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ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

SUBTASK 3.05 (ii) - CLOSEOUT REPORT
PROBABLE MAXIMUM FLOOD DETERMINATION

FIRST DRAFT

FEBRUARY 28, 1981

ACRES

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Subtask 3.05 (ii) Flood Studies - Probable Maximum Flood Addendum
March 1981

(a) Objectives

To re-evaluate probable maximum flood estimates based on a more comprehensive climatological study and modeling procedure.

(b) Approach

The approach would entail re-assessing precipitation maximums, temperature gradients and temperature maximums based on a thorough study of the meteorological characteristics of the Susitna River Basin. Applicable storm maximization techniques will be used to develop a probable maximum precipitation storm for both spring and summer seasons.

Paralleling the climatological study will be a further calibration of the SSARR model. The intent of this calibration is to develop a reasonable watershed model based on procedures that follow generally accepted mathematical modeling technique. The calibration will start with assuming that the basin's meteorological and hydrological parameters used in the Corps of Engineers (COE) PMF estimates are the most representative. These parameters may be adjusted as analysis proceeds.

When the set of watershed parameters that give the most reliable estimation of spring and summer floods are determined, a verification study will be conducted using this data set. Several floods will be used that are independent of the floods used in the calibration study.

The verification of the SSARR model will determine the accuracy that can reasonably be expected from the model.

Estimates of the probable maximum flood at critical locations along the Susitna River for both spring and summer will be determined using climatological data developed and the most reliable set of basin parameters.

(c) Discussion

The motivation for this addendum stems from the results of the assessment of the COE 1975 studies. The assessment determined the sensitivity of the PMF estimates to changes in critical meteorological and basin parameters. The magnitude of the changes are given in Table 1 and are discussed completely in Subtask 3.05 (ii) - Probable Maximum Flood Closeout Report.

The meteorological data used in the COE estimates were developed by they National Weather Service (NWS) in a preliminary study which give a general range of criteria within which it was believed values from a more comprehensive study would fall. In their conclusions to the study, the NWS noted... "Time hasn't allowed checks, evaluation, and comparison of the several types of data summarized here." The NWS naturally recommended further study. This is borne out by the increases to the PMF peak found in the sensitivity analysis.

The operation of Watana Reservoir for power generation will have an effect on storage attenuation of the spring and summer peaks. Consequently, it is not a clear cut case of developing a maximum storm as a smaller flood entering a full reservoir may require larger spillway facilities than a larger flood entering a depleted reservoir. The operation of Watana Reservoir will result in the lowest reservoir levels occurring in April or May each year. Therefore, there is substantial storage available to attenuate the spring flood peak. On the average, it would appear that approximately 2.3, 2.3 and 1.6 million acre-feet of storage is available in April, May and June respectively. These values are for Watana with full supply level of 2,200 feet and 800 MW installed capacity. In August, September and October, no significant storage is available. A preliminary estimate of the spring PMF volume is about 4.5 million acre-feet. Consequently, approximately 36 percent of the spring flood volume could be stored without reservoir surcharging. If 20 feet of surcharge is allowed, then about 50 percent of the spring flood volume can be stored. The effect of the storage is to attenuate the flood peak significantly.

what about minimum?

what is the relevance of this figure — we are only allowing 14' surcharge — design studies

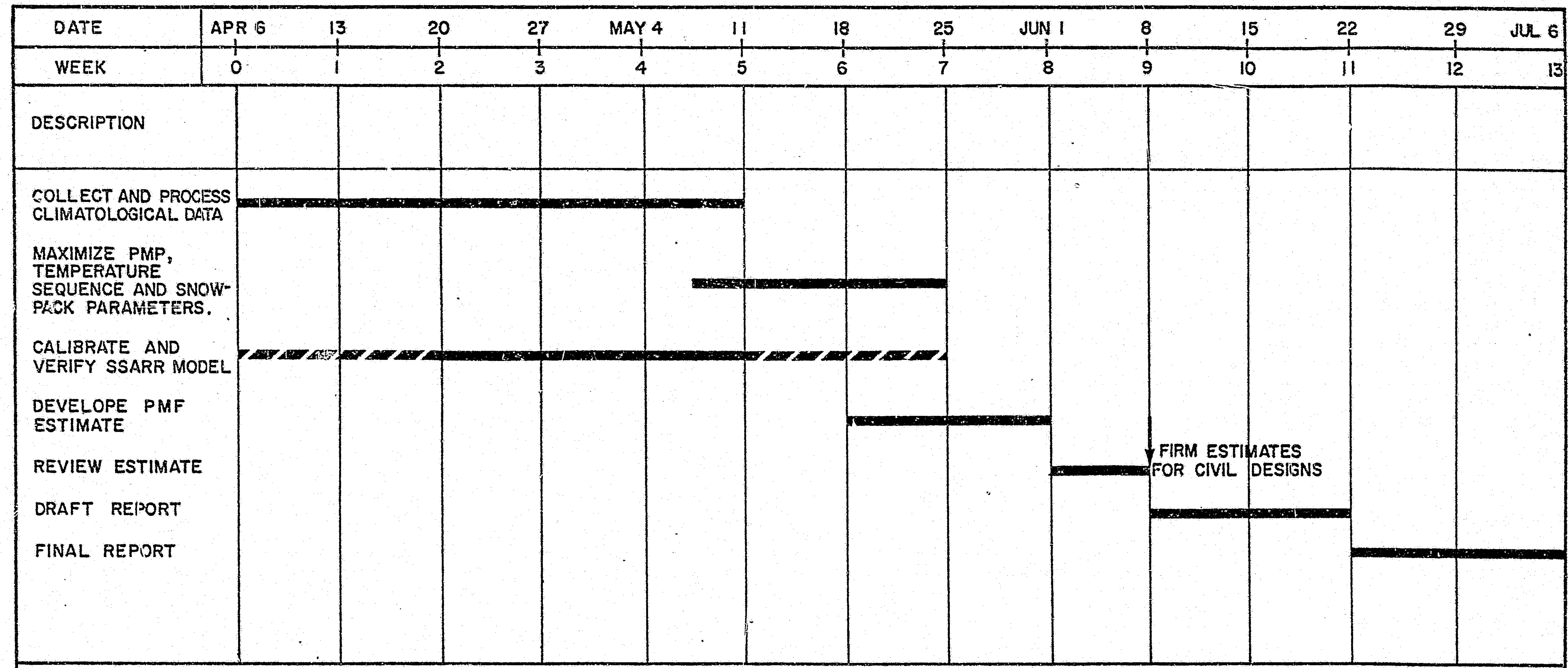
For the summer PMF, reservoir levels are close to maximum so no significant flood storage is likely available. The case for flood storage in spring is strong as the reservoir can only be full, assuming normal power operation, after snowmelt runoff. Therefore it may be only applicable to design spillway criteria based on summer floods and full reservoir conditions.

Doesn't ... ...

The above questions will be addressed in the proposed studies.

Schedule:

The study will require approximately 800 man-hours of effort. The latest possible date to start the study is April 6, 1981. This date is to ensure a new estimate of the PMF for spillway design by June 8, 1981. Expected completion of the study will be July 6, 1981. A Preliminary schedule is given in Figure 1.



NOTES:

TOTAL HRS: 20 MAN WEEKS = 800 MAN HOURS

EXPENSES: COMPUTER $ 2000

TRAVEL AND DATA $ 1000

$ 3000

SCHEDULE FOR PMF STUDY

ACRES

ACRES | **Calculations**

SUBJECT:

JOB NUMBER
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SHEET ____ OF ____
BY R. STOLL DATE 3 MAR 81
APP DC DATE 7 MAR 81

TABLE 1 Summary of PMF Sensitivity Studies

Discharge CFS.

SSARR MODEL RUN DESCRIPTION*	WATANA		DEVIL CANYON		GOLD CREEK
	INFLOW	OUTFLOW	INFLOW	OUTFLOW	
COE, 1975 ESTIMATE (BASE RUN)	233,000	192,000	226,000	222,000	236,000
TEMPERATURE SENSITIVITY RUN.	243,000	198,000	233,000	229,000	243,000
STORM TIMING SENSITIVITY	239,000	194,000	229,000	224,000	239,000
PRECIPITATION/SNOW PACK SENSITIVITY	342,000	250,000	307,000	290,000	308,000
INCREASED TEMPERATURE GRADIENT SENSITIVITY	302,000	243,000	282,000	275,000	289,000
describe COMBINED CASE SENSITIVITY	430,000	270,000	330,000	322,000	348,000
COE SNOW PACK SENSITIVITY	254,000	232,000	272,000	262,000	277,000

* detailed discussion of sensitivity studies given in Subtask 305(ii) – Probable Maximum Flood: Closeout Report

New Table in Standard format

Some indication of changes in parameter values in col. 1 should be given..

FORM NO. 152 REV. 1

Langerbellen

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

TASK 3 HYDROLOGY

SUBTASK 3.05 (ii) - CLOSEOUT REPORT
PROBABLE MAXIMUM FLOOD DETERMINATION

See Format on 3.01 report

FIRST DRAFT

FEBRUARY 28, 1981

Title & Format.

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1 - INTRODUCTION

The objective of the work conducted under Subtask 3.05 (ii) "Probable Maximum Flood Determination" was to determine if the probable maximum flood (PMF) peaks evaluated by the U.S. Army Corps of Engineers (COE) (1) are sufficiently accurate for use in the feasibility study and FERC license application.

2 - SUMMARY

The method used by the COE in evaluating the PMF involved the application of a calibrated river basin computer model which simulates stream flow in response to specified input temperature and precipitation inputs. This study included a detailed review of the model used, the calibration procedures adopted, the calibration results achieved and a range of additional sensitivity runs using the SSARR model and the COE data. The sensitivity runs involved making systematic plausible changes to the snowpack, temperature and precipitation input data in order to see what effect these have on the flood peak.

The results of these studies indicates the following:

- the calibration procedure used by the COE was not rigorous and does not allow a realistic assessment of the modelling accuracy to be made;

- the timing of the key input parameters, that is, temperature and precipitation used by the COE does not reasonably ensure that the flood peak is a probable maximum;

- the magnitude of the probable maximum precipitation and temperature sequences were based on a preliminary study made by NWB who themselves suggest more detailed work (Appendix A).

Indications are that the peak flow associated with the PMF event could be considerably higher than that estimated by the COE.* It is therefore recommended that the PMF studies be redone prior to completion of the current feasibility studies. The motivation for this recommendation is reinforced by the fact that the project is large, involving large capital outlays and very important to the future development of Alaska.

*This is of particular importance to spillways design as the rick of failure associated with a given design discharge may be substantially higher if the design discharge is exceeded.

3 - SCOPE OF WORK

3.1 - Probable Maximum Flood Evaluation

The probable maximum flood (PMF) is generally considered as a flood resulting from the worst possible combination of a number of maximum credible meteorological parameters and antecedent basin conditions. Although no annual probability of occurrence can be accurately attached to this PMF event, it is generally accepted to be in the 10^{-5} to 10^{-7} range.

The first step in the estimation of the PMF is to determine critical meteorological conditions such as maximum snowpack, temperature sequence, and the maximum probable precipitation (PMP). The timing of these maximum events are usually assumed to occur so that the resultant peak is minimized. However, in many cases, a judgement is made as to the reasonableness of the occurrence of such a combination of events. The response of the watershed to the Probable Maximum Precipitation (PMP), with antecedent conditions suitably primed to give severe flooding, can either be determined using computer mathematical models or by use of unit hydrographs and rainfall-runoff relationships.

Usually, a computer simulation model of the basin is preferred over the unit hydrograph or rainfall-runoff methods. The advantage of this method over conventional methods lies in the ability of the computer model to test hypotheses of runoff which involve complex interactions of hydrologic elements and in the relative case in which a non-homogeneous basin can be sub-divided into smaller homogeneous hydrologic units. Consequently, the selection of the SSARR (Stream Flow Synthesis and Reservoir Regulation) computer model by the COE to estimate streamflow is believed appropriate for the Susitna Basin.

3.2 - Scope of Work

The objective of the work was to assess the accuracy of the COE estimates spring and summer PMF events. In undertaking this work, the following rev steps were performed:

(a) Review of Work done by the COE

(i) Review of the COE input data to the SSARR Model particularly with respect to:

- basin and sub-basin physical characteristics;
- precipitation (antecedent storm and PMP storm);
- temperature sequences;
- snowpack accumulation over winter months.

(ii) Review of calibration runs made by COE with the SSARR Model to determine if the parameters selected to describe the physical characteristics of the basin are acceptable.

(b) Sensitivity runs with SSARR Model

(i) Additional computer runs to determine the sensitivity of PMF peak estimate to changes in either input variables (snowpack, temperature and precipitation) or basin characteristics.

Detailed discussion of the above review steps are given in the following section

4 - REVIEW OF COE PMF EVALUATION

The review of the work conducted by the COE included an assessment of the input data used and the SSARR Model calibration procedure and results. These two aspects are discussed below.

4.1 - Data Input to the SSARR Model

(a) Basin Characteristics

The SSARR computer model obtains the best estimates of streamflow when the basin is divided into relatively homogeneous sub-basins. Flows from these sub-basins are combined and routed downstream to derive the flow at specified collection points. A schematic showing the sub-basins used by the COE for the Susitna Basin above Gold Creek gaging station is given in Figure 4.1

Each sub-basin is ascribed physical characteristics that are believed representative of that sub-basin. The sub-basin characteristics are defined in the computer model by tables. These tables, converted to figures to present a clearer picture, are given in Figures 4.2 to 4.8. The majority of the parameters, describing the physical characteristics are determined by assuming likely values and relationships for each of the sub-basins. The assumed values are a function of the sub-basins hydrological characteristics such as soil types, slopes and aspect.

The assumed values are then "fine tuned" of obtained streamflow estimates that are within acceptable limits of observed values. This is the usual way to calibrate the model when only sparse data on hydrological parameters are available. This is further discussed in Section 4.2 (Calibration Studies). Generally, the basin parameters determined for the basin are acceptable at this stage.

Several discrepancies, common to both summer and spring PMF files exists. These are:

(a) For Maclaren Glacier a table, Number 4006 is specified for monthly evapotranspiration index. No Table 4006 is given so a zero evapotranspiration index would have been assumed. However, it is unlikely that this error would significantly affect peak values, but would probably seriously affect the accuracy of any long term streamflow simulations or would be important if antecedent soil moisture conditions fluctuate significantly. It is believed that this table should be Table 4009 which would make Maclaren Glacier similar to Susitna Glacier.

(b) A base flow initiation index of 0.03 inches/day has been assigned to Maclaren Glacier. We believe this should be 0.30 inches/day.

(c) The timing of the probable maximum precipitation (PMP) and critical temperatures during the PMP storm do not coincide with those values recommended by the National Weather Service (Appendix A). If timing of the PMP and temperatures are changed to match recommended values the spring PMF estimate for inflow into Watana reservoir is increased to 239,000 cfs, an increase of 1.3%, with peak flows occurring approximately twelve hours earlier.

In Acres sensitivity runs, the discrepancies noted above have been revised. The revision of discrepancies given in (a) and (b) do not seriously affect stream flow estimates as they only affect flows from Maclaren Glacier sub-basin which represents approximately 0.7% of the drainage basin area at Gold Creek station. Effects of revision to temperature sequence are given in (c) above.

4.2 - Calibration and Verification Studies

The results of calibration and verification studies are provided to indicate in an objective fashion as possible, the level of accuracy that can be expected from the use of the Model. It should be emphasized that the degree of acceptance of any model is ultimately judgemental in nature, and should be continuously reviewed and updated as new information and data are obtained.

Before proceeding further, it will be instructive to review the objectives of model calibration and verification. Model calibration and verification are separate but related activities, both of which should be performed in the process of the models' development and application. In the process of model calibration a data set is selected which is assumed to be representative of the type of problems to which the model will be applied. The model is then run with this data set and its coefficients are adjusted to provide the best agreement between estimates and observed values. Often several data sets are applied and a compromise set of coefficients obtained.

When the model coefficients are determined from the calibration exercise, the model should be run with one or more data sets which are independent of the one used for calibration. In no circumstance should the model's coefficients be adjusted when using the subsequent data set and the accuracy achieved by the model constitutes the measure of the model's verification or accuracy.

In the review of the COE studies, it ~~has been determined that~~ no verification of the model was undertaken; only calibration runs were made. Consequently, the accuracy of the modelling approach adopted has not been tested.

