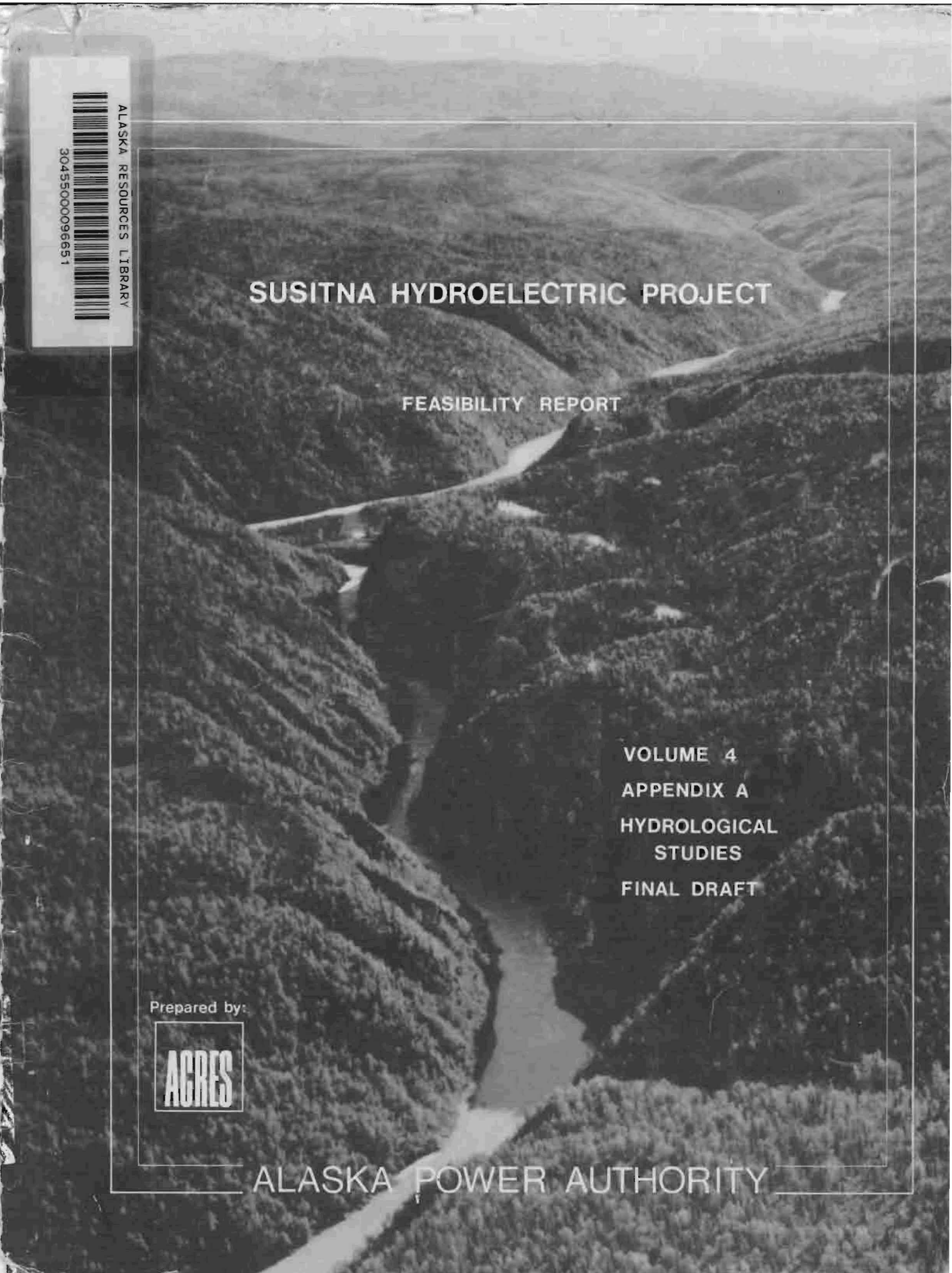
ALASKA RESOURCES LIBRARY
30455000096651



# SUSITNA HYDROELECTRIC PROJECT

## FEASIBILITY REPORT

VOLUME 4

APPENDIX A

HYDROLOGICAL STUDIES

FINAL DRAFT

Prepared by:

ACRES

ALASKA POWER AUTHORITY

SET I.D. No. 00007
COPY No. 04
Merged With A.R.L.I.S.
ANCHORAGE, ALASKA
Est. 1997

DATE DUE

| | | | |
|---|---|---|---|
| ~~4/26~~ | | | |
| ~~29 DEC 1982~~ | | | |
| ~~APR 2 2 1984~~ | | | |
| ~~27 MAR 1991~~ | | | |
| ~~06 MAY 1991~~ | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

HIGHSMITH 45-220

MAR 17 1982
ALASKA RESOURCES LIBRARY
U.S. Department of the Interior
Merged With
ARLIS
ANCHORAGE, ALASKA
Est. 1997
TK
1425
.S8
A23
no. 179

# SUSITNA HYDROELECTRIC PROJECT

## FEASIBILITY REPORT

VOLUME 4

APPENDIX A

HYDROLOGICAL STUDIES

FINAL DRAFT

Prepared by:

ACRES

ARLIS
Alaska Resources
Library & Information Services
Anchorage Alaska

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT
APPENDIX A

TABLE OF CONTENTS

APPENDIX A1

## WATER RESOURCES STUDIES

### 1 - STREAMFLOW EXTENSION

Historical streamflow data is available for several gaging stations on the Susitna River and its tributaries. The longest period of record is available for the station at Gold Creek (32 years from September 1949). At other stations, the record length varies from 8 to 25 years.

An Acres' in-house computer program has been used for filling in the incomplete streamflow data sets. It is based on the program FILLIN developed by the Texas Water Development Board (December 1970) (1). The procedure adopted is a multi-site regression technique which analyzes monthly time series data (streamflow, rainfall or evaporation data) and fills in missing portions in the incomplete records. The program evaluates statistical parameters which characterize the data set (i.e., seasonal means, seasonal standard deviations, lag-one auto-correlation coefficients and multi-site spatial correlation coefficients) and creates a filled-in data set in which these statistical parameters are preserved. For the analysis, all streamflow data up to September 1979 have been used (30 years data at Gold Creek).

A brief description of the steps involved in the program is presented in the following sections.

#### (a) Program Description

The fill in procedure comprises the following steps:

- The data sets pertaining to individual sites are arranged in descending order of the length of record in each set.

- Sample skewness is removed by a Gaussian transformation. The procedure chosen is a logastitimic transformation of each data item.

- The mean and standard deviation of the transformed data sets are computed.

- Each value of the transformed data is normalized by subtracting the monthly mean and dividing the remainder by the monthly standard deviation. This transformation renders the time series data stationary to the second order.

- The linear predictor equations for each site are estimated. The dependent variable at time step i at site s is a function of time step i, and variables at several other sites.

The general form of the predictor equation i is:

$$y_{s,i} = \sum_{k=1}^{s} a_{s,k}\, y_{k,\, i+1} + \sum_{k=1}^{s-1} b_{s,k}\, y_{k,\, i} + e_{s,\, i}$$



ARLIS
Alaska Resources
Library & Information Services
Anchorage, Alaska

where $A_{s,k}$ and $b_{s,k}$ are the regression coefficients and $e_{s,i}$ is a random Gaussian process with the covariance function equal to the multiple correlation coefficient matrix.

- The predictor equations are used to synthesize data for the gaps. The voids are filled in a reverse direction going from the denser to the sparser data.

- The synthesized values are adjusted in order to avoid abrupt transitions which sometimes occur at the interfaces of the synthesized and available data. This smoothing procedure uses the left-hand edge of the gap to set up a linear corrector which introduces it into the analysis as a maximum probable upper (or lower) bound of the process.

- The inverse transforms are carried out on the data to convert it back to the original units.

The fill-in procedure preserves the statistical parameters of the original time series: mean, variance, autocorrelation and cross correlation coefficients.

(b) Data and Computer Runs

Mean monthly flow data obtained from the USGS was used as input. A subroutine which interfaces the FILLIN program with the USGS data format was set up by Acres. Table A1.1 shows the available historical data at the gaging stations. Tables A1.2 to A1.9 summarize infilled recorded data. All the missing data are identified as -1 for computation reasons.

Records of all eight gaging sites were used in the first model run. Lack of overlapping data between Cantwell, Chulitna and Susitna stations resulted in a zero correlation which aborted the fill-in procedure. The extension of data for the Susitna station was therefore, carried out without the Cantwell and Chulitna station records.

The mean and standard deviation of the filled data sets (Table A1.10) are within the limits of the confidence interval of 5 percent. The lag-one correlation coefficients show similar limits (Table A1.11) for the unfilled data sets.

The spatial correlation matrix shows a good correspondence of the values in winter and fall and a fair correspondence in spring and summer. Spatial correlation coefficients for utilized and filled data sets are given in Tables A1.12 and A1.13, respectively. Filled-in data sets for the seven gaging sites are presented in Tables A1.14 to A1.21.

The fill-in procedure used appears superior to other existing regression procedures which have difficulties in preserving autocorrelation and spatial correlation. Probably the smoothing procedure used in this program has an important contribution to the fitness of the model.

(c) Estimate of Streamflow at Damsites On the Susitna River

Estimate of mean monthly flows at the sites was made adopting a linear drainage area relationship between the gaging stations and the damsites. For Denali site, such a relation could not be used due to lower unit runoff from the Lake Louise area. Since the local area at the damsite is similar to that below Cantwell station, the streamflow was directly related to the unit flows measured at Gold Creek, Cantwell and Denali gages. The following relationships were used to calculate streamflows at the damsites:

- $Q_{DC} = 0.827\ (Q_g - Q_c) + Q_c$
- $Q_{HDC} = 0.802\ (Q_g - Q_c) + Q_c$
- $Q_W = 0.515\ (Q_g - Q_c) + Q_c$
- $Q_{SIII} = 0.042\ (Q_g - LQ_c) + Q_c$
- $Q_V = Q_c$
- $Q_D = 0.153\ (Q_g = Q_c) + Q_d$
- $O_M = 0.429\ (Q_c - Q_d) + Q$

where: $Q$ = Streamflow in $ft^3/sec$
$A$ = Drainage area in $mi^2$

Subscript DC, HDC, W, SIII, V, D and M stand for damsites at Devil Canyon, High Devil Canyon, Watana, Susitna III, Vee, Denali and MacLaren, respectively.

Subscripts g, c, and d stand for gaging stations at Gold Creek, Cantwell and Denali, respectively.

The computed mean monthly flows for the 30 year period at each damsite are given in Tables A1.22 to A1.28 and were used in estimating the hydroelectric energy potential of the sites and in selection of the best Susitna developments (1981).

(d) Analysis of Watana Streamflow Records

An automatic water level recorder was established two miles downstream of the proposed Watana damsite in June 1980. A river discharge rating curve was developed based on ten discharge measurements taken during the 1980 and 1981 summers.

Estimated daily streamflow has been calculated for the record period along with peak instantaneous discharges (see Reference Report 2). Data is available only for the period with open water in the river (June through September).

The observed data at Watana along with simultaneous records observed at Cantwell and Gold Creek stations were analyzed in order to verify estimates of historical flow at the damsite (section (c) above). Table A1.29 compares the observed and calculated monthly flows at Watana for the two periods of record. It may be noted that the observed flow is somewhat higher than that calculated (average 4 percent). The results essentially confirm the historical estimates made in section (c). However, it is recommended that the streamflow gaging be continued at the Watana station to verify and improve the flow estimates used in this study with longer-term records.

## 2 - EVAPORATION STUDIES

Evaporation from the proposed Watana and Devil Canyon Reservoirs has been evaluated to determine its significance. Evaporation is influenced by air and water temperatures, wind, atmospheric pressure, and dissolved solids within the water. However, the evaluation of these factors' effects on evaporation is difficult because of their interdependence on each other. Consequently, more simplified methods were preferred and have been utilized to estimate evaporation losses from the two reservoirs.

Evaporation pans are widely used for directly measuring evaporation. Unfortunately, there are few evaporation pans in Alaska. None were located within the upper Susitna River basin until a U.S. Weather Bureau Class A pan was installed near the proposed Watana damsite in May 1981. Evaporation pans near the Susitna River basin include one located at McKinley Park, with 12 years of data (Table A1.30), and one at the Matanuska Agricultural Experiment Station, with 31 years of data (Table A1.31). Evaporation is reported as total evaporation, with daily changes in water level adjusted for precipitation.

The Matanuska station has a long-term average evaporation of 17.94 inches for May through September (3). In 1981, the evaporation at Matanuska was slightly below average at 15.34 inches. During this same period in 1981, the Watana pan recorded 14.85 inches of evaporation. A review of the monthly totals at the two stations (Table A1.32) showed a close comparison, with Matanuska slightly higher than Watana during all months except June. The June anomaly, with Watana's 5.15 inches exceeding Matanuska's 4.24 inches, cannot be explained. The climatic data for all three sites (including McKinley) are compared in Table A1.34, which shows similar trends in the climatic parameters for each of the months.

Comparison was also attempted between the McKinley pan and the Watana pan. Historically, McKinley data are only available for June, July and August although some evaporation does occur during May and September. For this reason, June through August values were the only ones compared. McKinley has a long-term average evaporation of 9.54 inches for June through August. This compares to a long-term June through August evaporation at Matanuska of 11.58 inches. A similar difference occurred during 1981 with McKinley recording 7.30 inches and Matanuska recording 9.31 inches. During this same period, Watana recorded 9.42 inches.

Evapotranspiration estimates for Alaskan locations have been computed by Patric and Black (4). Estimates for locations in and near the Susitna River basin are summarized in Table A1.35. Patric and Black used the Thornthwaite equation (5) to compute potential evapotranspiration, which is the water loss from fully vegetated land surfaces always abundantly supplied with soil moisture. The Thornthwaite equation uses only temperature data to estimate the potential evaportranspiration (PET), so estimates could be made for any station with monthly temperature values.

Hargreaves (6) indicated a high degree of correlation between U.S. Weather Bureau pan evaporation and vegetation consumptive use. The potential evapotranspiration estimate at Matanuska is about 10 percent higher than the longterm average pan evaporation for May through September. Patric and Black compared monthly potential evapotranspiration at the University Experiment Station in Fairbanks, using the Penman (7) and Thornthwaite equations and pan evaporation. The annual potential evapotranspiration agreed fairly closely (Penman, 15.70 inches; evaporation pan, 18.68 inches; Thornthwaite, 17.87 inches). Comparisons from other regions usually report Thornthwaite estimates as being higher than other estimates. In the comparison at the University Experiment Station in Fairbanks, relative humidity strongly influenced the Penman and evaporation pan estimates of potential evapotranspiration, but did not affect the Thornthwaite estimate, which is dependent solely on temperature. Based on these limited data, it would appear that the Thornthwaite estimates from Patric and Black would be slightly higher than pan evaporation estimates.

Patric and Black compared estimates of PET between high-elevation stations and nearby low-elevation sites. Their data suggested a decrease of about 1 inch of PET per year per 500 feet of elevation increases. As there is about a 2,000-foot difference in elevation between the Matanuska pan and the maximum pool level at Watana Reservoir, this would result in a difference of 4 inches of annual PET between the two sites. Similarly, the 1200-foot elevation difference between Matanuska and the full Devil Canyon Reservoir would result in a difference of about 2.4 inches of annual PET. The Thornthwaite estimate of PET at Matanuska is 19.76 inches. Using the elevation relationship, this results in an estimate of 15.8 inches of annual PET at Watana, and 17.4 inches at Devil Canyon.

Comparing the Thornthwaite estimate of PET to the actual historic evaporation at Matanuska, it is seen that the evaporation is less than the PET estimate. Thus the estimate of evaporation at Watana should be reduced by a similar proportion.

Estimated pan evaporation at Watana =

$$\frac{\text{Pan evaporation at Matanuska}}{\text{PET at Matanuska}} \quad [\text{PET at Watana}]$$

$$= (17.94/19.76)\ (15.8)$$
$$= 14.3 \text{ inches evaporation per year}$$

Similarly, Devil Canyon's estimated pan evaporation would be reduced from 17.4 to 15.8 inches per year. The monthly distribution of evaporation at both sites is assumed to follow that at the Matanuska station.

The rate of evaporation from small areas is greater than that from large areas Consequently, a pan coefficient of 0.7 is normally recommended for converting from pan evaporation to lake or reservoir evaporation, although observed values have been reported to vary from 0.6 to 0.8. The resulting monthly evaporation estimates are tabulated in Table A1.36, along with nearby monthly air temperatures for comparison.

## 3 - RESERVOIR OPERATION FOR POWER GENERATION

### 3.1 - Introduction

The energy potential of the Susitna Hydroelectric developments has been assessed using a monthly energy simulation model. This model determines the energy production given historical streamflow at the damsites and physical characteristics of the sites, such as storage-elevation relationships and tailwater levels.

The monthly simulation has been carried out for the 32 years of streamflow records available for the Sustina River at Gold Creek. Streamflows at the various damsites have been synthesized using a statistical and drainage area proration technique as explained in Section 1. Streamflow data at the damsites are given in Section 1. The storage-elevation relationships are presented in Volume 3 of main report. Tailwater discharge relationships were developed based on field discharge and stage measurements and river cross section surveys (see Reference Reports 2 and 8).

Model runs for each of the power developments identified in the earlier phases of this study have been made to assess the most desirable development. This analysis is reported in detail in the Development Selection Report, Section 8. Only the later model analyses for the selected Watana and Devil Canyon developments are reported here.

### 3.2 - Simulation Model

The model is essentially a monthly simulation of reservoir operation under historical streamflow conditions and physical parameters of the development These include installed capacity, dam height, and tailwater elevations. The model was used to determine optimum drawdown and dam height configuration for Watana. Devil Canyon's maximum water level is set by average tailwater level for Watana. Optimum drawdown at Devil Canyon has also been addressed using the model.

The model is driven by three criteria. They are, in order of their application:

- Monthly pattern required;
- Downstream flow requirement; and
- Reservoir rule curve.

(a) Energy Pattern

The energy pattern used in the model is based on monthly load forecasts developed by ISER and Woodward-Clyde Consultants and more recently by Battelle. This pattern is imposed as demand on the Susitna hydroelectric developments and reservoir operation is iteratively simulated to yield maximum energy production, thus yielding almost constant thermal energy demand throughout the year. The energy pattern is critical during periods of low inflow, particularly when drawdown limits are set. The assumed energy pattern is presented in Figure A1.1.

(b) Downstream Flow Requirement

Environmental considerations require the release of minimum flows during critical fish spawning periods and protection of the mitigation efforts associated with the project. The minimum flow required is a variable monthly value reaching a maximum in August, coincident with salmon spawning peaks.

The simulation model checks downstream flow requirements against the sum of the total powerhouse flow and spillage from the most downstream damsite. For the operations considered, generally the outflow exceeds the downstream flow requirement in the winter months of October through April. In the summer months, the outflow is at the lowest level because of low energy demand and the retention of river runoff in storage for release during the following winter. The exception to this is in late summer, usually September, when reservoirs can be full and spills could occur. When the required downstream flow is greater than the power flow simulated, additional discharge is made through outlet facility to meet the downstream requirement.

(c) Reservoir Rule Curve

The energy pattern described above controls the reservoir operation and energy production during critical low inflow periods. During other periods, it is apparent that additional energy could be produced because of larger river flows and greater reservoir storage available.

Essentially, with a reservoir rule curve which establishes minimum reservoir levels at different times during the year, it would be possible to produce more energy in wetter years during winter than by following a set energy pattern. At the same time, the rule curve ensures that low flow sequences do not materially reduce the energy potential below a set minimum or firm annual energy. Several sets of rule curves for the Watana and Devil Canyon sites were modeled and selected ones presented in Figure A1.2.

(d) Model Alogrithm

The energy simulation firstly determines the amount of flow required to meet the demand for power. For single reservoirs, the power output is given by Equation 1. For two reservoirs in cascade, the power output is given by Equation 2.

$$P = K_1 HQE \qquad (1)$$

where: P = Power produced in kilowatts (KW)
$K_1$ = Unit Conversion Constant = 0.084773
H = Average monthly head in feet (ft)
Q = Mean monthly powerhouse flow in cubic feet per second (cfs)
E = Overall hydraulic, mechanical and electrical efficiency (dimensionless)

$$TP = K_1 \ (H_1 Q_1 + H_2 \ (Q_1 + Q_c))E \qquad (2)$$

where: TP = Total power output (KW)

$H_1, H_2$ = Average monthly head in upper and lower reservoir, respectively (ft)

$Q_1$ = Mean monthly powerhouse flow plus spillage from upper reservoir (cfs)

$Q_c$ = Contribution flow from intervening drainage area between damsites (cfs)

$K_1$ = Unit Conversion Constant = 0.084773

E = Efficiency

The model procedure iteratively solves for powerhouse flow given power demand and change in storage.

Storage is depleted or replenished depending upon the magnitude of monthly inflow. Generally, storage is depleted during the months of October through May and replenished from June to September. The conversion from storage to flow is by Equation 3.

$$Q_A = \Delta SDm/K_2 \qquad (3)$$

where: $Q_A$ = Discharge (cfs)
$\Delta S$ = Change in storage (acre feet)
$K_2$ = Constant (cfs days to acre feet) - 1.984
$D_M$ = Number of days in month M.

For power computations using equation (1) or (2), monthly head is used and is determined from the average water surface elevation at the beginning and end of each month less tailwater elevation. A constant tailwater elevation of 1455 and 850 has been assumed for Watana and Devil Canyon, respectively. This is considered acceptable as the variation in tailwater elevation for the range of flows expected is $\pm 5$ feet from the assumed values and is within the reasonable limit of accuracy of the tailwater elevation discharge curves.

The water surface elevation is determined by linear interpolation of the storage-elevation curves input to the model. The power potential determined is effectively the average power during the month. Multiplying this power by the number of hours in each month results in monthly energy in kilowatt-hours.

The model next checks downstream flow requirement with total outflow (powerhouse plus spillage). If no flow deficit occurs, no action is taken. When outflow is below flow requirements, either further powerhouse flows are released or spillage occurs depending on demand for additional energy. This will deplete storage or replenish it more slowly depending upon inflow.

The final procedure in the model is to determine if further drawdown could occur to produce more usable energy particularly in winter months. The rule curve followed has been derived from several iterations of the reservoir operation and is believed to be close to the best fit for the energy produced up to the year 2010 and with the forecast developed by Battelle. In practice, with increase in system demand, the rule curve could be modified to yield energy that would fit into the system demand in a more economical manner.

The model procedure allows the reservoir to be drawn down in each month to the given levels when the water surface elevation at the start of the month is above these levels. Starting elevations below the target suggests that a dry sequence is experienced.

When the reservoir is being refilled during high streamflows, a further condition specifies the amount of surplus water that should be placed into storage. This is to ensure that during the early months of the filling sequence (May and June) the reservoir does not end up full too early in the summer. If filling occurred quickly, it is possible that spillage would be high in August and September. Preventing such spillage results in the production of more energy in May, June and July and a reduction in spillage amounts later on.

### 3.3 - Energy Simulation of Watana/Devil Canyon Development

The simulation model has a facility to determine the production of energy from a single or a two reservoir system. The operation of Watana or Devil Canyon alone and Devil Canyon with Watana upstream, have therefore been analyzed.

Energy production from Watana and from Watana/Devil Canyon has been determined to establish the optimum normal maximum pool elevation and reasonable drawdown hence live storage amounts. In addition, an assessment of the impact of downstream flow requirements on energy production has also been made using the model.

#### (a) Optimum Normal Maximum Water Surface Elevation

The normal maximum water surface elevation of 2185 for Watana has been established as the optimum water level with respect to energy production, project cost and total system economy. This level has been established based on the analysis of model energy simulation runs for three dam heights for Watana set at 2215, 2165 and 2115.

In all cases, the normal maximum operating level of Devil Canyon was assumed constant at 1455 feet. A detailed discussion of the selection of the optimum water level along with the OGP5 results are given in Sections 9 and 10 of the main report.

#### (b) Assessment of Impact on Energy Potential of Downstream Flow Requirements

Fishery mitigation efforts have been directed at assessing the impact of Watana and Devil Canyon developments on fish populations downstream of the damsites. To aid in this analysis, downstream flow requirements ranging from flow releases giving no serious impact to best power operation have been analyzed. The best power operation and intermediate flow conditions would require in-stream and remedial work at tributary confluences to prevent serious fishery damage.

The cases investigated have been called A, B, C, and D. Case A is the best power operation, Case B and C intermediate flow and power conditions and Case D the st acceptable operation with respect to impact on fisheries. The latter has also been termed the case with "avoidance flow" (avoiding impacts on fisheries). During the analysis, Case B and C were found to differ only in minor details and it was decided to eliminate Case B from further study.

Case D flows were derived from discussions with fisheries study groups and agencies and represent almost no fishery impact due to project operation. The monthly required flow at Gold Creek for the three cases (A, C and D) are given in Table A1.37. The flows required immediately downstream of the damsites have been calculated to reflect the contribution to flow from the drainage area between the damsite and Gold Creek.

Monthly energy production with Klatana maximum water level at 2215, 2165, and 2115 for the three flow conditions are summarized in Tables A1.38 to A1.40 for the period when Watana is operating alone and in Tables A1.41 to A1.47 for the total Watana/Devil Canyon development. Annual average and firm energy are summarized in Table A1.48 for the seven cases when Watana is alone and in Table A1.49 for Watana/Devil Canyon.

The energies given in Tables A1.38 to A1.49 represent the total energy production from the powerplants without any constraints to maximum energy demand of the system. As such, the energies represent the potential of the developments given the constraints of only plant capacity and required flows. In most cases, there is an excess of energy produced over system demand in the early years of the development. This production of unusable energy is duly considered in the generation planning analyses and is reflected in the overall system costs (Section 18 of the Main Report). Generally, the higher downstream flow requirement cases result in "dumping" of large quantities of unusable energy, particularly during summer months.

Monthly energies for the optimum water level of 2185 are given in Tables A1.50 to A1.52 for Watana alone, Case A, C and D and in Tables A1.53 to A1.58 for Watana and Devil Canyon. Several options for Watana operation have been investigated in an attempt to improve energy production. These represent a change in Watana operation when Devil Canyon comes on line and impact the energy production for Case C and D.

Tables A1.53, A1.55 and A1.57 present the best estimates of energy production from Watana/Devil Canyon for Cases A, C and D, respectively. These energies have been used in the generation planning and economic analyses (Section 18 of the Main Report).

(c) Reservoir Drawdown

For the assessment of fisher flows an energy production, it was assumed that no drawdown limit would be imposed on Watana or Devil Canyon. This, however, would not necessarily be the best operation for the development given intake costs and energy production but is valid in determining the impact of fishery flows on energy production. Drawdown limits for Watana were established using the normal maximum operating level of 2185 feet. Generally, the governing criteria in establishing the drawdown was to maximize winter energy production and to reduce spillage while maintaining reasonable costs for intake structures and acceptable temperatures in flow releases. Specifically, 115, 165, 190, and unlimited drawdown cases were investigated. Generally, the greater the drawdown results, the greater amount of annual firm energy produced. This is due to additional storage utilized in producing energy during critical low inflow periods. However, as firm energy increases, average energy decreases due to the longer period the reservoir is drawn down. As the economic analysis utilizes the average energy to estimate system costs and the firm energy to estimate system reliability, it is advantageous to produce the best combination of firm and average energy.

The increase in cost of the larger intake structure for greater drawdowns and additional costs for thermal generation to makeup production deficit is offset by additional system reliability. From Figures A1.3 to A1.5 and Tables A1.59 to A1.61, it appears that the most desirable drawdown is between 115 and 165 feet. Consequently, further analysis resulted in a drawdown of 140 feet as the optimum drawdown for Watana.

This drawdown of 140 feet is only required for two years in the 32 year period of simulation. For the other 30 years, the maximum drawdown is around 100 feet.

Detailed optimization studies for Devil Canyon reservoir was not undertaken due to the relatively smaller reservoir size and a potential single level of power intake from the reservoir. A drawdown of 50 feet has been selected as maximum permissible drawdown consistent with structural requirements of the arch dam.

(d) <u>Final Energy of Watana/Devil Canyon Development</u>

The potential energy production based on 32 years of simulation of Watana alone with a constraint in drawdown of 140 feet is an average approximately 3459 GW per year and would produce an annual firm energy of 2631 GW. Watana and Devil Canyon combined has an average annual energy production potential of 6793 GW, and a firm energy production of 5394 GW. The monthly energy production for average and firm years are given in Table A1.62.

The energy production useable from the development, considering the forecast annual energy developed by Battelle and the monthly distribution determined by WCC/ISER are given in Tables A1.63 and A1.64 for the average and firm years respectively.

Computer output sheets giving inflow, powerhouse flow, spillage, water surface elevation, heads, power and storage for each month in the simulation are given in Attachment 1 for the selected Watana/Devil Canyon Development.

## REFERENCES


1. Texas Water Development Board, 1970. A Completion Report on Stochastic Optimization and Simulation Techniques for Management of Regional Water Resource Systems - Volume IIB - FILLIN-1 Program Description.

2. R&M Consultants, Susitna Hydroelectric Project, Field Data Collection and Processing, December 1981.

3. U.S. Department of Commerce. Annual. Climatological Data, Alaska, Annual Summary, Environmental Science Services Administration, Asheville, North Carolina.

4. Patric, J.H. and Black, P.E. 1968. Potential Evapotranspiration and Climate in Alaska by Thornthwaite's Classification, Pacific Northwest Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service, Research Paper, PNW-71, Juneau, Alaska, 28 p.

5. Thornthwaite, C.W. 1948. An Approach Toward a Rational Classification of Climate, Geogr. Rev. 38: 55-94.

6. Hargreaves, G.H. 1958. Closing Discussion on Irrigation Requirements Based on Climatic Data, Proc. Am. Soc. Civil Engineers, J. Irrigation and Drainage Division, Volume , No. IR1, pp. 7-8, January.

7. Penman, H.L. 1948. Natural Evaporation from Open Water, Bare Soil, and Grass, Proc. Roy. Soc. London, ser. A., vol. 193, pp. 120-145.

8. R&M Consultants, Susitna Hydroelectric Project, Hydrographic Surveys, October 1981.

## LIST OF TABLES

LIST OF TABLES (Cont'd)

LIST OF TABLES (Cont'd)

## LIST OF FIGURES

<u>TABLE A1.1: AVAILABLE MEAN MONTHLY STREAMFLOW DATA</u>

| Sites | USGS Gage Number | 1950 | 1955 | 1960 | 1965 | 1970 | 1975 | 1979 | 1980 | 1981* |
|---|---|---|---|---|---|---|---|---|---|---|
| Gold Creek | (15292000) | 1950 | | | | | | | | 1981 |
| Denali | (15291000) | | 1957 | | | | | | | 1981 |
| Maclaren | (15291200) | | | 1958 | | | | | | 1981 |
| Skwenta | (15294300) | | | 1960 | | | | 1979 | | |
| Talkeetna | (15292800) | | | | 1964 | | | | | 1981 |
| Cantwell | (15291500) | | | 1961 | | 1972 | | | | 1981 |
| Chulitna | (15292400) | | | 1958 | | 1972 | | | | 1981 |
| Susitna | (15294350) | | | | | 1973 | | | | 1981 |

*Streamflow data for years 1980-81 have not been used in the correlation analysis.

