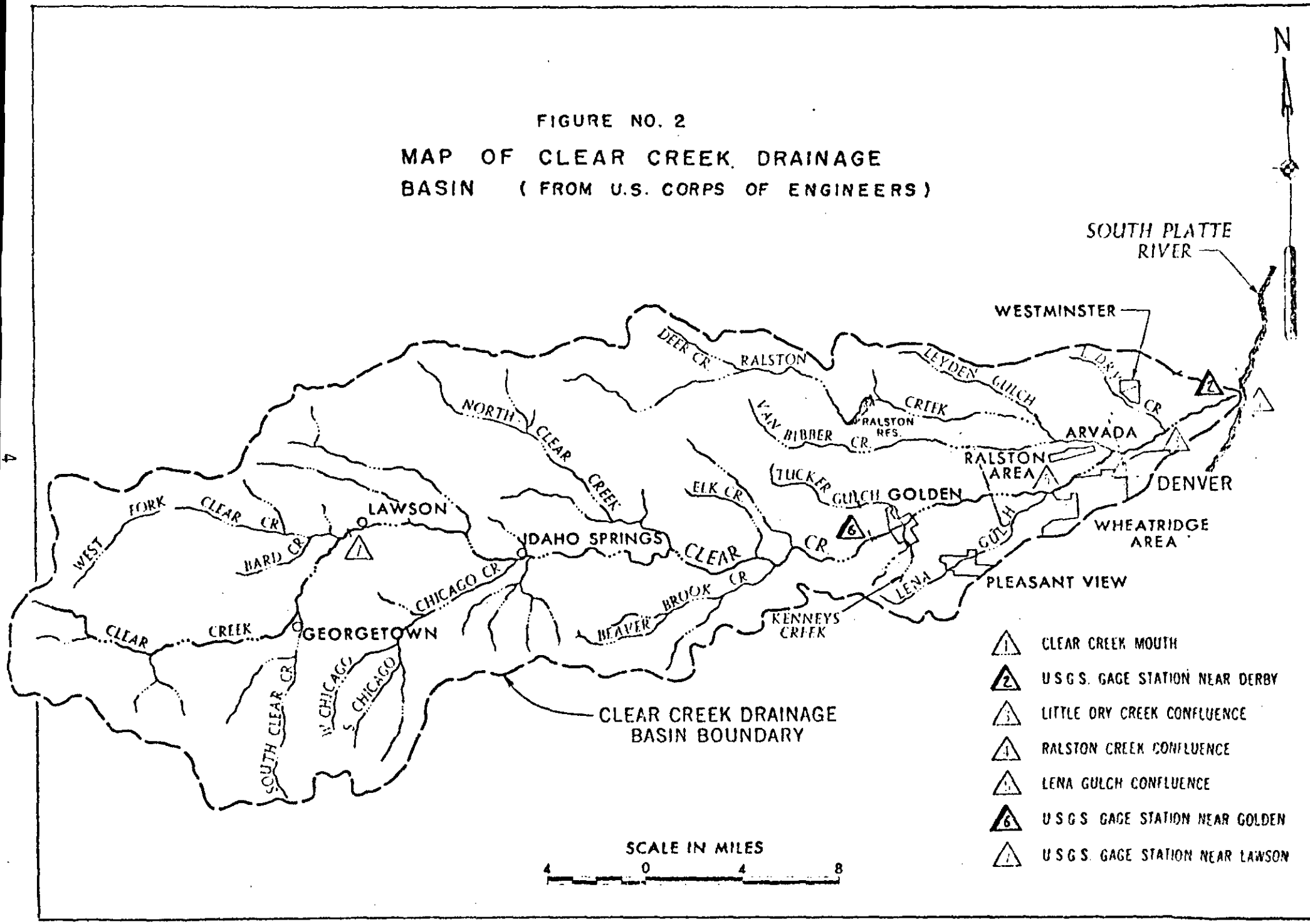
d. The peak flows were not substantially affected by diversion or regulation.

e. The gage had at least 10 years of record.

Only six gages were found to meet these criteria.

FIGURE NO. 2

MAP OF CLEAR CREEK DRAINAGE BASIN ( FROM U.S. CORPS OF ENGINEERS )



Work Sheet
No. (09-03)

176-1(35) P.E.
Project No.