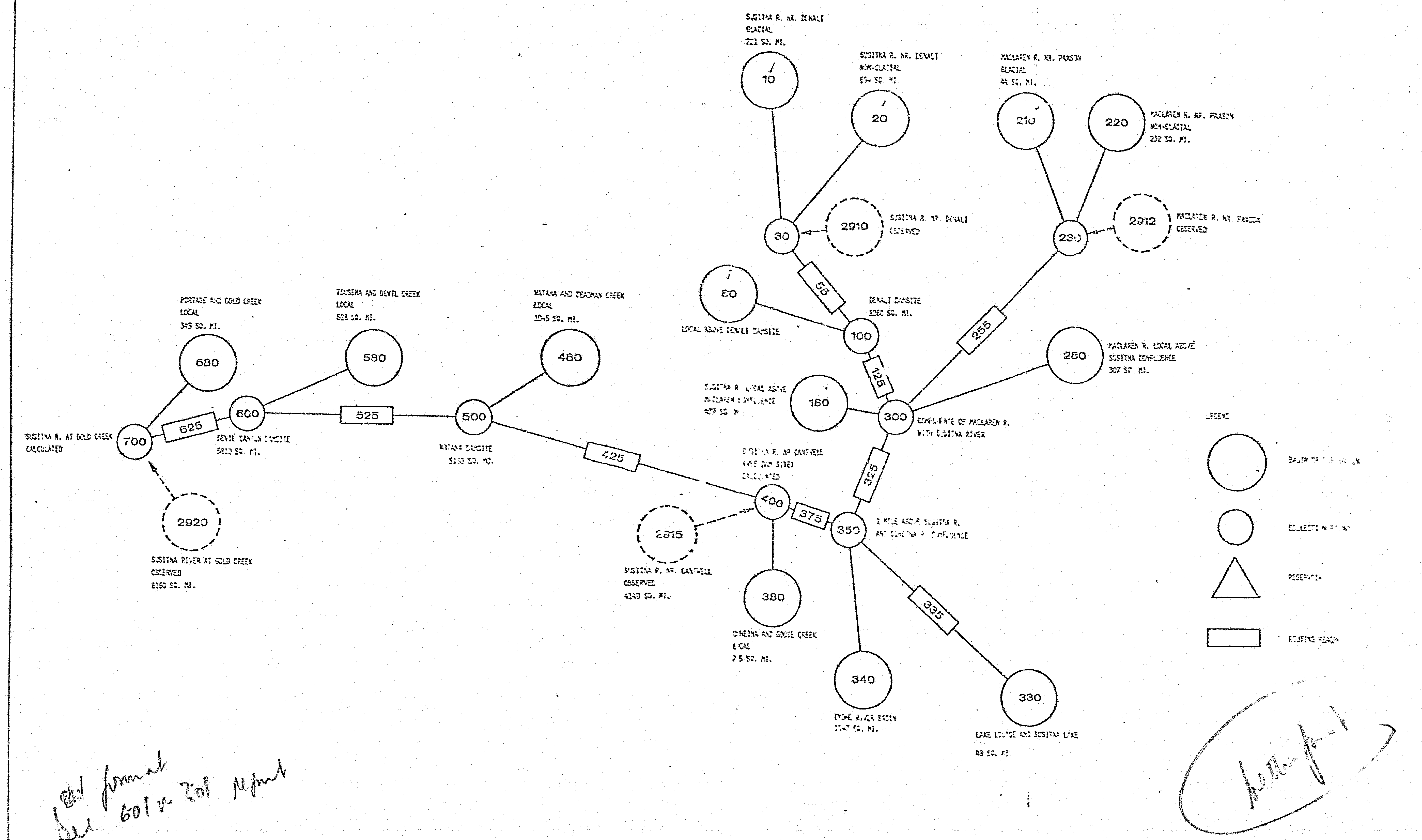
The COE selected spring floods in 1964 and 1972, and summer floods in 1967 and 1971 as representative of floods on the Susitna River and its tributaries upstream of the Gold Creek gage. Calibration was performed at four gaging stations; three on the Susitna River and the fourth on the Maclaren River. The results of these calibration runs are given in Tables 4.1 to 4.4. Flow values for the Gold Creek gage shown in the table on page A-31 of the COE, Interim Feasibility Report appear to be in error as they do not agree with the computer output values. Tables 4.2 to 4.4 also shows the return period for the observed floods at the four gaging stations. The observed and modeled hydrographs are given in Figures 4.8 to 4.14.

The results of the calibration study indicate that snowmelt flood peaks are consistently underestimated for floods at the Gold Creek gage; 6.3% and 14% for 1964 and 1972 floods respectively. However, snowmelt floods peaks at the next upstream gage (Cantwell) are consistently over-estimated by 4.1% and 0.5% for 1964 and 1972 respectively. No conclusive pattern exists for Denali and Maclaren Gages. Rainfall flood peak estimation for 1971 is 4.6% less than the observed value at Gold Creek gage and is 22.2% greater than the observed value at the Cantwell gage. All estimates and observed values are given in Tables 4.2 to 4.5 for the four locations.

The coefficients used in each calibration run are in many respects different. For PMF estimation the data sets developed through the calibration of the 1972 flood has been used for both the spring and summer floods. Consequently, the data sets developed for floods in 1964, 1967 and 1971 can only be assumed to be not representative of the basin. As the data sets are different for the two spring and summer calibration runs no verification of the data used for th PMF estimates has been made and the accuracy of the model has not been assesse

4.3 - Summary

The COE followed the usual procedure for calibrating a computer model of physical processes. However, no verification runs using independent data were made to determine the acceptability of the coefficients determined from the calibration activitiy. Consequently, no degree of accuracy in modelling the basin can be assumed based on the available calibration study.

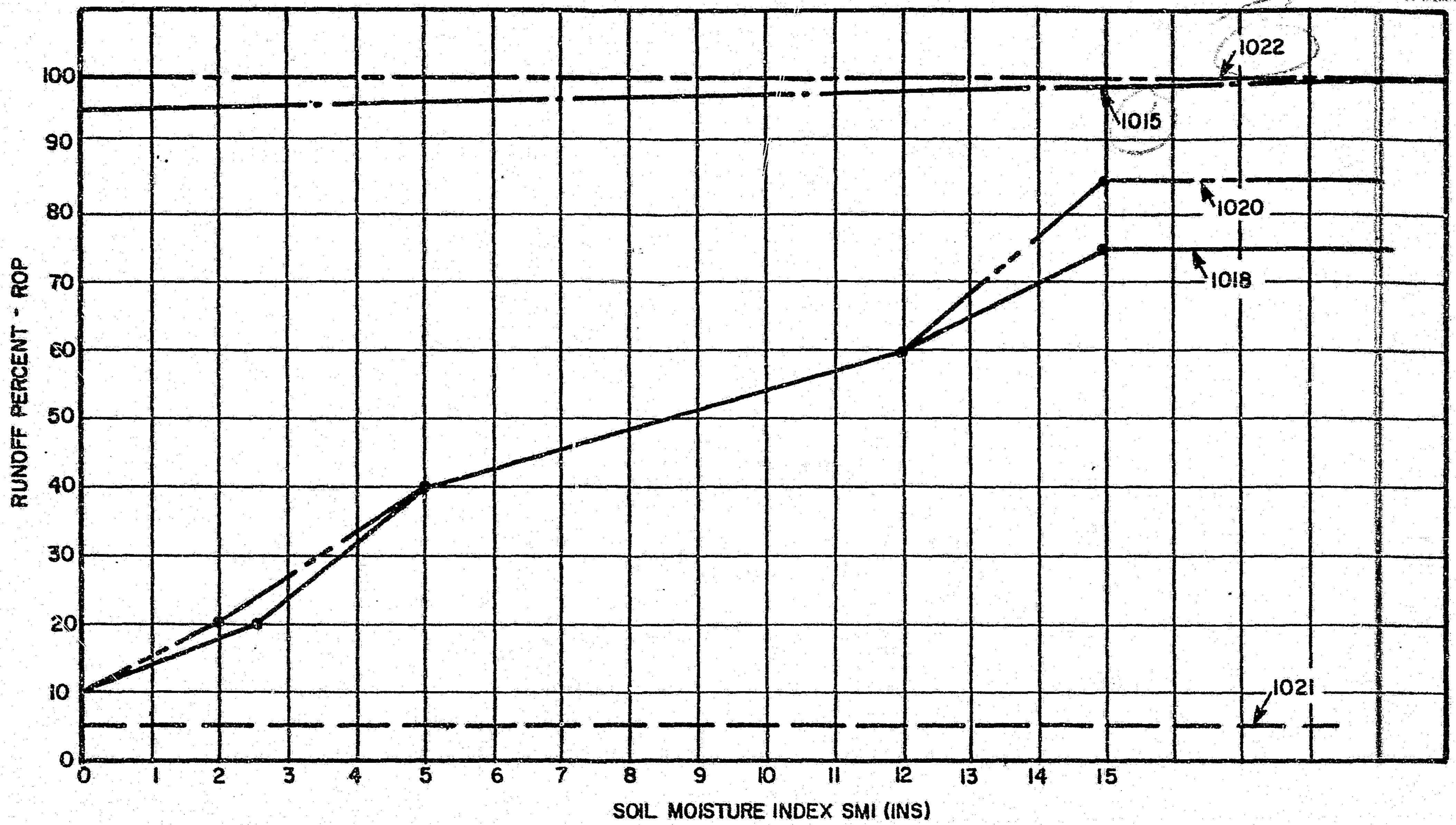


REFERENCE:
U.S. ARMY CORPS OF ENGINEERS INTERIM FEASIBILITY REPORT, 1975 APPENDIX I PART I

SCHEMATIC DIAGRAM OF SSARR COMPUTER MODEL

FIGURE 4.1

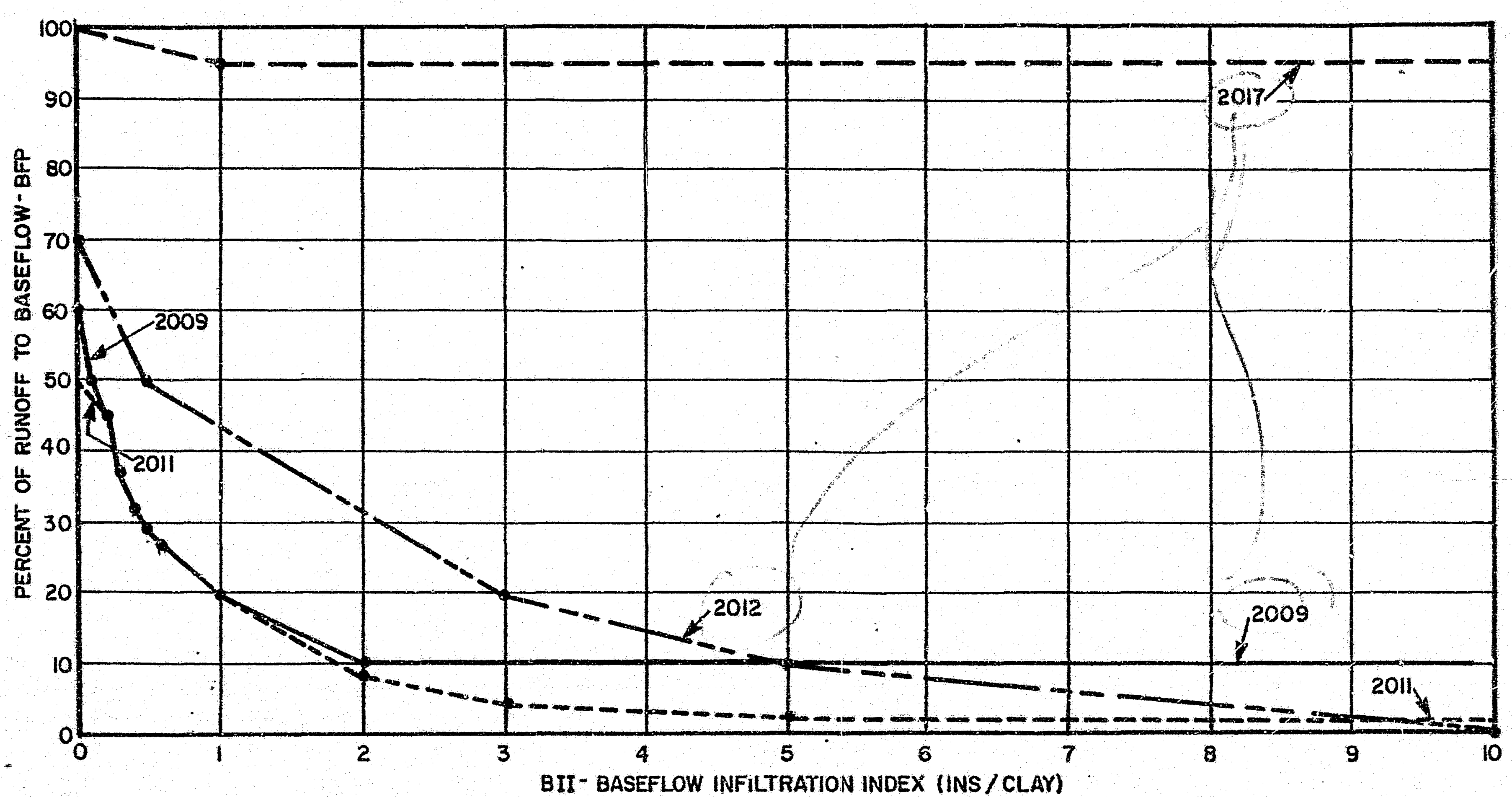
what do these mean?



SSARR MODEL SMI VS ROP

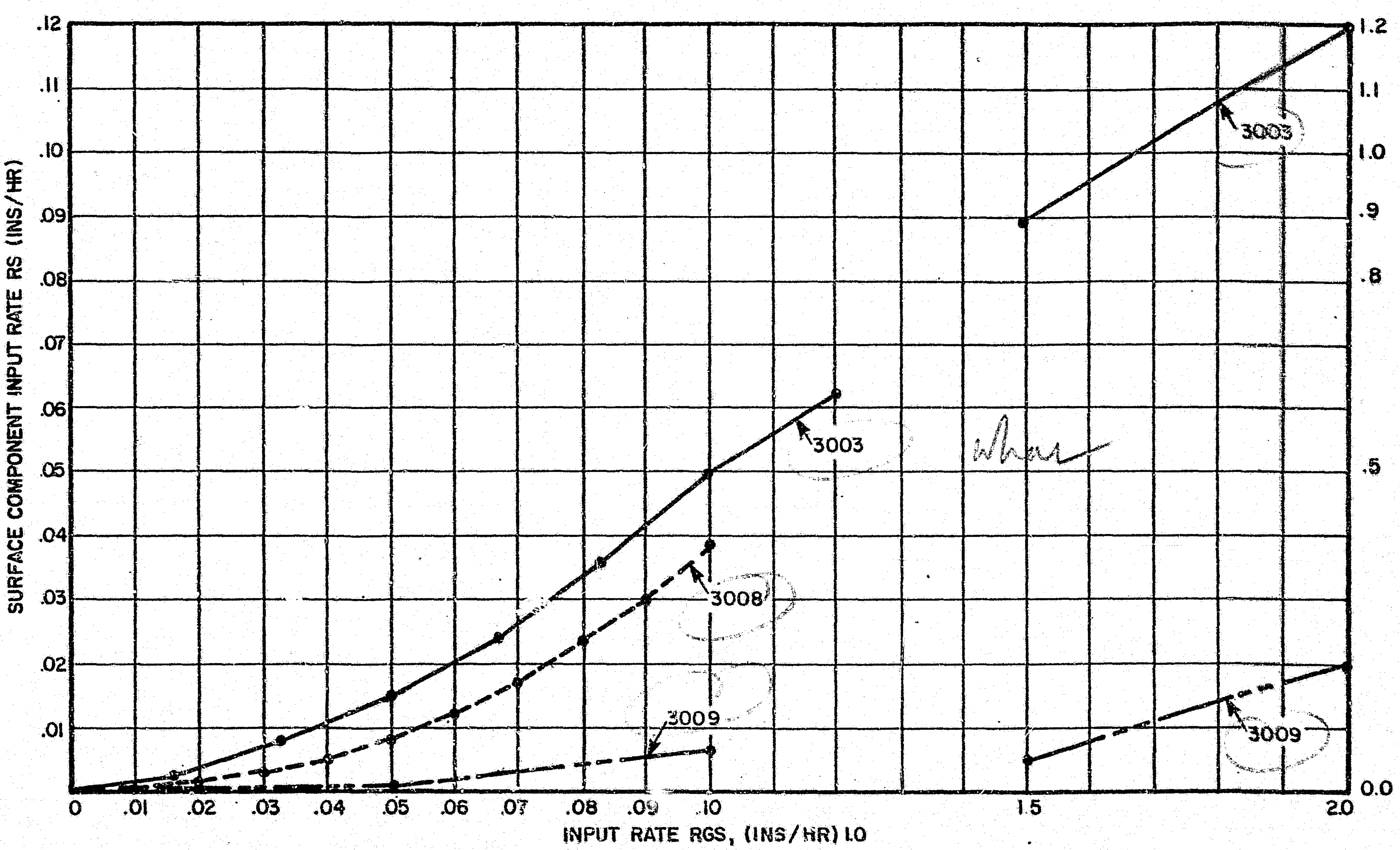
FIGURE 4.2

(what are these)