## TABLE A1.2: DENALI UNFILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1950 |
| 2 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1951 |
| 3 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1952 |
| 4 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1953 |
| 5 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1954 |
| 6 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1955 |
| 7 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1956 |
| 8 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 12210.0 | 11170.0 | 9769.0 | 4017.0 | 1957 |
| 9 | 1277.0 | 610.0 | 288.0 | 219.0 | 150.0 | 120.0 | 210.0 | 1163.0 | 8367.0 | 9150.0 | 6536.0 | 1879.0 | 1958 |
| 10 | 939.0 | 390.0 | 170.0 | 119.0 | 81.0 | 41.7 | 43.0 | 1782.0 | 8891.0 | 8333.0 | 7882.0 | 2498.0 | 1959 |
| 11 | 1577.0 | 760.0 | 575.0 | 444.0 | 321.0 | 275.0 | 265.0 | 3349.0 | 5237.0 | 9039.0 | 7910.0 | 4817.0 | 1960 |
| 12 | 1781.0 | 660.0 | 483.0 | 331.0 | 271.0 | 281.0 | 415.0 | 2959.0 | 6412.0 | 8078.0 | 7253.0 | 2695.0 | 1961 |
| 13 | 1290.0 | 680.0 | 440.0 | 280.0 | 240.0 | 220.0 | 280.0 | 2197.0 | 9087.0 | 10220.0 | 9454.0 | 3649.0 | 1962 |
| 14 | 1079.0 | 510.0 | 310.0 | 250.0 | 230.0 | 200.0 | 210.0 | 3253.0 | 6763.0 | 10500.0 | 10210.0 | 3949.0 | 1963 |
| 15 | 925.0 | 290.0 | 185.0 | 140.0 | 140.0 | 110.0 | 130.0 | 910.0 | 11630.0 | 7577.0 | 6552.0 | 2633.0 | 1964 |
| 16 | 1468.0 | 702.0 | 279.0 | 220.0 | 200.0 | 208.0 | 320.0 | 2464.0 | 4647.0 | 6756.0 | 5764.0 | 6955.0 | 1965 |
| 17 | 920.0 | 300.0 | 240.0 | 210.0 | 200.0 | 200.0 | 280.0 | 1629.0 | 6850.0 | 8287.0 | 6432.0 | 3200.0 | 1966 |
| 18 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1967 |
| 19 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 11840.0 | 9825.0 | 2192.0 | 1968 |
| 20 | 700.0 | 304.0 | 172.0 | 145.0 | 140.0 | 145.0 | 229.0 | 1768.0 | 8146.0 | 9445.0 | 3919.0 | 2213.0 | 1969 |
| 21 | 1002.0 | 501.0 | 339.0 | 265.0 | 221.0 | 193.0 | 319.0 | 2210.0 | 5013.0 | 8454.0 | 6216.0 | 1946.0 | 1970 |
| 22 | 528.0 | 395.0 | 276.0 | 170.0 | 125.0 | 120.0 | 135.0 | 629.0 | 8099.0 | 10410.0 | 10400.0 | 3288.0 | 1971 |
| 23 | 1039.0 | 478.0 | 380.0 | 339.0 | 307.0 | 286.0 | 270.0 | 3468.0 | 6562.0 | 10450.0 | 8664.0 | 2778.0 | 1972 |
| 24 | 667.0 | 323.0 | 211.0 | 178.0 | 164.0 | 153.0 | 153.0 | 1042.0 | 5741.0 | 8346.0 | 7268.0 | 2445.0 | 1973 |
| 25 | 876.0 | 462.0 | 366.0 | 310.0 | 271.0 | 235.0 | 262.0 | 2541.0 | 5642.0 | 9547.0 | 9292.0 | 5452.0 | 1974 |
| 26 | 2135.0 | 673.0 | 381.0 | 300.0 | 200.0 | 200.0 | 200.0 | 1640.0 | 7040.0 | 12110.0 | 7295.0 | 3571.0 | 1975 |
| 27 | 1539.0 | 375.0 | 169.0 | 112.0 | 97.0 | 90.0 | 123.0 | 1805.0 | 5939.0 | 8558.0 | 10080.0 | 1822.0 | 1976 |
| 28 | 894.0 | 467.0 | 331.0 | 266.0 | 240.0 | 231.0 | 246.0 | 1498.0 | 8253.0 | 10010.0 | 10180.0 | 3707.0 | 1977 |
| 29 | 1148.0 | 652.0 | 439.0 | 348.0 | 300.0 | 246.0 | 263.0 | 2031.0 | 5250.0 | 8993.0 | 8644.0 | 3622.0 | 1978 |
| 30 | 865.0 | 463.0 | 312.0 | 263.0 | 229.0 | 203.0 | 250.0 | 2791.0 | 7650.0 | 9504.0 | 9178.0 | 4512.0 | 1979 |

## TABLE A1.3: MACLAREN UNFILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1950 |
| 2 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1951 |
| 3 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1952 |
| 4 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1953 |
| 5 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1954 |
| 6 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1955 |
| 7 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1956 |
| 8 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1957 |
| 9 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 3532.0 | 3525.0 | 2699.0 | 784.0 | 1958 |
| 10 | 378.0 | 115.0 | 123.0 | 129.0 | 95.4 | 62.5 | 77.5 | 587.0 | 2879.0 | 2680.0 | 2083.0 | 856.0 | 1959 |
| 11 | 549.0 | 250.0 | 190.0 | 150.0 | 110.0 | 94.3 | 91.5 | 1742.0 | 2124.0 | 3359.0 | 3048.0 | 2439.0 | 1960 |
| 12 | 687.0 | 195.0 | 149.0 | 110.0 | 93.9 | 96.0 | 145.0 | 1237.0 | 2678.0 | 3369.0 | 3299.0 | 1168.0 | 1961 |
| 13 | 381.0 | 210.0 | 170.0 | 120.0 | 100.0 | 92.0 | 120.0 | 632.0 | 2916.0 | 3265.0 | 2927.0 | 1127.0 | 1962 |
| 14 | 383.0 | 210.0 | 130.0 | 100.0 | 91.0 | 80.0 | 83.0 | 2131.0 | 3110.0 | 4649.0 | 3136.0 | 1213.0 | 1963 |
| 15 | 416.0 | 140.0 | 98.0 | 85.0 | 88.0 | 71.0 | 72.0 | 386.0 | 4297.0 | 2764.0 | 2224.0 | 871.0 | 1964 |
| 16 | 379.0 | 147.0 | 49.3 | 44.0 | 42.0 | 41.0 | 62.0 | 984.0 | 2268.0 | 3223.0 | 2409.0 | 2098.0 | 1965 |
| 17 | 522.0 | 180.0 | 55.0 | 45.0 | 45.0 | 43.0 | 50.0 | 265.0 | 2990.0 | 2505.0 | 2095.0 | 954.0 | 1966 |
| 18 | 369.0 | 95.0 | 70.0 | 65.0 | 60.0 | 55.0 | 53.3 | 1023.0 | 3634.0 | 3255.0 | 3605.0 | 1416.0 | 1967 |
| 19 | 417.0 | 130.0 | 100.0 | 97.4 | 95.0 | 95.0 | 95.0 | 208.0 | 3245.0 | 3427.0 | 2129.0 | 680.0 | 1968 |
| 20 | 265.0 | 121.0 | 68.5 | 58.2 | 55.0 | 57.6 | 95.3 | 849.0 | 2613.0 | 2692.0 | 974.0 | 470.0 | 1969 |
| 21 | 249.0 | 117.0 | 73.2 | 59.4 | 50.4 | 52.7 | 69.2 | 746.0 | 1751.0 | 2441.0 | 2367.0 | 773.0 | 1970 |
| 22 | 301.0 | 192.0 | 131.0 | 83.4 | 60.4 | 55.0 | 66.0 | 365.0 | 3414.0 | 3528.0 | 3659.0 | 1165.0 | 1971 |
| 23 | 375.0 | 156.0 | 123.0 | 115.0 | 107.0 | 97.4 | 98.5 | 1218.0 | 3069.0 | 3255.0 | 2676.0 | 1366.0 | 1972 |
| 24 | 550.0 | 243.0 | 136.0 | 87.4 | 65.2 | 53.4 | 51.2 | 576.0 | 2906.0 | 2856.0 | 2271.0 | 821.0 | 1973 |
| 25 | 307.0 | 123.0 | 82.6 | 68.5 | 61.8 | 56.6 | 56.7 | 649.0 | 2069.0 | 2634.0 | 2439.0 | 1543.0 | 1974 |
| 26 | 385.0 | 232.0 | 140.0 | 115.0 | 110.0 | 100.0 | 103.0 | 768.0 | 3178.0 | 3649.0 | 1982.0 | 1574.0 | 1975 |
| 27 | 553.0 | 235.0 | 139.0 | 106.0 | 94.1 | 90.0 | 105.0 | 781.0 | 2870.0 | 2810.0 | 2604.0 | 600.0 | 1976 |
| 28 | 302.0 | 168.0 | 119.0 | 97.3 | 92.0 | 90.0 | 92.9 | 366.0 | 3942.0 | 3834.0 | 3394.0 | 1297.0 | 1977 |
| 29 | 512.0 | 265.0 | 186.0 | 162.0 | 140.0 | 121.0 | 134.0 | 709.0 | 2317.0 | 3196.0 | 2356.0 | 924.0 | 1978 |
| 30 | 307.0 | 192.0 | 142.0 | 122.0 | 110.0 | 100.0 | 111.0 | 634.0 | 2430.0 | 3056.0 | 2223.0 | 1137.0 | 1979 |

## TABLE A1.4: CANTWELL UNFILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1950 |
| 2 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1951 |
| 3 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1952 |
| 4 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1953 |
| 5 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1954 |
| 6 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1955 |
| 7 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1956 |
| 8 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1957 |
| 9 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1958 |
| 10 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1959 |
| 11 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1960 |
| 12 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 9688.0 | 15710.0 | 14820.0 | 16700.0 | 6725.0 | 1961 |
| 13 | 3281.0 | 1800.0 | 1400.0 | 1300.0 | 1000.0 | 940.0 | 1200.0 | 10000.0 | 28320.0 | 20890.0 | 16000.0 | 9410.0 | 1962 |
| 14 | 4326.0 | 2200.0 | 1400.0 | 1000.0 | 850.0 | 760.0 | 720.0 | 11340.0 | 15000.0 | 22790.0 | 18190.0 | 9187.0 | 1963 |
| 15 | 3848.0 | 1300.0 | 877.0 | 644.0 | 586.0 | 429.0 | 465.0 | 2806.0 | 34630.0 | 17040.0 | 11510.0 | 5352.0 | 1964 |
| 16 | 3134.0 | 1911.0 | 921.0 | 760.0 | 680.0 | 709.0 | 1097.0 | 8818.0 | 16430.0 | 18350.0 | 13440.0 | 12910.0 | 1965 |
| 17 | 3116.0 | 1000.0 | 750.0 | 700.0 | 650.0 | 650.0 | 875.0 | 4387.0 | 18500.0 | 12220.0 | 12680.0 | 6523.0 | 1966 |
| 18 | 2322.0 | 780.0 | 720.0 | 680.0 | 640.0 | 560.0 | 513.0 | 9452.0 | 19620.0 | 16880.0 | 19190.0 | 10280.0 | 1967 |
| 19 | 3084.0 | 1490.0 | 1332.0 | 1232.0 | 1200.0 | 1200.0 | 1223.0 | 9268.0 | 19500.0 | 17480.0 | 10940.0 | 5410.0 | 1968 |
| 20 | 2406.0 | 1063.0 | 618.0 | 508.0 | 485.0 | 548.0 | 998.0 | 7471.0 | 12330.0 | 13510.0 | 6597.0 | 3376.0 | 1969 |
| 21 | 1638.0 | 815.0 | 543.0 | 437.0 | 426.0 | 463.0 | 887.0 | 7580.0 | 9909.0 | 13900.0 | 12320.0 | 5211.0 | 1970 |
| 22 | 2155.0 | 1530.0 | 1048.0 | 731.0 | 503.0 | 470.0 | 529.0 | 1915.0 | 21970.0 | 18130.0 | 22710.0 | 9800.0 | 1971 |
| 23 | 4058.0 | 2050.0 | 1371.0 | 1068.0 | 922.0 | 881.0 | 876.0 | 9694.0 | 20000.0 | 16690.0 | 15620.0 | 9423.0 | 1972 |
| 24 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1973 |
| 25 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1974 |
| 26 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1975 |
| 27 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1976 |
| 28 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1977 |
| 29 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1978 |
| 30 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1979 |

## TABLE A1.5: GOLD CREEK UNFILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6335.0 | 2583.0 | 1439.0 | 1027.0 | 788.0 | 726.0 | 870.0 | 11510.0 | 19600.0 | 22600.0 | 19880.0 | 8301.0 | 1950 |
| 2 | 3848.0 | 1300.0 | 1100.0 | 960.0 | 820.0 | 740.0 | 1617.0 | 14090.0 | 20790.0 | 22570.0 | 19670.0 | 21240.0 | 1951 |
| 3 | 5571.0 | 2744.0 | 1900.0 | 1600.0 | 1000.0 | 880.0 | 920.0 | 5419.0 | 32370.0 | 26390.0 | 20920.0 | 14480.0 | 1952 |
| 4 | 8202.0 | 3497.0 | 1700.0 | 1100.0 | 820.0 | 820.0 | 1615.0 | 19270.0 | 27320.0 | 20200.0 | 20610.0 | 15270.0 | 1953 |
| 5 | 5604.0 | 2100.0 | 1500.0 | 1300.0 | 1000.0 | 780.0 | 1235.0 | 17280.0 | 25250.0 | 20360.0 | 26100.0 | 12920.0 | 1954 |
| 6 | 5370.0 | 2760.0 | 2045.0 | 1794.0 | 1400.0 | 1100.0 | 1200.0 | 9319.0 | 29860.0 | 27560.0 | 25750.0 | 14290.0 | 1955 |
| 7 | 4951.0 | 1900.0 | 1300.0 | 980.0 | 970.0 | 940.0 | 950.0 | 17660.0 | 33340.0 | 31090.0 | 24530.0 | 18330.0 | 1956 |
| 8 | 5806.0 | 3050.0 | 2142.0 | 1700.0 | 1500.0 | 1200.0 | 1200.0 | 13750.0 | 30160.0 | 23310.0 | 20540.0 | 19800.0 | 1957 |
| 9 | 8212.0 | 3954.0 | 3264.0 | 1965.0 | 1307.0 | 1148.0 | 1533.0 | 12900.0 | 25700.0 | 22880.0 | 22540.0 | 7550.0 | 1958 |
| 10 | 4811.0 | 2150.0 | 1513.0 | 1448.0 | 1307.0 | 980.0 | 1250.0 | 15990.0 | 23320.0 | 25000.0 | 31180.0 | 16920.0 | 1959 |
| 11 | 6558.0 | 2850.0 | 2200.0 | 1845.0 | 1452.0 | 1197.0 | 1300.0 | 15780.0 | 15530.0 | 22980.0 | 23590.0 | 20510.0 | 1960 |
| 12 | 7794.0 | 3000.0 | 2694.0 | 2452.0 | 1754.0 | 1810.0 | 2650.0 | 17360.0 | 29450.0 | 24570.0 | 22100.0 | 13370.0 | 1961 |
| 13 | 5916.0 | 2700.0 | 2100.0 | 1900.0 | 1500.0 | 1400.0 | 1700.0 | 12590.0 | 43270.0 | 25850.0 | 23550.0 | 15890.0 | 1962 |
| 14 | 6723.0 | 2800.0 | 2000.0 | 1600.0 | 1500.0 | 1000.0 | 830.0 | 19030.0 | 26000.0 | 34400.0 | 23670.0 | 12320.0 | 1963 |
| 15 | 6449.0 | 2250.0 | 1494.0 | 1048.0 | 966.0 | 713.0 | 745.0 | 4307.0 | 50580.0 | 22950.0 | 16440.0 | 9571.0 | 1964 |
| 16 | 6291.0 | 2799.0 | 1211.0 | 960.0 | 860.0 | 900.0 | 1360.0 | 12990.0 | 25720.0 | 27840.0 | 21120.0 | 19350.0 | 1965 |
| 17 | 7205.0 | 2098.0 | 1631.0 | 1400.0 | 1300.0 | 1300.0 | 1775.0 | 9645.0 | 32950.0 | 19860.0 | 21830.0 | 11750.0 | 1966 |
| 18 | 4163.0 | 1600.0 | 1500.0 | 1500.0 | 1400.0 | 1200.0 | 1167.0 | 15480.0 | 29510.0 | 26800.0 | 32620.0 | 16870.0 | 1967 |
| 19 | 4900.0 | 2353.0 | 2055.0 | 1981.0 | 1900.0 | 1900.0 | 1910.0 | 16180.0 | 31550.0 | 26420.0 | 17170.0 | 8816.0 | 1968 |
| 20 | 3822.0 | 1630.0 | 882.0 | 724.0 | 723.0 | 816.0 | 1510.0 | 11050.0 | 15500.0 | 16100.0 | 8879.0 | 5093.0 | 1969 |
| 21 | 3124.0 | 1215.0 | 866.0 | 824.0 | 768.0 | 776.0 | 1080.0 | 11380.0 | 18630.0 | 22660.0 | 19980.0 | 9121.0 | 1970 |
| 22 | 5288.0 | 3407.0 | 2290.0 | 1442.0 | 1036.0 | 950.0 | 1082.0 | 3745.0 | 32930.0 | 23950.0 | 31910.0 | 14440.0 | 1971 |
| 23 | 5847.0 | 3093.0 | 2510.0 | 2239.0 | 2028.0 | 1823.0 | 1710.0 | 21890.0 | 34430.0 | 22770.0 | 19290.0 | 12400.0 | 1972 |
| 24 | 4826.0 | 2253.0 | 1465.0 | 1200.0 | 1200.0 | 1000.0 | 1027.0 | 8235.0 | 27800.0 | 18250.0 | 20290.0 | 9074.0 | 1973 |
| 25 | 3733.0 | 1523.0 | 1034.0 | 874.0 | 777.0 | 724.0 | 992.0 | 16180.0 | 17870.0 | 18800.0 | 16220.0 | 12250.0 | 1974 |
| 26 | 3739.0 | 1700.0 | 1603.0 | 1516.0 | 1471.0 | 1400.0 | 1593.0 | 15350.0 | 32310.0 | 27720.0 | 18090.0 | 16310.0 | 1975 |
| 27 | 7739.0 | 1993.0 | 1081.0 | 974.0 | 950.0 | 900.0 | 1373.0 | 12620.0 | 24380.0 | 18940.0 | 19800.0 | 6881.0 | 1976 |
| 28 | 3874.0 | 2650.0 | 2403.0 | 1829.0 | 1618.0 | 1500.0 | 1680.0 | 12680.0 | 37970.0 | 22870.0 | 19240.0 | 12640.0 | 1977 |
| 29 | 7571.0 | 3525.0 | 2589.0 | 2029.0 | 1668.0 | 1605.0 | 1702.0 | 11950.0 | 19050.0 | 21020.0 | 16390.0 | 8607.0 | 1978 |
| 30 | 4907.0 | 2535.0 | 1681.0 | 1397.0 | 1286.0 | 1200.0 | 1450.0 | 13870.0 | 24690.0 | 28880.0 | 20460.0 | 10770.0 | 1979 |

## TABLE A1.6: CHULITNA UNFILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1950 |
| 2 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1951 |
| 3 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1952 |
| 4 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1953 |
| 5 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1954 |
| 6 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1955 |
| 7 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1956 |
| 8 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1957 |
| 9 | -1.0 | -1.0 | -1.0 | -1.0 | 1044.0 | 948.0 | 1220.0 | 10460.0 | 23170.0 | 25010.0 | 20760.0 | 8000.0 | 1958 |
| 10 | 4197.0 | 1883.0 | 1262.0 | 1097.0 | 1049.0 | 738.0 | 890.0 | 7413.0 | 23660.0 | 25650.0 | 22100.0 | 9957.0 | 1959 |
| 11 | 4723.0 | 2283.0 | 1700.0 | 1448.0 | 1103.0 | 933.0 | 1000.0 | 13890.0 | 17390.0 | 23650.0 | 19320.0 | 12420.0 | 1960 |
| 12 | 5135.0 | 1950.0 | 1745.0 | 1452.0 | 1100.0 | 1079.0 | 1600.0 | 10100.0 | 20490.0 | 27420.0 | 24580.0 | 16030.0 | 1961 |
| 13 | 5777.0 | 2400.0 | 1500.0 | 1300.0 | 1000.0 | 930.0 | 1170.0 | 7743.0 | 20620.0 | 27220.0 | 21980.0 | 13490.0 | 1962 |
| 14 | 3506.0 | 1500.0 | 1552.0 | 1600.0 | 1300.0 | 846.0 | 700.0 | 11060.0 | 17750.0 | 28950.0 | 18390.0 | 11330.0 | 1963 |
| 15 | 8062.0 | 2300.0 | 1000.0 | 1007.0 | 820.0 | 770.0 | 1133.0 | 2355.0 | 40330.0 | 24430.0 | 20250.0 | 9235.0 | 1964 |
| 16 | 5642.0 | 2900.0 | 2100.0 | 1600.0 | 1400.0 | 1300.0 | 1400.0 | 7452.0 | 20070.0 | 23230.0 | 22550.0 | 22260.0 | 1965 |
| 17 | 6071.0 | 1620.0 | 1350.0 | 1200.0 | 1100.0 | 1100.0 | 1300.0 | 3971.0 | 21740.0 | 23750.0 | 27720.0 | 12200.0 | 1966 |
| 18 | 4682.0 | 1680.0 | 1500.0 | 1458.0 | 1257.0 | 1045.0 | 972.0 | 12400.0 | 25520.0 | 35570.0 | 33670.0 | 12510.0 | 1967 |
| 19 | 3483.0 | 1660.0 | 1397.0 | 1235.0 | 1200.0 | 1148.0 | 1347.0 | 10940.0 | 29000.0 | 30140.0 | 20710.0 | 7375.0 | 1968 |
| 20 | 2898.0 | 1480.0 | 1139.0 | 974.0 | 900.0 | 824.0 | 1333.0 | 6001.0 | 18560.0 | 20820.0 | 11300.0 | 6704.0 | 1969 |
| 21 | 4578.0 | 1887.0 | 1316.0 | 1200.0 | 1154.0 | 1100.0 | 1437.0 | 9643.0 | 19670.0 | 26100.0 | 24660.0 | 11330.0 | 1970 |
| 22 | 3826.0 | 2210.0 | 1403.0 | 1113.0 | 950.0 | 934.0 | 982.0 | 4468.0 | 22180.0 | 27280.0 | 23810.0 | 11080.0 | 1971 |
| 23 | 5439.0 | 2157.0 | 1432.0 | 1174.0 | 1041.0 | 939.0 | 893.0 | 9765.0 | 17900.0 | 25770.0 | 20970.0 | 12120.0 | 1972 |
| 24 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1973 |
| 25 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1974 |
| 26 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1975 |
| 27 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1976 |
| 28 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1977 |
| 29 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1978 |
| 30 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1979 |

## TABLE A1.7: TALKEETNA UNFILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1950 |
| 2 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1951 |
| 3 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1952 |
| 4 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1953 |
| 5 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1954 |
| 6 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1955 |
| 7 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1956 |
| 8 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1957 |
| 9 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1958 |
| 10 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1959 |
| 11 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1960 |
| 12 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1961 |
| 13 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1962 |
| 14 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1963 |
| 15 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 17080.0 | 9820.0 | 8396.0 | 3815.0 | 1964 |
| 16 | 3115.0 | 1568.0 | 1100.0 | 720.0 | 620.0 | 540.0 | 580.0 | 3474.0 | 11090.0 | 12180.0 | 11150.0 | 10610.0 | 1965 |
| 17 | 4438.0 | 1460.0 | 876.0 | 711.0 | 526.0 | 395.0 | 422.0 | 2410.0 | 12970.0 | 10100.0 | 10730.0 | 5370.0 | 1966 |
| 18 | 2388.0 | 897.0 | 750.0 | 637.0 | 546.0 | 471.0 | 427.0 | 4112.0 | 9286.0 | 12600.0 | 14160.0 | 6971.0 | 1967 |
| 19 | 2029.0 | 1253.0 | 987.0 | 851.0 | 777.0 | 743.0 | 983.0 | 8840.0 | 14100.0 | 11230.0 | 7546.0 | 4120.0 | 1968 |
| 20 | 1637.0 | 827.0 | 556.0 | 459.0 | 401.0 | 380.0 | 519.0 | 3869.0 | 5207.0 | 7080.0 | 3787.0 | 2070.0 | 1969 |
| 21 | 1450.0 | 765.0 | 587.0 | 504.0 | 458.0 | 440.0 | 545.0 | 3950.0 | 7979.0 | 10320.0 | 8752.0 | 5993.0 | 1970 |
| 22 | 2817.0 | 1647.0 | 1103.0 | 679.0 | 459.0 | 402.0 | 503.0 | 2145.0 | 19040.0 | 11760.0 | 16770.0 | 5990.0 | 1971 |
| 23 | 2632.0 | 1310.0 | 845.0 | 727.0 | 628.0 | 481.0 | 519.0 | 3516.0 | 12700.0 | 12030.0 | 9576.0 | 8709.0 | 1972 |
| 24 | 3630.0 | 1373.0 | 889.0 | 748.0 | 654.0 | 574.0 | 577.0 | 3860.0 | 12210.0 | 7676.0 | 9927.0 | 3861.0 | 1973 |
| 25 | 1807.0 | 960.0 | 745.0 | 645.0 | 559.0 | 482.0 | 535.0 | 5678.0 | 8030.0 | 7755.0 | 7704.0 | 4763.0 | 1974 |
| 26 | 1967.0 | 1002.0 | 774.0 | 694.0 | 586.0 | 508.0 | 522.0 | 4084.0 | 13180.0 | 12070.0 | 8487.0 | 7960.0 | 1975 |
| 27 | 2884.0 | 773.0 | 558.0 | 524.0 | 480.0 | 470.0 | 613.0 | 3439.0 | 10580.0 | 9026.0 | 8088.0 | 3205.0 | 1976. |
| 28 | 1857.0 | 1105.0 | 1069.0 | 700.0 | 549.0 | 506.0 | 548.0 | 4244.0 | 18280.0 | 9344.0 | 8005.0 | 5826.0 | 1977 |
| 29 | 3268.0 | 1121.0 | 860.0 | 746.0 | 576.0 | 485.0 | 534.0 | 2950.0 | 7429.0 | 10790.0 | 7001.0 | 3567.0 | 1978 |
| 30 | 1660.0 | 1138.0 | 932.0 | 762.0 | 652.0 | 577.0 | 710.0 | 7790.0 | 12010.0 | 14440.0 | 8274.0 | 4039.0 | 1979 |

## TABLE A1.8: SKWENTNA UNFILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1950 |
| 2 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1951 |
| 3 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1952 |
| 4 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1953 |
| 5 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1954 |
| 6 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1955 |
| 7 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1956 |
| 8 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1957 |
| 9 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1958 |
| 10 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1959 |
| 11 | 3532.0 | 1850.0 | 1400.0 | 1097.0 | 961.0 | 843.0 | 835.0 | 10480.0 | 13440.0 | 16690.0 | 15990.0 | 9171.0 | 1960 |
| 12 | 3889.0 | 1600.0 | 1597.0 | 1403.0 | 1154.0 | 1155.0 | 1700.0 | 11210.0 | 20570.0 | 16480.0 | 13910.0 | 12020.0 | 1961 |
| 13 | 4605.0 | 2200.0 | 1400.0 | 1200.0 | 860.0 | 760.0 | 1000.0 | 6613.0 | 15630.0 | 14930.0 | 12080.0 | 6723.0 | 1962 |
| 14 | 2801.0 | 1250.0 | 1100.0 | 1000.0 | 810.0 | 700.0 | 650.0 | 7765.0 | 14050.0 | 20430.0 | 12020.0 | 7180.0 | 1963 |
| 15 | 5355.0 | 1550.0 | 840.0 | 970.0 | 750.0 | 600.0 | 840.0 | 1635.0 | 27250.0 | 16480.0 | 12680.0 | 6224.0 | 1964 |
| 16 | 4425.0 | 1790.0 | 1300.0 | 920.0 | 800.0 | 740.0 | 770.0 | 4810.0 | 17160.0 | 19370.0 | 14010.0 | 13090.0 | 1965 |
| 17 | 4122.0 | 1575.0 | 1150.0 | 1100.0 | 1100.0 | 1100.0 | 1300.0 | 4502.0 | 19550.0 | 14180.0 | 17320.0 | 9812.0 | 1966 |
| 18 | 5576.0 | 1400.0 | 900.0 | 720.0 | 650.0 | 650.0 | 780.0 | 1794.0 | 14430.0 | 14740.0 | 15760.0 | 9517.0 | 1967 |
| 19 | 3832.0 | 1560.0 | 1181.0 | 1023.0 | 1000.0 | 950.0 | 1293.0 | 13460.0 | 20770.0 | 17480.0 | 10560.0 | 3855.0 | 1968 |
| 20 | 1929.0 | 678.0 | 624.0 | 600.0 | 600.0 | 626.0 | 1487.0 | 11070.0 | 19580.0 | 13650.0 | 7471.0 | 3783.0 | 1969 |
| 21 | 5654.0 | 1607.0 | 832.0 | 766.0 | 700.0 | 650.0 | 728.0 | 11710.0 | 22880.0 | 21120.0 | 13030.0 | 6665.0 | 1970 |
| 22 | 2919.0 | 2023.0 | 1184.0 | 865.0 | 721.0 | 613.0 | 607.0 | 5963.0 | 25400.0 | 20600.0 | 15920.0 | 6024.0 | 1971 |
| 23 | 3020.0 | 1327.0 | 1103.0 | 989.0 | 898.0 | 811.0 | 742.0 | 8045.0 | 15330.0 | 16840.0 | 13370.0 | 9256.0 | 1972 |
| 24 | 4551.0 | 2340.0 | 1316.0 | 910.0 | 702.0 | 606.0 | 727.0 | 6349.0 | 15200.0 | 13850.0 | 9874.0 | 6164.0 | 1973 |
| 25 | 3540.0 | 1700.0 | 1265.0 | 1023.0 | 902.0 | 811.0 | 1005.0 | 6765.0 | 10650.0 | 11670.0 | 10480.0 | 11800.0 | 1974 |
| 26 | 4557.0 | 2328.0 | 919.0 | 800.0 | 750.0 | 750.0 | 767.0 | 7852.0 | 19060.0 | 19520.0 | 11710.0 | 8471.0 | 1975 |
| 27 | 4704.0 | 1973.0 | 1258.0 | 971.0 | 897.0 | 800.0 | 1270.0 | 8806.0 | 15120.0 | 14580.0 | 11120.0 | 8165.0 | 1976 |
| 28 | 6196.0 | 2880.0 | 2871.0 | 2829.0 | 1821.0 | 1200.0 | 1200.0 | 8906.0 | 36670.0 | 25270.0 | 20160.0 | 10290.0 | 1977 |
| 29 | 5799.0 | 2373.0 | 1548.0 | 1213.0 | 944.0 | 841.0 | 1023.0 | 9006.0 | 13840.0 | 18100.0 | 13740.0 | 7335.0 | 1978 |
| 30 | 4936.0 | 1580.0 | 1555.0 | 1165.0 | 1036.0 | 981.0 | 1597.0 | 11660.0 | 14980.0 | 15830.0 | 16210.0 | 7448.0 | 1979 |

## TABLE A1.9: SUSITNA STATION UNFILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1950 |
| 2 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1951 |
| 3 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1952 |
| 4 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1953 |
| 5 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1954 |
| 6 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1955 |
| 7 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1956 |
| 8 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1957 |
| 9 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1958 |
| 10 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1959 |
| 11 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1960 |
| 12 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1961 |
| 13 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1962 |
| 14 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1963 |
| 15 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1964 |
| 16 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1965 |
| 17 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1966 |
| 18 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1967 |
| 19 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1968 |
| 20 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1969 |
| 21 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1970 |
| 22 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1971 |
| 23 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1972 |
| 24 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1973 |
| 25 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | 1974 |
| 26 | 19520.0 | 10400.0 | 9419.0 | 8597.0 | 7804.0 | 7048.0 | 6867.0 | 47540.0 | 128800.0 | 135700.0 | 91360.0 | 77740.0 | 1975 |
| 27 | 31550.0 | 9933.0 | 6000.0 | 6529.0 | 5614.0 | 5368.0 | 7253.0 | 70460.0 | 107000.0 | 115200.0 | 99650.0 | 48910.0 | 1976 |
| 28 | 30140.0 | 18270.0 | 13100.0 | 10100.0 | 8911.0 | 6774.0 | 6233.0 | 56180.0 | 165900.0 | 143900.0 | 125500.0 | 83810.0 | 1977 |
| 29 | 38230.0 | 12830.0 | 7529.0 | 6974.0 | 6771.0 | 6590.0 | 7033.0 | 48670.0 | 90930.0 | 117600.0 | 102100.0 | 55500.0 | 1978 |
| 30 | 36810.0 | 15000.0 | 9306.0 | 8823.0 | 7946.0 | 7032.0 | 8683.0 | 81260.0 | 119900.0 | 142500.0 | 128200.0 | 74340.0 | 1979 |