MAR. 1977
Date

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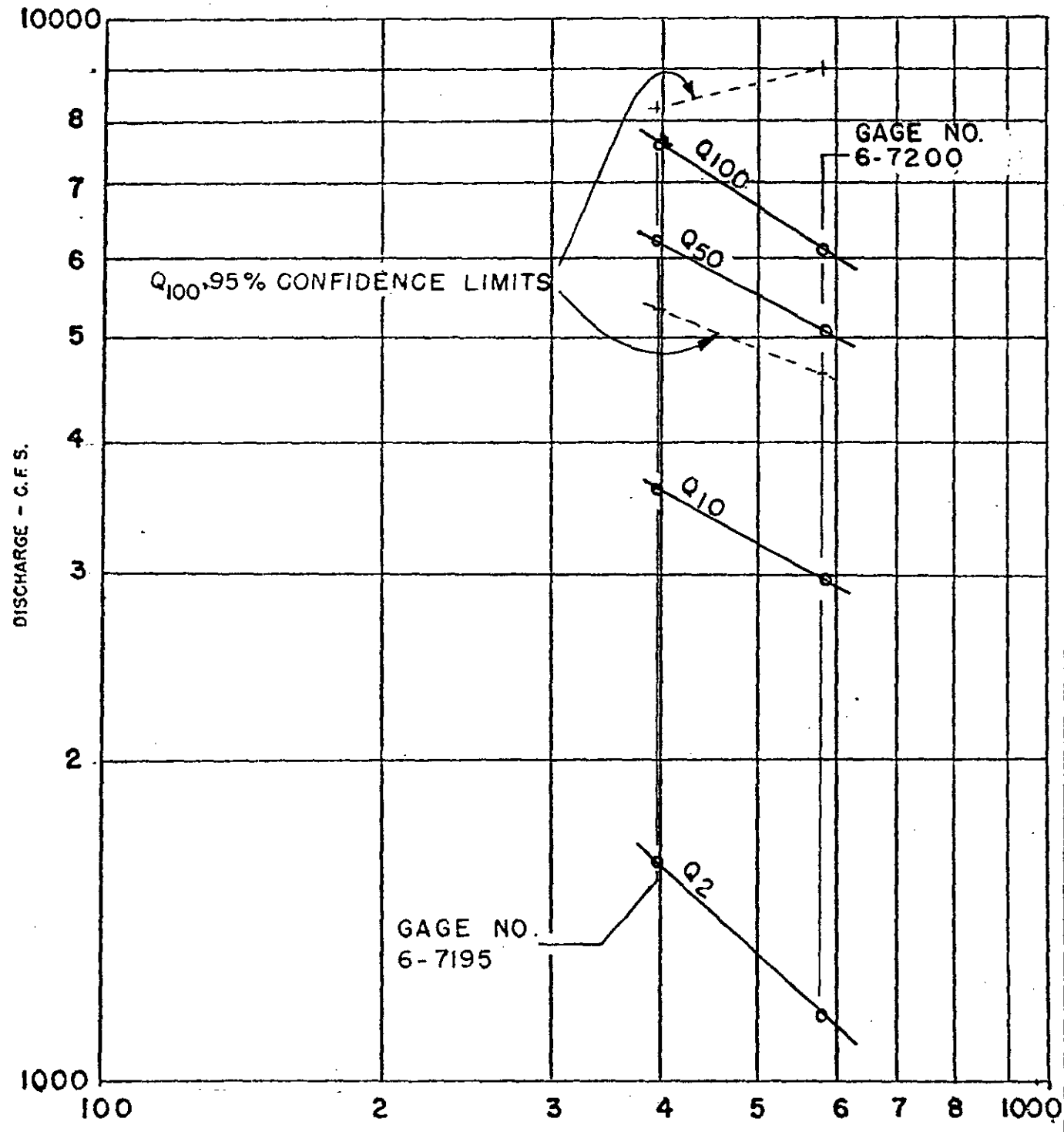
# FIGURE NO. 3
## DISCHARGE vs DRAINAGE AREA FOR CLEAR CREEK GAGES




COMMENTS; LOG PEARSON TYPE III ANALYSIS

TABLE I

| GAGE NO. | STREAM/LOCATION | YEARS OF RECORD | DRAINAGE AREA-SQ. MI. TOTAL | DRAINAGE AREA-SQ. MI. BELOW 7500 FT. |
|---|---|---|---|---|
| 6-7105 | Bear Creek at Morrison | 62 | 164 | 30 |
| 6-7110 | Turkey Creek near Morrison | 11 | 50 | 16 |
| 6-7220 | North St. Vrain at Longmont | 28 | 106 | 14 |
| 6-7295 [to 1955] | South Boulder Creek near Eldorado Springs | 60 | 109 | 13 |
| 6-7330 | Big Thompson at Estes Park | 25 | 137 | 19 |
| 6-7420 | Little Thompson near Berthoud | 16 | 101 | 46 |

Figure No. 4 is a plot of drainage area versus $Q_{100}$ for these gages. Both the total drainage area and the drainage area below elevation 7500 feet are plotted. The 7500 foot criteria has been established by McCain[2] to delineate snow melt from rainfall peak flows.

From Figure No. 4 it is apparent that a conservative discharge prediction could be obtained by giving more weight to Gages 6-7105, 7195, and 7420. Gage 6-7420 shows the highest results for drainage area below 7500 feet, but this gage had only 16 years of record. It had a skew coefficient of 0.6384, which is much higher than the regionalized coefficient of -0.15, published in Bulletin No. 17.[3] Therefore it is considered less reliable than Gages 6-7105 and 7195. Using the regionalized skew coefficient, Gage 6-7420 gave $Q_{100}$ = 13,800 cfs, which is in line with Gages 6-7105 and 7195.