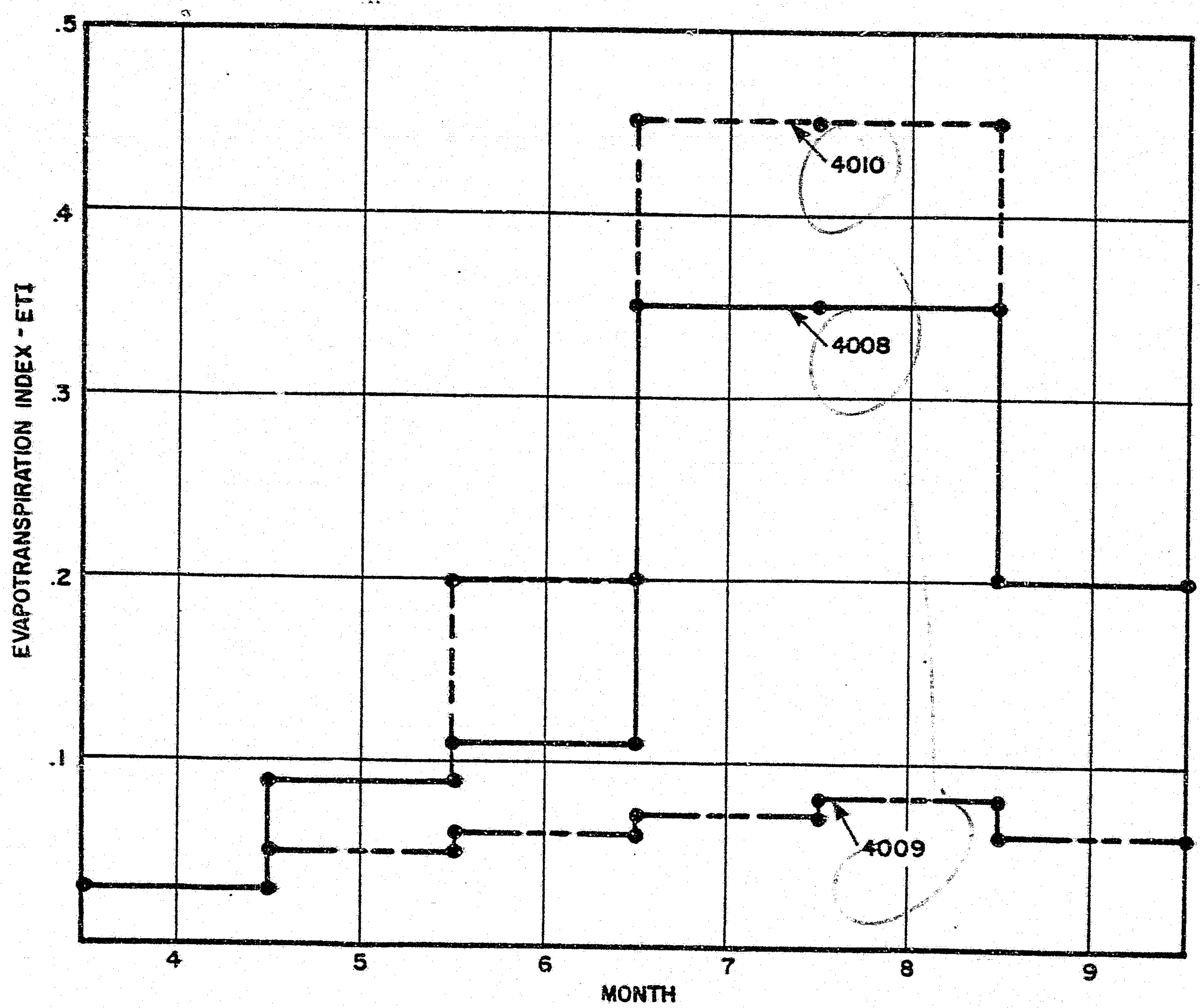
SSARR MODEL BII VS BFP

FIGURE 4.4



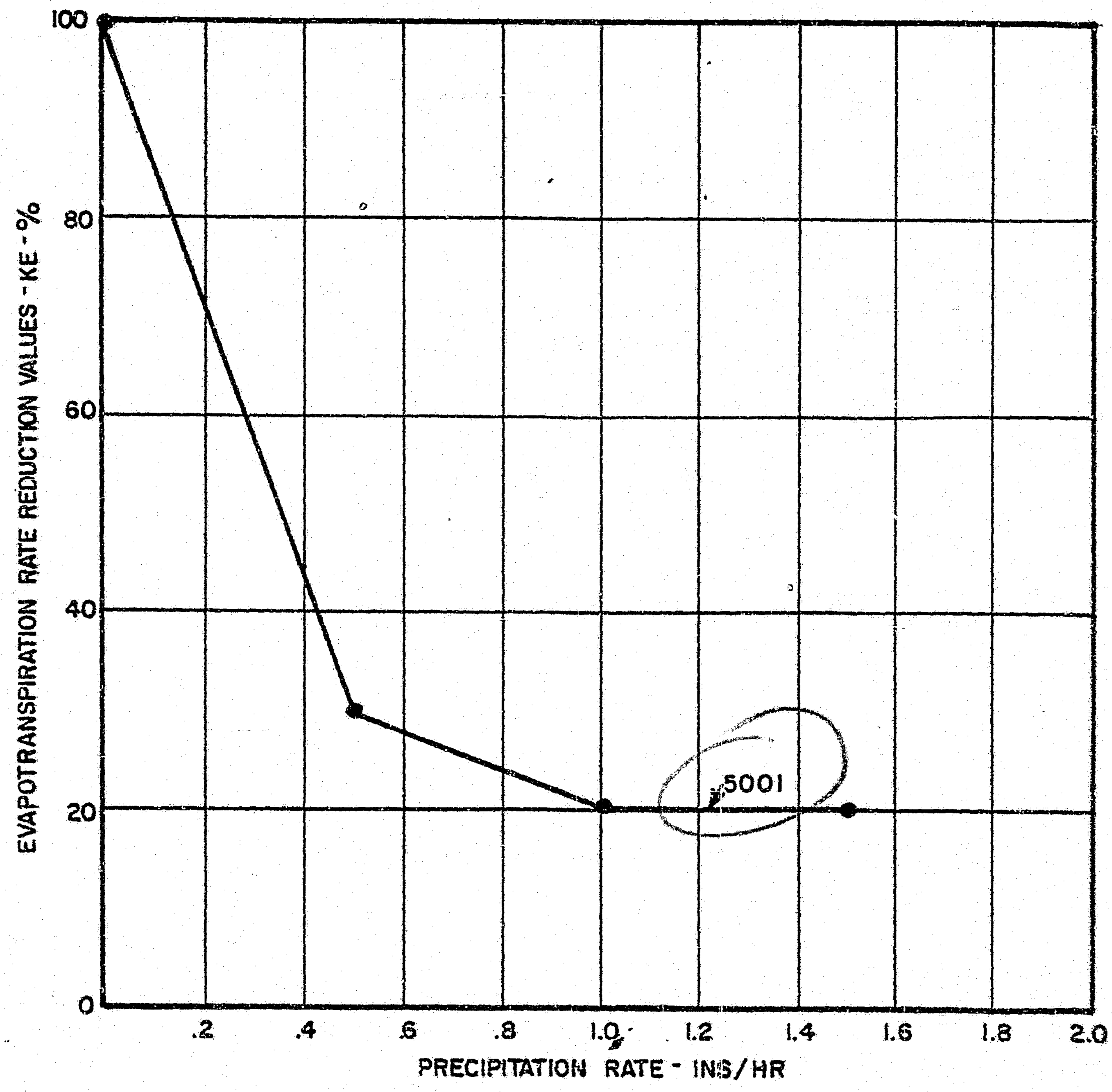
SSARR MODEL RGS VS RS

FIGURE 4.4



SSARR MODEL MONTH VS ETI

FIGURE 4.5



SSARR MODEL PPT VS KE

FIGURE 4.6

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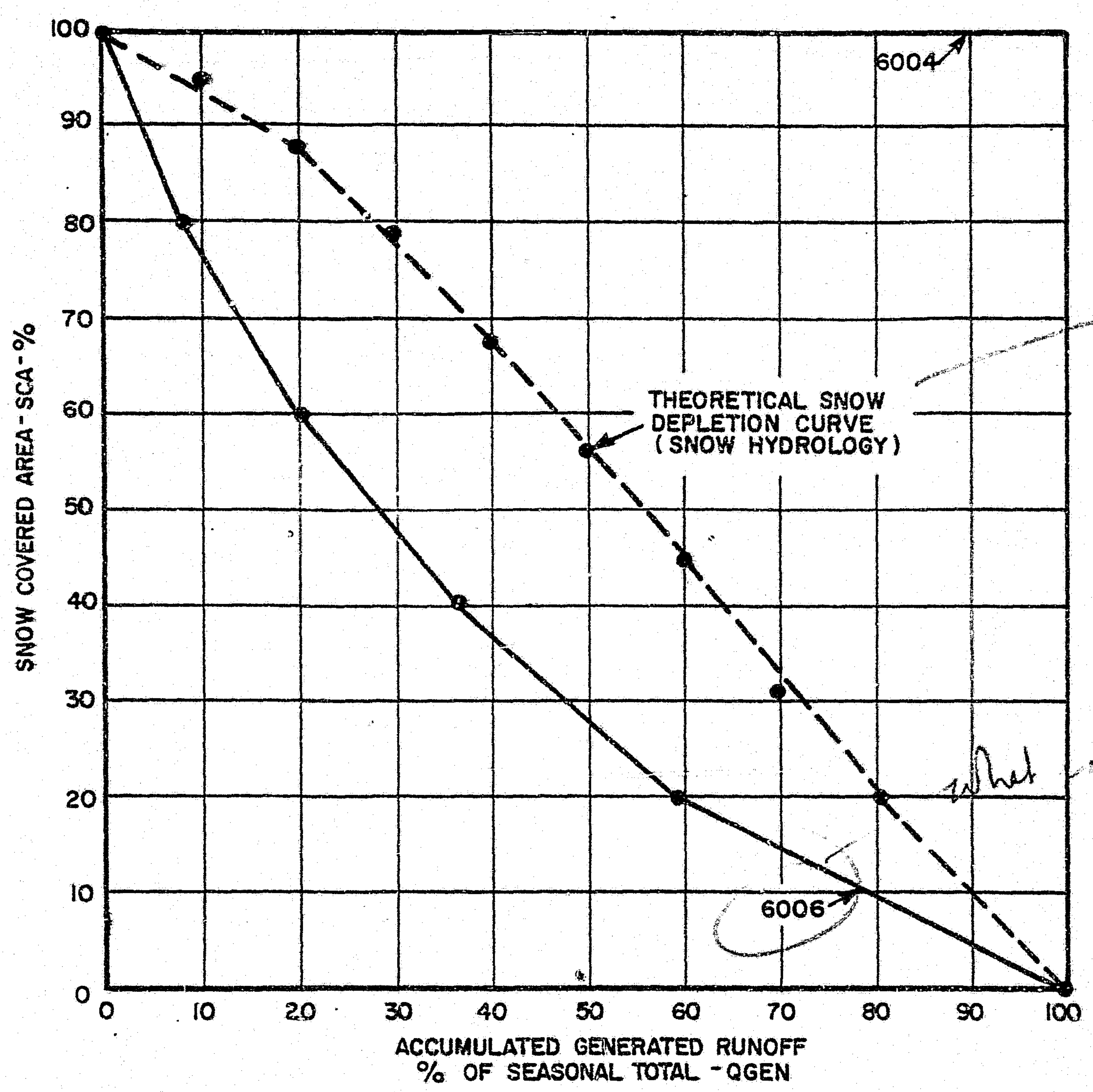

SSARR MODEL QGEN VS SCA

FIGURE 4.7

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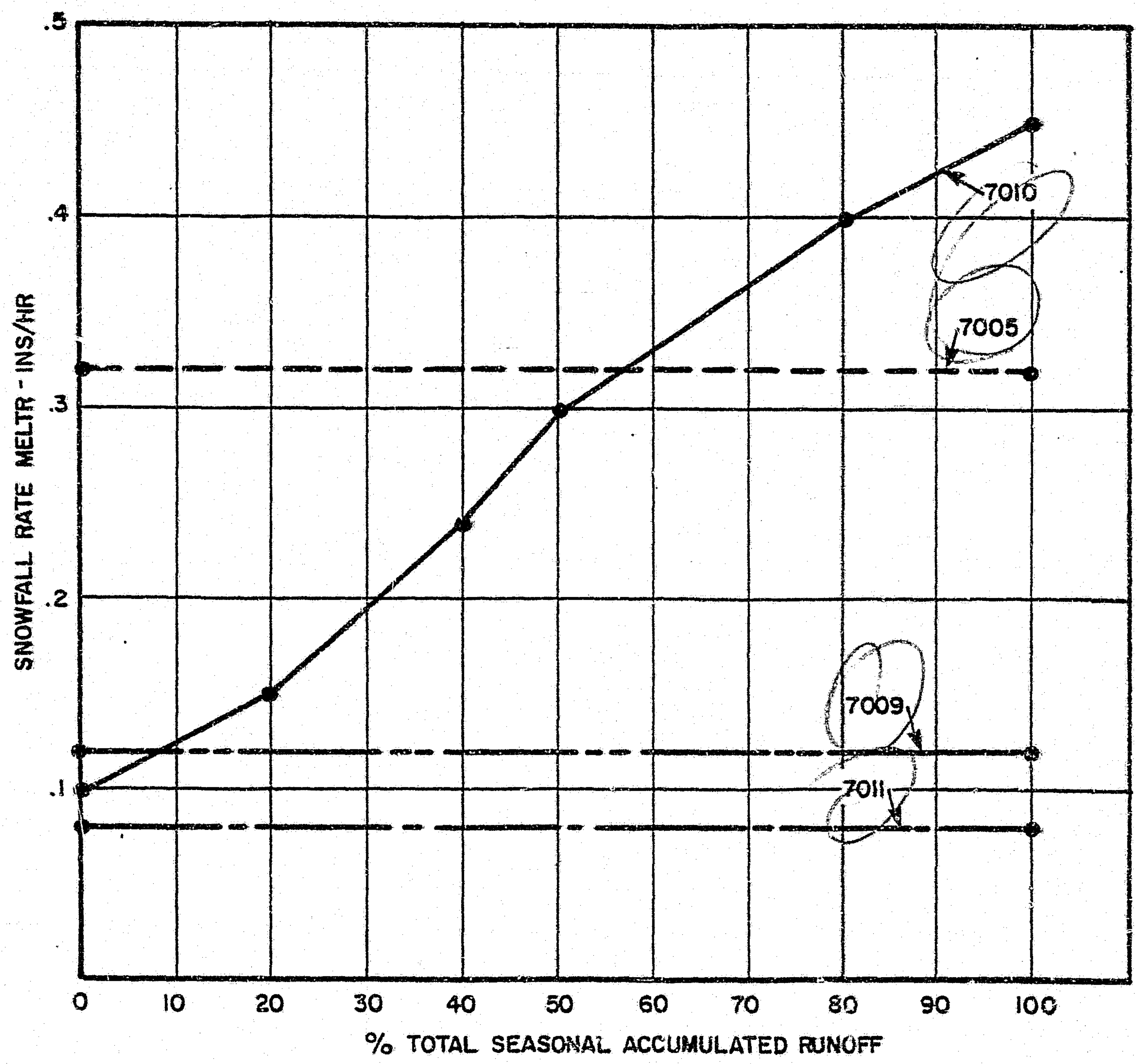
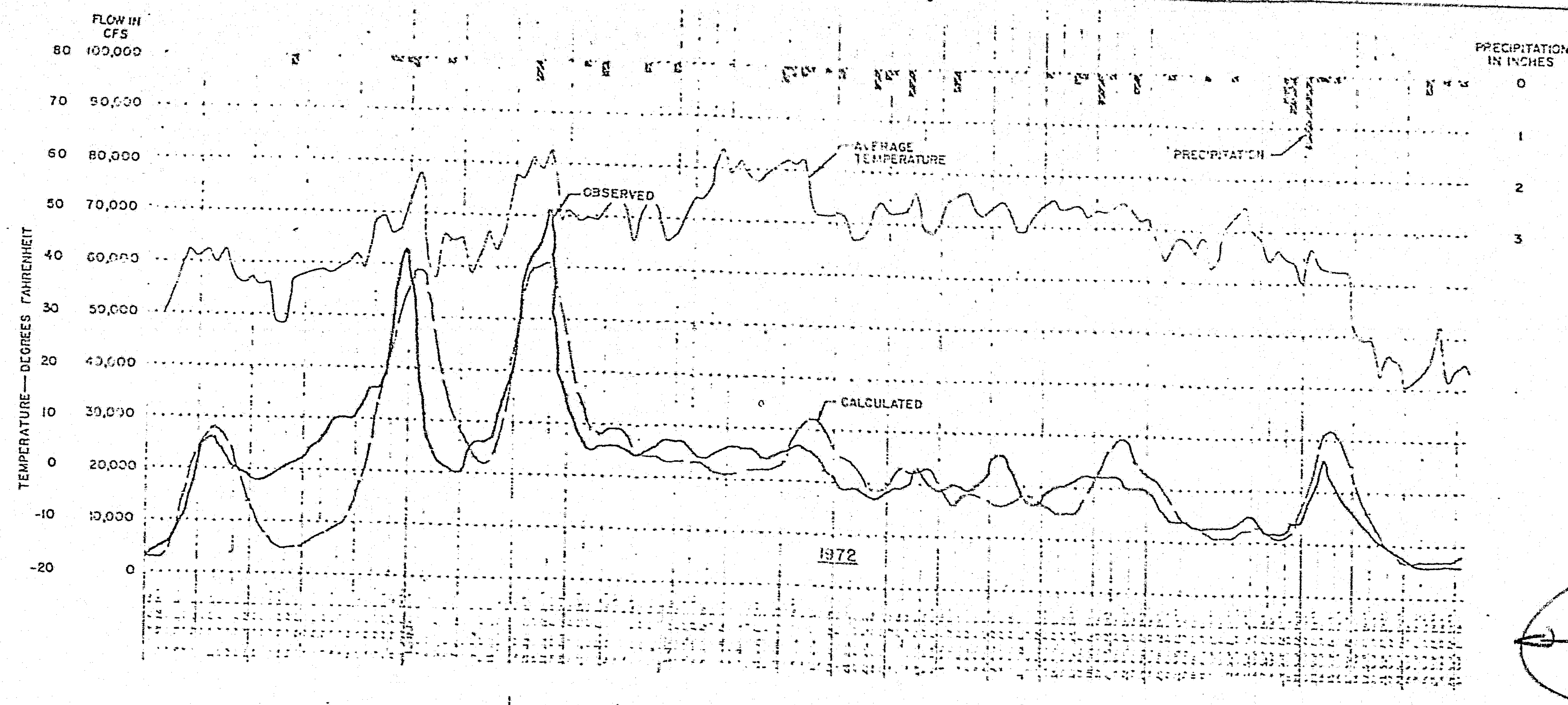
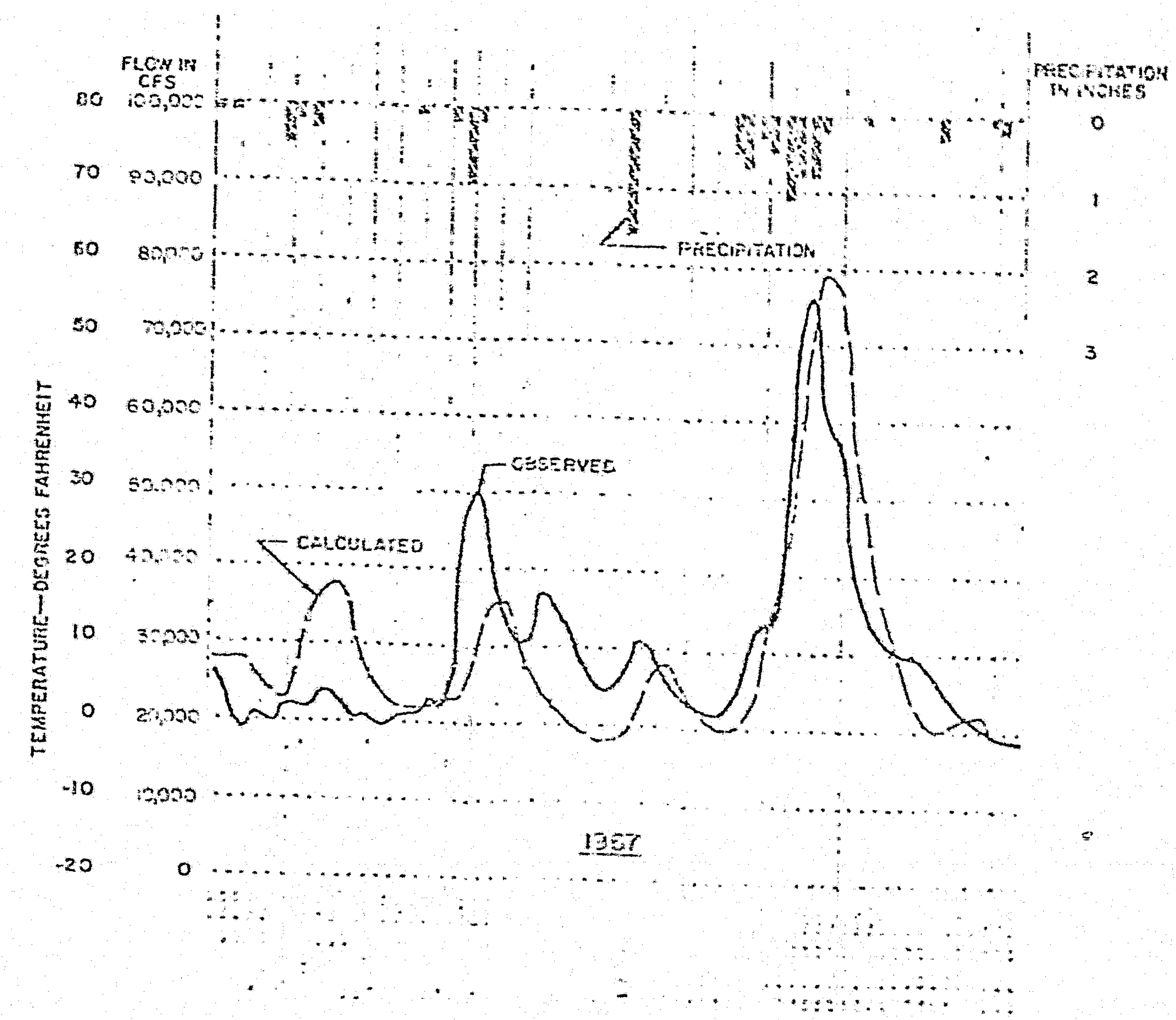