ALASKA RESOURCES LIBRARY
U.S. Department of the Interior

TABLE A1.10: MEAN AND STANDARD DEVIATION BEFORE AND AFTER FILLING IN

| Site (No. of Data) | Statistical Parameter | Before(B) or After(A) | MONTH 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gold Creek (360) | Mean | B | 5639 | 2467 | 1773 | 1454 | 1236 | 1114 | 1368 | 13317 | 27928 | 23853 | 21479 | 13171 |
| | | A | 5639 | 2467 | 1773 | 1454 | 1236 | 1114 | 1368 | 13317 | 27928 | 23853 | 21479 | 13171 |
| | SD | B | 1422 | 678.5 | 571.2 | 446.3 | 356.5 | 340.3 | 392.6 | 4236 | 7740 | 3921 | 4775 | 4235 |
| | | A | 1422 | 678.5 | 571.2 | 446.3 | 356.4 | 340.3 | 392.6 | 4236 | 7740 | 3921 | 4775 | 4235 |
| Maclaren (256) | Mean | B | 408.9 | 177.0 | 117.8 | 96.2 | 84.1 | 76.4 | 87.2 | 802.7 | 2920 | 3181 | 2573 | 1149 |
| | | A | 408.6 | 172.8 | 110.3 | 94.5 | 78.7 | 73.0 | 86.4 | 818.3 | 2913 | 3217 | 2600 | 1177 |
| | SD | B | 110.8 | 49.8 | 39.7 | 31.5 | 25.6 | 22.4 | 26.3 | 462.0 | 611.1 | 496.0 | 609.9 | 460.3 |
| | | A | 107.3 | 49.0 | 37.2 | 29.1 | 25.7 | 22.5 | 26.9 | 486.7 | 597.8 | 482.4 | 610.9 | 434.6 |
| Skwentna (240) | Mean | B | 4297 | 1779 | 1267 | 1078 | 902.8 | 809.4 | 1016 | 7920 | 18578 | 17091 | 13371 | 8150 |
| | | A | 4188 | 1762 | 1258 | 1039 | 875.9 | 804.9 | 1024 | 7985 | 18044 | 16463 | 13212 | 8382 |
| | | B | 1101 | 477.0 | 447.6 | 440.8 | 256.4 | 178.7 | 321.6 | 3139 | 5854 | 3147 | 2871 | 2453 |
| | | A | 1063 | 560.5 | 416.4 | 383.0 | 219.2 | 155.5 | 328.5 | 4115 | 6329 | 2880 | 2693 | 3260 |
| Denali (247) | Mean | B | 1132 | 499.8 | 317.3 | 245.5 | 206.4 | 187.9 | 230.2 | 2056 | 7306 | 9399 | 8124 | 3356 |
| | | A | 1127 | 478.7 | 302.3 | 240.1 | 199.3 | 187.2 | 230.0 | 2297 | 7582 | 9547 | 8354 | 3378 |
| | SD | B | 391 | 146.4 | 109.2 | 84.7 | 67.9 | 65.1 | 81.8 | 805.1 | 1973 | 1320 | 1719 | 1243 |
| | | A | 367 | 148.4 | 102.2 | 77.8 | 68.3 | 71.8 | 77.0 | 1081 | 2436 | 1479 | 1943 | 1269 |
| Talkeetna (184) | Mean | B | 2505 | 1147 | 842.1 | 673.8 | 564.7 | 496.9 | 569.1 | 4291 | 11948 | 10514 | 9272 | 5429 |
| | | A | 2702 | 1194 | 849.9 | 678.9 | 562.9 | 482.0 | 554.5 | 4115 | 11578 | 10882 | 10426 | 6163 |
| | SD | B | 825.9 | 273.7 | 176.8 | 102.3 | 92.0 | 86.9 | 129.1 | 1777 | 3801 | 1955 | 2879 | 2180 |
| | | A | 729.4 | 263.9 | 169.3 | 100.8 | 97.0 | 72.1 | 114.6 | 1526 | 3754 | 2016 | 3028 | 2304 |
| Cantwell (137) | Mean | B | 3033 | 1449 | 998.2 | 823.6 | 722.0 | 691.8 | 853.0 | 7702 | 19327 | 16892 | 14658 | 7801 |
| | | A | 3072 | 1426 | 927.3 | 822.0 | 689.5 | 650.7 | 822.6 | 7317 | 17962 | 16620 | 14334 | 7901 |
| | SD | B | 802 | 476 | 314.5 | 272.1 | 230.8 | 227.8 | 257.4 | 2911 | 6462 | 2906 | 4126 | 2649 |
| | | A | 732.4 | 361.4 | 245.2 | 215.4 | 179.4 | 193.8 | 240.6 | 2683 | 5118 | 2508 | 3216 | 2528 |
| Chulitna (176) | Mean | B | 4859 | 1994 | 1457 | 1276 | 1095 | 975.6 | 1158 | 8511 | 22537 | 26333 | 22185 | 11736 |
| | | A | 4972 | 2009 | 1461 | 1269 | 1072 | 961.8 | 1167 | 9516 | 22921 | 26687 | 22449 | 12080 |
| | SD | B | 1276 | 389 | 261 | 198 | 147.7 | 147.8 | 240.2 | 3159 | 5648 | 3363 | 4674 | 3671 |
| | | A | 1045 | 389.5 | 234.4 | 185.7 | 155.0 | 128.7 | 249.8 | 4546 | 5245 | 3500 | 4476 | 3418 |

## TABLE A1.11: LAG-ONE CORRELATION COEFFICIENTS

| | Before Filling | After Filling |
|---|---|---|
| Gold Creek | .612 | .612 |
| Denali | .567 | .597 |
| Maclaren | .594 | .600 |
| Skwentna | .602 | .587 |
| Talkeetna | .664 | .616 |
| Cantwell | .645 | .616 |
| Chulitna | .416 | .527 |

TABLE A1.12: SPATIAL CORRELATION MATRIX UNFILLED TRANSFORMED DATA SET

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gold Creek | i | 1.000 | 0.589 | 0.621 | 0.612 | 0.593 | 0.299 | 0.486 | 0.546 | 0.384 | 0.449 | 0.256 | 0.247 | 0.097 | 0.275 |
| Denali | i | | 1.000 | 0.726 | 0.619 | 0.464 | 0.718 | 0.873 | 0.207 | 0.625 | 0.445 | 0.242 | 0.170 | 0.437 | 0.549 |
| Maclaren | i | | | 1.000 | 0.337 | 0.504 | 0.587 | 0.733 | 0.426 | 0.540 | 0.714 | 0.156 | 0.306 | 0.371 | 0.517 |
| Skwentna | i | | | | 1.000 | 0.424 | 0.527 | 0.519 | 0.193 | 0.311 | 0.131 | 0.396 | 0.060 | 0.187 | 0.236 |
| Talkeetna | i | | | | | 1.000 | 0.407 | 0.550 | 0.307 | 0.307 | 0.375 | 0.261 | 0.551 | 0.230 | 0.372 |
| Cantwell | i | | | | | | 1.000 | 0.730 | 0.039 | 0.376 | 0.390 | 0.123 | 0.127 | 0.587 | 0.413 |
| Chulitna | i | | | | | | | 1.000 | 0.177 | 0.555 | 0.478 | 0.213 | 0.278 | 0.481 | 0.663 |
| Gold Creek | i | | | | | | | | 1.000 | 0.550 | 0.611 | 0.570 | 0.571 | 0.224 | 0.438 |
| Denali | i-1 | | | | | | | | | 1.000 | 0.724 | 0.588 | 0.436 | 0.699 | 0.860 |
| Maclaren | i-1 | | | | | | | | | | 1.000 | 0.304 | 0.495 | 0.583 | 0.721 |
| Skwentna | i-1 | | | | | | | | | | | 1.000 | 0.391 | 0.475 | 0.481 |
| Talkeetna | i-1 | | | | | | | | | | | | 1.000 | 0.380 | 0.524 |
| Cantwell | i-1 | | | | | | | | | | | | | 1.000 | 0.705 |
| Chulitna | i-1 | | | | | | | | | | | | | | 1.000 |

TABLE A1.13: SPATIAL CORRELATION MATRIX FILLED TRANSFORMED DATA SET

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gold Creek | i | 1.000 | 0.516 | 0.534 | 0.552 | 0.500 | 0.258 | 0.486 | 0.525 | 0.315 | 0.350 | 0.312 | 0.241 | 0.047 | 0.266 |
| Denali | i | | 1.000 | 0.728 | 0.565 | 0.398 | 0.639 | 0.833 | 0.210 | 0.615 | 0.415 | 0.286 | 0.196 | 0.358 | 0.474 |
| Maclaren | i | | | 1.000 | 0.311 | 0.366 | 0.459 | 0.732 | 0.281 | 0.464 | 0.615 | 0.148 | 0.212 | 0.239 | 0.440 |
| Skwentna | i | | | | 1.000 | 0.353 | 0.490 | 0.506 | 0.285 | 0.360 | 0.167 | 0.597 | 0.160 | 0.238 | 0.307 |
| Talkeetna | i | | | | | 1.000 | 0.445 | 0.476 | 0.243 | 0.229 | 0.211 | 0.253 | 0.586 | 0.250 | 0.285 |
| Cantwell | i | | | | | | 1.000 | 0.650 | 0.072 | 0.357 | 0.252 | 0.249 | 0.256 | 0.598 | 0.370 |
| Chulitna | i | | | | | | | 1.000 | 0.210 | 0.511 | 0.422 | 0.286 | 0.261 | 0.407 | 0.611 |
| Gold Creek | i | | | | | | | | 1.000 | 0.516 | 0.534 | 0.551 | 0.501 | 0.258 | 0.486 |
| Denali | i-1 | | | | | | | | | 1.000 | 0.727 | 0.564 | 0.398 | 0.639 | 0.833 |
| Maclaren | i-1 | | | | | | | | | | 1.000 | 0.307 | 0.366 | 0.458 | 0.733 |
| Skwentna | i-1 | | | | | | | | | | | 1.000 | 0.353 | 0.490 | 0.505 |
| Talkeetna | i-1 | | | | | | | | | | | | 1.000 | 0.446 | 0.476 |
| Cantwell | i-1 | | | | | | | | | | | | | 1.000 | 0.651 |
| Chulitna | i-1 | | | | | | | | | | | | | | 1.000 |

## TABLE A1.14: DENALI FILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | SUMYR | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1272.9 | 591.5 | 321.0 | 382.5 | 251.2 | 230.7 | 258.8 | 2152.1 | 6977.0 | 9185.2 | 7934.9 | 1794.5 | 31352.3 | 1950 |
| 2 | 711.1 | 242.1 | 152.4 | 122.9 | 113.9 | 101.8 | 315.8 | 1560.0 | 6155.5 | 8022.1 | 5167.0 | 2860.2 | 25524.6 | 1951 |
| 3 | 1084.4 | 549.7 | 336.5 | 297.5 | 198.9 | 170.9 | 178.4 | 1367.4 | 8032.8 | 9411.0 | 7715.6 | 3092.5 | 32435.7 | 1952 |
| 4 | 1028.2 | 391.1 | 232.2 | 238.7 | 134.7 | 77.9 | 216.0 | 1601.3 | 6270.8 | 8950.7 | 6349.5 | 2255.9 | 27747.2 | 1953 |
| 5 | 914.7 | 192.2 | 145.5 | 84.8 | 64.3 | 88.7 | 217.3 | 2593.9 | 5077.0 | 7864.5 | 6286.8 | 2287.0 | 25816.8 | 1954 |
| 6 | 1120.6 | 546.8 | 450.0 | 299.3 | 229.1 | 146.6 | 164.2 | 1380.0 | 7192.5 | 10378.4 | 10047.8 | 2831.5 | 34786.8 | 1955 |
| 7 | 1455.2 | 373.7 | 247.4 | 196.5 | 300.4 | 275.0 | 249.3 | 4259.3 | 9754.7 | 9449.4 | 5306.8 | 3242.2 | 35109.9 | 1956 |
| 8 | 1057.7 | 475.1 | 439.7 | 650.9 | 422.4 | 287.1 | 291.9 | 3017.3 | 12210.0 | 11170.0 | 9769.0 | 4017.0 | 43808.1 | 1957 |
| 9 | 1277.0 | 610.0 | 288.0 | 219.0 | 150.0 | 120.0 | 210.0 | 1163.0 | 8367.0 | 9150.0 | 6536.0 | 1879.0 | 29969.0 | 1958 |
| 10 | 939.0 | 390.0 | 170.0 | 119.0 | 81.0 | 41.7 | 43.0 | 1782.0 | 8891.0 | 8333.0 | 7882.0 | 2498.0 | 31169.7 | 1959 |
| 11 | 1577.0 | 760.0 | 575.0 | 444.0 | 321.0 | 275.0 | 265.0 | 3349.0 | 5237.0 | 9039.0 | 7910.0 | 4817.0 | 34569.0 | 1960 |
| 12 | 1781.0 | 660.0 | 483.0 | 331.0 | 271.0 | 281.0 | 415.0 | 2959.0 | 6412.0 | 8078.0 | 7253.0 | 2695.0 | 31619.0 | 1961 |
| 13 | 1290.0 | 680.0 | 440.0 | 280.0 | 240.0 | 220.0 | 280.0 | 2197.0 | 9087.0 | 10220.0 | 9454.0 | 3649.0 | 38037.0 | 1962 |
| 14 | 1079.0 | 510.0 | 310.0 | 250.0 | 230.0 | 200.0 | 210.0 | 3253.0 | 6763.0 | 10500.0 | 10210.0 | 3949.0 | 37464.0 | 1963 |
| 15 | 925.0 | 290.0 | 185.0 | 140.0 | 140.0 | 110.0 | 130.0 | 910.0 | 11630.0 | 7577.0 | 6552.0 | 2633.0 | 31222.0 | 1964 |
| 16 | 1468.0 | 702.0 | 279.0 | 220.0 | 200.0 | 208.0 | 320.0 | 2464.0 | 4647.0 | 6756.0 | 5764.0 | 6955.0 | 29983.0 | 1965 |
| 17 | 920.0 | 300.0 | 240.0 | 210.0 | 200.0 | 200.0 | 280.0 | 1629.0 | 6850.0 | 8287.0 | 6432.0 | 3200.0 | 28748.0 | 1966 |
| 18 | 920.0 | 300.0 | 240.0 | 210.0 | 200.0 | 200.0 | 280.0 | 1629.0 | 6850.0 | 8287.0 | 6432.0 | 3200.0 | 28748.0 | 1967 |
| 19 | 973.5 | 616.9 | 323.6 | 189.0 | 266.9 | 266.7 | 325.0 | 1495.3 | 6138.2 | 11840.0 | 9825.0 | 2192.0 | 34452.1 | 1968 |
| 20 | 700.0 | 304.0 | 172.0 | 145.0 | 140.0 | 145.0 | 229.0 | 1768.0 | 8146.0 | 9445.0 | 3919.0 | 2213.0 | 27326.0 | 1969 |
| 21 | 1002.0 | 501.0 | 339.0 | 265.0 | 221.0 | 193.0 | 319.0 | 2210.0 | 5013.0 | 8454.0 | 6216.0 | 1946.0 | 26679.0 | 1970 |
| 22 | 528.0 | 395.0 | 276.0 | 170.0 | 125.0 | 120.0 | 135.0 | 629.0 | 8099.0 | 10410.0 | 10400.0 | 3288.0 | 34575.0 | 1971 |
| 23 | 1039.0 | 478.0 | 380.0 | 339.0 | 307.0 | 286.0 | 270.0 | 3468.0 | 6562.0 | 10450.0 | 8664.0 | 2778.0 | 35021.0 | 1972 |
| 24 | 667.0 | 323.0 | 211.0 | 178.0 | 164.0 | 153.0 | 153.0 | 1042.0 | 5741.0 | 8346.0 | 7268.0 | 2445.0 | 26691.0 | 1973 |
| 25 | 876.0 | 462.0 | 366.0 | 310.0 | 271.0 | 235.0 | 262.0 | 2541.0 | 5642.0 | 9547.0 | 9292.0 | 5452.0 | 35256.0 | 1974 |
| 26 | 2135.0 | 673.0 | 381.0 | 300.0 | 200.0 | 200.0 | 200.0 | 1640.0 | 7040.0 | 12110.0 | 7295.0 | 3571.0 | 35745.0 | 1975 |
| 27 | 1539.0 | 375.0 | 169.0 | 112.0 | 97.0 | 90.0 | 123.0 | 1805.0 | 5939.0 | 8558.0 | 10080.0 | 1822.0 | 30709.0 | 1976 |
| 28 | 894.0 | 467.0 | 331.0 | 266.0 | 240.0 | 231.0 | 246.0 | 1498.0 | 8253.0 | 10010.0 | 10180.0 | 3707.0 | 36323.0 | 1977 |
| 29 | 1148.0 | 652.0 | 439.0 | 348.0 | 300.0 | 246.0 | 263.0 | 2031.0 | 5250.0 | 8993.0 | 8644.0 | 3622.0 | 31936.0 | 1978 |
| 30 | 865.0 | 463.0 | 312.0 | 263.0 | 229.0 | 203.0 | 250.0 | 2791.0 | 7650.0 | 9504.0 | 9178.0 | 4512.0 | 36220.0 | 1979 |

## TABLE A1.15: MACLAREN FILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | SUMYR | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 503.2 | 195.6 | 96.7 | 90.2 | 110.8 | 65.7 | 63.4 | 705.9 | 2345.7 | 3029.7 | 2394.7 | 555.6 | 10157.2 | 1950 |
| 2 | 286.9 | 97.8 | 50.9 | 48.3 | 50.7 | 35.8 | 96.3 | 783.1 | 2380.2 | 2966.1 | 2530.5 | 2085.4 | 11412.0 | 1951 |
| 3 | 381.7 | 160.9 | 115.3 | 99.6 | 66.8 | 50.7 | 51.6 | 322.9 | 2752.2 | 3533.1 | 3092.9 | 1692.7 | 12320.5 | 1952 |
| 4 | 449.3 | 156.6 | 69.7 | 61.6 | 46.0 | 50.8 | 82.8 | 520.6 | 2403.9 | 2924.6 | 2601.9 | 979.1 | 10346.8 | 1953 |
| 5 | 370.7 | 131.4 | 85.7 | 100.3 | 56.3 | 45.8 | 68.7 | 2083.7 | 3332.7 | 3132.4 | 2797.8 | 885.9 | 13091.4 | 1954 |
| 6 | 368.2 | 159.9 | 102.9 | 97.3 | 107.0 | 73.0 | 72.8 | 397.9 | 2889.5 | 3137.6 | 3741.1 | 1748.4 | 12895.7 | 1955 |
| 7 | 604.3 | 246.2 | 102.6 | 66.5 | 105.2 | 83.4 | 103.3 | 1549.8 | 3303.3 | 3415.6 | 2178.4 | 1080.7 | 12839.4 | 1956 |
| 8 | 287.5 | 125.8 | 96.1 | 88.4 | 70.5 | 92.4 | 71.5 | 682.8 | 3158.5 | 3271.5 | 2246.0 | 1528.9 | 11719.8 | 1957 |
| 9 | 430.3 | 171.1 | 118.6 | 108.7 | 80.8 | 64.0 | 118.1 | 828.0 | 3532.0 | 3525.0 | 2699.0 | 784.0 | 12459.8 | 1958 |
| 10 | 378.0 | 115.0 | 123.0 | 129.0 | 95.4 | 62.5 | 77.5 | 587.0 | 2879.0 | 2680.0 | 2083.0 | 856.0 | 10065.4 | 1959 |
| 11 | 549.0 | 250.0 | 190.0 | 150.0 | 110.0 | 94.3 | 91.5 | 1742.0 | 2124.0 | 3359.0 | 3048.0 | 2439.0 | 14143.8 | 1960 |
| 12 | 687.0 | 195.0 | 149.0 | 110.0 | 93.9 | 96.0 | 145.0 | 1237.0 | 2678.0 | 3369.0 | 3299.0 | 1168.0 | 13226.9 | 1961 |
| 13 | 381.0 | 210.0 | 170.0 | 120.0 | 100.0 | 92.0 | 120.0 | 632.0 | 2916.0 | 3265.0 | 2927.0 | 1127.0 | 12060.0 | 1962 |
| 14 | 383.0 | 210.0 | 130.0 | 100.0 | 91.0 | 80.0 | 83.0 | 2131.0 | 3110.0 | 4649.0 | 3136.0 | 1213.0 | 15316.0 | 1963 |
| 15 | 416.0 | 140.0 | 98.0 | 85.0 | 88.0 | 71.0 | 72.0 | 386.0 | 4297.0 | 2764.0 | 2224.0 | 871.0 | 11512.0 | 1964 |
| 16 | 379.0 | 147.0 | 49.3 | 44.0 | 42.0 | 41.0 | 62.0 | 984.0 | 2268.0 | 3223.0 | 2409.0 | 2098.0 | 11746.3 | 1965 |
| 17 | 522.0 | 180.0 | 55.0 | 45.0 | 45.0 | 43.0 | 50.0 | 265.0 | 2990.0 | 2505.0 | 2095.0 | 954.0 | 9749.0 | 1966 |
| 18 | 369.0 | 95.0 | 70.0 | 65.0 | 60.0 | 55.0 | 53.3 | 1023.0 | 3634.0 | 3255.0 | 3605.0 | 1416.0 | 13700.3 | 1967 |
| 19 | 417.0 | 130.0 | 100.0 | 97.4 | 95.0 | 95.0 | 95.0 | 208.0 | 3245.0 | 3427.0 | 2129.0 | 680.0 | 10718.4 | 1968 |
| 20 | 265.0 | 121.0 | 68.5 | 58.2 | 55.0 | 57.6 | 95.3 | 849.0 | 2613.0 | 2692.0 | 974.0 | 470.0 | 8318.6 | 1969 |
| 21 | 249.0 | 117.0 | 73.2 | 59.4 | 50.4 | 52.7 | 69.2 | 746.0 | 1751.0 | 2441.0 | 2367.0 | 773.0 | 8748.9 | 1970 |
| 22 | 301.0 | 192.0 | 131.0 | 83.4 | 60.4 | 55.0 | 66.0 | 365.0 | 3414.0 | 3528.0 | 3659.0 | 1165.0 | 13019.8 | 1971 |
| 23 | 375.0 | 156.0 | 123.0 | 115.0 | 107.0 | 97.4 | 98.5 | 1218.0 | 3069.0 | 3255.0 | 2676.0 | 1366.0 | 12655.9 | 1972 |
| 24 | 550.0 | 243.0 | 136.0 | 87.4 | 65.2 | 53.4 | 51.2 | 576.0 | 2906.0 | 2856.0 | 2271.0 | 821.0 | 10616.2 | 1973 |
| 25 | 307.0 | 123.0 | 82.6 | 68.5 | 61.8 | 56.6 | 56.7 | 649.0 | 2069.0 | 2634.0 | 2439.0 | 1543.0 | 10090.2 | 1974 |
| 26 | 385.0 | 232.0 | 140.0 | 115.0 | 110.0 | 100.0 | 103.0 | 768.0 | 3178.0 | 3649.0 | 1982.0 | 1574.0 | 12336.0 | 1975 |
| 27 | 553.0 | 235.0 | 139.0 | 106.0 | 94.1 | 90.0 | 105.0 | 781.0 | 2870.0 | 2810.0 | 2604.0 | 600.0 | 10987.1 | 1976 |
| 28 | 302.0 | 168.0 | 119.0 | 97.3 | 92.0 | 90.0 | 92.9 | 366.0 | 3942.0 | 3834.0 | 3394.0 | 1297.0 | 13794.2 | 1977 |
| 29 | 512.0 | 265.0 | 186.0 | 162.0 | 140.0 | 121.0 | 134.0 | 709.0 | 2317.0 | 3196.0 | 2356.0 | 924.0 | 11022.0 | 1978 |
| 30 | 307.0 | 192.0 | 142.0 | 122.0 | 110.0 | 100.0 | 111.0 | 634.0 | 2430.0 | 3056.0 | 2223.0 | 1137.0 | 10564.0 | 1979 |

## TABLE A1.16: CANTWELL FILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | SUMYR | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4218.3 | 1824.1 | 924.6 | 828.3 | 662.6 | 562.7 | 618.3 | 7827.5 | 15670.4 | 16690.4 | 13901.9 | 5631.6 | 69360.7 | 1950 |
| 2 | 2710.0 | 889.0 | 710.7 | 556.2 | 494.8 | 409.5 | 999.4 | 6194.6 | 12003.0 | 14652.4 | 11642.8 | 11693.5 | 62955.8 | 1951 |
| 3 | 3255.8 | 1575.1 | 956.5 | 740.4 | 492.3 | 560.5 | 639.3 | 2642.7 | 16465.7 | 17394.7 | 13705.1 | 8185.0 | 66613.1 | 1952 |
| 4 | 3431.2 | 1668.6 | 932.4 | 731.2 | 511.6 | 476.7 | 833.7 | 5960.2 | 13671.0 | 13140.8 | 11158.3 | 5876.8 | 58392.4 | 1953 |
| 5 | 2334.1 | 916.8 | 794.1 | 708.4 | 482.6 | 443.3 | 638.4 | 7852.1 | 16795.4 | 16371.9 | 19033.7 | 9832.6 | 76203.3 | 1954 |
| 6 | 3293.4 | 1784.7 | 1105.3 | 930.6 | 797.6 | 491.0 | 563.2 | 3014.7 | 14675.8 | 16621.7 | 12900.7 | 6064.7 | 62243.4 | 1955 |
| 7 | 2465.1 | 1075.3 | 855.2 | 684.3 | 727.2 | 614.7 | 569.2 | 8231.9 | 20082.3 | 18916.4 | 14164.8 | 8487.2 | 76873.6 | 1956 |
| 8 | 2547.4 | 1279.1 | 902.1 | 888.4 | 843.4 | 851.3 | 802.6 | 8230.5 | 19438.8 | 16361.0 | 13422.6 | 8899.4 | 74466.8 | 1957 |
| 9 | 3410.4 | 2051.9 | 1096.8 | 876.9 | 592.2 | 454.1 | 689.9 | 3004.9 | 13973.2 | 15743.3 | 12723.2 | 4464.4 | 59081.3 | 1958 |
| 10 | 2690.1 | 969.6 | 733.6 | 661.7 | 644.9 | 501.2 | 671.2 | 7894.5 | 16362.3 | 15620.2 | 16790.6 | 8063.5 | 71603.4 | 1959 |
| 11 | 3711.0 | 1718.7 | 1187.7 | 1042.0 | 826.4 | 695.6 | 785.6 | 13750.5 | 11108.1 | 16291.3 | 17056.1 | 12704.7 | 80877.7 | 1960 |
| 12 | 4625.6 | 2012.7 | 1534.8 | 1207.4 | 984.7 | 1056.1 | 1701.7 | 9688.0 | 15710.0 | 14820.0 | 16700.0 | 6725.0 | 76766.0 | 1961 |
| 13 | 3281.0 | 1800.0 | 1400.0 | 1300.0 | 1000.0 | 940.0 | 1200.0 | 10000.0 | 28320.1 | 20890.0 | 16000.0 | 9410.0 | 95541.1 | 1962 |
| 14 | 4326.0 | 2200.0 | 1400.0 | 1000.0 | 850.0 | 760.0 | 720.0 | 11340.0 | 15000.0 | 22790.0 | 18190.0 | 9187.0 | 87763.1 | 1963 |
| 15 | 3848.0 | 1300.0 | 877.0 | 644.0 | 586.0 | 429.0 | 465.0 | 2806.0 | 34630.0 | 17040.0 | 11510.0 | 5352.0 | 79487.0 | 1964 |
| 16 | 3134.0 | 1911.0 | 921.0 | 760.0 | 680.0 | 709.0 | 1097.0 | 8818.0 | 16430.0 | 18350.0 | 13440.0 | 12910.0 | 79160.1 | 1965 |
| 17 | 3116.0 | 1000.0 | 750.0 | 700.0 | 650.0 | 650.0 | 875.0 | 4387.0 | 18500.0 | 12220.0 | 12680.0 | 6523.0 | 62051.0 | 1966 |
| 18 | 2322.0 | 780.0 | 720.0 | 680.0 | 640.0 | 560.0 | 513.0 | 9452.0 | 19620.0 | 16880.0 | 19190.0 | 10280.0 | 81637.1 | 1967 |
| 19 | 3084.0 | 1490.0 | 1332.0 | 1232.0 | 1200.0 | 1200.0 | 1223.0 | 9268.0 | 19500.0 | 17480.0 | 10940.0 | 5410.0 | 73359.1 | 1968 |
| 20 | 2406.0 | 1063.0 | 618.0 | 508.0 | 485.0 | 548.0 | 998.0 | 7471.0 | 12330.0 | 13510.0 | 6597.0 | 3376.0 | 49910.0 | 1969 |
| 21 | 1638.0 | 815.0 | 543.0 | 437.0 | 426.0 | 463.0 | 887.0 | 7580.0 | 9909.0 | 13900.0 | 12320.0 | 5211.0 | 54129.0 | 1970 |
| 22 | 2155.0 | 1530.0 | 1048.0 | 731.0 | 503.0 | 470.0 | 529.0 | 1915.0 | 21970.0 | 18130.0 | 22710.0 | 9800.0 | 81491.1 | 1971 |
| 23 | 4058.0 | 2050.0 | 1371.0 | 1068.0 | 922.0 | 881.0 | 876.0 | 9694.0 | 20000.0 | 16690.0 | 15620.0 | 9423.0 | 82653.0 | 1972 |
| 24 | 3619.2 | 1962.0 | 1138.5 | 895.6 | 778.9 | 638.9 | 723.2 | 4763.6 | 16762.6 | 12619.1 | 12379.8 | 5037.5 | 61318.9 | 1973 |
| 25 | 2037.4 | 929.4 | 651.2 | 583.7 | 467.7 | 407.8 | 553.0 | 9163.1 | 12544.9 | 13434.2 | 11833.3 | 7888.1 | 60493.8 | 1974 |
| 26 | 2108.9 | 1191.4 | 929.8 | 812.5 | 779.6 | 669.5 | 807.2 | 5583.5 | 19277.4 | 20812.1 | 14871.9 | 10648.4 | 78492.2 | 1975 |
| 27 | 3879.3 | 1052.1 | 564.4 | 549.6 | 529.7 | 496.4 | 628.4 | 4788.3 | 16571.4 | 14057.3 | 14468.0 | 4585.6 | 62170.6 | 1976 |
| 28 | 2198.5 | 1195.9 | 1150.1 | 848.6 | 689.9 | 777.8 | 996.2 | 9619.2 | 30705.6 | 16666.4 | 12242.6 | 7420.0 | 84510.7 | 1977 |
| 29 | 3968.8 | 1833.7 | 1263.7 | 1192.1 | 1034.4 | 1272.7 | 1368.8 | 7819.4 | 15655.3 | 16812.8 | 10181.5 | 5488.6 | 67891.8 | 1978 |
| 30 | 2345.0 | 1288.6 | 1032.3 | 878.5 | 808.3 | 746.7 | 870.6 | 6209.9 | 15598.4 | 18493.7 | 12750.7 | 7320.9 | 68343.7 | 1979 |