Technical Manual No. 1.[2] - The peak flow predictions using the regression equation in this Manual at four selected points along Clear Creek are:

TABLE II

| LOCATION | DRAINAGE AREA - SQ. MI. TOTAL | DRAINAGE AREA - SQ. MI. BELOW 7500 FT. | $Q_{100}$* |
|---|---|---|---|
| Golden (at Gage 6-7195) | 399 | 23 | 11,300 cfs |
| Above Ralston Creek confluence | 454 | 76 | 19,300 |
| Below Ralston Creek | 543 | 122 | 24,000 |
| At Mouth (at Gage 6-7200) | 575 | 153 | 26,400 |

* These predictions based on drainage areas below 7500 ft. elevation.

[2] J. F. McCain and R. D. Jarrett, "Manual for Estimating Flood Characteristics of Natural-Flow Streams in Colorado", Technical Manual No. 1, Colorado Water Conservation Board, (1976). 68 pp.

[3] United States Water Resources Council, "Guidelines for Determining Flood Flow Frequency", Bulletin #17 of the Hydrology Committee, (March 1976) p. 9-6.

Work Sheet
No (09-03) 6Id
August, 1971

# FIGURE NO. 4

## DISCHARGE vs DRAINAGE AREA FOR SIMILAR DRAINAGE BASINS

176-1(35) P.E.
Project No.

MAR. 1977
Date

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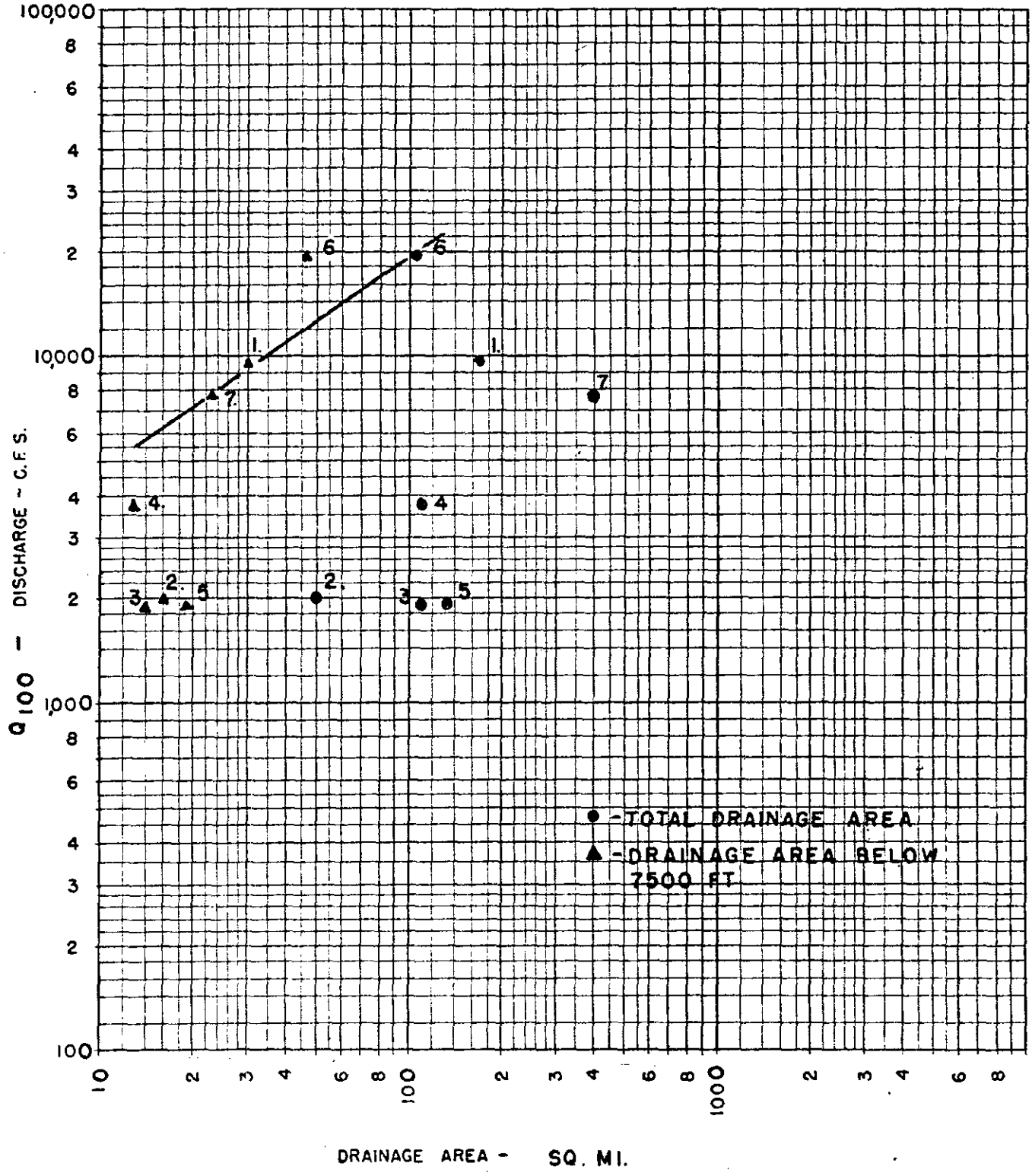