SSARR MODEL QGEN VS MELTR

FIGURE 4.8



not readable



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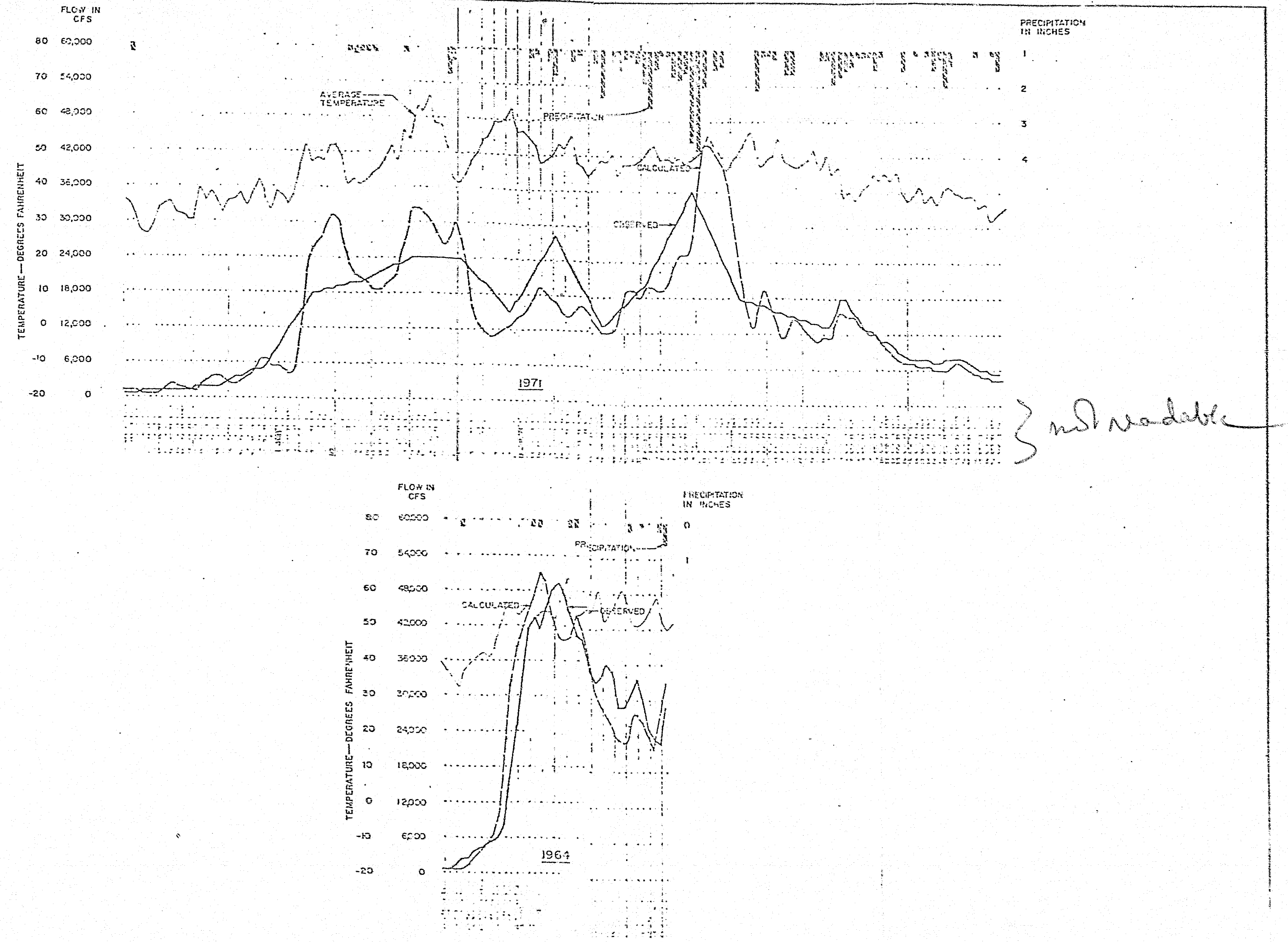
HYDROGRAPH SUSITNA RIVER AT GOLD CREEK

FIGURE 4.9



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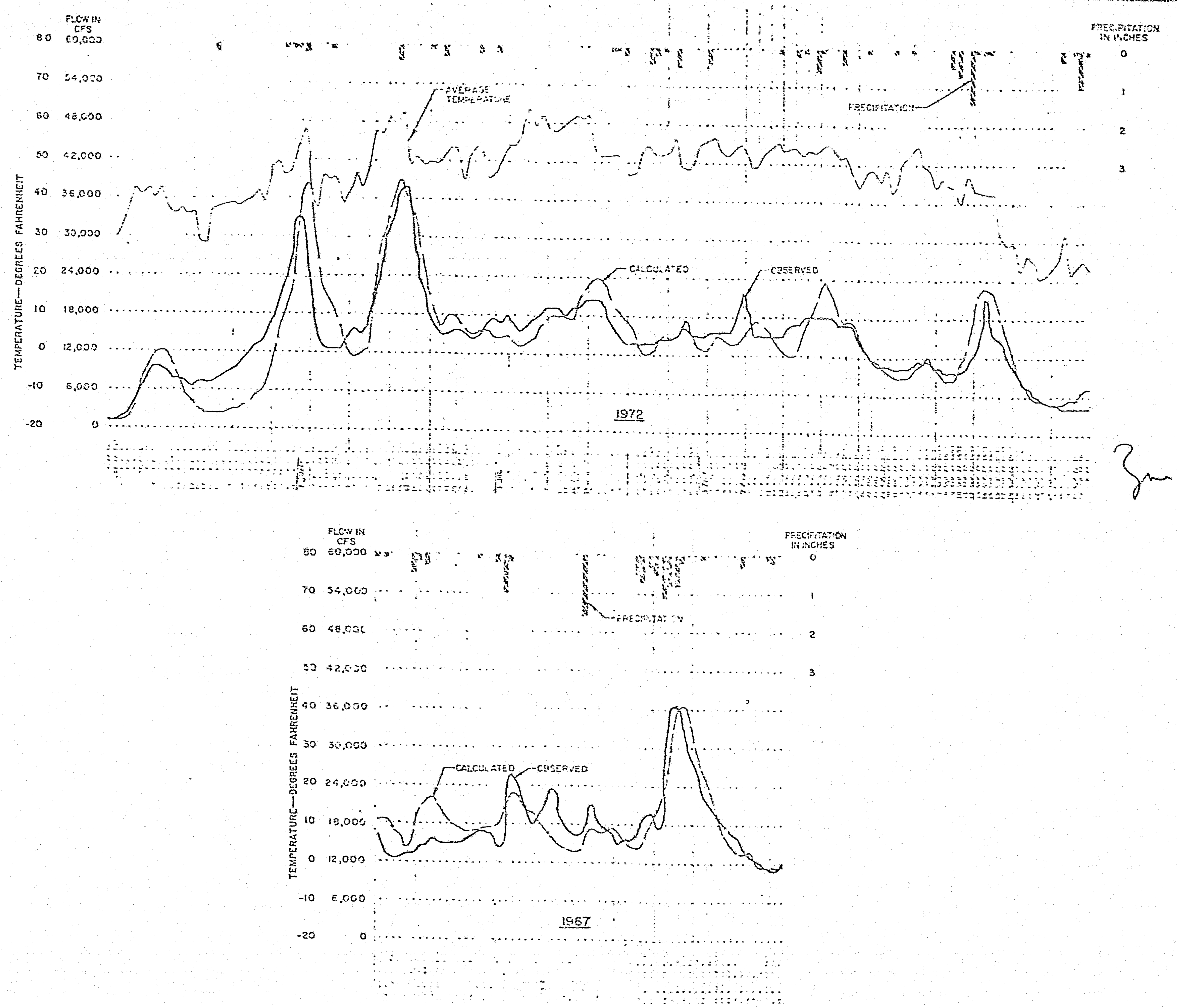
U.S. ARMY CORPS OF ENGINEERS INTERIM FEASIBILITY REPORT, 1975 APPENDIX I PART I

HYDROGRAPHIC SUSITNA RIVER NEAR CANTWELL

FIGURE 4.10



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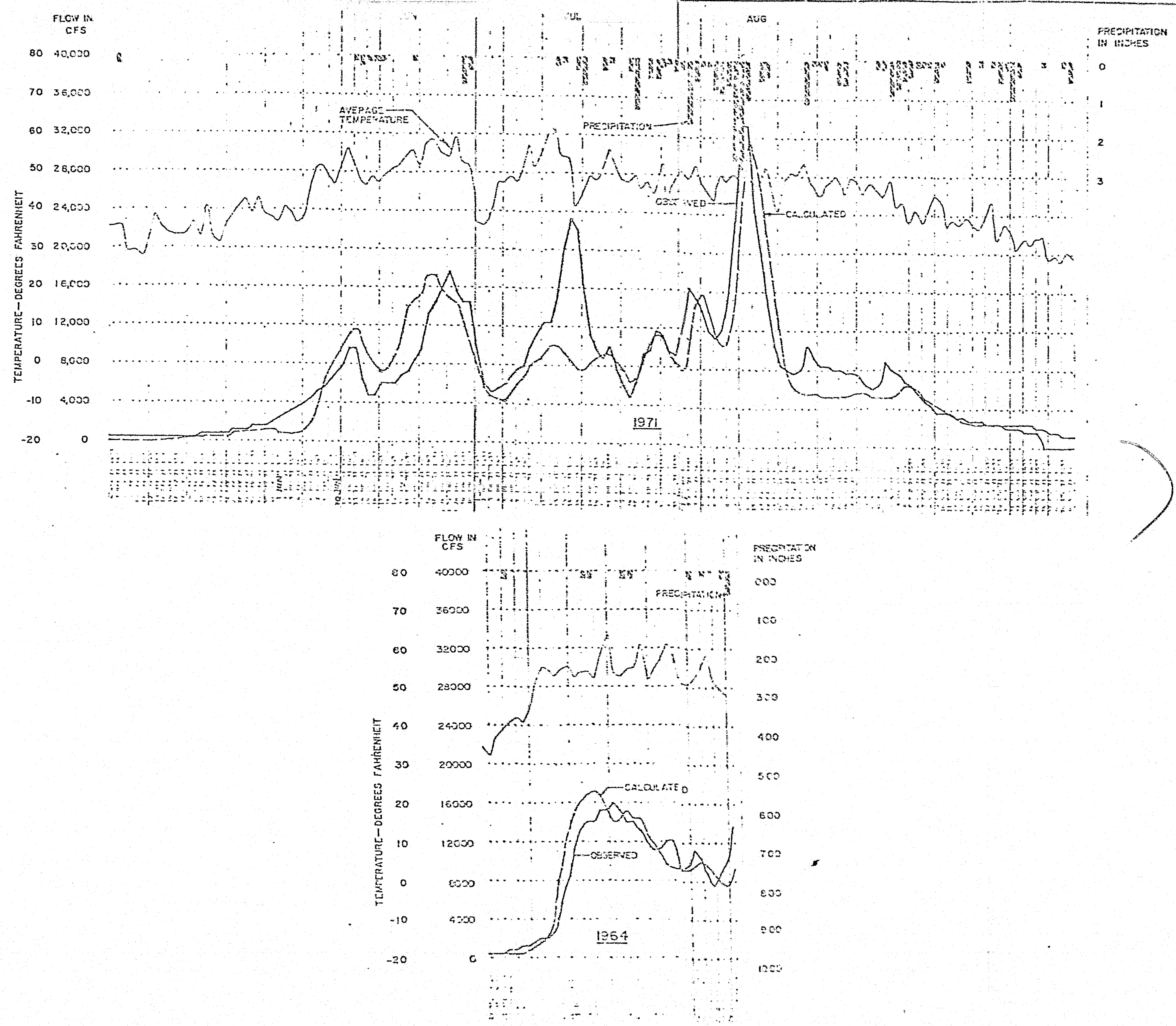
U.S. ARMY CORPS OF ENGINEERS INTERIM FEASIBILITY REPORT, 1975 APPENDIX I PART I

HYDROGRAPH SUSITNA RIVER NEAR CANTWELL

FIGURE 4.11



REFERENCE.
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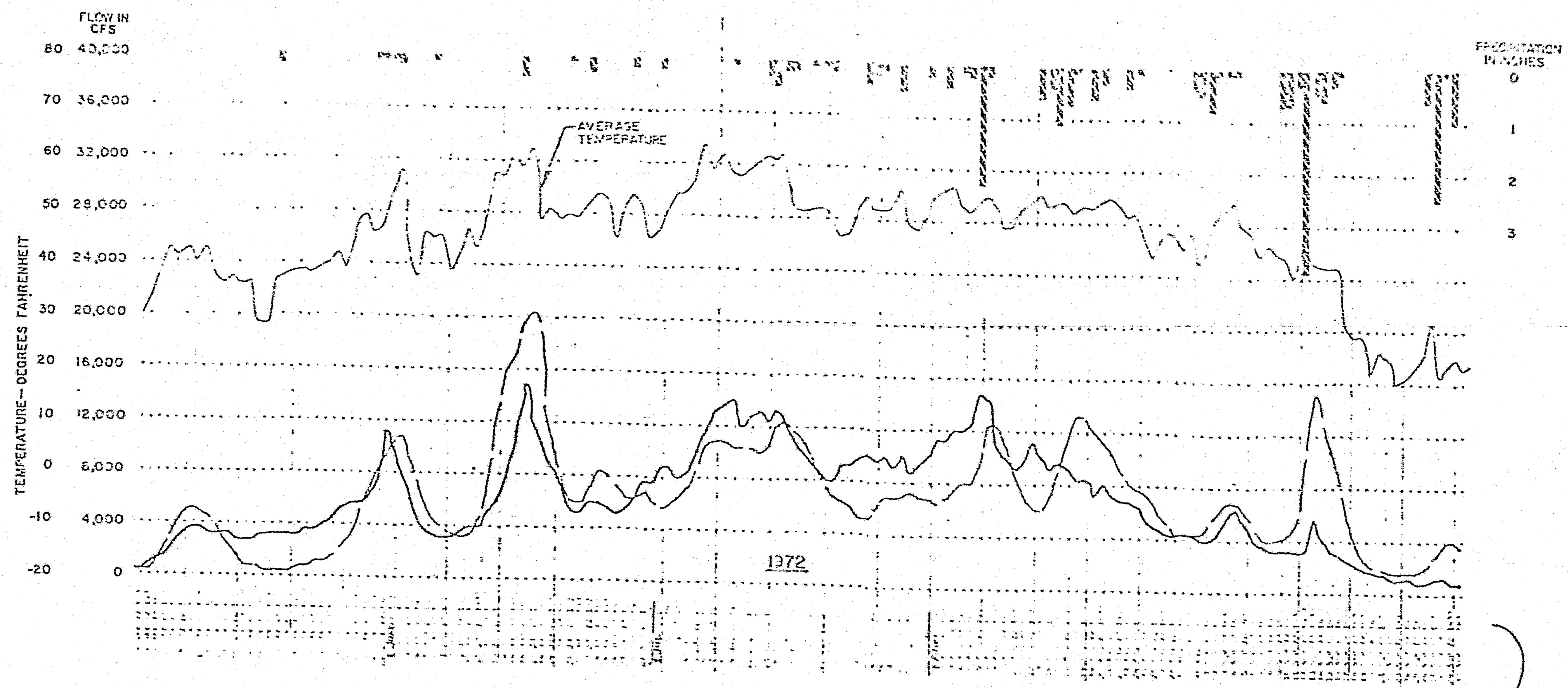
HYDROGRAPH SUSITNA RIVER NEAR DENALI