## TABLE A1.17: GOLD CREEK FILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | SUMYR | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6335.0 | 2583.0 | 1439.0 | 1027.0 | 788.0 | 726.0 | 870.0 | 11510.0 | 19600.0 | 22600.0 | 19880.0 | 8301.0 | 95659.1 | 1950 |
| 2 | 3848.0 | 1300.0 | 1100.0 | 960.0 | 820.0 | 740.0 | 1617.0 | 14090.0 | 20790.0 | 22570.0 | 19670.0 | 21240.0 | 108745.1 | 1951 |
| 3 | 5571.0 | 2744.0 | 1900.0 | 1600.0 | 1000.0 | 880.0 | 920.0 | 5419.0 | 32370.1 | 26390.0 | 20920.0 | 14480.0 | 114194.1 | 1952 |
| 4 | 8202.0 | 3497.0 | 1700.0 | 1100.0 | 820.0 | 820.0 | 1615.0 | 19270.0 | 27320.1 | 20200.0 | 20610.0 | 15270.0 | 120424.1 | 1953 |
| 5 | 5604.0 | 2100.0 | 1500.0 | 1300.0 | 1000.0 | 780.0 | 1235.0 | 17280.0 | 25250.0 | 20360.0 | 26100.0 | 12920.0 | 115429.1 | 1954 |
| 6 | 5370.0 | 2760.0 | 2045.0 | 1794.0 | 1400.0 | 1100.0 | 1200.0 | 9319.0 | 29860.0 | 27560.0 | 25750.0 | 14290.0 | 122448.1 | 1955 |
| 7 | 4951.0 | 1900.0 | 1300.0 | 980.0 | 970.0 | 940.0 | 950.0 | 17660.0 | 33340.0 | 31090.1 | 24530.0 | 18330.0 | 136941.2 | 1956 |
| 8 | 5806.0 | 3050.0 | 2142.0 | 1700.0 | 1500.0 | 1200.0 | 1200.0 | 13750.0 | 30160.0 | 23310.0 | 20540.0 | 19800.0 | 124158.1 | 1957 |
| 9 | 8212.0 | 3954.0 | 3264.0 | 1965.0 | 1307.0 | 1148.0 | 1533.0 | 12900.0 | 25700.0 | 22880.0 | 22540.0 | 7550.0 | 112953.1 | 1958 |
| 10 | 4811.0 | 2150.0 | 1513.0 | 1448.0 | 1307.0 | 980.0 | 1250.0 | 15990.0 | 23320.0 | 25000.0 | 31180.0 | 16920.0 | 125869.1 | 1959 |
| 11 | 6558.0 | 2850.0 | 2200.0 | 1845.0 | 1452.0 | 1197.0 | 1300.0 | 15780.0 | 15530.0 | 22980.0 | 23590.0 | 20510.0 | 115792.1 | 1960 |
| 12 | 7794.0 | 3000.0 | 2694.0 | 2452.0 | 1754.0 | 1810.0 | 2650.0 | 17360.0 | 29450.0 | 24570.0 | 22100.0 | 13370.0 | 129004.1 | 1961 |
| 13 | 5916.0 | 2700.0 | 2100.0 | 1900.0 | 1500.0 | 1400.0 | 1700.0 | 12590.0 | 43270.0 | 25850.0 | 23550.0 | 15890.0 | 138366.0 | 1962 |
| 14 | 6723.0 | 2800.0 | 2000.0 | 1600.0 | 1500.0 | 1000.0 | 830.0 | 19030.0 | 26000.0 | 34400.0 | 23670.0 | 12320.0 | 131873.0 | 1963 |
| 15 | 6449.0 | 2250.0 | 1494.0 | 1048.0 | 966.0 | 713.0 | 745.0 | 4307.0 | 50580.0 | 22950.0 | 16440.0 | 9571.0 | 117513.1 | 1964 |
| 16 | 6291.0 | 2799.0 | 1211.0 | 960.0 | 860.0 | 900.0 | 1360.0 | 12990.0 | 25720.0 | 27840.0 | 21120.0 | 19350.0 | 121401.1 | 1965 |
| 17 | 7205.0 | 2098.0 | 1631.0 | 1400.0 | 1300.0 | 1300.0 | 1775.0 | 9645.0 | 32950.0 | 19860.0 | 21830.0 | 11750.0 | 112744.1 | 1966 |
| 18 | 4163.0 | 1600.0 | 1500.0 | 1500.0 | 1400.0 | 1200.0 | 1167.0 | 15480.0 | 29510.0 | 26800.0 | 32620.0 | 16870.0 | 133810.1 | 1967 |
| 19 | 4900.0 | 2353.0 | 2055.0 | 1981.0 | 1900.0 | 1900.0 | 1910.0 | 16180.0 | 31550.0 | 26420.0 | 17170.0 | 8816.0 | 117135.1 | 1968 |
| 20 | 3822.0 | 1630.0 | 882.0 | 724.0 | 723.0 | 816.0 | 1510.0 | 11050.0 | 15500.0 | 16100.0 | 8879.0 | 5093.0 | 66729.0 | 1969 |
| 21 | 3124.0 | 1215.0 | 866.0 | 824.0 | 768.0 | 776.0 | 1080.0 | 11380.0 | 18630.0 | 22660.0 | 19980.0 | 9121.0 | 90424.1 | 1970 |
| 22 | 5288.0 | 3407.0 | 2290.0 | 1442.0 | 1036.0 | 950.0 | 1082.0 | 3745.0 | 32930.0 | 23950.0 | 31910.0 | 14440.0 | 122470.1 | 1971 |
| 23 | 5847.0 | 3093.0 | 2510.0 | 2239.0 | 2028.0 | 1823.0 | 1710.0 | 21890.0 | 34430.0 | 22770.0 | 19290.0 | 12400.0 | 130030.1 | 1972 |
| 24 | 4826.0 | 2253.0 | 1465.0 | 1200.0 | 1200.0 | 1000.0 | 1027.0 | 8235.0 | 27800.0 | 18250.0 | 20290.0 | 9074.0 | 96620.1 | 1973 |
| 25 | 3733.0 | 1523.0 | 1034.0 | 874.0 | 777.0 | 724.0 | 992.0 | 16180.0 | 17870.0 | 18800.0 | 16220.0 | 12250.0 | 90977.1 | 1974 |
| 26 | 3739.0 | 1700.0 | 1603.0 | 1516.0 | 1471.0 | 1400.0 | 1593.0 | 15350.0 | 32310.0 | 27720.0 | 18090.0 | 16310.0 | 122802.1 | 1975 |
| 27 | 7739.0 | 1993.0 | 1081.0 | 974.0 | 950.0 | 900.0 | 1373.0 | 12620.0 | 24380.0 | 18940.0 | 19800.0 | 6881.0 | 97631.1 | 1976 |
| 28 | 3874.0 | 2650.0 | 2403.0 | 1829.0 | 1618.0 | 1500.0 | 1680.0 | 12680.0 | 37970.0 | 22870.0 | 19240.0 | 12640.0 | 120954.1 | 1977 |
| 29 | 7571.0 | 3525.0 | 2589.0 | 2029.0 | 1668.0 | 1605.0 | 1702.0 | 11950.0 | 19050.0 | 21020.0 | 16390.0 | 8607.0 | 97706.1 | 1978 |
| 30 | 4907.0 | 2535.0 | 1681.0 | 1397.0 | 1286.0 | 1200.0 | 1450.0 | 13870.0 | 24690.0 | 28880.1 | 20460.0 | 10770.0 | 113126.1 | 1979 |

TABLE A1.18: CHULITNA FILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | SUMYR | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9314.0 | 3276.9 | 2142.9 | 1588.2 | 1171.9 | 1029.9 | 1143.2 | 19888.0 | 27251.6 | 33669.3 | 25265.0 | 6424.4 | 132165.4 | 1950 |
| 2 | 3268.1 | 1236.0 | 890.7 | 979.9 | 911.6 | 845.4 | 1282.5 | 6100.5 | 19759.9 | 24160.5 | 20960.9 | 14192.6 | 94588.8 | 1951 |
| 3 | 6525.7 | 2406.5 | 1770.8 | 1385.3 | 1165.7 | 1074.5 | 1408.9 | 11664.4 | 28489.4 | 26546.6 | 19652.6 | 11001.1 | 113091.3 | 1952 |
| 4 | 6141.9 | 2046.5 | 1495.9 | 1597.1 | 1140.5 | 955.7 | 1266.6 | 9575.0 | 19571.0 | 22848.3 | 17478.3 | 10756.5 | 94873.1 | 1953 |
| 5 | 4380.8 | 1680.2 | 1287.2 | 1220.5 | 1042.8 | 833.6 | 1054.4 | 16617.6 | 22528.3 | 25827.2 | 27063.5 | 11887.7 | 115423.6 | 1954 |
| 6 | 4668.2 | 2303.5 | 1436.6 | 1148.3 | 893.6 | 861.1 | 1046.7 | 7928.7 | 26568.4 | 34255.7 | 31861.7 | 12604.0 | 125576.6 | 1955 |
| 7 | 6086.8 | 2005.1 | 1476.3 | 1323.2 | 1295.7 | 1104.2 | 1030.3 | 20025.4 | 33241.0 | 31196.3 | 23329.2 | 23259.6 | 145373.1 | 1956 |
| 8 | 6516.1 | 3013.7 | 1741.2 | 1673.3 | 1298.1 | 1237.5 | 1305.9 | 8447.2 | 24913.7 | 28654.7 | 26519.3 | 14016.7 | 119337.4 | 1957 |
| 9 | 5718.3 | 2752.0 | 1419.0 | 1305.9 | 1044.0 | 948.0 | 1220.0 | 10460.0 | 23170.0 | 25010.0 | 20760.0 | 8000.0 | 101807.2 | 1958 |
| 10 | 4197.0 | 1883.0 | 1262.0 | 1097.0 | 1049.0 | 738.0 | 890.0 | 7413.0 | 23660.0 | 25650.0 | 22100.0 | 9957.0 | 99896.1 | 1959 |
| 11 | 4723.0 | 2283.0 | 1700.0 | 1448.0 | 1103.0 | 933.0 | 1000.0 | 13890.0 | 17390.0 | 23650.0 | 19320.0 | 12420.0 | 99860.1 | 1960 |
| 12 | 5135.0 | 1950.0 | 1745.0 | 1452.0 | 1100.0 | 1079.0 | 1600.0 | 10100.0 | 20490.0 | 27420.0 | 24580.0 | 16030.0 | 112681.1 | 1961 |
| 13 | 5777.0 | 2400.0 | 1500.0 | 1300.0 | 1000.0 | 930.0 | 1170.0 | 7743.0 | 20620.0 | 27220.0 | 21980.0 | 13490.0 | 105130.1 | 1962 |
| 14 | 3506.0 | 1500.0 | 1552.0 | 1600.0 | 1300.0 | 846.0 | 700.0 | 11060.0 | 17750.0 | 28950.0 | 18390.0 | 11330.0 | 98484.0 | 1963 |
| 15 | 8062.0 | 2300.0 | 1000.0 | 1007.0 | 820.0 | 770.0 | 1133.0 | 2355.0 | 40330.0 | 24430.0 | 20250.0 | 9235.0 | 111692.1 | 1964 |
| 16 | 5642.0 | 2900.0 | 2100.0 | 1600.0 | 1400.0 | 1300.0 | 1400.0 | 7452.0 | 20070.0 | 23230.0 | 22550.0 | 22260.0 | 111904.1 | 1965 |
| 17 | 6071.0 | 1620.0 | 1350.0 | 1200.0 | 1100.0 | 1100.0 | 1300.0 | 3971.0 | 21740.0 | 23750.0 | 27720.0 | 12200.0 | 103122.1 | 1966 |
| 18 | 4682.0 | 1680.0 | 1500.0 | 1458.0 | 1257.0 | 1045.0 | 972.0 | 12400.0 | 25520.0 | 35570.0 | 33670.0 | 12510.0 | 132264.1 | 1967 |
| 19 | 3483.0 | 1660.0 | 1397.0 | 1235.0 | 1200.0 | 1148.0 | 1347.0 | 10940.0 | 29000.0 | 30140.0 | 20710.0 | 7375.0 | 109635.1 | 1968 |
| 20 | 2898.0 | 1480.0 | 1139.0 | 974.0 | 900.0 | 824.0 | 1333.0 | 6001.0 | 18560.0 | 20820.0 | 11300.0 | 6704.0 | 72933.1 | 1969 |
| 21 | 4578.0 | 1887.0 | 1316.0 | 1200.0 | 1154.0 | 1100.0 | 1437.0 | 9643.0 | 19670.0 | 26100.0 | 24660.0 | 11330.0 | 104075.1 | 1970 |
| 22 | 3826.0 | 2210.0 | 1403.0 | 1113.0 | 950.0 | 934.0 | 982.0 | 4468.0 | 22180.0 | 27280.0 | 23810.0 | 11080.0 | 100236.1 | 1971 |
| 23 | 5439.0 | 2157.0 | 1432.0 | 1174.0 | 1041.0 | 939.0 | 893.0 | 9765.0 | 17900.0 | 25770.0 | 20970.0 | 12120.0 | 99600.1 | 1972 |
| 24 | 6461.2 | 2174.9 | 1508.4 | 1160.2 | 1031.1 | 888.7 | 1105.6 | 4896.2 | 20005.4 | 22760.7 | 18676.2 | 7112.0 | 87780.8 | 1973 |
| 25 | 4474.7 | 1891.2 | 1397.4 | 1334.6 | 954.6 | 908.7 | 1218.4 | 15330.4 | 20941.2 | 26818.8 | 24748.5 | 12526.5 | 112545.1 | 1974 |
| 26 | 4841.1 | 1782.9 | 1371.2 | 1286.5 | 1055.7 | 1060.5 | 1345.2 | 6927.6 | 25243.9 | 33978.6 | 22306.8 | 12169.9 | 113369.9 | 1975 |
| 27 | 5525.1 | 1525.2 | 1091.1 | 1120.1 | 1076.9 | 892.9 | 1168.2 | 10429.5 | 22642.0 | 25394.9 | 24290.7 | 10334.7 | 105491.4 | 1976 |
| 28 | 6208.8 | 2537.2 | 2090.5 | 1497.5 | 989.0 | 962.0 | 1446.8 | 8159.6 | 33629.0 | 25801.8 | 20186.2 | 12388.3 | 115896.7 | 1977 |
| 29 | 5429.0 | 2113.0 | 1640.7 | 1458.4 | 1122.9 | 986.6 | 1052.1 | 4702.3 | 15587.2 | 24832.7 | 15322.5 | 10350.5 | 84597.9 | 1978 |
| 30 | 4899.8 | 2184.4 | 1651.0 | 1405.5 | 1116.9 | 935.6 | 1275.6 | 11395.8 | 19615.5 | 27739.8 | 22897.4 | 11233.5 | 106350.8 | 1979 |

## TABLE A1.19: TALKEETNA FILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | SUMYR | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3895.8 | 1576.9 | 1026.9 | 614.5 | 468.3 | 396.8 | 384.3 | 4318.5 | 8918.1 | 11734.6 | 10605.3 | 5210.8 | 49150.8 | 1950 |
| 2 | 2319.4 | 770.3 | 514.5 | 536.3 | 402.6 | 378.6 | 607.0 | 3155.9 | 7542.5 | 10122.6 | 9355.4 | 8464.7 | 44169.7 | 1951 |
| 3 | 2387.8 | 1094.8 | 779.8 | 582.5 | 466.5 | 412.8 | 489.3 | 2638.3 | 11368.8 | 9476.0 | 8289.7 | 7047.8 | 45034.1 | 1952 |
| 4 | 3188.0 | 1554.7 | 931.0 | 635.0 | 470.4 | 453.2 | 652.5 | 4946.2 | 9867.9 | 9499.4 | 8028.7 | 5615.6 | 45842.6 | 1953 |
| 5 | 2023.6 | 1134.0 | 693.2 | 648.8 | 472.1 | 386.2 | 429.2 | 3563.7 | 9554.8 | 10044.6 | 18033.2 | 6924.8 | 53908.1 | 1954 |
| 6 | 2426.0 | 926.2 | 632.4 | 594.4 | 522.0 | 444.2 | 450.1 | 2529.8 | 10206.6 | 12340.6 | 14206.1 | 6302.3 | 51580.8 | 1955 |
| 7 | 2290.7 | 1033.4 | 789.1 | 629.9 | 628.2 | 502.4 | 497.1 | 6414.7 | 14813.5 | 11720.6 | 12931.5 | 8179.4 | 60430.4 | 1956 |
| 8 | 3017.4 | 1786.3 | 1034.0 | 707.3 | 605.6 | 501.6 | 524.4 | 4355.4 | 12778.8 | 10847.8 | 11373.2 | 9326.5 | 56858.4 | 1957 |
| 9 | 3662.4 | 1688.5 | 1014.7 | 822.1 | 609.3 | 515.3 | 705.2 | 4462.7 | 16038.6 | 13653.5 | 12199.7 | 4513.8 | 59885.9 | 1958 |
| 10 | 2424.2 | 820.8 | 614.8 | 578.9 | 526.5 | 436.2 | 568.5 | 4173.6 | 7498.7 | 10509.2 | 13065.2 | 7053.4 | 48270.0 | 1959 |
| 11 | 2946.6 | 932.5 | 802.8 | 623.0 | 478.5 | 411.7 | 496.4 | 3826.2 | 5317.8 | 9181.2 | 12318.5 | 7648.0 | 44983.2 | 1960 |
| 12 | 3264.0 | 1485.1 | 1239.1 | 1001.4 | 804.9 | 621.0 | 741.9 | 4106.8 | 15161.4 | 12515.9 | 14030.1 | 7879.3 | 62850.7 | 1961 |
| 13 | 3095.2 | 1554.6 | 1033.9 | 814.9 | 734.5 | 569.1 | 648.2 | 3259.9 | 16992.5 | 9664.8 | 9289.7 | 5663.1 | 53320.4 | 1962 |
| 14 | 3576.4 | 1377.5 | 1107.3 | 776.7 | 700.4 | 537.3 | 454.8 | 4327.7 | 9949.3 | 13023.0 | 10087.2 | 3777.5 | 49695.1 | 1963 |
| 15 | 2839.9 | 916.2 | 693.0 | 528.9 | 440.3 | 383.6 | 371.2 | 1694.3 | 17080.0 | 9820.0 | 8396.0 | 3815.0 | 46978.4 | 1964 |
| 16 | 3115.0 | 1568.0 | 1100.0 | 720.0 | 620.0 | 540.0 | 580.0 | 3474.0 | 11090.0 | 12180.0 | 11150.0 | 10610.0 | 56747.0 | 1965 |
| 17 | 4438.0 | 1460.0 | 876.0 | 711.0 | 526.0 | 395.0 | 422.0 | 2410.0 | 12970.0 | 10100.0 | 10730.0 | 5370.0 | 50408.0 | 1966 |
| 18 | 2388.0 | 897.0 | 750.0 | 637.0 | 546.0 | 471.0 | 427.0 | 4112.0 | 9286.0 | 12600.0 | 14160.0 | 6971.0 | 53245.0 | 1967 |
| 19 | 2029.0 | 1253.0 | 987.0 | 851.0 | 777.0 | 743.0 | 983.0 | 8840.0 | 14100.0 | 11230.0 | 7546.0 | 4120.0 | 53459.0 | 1968 |
| 20 | 1637.0 | 827.0 | 556.0 | 459.0 | 401.0 | 380.0 | 519.0 | 3869.0 | 5207.0 | 7080.0 | 3787.0 | 2070.0 | 26792.0 | 1969 |
| 21 | 1450.0 | 765.0 | 587.0 | 504.0 | 458.0 | 440.0 | 545.0 | 3950.0 | 7979.0 | 10320.0 | 8752.0 | 5993.0 | 41743.0 | 1970 |
| 22 | 2817.0 | 1647.0 | 1103.0 | 679.0 | 459.0 | 402.0 | 503.0 | 2145.0 | 19040.0 | 11760.0 | 16770.0 | 5990.0 | 63315.0 | 1971 |
| 23 | 2632.0 | 1310.0 | 845.0 | 727.0 | 628.0 | 481.0 | 519.0 | 3516.0 | 12700.0 | 12030.0 | 9576.0 | 8709.0 | 53673.0 | 1972 |
| 24 | 3630.0 | 1373.0 | 889.0 | 748.0 | 654.0 | 574.0 | 577.0 | 3860.0 | 12210.0 | 7676.0 | 9927.0 | 3861.0 | 45979.0 | 1973 |
| 25 | 1807.0 | 960.0 | 745.0 | 645.0 | 559.0 | 482.0 | 535.0 | 5678.0 | 8030.0 | 7755.0 | 7704.0 | 4763.0 | 39663.0 | 1974 |
| 26 | 1967.0 | 1002.0 | 774.0 | 694.0 | 586.0 | 508.0 | 522.0 | 4084.0 | 13180.0 | 12070.0 | 8487.0 | 7960.0 | 51834.0 | 1975 |
| 27 | 2884.0 | 773.0 | 558.0 | 524.0 | 480.0 | 470.0 | 613.0 | 3439.0 | 10580.0 | 9026.0 | 8088.0 | 3205.0 | 40640.0 | 1976 |
| 28 | 1857.0 | 1105.0 | 1069.0 | 700.0 | 549.0 | 506.0 | 548.0 | 4244.0 | 18280.0 | 9344.0 | 8005.0 | 5826.0 | 52033.0 | 1977 |
| 29 | 3268.0 | 1121.0 | 860.0 | 746.0 | 576.0 | 485.0 | 534.0 | 2950.0 | 7429.0 | 10790.0 | 7001.0 | 3567.0 | 39327.0 | 1978 |
| 30 | 1660.0 | 1138.0 | 932.0 | 762.0 | 652.0 | 577.0 | 710.0 | 7790.0 | 12010.0 | 14440.0 | 8274.0 | 4039.0 | 52984.0 | 1979 |

## TABLE A1.20: SKWENTNA FILLED DATA SET

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | SUMYR | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3914.4 | 1208.1 | 1012.1 | 720.8 | 695.3 | 753.7 | 932.7 | 10833.8 | 16583.8 | 16325.4 | 12895.4 | 5176.6 | 71052.2 | 1950 |
| 2 | 2741.5 | 747.5 | 628.3 | 733.7 | 891.9 | 768.4 | 1460.6 | 10775.6 | 13874.9 | 15583.3 | 11340.5 | 7822.1 | 67368.3 | 1951 |
| 3 | 3116.0 | 1552.9 | 924.2 | 1074.9 | 822.8 | 696.0 | 864.9 | 8077.6 | 22948.5 | 17793.5 | 11668.3 | 5492.4 | 75032.1 | 1952 |
| 4 | 4024.5 | 1106.4 | 824.1 | 1013.5 | 828.6 | 775.4 | 1018.4 | 8743.6 | 13573.8 | 14073.4 | 9533.7 | 4786.8 | 60302.1 | 1953 |
| 5 | 2723.1 | 1228.7 | 698.8 | 687.2 | 490.2 | 562.7 | 766.2 | 11172.8 | 19246.9 | 12761.3 | 17702.9 | 10650.8 | 78691.7 | 1954 |
| 6 | 4211.4 | 1223.2 | 1202.3 | 1191.9 | 686.6 | 732.0 | 911.7 | 11900.3 | 40356.0 | 24816.5 | 20590.6 | 9652.0 | 117474.5 | 1955 |
| 7 | 5923.6 | 2831.9 | 1506.0 | 854.4 | 996.2 | 707.1 | 943.5 | 17845.3 | 34533.9 | 23137.7 | 14854.5 | 13371.3 | 117505.5 | 1956 |
| 8 | 4936.3 | 3094.2 | 1989.7 | 2165.8 | 1130.2 | 1144.0 | 900.7 | 5015.3 | 29642.6 | 19122.7 | 13917.9 | 8835.0 | 91894.4 | 1957 |
| 9 | 5544.7 | 2174.4 | 976.2 | 600.4 | 613.5 | 761.4 | 1253.5 | 12067.6 | 19677.0 | 17800.6 | 15359.6 | 6205.8 | 83034.6 | 1958 |
| 10 | 4038.4 | 1184.7 | 761.1 | 1091.1 | 629.9 | 522.0 | 759.8 | 4698.4 | 13830.5 | 15086.5 | 11729.1 | 4937.1 | 59268.6 | 1959 |
| 11 | 3532.0 | 1850.0 | 1400.0 | 1097.0 | 961.0 | 843.0 | 835.0 | 10480.0 | 13440.0 | 16690.0 | 15990.0 | 9171.0 | 76289.0 | 1960 |
| 12 | 3889.0 | 1600.0 | 1597.0 | 1403.0 | 1154.0 | 1155.0 | 1700.0 | 11210.0 | 20570.0 | 16480.0 | 13910.0 | 12020.0 | 86688.0 | 1961 |
| 13 | 4605.0 | 2200.0 | 1400.0 | 1200.0 | 860.0 | 760.0 | 1000.0 | 6613.0 | 15630.0 | 14930.0 | 12080.0 | 6723.0 | 68001.0 | 1962 |
| 14 | 2801.0 | 1250.0 | 1100.0 | 1000.0 | 810.0 | 700.0 | 650.0 | 7765.0 | 14050.0 | 20430.0 | 12020.0 | 7180.0 | 69756.1 | 1963 |
| 15 | 5355.0 | 1550.0 | 840.0 | 970.0 | 750.0 | 600.0 | 840.0 | 1635.0 | 27250.0 | 16480.0 | 12680.0 | 6224.0 | 75174.1 | 1964 |
| 16 | 4425.0 | 1790.0 | 1300.0 | 920.0 | 800.0 | 740.0 | 770.0 | 4810.0 | 17160.0 | 19370.0 | 14010.0 | 13090.0 | 79185.1 | 1965 |
| 17 | 4122.0 | 1575.0 | 1150.0 | 1100.0 | 1100.0 | 1100.0 | 1300.0 | 4502.0 | 19550.0 | 14180.0 | 17320.0 | 9812.0 | 76811.1 | 1966 |
| 18 | 5576.0 | 1400.0 | 900.0 | 720.0 | 650.0 | 650.0 | 780.0 | 1794.0 | 14430.0 | 14740.0 | 15760.0 | 9517.0 | 66917.0 | 1967 |
| 19 | 3832.0 | 1560.0 | 1181.0 | 1023.0 | 1000.0 | 950.0 | 1293.0 | 13460.0 | 20770.0 | 17480.0 | 10560.0 | 3855.0 | 76964.1 | 1968 |
| 20 | 1929.0 | 678.0 | 624.0 | 600.0 | 600.0 | 626.0 | 1487.0 | 11070.0 | 19580.0 | 13650.0 | 7471.0 | 3783.0 | 62098.1 | 1969 |
| 21 | 5654.0 | 1607.0 | 832.0 | 766.0 | 700.0 | 650.0 | 728.0 | 11710.0 | 22880.0 | 21120.0 | 13030.0 | 6665.0 | 86342.1 | 1970 |
| 22 | 2919.0 | 2023.0 | 1184.0 | 865.0 | 721.0 | 613.0 | 607.0 | 5963.0 | 25400.0 | 20600.0 | 15920.0 | 6024.0 | 82839.1 | 1971 |
| 23 | 3020.0 | 1327.0 | 1103.0 | 989.0 | 898.0 | 811.0 | 742.0 | 8045.0 | 15330.0 | 16840.0 | 13370.0 | 9256.0 | 71731.0 | 1972 |
| 24 | 4551.0 | 2340.0 | 1316.0 | 910.0 | 702.0 | 606.0 | 727.0 | 6349.0 | 15200.0 | 13850.0 | 9874.0 | 6164.0 | 62589.0 | 1973 |
| 25 | 3540.0 | 1700.0 | 1265.0 | 1023.0 | 902.0 | 811.0 | 1005.0 | 6765.0 | 10650.0 | 11670.0 | 10480.0 | 11800.0 | 61611.0 | 1974 |
| 26 | 4557.0 | 2328.0 | 919.0 | 800.0 | 750.0 | 750.0 | 767.0 | 7852.0 | 19060.0 | 19520.0 | 11710.0 | 8471.0 | 77484.1 | 1975 |
| 27 | 4704.0 | 1973.0 | 1258.0 | 971.0 | 897.0 | 800.0 | 1270.0 | 8806.0 | 15120.0 | 14580.0 | 11120.0 | 8165.0 | 69664.0 | 1976 |
| 28 | 6196.0 | 2880.0 | 2871.0 | 2829.0 | 1821.0 | 1200.0 | 1200.0 | 8906.0 | 36670.0 | 25270.0 | 20160.0 | 10290.0 | 120293.1 | 1977 |
| 29 | 5799.0 | 2373.0 | 1548.0 | 1213.0 | 944.0 | 841.0 | 1023.0 | 9006.0 | 13840.0 | 18100.0 | 13740.0 | 7335.0 | 75762.0 | 1978 |
| 30 | 4936.0 | 1580.0 | 1555.0 | 1165.0 | 1036.0 | 981.0 | 1597.0 | 11660.0 | 14980.0 | 15830.0 | 16210.0 | 7448.0 | 78978.0 | 1979 |

## TABLE A1.21: SUSITNA STATION FILLED DATA SET

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | SUMYR | CALYR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26869.4 | 11367.1 | 6197.0 | 6071.9 | 5255.5 | 5376.7 | 5656.9 | 66293.5 | 101615.7 | 124889.8 | 106431.8 | 39331.2 | 505356.5 | 1950 |
| 18026.1 | 6932.8 | 5980.9 | 7073.6 | 7294.9 | 6381.5 | 7354.2 | 59272.5 | 82254.6 | 123164.1 | 100946.9 | 73471.0 | 498153.1 | 1951 |
| 31052.6 | 16363.8 | 6988.5 | 8274.3 | 7036.4 | 5853.0 | 5985.1 | 45294.3 | 132547.3 | 137321.8 | 116186.1 | 82076.3 | 594979.5 | 1952 |
| 44952.4 | 16289.1 | 9746.0 | 8068.7 | 6774.5 | 6349.8 | 7992.6 | 88840.0 | 130561.3 | 125949.2 | 97610.0 | 44167.7 | 587301.3 | 1953 |
| 20168.5 | 11829.1 | 5271.6 | 7202.0 | 4993.1 | 4979.7 | 6305.5 | 58516.4 | 108881.0 | 116731.6 | 128586.7 | 66275.3 | 539740.5 | 1954 |
| 23895.7 | 9167.8 | 6183.0 | 7254.6 | 5845.1 | 5315.6 | 6412.4 | 58164.0 | 169044.8 | 148876.5 | 120120.0 | 53504.2 | 613783.7 | 1955 |
| 19923.4 | 10521.9 | 7294.7 | 6179.2 | 6830.8 | 6324.4 | 7182.2 | 82485.8 | 161346.1 | 168814.6 | 131619.5 | 104218.4 | 712741.0 | 1956 |
| 41821.6 | 21547.5 | 14146.3 | 10600.1 | 8356.1 | 7353.1 | 7705.3 | 63204.4 | 176218.8 | 140318.3 | 124812.9 | 87825.0 | 703909.4 | 1957 |
| 52636.0 | 19886.6 | 10635.3 | 7552.9 | 6386.9 | 6678.8 | 8098.6 | 70320.5 | 112896.8 | 122280.2 | 99608.5 | 53053.3 | 570034.4 | 1958 |
| 30543.1 | 9528.4 | 4763.4 | 7795.1 | 6564.3 | 5665.5 | 6467.8 | 56601.4 | 110602.3 | 146216.8 | 138334.3 | 67903.5 | 590985.9 | 1959 |
| 25754.1 | 10164.5 | 7004.6 | 6716.3 | 6310.0 | 5651.4 | 5829.6 | 50081.6 | 84134.4 | 129403.4 | 113971.6 | 81565.4 | 526566.9 | 1960 |
| 33782.3 | 12914.2 | 13768.2 | 12669.1 | 10034.0 | 9192.6 | 9802.6 | 85456.7 | 151715.1 | 138968.5 | 116696.5 | 62504.3 | 657504.1 | 1961 |
| 29028.7 | 13043.3 | 8976.6 | 9050.1 | 6182.5 | 5950.6 | 6635.2 | 54553.8 | 163049.0 | 143441.3 | 121220.5 | 74806.4 | 635938.0 | 1962 |
| 27716.2 | 10754.5 | 8864.6 | 8670.7 | 7853.6 | 6058.1 | 5564.7 | 53903.2 | 85647.9 | 146420.1 | 106706.8 | 70782.4 | 538942.8 | 1963 |
| 37846.3 | 11701.6 | 5626.0 | 6351.1 | 5761.6 | 4910.4 | 5530.8 | 35536.2 | 153126.4 | 124805.8 | 92279.5 | 46109.8 | 529585.5 | 1964 |
| 28746.9 | 10458.0 | 6126.6 | 6951.9 | 6195.8 | 6169.9 | 7120.1 | 49485.4 | 110074.6 | 138406.5 | 111845.9 | 89944.3 | 571525.9 | 1965 |
| 36553.2 | 12312.5 | 9159.3 | 8030.8 | 7489.4 | 7090.5 | 8048.3 | 52311.4 | 125182.8 | 117607.4 | 118729.3 | 63887.3 | 566402.2 | 1966 |
| 26396.2 | 12962.6 | 8321.9 | 8028.5 | 7726.1 | 6683.2 | 7280.6 | 58106.6 | 134880.9 | 136306.3 | 137318.0 | 89527.0 | 633537.9 | 1967 |
| 37724.5 | 15872.8 | 15081.0 | 11604.2 | 11532.2 | 8772.0 | 8762.6 | 94143.2 | 137867.2 | 130513.6 | 86874.5 | 42384.8 | 601132.6 | 1968 |
| 15939.8 | 6605.7 | 4279.1 | 5032.5 | 5137.2 | 5171.9 | 6452.4 | 44317.3 | 83225.5 | 102121.2 | 62368.2 | 34085.4 | 374736.2 | 1969 |
| 22683.4 | 6799.3 | 5016.4 | 6074.2 | 5581.3 | 5731.6 | 5769.1 | 53036.2 | 94612.1 | 132984.7 | 117728.0 | 80584.8 | 536601.1 | 1970 |
| 32817.3 | 16607.2 | 8633.2 | 6508.7 | 6253.8 | 5882.6 | 5787.5 | 29809.3 | 122258.2 | 139183.4 | 133310.1 | 69021.2 | 576072.5 | 1971 |
| 32763.2 | 14921.9 | 8790.8 | 9379.7 | 8458.3 | 6645.8 | 6894.9 | 74062.0 | 176023.9 | 142786.8 | 107596.6 | 60220.4 | 648544.3 | 1972 |
| 26781.9 | 14852.9 | 8147.1 | 7609.2 | 7476.7 | 6312.6 | 7688.2 | 64534.0 | 122797.1 | 123362.2 | 107260.8 | 45226.8 | 542049.6 | 1973 |
| 20975.7 | 10113.3 | 6081.0 | 7401.6 | 6747.3 | 6293.7 | 6962.8 | 61457.8 | 67838.0 | 102184.3 | 80251.5 | 56123.5 | 432430.5 | 1974 |
| 19520.0 | 10400.0 | 9419.0 | 8597.0 | 7804.0 | 7048.0 | 6867.0 | 47540.0 | 128800.2 | 135700.0 | 91360.1 | 77740.1 | 550795.4 | 1975 |
| 31550.0 | 9933.0 | 6000.0 | 6529.0 | 5614.0 | 5368.0 | 7253.0 | 70460.1 | 107000.0 | 115200.1 | 99650.1 | 48910.0 | 513467.3 | 1976 |
| 30140.0 | 18270.0 | 13100.0 | 10100.0 | 8911.0 | 6774.0 | 6233.0 | 56180.0 | 165900.3 | 143900.0 | 125500.1 | 83810.1 | 668818.6 | 1977 |
| 38230.0 | 12630.0 | 7529.0 | 6974.0 | 6771.0 | 6590.0 | 7033.0 | 48670.0 | 90930.0 | 117600.1 | 102100.2 | 55500.0 | 500557.3 | 1978 |
| 36810.0 | 15000.0 | 9306.0 | 8823.0 | 7946.0 | 7032.0 | 8683.0 | 81260.1 | 119900.0 | 142500.0 | 128200.0 | 74340.0 | 639800.1 | 1979 |