COMMENTS; LOG PEARSON TYPE III ANALYSIS

PT. 1 = 6-7105 , 2 = 6-7110 , 3 = 6-7220 , 4 = 6-7295

5 = 6-7330 , 6 = 6-7420 , 7 = 6-7195

The Manual recommends that these predictions should be weighted with stream gage data. The weighting equation is:

$$Q_w = \frac{Q_g N + Q_p E}{N + E}$$

where: $Q_w$ = weighted peak flow

$Q_g$ = log pearson III of gage

$N$ = Number years of gage record

$Q_p$ = predicted peak flow by Manual

$E$ = equivalent years of record

Using E = 10 years as recommended in the Manual, we get:

At Golden using 6-7195 $Q_{100}(w) = \frac{7570 \times 77 \text{ yr.} + 11{,}300 \times 10}{77+10} = 8000$ cfs

At Mouth using 6-7200 $Q_{100}(w) = \frac{6060 \times 48 \text{ yr.} + 26{,}400 \times 10}{48+10} = 9750$ cfs

Some USGS personnel feel that the Manual deserves more than 10 years equivalent record. They suggest as much as 50 years. This gives:

At Golden using 6-7195 $Q_{100}(w) = \frac{7570 \times 77 \text{ yr.} + 11{,}300 \times 50}{77+50} = 9000$ cfs

At Mouth using 6-7200 $Q_{100}(w) = \frac{6060 \times 48 \text{ yr.} + 26{,}400 \times 50}{48+50} = 16{,}400$ cfs

These discharges are plotted on Figure No. 5.

Studies by Others - In 1964 the U. S. Corps of Engineers[4] published a predicted $Q_{100} = 7300$ cfs for the flow above the Ralston Creek confluence and 8000 cfs below the confluence. However, in their letter of August 14, 1975 to Mr. Brasher, District 6 Engineer, the U. S. Corps of Engineers suggested that the $Q_{100}$ at the mouth would be in the range of 15,000 cfs to 25,000 cfs. (See Appendix). This preliminary range was estimated using the E.P.A.'s Storm Water Management Model (S.W.M.M.).

[4] U. S. Army Corps of Engineers, "Flood Plain Information", Volume III Technical Appendix Bear and Clear Creeks, (January 1966), p. C-4.