FIGURE 4.12



REFERENCE:
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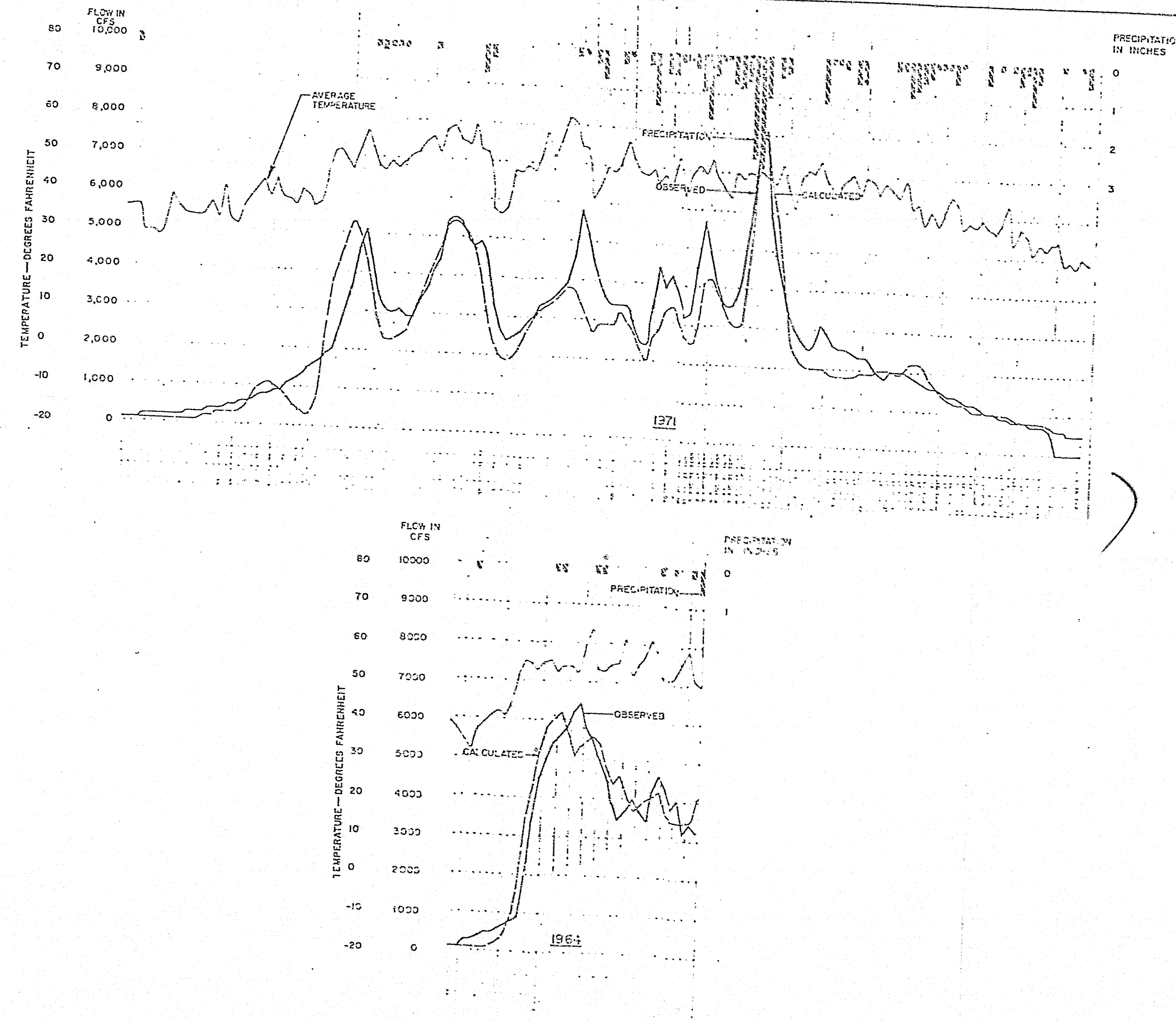
HYDROGRAPH SUSITNA RIVER NEAR DENALI

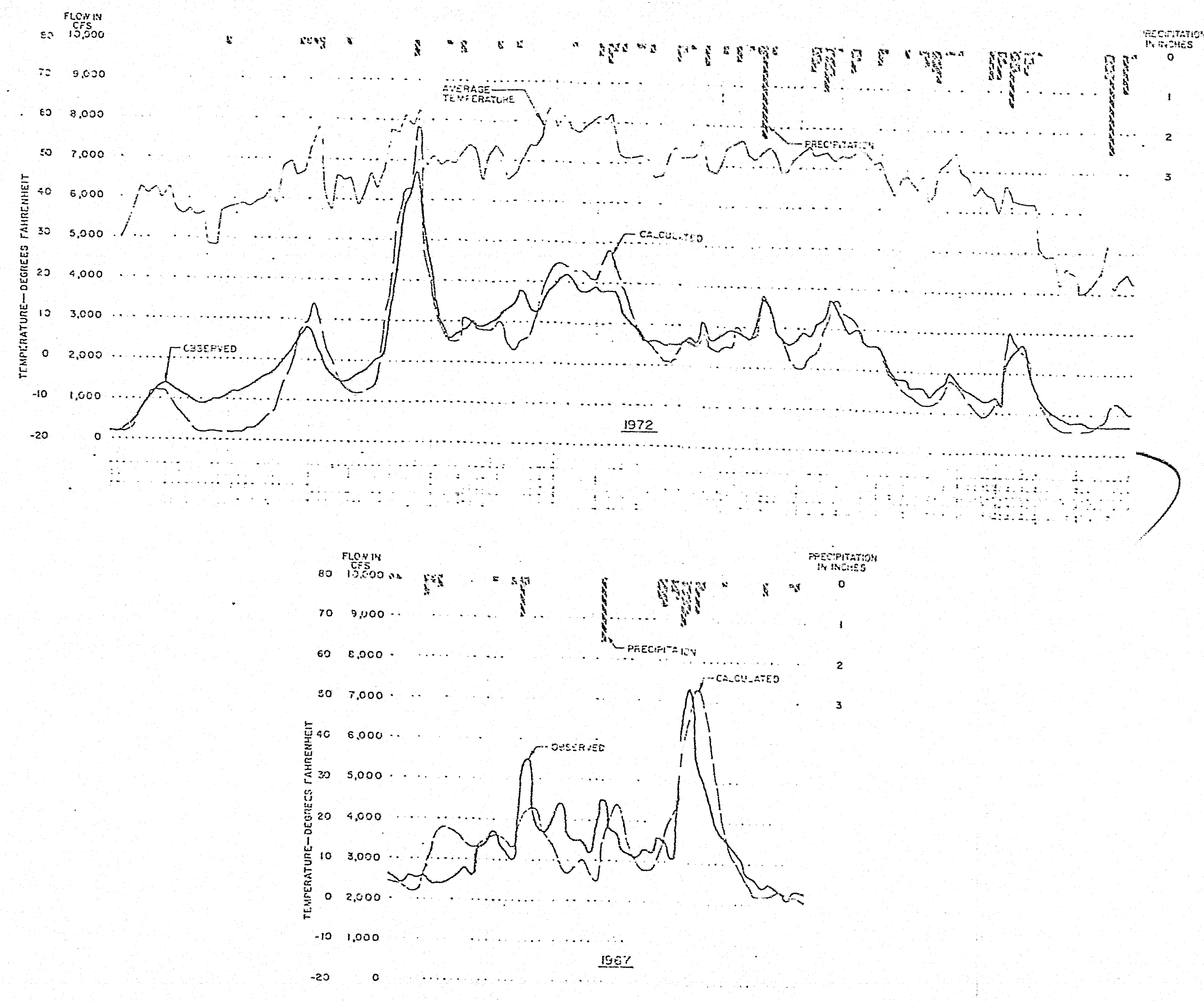
FIGURE 4.13



REFERENCE:
U.S. ARMY CORPS OF ENGINEERS INTERIM FEASIBILITY REPORT, 1975 APPENDIX I PART I

HYDROGRAPH MACLAREN RIVER NEAR PAXSON

FIGURE 4.14



REFERENCE:
U.S. ARMY CORPS OF ENGINEERS INTERIM FEASIBILITY
REPORT, 1975 APPENDIX I PART I

HYDROGRAPH MACLAREN RIVER NEAR PAXSON

FIGURE 4.15

ACRES **Calculations**

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BY DC DATE 23 Feb 81
APP DATE

Table 4.2 COE Calibration ~~Reconstitution~~ Study Results
Susitna River at Gold Creek
USGS Gage No. 15292000 Drainage Area 6160 mi²

Flood Period	Flood Event	Maximum Discharge				% Error	Observed Peak Return Period
		observed	date	Calculated	date		
1964 19 May to 25 June	Snowmelt	85900	7 Jun	80,500	5 Jun	-6.3	?
1967 1 Jul to 31 Aug	Rainfall	76000	15 Aug	78,800	16 Aug	+3.7	
1971 6 May to 30 Sep	Snowmelt	66300	12 Jun	53000	11 Jun	-20.1	–
	Rainfall	77700	10 Aug	74100	12 Aug	-4.6	
1972 2 May to 30 Sep	Snowmelt	70700	17 Jun	60800	17 Jun	-14.0	
	Rainfall	26400	14 Sep	32300	15 Sep	+22.4	–

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APP ____ DATE ____

COE Calibration

Table 4.2 ~~Reconstitution~~ Study Results
Susitna River near Cantwell
USGS Gage No. 15291500 Drainage Area 4140 mi^2

(Cons) Period	Flood Event	Maximum Discharge observed	date	Calculated	date	% Error	Observed Peak Return Period
1964 19 May to 25 June	Snowmelt	49,100	7 June	51,100	4 June	+4.1	
1967 1 Jul to 31 Aug	Rainfall	36,400	15 Aug	36,600	16 Aug	+0.1	
1971 6 May to 30 Sep	Snowmelt	24000	23 Jun	32600	23 Jun	+35.8	–
	Rainfall	36000	9 Aug	44000	11 Aug	+22.2	
1972 2 May to 30 Sep	Snowmelt	37600	17 Jun	37800	17 Jun	+0.5	
	Rainfall	21000	14 Sep	22800	15 Sep	+8.6	–

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Table 4.3 CCE Calibration ~~Reconstitution~~ Study Results
Maclaren River near Paxson
USGS Gage No. 15291200 Drainage Area 280 mi^2

Period	Flood Event	Maximum Discharge observed	date	Calculated	date	% Error	Observed Peak Return Period
1964 19 May to 25 June	Snowmelt	6400	7 Jun	6230	4 Jun	-2.7	
1967 1 Jul to 31 Aug	Rainfall	7280	14 Aug	7290	15 Aug	0.0	
1971 6 May to 30 Sep	Snowmelt	5520	25 Jun	5430	25 Jun	-1.6	
	rainfall	8100	11 Aug	7980	10 Aug	-1.5	
1972 2 May to 30 Sep	Snowmelt	6680	16 Jun	7780	16 Jun	+16.5	
	Rainfall	3980	13 Sep	2950	12 Sep	-25.9	

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Table 44 COE Calibration ~~Reconstitution~~ Study Results
Susitna River near Denali.
USGS Gage No. 15291000 Drainage Area 950 mi²

Period	Flood Event	Maximum Discharge observed	date	Calculated	date	% Error	Observed Peak Return Period
1964 19 May to June 25	Snowmelt	16000	7 Jun	17,200	4 Jun 64	+7.5	
1967 1 Jul to 31 Aug	Rainfall	*	—	16000	16 Aug	—	—
1971 6 May to 30 Sep	Snowmelt	17600	27 Jun	17300	24 Jun	-1.7	—
	Rainfall	33400	10 Aug	31500	11 Aug	-5.7	
1972 2 May to 30 Sep	Snowmelt	14700	16 Jun	20300	17 Jun	+38.1	
	Rainfall	5690	13 Sep	15300	13 Sep	+169	—

* no Record.

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5 - ADDITIONAL SENSITIVITY ANALYSES

5.1 - Introduction

The objective of this part of the study was to obtain an indication of the sensitivity of the model to changes in critical parameters. The sensitivity of the SSARR model to variations in soil moisture index or any of the other physical parameters is small when compared to the model's sensitivity to changes in snowpack volumes, temperature sequences, and the volume and distribution of the PMP storm. Consequently, no changes to the physical parameters were made at this stage and sensitivity studies were only made to study variations in flood peaks due to snowpack, temperature and precipitation changes.

Accepting that no verification of the model has been undertaken, it has been assumed that the model will reasonably reflect the basin's response to PMF input conditions.

ACFES

5.2 - Base Case

The data files for the spring and summer PMF estimate was obtained from the COE and loaded onto the computer system. As a first check, the spring PMF was run again to obtain the same hydrograph as that obtained by the COE in 1975. This indicated that the SSARR program and that data file were unchanged. The COE estimate was used as the base case which each sensitivity run was compared. The base run hydrograph for peak flow periods is given in Figure 5.1

The spring PMF base run is distinguished by two distinct peaks, one due to snowmelt on June 11 and a precipitation-snowmelt maximum on June 16. The decline in discharge between the two peaks is due primarily to a temperature drop during the PMP storm. The temperature sequence used by the COE is given in Figure 5.2. The temperature sequency during the PMP and for the four preceeding days was obtained by the COE from the National Weather Service (now NOAA). The temperature and PMP storm are given in a memo from the NWS to COE and is attached in Appendix B. The temperature sequence used by the COE was divided into the following four periods:

- May 1 to May 28 - This period was given by actual 1971 records at Summit Station

- May 29 to June 10 - This period was synthesized by the COE to obtain the maximum flood peak. For this period, the COE tried three temperature sequences as shown on Figure 5.2. The peak discharge was obtained with the third and lowest temperature used.

- June 11 to June 16 - This period follows the recommended temperature as computed from values given by the NWS, Appendix A.

- June 17 to July 30 - Records for Summit in 1971 applied.

Precipitation in the base run consists of two storms, on centered on May 31 and represents the 1:100 year storm and the other the PMP storm centered on June 15. The intensity of the two storms are given in Tables 5.1 and 5.2. Snowpack was obtained by estimating maximum water equivalents and gross smoothing to obtain a contour map of water equivalents throughout the basin, Figure 5.3.

Basin parameters used during the base run have been given in Section 4.1 and are duplicated for the sensitivity runs described below.

Dewpoint ?

5.4 - Sensitivity Runs

Three main groups of sensitivity runs were performed to determine the effect on the flood peak due to like changes in temperature, snowpack and precipitation input data. These are discussed below.

(a) Temperature Sensitivity

The COE may have over-estimated the temperatures in May resulting in too much runoff prior to the critical snowmelt period in June. In some cases, notably in the lower reaches of the basin, snow cover has been depleted to as much as 60% of the available area. In the base run, approximately 1270 sq. miles or 20% of the basin is snow free before the critical snowmelt period. Although it is recommended that some melting should occur prior to PMP storms, to ripen the snowpack and saturate soil moisture, it is believed that a cooler May could result in a higher flood peak. Temperature records at Summit indicate a normal monthly temperature for May of 37.4°F. Consequently, a temperature of 32°F has been assumed as representative of a cool May. Coldest mean May temperature on record at Summit station is 29.1°F. The sharp rise in temperature necessary to produce substantial snowmelt has been further delayed in June to attempt a juxtoposition of maximum runoff from snowmelt and precipitation. The temperature sequence assumed is given in Figure 5.4.

The assumed temperature sequence produced a peak inflow to Watana reservoir of 243,000 cfs as compared to 233,000 cfs for the base run. This represents a 4.3% increase in peak inflow. The hydrograph is given in Figure 5.5. The above results indicates that spring PMF estimates are relatively insensitive to temperatures during May.

The sensitivity of peak discharge to temperature gradients immediately before severe storms is believed to be important. The results of the COE runs in obtaining the critical temperature sequence immediately before the PMP storm did not take into account the temperature gradient; only the timing of the temperature rise. The three temperature sequences assumed are essentially parallel as shown in Figure 5.2. The effects of a sharp temperature rise are mainly in producing very large amounts of snowmelt in short periods of time. This effectively saturates soil moisture capacity very quickly resulting in quick runoff and large streamflow rises. The temperature gradient is consequently of the more influencial parameters in the estimation of peak spring floods. The temperature gradient is also one of the main parameters that should be maximized with the usual constraints beeing applied based on what are reasonable for the basin.

The COE has a temperature rise of approximately 4.3°F/day over a six day period. Records at Talkeetna Airport and Summit Station indicate that temperature gradients of this order are typical for May and June and therefore cannot be assumed to be representative of extreme events.

The determination of the maximum observed temperature rise in May or June is beyond the scope of work under this task. However, it appears from a very cursory appraisal of available data that a temperature gradient of about twice that assumed by the COE may be close to a maximum. Consequently, a sensitivity run with a temperature gradient of 8.5°F/day has been performed. In addition, the temperatures during the PMP storm have been increased by 9°F to produce a maximum temperature of 66°F instead of 57°F. This is believed to be not unreasonable based on records available at Summit and other stations.

The above changes to temperatures produced an inflow peak of 302,000 cfs an increase of 29.6%, Figure 5.5. Obviously, the temperature gradient prior to the PMP storm and temperatures during the storm are very important parameters in determining PMF discharges. The temperatures selected, although higher than assumed by the COE, are not unreasonable. However, it should be noted that the temperatures were only selected to determine the sensitivity of peak discharges to such changes and do not necessarily represent the sequence that should be used.

(b) Initial Snowpack Sensitivity

The derivation of snowpack quantities for each sub-basin of the study area has been based on records from stations outside the area and on judgement. The available data was only available for lower elevations. The method used to obtain snowpack amounts was to accumulate the maximum recorded snowfall for the months of November through April. This produced snowpack amounts at various points surrounding the basin. Using available regional mean precipitation distributions, the COE developed a minimum water equivalent contour map for the basin, Figure 5.3. This was further averaged to given snowpack water equivalents for each sub-basin as shown in Table 5.3.