TABLE A1.22: COMPUTED STREAMFLOW AT DENALI

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1493.5 | 618.9 | 398.2 | 219.4 | 220.1 | 149.6 | 218.8 | 2531.9 | 6232.7 | 10078.0 | 8015.0 | 2478.8 |
| 899.0 | 310.2 | 250.8 | 173.1 | 147.9 | 151.8 | 363.7 | 3456.3 | 7189.2 | 10352.8 | 8506.8 | 5878.0 |
| 1216.4 | 488.0 | 338.6 | 359.1 | 309.3 | 282.9 | 298.1 | 2065.4 | 9767.3 | 11392.7 | 8965.7 | 3758.5 |
| 1600.3 | 780.5 | 362.2 | 269.1 | 193.9 | 166.9 | 456.8 | 5754.4 | 9952.4 | 9773.4 | 7960.8 | 3494.4 |
| 1485.8 | 442.3 | 309.4 | 351.6 | 251.6 | 215.9 | 262.5 | 3757.7 | 7509.7 | 9467.0 | 9416.6 | 3189.8 |
| 1247.9 | 680.9 | 371.8 | 341.6 | 248.0 | 237.1 | 264.7 | 2669.5 | 9680.5 | 9760.9 | 12473.6 | 5239.0 |
| 1297.5 | 396.4 | 305.7 | 296.6 | 172.0 | 212.7 | 224.6 | 6666.0 | 18527.2 | 15779.2 | 15313.5 | 7290.9 |
| 2000.2 | 972.3 | 573.3 | 342.6 | 301.4 | 221.9 | 338.7 | 4577.1 | 13750.6 | 12230.0 | 10785.2 | 5580.9 |
| 1963.6 | 931.1 | 605.1 | 371.8 | 233.7 | 175.0 | 294.4 | 2090.9 | 9503.0 | 10136.3 | 7701.8 | 2374.6 |
| 1299.5 | 522.6 | 295.5 | 234.7 | 193.9 | 131.9 | 157.9 | 3626.7 | 10464.8 | 9754.3 | 10165.1 | 3902.4 |
| 2016.2 | 960.7 | 741.4 | 584.2 | 419.7 | 349.4 | 337.6 | 4211.8 | 5961.3 | 10134.5 | 9255.6 | 6212.3 |
| 2331.2 | 872.0 | 710.3 | 543.0 | 412.6 | 432.1 | 631.0 | 4132.8 | 8514.2 | 9569.8 | 8079.2 | 3711.7 |
| 1693.2 | 817.7 | 547.1 | 371.8 | 316.5 | 290.4 | 356.5 | 2593.3 | 11374.3 | 10978.9 | 10609.2 | 4640.4 |
| 1445.7 | 601.8 | 401.8 | 341.8 | 329.5 | 236.7 | 226.8 | 4429.6 | 8446.0 | 12276.3 | 11048.4 | 4428.3 |
| 1323.0 | 435.4 | 279.4 | 201.8 | 198.1 | 153.5 | 172.8 | 1139.7 | 14070.3 | 8481.2 | 7306.3 | 3278.5 |
| 1951.0 | 837.9 | 323.4 | 250.6 | 227.5 | 237.2 | 360.2 | 3102.3 | 6068.4 | 8208.0 | 6939.0 | 7940.3 |
| 1545.6 | 468.0 | 374.8 | 317.1 | 299.5 | 299.5 | 417.7 | 2433.5 | 9060.8 | 9455.9 | 7832.0 | 3999.7 |
| 1850.3 | 655.9 | 461.4 | 465.1 | 356.1 | 430.2 | 348.6 | 5020.6 | 10672.6 | 12672.4 | 11778.1 | 3946.0 |
| 1912.1 | 634.8 | 460.8 | 371.0 | 422.1 | 446.4 | 322.7 | 1850.2 | 8846.9 | 13207.8 | 10778.2 | 2713.1 |
| 916.6 | 390.8 | 212.4 | 178.0 | 176.4 | 186.0 | 307.3 | 2315.6 | 8631.0 | 9841.3 | 4268.1 | 2475.7 |
| 1229.4 | 562.2 | 388.4 | 324.2 | 273.3 | 240.9 | 348.5 | 2791.4 | 6347.3 | 9794.3 | 7388.0 | 2544.2 |
| 1007.3 | 682.2 | 466.0 | 278.8 | 206.5 | 193.4 | 219.6 | 909.0 | 9775.9 | 11300.5 | 11807.6 | 3997.9 |
| 1312.7 | 637.6 | 554.3 | 518.2 | 476.2 | 430.1 | 397.6 | 5334.0 | 8769.8 | 11380.2 | 9225.5 | 3233.5 |
| 832.5 | 409.8 | 279.9 | 231.2 | 227.0 | 192.8 | 188.6 | 1341.0 | 6983.8 | 8944.8 | 7984.9 | 2752.3 |
| 1089.4 | 515.1 | 398.3 | 337.6 | 298.5 | 265.5 | 299.9 | 3578.9 | 6616.3 | 10438.9 | 10142.3 | 6229.0 |
| 2340.1 | 744.1 | 483.9 | 394.7 | 313.7 | 313.1 | 320.4 | 2799.9 | 8812.6 | 13462.8 | 8229.6 | 4591.1 |
| 2188.6 | 498.6 | 233.6 | 180.2 | 162.2 | 156.0 | 221.8 | 2965.9 | 7322.2 | 9165.0 | 10523.6 | 2190.8 |
| 1178.0 | 695.1 | 556.6 | 417.5 | 370.9 | 353.7 | 396.3 | 2794.4 | 10339.8 | 11007.4 | 10947.2 | 4346.2 |
| 1708.4 | 929.4 | 631.2 | 490.3 | 426.3 | 355.9 | 355.6 | 2257.6 | 5809.1 | 9823.9 | 9583.1 | 4087.0 |
| 1222.3 | 649.1 | 428.2 | 345.1 | 301.7 | 234.2 | 291.7 | 3264.3 | 8213.0 | 10755.5 | 10373.0 | 5039.7 |

TABLE A1.23: COMPUTED STREAMFLOW AT MACLAREN

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1851.5 | 930.0 | 557.2 | 340.3 | 308.0 | 229.9 | 296.0 | 3345.8 | 8595.6 | 11824.2 | 9947.8 | 3932.9 |
| 1579.9 | 529.7 | 408.8 | 348.9 | 279.7 | 276.2 | 566.3 | 5420.9 | 10605.6 | 12631.5 | 9898.4 | 8174.3 |
| 2043.6 | 845.0 | 583.8 | 544.9 | 436.3 | 384.7 | 441.3 | 2224.2 | 12442.8 | 13272.1 | 10301.1 | 5261.9 |
| 2392.9 | 1158.0 | 490.4 | 326.4 | 240.8 | 288.2 | 705.7 | 7047.4 | 11176.5 | 11218.7 | 9206.1 | 4547.9 |
| 1778.3 | 620.8 | 483.7 | 532.7 | 363.1 | 307.0 | 368.5 | 3616.3 | 8975.5 | 10546.4 | 10528.9 | 3368.0 |
| 1408.2 | 818.3 | 562.2 | 532.8 | 370.2 | 379.6 | 390.1 | 2753.9 | 13038.6 | 13381.9 | 15813.8 | 8225.5 |
| 1961.5 | 709.6 | 454.1 | 416.2 | 285.3 | 263.4 | 289.2 | 6372.9 | 18316.8 | 16750.4 | 13544.8 | 6560.6 |
| 1932.0 | 1040.5 | 783.2 | 576.9 | 484.6 | 359.4 | 436.9 | 4708.5 | 15590.9 | 13406.0 | 11540.4 | 6402.9 |
| 2327.0 | 1144.3 | 675.6 | 539.7 | 411.7 | 406.7 | 541.0 | 3596.5 | 12617.6 | 12274.8 | 10132.9 | 2922.4 |
| 1589.4 | 773.2 | 394.3 | 364.6 | 290.4 | 191.3 | 238.7 | 2704.8 | 10668.2 | 11497.9 | 11475.1 | 4747.3 |
| 2482.5 | 1093.8 | 805.5 | 651.9 | 529.3 | 462.0 | 505.6 | 6262.8 | 7621.9 | 11947.9 | 10863.7 | 7637.0 |
| 2817.8 | 1069.4 | 794.1 | 646.6 | 510.0 | 513.4 | 768.1 | 5845.7 | 10400.8 | 10970.3 | 11305.8 | 4423.9 |
| 2144.1 | 1160.5 | 851.8 | 717.6 | 566.0 | 528.9 | 674.7 | 5544.5 | 17338.0 | 14797.4 | 12262.2 | 6120.5 |
| 2472.0 | 1235.0 | 777.6 | 571.8 | 496.0 | 440.2 | 428.8 | 6722.3 | 10296.7 | 15772.4 | 13633.4 | 6196.1 |
| 2179.0 | 723.3 | 481.9 | 356.2 | 331.3 | 246.9 | 273.7 | 1723.4 | 21497.0 | 11636.6 | 8679.0 | 3799.5 |
| 2182.7 | 1220.7 | 554.4 | 451.7 | 405.9 | 422.9 | 653.3 | 5189.9 | 9701.9 | 11729.8 | 9057.0 | 9509.7 |
| 1862.1 | 600.3 | 458.8 | 420.2 | 393.1 | 393.1 | 535.3 | 2812.2 | 11847.9 | 9974.3 | 9112.4 | 4625.6 |
| 1891.8 | 637.5 | 504.2 | 485.6 | 411.5 | 430.0 | 362.0 | 6395.0 | 13647.0 | 13610.8 | 13784.5 | 6087.5 |
| 2256.2 | 926.3 | 771.4 | 674.9 | 694.7 | 708.5 | 648.9 | 4428.6 | 12364.3 | 14259.6 | 10303.3 | 3572.5 |
| 1431.9 | 629.6 | 363.3 | 300.7 | 288.0 | 317.9 | 558.9 | 4214.6 | 9940.9 | 11188.9 | 5067.9 | 2711.9 |
| 1274.8 | 635.7 | 426.5 | 338.8 | 308.9 | 308.8 | 562.7 | 4513.7 | 7113.4 | 10790.3 | 8834.6 | 3346.7 |
| 1226.0 | 881.9 | 607.2 | 410.7 | 287.2 | 270.1 | 304.0 | 1180.7 | 14049.7 | 13721.9 | 15681.0 | 6081.6 |
| 2334.2 | 1152.4 | 805.1 | 651.7 | 570.8 | 541.3 | 530.0 | 6139.0 | 12326.9 | 13127.0 | 11648.1 | 5628.7 |
| 1987.2 | 907.7 | 555.7 | 467.4 | 431.8 | 404.9 | 428.1 | 3289.5 | 11719.7 | 10915.7 | 10844.3 | 4427.3 |
| 1503.4 | 768.3 | 562.1 | 474.5 | 411.1 | 359.3 | 469.0 | 5482.0 | 8156.0 | 11015.7 | 9879.9 | 6189.7 |
| 2248.1 | 914.1 | 616.7 | 556.2 | 426.3 | 397.7 | 460.0 | 4269.4 | 12910.5 | 15013.6 | 9305.6 | 6175.7 |
| 2377.3 | 722.6 | 379.2 | 290.6 | 280.1 | 252.4 | 382.3 | 3189.5 | 9971.8 | 11309.9 | 13006.1 | 2958.2 |
| 1376.1 | 763.9 | 587.2 | 511.8 | 464.1 | 431.3 | 439.8 | 2660.2 | 15150.2 | 12730.3 | 11915.6 | 5747.0 |
| 2332.1 | 1106.6 | 822.6 | 670.2 | 532.9 | 521.0 | 620.7 | 5650.9 | 9602.5 | 11822.7 | 9333.7 | 4456.8 |
| 1597.1 | 830.1 | 573.6 | 519.4 | 478.5 | 543.3 | 648.0 | 6216.9 | 13381.5 | 14307.2 | 10667.2 | 5717.0 |

TABLE A1.24: COMPUTED STREAMFLOW AT VEE

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3005.9 | 1553.7 | 882.3 | 590.2 | 486.4 | 402.6 | 478.5 | 5627.1 | 13070.3 | 15578.3 | 13765.5 | 6279.8 |
| 2716.6 | 902.8 | 700.5 | 646.7 | 517.0 | 492.3 | 968.1 | 9060.2 | 16106.6 | 16832.8 | 13090.5 | 12924.0 |
| 3555.0 | 1561.0 | 1077.6 | 929.0 | 672.2 | 581.1 | 680.7 | 2940.3 | 18772.9 | 17569.8 | 13574.4 | 8483.9 |
| 4252.1 | 1971.2 | 836.8 | 520.6 | 390.6 | 512.3 | 1134.8 | 10545.2 | 15261.4 | 14336.5 | 12512.6 | 7527.0 |
| 2749.0 | 1068.5 | 848.3 | 862.7 | 594.1 | 487.8 | 632.4 | 5771.8 | 13349.9 | 13400.4 | 14393.4 | 5181.2 |
| 2255.8 | 1298.8 | 1023.7 | 957.7 | 679.6 | 659.1 | 665.7 | 3958.0 | 19598.0 | 19784.9 | 21188.5 | 12554.0 |
| 3201.6 | 1257.2 | 761.2 | 643.8 | 526.4 | 433.8 | 472.5 | 7958.4 | 20625.9 | 20250.5 | 13447.6 | 7744.3 |
| 2512.1 | 1455.9 | 1245.3 | 1025.9 | 858.9 | 653.8 | 674.6 | 6383.6 | 20090.9 | 16382.1 | 13898.2 | 9578.6 |
| 3724.5 | 1855.4 | 1191.4 | 966.5 | 760.1 | 788.4 | 981.5 | 6835.5 | 18275.1 | 16433.9 | 14920.4 | 4311.1 |
| 2455.1 | 1283.2 | 692.8 | 691.5 | 569.0 | 390.5 | 499.1 | 3933.0 | 13033.6 | 15710.3 | 16257.6 | 7741.2 |
| 3687.7 | 1538.0 | 1112.2 | 928.6 | 806.6 | 710.8 | 825.8 | 10141.0 | 10796.2 | 15819.6 | 14795.0 | 11390.4 |
| 4197.7 | 1614.4 | 1208.2 | 1066.6 | 828.2 | 822.7 | 1238.1 | 9688.0 | 15710.0 | 14820.0 | 16700.0 | 6725.0 |
| 3281.0 | 1800.0 | 1400.0 | 1300.0 | 1000.0 | 940.0 | 1200.0 | 10000.0 | 28320.1 | 20890.0 | 16000.0 | 9410.0 |
| 4326.0 | 2200.0 | 1400.0 | 1000.0 | 850.0 | 760.0 | 720.0 | 11340.0 | 15000.0 | 22790.0 | 18190.0 | 9187.0 |
| 3848.0 | 1300.0 | 877.0 | 644.0 | 586.0 | 429.0 | 465.0 | 2806.0 | 34630.0 | 17040.0 | 11510.0 | 5352.0 |
| 3134.0 | 1911.0 | 921.0 | 760.0 | 680.0 | 709.0 | 1097.0 | 8818.0 | 16430.0 | 18350.0 | 13440.0 | 12910.0 |
| 3116.0 | 1000.0 | 750.0 | 700.0 | 650.0 | 650.0 | 875.0 | 4387.0 | 18500.0 | 12220.0 | 12680.0 | 6523.0 |
| 2322.0 | 780.0 | 720.0 | 680.0 | 640.0 | 560.0 | 513.0 | 9452.0 | 19620.0 | 16880.0 | 19190.0 | 10280.0 |
| 3084.0 | 1490.0 | 1332.0 | 1232.0 | 1200.0 | 1200.0 | 1223.0 | 9268.0 | 19500.0 | 17480.0 | 10940.0 | 5410.0 |
| 2406.0 | 1063.0 | 618.0 | 508.0 | 485.0 | 548.0 | 998.0 | 7471.0 | 12330.0 | 13510.0 | 6597.0 | 3376.0 |
| 1638.0 | 815.0 | 543.0 | 437.0 | 426.0 | 463.0 | 887.0 | 7580.0 | 9909.0 | 13900.0 | 12320.0 | 5211.0 |
| 2155.0 | 1530.0 | 1048.0 | 731.0 | 503.0 | 470.0 | 529.0 | 1915.0 | 21970.0 | 18130.0 | 22710.0 | 9800.0 |
| 4058.0 | 2050.0 | 1371.0 | 1068.0 | 922.0 | 881.0 | 876.0 | 9694.0 | 20000.0 | 16690.0 | 15620.0 | 9423.0 |
| 3744.3 | 1686.0 | 1014.6 | 852.6 | 788.2 | 740.1 | 794.3 | 6281.0 | 19677.3 | 14336.0 | 15604.3 | 7065.8 |
| 2338.5 | 1176.0 | 823.0 | 693.5 | 597.5 | 524.7 | 744.5 | 9396.5 | 11502.1 | 12970.6 | 10662.4 | 7171.6 |
| 2398.7 | 1235.0 | 930.5 | 897.3 | 727.6 | 660.8 | 806.1 | 7769.2 | 20724.2 | 18878.2 | 11981.7 | 9642.5 |
| 3493.1 | 1185.2 | 658.9 | 528.4 | 523.8 | 468.5 | 727.5 | 5032.2 | 15339.4 | 14972.8 | 16900.8 | 4470.5 |
| 2017.8 | 1159.1 | 928.2 | 838.9 | 762.3 | 697.8 | 697.7 | 4207.1 | 24330.5 | 16351.0 | 14225.7 | 8462.2 |
| 3908.1 | 1711.7 | 1333.1 | 1099.1 | 842.8 | 887.0 | 1096.8 | 10469.1 | 15395.8 | 15589.1 | 10251.8 | 5568.0 |
| 2571.5 | 1318.7 | 921.7 | 860.6 | 810.6 | 996.3 | 1177.7 | 10776.8 | 21010.2 | 20700.3 | 12649.3 | 7320.9 |

TABLE A1.25: COMPUTED STREAMFLOW AT SUSITNA III

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3137.7 | 1594.5 | 904.3 | 607.5 | 498.3 | 415.4 | 494.0 | 5860.1 | 13328.9 | 15856.4 | 14007.7 | 6359.8 |
| 2761.4 | 918.5 | 716.3 | 659.1 | 529.0 | 502.1 | 993.8 | 9259.4 | 16292.1 | 17060.0 | 13351.1 | 13253.3 |
| 3634.8 | 1607.9 | 1110.2 | 955.6 | 685.2 | 592.9 | 690.2 | 3038.5 | 19311.4 | 17919.1 | 13865.3 | 8721.4 |
| 4408.5 | 2031.6 | 871.0 | 543.5 | 407.6 | 524.5 | 1153.8 | 10890.7 | 15739.0 | 14568.7 | 12833.3 | 7833.7 |
| 2862.1 | 1109.4 | 874.1 | 880.0 | 610.2 | 499.4 | 656.3 | 6227.6 | 13821.2 | 13676.0 | 14857.0 | 5487.7 |
| 2379.1 | 1356.7 | 1064.1 | 990.8 | 708.1 | 676.6 | 686.9 | 4170.3 | 20004.4 | 20092.8 | 21369.2 | 12622.8 |
| 3270.9 | 1282.7 | 782.5 | 657.1 | 544.0 | 453.8 | 491.4 | 8342.6 | 21129.4 | 20679.8 | 13886.5 | 8163.5 |
| 2642.6 | 1519.0 | 1280.8 | 1052.6 | 884.3 | 675.4 | 695.4 | 6675.3 | 20489.7 | 16656.5 | 14161.2 | 9983.4 |
| 3902.2 | 1938.5 | 1273.5 | 1006.0 | 781.8 | 802.6 | 1003.3 | 7075.7 | 18569.2 | 16689.2 | 15222.2 | 4439.4 |
| 2548.4 | 1317.5 | 725.3 | 721.5 | 598.2 | 413.8 | 528.8 | 4410.5 | 13441.0 | 16078.2 | 16848.6 | 8104.7 |
| 3801.4 | 1590.0 | 1155.3 | 964.9 | 832.2 | 730.1 | 844.6 | 10364.3 | 10983.7 | 16103.2 | 15143.3 | 11751.6 |
| 4340.1 | 1669.3 | 1267.0 | 1121.5 | 864.9 | 861.8 | 1294.0 | 9991.8 | 16254.2 | 15206.1 | 16913.9 | 6988.2 |
| 3385.4 | 1835.6 | 1427.7 | 1323.8 | 1019.8 | 958.2 | 1219.8 | 10102.6 | 28912.2 | 21086.4 | 16299.0 | 9666.6 |
| 4420.9 | 2223.8 | 1423.8 | 1023.8 | 875.7 | 769.5 | 724.4 | 11644.6 | 15435.6 | 23249.8 | 18407.0 | 9311.1 |
| 3951.0 | 1337.6 | 901.4 | 660.0 | 601.0 | 440.2 | 476.1 | 2865.4 | 35261.7 | 17274.1 | 11705.2 | 5519.1 |
| 3259.0 | 1946.2 | 932.5 | 767.9 | 687.1 | 716.6 | 1107.4 | 8983.2 | 16797.9 | 18725.8 | 13744.2 | 13165.0 |
| 3277.9 | 1043.5 | 784.9 | 727.7 | 675.7 | 675.7 | 910.6 | 4595.2 | 19072.3 | 12522.6 | 13042.4 | 6730.0 |
| 2394.9 | 812.5 | 750.9 | 712.5 | 670.1 | 585.3 | 538.9 | 9690.7 | 20011.7 | 17272.9 | 19721.9 | 10541.0 |
| 3155.9 | 1524.2 | 1360.6 | 1261.7 | 1227.7 | 1227.7 | 1250.2 | 9541.7 | 19977.2 | 17834.1 | 11186.7 | 5544.9 |
| 2462.1 | 1085.5 | 628.5 | 516.6 | 494.4 | 558.6 | 1018.3 | 7612.7 | 12455.5 | 13612.6 | 6687.4 | 3444.0 |
| 1696.9 | 830.8 | 555.8 | 452.3 | 439.5 | 475.4 | 894.6 | 7730.5 | 10254.4 | 14246.9 | 12623.4 | 5365.9 |
| 2279.1 | 1604.3 | 1097.2 | 759.2 | 524.1 | 489.0 | 550.9 | 1987.5 | 22404.1 | 18360.5 | 23074.4 | 9983.8 |
| 4128.9 | 2091.3 | 1416.1 | 1114.4 | 965.8 | 918.3 | 909.0 | 10177.0 | 20571.5 | 16930.8 | 15765.3 | 9540.9 |
| 3787.1 | 1708.5 | 1032.4 | 866.4 | 804.5 | 750.4 | 803.5 | 6358.4 | 19999.0 | 14491.0 | 15789.9 | 7145.3 |
| 2393.7 | 1189.7 | 831.4 | 700.6 | 604.6 | 532.6 | 754.3 | 9665.2 | 11754.3 | 13201.5 | 10882.5 | 7372.7 |
| 2451.8 | 1253.4 | 957.1 | 921.8 | 757.0 | 690.1 | 837.3 | 8069.4 | 21183.0 | 19228.4 | 12223.6 | 9906.6 |
| 3661.3 | 1217.2 | 675.6 | 546.0 | 540.7 | 485.6 | 753.1 | 5332.7 | 15697.4 | 15129.9 | 17015.6 | 4566.0 |
| 2091.3 | 1218.1 | 986.6 | 878.1 | 796.2 | 729.6 | 736.6 | 4542.7 | 24870.7 | 16609.2 | 14424.3 | 8627.7 |
| 4053.2 | 1783.5 | 1382.8 | 1135.9 | 875.5 | 915.4 | 1120.8 | 10527.7 | 15540.5 | 15804.2 | 10494.9 | 5688.4 |
| 2664.0 | 1366.9 | 951.8 | 881.8 | 829.4 | 1004.4 | 1188.5 | 10899.3 | 21155.9 | 21024.3 | 12958.6 | 7457.5 |

TABLE A1.26: COMPUTED STREAMFLOW AT WATANA

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4719.9 | 2083.6 | 1168.9 | 815.1 | 641.7 | 569.1 | 680.1 | 8655.9 | 16432.1 | 19193.4 | 16913.6 | 7320.4 |
| 3299.1 | 1107.3 | 906.2 | 808.0 | 673.0 | 619.8 | 1302.2 | 11649.8 | 18517.9 | 19786.6 | 16478.0 | 17205.5 |
| 4592.9 | 2170.1 | 1501.0 | 1274.5 | 841.0 | 735.0 | 803.9 | 4216.5 | 25773.4 | 22110.9 | 17356.3 | 11571.0 |
| 6285.7 | 2756.8 | 1281.2 | 818.9 | 611.7 | 670.7 | 1382.0 | 15037.2 | 21469.8 | 17355.3 | 16681.6 | 11513.5 |
| 4218.9 | 1599.6 | 1183.8 | 1087.8 | 803.1 | 638.2 | 942.6 | 11696.8 | 19476.7 | 16983.6 | 20420.6 | 9165.5 |
| 3859.2 | 2051.1 | 1549.5 | 1388.3 | 1050.5 | 886.1 | 940.8 | 6718.1 | 24881.4 | 23787.9 | 23537.0 | 13447.8 |
| 4102.3 | 1588.1 | 1038.6 | 816.9 | 754.8 | 694.4 | 718.3 | 12953.3 | 27171.8 | 25831.3 | 19153.4 | 13194.4 |
| 4208.0 | 2276.6 | 1707.0 | 1373.0 | 1189.0 | 935.0 | 945.1 | 10176.2 | 25275.0 | 19948.9 | 17317.7 | 14841.1 |
| 6034.9 | 2935.9 | 2258.5 | 1480.6 | 1041.7 | 973.5 | 1265.4 | 9957.8 | 22097.8 | 19752.7 | 18843.4 | 5978.7 |
| 3668.0 | 1729.5 | 1115.1 | 1081.0 | 949.0 | 694.0 | 885.7 | 10140.6 | 18329.6 | 20493.1 | 23940.4 | 12466.9 |
| 5165.5 | 2213.5 | 1672.3 | 1400.4 | 1138.9 | 961.1 | 1069.9 | 13044.2 | 13233.4 | 19506.1 | 19323.1 | 16085.6 |
| 6049.3 | 2327.8 | 1973.2 | 1779.9 | 1304.8 | 1331.0 | 1965.0 | 13637.9 | 22784.1 | 19839.8 | 19480.2 | 10146.2 |
| 4637.6 | 2263.4 | 1760.4 | 1608.9 | 1257.4 | 1176.8 | 1457.4 | 11333.5 | 36017.1 | 23443.7 | 19887.1 | 12746.2 |
| 5560.1 | 2508.9 | 1708.9 | 1308.9 | 1184.7 | 883.6 | 776.6 | 15299.2 | 20663.4 | 28767.4 | 21011.4 | 10800.0 |
| 5187.1 | 1789.1 | 1194.7 | 852.0 | 781.6 | 575.2 | 609.2 | 3578.8 | 42841.9 | 20082.8 | 14048.2 | 7524.2 |
| 4759.4 | 2368.2 | 1070.3 | 863.0 | 772.7 | 807.3 | 1232.4 | 10966.0 | 21213.0 | 23235.9 | 17394.1 | 16225.6 |
| 5221.2 | 1565.3 | 1203.6 | 1060.4 | 984.7 | 984.7 | 1338.4 | 7094.1 | 25939.6 | 16153.5 | 17390.9 | 9214.1 |
| 3269.8 | 1202.2 | 1121.6 | 1102.2 | 1031.3 | 889.5 | 849.7 | 12555.5 | 24711.9 | 21987.3 | 26104.5 | 13672.9 |
| 4019.0 | 1934.3 | 1704.2 | 1617.6 | 1560.4 | 1560.4 | 1576.7 | 12826.7 | 25704.0 | 22082.8 | 14147.5 | 7163.6 |
| 3135.0 | 1354.9 | 753.9 | 619.2 | 607.5 | 686.0 | 1261.6 | 9313.7 | 13962.1 | 14843.5 | 7771.9 | 4260.0 |
| 2403.1 | 1020.9 | 709.3 | 636.2 | 602.1 | 624.1 | 986.4 | 9536.4 | 14399.0 | 18410.1 | 16263.8 | 7224.1 |
| 3768.0 | 2496.4 | 1687.4 | 1097.1 | 777.4 | 717.1 | 813.7 | 2857.2 | 27612.8 | 21126.4 | 27446.6 | 12188.9 |
| 4979.1 | 2587.0 | 1957.4 | 1670.9 | 1491.4 | 1366.0 | 1305.4 | 15973.1 | 27429.3 | 19820.3 | 17509.5 | 10955.7 |
| 4301.2 | 1977.9 | 1246.5 | 1031.5 | 1000.2 | 873.9 | 914.1 | 7287.0 | 23859.3 | 16351.1 | 18016.7 | 8099.7 |
| 3056.5 | 1354.7 | 931.6 | 786.4 | 689.9 | 627.3 | 871.9 | 12889.0 | 14780.6 | 15971.9 | 13523.7 | 9786.2 |
| 3088.8 | 1474.4 | 1276.7 | 1215.8 | 1110.3 | 1041.4 | 1211.2 | 11672.2 | 26689.2 | 23430.4 | 15126.6 | 13075.3 |
| 5679.1 | 1601.1 | 876.2 | 757.8 | 743.2 | 690.7 | 1059.8 | 8938.8 | 19994.0 | 17015.3 | 18393.5 | 5711.5 |
| 2973.5 | 1926.7 | 1687.5 | 1348.7 | 1202.9 | 1110.8 | 1203.4 | 8569.4 | 31352.8 | 19707.3 | 16807.3 | 10613.1 |
| 5793.9 | 2645.3 | 1979.7 | 1577.9 | 1267.7 | 1256.7 | 1408.4 | 11231.5 | 17277.2 | 18385.2 | 13412.1 | 7132.6 |
| 3773.9 | 1944.9 | 1312.6 | 1136.8 | 1055.4 | 1101.2 | 1317.9 | 12369.3 | 22904.8 | 24911.7 | 16670.7 | 9096.7 |