Work Sheet
No (09-03) 61d
August, 1971

176-1(35) P.E.
Project No.
APR. 1977
Date
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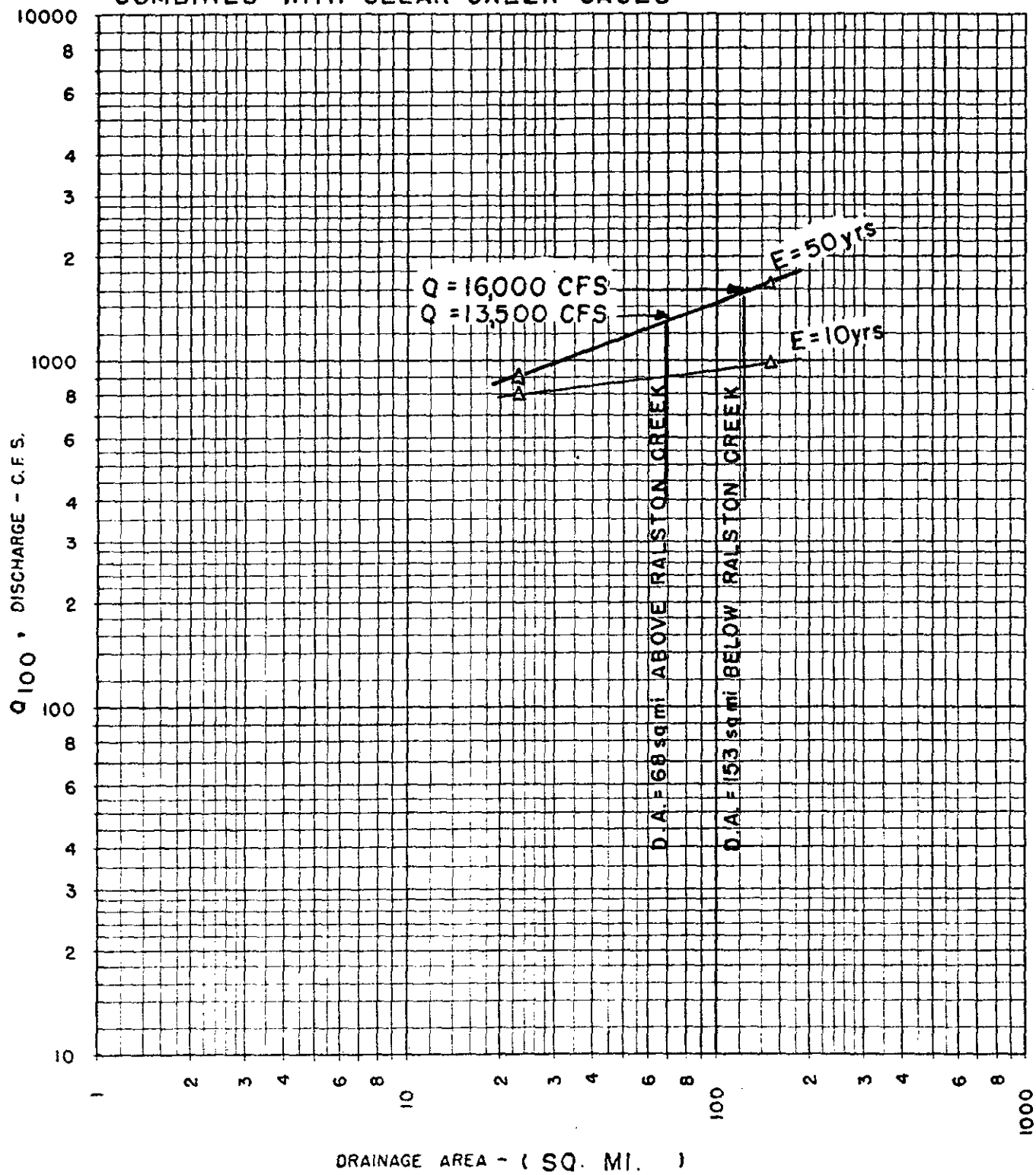
# FIGURE NO. 5
## DISCHARGE vs DRAINAGE AREA
## TECHNICAL MANUAL NO. 1
## COMBINED WITH CLEAR CREEK GAGES




COMMENTS: DRAINAGE AREA BELOW ELEV. 7500'

A preliminary study for the Federal Insurance Administration by Gingery Associates Inc. predicts $Q_{100}$ = 25,000 cfs below Sheridan Boulevard, which is below the Ralston Creek confluence.

The Water Resources Division of the USGS is preparing a study of Clear Creek in Jefferson County. No published values are presently available.

Discussion of Analyses

A range of discharges are available from the various described analyses. The range is too large to select the mean as a reliable value.

Gages on Clear Creek with their many years of record should provide good confidence. However, we concur with the U. S. Corps of Engineers that the true flood potential through this study reach probably has not been realized. The retention effects of the sand and gravel pits, irrigation diversion and channel storage have lowered the peak flow at Gage 6-7200. Thus it is felt that this gage gives too low a prediction.

Consideration of stream gages with similar characteristics should indicate the potential range of floods. Rather than an average of all these gages, the higher values of $Q_{100}$ were weighted more heavily. Certainly the gage on Bear Creek at Morrison, No. 6-7105, with 62 years of record, is a good indicator. The Bear Creek and Clear Creek at Golden gages are similar when adjusted for drainage area below 7500 feet. These gages with their high confidence limits should represent the upper limits of the predicted discharge.

Technical Manual No. 1 is a result of extensive study. This method gives quite high peak predictions for Clear Creek unless weighted by the gages. Weighted values using 50 years of equivalent record are assigned good confidence.

The U. S. Corps of Engineers have discounted their earlier prediction by suggesting a range for the 100-year flood from 15,000 to 25,000 cfs at the mouth. They are not prepared to make a final prediction at this time.

A summary of the above predictions is tabulated below:

TABLE III

| PREDICTION METHOD | ABOVE RALSTON CREEK | BELOW RALSTON CREEK |
|---|---|---|
| | cfs | cfs |
| Drainage Area Vs. Q Gages 6-7195, 7200 Total D.A. (Fig. No. 3) | 7,000 (5000/ 8500Ø | 6,400 (4700/9000) Ø |
| Drainage Area Vs. Q Gages 6-7105, 7195 D.A. $\leq$ 7500' (Fig. No. 4) | 16,000 | 21,000 |
| Technical Manual No. 1 Weighted with gages 6-7195, 7200 (Fig. No. 5) | 13,500 | 16,000 |
| Federal Ins. Adm. Study | | 25,000 |
| U. S. Corps of Engineers | | 15,000 - 25,000 |

Ø 95% confidence limits from Bulletin No. 17.[3]

CONCLUSION

The selection of the design flood peak was primarily based on Stream Gages 6-7105 and 7195 and Technical Manual No. 1. The gages were adjusted to exclude the snow melt areas. The Manual's regression values were weighted to include the Clear Creek gages. The Clear Creek gages and the prediction by the F.I.A. served to provide the outer confidence limits.