The additional years of records obtained from the snow course stations, subsequent to the COE studies and the data obtained from the additional stations established during 1980 do not indicate that any significant heavy snow accumulations have occurred. Consequently, no conclusive statements as to the accuracy of the assumed snowpack water equivalents used by the COE can be made. In all the spring PMF estimates, the COE has not assumed any precipitation during May. Therefore, it can only be assumed that May precipitation is also included in initial snowpack amounts.

The sensitivity of the peak discharge to initial snowpack water equivalents has been determined by increasing the initial snowpack by 50%. This analysis was in fact performed by the COE in 1975 and was not repeated by AAI. The peak inflow to Watana was found to increase to 254,000 cfs, a 9.0% increase, Figure 5.1. The result indicates that the PMF peaks are fairly insensitive to changes in initial snowpack water equivalents.

(c) Precipitation Sensitivity

The PMP estimates ~~conducted~~ made for the COE by the NWS involved only a summer rainfall event. The NWS recommended that 70% of the summer PMP be used as the PMP storm for spring PMF estimates. No basis for this decision to use 70% PMP is given in either NWS or COE documents and ~~it would be difficult~~ to defend this number. A separate study of spring storms would have been more appropriate.

To determine sensitivity to changes in quantity of precipitation falling on the basin, it was decided to assume that the full PMP occured in June, but remains centered on June 15. To observe only the effect of the precipitation change it was decided to assume antecedent conditions equal to these in the base run except for 50% more initial snowpack water equivalent. Temperature sequences were unchanged.

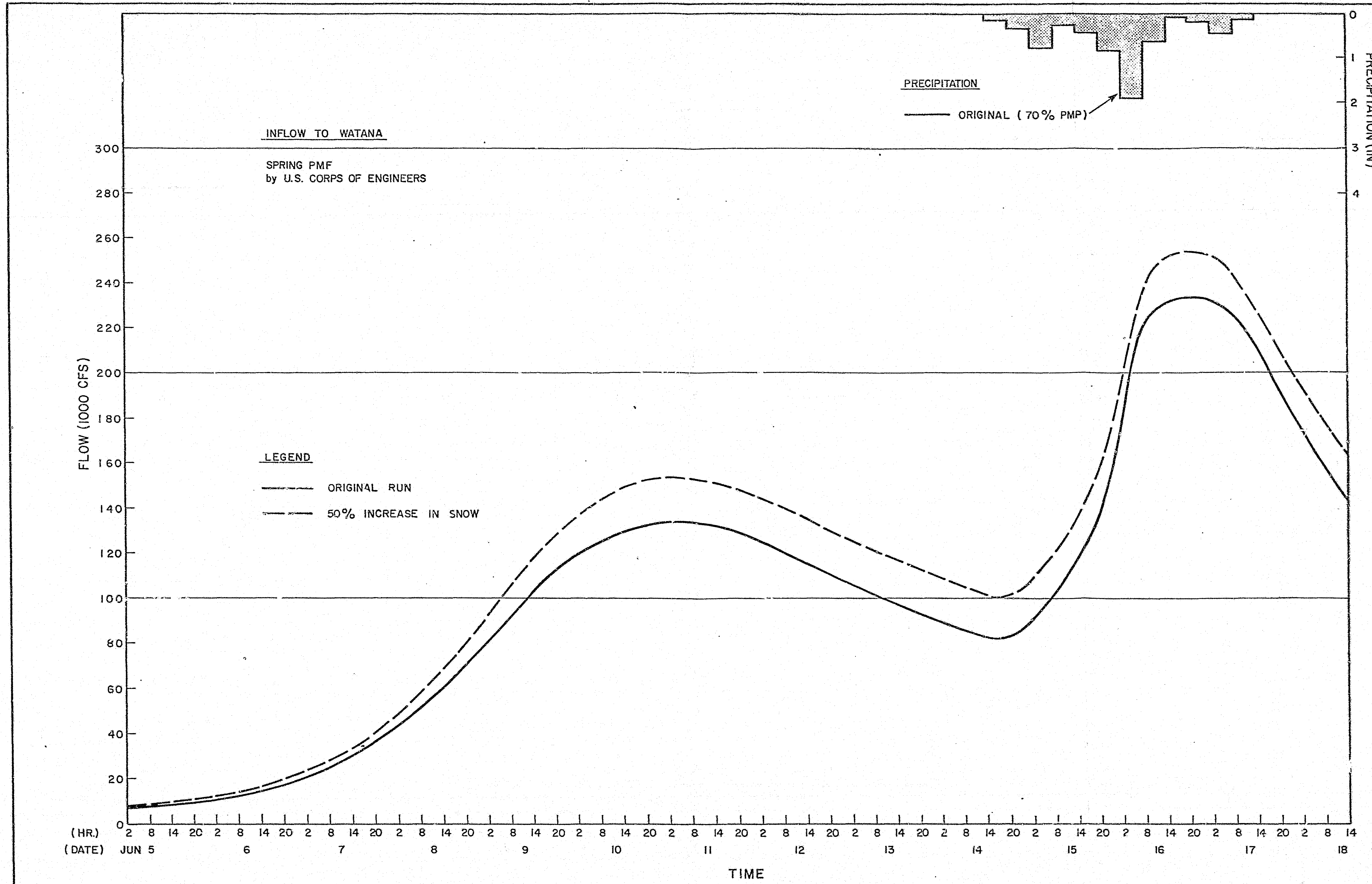
The result of this run is a substantial increase in peak inflow to Watana to 342,000 cfs, a 46.8% increase Figure 5.5. Obviously, it may not be correct that the recommended PMP storm occurs in June, but the result of this run clearly indicates that precipitation amounts are by far the most important parameters in PMF estimation. It is therefore essential to ensure that a well defined PMP storm be used for flood ~~station~~ estimation purposes.

As a concluding run, it was decided to obtain an estimate with the case of ~~full~~ PMP storm with the 8.5°F/day temperature rise to a maximum of 66°F. This run clearly indicates that the PMF estimate can change substantially when what can be regarded as plausible changes to a range of input parameters are made. The peak inflow to Watana obtained from this combination was 430,000 cfs, an increase of 85%. Outflow from Watana Reservoir obtained from the above sensitivity runs are shown on Figure 5.6.

5.4 - Summary

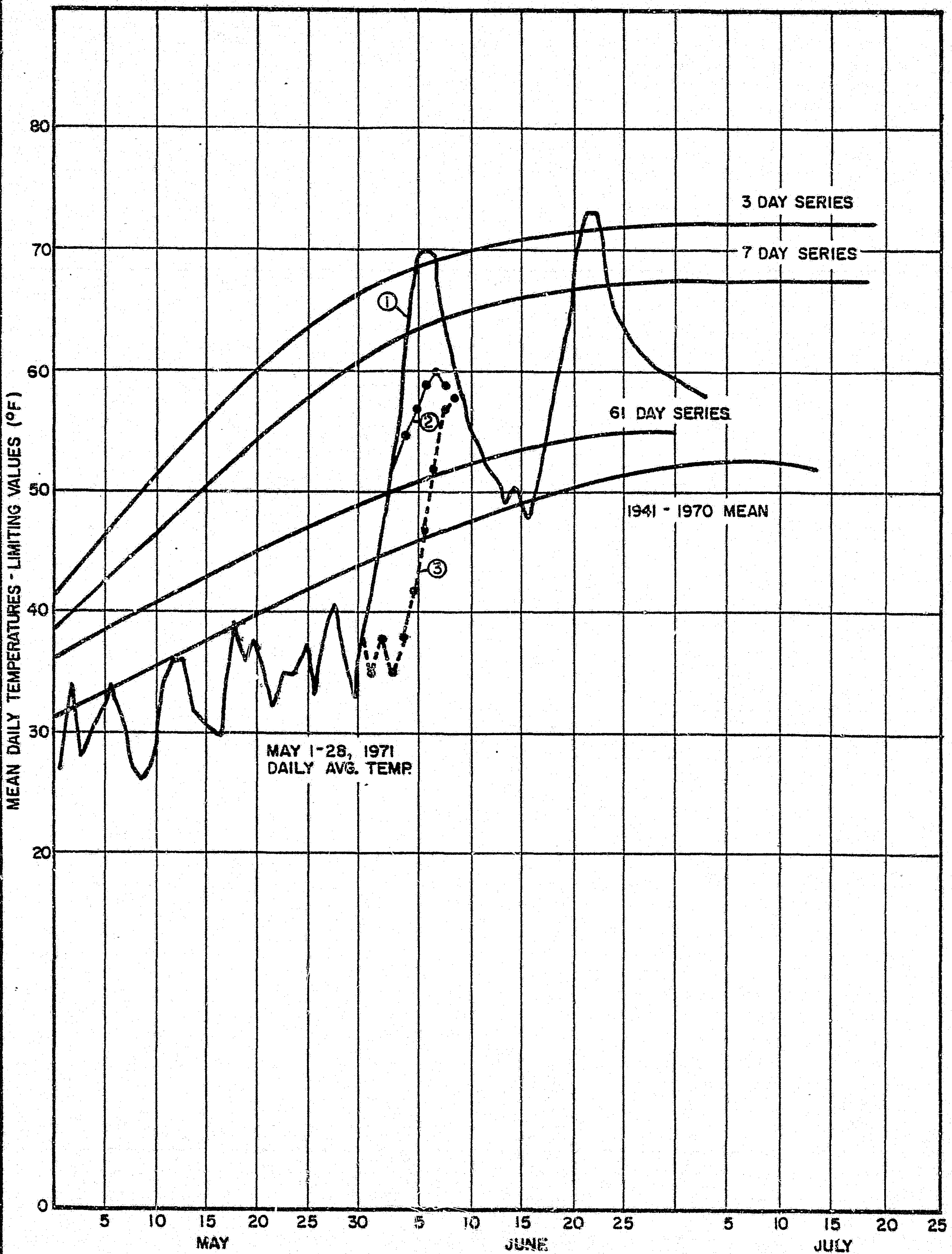
The sensitivity runs indicate that the estimates of peak inflow to Watana Reservoir and discharges at any other locations are particularly sensitive to variations in ~~snowpack water equivalents~~, temperature gradient and temperature maximums, and precipitation volumes and intensity. Sensitivity to changes in sub-basin parameters are small relative to the sensitivity of the basin to the three main input parameters given above. Table 5.4 summarizes each sensitivity run and gives the percent change from the COE estimate for inflow into Watana Reservoir. Percent changes to inflow for Devil Canyon Reservoir are summarized in Table 5.5

Tables for fig.



INFLOW TO WATANA FIGURE 5.1

ACRES

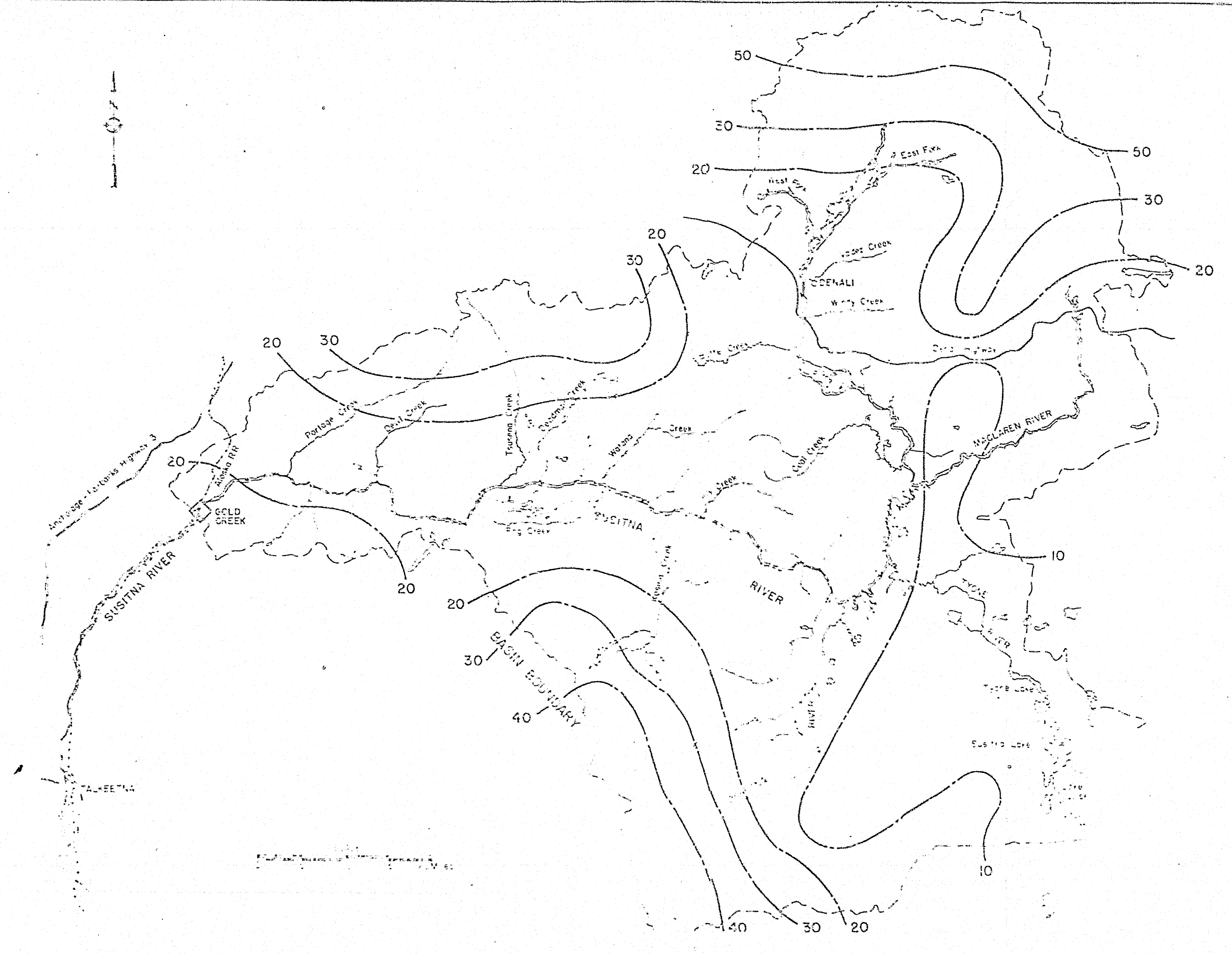


SPRING PMF TEMPERATURE REGIME (COE)