## TABLE A1.27: COMPUTED STREAMFLOW AT HIGH DEVIL CANYON

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5675.8 | 2379.2 | 1328.8 | 940.5 | 728.3 | 662.0 | 792.5 | 10345.1 | 18307.0 | 21209.6 | 18669.2 | 7900.8 |
| 3624.0 | 1221.3 | 1020.9 | 898.0 | 760.0 | 691.0 | 1488.5 | 13094.0 | 19862.6 | 21433.9 | 18367.1 | 19593.3 |
| 5171.8 | 2509.7 | 1737.1 | 1467.1 | 935.1 | 820.8 | 872.6 | 4928.2 | 29677.6 | 24643.4 | 19465.4 | 13292.7 |
| 7419.8 | 3194.9 | 1529.1 | 985.3 | 735.0 | 759.1 | 1519.9 | 17542.3 | 24932.2 | 19038.9 | 19006.6 | 13736.7 |
| 5038.7 | 1895.7 | 1371.0 | 1213.4 | 919.6 | 722.1 | 1115.7 | 15001.1 | 22893.5 | 18981.9 | 23781.9 | 11387.6 |
| 4753.3 | 2470.7 | 1842.8 | 1628.4 | 1257.3 | 1012.7 | 1094.2 | 8257.4 | 27827.9 | 26020.4 | 24846.7 | 13946.2 |
| 4604.6 | 1772.7 | 1193.3 | 913.4 | 882.2 | 839.8 | 855.4 | 15738.9 | 30822.4 | 28943.6 | 22335.5 | 16233.8 |
| 5153.7 | 2734.3 | 1964.4 | 1566.5 | 1373.0 | 1091.8 | 1096.0 | 12291.3 | 28166.1 | 21938.1 | 19224.8 | 17776.0 |
| 7323.4 | 3538.4 | 2853.6 | 1767.3 | 1198.7 | 1076.8 | 1423.8 | 11699.1 | 24229.7 | 21603.5 | 21031.2 | 6908.6 |
| 4344.5 | 1978.4 | 1350.6 | 1298.2 | 1160.9 | 863.3 | 1101.3 | 13602.5 | 21283.1 | 23160.5 | 28225.1 | 15102.4 |
| 5989.6 | 2590.2 | 1984.6 | 1663.5 | 1324.2 | 1100.7 | 1206.1 | 14663.4 | 14592.6 | 21562.1 | 21848.4 | 18704.1 |
| 7081.9 | 2725.6 | 2399.8 | 2177.7 | 1570.7 | 1614.5 | 2370.4 | 15840.8 | 26729.2 | 22639.3 | 21030.7 | 12054.2 |
| 5394.2 | 2521.8 | 1961.4 | 1781.2 | 1401.0 | 1308.9 | 1601.0 | 12077.1 | 40309.6 | 24867.8 | 22055.0 | 14606.8 |
| 6248.3 | 2681.2 | 1881.2 | 1481.2 | 1371.3 | 952.5 | 808.2 | 17507.2 | 23821.8 | 32101.0 | 22584.9 | 11699.6 |
| 5934.0 | 2061.9 | 1371.8 | 968.0 | 890.8 | 656.8 | 689.6 | 4009.8 | 47421.6 | 21779.7 | 15463.8 | 8735.6 |
| 5665.9 | 2623.2 | 1153.6 | 920.4 | 824.4 | 862.2 | 1307.9 | 12163.9 | 23880.4 | 25960.8 | 19599.2 | 18074.8 |
| 6395.3 | 1880.6 | 1456.5 | 1261.4 | 1171.3 | 1171.3 | 1596.8 | 8603.8 | 30088.6 | 18347.1 | 20018.1 | 10715.0 |
| 3798.4 | 1437.6 | 1345.5 | 1337.6 | 1249.5 | 1073.3 | 1037.5 | 14286.3 | 27551.6 | 24835.6 | 29960.6 | 15565.0 |
| 4540.4 | 2182.1 | 1911.8 | 1832.7 | 1761.4 | 1761.4 | 1774.0 | 14811.3 | 29163.9 | 24649.7 | 15936.3 | 8141.5 |
| 3541.6 | 1517.7 | 829.7 | 681.2 | 675.9 | 762.9 | 1408.6 | 10341.3 | 14872.3 | 15587.1 | 8427.1 | 4753.0 |
| 2829.7 | 1135.8 | 802.0 | 747.4 | 700.3 | 714.0 | 1041.8 | 10627.5 | 16903.1 | 20925.3 | 18463.2 | 8346.7 |
| 4667.6 | 3035.3 | 2044.1 | 1301.2 | 930.5 | 855.0 | 972.5 | 3382.6 | 30759.7 | 22797.5 | 30088.2 | 13521.2 |
| 5492.7 | 2886.5 | 2284.5 | 2007.1 | 1809.0 | 1636.5 | 1544.9 | 19475.0 | 31572.6 | 21566.0 | 18563.3 | 11810.5 |
| 4611.8 | 2140.7 | 1375.8 | 1131.2 | 1118.5 | 948.5 | 980.9 | 7848.1 | 26191.5 | 17475.0 | 19362.1 | 8676.3 |
| 3456.9 | 1454.3 | 992.2 | 838.3 | 741.5 | 684.5 | 943.0 | 14836.7 | 16609.0 | 17645.7 | 15119.5 | 11244.4 |
| 3473.6 | 1607.9 | 1469.8 | 1393.5 | 1323.8 | 1253.6 | 1437.2 | 13848.9 | 30015.8 | 25969.1 | 16880.4 | 14989.7 |
| 6898.2 | 1833.0 | 997.4 | 885.8 | 865.6 | 814.6 | 1245.2 | 11117.5 | 22589.8 | 18154.4 | 19225.9 | 6403.7 |
| 3506.4 | 2354.8 | 2111.0 | 1632.9 | 1448.6 | 1341.1 | 1485.5 | 11002.2 | 35269.1 | 21579.1 | 18247.1 | 11812.7 |
| 6845.7 | 3165.9 | 2340.3 | 1844.9 | 1504.6 | 1462.8 | 1582.2 | 11656.8 | 18326.4 | 19944.6 | 15174.5 | 8005.2 |
| 4444.5 | 2294.1 | 1530.6 | 1290.8 | 1191.9 | 1159.7 | 1396.1 | 13257.5 | 23961.3 | 27260.3 | 18913.3 | 10087.0 |

TABLE A1.28: COMPUTED STREAMFLOW AT DEVIL CANYON

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5758.2 | 2404.7 | 1342.5 | 951.3 | 735.7 | 670.0 | 802.2 | 10490.7 | 18468.6 | 21383.4 | 18820.6 | 7950.8 |
| 3652.0 | 1231.2 | 1030.8 | 905.7 | 767.5 | 697.1 | 1504.6 | 13218.5 | 19978.5 | 21575.9 | 18530.0 | 19799.1 |
| 5221.7 | 2539.0 | 1757.5 | 1483.7 | 943.2 | 828.2 | 878.5 | 4989.5 | 30014.2 | 24861.7 | 19647.2 | 13441.1 |
| 7517.6 | 3232.6 | 1550.4 | 999.6 | 745.6 | 766.7 | 1531.8 | 17758.3 | 25230.7 | 19184.0 | 19207.0 | 13928.4 |
| 5109.3 | 1921.3 | 1387.1 | 1224.2 | 929.7 | 729.4 | 1130.6 | 15286.0 | 23188.1 | 19154.1 | 24071.6 | 11579.1 |
| 4830.4 | 2506.8 | 1868.0 | 1649.1 | 1275.2 | 1023.6 | 1107.4 | 8390.1 | 28081.9 | 26212.8 | 24959.6 | 13989.2 |
| 4647.9 | 1788.6 | 1206.6 | 921.7 | 893.1 | 852.3 | 867.3 | 15979.0 | 31137.1 | 29212.0 | 22609.8 | 16495.8 |
| 5235.3 | 2773.8 | 1986.6 | 1583.2 | 1388.9 | 1105.4 | 1109.0 | 12473.6 | 28415.4 | 22109.6 | 19389.2 | 18029.0 |
| 7434.5 | 3590.4 | 2904.9 | 1792.0 | 1212.2 | 1085.7 | 1437.4 | 11849.2 | 24413.5 | 21763.1 | 21219.8 | 6988.8 |
| 4402.8 | 1999.8 | 1370.9 | 1316.9 | 1179.1 | 877.9 | 1119.9 | 13900.9 | 21537.7 | 23390.4 | 28594.4 | 15329.6 |
| 6060.7 | 2622.7 | 2011.5 | 1686.2 | 1340.2 | 1112.8 | 1217.8 | 14802.9 | 14709.8 | 21739.3 | 22066.1 | 18929.9 |
| 7170.9 | 2759.9 | 2436.6 | 2212.0 | 1593.6 | 1638.9 | 2405.4 | 16030.7 | 27069.3 | 22880.6 | 21164.4 | 12218.6 |
| 5459.4 | 2544.1 | 1978.7 | 1796.0 | 1413.4 | 1320.3 | 1613.4 | 12141.2 | 40679.7 | 24990.6 | 22241.8 | 14767.2 |
| 6307.7 | 2696.0 | 1896.0 | 1496.0 | 1387.4 | 958.4 | 810.9 | 17697.6 | 24094.1 | 32388.4 | 22720.5 | 11777.2 |
| 5998.3 | 2085.4 | 1387.1 | 978.0 | 900.2 | 663.8 | 696.5 | 4046.9 | 47816.4 | 21926.0 | 15585.8 | 8840.0 |
| 5744.0 | 2645.1 | 1160.8 | 925.3 | 828.8 | 866.9 | 1314.4 | 12267.1 | 24110.3 | 26195.7 | 19789.3 | 18234.2 |
| 6496.5 | 1907.8 | 1478.4 | 1278.7 | 1187.4 | 1187.4 | 1619.1 | 8734.0 | 30446.3 | 18536.2 | 20244.6 | 10844.3 |
| 3844.0 | 1457.9 | 1364.9 | 1357.9 | 1268.3 | 1089.1 | 1053.7 | 14435.5 | 27796.4 | 25081.2 | 30293.0 | 15728.2 |
| 4585.3 | 2203.5 | 1929.7 | 1851.2 | 1778.7 | 1778.7 | 1791.0 | 14982.4 | 29462.1 | 24871.0 | 16090.5 | 8225.9 |
| 3576.7 | 1531.8 | 836.3 | 686.6 | 681.8 | 769.6 | 1421.3 | 10429.9 | 14950.7 | 15651.2 | 8483.6 | 4795.5 |
| 2866.5 | 1145.7 | 810.0 | 756.9 | 708.7 | 721.8 | 1046.6 | 10721.6 | 17118.9 | 21142.2 | 18652.8 | 8443.5 |
| 4745.2 | 3081.8 | 2074.8 | 1318.8 | 943.6 | 866.8 | 986.2 | 3427.9 | 31031.0 | 22941.6 | 30315.9 | 13636.0 |
| 5537.0 | 2912.3 | 2312.6 | 2036.1 | 1836.4 | 1659.8 | 1565.5 | 19776.8 | 31929.8 | 21716.5 | 18654.1 | 11884.2 |
| 4638.6 | 2154.8 | 1387.0 | 1139.8 | 1128.6 | 955.0 | 986.7 | 7896.4 | 26392.6 | 17571.8 | 19478.1 | 8726.0 |
| 3491.4 | 1462.9 | 997.4 | 842.7 | 745.9 | 689.5 | 949.1 | 15004.6 | 16766.7 | 17790.0 | 15257.0 | 11370.1 |
| 3506.8 | 1619.4 | 1486.5 | 1408.8 | 1342.2 | 1271.9 | 1456.7 | 14036.5 | 30302.6 | 26188.0 | 17031.6 | 15154.7 |
| 7003.3 | 1853.0 | 1007.9 | 896.8 | 876.2 | 825.2 | 1261.2 | 11305.3 | 22813.6 | 18252.6 | 19297.7 | 6463.3 |
| 3552.4 | 2391.7 | 2147.5 | 1657.4 | 1469.7 | 1361.0 | 1509.8 | 11211.9 | 35606.7 | 21740.5 | 18371.2 | 11916.1 |
| 6936.3 | 3210.8 | 2371.4 | 1867.9 | 1525.0 | 1480.6 | 1597.1 | 11693.4 | 18416.8 | 20079.0 | 15326.5 | 8080.4 |
| 4502.3 | 2324.3 | 1549.4 | 1304.1 | 1203.6 | 1164.7 | 1402.8 | 13334.0 | 24052.4 | 27462.8 | 19106.7 | 10172.4 |

TABLE A1.29: OBSERVED AND CALCULATED STREAMFLOWS AT WATANA DAMSITE

| Month | Average Monthly Streamflow in cfs | |
|---|---|---|
| | Observed | Calculated[1] |
| July 1980 | 28133[2] | 26743 |
| August 1980 | 18490 | 18006 |
| September 1980 | 11557 | 10996 |
| June 1981 | 17323 | 15911 |
| July 1981 | 27890 | 26592 |
| August 1981 | 31435 | 31683 |

1 See Section (C)
2 Partial records were averaged

TABLE A1.30: HISTORICAL EVAPORATION* (INCHES) - MCKINLEY PARK

| | June | July | August |
|---|---|---|---|
| 1967 | 3.97 | 3.20 | 2.42 |
| 1968 | 3.31 | 3.67 | 2.25 |
| 1969 | -- | 3.48 | 2.39 |
| 1970 | -- | 3.35 | 2.20 |
| 1971 | 6.38 | 3.75 | 2.06 |
| 1972 | 3.97 | 4.10 | 2.61 |
| 1973 | 3.37 | 3.25 | 1.55 |
| 1974 | -- | -- | -- |
| 1975 | -- | -- | -- |
| 1976 | -- | -- | -- |
| 1977 | 3.77 | 4.02 | 3.37 |
| 1978 | 3.02 | 3.46 | 3.31 |
| 1979 | 2.81 | 2.97 | 2.73 |
| 1980 | 4.04 | 2.92 | 1.88 |
| 1981 | 3.24 | 1.89 | 2.18 |
| Average | 3.78 | 3.35 | 2.41 |
| Maximum | 6.38 | 4.02 | 3.37 |
| Minimum | 2.81 | 1.89 | 1.55 |

*From NOAA Climatological Data Reports

TABLE A1.31: HISTORICAL EVAPORATION* (INCHES)
MATANUSKA AGRICULTURAL EXPERIMENT STATION

| | May | June | July | August | September |
|---|---|---|---|---|---|
| 1951 | -- | -- | 4.16 | 2.21 | 1.79 |
| 1952 | -- | 4.45 | -- | 2.98 | 1.64 |
| 1953 | 3.99 | 4.96 | 4.88 | 2.58 | 1.71 |
| 1954 | 4.74 | 4.80 | 4.10 | 3.03 | 2.23 |
| 1955 | -- | 3.48 | 4.91 | 3.96 | 2.50 |
| 1956 | 4.83 | 4.32 | 4.44 | -- | 1.47 |
| 1957 | 6.41 | 5.45 | 4.80 | 3.59 | 2.03 |
| 1958 | 4.35 | 5.00 | 3.97 | 3.53 | 2.00 |
| 1959 | 4.76 | 5.23 | 2.79 | 2.82 | 1.46 |
| 1960 | 3.76 | 4.44 | 3.59 | 2.47 | 1.08 |
| 1961 | 5.18 | 4.17 | 3.40 | 2.41 | 1.62 |
| 1962 | 3.66 | 4.09 | 3.85 | 2.81 | 1.66 |
| 1963 | -- | 3.56 | 3.42 | 2.50 | 1.48 |
| 1964 | -- | 4.04 | -- | 3.06 | 1.60 |
| 1965 | -- | 4.18 | 7.19 | 4.34 | -- |
| 1966 | 3.56 | 4.08 | 4.36 | 2.60 | 2.25 |
| 1967 | 4.35 | 3.07 | 3.99 | 2.91 | 1.76 |
| 1968 | -- | 4.57 | 3.56 | 3.30 | 1.66 |
| 1969 | -- | 5.42 | 4.38 | 3.53 | 2.07 |
| 1970 | -- | -- | 5.03 | 3.13 | 2.36 |
| 1971 | 5.34 | 4.93 | 4.90 | 2.68 | 1.57 |
| 1972 | 3.43 | 4.06 | 4.90 | 3.79 | 2.63 |
| 1973 | 5.05 | 3.56 | 4.38 | 3.52 | -- |
| 1974 | 5.06 | 4.96 | 3.96 | 3.79 | 2.20 |
| 1975 | 4.20 | 3.56 | 3.16 | 3.17 | 1.73 |
| 1976 | 4.22 | 5.34 | 4.55 | 3.21 | 2.13 |
| 1977 | 4.11 | 5.20 | 5.24 | 3.18 | 1.84 |
| 1978 | 4.60 | 3.01 | 3.33 | 3.23 | 1.70 |
| 1979 | 4.84 | 3.90 | 4.01 | 3.73 | 2.54 |
| 1980 | 3.72 | 2.98 | 3.27 | 2.74 | -- |
| 1981 | 4.41 | 3.98 | 2.82 | 2.25 | -- |
| Average | 4.48 | 4.30 | 4.18 | 3.10 | 1.88 |
| Maximum | 6.41 | 5.45 | 7.19 | 4.34 | 2.63 |
| Minimum | 3.43 | 2.98 | 2.82 | 2.21 | 1.08 |

*From NOAA Climatological Data Reports

TABLE A1.32: 1981 PAN EVAPORATION (INCHES)

| Pan Location | May (8-31)[1] | June | July | August |
|---|---|---|---|---|
| Watana | 2.10 (.15) | 5.15 (.17) | 2.44 (.08) | 1.83 (.06) |
| McKinley | 1.64 (.12) | 3.23 (.11) | 1.89 (.06) | 2.18 (.07) |
| Matanuska | 1.99 (.14) | 4.24 (.14) | 2.82 (.09) | 2.25 (.07) |

Note: Values in parentheses are average daily evaporation for the month.

[1] Values for the full record were 4.24 inches (.18 inches per day) for May 8-31 at Watana and 4.41 inches (.14 inches per day) for May 2-31 at Matanuska

TABLE A1.33: SUMMER 1981 CLIMATIC COMPARISON - WATANA, MATANUSKA, MCKINLEY SITES

| | Monthly Evaporation (inches) | | | Average Daily Temp. (°F) | | | Precipitation (inches) | | | Wind Run (miles) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June | July | August | June | July | August | June | July | August | June | July | August |
| Watana | 5.15 | 2.44 | 1.83 | 49 | 51 | 50[1] | 5.11 | 6.60 | 6.34 | 4670 | 4698[2] | 4994[2] |
| Matanuska | 4.24 | 2.82 | 2.25 | 54 | 56 | 54 | 1.93 | 4.57 | 3.65 | 627 | 463 | 680 |
| McKinley | 3.23 | 1.89 | 2.18 | 50 | 52 | 49 | 3.75 | 4.18 | 3.83 | 306 | 263 | 262 |

[1] Half of August temperature data at Watana was bad and not included.
[2] July and August wind runs at Watana are preliminary, approximate figures.

TABLE A1.34: COMPARISON OF 1981 AND HISTORICAL EVAPORATION DATA

| | 1981 Evaporation (inches) | | Average Historical Evaporation (inches) | |
|---|---|---|---|---|
| | June-August 1981 | May-September 1981 | June-August | May-September |
| Watana | 9.42 | 14.85 | -- | -- |
| Matanuska | 9.31 | 15.34 | 11.58 | 17.94 |
| McKinley | 7.30 | -- | 9.54 | -- |

## TABLE A1.35: POTENTIAL EVAPOTRANSPIRATION BY THORNTHWAITE METHOD*

| Station Name | Elevation (Feet) | Latitude (North) | Longitude (West) | Mean Annual Temperature (°F) | Mean Annual Precipitation (in.) | Potential Evapotranspiration (in.) |
|---|---|---|---|---|---|---|
| Black Rapids | 2128 | 63°32' | 145°51' | 29.9 | 18.58 | 17.24 |
| Broad Pass | 2127 | 63°12' | 149°15' | 28.3 | 11.40 | 16.69 |
| Caswell | 290 | 61°58' | 150°01' | 31.0 | 25.06 | 18.66 |
| Chickaloon | 929 | 61°48' | 148°27' | 32.7 | 14.00 | 18.11 |
| Curry | 516 | 62°37' | 150°02' | 34.9 | 43.67 | 18.94 |
| Eureka | 3326 | 61°57' | 147°10' | 24.0 | 17.09 | 12.33 |
| Glenallen | 1456 | 62°07' | 145°32' | 22.9 | 8.21 | 15.57 |
| Gulkana | 1572 | 62°17' | 145°27' | 26.9 | 11.70 | 17.44 |
| High Lake Lodge | 2760 | 62°54' | 149°05' | 27.1 | 24.50 | 14.18 |
| Indian River | 735 | 62°45' | 149°50' | 31.1 | 36.70 | 16.97 |
| Matanuska Exp. Station | 150 | 61°34' | 149°16' | 35.5 | 15.40 | 19.76 |
| McKinley Park | 2092 | 63°42' | 149°00' | 27.5 | 14.44 | 14.61 |
| Palmer | 220 | 61°37' | 149°06' | 35.6 | 16.61 | 19.72 |
| Paxson | 2697 | 63°03' | 145°27' | 24.3 | 19.65 | 14.53 |
| Sheep Mountain | 2280 | 61°48' | 147°41' | 28.8 | 11.01 | 16.42 |
| Skwentna | 153 | 61°57' | 151°10' | 32.6 | 29.87 | 18.46 |
| Snowshoe Lake | 2500 | 62°02' | 146°40' | 21.5 | 11.60 | 12.58 |
| Stampede | 2500 | 63°44' | 150°22' | 26.6 | 19.28 | 15.85 |
| Summit | 2401 | 63°20' | 149°09' | 25.8 | 22.25 | 15.51 |
| Susitna | 40 | 61°30' | 150°40' | 36.0 | 28.60 | 19.76 |
| Talkeetna | 345 | 62°18' | 150°06' | 33.2 | 28.85 | 18.70 |
| Trims Camp | 2408 | 63°26' | 145°46' | 26.5 | 36.11 | 17.29 |
| Wasilla | 400 | 61°35' | 149°28' | 35.0 | 17.21 | 17.79 |
| Willow | 600 | 61°45' | 150°00' | 32.4 | 29.16 | 17.28 |
| Wonder Lake | 2000 | 63°28' | 150°52' | 31.8 | 19.50 | 18.48 |

*Patric and Black (1968)

TABLE A1.36: ESTIMATED EVAPORATION LOSSES - WATANA AND DEVIL CANYON RESERVOIRS

| Month | WATANA Pan Evaporation (inches) | WATANA Reservoir Evaporation (inches) | DEVIL CANYON Pan Evaporation (inches) | DEVIL CANYON Reservoir Evaporation (inches) | Average Monthly Air Temperature (°C) Watana[1] | Devil Canyon[2] | Talkeetna[3] |
|---|---|---|---|---|---|---|---|
| January | 0.0 | 0.0 | 0.0 | 0.0 | - 2.5 | - 4.5 | -13.0 |
| February | 0.0 | 0.0 | 0.0 | 0.0 | - 7.3 | - 5.0 | - 9.3 |
| March | 0.0 | 0.0 | 0.0 | 0.0 | - 1.8 | - 4.3 | - 6.7 |
| April | 0.0 | 0.0 | 0.0 | 0.0 | - 1.8 | - 2.5 | 0.7 |
| May | 3.6 | 2.5 | 3.9 | 2.7 | 8.7 | 6.1 | 7.0 |
| June | 3.4 | 2.4 | 3.8 | 2.7 | 10.0 | 9.2 | 12.6 |
| July | 3.3 | 2.3 | 3.7 | 2.6 | 13.7 | 11.9 | 14.4 |
| August | 2.5 | 1.8 | 2.7 | 1.9 | 12.5 | N/A | 12.7 |
| September | 1.5 | 1.0 | 1.7 | 1.2 | N/A | 4.8 | 7.8 |
| October | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | - 1.8 | 0.2 |
| November | 0.0 | 0.0 | 0.0 | 0.0 | - 5.1 | - 7.2 | - 7.8 |
| December | 0.0 | 0.0 | 0.0 | 0.0 | -17.9 | -21.1 | -12.7 |
| Annual Evap. | 14.3 | 10.0 | 15.8 | 11.1 | | | |

[1] Based on data - April 1980-June 1981
[2] Based on data - July 1980-June 1981
[3] Based on data - January 1941-December 1980

## TABLE A1.37: MONTHLY FLOW REQUIREMENT

| Month | Monthly Flow (cfs) Case A | Band C | D |
|---|---|---|---|
| Oct | 1000 | 5500 | 5500 |
| Nov | 900 | 1200 | 1200 |
| Dec | 900 | 1200 | 1200 |
| Jan | 900 | 1200 | 1200 |
| Feb | 900 | 1200 | 1200 |
| Mar | 900 | 1200 | 1200 |
| Apr | 900 | 1200 | 1200 |
| May | 1000 | 6000 | 6000 |
| Jun | 2000 | 7000 | 7000 |
| Jul | 2000 | 9500 | 7000/1900 (1) |
| Aug | 2000 | 12000 | 19000 |
| Sep | 1000 | 12000 | 12000 |

(1) Split Month: 7000 cfs to 15th then 19000 cfs to month end.

TABLE A1.38: MONTHLY ENERGY PRODUCTION CASE A - WATANA ALONE

| | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | 2215 | | 2165 | | 2115 | |
| Month | Average | Firm | Average | Firm | Average | Firm |
| Oct | 311 | 312 | 277 | 277 | 244 | 243 |
| Nov | 366 | 366 | 327 | 327 | 287 | 287 |
| Dec | 427 | 427 | 381 | 381 | 335 | 335 |
| Jan | 375 | 375 | 335 | 335 | 294 | 294 |
| Feb | 311 | 311 | 278 | 278 | 244 | 244 |
| Mar | 311 | 311 | 278 | 278 | 244 | 244 |
| Apr | 256 | 256 | 228 | 228 | 201 | 201 |
| May | 234 | 232 | 209 | 209 | 184 | 183 |
| Jun | 206 | 201 | 185 | 185 | 164 | 157 |
| Jul | 203 | 195 | 190 | 168 | 182 | 147 |
| Aug | 221 | 56 | 272 | 52 | 303 | 44 |
| Sep | 292 | 43 | 320 | 44 | 295 | 39 |
| Ann | 3513 | 3085 | 3280 | 2762 | 2977 | 2418 |

TABLE A1.39: MONTHLY ENERGY PRODUCTION CASE C - WATANA ALONE

| Month | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | Case C1 (2215)[1] | | Case C2 (2165) | | Case 3 (2115) | |
| | Average | Firm | Average | Firm | Average | Firm |
| Oct | 268 | 269 | 239 | 249 | 211 | 211 |
| Nov | 315 | 316 | 281 | 282 | 247 | 248 |
| Dec | 368 | 368 | 328 | 328 | 289 | 289 |
| Jan | 324 | 324 | 289 | 289 | 254 | 254 |
| Feb | 268 | 268 | 240 | 240 | 211 | 211 |
| Mar | 268 | 268 | 240 | 240 | 211 | 211 |
| Apr | 221 | 221 | 197 | 197 | 173 | 173 |
| May | 202 | 202 | 181 | 180 | 159 | 158 |
| Jun | 178 | 177 | 160 | 154 | 145 | 136 |
| Jul | 289 | 222 | 306 | 193 | 321 | 172 |
| Aug | 467 | 324 | 491 | 285 | 499 | 258 |
| Sep | 374 | 220 | 370 | 236 | 351 | 213 |
| Ann | 3542 | 3179 | 3322 | 2864 | 3071 | 2534 |

(1) Normal maximum operating level (feet).

TABLE A1.40: MONTHLY ENERGY PRODUCTION CASE D - WATANA ALONE

| Month | ENERGY (GWH) | |
|---|---|---|
| | Average | Firm |
| Oct | 230 | 228 |
| Nov | 267 | 268 |
| Dec | 311 | 312 |
| Jan | 274 | 274 |
| Feb | 228 | 228 |
| Mar | 228 | 228 |
| Apr | 187 | 187 |
| May | 172 | 172 |
| Jun | 168 | 147 |
| Jul | 480 | 349 |
| Aug | 614 | 578 |
| Sep | 400 | 269 |
| Ann | 3559 | 3240 |

TABLE A1.41: WATANA (2215)/DEVIL CANYON MONTHLY ENERGY PRODUCTION CASE A1

| | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| Month | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 311 | 280 | 591 | 312 | 287 | 599 |
| Nov | 366 | 329 | 695 | 367 | 319 | 686 |
| Dec | 427 | 381 | 808 | 427 | 380 | 807 |
| Jan | 375 | 335 | 710 | 376 | 334 | 710 |
| Feb | 311 | 280 | 591 | 311 | 278 | 589 |
| Mar | 311 | 280 | 591 | 311 | 271 | 582 |
| Apr | 256 | 232 | 488 | 256 | 230 | 486 |
| May | 234 | 230 | 464 | 232 | 213 | 445 |
| Jun | 206 | 239 | 445 | 201 | 187 | 388 |
| Jul | 203 | 235 | 438 | 195 | 177 | 372 |
| Aug | 221 | 224 | 445 | 56 | 103 | 159 |
| Sep | 292 | 265 | 557 | 43 | 77 | 120 |
| Ann | 3513 | 3310 | 6823 | 3087 | 2856 | 5943 |

TABLE A1.42: WATANA (2165)/DEVIL CANYON MONTHLY ENERGY PRODUCTION CASE A

| Month | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 277 | 270 | 547 | 280 | 271 | 551 |
| Nov | 327 | 318 | 645 | 327 | 317 | 644 |
| Dec | 381 | 369 | 750 | 381 | 367 | 748 |
| Jan | 335 | 325 | 660 | 335 | 324 | 659 |
| Feb | 278 | 270 | 548 | 278 | 258 | 536 |
| Mar | 278 | 270 | 548 | 278 | 265 | 543 |
| Apr | 228 | 222 | 450 | 228 | 224 | 452 |
| May | 209 | 216 | 425 | 209 | 205 | 414 |
| Jun | 185 | 225 | 410 | 186 | 185 | 371 |
| Jul | 190 | 231 | 421 | 168 | 195 | 363 |
| Aug | 272 | 263 | 535 | 52 | 93 | 145 |
| Sep | 320 | 300 | 620 | 44 | 64 | 108 |
| Ann | 3280 | 3279 | 6559 | 2766 | 2768 | 5534 |

TABLE A1.43: WATANA (2115)/DEVIL CANYON MONTHLY ENERGY PRODUCTION CASE A

| | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| Month | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 244 | 262 | 506 | 243 | 264 | 507 |
| Nov | 287 | 310 | 597 | 288 | 308 | 596 |
| Dec | 335 | 358 | 693 | 335 | 356 | 691 |
| Jan | 294 | 316 | 610 | 295 | 314 | 609 |
| Feb | 244 | 263 | 507 | 244 | 261 | 505 |
| Mar | 244 | 267 | 511 | 244 | 262 | 506 |
| Apr | 201 | 221 | 422 | 201 | 209 | 410 |
| May | 184 | 216 | 400 | 183 | 200 | 383 |
| Jun | 164 | 209 | 373 | 157 | 172 | 329 |
| Jul | 182 | 223 | 405 | 147 | 166 | 313 |
| Aug | 303 | 286 | 589 | 44 | 59 | 103 |
| Sep | 295 | 295 | 590 | 39 | 59 | 98 |
| Ann | 2977 | 3226 | 6203 | 2420 | 2630 | 5050 |

TABLE A1.44: WATANA (2215)/DEVIL CANYON MONTHLY ENERGY PRODUCTION CASE C

| Month | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 311 | 220 | 531 | 314 | 166 | 480 |
| Nov | 366 | 251 | 617 | 367 | 185 | 552 |
| Dec | 427 | 308 | 735 | 427 | 221 | 648 |
| Jan | 375 | 294 | 669 | 376 | 194 | 570 |
| Feb | 311 | 263 | 574 | 312 | 160 | 472 |
| Mar | 311 | 276 | 587 | 312 | 224 | 536 |
| Apr | 256 | 235 | 491 | 256 | 244 | 500 |
| May | 234 | 271 | 505 | 235 | 288 | 523 |
| Jun | 206 | 282 | 488 | 201 | 248 | 449 |
| Jul | 203 | 267 | 470 | 188 | 261 | 449 |
| Aug | 221 | 345 | 566 | 56 | 317 | 373 |
| Sep | 292 | 284 | 576 | 45 | 212 | 257 |
| Ann | 3513 | 3296 | 6809 | 3089 | 2720 | 5809 |

TABLE A1.45: WATANA (2165)/DEVIL CANYON MONTHLY ENERGY PRODUCTION CASE C

| Month | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 277 | 217 | 494 | 280 | 141 | 421 |
| Nov | 327 | 253 | 507 | 327 | 165 | 492 |
| Dec | 381 | 306 | 687 | 381 | 194 | 575 |
| Jan | 335 | 293 | 628 | 335 | 170 | 505 |
| Feb | 278 | 259 | 537 | 278 | 211 | 489 |
| Mar | 278 | 272 | 550 | 278 | 275 | 553 |
| Apr | 228 | 232 | 460 | 228 | 233 | 461 |
| May | 209 | 268 | 477 | 209 | 233 | 442 |
| Jun | 185 | 276 | 461 | 186 | 263 | 449 |
| Jul | 190 | 270 | 460 | 168 | 259 | 427 |
| Aug | 272 | 357 | 629 | 52 | 310 | 362 |
| Sep | 320 | 303 | 623 | 44 | 181 | 225 |
| Ann | 3380 | 3306 | 6586 | 2766 | 2635 | 5401 |