Selected Design Discharge

| | |
|---|---|
| Above Ralston Creek | $Q_{100}$ = 14,000 cfs |
| Below Ralston Creek | $Q_{100}$ = 18,000 cfs |

Discharges for $Q_{10}$ and $Q_{50}$ are derived from $Q_{100}$ by applying the ratios determined from the "Plains Region" of Technical Manual No. 1. See Figure No. 6.

Work Sheet No. (09-03)61b
May 1974

# FIGURE NO. 6

RECURRENCE INTERVAL CURVE

FOR DESIGN

I 76-1(35) P.E.
Project No.

MAR. 1977
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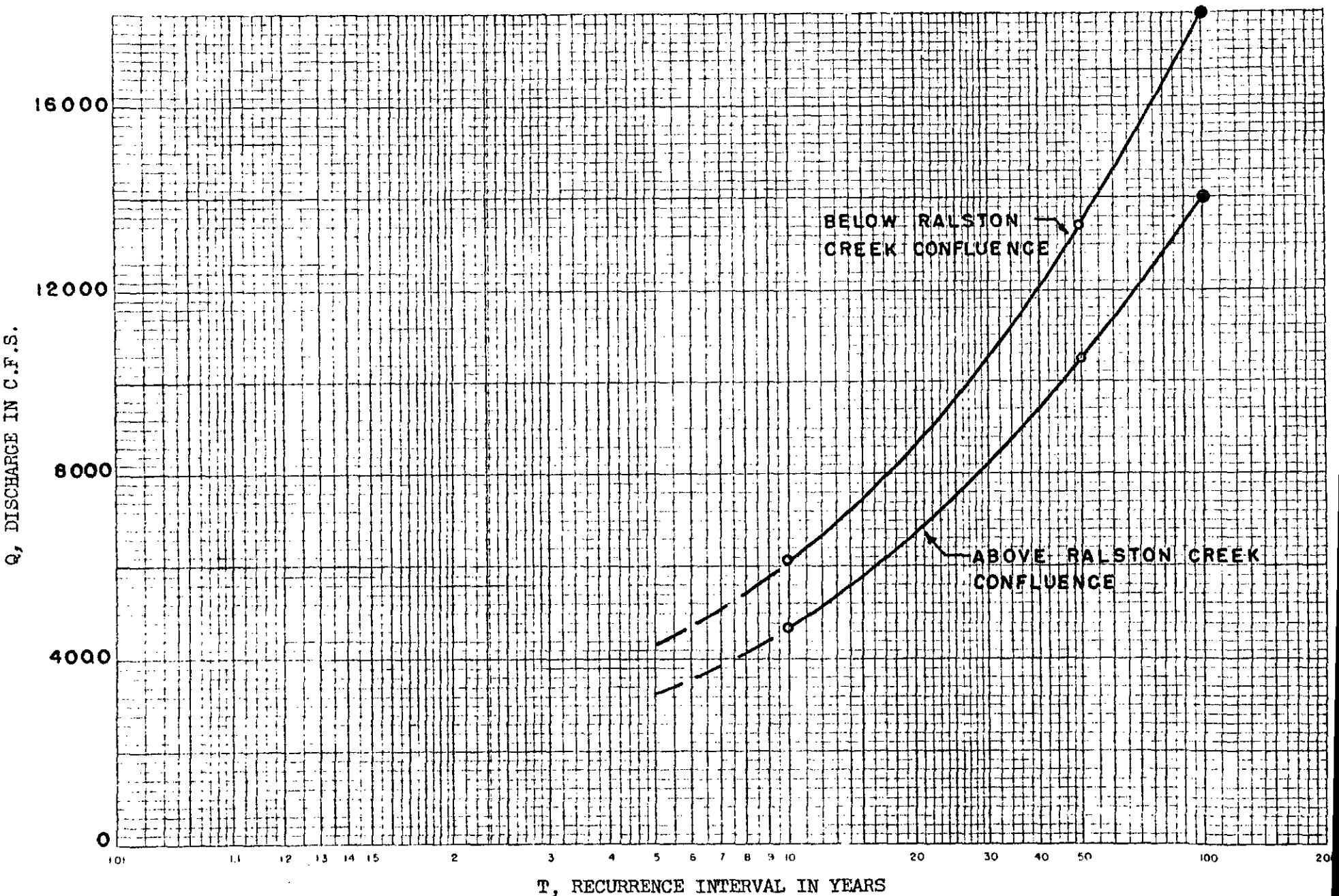


DEPARTMENT OF THE ARMY
OMAHA DISTRICT, CORPS OF ENGINEERS
6014 U.S. POST OFFICE AND COURT HOUSE
OMAHA, NEBRASKA 68102

MROPD-R

14 August 1975

Mr. Richard J. Brasher
District Engineer, District 6
State Department of Highways
2000 South Holly
Denver, Colorado 80222

Dear Mr. Brasher:

This is in further response to your letter of 17 July 1975 regarding the hydrologic report relating to your Project I 76-1(35). Our Engineering Division has reviewed your hydrologic report, and their analysis is as follows.