REFERENCE:
U.S. ARMY CORPS OF ENGINEERS
INTERIM FEASIBILITY REPORT,
1975 APPENDIX I PART I

ACRES

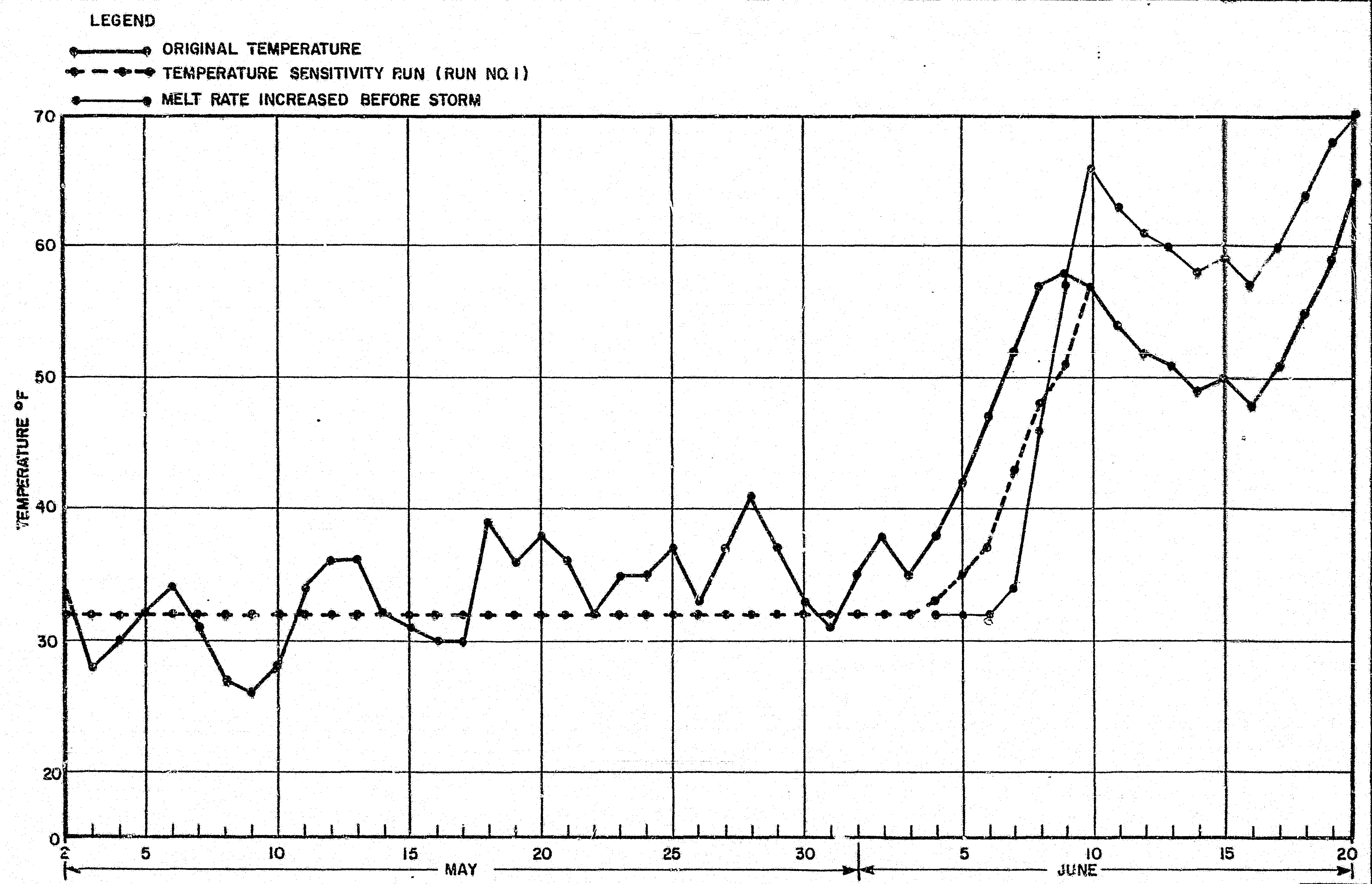
FIGURE 5.2



REFERENCE:
U.S. ARMY CORPS OF ENGINEERS
INTERIM FEASIBILITY REPORT, 1975
APPENDIX I, PART I

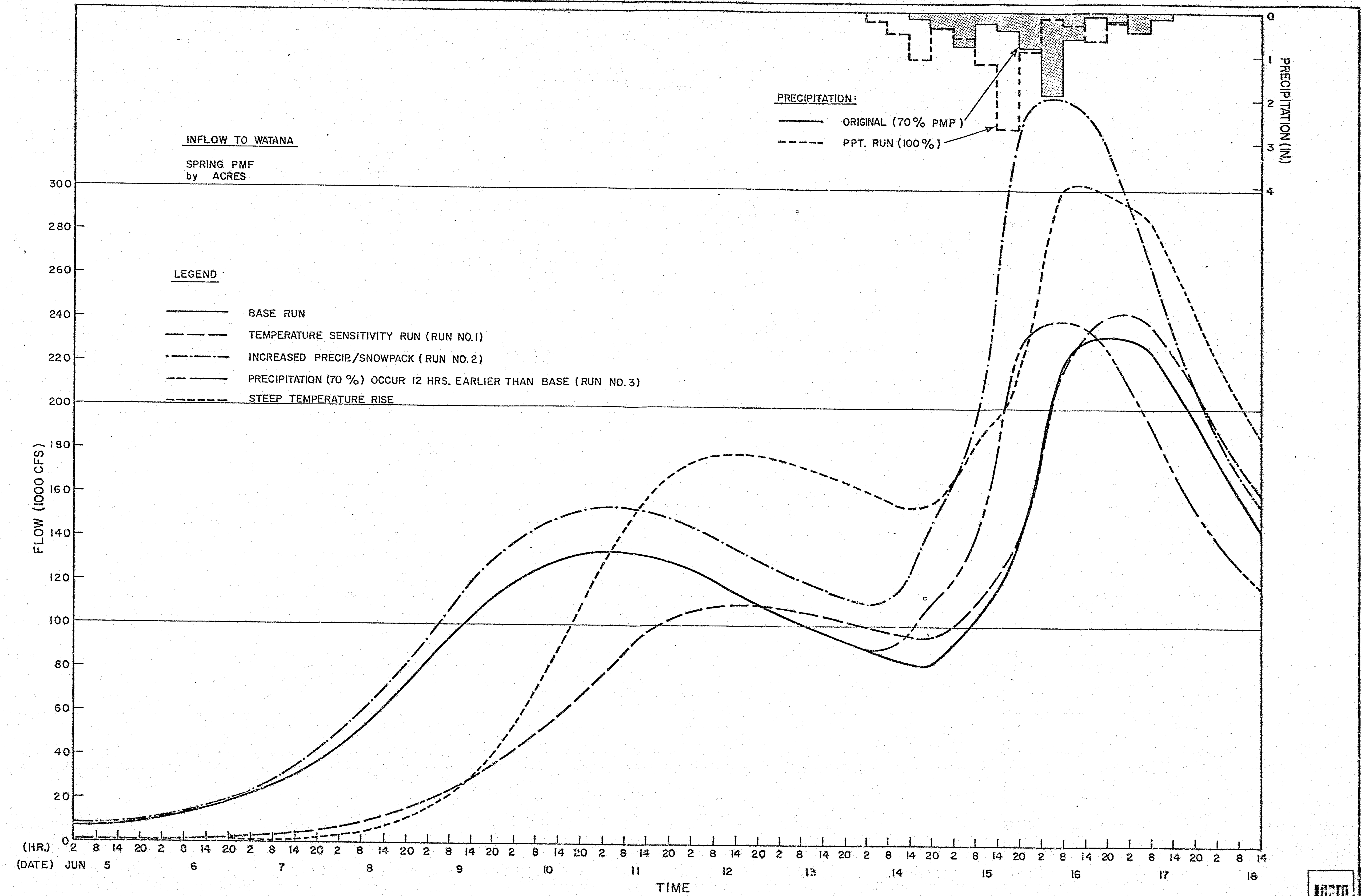
ASSUMED SNOW PACK

FIGURE 5.3



SPRING PMF TEMPERATURE SEQUENCE 2 MAY - 20 JUNE

FIGURE 5.4



INFLOW TO WATANA FIGURE 5.5

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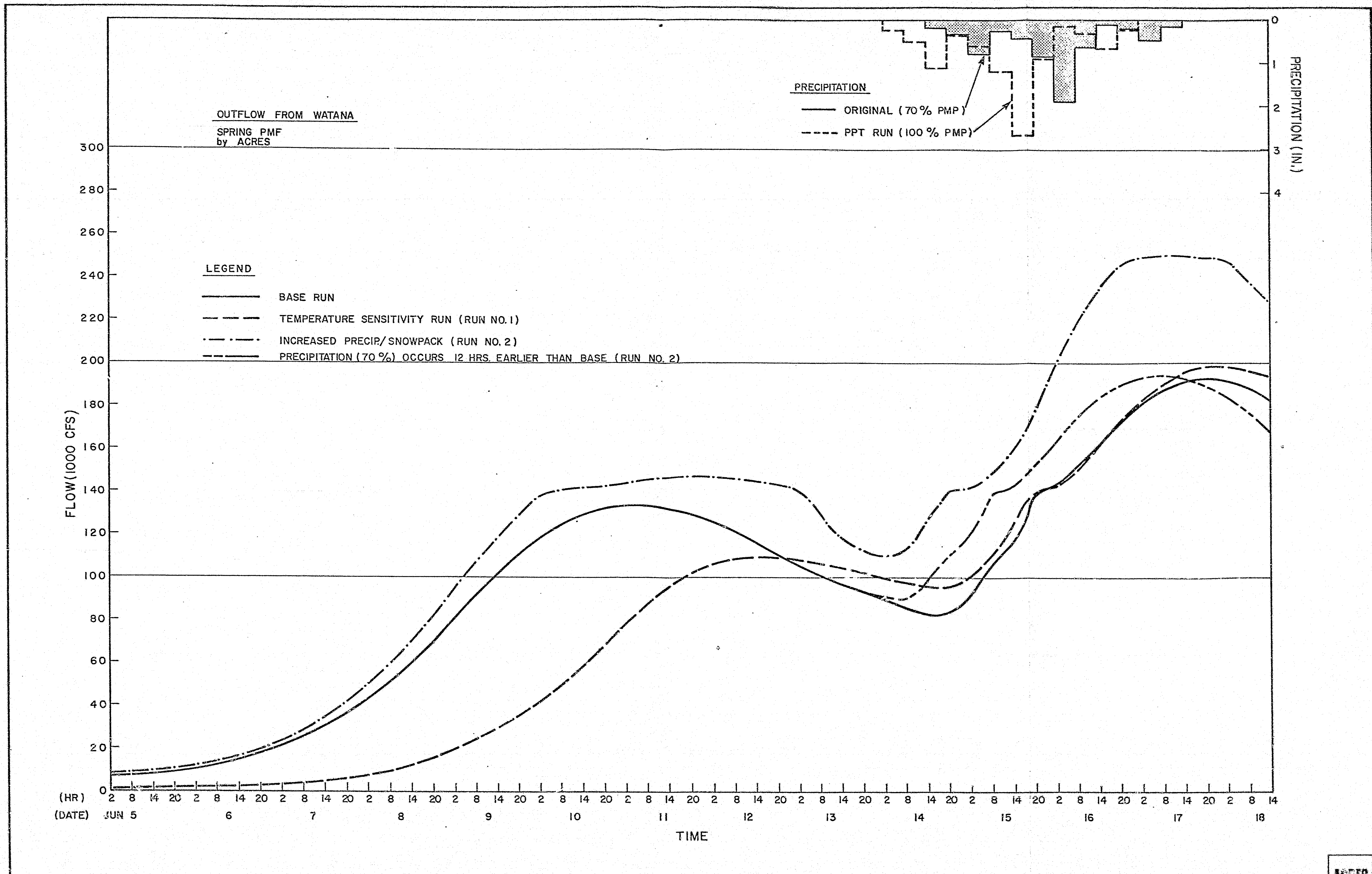

OUTFLOW FROM WATANA FIGURE 5.6

TABLE 5.1 Precipitation — 1:100 YR STORM (inches).

Hour	1st Day	2nd Day	3rd Day	
0 - 6	.04	.14	.04	
6 - 12	.07	.29	.09	
12 - 18	.17	.65	.21	
18 - 24	.06	.22	.07	
Total	.34	1.30	.41	Σ 3.05 ins

TABLE 5.2 Precipitation — Propable Maximum Precipitation (inches)

Hour	1st Day	2nd Day	3rd Day	
0 - 6	.25	.6	.15	
6 - 12	.50	1.2	.30	
12 - 18	1.12	2.7	.67	
18 - 24	.38	.9	.23	
Totals	2.25	5.40	1.35	Σ 9.0 ins

5.3

Table 8 Snowpack Water Equivalents on May 1.

Subbasin		Minimum Snowpack (ins)	
Code	Name	COE	AAI
10	Denali Glacial	99	99
20	Denali non-glacial	36	54
80	Denali Local	15	23
180	Local above Maclaren Confluence	14	21
210	Maclaren Glacial	99	99
220	Maclaren non-Glacial	27	41
280	Maclaren Local	13	20
330	Lake Louise	10	15
340	Tyone	12	18
380	Oshetna	26	39
480	Watana Local	25.5	38
580	Tsusena Local	21	32
680	Portage Local	21.5	32

ACRES **Calculations**

SUBJECT:

JOB NUMBER
FILE NUMBER
SHEET OF
BY R. Stow DATE 3 Nov 81
APP DATE

TABLE 5.4 Summary of Sensitivity Runs – WATANA

Watana

Run Description	Maximum Inflow FT³/s	% Increase From Base	Maximum Outflow FT³/s	% Increase From Base
COE – BASE RUN	233,000	0.0	192,000	0.0
Temperature Sensitivity Run	243,000	4.3	198,000	3.1
Storm Timing Sensitivity	239,000	2.6	194,000	1.0
Precipitation/Snow Pack Sensitivity	342,000	47	250,000	30
Increased Temperature Gradient Senitivity	302,000	29.6	243,000	26.6
Combined Case Sensitivity	430,000	84.5		
COE Snow Pack Sensitivity	254,000	9.0	232,000	17

what is the max water level at watana for these routing exercises?

FORM NO. 152 REV. 1

ACRES

Calculations

SUBJECT:

JOB NUMBER

FILE NUMBER

SHEET OF

BY R. Stowe DATE 3 Mar 81

APP DATE

TABLE 5.5 SUMMARY OF SENSITIVITY RUNS - DEVIL CANYON.

DEVIL CANYON

RUN DESCRIPTION	MAXIMUM INFLOW (FT^3/S)	% INCREASE FROM BASE	MAXIMUM OUTFLOW (FT^3/S)	% INCREASED FROM BASE
COE - BASE RUN	226,000	0.0	222,000	0.0
Temperature Sensitivity Run	233,000	3.1	229,000	3.2
Storm timing Sensitivity	229,000	1.3	224,000	0.9
Precipitation/Snow Pack Sensitivity	302,000	33.6	290,000	30.6
Increased Temperature Gradient Sensitivity	282,000	24.8	275,000	23.9
Combined Case Sensitivity				
COE Snow Pack Sensitivity	272,000	20.4	262,000	8.0

FORM NO. 152 REV. 1

6 - CONCLUSIONS AND RECOMMENDATIONS

6.1 - Conclusions

The basis of any model of physical processes is the ability to accurately simulate the processes with different input conditions. The model must therefore be calibrated to within acceptable limits by the selection of the best combination of parameters, coefficients and relationships that make up the model. The calibration of the SSARR model by the COE has produced inconclusive and indefensible results. The acceptance of the parameters in the SSARR model is therefore not fully justifiable. The acceptance of the model is further compounded by the lack of any verification runs. Therefore, we conclude that the procedures of calibration should be repeated and several verification runs be made to prove the acceptability of model parameters and the accuracy limits that can be applied to PMF estimates.

The estimate of flood flows is particularly sensitive to precipitation. The estimate of the PMP storm was derived by analyses performed by the National Weather Service in early 1975. No comment can be made on the validity of these precipitation analyses as no back-up computations are available or even which form of storm maximization procedure was used. Due to the sensitivity of the PMF estimate to precipitation, further analyses to develop both a spring PMP and a summer PMP is required. These analyses should be performed under established guidelines and with reliable procedures.

In conjunction with precipitation maximization, studies should be conducted to determine reasonable temperature sequences. The sequences determined should define antecedent temperatures (cool period followed by a sharp temperature rise) and temperature during storm periods. It is particularly important to redefine maximum dew point temperatures.

The present snow course data should be utilized in determining areal distributions of snowfall, particularly the distribution with respect to elevation. Unfortunately, the first year records (1980-1981) are indicating a below normal snowfall, so it is unlikely that a better definition of maximum snowpack water equivalents can be determined.

Records collected within the basin should now be utilized to reconstitute discharges for 1981. The reconstitution with more representative temperature and precipitation data may lead to a more accurate model of the physical characteristics of the basin and will probably reduce the error in estimating peak flows at the various collection points.

6.2 - Recommendations

It is recommended that a more comprehensive PMF study be undertaken as soon as possible so that the results can be incorporated in the ongoing engineering feasibility studies.

This more comprehensive study should include the following:

- recalibration of the SSARR computer model using the data collected within the basin since the COE study;
- verify the acceptability of the model and define limits of accuracy by applying independent input data not used in calibration studies;
- redefinition of the probable maximum precipitation during spring and summer periods;
- the maximum likely dew point temperatures and temperature gradients plus temperatures during severe storm events should be redefined;
- the appropriate timing of the precipitation and temperature events should be reassessed and used in conjuction to re-evaluate the PMF.

- results to be available by ———— for inclusion
- feasibility design of ... application

References

(1) U.S. Army Corps of Engineers "Interim Feasibility Report, Southcentral Railbelt Area, Alaska," Appendix 1, Part 1, Section A, 1975

APPENDIX A

DRAFT

TO: Mr. Vernon K. Hagen
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Corps of Engineers
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Washington, D.C. 20314

FROM: John T. Riedel
Chief, Hydrometeorological Branch

SUBJ: Tentative Estimates of Probable Maximum Precipitation (PMP) and Snowmelt Criteria for Four Susitna River Drainages

Introduction

The Office of Chief of Engineers, Corps of Engineers requested PMP and snowmelt criteria for the subject drainages in a memorandum to the Hydrometeorological Branch, dated December 12, 1974. The Alaska District requested the study be completed by February 1, 1975; however, a more realistic date for completing a study in which we have confidence is June 1, 1975. Because of the need to soon begin hydrologic studies based on meteorological criteria, the Branch has concentrated on the problem and has determined the general level of criteria. A range of PMP values are given in this memorandum within which we believe values from a more comprehensive study will fall. The sequences of snowmelt winds, temperatures, and dew points should be checked with additional studies. In addition, if we knew in detail how snowmelt will be computed, we could give emphasis to the more important elements.

PMP estimates for four drainages

A range of estimates of PMP for 6, 24, and 72 hours for four drainages outlined on the map accompanying the December 12, 1974 memorandum are listed in table 1. These are numbered from 1 to 4 (smallest to largest).

The estimates are for the months of August and September - the season of greatest rainfall potential. For the snowmelt season, multiply the estimates by 70 percent.

The estimates take into account numerous considerations including several methods of modifying PMP estimates made previously for other Alaska drainages, and PMP estimates from the Western United States for areas with similar terrain.

Temperatures and Dew Points for Snowmelt

A. During PMP Storm

1. Dew point for PMP centered on June 15 = 56°F (assume maximum 1-day PMP in middle of 3-day storm).

2. For PMP placement prior to June 15 subtract 0.8°F for each 3-day period prior to June 15 (e.g., the PMP dew point for June 12 will be 55.2°F). This -0.8°F per 3-days may be applied to obtain the maximum 1-day dew point during the PMP back to as early as May 15.

3. For first day of PMP storm, subtract 1°F from criteria of 2; for 3rd day of PMP storm subtract 2°F.

4. Add 2°F to each of the three daily dew points to get daily temperatures for the 3-day PMP period.

B. Temperatures and Dew Points Prior to 3-Day PMP Storm (High dew point case)

Adjustment to temperature and dew point on day of maximum PMP

Day prior to PMP	Temperature (°F)	Dew point (°F)
1st	-2	-2
2d	-1	-4
3rd	0	-4
4th	+1	-5

C. Temperatures, Dew Points Prior to 3-day PMP
(High temperature case)

Adjustment of temperature and dew point on
day of maximum PMP

Day prior to PMP	Temperature (°F)	Dew point (°F)
1st	+1	-12
2d	+2	- 9
3rd	+4	- 7
4th	+7	- 6

Elevation Adjustment

For the 3 days of PMP and for the high dew point case apply a -3°F per 1000 ft to the temperatures and dew points. The basic criteria are considered applicable to 1000 mb or zero elevation.

For the high temperature criteria apply a -4°F per 1000 ft increase in elevation.

Half-day Values

If half-day values are desired for temperatures and dew points, the following rules should be followed:

1. For the high-temperature sequence, apply an 18°F spread for temperatures and a 6°F spread for dew point. For example, for a mean daily dew point of 50°F, the half-day values would be 47°F and 53°F.

2. For the high dew point case, apply a 12°F spread for temperature and a 4°F spread for dew point.

3. In no case, however, should a 12-hr dew point be used that exceeds the 1-day value for that date. For example, the value not to be exceeded for June 15 is 56°F, for June 3 (four 3-day periods before June 15) is 52.8°F.