## TABLE A1.46: WATANA (2115)/DEVIL CANYON MONTHLY ENERGY PRODUCTION CASE C

| | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| Month | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 244 | 213 | 457 | 245 | 144 | 389 |
| Nov | 287 | 238 | 525 | 288 | 161 | 449 |
| Dec | 335 | 289 | 624 | 335 | 190 | 525 |
| Jan | 294 | 283 | 577 | 295 | 166 | 461 |
| Feb | 244 | 255 | 499 | 244 | 211 | 455 |
| Mar | 244 | 270 | 514 | 244 | 282 | 526 |
| Apr | 201 | 232 | 433 | 201 | 244 | 445 |
| May | 184 | 270 | 454 | 184 | 246 | 430 |
| Jun | 164 | 277 | 441 | 167 | 275 | 442 |
| Jul | 182 | 277 | 459 | 148 | 259 | 407 |
| Aug | 303 | 371 | 674 | 44 | 310 | 354 |
| Sep | 295 | 312 | 607 | 40 | 181 | 221 |
| Ann | 2977 | 3287 | 6264 | 2435 | 2669 | 5104 |

TABLE A1.47: WATANA (2215)/DEVIL CANYON MONTHLY ENERGY PRODUCTION CASE D

| Month | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 230 | 215 | 445 | 232 | 228 | 460 |
| Nov | 267 | 234 | 501 | 267 | 239 | 506 |
| Dec | 311 | 270 | 581 | 309 | 270 | 579 |
| Jan | 274 | 241 | 515 | 274 | 241 | 515 |
| Feb | 228 | 203 | 431 | 228 | 203 | 431 |
| Mar | 228 | 204 | 432 | 228 | 204 | 432 |
| Apr | 187 | 171 | 358 | 187 | 169 | 356 |
| May | 172 | 207 | 379 | 172 | 165 | 337 |
| Jun | 168 | 245 | 413 | 150 | 173 | 323 |
| Jul | 480 | 468 | 948 | 403 | 385 | 788 |
| Aug | 614 | 561 | 1175 | 536 | 503 | 1032 |
| Sep | 400 | 382 | 782 | 285 | 265 | 550 |
| Ann | 3559 | 3401 | 6960 | 3271 | 3045 | 6316 |

TABLE A1.48: WATANA ANNUAL AVERAGE AND FIRM ENERGY PRODUCTION

| Watana Elevation | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | Case A | | Case C | | Case D | |
| | Average | Firm | Average | Firm | Average | Firm |
| 2215 | 3513 | 3085 | 3542 | 3179 | 3559 | 3240 |
| 2165 | 3280 | 2762 | 3322 | 2864 | - | - |
| 2115 | 2977 | 2418 | 3071 | 2534 | - | - |

TABLE A1.49: WATANA/DEVIL CANYON ANNUAL AVERAGE AND FIRM ENERGY PRODUCTION

| Watana Elevation | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | Case A | | Case C | | Case D | |
| | Average | Firm | Average | Firm | Average | Firm |
| 2215 | 6823 | 5943 | 6809 | 5809 | 6960 | 6316 |
| 2165 | 6559 | 5534 | 6586 | 5401 | - | - |
| 2115 | 6203 | 5050 | 6264 | 5104 | - | - |

TABLE A1.50: WATANA (2185) ALONE MONTHLY ENERGY PRODUCTION CASE A

| Month | ENERGY (GWH) | |
|---|---|---|
| | Average | Firm |
| Oct | 263 | 262 |
| Nov | 302 | 303 |
| Dec | 361 | 361 |
| Jan | 318 | 318 |
| Feb | 256 | 256 |
| Mar | 264 | 264 |
| Apr | 224 | 224 |
| May | 202 | 203 |
| Jun | 189 | 184 |
| Jul | 247 | 191 |
| Aug | 413 | 181 |
| Sep | 361 | 177 |
| Ann | 3400 | 2752 |

TABLE A1.51: WATANA (2185) ALONE MONTHLY ENERGY PRODUCTION CASE C

| Month | ENERGY (GWH) | |
|---|---|---|
| | Average | Firm |
| Oct | 249 | 248 |
| Nov | 292 | 294 |
| Dec | 341 | 341 |
| Jan | 300 | 300 |
| Feb | 249 | 249 |
| Mar | 249 | 249 |
| Apr | 205 | 205 |
| May | 188 | 187 |
| Jun | 166 | 161 |
| Jul | 304 | 200 |
| Aug | 494 | 295 |
| Sep | 373 | 243 |
| Ann | 3410 | 2972 |

TABLE A1.52: WATANA (2185) ALONE MONTHLY ENERGY PRODUCTION CASE D

| Month | ENERGY (GWH) | |
|---|---|---|
| | Average | Firm |
| Oct | 218 | 215 |
| Nov | 252 | 254 |
| Dec | 295 | 295 |
| Jan | 260 | 260 |
| Feb | 216 | 216 |
| Mar | 216 | 216 |
| Apr | 177 | 177 |
| May | 163 | 163 |
| Jun | 161 | 139 |
| Jul | 471 | 332 |
| Aug | 602 | 551 |
| Sep | 384 | 256 |
| Ann | 3415 | 3074 |

TABLE A1.53: WATANA (2185)/DEVIL CANYON MONTHLY ENERGY PRODUCTION CASE A

| Month | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 263 | 251 | 514 | 262 | 248 | 510 |
| Nov | 302 | 289 | 591 | 303 | 287 | 590 |
| Dec | 361 | 340 | 701 | 361 | 341 | 702 |
| Jan | 318 | 300 | 618 | 318 | 300 | 618 |
| Feb | 256 | 242 | 498 | 256 | 242 | 498 |
| Mar | 264 | 249 | 513 | 264 | 248 | 512 |
| Apr | 224 | 211 | 435 | 224 | 211 | 435 |
| May | 202 | 198 | 400 | 201 | 191 | 392 |
| Jun | 189 | 207 | 396 | 184 | 175 | 359 |
| Jul | 247 | 259 | 506 | 200 | 182 | 382 |
| Aug | 413 | 343 | 756 | 181 | 171 | 352 |
| Sep | 361 | 326 | 687 | 177 | 168 | 345 |
| Ann | 3400 | 3215 | 6615 | 2931 | 2764 | 5695 |

TABLE A1.54: WATANA (2185)/DEVIL CANYON MONTHLY ENERGY PRODUCTION CASE C

| Month | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 249 | 233 | 482 | 248 | 220 | 468 |
| Nov | 292 | 261 | 553 | 294 | 258 | 552 |
| Dec | 341 | 303 | 644 | 341 | 302 | 643 |
| Jan | 300 | 268 | 568 | 300 | 266 | 566 |
| Feb | 249 | 225 | 474 | 249 | 219 | 468 |
| Mar | 249 | 227 | 476 | 249 | 219 | 468 |
| Apr | 205 | 192 | 397 | 205 | 180 | 385 |
| May | 188 | 223 | 411 | 188 | 166 | 354 |
| Jun | 166 | 240 | 406 | 161 | 157 | 318 |
| Jul | 304 | 311 | 615 | 215 | 247 | 462 |
| Aug | 494 | 399 | 893 | 312 | 320 | 632 |
| Sep | 373 | 340 | 713 | 257 | 255 | 512 |
| Ann | 3410 | 3222 | 6632 | 3019 | 2809 | 5828 |

TABLE A1.55: WATANA (2185)/DEVIL CANYON MONTHLY ENERGY PRODUCTION MODIFIED CASE C[1]

| Month | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 272 | 234 | 506 | 272 | 199 | 471 |
| Nov | 321 | 265 | 586 | 322 | 235 | 557 |
| Dec | 374 | 311 | 685 | 374 | 274 | 648 |
| Jan | 329 | 281 | 610 | 329 | 239 | 568 |
| Feb | 273 | 241 | 514 | 273 | 199 | 472 |
| Mar | 273 | 247 | 520 | 273 | 198 | 471 |
| Apr | 225 | 208 | 433 | 225 | 163 | 388 |
| May | 206 | 245 | 451 | 204 | 152 | 356 |
| Jun | 181 | 261 | 442 | 182 | 199 | 381 |
| Jul | 210 | 280 | 490 | 165 | 258 | 423 |
| Aug | 364 | 374 | 738 | 146 | 317 | 463 |
| Sep | 355 | 317 | 672 | 186 | 232 | 418 |
| Ann | 3383 | 3264 | 6647 | 2951 | 2665 | 5616 |

(1) 105 foot drawdown at Devil Canyon.

TABLE A1.56: WATANA (2185)/DEVIL CANYON MONTHLY ENERGY PRODUCTION MODIFIED CASE C[1]

| Month | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 291 | 209 | 500 | 292 | 139 | 431 |
| Nov | 344 | 246 | 590 | 344 | 163 | 507 |
| Dec | 400 | 300 | 700 | 400 | 189 | 589 |
| Jan | 352 | 293 | 645 | 352 | 217 | 569 |
| Feb | 292 | 269 | 561 | 292 | 274 | 566 |
| Mar | 292 | 278 | 570 | 292 | 278 | 570 |
| Apr | 240 | 238 | 478 | 240 | 234 | 474 |
| May | 220 | 274 | 494 | 220 | 223 | 443 |
| Jun | 194 | 282 | 476 | 193 | 215 | 408 |
| Jul | 194 | 269 | 463 | 182 | 260 | 442 |
| Aug | 229 | 348 | 577 | 52 | 315 | 367 |
| Sep | 289 | 289 | 578 | 45 | 196 | 241 |
| Ann | 3337 | 3295 | 6632 | 2904 | 2703 | 5607 |

(1) Unlimited drawdown at Devil Canyon.

## TABLE A1.57: WATANA (2185)/DEVIL CANYON MONTHLY ENERGY PRODUCTION MODIFIED CASE D

| | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| Month | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 249 | 189 | 438 | 248 | 221 | 469 |
| Nov | 293 | 216 | 509 | 294 | 253 | 547 |
| Dec | 341 | 260 | 601 | 341 | 296 | 637 |
| Jan | 300 | 242 | 542 | 300 | 265 | 565 |
| Feb | 249 | 218 | 467 | 249 | 225 | 474 |
| Mar | 249 | 228 | 477 | 249 | 229 | 478 |
| Apr | 205 | 194 | 399 | 205 | 194 | 399 |
| May | 188 | 233 | 421 | 188 | 209 | 397 |
| Jun | 166 | 247 | 413 | 161 | 177 | 338 |
| Jul | 322 | 405 | 727 | 251 | 363 | 614 |
| Aug | 466 | 521 | 987 | 282 | 255 | 537 |
| Sep | 368 | 332 | 700 | 155 | 144 | 299 |
| Ann | 3396 | 3285 | 6681 | 2923 | 2831 | 5754 |

(1) Unlimited drawdown at Devil Canyon.

TABLE A1.58: WATANA (2185)/DEVIL CANYON MONTHLY ENERGY PRODUCTION MODIFIED CASE D[1]

| Month | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 226 | 201 | 427 | 225 | 175 | 400 |
| Nov | 264 | 223 | 487 | 263 | 207 | 470 |
| Dec | 309 | 264 | 573 | 309 | 240 | 549 |
| Jan | 272 | 239 | 511 | 272 | 213 | 485 |
| Feb | 225 | 201 | 426 | 225 | 176 | 401 |
| Mar | 225 | 203 | 428 | 225 | 176 | 401 |
| Apr | 185 | 170 | 355 | 185 | 145 | 330 |
| May | 170 | 210 | 380 | 169 | 153 | 322 |
| Jun | 160 | 238 | 398 | 149 | 165 | 314 |
| Jul | 439 | 444 | 983 | 334 | 367 | 701 |
| Aug | 557 | 547 | 1004 | 453 | 527 | 980 |
| Sep | 389 | 366 | 755 | 308 | 252 | 560 |
| Ann | 3421 | 3306 | 6727 | 3117 | 2796 | 5913 |

(1) Devil Canyon drawdown limited to 55'.

TABLE A1.59: DEVIL CANYON ANNUAL ENERGY WITH VARIABLE DRAWDOWN

| | ANNUAL ENERGY, (GWH) | | |
|---|---|---|---|
| Drawdown | Average | Lowest | 2nd Lowest |
| WATANA: | | | |
| Unlimited (227) | 3395 | 2924 | 2935 |
| 190 | 3443 | 2797 | 2824 |
| 165 | 3452 | 2717 | 2741 |
| 140 | 3459 | 2611 | 2632 |
| 115 | 3471 | 2372 | 2896 |
| DEVIL CANYON:[1] | | | |
| 90 | 3315 | 2384 | 2697 |
| 55 | 3334 | 2503 | 2745 |
| 0 | 3405 | 2776 | 2807 |

NOTES:

(1) With Watana at 140 feet drawdown.

TABLE A1.60: WATANA AVERAGE MONTHLY ENERGY WITH VARIABLE DRAWDOWN

| Month | AVERAGE ENERGY (GWH) | | | | |
|---|---|---|---|---|---|
| | DRAWDOWN (FEET) | | | | |
| | 115 | 140 | 165 | 190 | Umlimited (227) |
| Oct | 278 | 281 | 284 | 287 | 286 |
| Nov | 351 | 348 | 348 | 349 | 344 |
| Dec | 453 | 445 | 437 | 436 | 425 |
| Jan | 388 | 383 | 377 | 376 | 370 |
| Feb | 317 | 318 | 311 | 309 | 301 |
| Mar | 274 | 276 | 276 | 274 | 274 |
| Apr | 197 | 203 | 208 | 213 | 224 |
| May | 164 | 180 | 188 | 193 | 202 |
| Jun | 162 | 175 | 180 | 185 | 192 |
| Jul | 263 | 258 | 256 | 248 | 240 |
| Aug | 374 | 344 | 338 | 327 | 305 |
| Sep | 250 | 248 | 249 | 245 | 234 |
| Ann | 3471 | 3459 | 3452 | 3443 | 3397 |

TABLE A1.61: WATANA FIRM MONTHLY ENERGY WITH VARIABLE DRAWDOWN

| Month | FIRM ENERGY (GWH) | | | | |
|---|---|---|---|---|---|
| | DRAWDOWN (FEET) | | | | |
| | 115 | 140 | 165 | 190 | Umlimited 2627) |
| Oct | 213 | 234 | 243 | 250 | 262 |
| Nov | 318 | 270 | 281 | 290 | 303 |
| Dec | 446 | 321 | 335 | 345 | 361 |
| Jan | 377 | 283 | 295 | 303 | 318 |
| Feb | 310 | 228 | 238 | 245 | 256 |
| Mar | 271 | 235 | 244 | 252 | 264 |
| Apr | 203 | 199 | 208 | 214 | 224 |
| May | 164 | 180 | 188 | 193 | 201 |
| Jun | 149 | 170 | 178 | 183 | 184 |
| Jul | 155 | 182 | 191 | 197 | 200 |
| Aug | 146 | 170 | 178 | 183 | 181 |
| Sep | 144 | 158 | 164 | 169 | 177 |
| Ann | 2896 | 2630 | 2743 | 2824 | 2931 |

TABLE A1.62: WATANA/DEVIL CANYON DEVELOPMENT MONTHLY ENERGY PRODUCTION POTENTIAL

| | ENERGY (GWH) | | | | | |
|---|---|---|---|---|---|---|
| | AVERAGE | | | FIRM | | |
| Month | Watana | Devil Canyon | Total | Watana | Devil Canyon | Total |
| Oct | 281 | 230 | 511 | 234 | 203 | 437 |
| Nov | 348 | 295 | 643 | 270 | 232 | 502 |
| Dec | 445 | 373 | 818 | 322 | 276 | 598 |
| Jan | 383 | 332 | 715 | 283 | 257 | 540 |
| Feb | 318 | 281 | 599 | 228 | 224 | 452 |
| Mar | 276 | 256 | 532 | 235 | 235 | 470 |
| Apr | 203 | 248 | 451 | 199 | 261 | 460 |
| May | 180 | 285 | 465 | 180 | 262 | 442 |
| Jun | 175 | 303 | 478 | 170 | 322 | 492 |
| Jul | 258 | 263 | 521 | 182 | 205 | 387 |
| Aug | 344 | 253 | 597 | 170 | 151 | 321 |
| Sep | 248 | 215 | 463 | 158 | 135 | 293 |
| Ann | 3459 | 3334 | 6793 | 2631 | 2763 | 5394 |

TABLE A1.63: WATANA/DEVIL CANYON DEVELOPMENT
AVERAGE MONTHLY ENERGY PRODUCTION

| Month | AVERAGE ENERGY[1] | | | | | |
|---|---|---|---|---|---|---|
| | Watana | Forecast[2] 2000 | % | Watana/ Devil Canyon | Forecast[3] 2010 | % |
| Oct | 281 | 416 | 68 | 507 | 617 | 82 |
| Nov | 348 | 490 | 71 | 634 | 723 | 88 |
| Dec | 445 | 535 | 83 | 749 | 787 | 95 |
| Jan | 383 | 485 | 79 | 684 | 715 | 96 |
| Feb | 318 | 462 | 69 | 599 | 680 | 88 |
| Mar | 276 | 412 | 67 | 532 | 609 | 87 |
| Apr | 203 | 371 | 55 | 451 | 546 | 83 |
| May | 180 | 331 | 54 | 461 | 493 | 94 |
| Jun | 175 | 321 | 55 | 461 | 481 | 96 |
| Jul | 224 | 307 | 73 | 412 | 461 | 89 |
| Aug | 270 | 329 | 82 | 430 | 493 | 87 |
| Sep | 237 | 364 | 65 | 405 | 541 | 75 |
| Ann | 3459 | 4823 | 72 | 6325 | 7146 | 89 |

NOTES:

(1) Average energy from Watana and Watana/Devil Canyon adjusted to reflect overproduction.

(2) Battelle forecast less small hydroelectric production for 2000.

(3) Battelle forecast less small hydroelectric production for 2010.

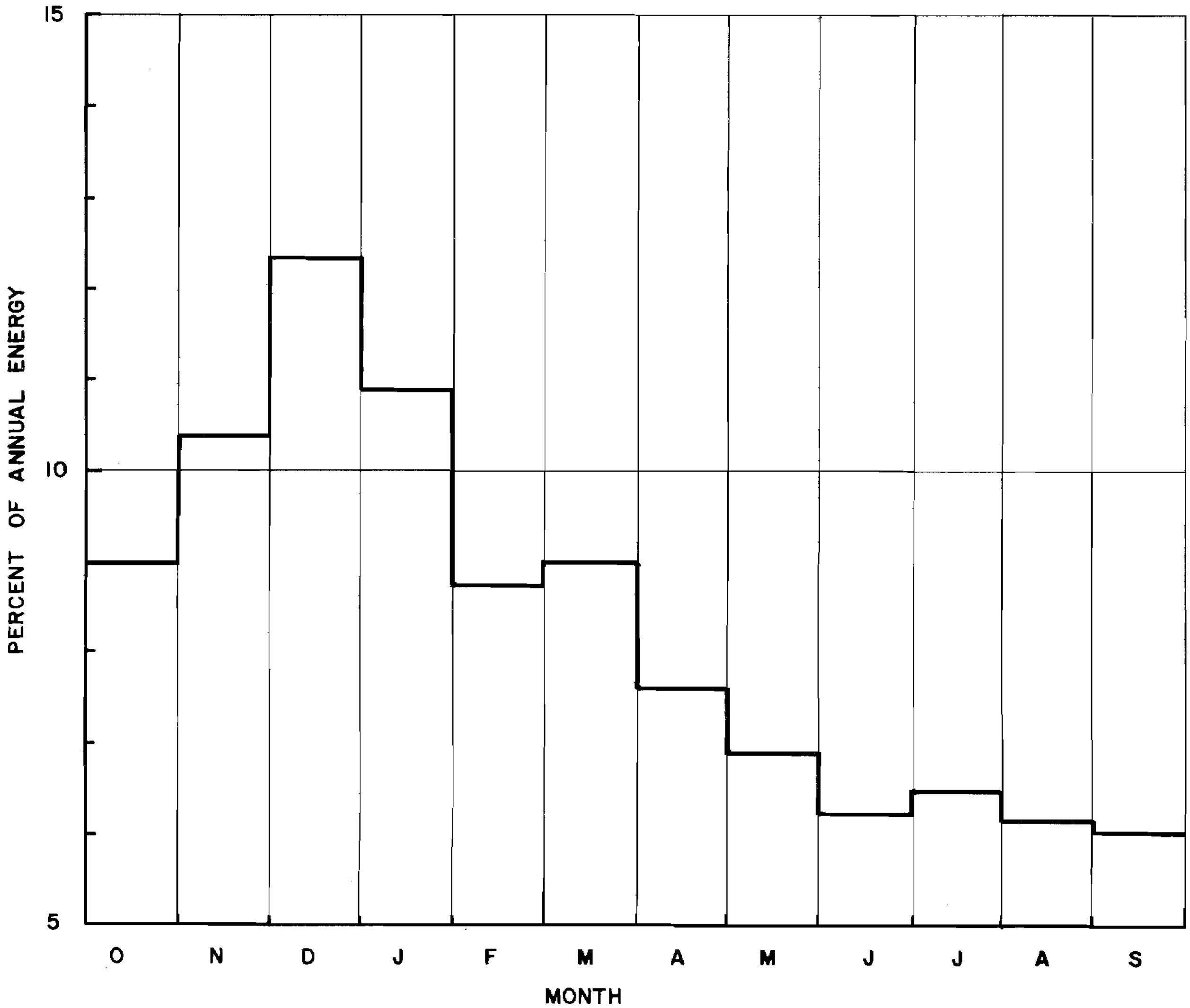
TABLE A1.64: WATANA/DEVIL CANYON DEVELOPMENT FIRM MONTHLY ENERGY PRODUCTION

| Month | AVERAGE ENERGY[1] | | | | | |
|---|---|---|---|---|---|---|
| | Watana | Forecast[1] 2000 | % | Watana/ Devil Canyon | Forecast[2] 2010 | % |
| Oct | 234 | 416 | 56 | 437 | 617 | 71 |
| Nov | 270 | 490 | 55 | 502 | 723 | 69 |
| Dec | 322 | 535 | 60 | 598 | 787 | 76 |
| Jan | 283 | 485 | 58 | 540 | 715 | 76 |
| Feb | 228 | 462 | 49 | 452 | 680 | 66 |
| Mar | 235 | 412 | 57 | 470 | 609 | 77 |
| Apr | 199 | 371 | 54 | 460 | 546 | 84 |
| May | 180 | 331 | 54 | 442 | 493 | 90 |
| Jun | 170 | 321 | 53 | 461 | 481 | 96 |
| Jul | 182 | 307 | 59 | 387 | 461 | 84 |
| Aug | 170 | 329 | 52 | 321 | 493 | 65 |
| Sep | 158 | 364 | 43 | 293 | 541 | 54 |
| Ann | 2631 | 4823 | 55 | 5363 | 7146 | 75 |

NOTES:

(1) Battelle forecast less small hydroelectric production for 2000.

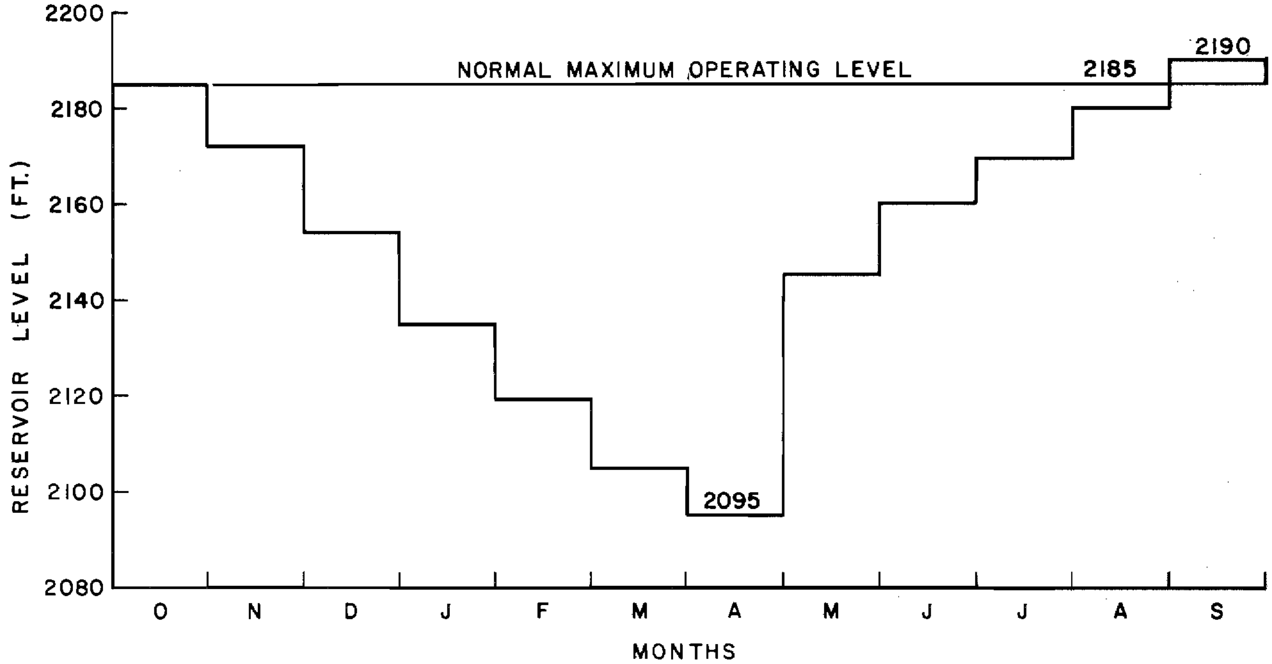
(2) Battelle forecast less small hydroelectric production for 2010.