The section on design consideration in your report indicates that development is occurring rapidly in the Clear Creek basin and along the Clear Creek channel. This consideration, among others, is the reason we feel that the flow records on Clear Creek do not reflect the true flood potential of the basin now and especially in the future. A preliminary analysis of the lower 117 square miles of the basin, using the runoff block of EPA's Surface Water Management Model, indicated a 100-year peak might be somewhere in the range of 15,000 cubic feet per second to 25,000 cubic feet per second at the mouth. These figures are based on crude model runs in that many of the channel dimensions were estimated. In addition, our experience with the model is severely limited at this time. The results do point out, however, a likely chance that historical records do not reflect the true flood potential of the basin. Additional studies of Clear Creek will be made in connection with the Denver urban studies in the near future, and hopefully the results will provide a much narrower range of numbers.

We are planning to publish an analysis of the current hydrology of the South Platte River and its tributaries in the Fall of 1975. This information will be provided Federal, State, and local agencies for their use as they deem appropriate.

We appreciate the opportunity to review your report.

Sincerely yours,

C. F. THOMAS
Chief, Planning Division

DIVISION OF HIGHWAYS, STATE OF COLORADO

LOG PEARSON TYPE III STATISTICAL ANALYSIS USED TO DETERMINE FLOOD FLOWS FOR SELECTED RECURRENCE INTERVALS

CLEAR CREEK NR GOLDEN 6-7195 DA=399 SQ MI 1888,1898-1974

THE FOLLOWING PEAK DISCHARGES WERE USED IN THIS ANALYSIS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 8700.0 | 1460.0 | 1340.0 | 889.0 | 600.0 | 1660.0 | 1750.0 | 2070.0 | 1630.0 | 5000.0 |
| 647.0 | 2290.0 | 1270.0 | 1620.0 | 3200.0 | 1120.0 | 2900.0 | 1520.0 | 872.0 | 1670.0 |
| 2090.0 | 1090.0 | 1390.0 | 4420.0 | 1170.0 | 2110.0 | 2450.0 | 720.0 | 2100.0 | 1080.0 |
| 1560.0 | 1280.0 | 1280.0 | 1310.0 | 863.0 | 5890.0 | 2160.0 | 4900.0 | 1840.0 | 1750.0 |
| 4090.0 | 927.0 | 1110.0 | 5140.0 | 1220.0 | 1040.0 | 1260.0 | 1200.0 | 1010.0 | 1900.0 |
| 1900.0 | 3190.0 | 1560.0 | 2020.0 | 3140.0 | 1900.0 | 526.0 | 1280.0 | 5250.0 | 2840.0 |
| 2040.0 | 1410.0 | 1580.0 | 1230.0 | 1110.0 | 670.0 | 786.0 | 3510.0 | 415.0 | 950.0 |
| 1240.0 | 1860.0 | 1790.0 | 1730.0 | 1910.0 | 2210.0 | 1360.0 | | | |

NUMBER OF EVENTS IN RECORD N= 77
MEAN OF LOGS OF DISCHARGES M= 3.2166
STANDARD DEVIATION OF LOGS S= .2534
SKEW COEFFICIENT OF LOGS G= .4350

COMPUTED FLOOD MAGNITUDES

Q2= 1584.4
Q5= 2650.5
Q10= 3550.4
Q25= 4930.9
Q50= 6158.3
Q100= 7571.0

DIVISION OF HIGHWAYS, STATE OF COLORADO

LOG PEARSON TYPE III STATISTICAL ANALYSIS USED TO DETERMINE FLOOD FLOWS FOR SELECTED RECURRENCE INTERVALS

CLEAR CREEK AT MOUTH NR DERBY, 1927-1974 GAGE 6-7200 DA = 575 SQ. MI.