Wind Criteria for Snowmelt

Since two sets of criteria (one emphasizing high temperature and the other high dew point sequences) are given for snowmelt prior to PMP, two sets of wind criteria are also necessary since the pre-PMP synoptic situation favoring high temperatures differs from the criteria favoring high dew points. The recommended winds, tables 2 and 3, are given by elevation bands. In the high dew-point case, table 2, (where synoptic conditions exist favoring maritime influences prior to PMP), the same wind for 4-days prior to PMP is appropriate.

All of the winds presented in tables 2 and 3 have been adjusted for applicability over a snow surface. Although a seasonal variation in the high dew point wind criteria is realistic for the present tentative criteria, they are considered applicable to May and June.

Snowmelt Winds During the PMP

Wind criteria for the 3-day PMP are the same for both the high temperature and high dew point sequences. They are shown in table 4.

Snow Pack Available for Melt

Some work was done in determining the mean and maximum October-April precipitation of record for the available precipitation stations. These stations and other data are tabulated in table 5. The drainages and available stations are shown in figure 1.

Table 5 also shows the years of record available for October-April precipitation, as well as a column labeled "synthetic October-April precipitation." This gives the sum of the greatest October, greatest November, etc., to the greatest April precipitation total from the available record. These synthetic October-April precipitation values and the means are plotted on figure 1.

Approximately 9 years of snow course data are available for 14 locations in and surrounding the Susitna drainage. From these records, the greatest water equivalents were plotted on a map. These varied from a low of 6 inches at Oshetka Lake (elevation 2950 ft) to an extreme of 94.5 inches at Gulkana Glacier, station C (elevation 6360 ft). A smooth plot of all maxima against elevation gave a method of determining depths at other elevations. Figure 2 shows resulting smooth water equivalents based on smoothed elevation contours and this relation.

Some additional guidance could be obtained from mean annual precipitation maps. One such map available to us is in NOAA Technical Memorandum NWS AR-10, "Mean Monthly and Annual Precipitation, Alaska." The mean annual of this report covering the Susitna drainage is shown in figure 3.

Also on this figure is shown the mean runoff for three portions of the Susitna River drainage based on the years of record shown. No adjustment has been made for evapotranspiration or any other losses. This indicates that the actual mean annual precipitation is probably greater than that given by NWS AR-10.

Conclusion. Time hasn't allowed checks, evaluation, and comparison of the several types of data summarized here. It appears the "synthetic October-April precipitation" generally is less than the maximum depths over the drainages based on snow course measurements. There depths, or figure 2, would be considered the least that could be available for melt in the spring.

Further Studies

The variation of precipitation with terrain features in Alaska is important but yet mostly unknown and unstudied. More effort should be placed on attempts to develop mean annual or mean seasonal precipitation maps, at least for the region of the Susitna River. Some 10 years of data at about a dozen or so snow courses could be used in this attempt, as well as stream runoff values.

Some work has been done toward estimating maximum depth-area-duration values in the August 1967 storm; an important input to the present estimates. Attempts should be made to carry out a complete Part I and Part II for this storm, although data are sparse and emphasizing the use of streamflow as a data source.

The objective of these two studies with regard to the Susitna drainages is to attempt a better evaluation of topographic effects, and to make a better evaluation of snow pack available for melt.

Study of additional storms could give some important conclusions and guidance on how moisture is brought up the Cook Inlet to the Talkeetna Mountains and how these mountains effect the moisture.

Snowmelt criteria in this quick study is limited to 7 days. Considerably more work needs to be done to extend this to a longer period. Then we would need to emphasize compatability of a large snow cover and high temperatures. More known periods of high snowmelt runoff need to be studied to determine the synoptic values of the meteorological parameters.

Table 1

General level of PMP estimates for 4
Susitna River drainages

Drainage Number	Area (sq mi)	72-hr PMP (in.)
1	1260	9-12
2	4140	7.5-10.5
3	5180	7-9
4	5810	7-9

For 24-hr PMP, multiply 72-hr value by 0.60.

For 6-hr PMP, multiply 72-hr value by 0.30.

PMP for intermediate durations may be obtained from a plotted smooth curve through the origin and the 3 values specified.

Table 2

Snowmelt Winds preceding PMP for Susitna Basins
for high dew point sequence

Elevation (ft)	Daily Wind speed* (mph)
sfc	8
1000	9
2000	12
3000	18
4000	25
5000	34
6000	36
7000	37
8000	39
9000	40
10,000	42

*For each of the 4 days preceding the 3-day PMP.

Table 3

Snowmelt winds preceding PMP for Susitna Basins
for high temperature sequence

Elevation (ft)	Daily wind speed (mph) Day prior to 3-day PMP			
	1st	2nd	3rd	4th
sfc	10	13	4	4
1000	10	13	4	4
2000	11	14	5	5
3000	12	16	5	5
4000	13	16	6	6
5000	13	17	6	6
6000	14	18	6	6
7000	15	20	6	6
8000	16	20	7	7
9000	16	20	7	7
10,000	17	21	7	7

Table 4

Winds during 3-day PMP

Elevation (ft)	Wind speed (mph)		
	Day of maximum PMP	Day of 2nd highest PMP	Day of 3rd highest PMP
sfc	12	9	8
1000	14	10	9
2000	19	14	12
3000	29	21	18
4000	42	31	27
5000	56	42	36
6000	58	44	38
7000	62	46	40
8000	64	48	41
9000	68	51	44
10,000	70	52	45

Table 5

Stations with Precipitation Records in and surrounding the Susitna Drainage

Station	Elevation (ft.)	Yrs of record for complete Oct.-Apr. precipitation	Maximum obs. Oct-Apr. prec. (in.)	Yr. of Maximum	Mean Number of months for synthetic Oct.-Apr. season	Synthetic Oct.-Apr. precip. (in.)	Mean Oct.-Apr. Precip. (in.)
Susitna Meadows	750	4	17.18	70-71	4	23.18	13.77
Gulkana	1572	18	6.77	56-57	18	12.68	4.19
Paxson	2697	2	8.42	43-44	6	14.25	7.64
Trims Camp	2408	3	23.26	59-60	5	35.82	15.3
Summit	2401	19	14.09	51-52	20	26.59	7.93
Talkeetna	345	35	21.17	29-30	37	40.59	12.26
Sheep Mountain	2316	13	11.91	59-60	12	18.42	4.78

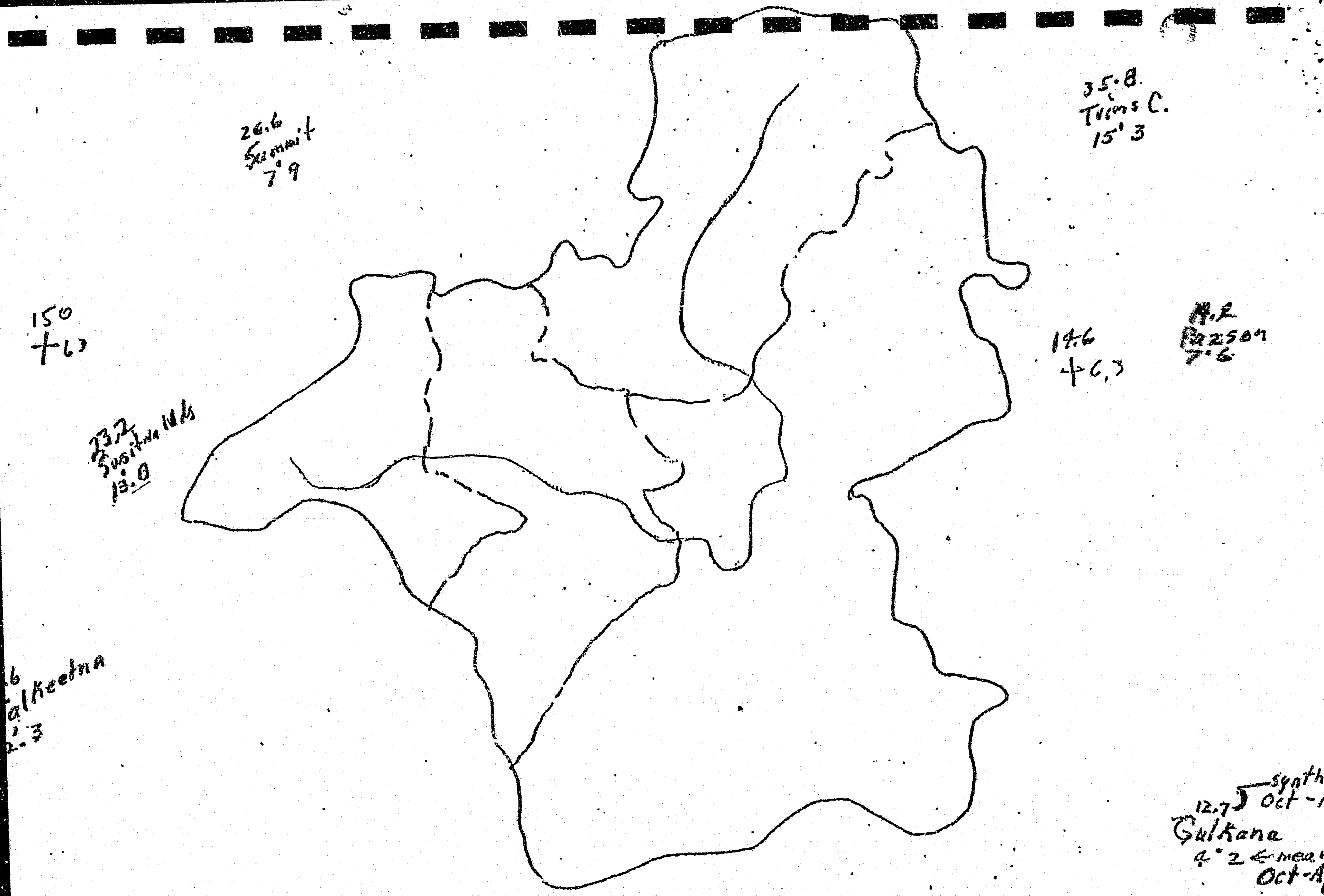

Figure 1.--Drainage outlines and October-April precipitation in inches.
(Upper values = synthetic October-April precipitation;
Lower = mean October-April precipitation.)

18.4
Sharp Mtn

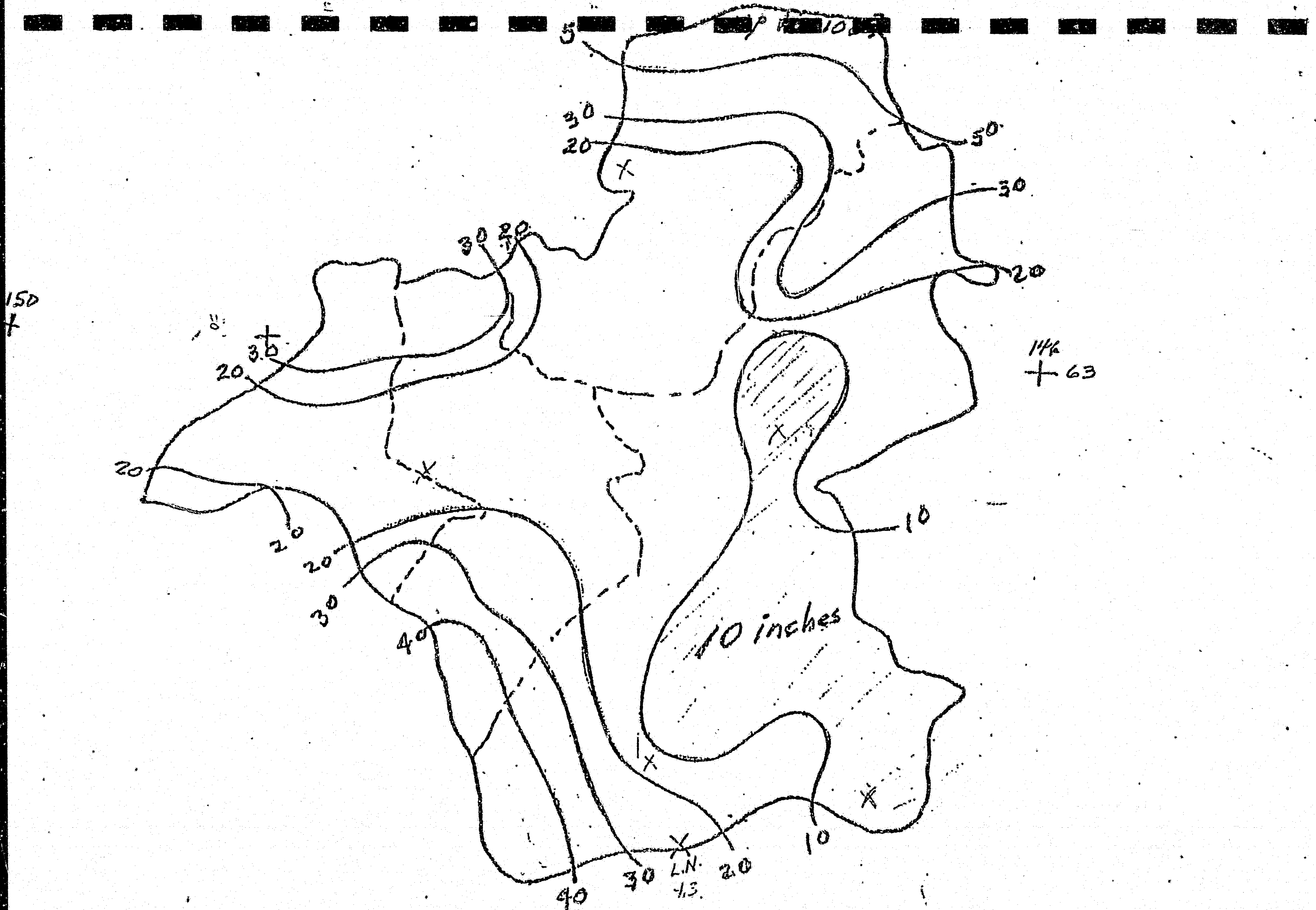

Figure 2.--Minimum water equivalents of snow pack in inches (based on gross smoothing of maximum snow course measurements.)

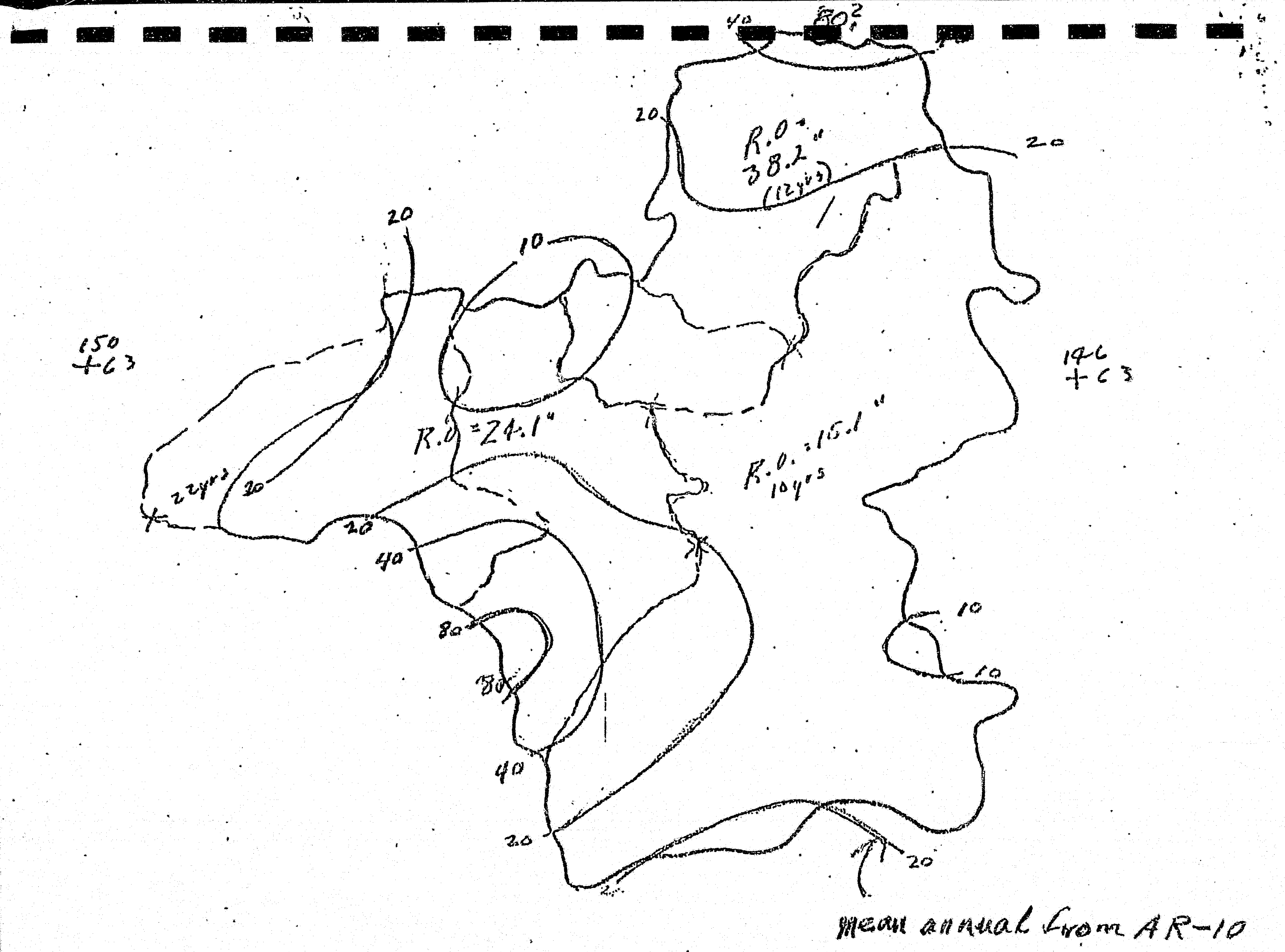

Figure 3.--Mean annual precipitation and stream runoff (in inches).