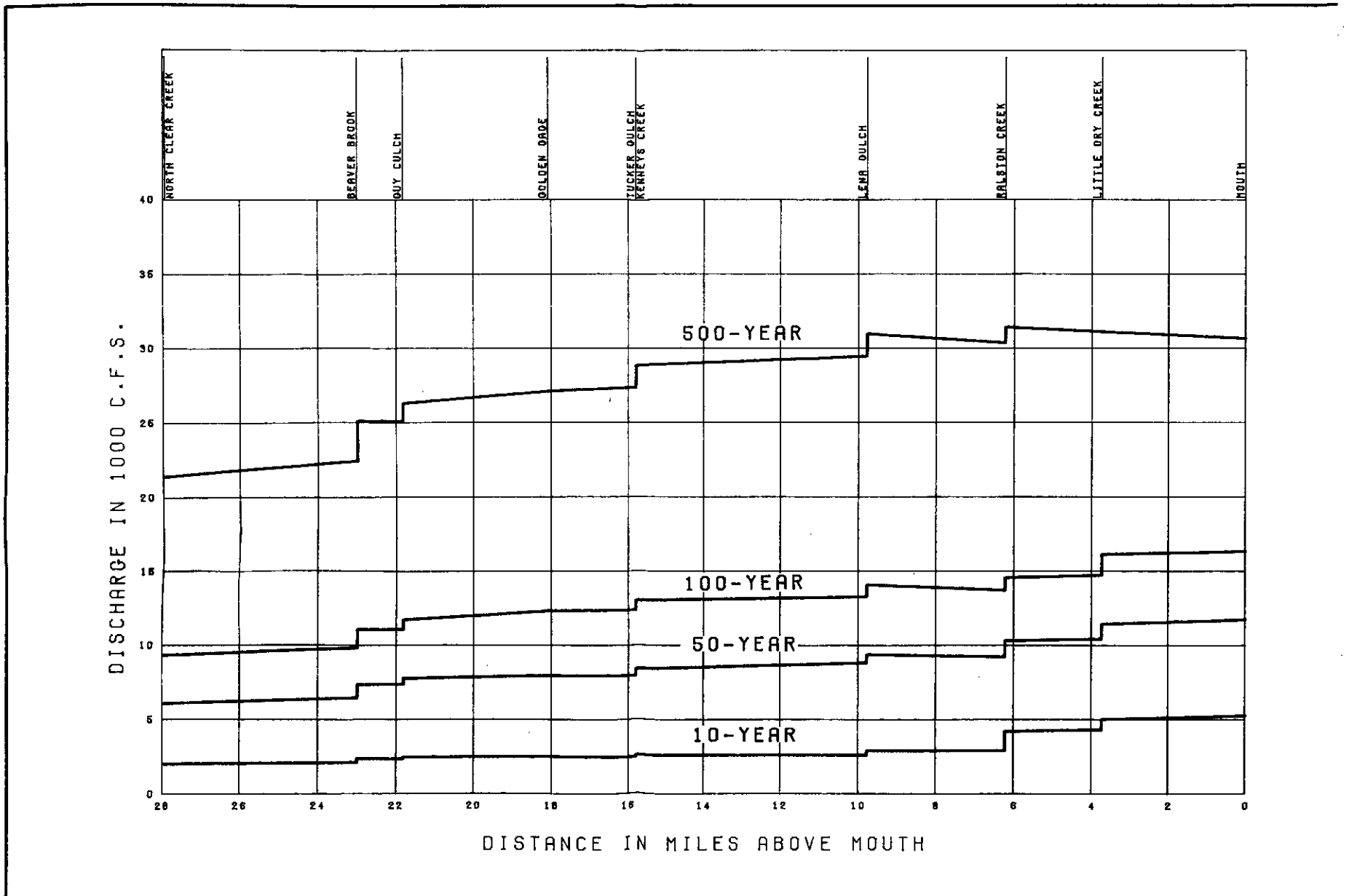
THE FOLLOWING PEAK DISCHARGES WERE USED IN THIS ANALYSIS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1000.0 | 1290.0 | 482.0 | 368.0 | 274.0 | 345.0 | 1530.0 | 690.0 | 537.0 | 1700.0 |
| 2170.0 | 3650.0 | 586.0 | 918.0 | 1490.0 | 1560.0 | 766.0 | 889.0 | 747.0 | 644.0 |
| 2680.0 | 1160.0 | 2920.0 | 982.0 | 1970.0 | 2860.0 | 1940.0 | 209.0 | 579.0 | 2880.0 |
| 1880.0 | 1730.0 | 1080.0 | 1010.0 | 1020.0 | 680.0 | 970.0 | 638.0 | 5070.0 | 458.0 |
| 1990.0 | 870.0 | 2810.0 | 2820.0 | 1080.0 | 1250.0 | 4700.0 | 1280.0 | | |

| | | |
|---|---|---|
| NUMBER OF EVENTS IN RECORD | N= | 48 |
| MEAN OF LOGS OF DISCHARGES | M= | 3.0639 |
| STANDARD DEVIATION OF LOGS | S= | .3190 |
| SKEW COEFFICIENT OF LOGS | G= | -.1108 |

COMPUTED FLOOD MAGNITUDES

| | |
|---|---|
| Q2= | 1173.2 |
| Q5= | 2156.6 |
| Q10= | 2944.5 |
| Q25= | 4085.8 |
| Q50= | 5033.4 |
| Q100= | 6056.8 |


NORTH CLEAR CREEK
BEAVER BROOK
GUY GULCH
GOLDEN GATE
TUCKER GULCH
KENNEYS CREEK
LENA GULCH
RALSTON CREEK
LITTLE DRY CREEK
MOUTH
500-YEAR
100-YEAR
50-YEAR
10-YEAR
DISCHARGE IN 1000 C.F.S.
DISTANCE IN MILES ABOVE MOUTH
0
5
10
15
20
25
30
35
40
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0