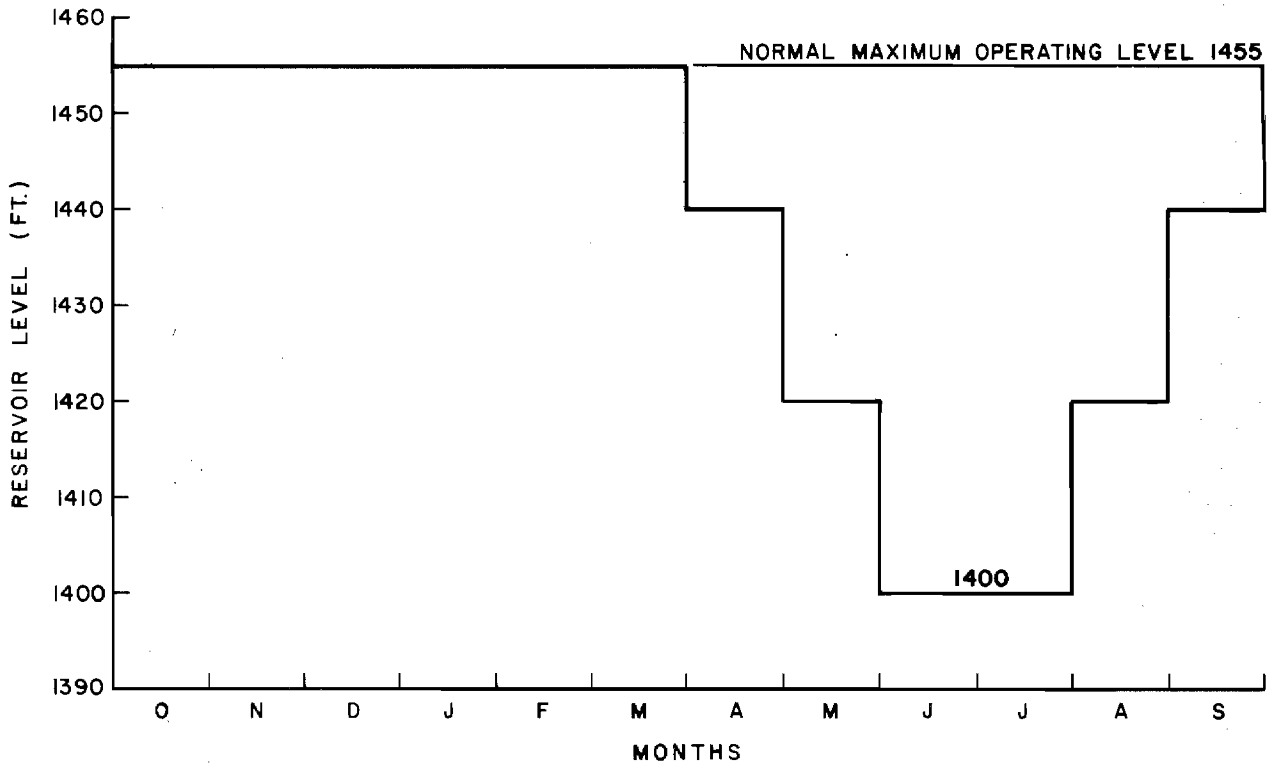

MONTHLY ENERGY PATTERN

FIGURE A1.1

ACRES




WATANA RESERVOIR

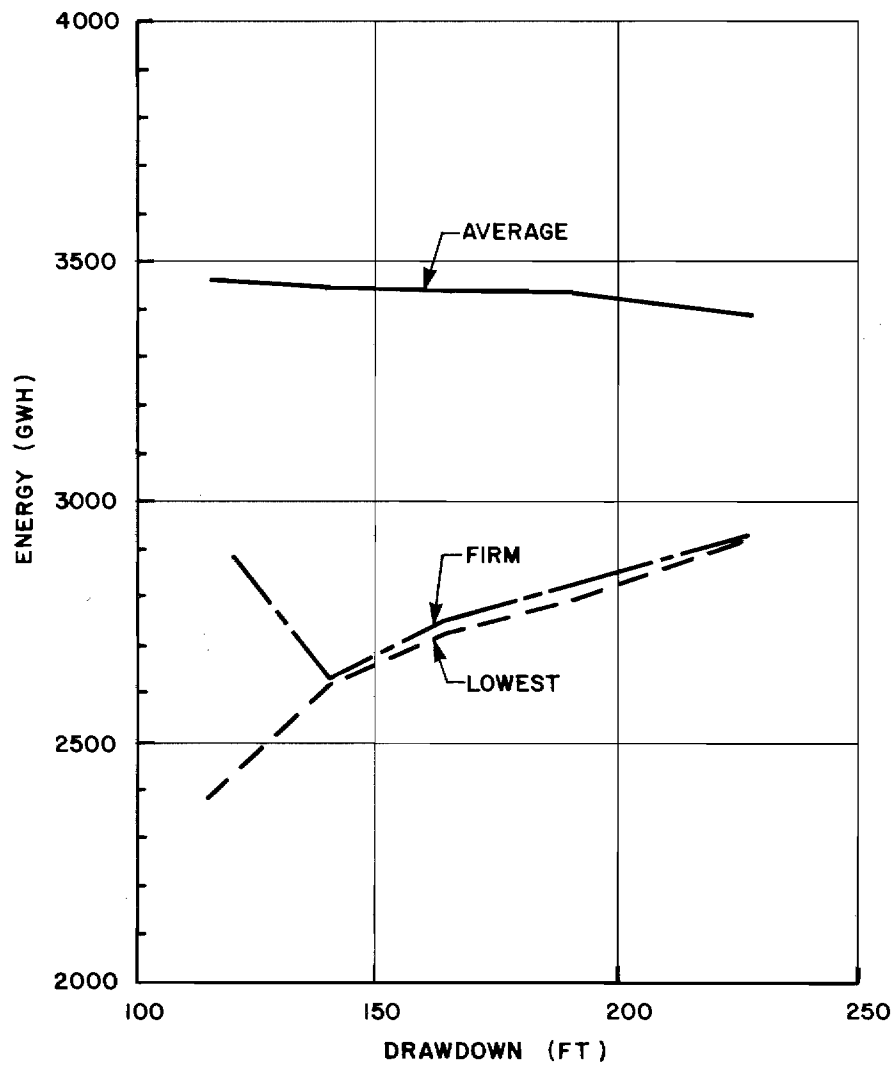



DEVIL CANYON RESERVOIR

MONTHLY TARGET MINIMUM RESERVOIR LEVELS

ACRES

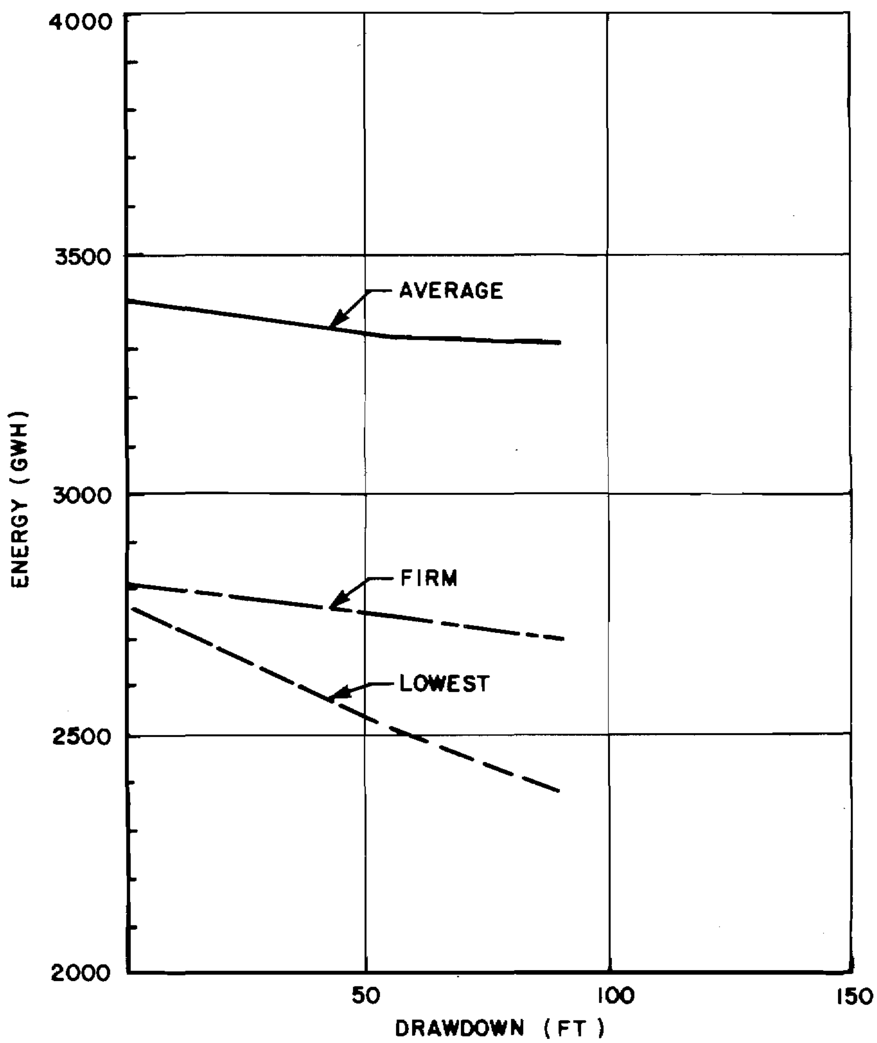
FIGURE A1.2




**WATANA**
**ANNUAL ENERGY vs. DRAWDOWN**

ACRES

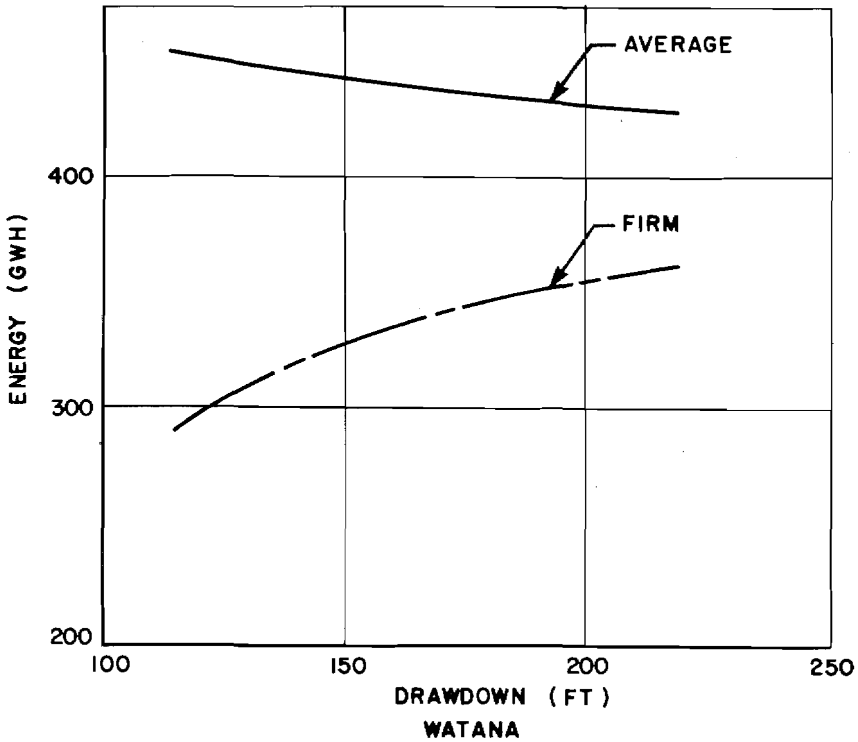
FIGURE A1.3

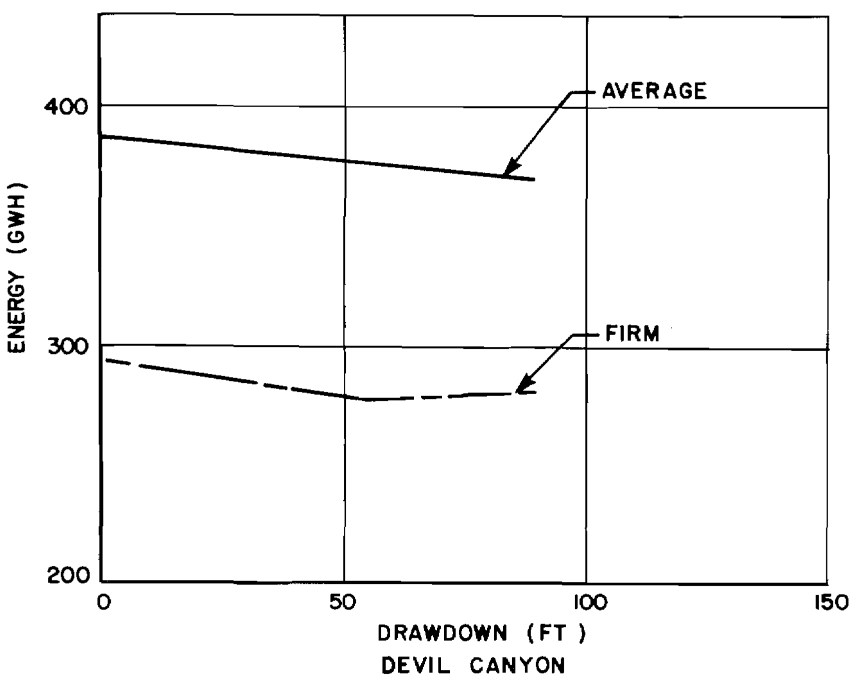



NOTE:
WATANA UPSTREAM: DRAWDOWN
LIMITED TO 140

**DEVIL CANYON**
**ANNUAL ENERGY vs. DRAWDOWN**

FIGURE A1.4




NOTE:

DEVIL CANYON WITH WATANA DRAWDOWN LIMITED TO 140'

DECEMBER ENERGY vs DRAWDOWN

ACRES

FIGURE A1.5

ATTACHMENT 1

SUSITNA HEP:
DEVIL CANYON 1455
600 MW (NO FLO REQ)

| EL | STORAGE |
|---|---|
| 925.0 | 0.0 |
| 1000.0 | 7500.0 |
| 1050.0 | 25000.0 |
| 1150.0 | 85000.0 |
| 1200.0 | 132000.0 |
| 1250.0 | 195000.0 |
| 1300.0 | 292000.0 |
| 1350.0 | 456000.0 |
| [illegible] | [illegible] |
| 1450.0 | 1048000.0 |
| 1500.0 | 1484000.0 |

MINIMUM STORAGE= 707000.0 MAXIMUM STORAGE 1092000.0

MAXIMUM P.H.Q = 13763.2 START WSEL=1455.0 TWEL= 850.0 PMAX=.60000E+06

MONTHLY BASELOAD DEMAND

| | | | | | |
|---|---|---|---|---|---|
| 0.275940E+06 | 0.317520E+06 | 0.378000E+06 | 0.332640E+06 | 0.268380E+06 | 0.275940E+06 |
| 0.234360E+06 | 0.211680E+06 | 0.192780E+06 | 0.200340E+06 | 0.189000E+06 | 0.185220E+06 |

MONTHLY DISCHARGE REQUIREMENT

1000.0 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0 2000.0 2000.0 2000.0 2000.0

MONTHLY WATER LEVEL

1455.0 1455.0 1455.0 1455.0 1455.0 1455.0 1440.0 1420.0 1390.0 1390.0 1420.0 1440.0

MONTHLY FLOW DISTRIBUTION

1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.9 1.0 0.8 0.6

MONTHLY L.F. = 0.630

NO. YEARS OF SIMULATION = 32

PDS= 0 NSEC= 366 NDEF= 18 NDEF1= 0 NDSFL= 0

| YEAR | TOTE | TOTSEC | TOTDEF |
|---|---|---|---|
| 1 | 0.30636E+10 | 0.82971E+09 | 0.00000E+00 |
| 2 | 0.27479E+10 | 0.51817E+09 | 0.41083E+07 |
| 3 | 0.33050E+10 | 0.10711E+10 | 0.00000E+00 |
| 4 | 0.34637E+10 | 0.12299E+10 | 0.00000E+00 |
| 5 | 0.33023E+10 | 0.10684E+10 | 0.00000E+00 |
| 6 | 0.35615E+10 | 0.13276E+10 | 0.00000E+00 |
| 7 | 0.39289E+10 | 0.16950E+10 | 0.00000E+00 |
| 8 | 0.35837E+10 | 0.13498E+10 | 0.00000E+00 |
| 9 | 0.34136E+10 | 0.11797E+10 | 0.00000E+00 |
| 10 | 0.33928E+10 | 0.11589E+10 | 0.00000E+00 |
| 11 | 0.33646E+10 | 0.11307E+10 | 0.00000E+00 |
| 12 | 0.37060E+10 | 0.14721E+10 | 0.00000E+00 |
| 13 | 0.40400E+10 | 0.18062E+10 | 0.00000E+00 |
| 14 | 0.38602E+10 | 0.16263E+10 | 0.00000E+00 |
| 15 | 0.35069E+10 | 0.12730E+10 | 0.00000E+00 |
| 16 | 0.34395E+10 | 0.12056E+10 | 0.00000E+00 |
| 17 | 0.32877E+10 | 0.10538E+10 | 0.00000E+00 |
| 18 | 0.37335E+10 | 0.14996E+10 | 0.00000E+00 |
| 19 | 0.35242E+10 | 0.12903E+10 | 0.00000E+00 |
| 20 | 0.27755E+10 | 0.54259E+09 | 0.10020E+07 |
| 21 | 0.25031E+10 | 0.27054E+09 | 0.13586E+07 |
| 22 | 0.27624E+10 | 0.52850E+09 | 0.00000E+00 |
| 23 | 0.35625E+10 | 0.13286E+10 | 0.00000E+00 |
| 24 | 0.30442E+10 | 0.81034E+09 | 0.00000E+00 |
| 25 | 0.27452E+10 | 0.51336E+09 | 0.20380E+07 |
| 26 | 0.31224E+10 | 0.89052E+09 | 0.19818E+07 |
| 27 | 0.31528E+10 | 0.91891E+09 | 0.00000E+00 |
| 28 | 0.31084E+10 | 0.87559E+09 | 0.11140E+07 |
| 29 | 0.32181E+10 | 0.98421E+09 | 0.00000E+00 |
| 30 | 0.29489E+10 | 0.71611E+09 | 0.11287E+07 |
| 31 | 0.36469E+10 | 0.14130E+10 | 0.00000E+00 |
| 32 | 0.38651E+10 | 0.16312E+10 | 0.00000E+00 |

AVERAGE MONTHLY ENERGY AND POWER

| MONTH | TOTAL POWER MW | PEAK POWER MW | OFFPEAK POWER MW | TOTAL ENERGY GWH | OFFPEAK ENERGY GWH | PEAK ENERGY GWH | DEFICIT MW | SEC MW |
|---|---|---|---|---|---|---|---|---|
| OCT | 315.461 | 315.461 | 315.461 | 230.161 | 230.161 | 0.000 | 0.084 | 39.606 |
| NOV | 404.520 | 404.520 | 404.520 | 295.138 | 295.138 | 0.000 | 0.220 | 87.219 |
| DEC | 510.842 | 510.842 | 510.842 | 372.711 | 372.711 | 0.000 | 0.222 | 133.064 |
| JAN | 454.507 | 454.507 | 454.507 | 331.608 | 331.608 | 0.000 | 0.020 | 121.887 |
| FEB | 385.348 | 385.348 | 385.348 | 281.150 | 281.150 | 0.000 | 0.000 | 116.968 |
| MAR | 350.792 | 350.792 | 350.792 | 255.938 | 255.938 | 0.000 | 0.000 | 74.852 |
| APR | 339.680 | 339.680 | 339.680 | 247.830 | 247.830 | 0.000 | 0.000 | 105.319 |
| MAY | 390.322 | 390.322 | 390.322 | 284.779 | 284.779 | 0.000 | 0.000 | 178.642 |
| JUN | 415.271 | 415.271 | 415.271 | 302.982 | 302.982 | 0.000 | 0.000 | 222.491 |
| JUL | 360.945 | 360.945 | 360.945 | 263.345 | 263.345 | 0.000 | 0.000 | 160.605 |
| AUG | 347.071 | 347.071 | 347.071 | 253.223 | 253.223 | 0.000 | 0.000 | 158.071 |
| SEP | 294.562 | 294.562 | 294.562 | 214.912 | 214.912 | 0.000 | 0.000 | 109.342 |

AVERAGE MONTHLY DISCHARGES AND HEAD

| MONTH | INFLOW | P.H.FLOW | PEAK | OFFPEAK | HEAD | SPILL | HLOSS |
|---|---|---|---|---|---|---|---|
| OCT | 8137.06 | 7402.73 | 7402.73 | 7402.73 | 590.48 | 0.00 | 0.00 |
| NOV | 9517.00 | 9424.62 | 9424.62 | 9424.62 | 593.71 | 0.00 | 0.00 |
| DEC | 12245.78 | 11864.40 | 11864.40 | 11864.40 | 595.61 | 11.38 | 0.00 |
| JAN | 10811.88 | 10514.40 | 10514.40 | 10514.40 | 598.44 | 0.00 | 0.00 |
| FEB | 9195.31 | 8883.18 | 8883.18 | 8883.18 | 601.06 | 0.00 | 0.00 |
| MAR | 8156.16 | 8072.30 | 8072.30 | 8072.30 | 602.74 | 0.00 | 0.00 |
| APR | 6180.34 | 7903.23 | 7903.23 | 7903.23 | 596.12 | 0.00 | 0.00 |
| MAY | 7176.88 | 9343.79 | 9343.79 | 9343.79 | 579.58 | 0.00 | 0.00 |
| JUN | 8059.03 | 10287.59 | 10287.59 | 10287.59 | 560.15 | 0.00 | 0.00 |
| JUL | 9344.44 | 9069.74 | 9069.74 | 9069.74 | 551.51 | 0.00 | 0.00 |
| AUG | 11467.28 | 8477.50 | 8477.50 | 8477.50 | 565.02 | 187.52 | 0.00 |
| SEP | 8114.75 | 6971.77 | 6971.77 | 6971>77 | 582.43 | 0.00 | 0.00 |

AVERAGE ANNUAL ENERGY = 0.333378E+10 KWH

DELMASS = -0.15893401E+05
STOREND = 0.10757076E+07
STORSTART = 0.10920000E+07
INFLOW MASS = 0.34689890E+07
OUTFL. MASS = 0.34692513E+07

INFLOW CFS

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7159.0 | 8895.0 | 12572.0 | 10738.0 | 8909.0 | 7821.0 | 6009.0 | 7153.0 | 6783.0 | 7121.0 | 6235.0 | 4795.0 |
| 2 | 6535.0 | 7334.0 | 8848.0 | 8600.0 | 8940.0 | 7848.0 | 6231.0 | 6882.0 | 6288.0 | 6656.0 | 7308.0 | 14009.0 |
| 3 | 8224.0 | 10430.0 | 12987.0 | 11270.0 | 9116.0 | 7979.0 | 5960.0 | 6146.0 | 9134.0 | 7683.0 | 9557.0 | 8119.0 |
| 4 | 10519.0 | 11124.0 | 12780.0 | 10786.0 | 8918.0 | 7918.0 | 6258.0 | 8035.0 | 8564.0 | 6626.0 | 11137.0 | 8988.0 |
| 5 | 8111.0 | 9812.0 | 12616.0 | 11011.0 | 9103.0 | 7881.0 | 6072.0 | 8905.0 | 8542.0 | 6854.0 | 10623.0 | 6521.0 |
| 6 | 7492.0 | 10398.0 | 13097.0 | 11436.0 | 9448.0 | 8175.0 | 6051.0 | 6988.0 | 8069.0 | 7511.0 | 17730.0 | 9160.0 |
| 7 | 7650.0 | 9680.0 | 12436.0 | 10708.0 | 9066.0 | 8004.0 | 6035.0 | 8344.0 | 8790.0 | 16756.0 | 17477.0 | 11666.0 |
| 8 | 8237.0 | 10665.0 | 13216.0 | 11370.0 | 9562.0 | 8257.0 | 6048.0 | 7613.0 | 7982.0 | 7272.0 | 12179.0 | 13200.0 |
| 9 | 10436.0 | 11481.0 | 14134.0 | 11579.0 | 9385.0 | 8237.0 | 6164.0 | 7205.0 | 7155.0 | 6875.0 | 11024.0 | 5128.0 |
| 10 | 6857.0 | 7334.0 | 12593.0 | 11103.0 | 9352.0 | 8029.0 | 6119.0 | 9077.0 | 8051.0 | 7791.0 | 15103.0 | 10500.0 |
| 11 | 9063.0 | 10514.0 | 13241.0 | 11473.0 | 9513.0 | 8264.0 | 6031.0 | 7073.0 | 6177.0 | 7118.0 | 7202.0 | 12632.0 |
| 12 | 10173.0 | 10651.0 | 13666.0 | 11999.0 | 9766.0 | 8790.0 | 7132.0 | 7706.0 | 9098.0 | 9029.0 | 14182.0 | 7389.0 |
| 13 | 8461.0 | 10435.0 | 13208.0 | 11583.0 | 9586.0 | 8472.0 | 6340.0 | 6121.0 | 12575.0 | 16842.0 | 17386.0 | 9938.0 |
| 14 | 9310.0 | 10587.0 | 13125.0 | 11283.0 | 9560.0 | 8110.0 | 5920.0 | 7716.0 | 8238.0 | 16079.0 | 17356.0 | 6948.0 |
| 15 | 9000.0 | 9976.0 | 12616.0 | 10765.0 | 9073.0 | 7815.0 | 5975.0 | 5851.0 | 11498.0 | 14166.0 | 10259.0 | 5467.0 |
| 16 | 7209.0 | 10536.0 | 12390.0 | 10712.0 | 9002.0 | 8018.0 | 6041.0 | 6615.0 | 7730.0 | 8264.0 | 12624.0 | 13405.0 |
| 17 | 9498.0 | 9799.0 | 12708.0 | 11065.0 | 9360.0 | 8339.0 | 6346.0 | 6954.0 | 9368.0 | 7046.0 | 8387.0 | 5741.0 |
| 18 | 6662.0 | 8883.0 | 12594.0 | 11144.0 | 9441.0 | 8240.0 | 6089.0 | 7197.0 | 7910.0 | 11218.0 | 21298.0 | 13444.0 |
| 19 | 7587.0 | 10094.0 | 13159.0 | 11638.0 | 9952.0 | 8930.0 | 6518.0 | 7469.0 | 8577.0 | 12251.0 | 10182.0 | 5175.0 |
| 20 | 6548.0 | 7472.0 | 12066.0 | 10473.0 | 8855.0 | 7921.0 | 6148.0 | 6430.0 | 5736.0 | 5604.0 | 5150.0 | 4885.0 |
| 21 | 6914.0 | 7703.0 | 9321.0 | 8438.0 | 6979.0 | 7333.0 | 6345.0 | 6863.0 | 7779.0 | 7988.0 | 6974.0 | 5618.0 |
| 22 | 7504.0 | 8210.0 | 9634.0 | 8545.0 | 7036.0 | 7379.0 | 6453.0 | 6339.0 | 8673.0 | 7078.0 | 7518.0 | 5605.0 |
| 23 | 6694.0 | 8472.0 | 13542.0 | 11823.0 | 10009.0 | 8811.0 | 6292.0 | 9117.0 | 9297.0 | 13455.0 | 13079.0 | 7055.0 |
| 24 | 7640.0 | 10046.0 | 12616.0 | 10926.0 | 9301.0 | 8106.0 | 5957.0 | 5925.0 | 7397.0 | 5909.0 | 5930.0 | 4744.0 |
| 25 | 6542.0 | 7262.0 | 12227.0 | 10629.0 | 8919.0 | 7841.0 | 5962.0 | 7432.0 | 6681.0 | 6550.0 | 6080.0 | 5771.0 |
| 26 | 6616.0 | 7375.0 | 8952.0 | 8415.0 | 9515.0 | 8423.0 | 6183.0 | 7678.0 | 8441.0 | 13158.0 | 11152.0 | 10325.0 |
| 27 | 10005.0 | 9744.0 | 12237.0 | 10683.0 | 9049.0 | 7976.0 | 6084.0 | 7681.0 | 7668.0 | 5947.0 | 5346.0 | 4891.0 |
| 28 | 6733.0 | 7572.0 | 10452.0 | 11444.0 | 9643.0 | 8512.0 | 6236.0 | 7956.0 | 9104.0 | 10688.0 | 12052.0 | 7087.0 |
| 29 | 9938.0 | 11102.0 | 13601.0 | 11654.0 | 9698.0 | 8632.0 | 6324.0 | 5776.0 | 5970.0 | 6575.0 | 6229.0 | 5117.0 |
| 30 | 6919.0 | 7522.0 | 8940.0 | 10177.0 | 9376.0 | 8316.0 | 6129.0 | 6278.0 | 5970.0 | 11674.0 | 12904.0 | 5343.0 |
| 31 | 9902.0 | 11846.0 | 13508.0 | 11436.0 | 9556.0 | 8472.0 | 6302.0 | 6551.0 | 7694.0 | 12453.0 | 14003.0 | 7513.0 |
| 32 | 10248.0 | 11590.0 | 12783.0 | 11074.0 | 9262.0 | 8148.0 | 6017.0 | 6584.0 | 6950.0 | 8785.0 | 23287.0 | 13493.0 |

INFLOW TO SECOND RESERVOIR

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5758.2 | 2404.7 | 1342.5 | 951.3 | 735.7 | 670.0 | 802.2 | 10490.7 | 18468.6 | 21383.4 | 18820.6 | 7950.8 |
| | 3652.0 | 1231.2 | 1030.8 | 905.7 | 767.5 | 697.1 | 1504.6 | 13218.5 | 19978.5 | 21575.9 | 18530.0 | 19799.1 |
| | 5221.7 | 2539.0 | 1757.5 | 1483.7 | 943.2 | 828.2 | 878.5 | 4989.5 | 30014.2 | 24861.7 | 19647.2 | 13441.1 |
| | 7517.6 | 3232.6 | 1550.4 | 999.6 | 745.6 | 766.7 | 1531.8 | 17758.3 | 25230.7 | 19184.0 | 19207.0 | 13928.4 |
| | 5109.3 | 1921.3 | 1387.1 | 1224.2 | 929.7 | 729.4 | 1130.6 | 15286.0 | 23188.1 | 19154.1 | 24071.6 | 11579.1 |
| | 4830.4 | 2506.8 | 1868.0 | 1649.1 | 1275.2 | 1023.6 | 1107.4 | 8390.1 | 28081.9 | 26212.8 | 24959.6 | 13989.2 |
| | 4647.9 | 1788.6 | 1206.6 | 921.7 | 893.1 | 852.3 | 867.3 | 15979.0 | 31137.1 | 29212.0 | 22609.8 | 16495.8 |
| | 5235.3 | 2773.8 | 1986.6 | 1583.2 | 1388.9 | 1105.4 | 1109.0 | 12473.6 | 28415.4 | 22109.6 | 19389.2 | 18029.0 |
| | 7434.5 | 3590.4 | 2904.9 | 1792.0 | 1212.2 | 1085.7 | 1437.4 | 11849.2 | 24413.5 | 21763.1 | 21219.8 | 6988.8 |
| | 4402.8 | 1999.8 | 1370.9 | 1316.9 | 1179.1 | 877.9 | 1119.9 | 13900.9 | 21537.7 | 23390.4 | 28594.4 | 15329.6 |
| | 6060.7 | 2622.7 | 2011.5 | 1686.2 | 1340.2 | 1112.8 | 1217.8 | 14802.9 | 14709.8 | 21739.3 | 22066.1 | 18929.9 |
| | 7170.9 | 2759.9 | 2436.6 | 2212.0 | 1593.6 | 1638.9 | 2405.4 | 16030.7 | 27069.3 | 22880.6 | 21164.4 | 12218.6 |
| | 5459.4 | 2544.1 | 1978.7 | 1796.0 | 1413.4 | 1320.3 | 1613.4 | 12141.2 | 40679.7 | 24990.6 | 22241.8 | 14767.2 |
| | 6307.7 | 2696.0 | 1896.0 | 1496.0 | 1387.4 | 958.4 | 810.9 | 17697.6 | 24094.1 | 32388.4 | 22720.5 | 11777.2 |
| | 5998.3 | 2085.4 | 1387.1 | 978.0 | 900.2 | 663.8 | 696.5 | 4046.9 | 47816.4 | 21926.0 | 15585.8 | 8840.0 |
| | 5744.0 | 2645.1 | 1160.8 | 925.3 | 828.8 | 866.9 | 1314.4 | 12267.1 | 24110.3 | 26195.7 | 19789.3 | 18234.2 |
| | 6496.5 | 1907.8 | 1478.4 | 1278.7 | 1187.4 | 1187.4 | 1619.1 | 8734.0 | 30446.3 | 18536.2 | 20244.6 | 10844.3 |
| | 3844.0 | 1457.9 | 1364.9 | 1357.9 | 1268.3 | 1089.1 | 1053.7 | 14435.5 | 27796.4 | 25081.2 | 30293.0 | 15728.2 |
| | 4585.3 | 2203.5 | 1929.7 | 1851.2 | 1778.7 | 1778.7 | 1791.0 | 14982.4 | 29462.1 | 24871.0 | 16090.5 | 8225.9 |
| | 3576.7 | 1531.8 | 836.3 | 686.6 | 681.8 | 769.6 | 1421.3 | 10429.9 | 14950.7 | 15651.2 | 8483.6 | 4795.5 |
| | 2866.5 | 1145.7 | 810.0 | 756.9 | 708.7 | 721.8 | 1046.6 | 10721.6 | 17118.9 | 21142.2 | 18652.8 | 8443.5 |
| | 4745.2 | 3081.8 | 2074.8 | 1318.8 | 943.6 | 866.8 | 986.2 | 3427.9 | 31031.0 | 22941.6 | 30315.9 | 13636.0 |
| | 5537.0 | 2912.3 | 2312.6 | 2036.1 | 1836.4 | 1659.8 | 1565.5 | 19776.8 | 31929.8 | 21716.5 | 18654.1 | 11884.2 |
| | 4638.6 | 2154.8 | 1387.0 | 1139.8 | 1128.6 | 955.0 | 986.7 | 7896.4 | 26392.6 | 17571.8 | 19478.1 | 8726.0 |
| | 3491.4 | 1462.9 | 997.4 | 842.7 | 745.9 | 689.5 | 949.1 | 15004.6 | 16766.7 | 17790.0 | 15257.0 | 11370.1 |
| | 3506.8 | 1619.4 | 1486.5 | 1408.8 | 1342.2 | 1271.9 | 1456.7 | 14036.5 | 30302.6 | 26188.0 | 17031.6 | 15154.7 |
| | 7003.3 | 1853.0 | 1007.9 | 896.8 | 876.2 | 825.2 | 1261.2 | 11305.3 | 22813.6 | 18252.6 | 19297.7 | 6463.3 |
| | 3552.4 | 2391.7 | 2147.5 | 1657.4 | 1469.7 | 1361.0 | 1509.8 | 11211.9 | 35606.7 | 21740.5 | 18371.2 | 11916.1 |
| | 6936.3 | 3210.8 | 2371.4 | 1867.9 | 1525.0 | 1480.6 | 1597.1 | 11693.4 | 18416.8 | 20079.0 | 15326.5 | 8080.4 |
| | 4502.3 | 2324.3 | 1549.4 | 1304.1 | 1203.6 | 1164.7 | 1402.8 | 13334.0 | 24052.4 | 27462.8 | 19106.7 | 10172.4 |
| | 605.0 | 564.5 | 600.8 | 600.8 | 600.8 | 596.6 | 600.8 | 600.8 | 600.8 | 584.7 | 600.8 | 600.8 |
| | 600.3 | 600.8 | 600.8 | 589.0 | 600.8 | 584.5 | 603.9 | 582.4 | 555.4 | 584.2 | 581.6 | 599.2 |

POWERHOUSE FLOW CFS

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7159.0 | 8895.0 | 12572.0 | 10738.0 | 8909.0 | 7821.0 | 7863.1 | 9415.1 | 9045.1 | 7121.0 | 4713.4 | 4555.6 |
| 2 | 6771.0 | 7805.7 | 9344.3 | 8286.1 | 6561.6 | 6561.5 | 6242.6 | 9144.1 | 8550.1 | 6656.0 | 4971.4 | 11077.0 |
| 3 | 7114.2 | 10430.0 | 12987.0 | 11270.0 | 9116.0 | 7979.0 | 7814.1 | 8408.1 | 11396.1 | 7683.0 | 6754.4 | 5653.1 |
| 4 | 9409.2 | 11124.0 | 12780.0 | 10786.0 | 8918.0 | 7918.0 | 8112.1 | 10297.1 | 10826.1 | 6626.0 | 8050.3 | 6806.2 |
| 5 | 7001.2 | 9812.0 | 12616.0 | 11011.0 | 9103.0 | 7881.0 | 7926.1 | 11167.1 | 10804.1 | 6854.0 | 7599.9 | 4768.3 |
| 6 | 6466.3 | 9821.1 | 13097.0 | 11436.0 | 9448.0 | 8175.0 | 7905.1 | 9250.1 | 10331.1 | 7511.0 | 13763.2 | 7858.3 |
| 7 | 6540.2 | 9680.0 | 12436.0 | 10708.0 | 9066.0 | 8004.0 | 7889.1 | 10606.1 | 11052.1 | 13763.2 | 13763.2 | 12782.5 |
| 8 | 7127.2 | 10665.0 | 13216.0 | 11370.0 | 9562.0 | 8257.0 | 7902.1 | 9875.1 | 10244.1 | 7272.0 | 9092.3 | 11018.2 |
| 9 | 9326.2 | 11481.0 | 13763.2 | 11585.6 | 9385.0 | 8237.0 | 8018.1 | 9467.1 | 9417.1 | 6875.0 | 7937.3 | 4433.4 |
| 10 | 6563.7 | 7536.0 | 10087.3 | 11103.0 | 9352.0 | 8029.0 | 7973.1 | 11339.1 | 10313.1 | 7791.0 | 12016.3 | 8318.2 |
| 11 | 7953.2 | 10514.0 | 13241.0 | 11473.0 | 9513.0 | 8264.0 | 7885.1 | 9335.1 | 8439.1 | 7118.0 | 4887.4 | 9678.1 |
| 12 | 9063.2 | 10651.0 | 13666.0 | 11999.0 | 9766.0 | 8790.0 | 8986.1 | 9968.1 | 11360.1 | 9029.0 | 11095.3 | 5314.9 |
| 13 | 7243.4 | 10435.0 | 13208.0 | 11583.0 | 9586.0 | 8472.0 | 8194.1 | 8383.1 | 13763.2 | 13763.2 | 13763.2 | 11054.5 |
| 14 | 8200.2 | 10587.0 | 13125.0 | 11283.0 | 9560.0 | 8110.0 | 7774.1 | 9978.1 | 10500.1 | 13763.2 | 13763.2 | 7588.1 |
| 15 | 7890.2 | 9976.0 | 12616.0 | 10765.0 | 9073.0 | 7815.0 | 7829.1 | 8113.1 | 13760.1 | 13763.2 | 7627.9 | 4425.1 |
| 16 | 6534.5 | 8908.0 | 12390.0 | 10712.0 | 9002.0 | 8018.0 | 7895.1 | 8877.1 | 9992.1 | 8264.0 | 9537.3 | 11223.2 |
| 17 | 8388.2 | 9799.0 | 12708.0 | 11065.0 | 9360.0 | 8339.0 | 8200.1 | 9216.1 | 11630.1 | 7046.0 | 5826.7 | 4448.9 |
| 18 | 6556.6 | 7456.9 | 11599.5 | 11144.0 | 9441.0 | 8240.0 | 7943.1 | 9459.1 | 10172.1 | 11218.0 | 13763.2 | 13763.2 |
| 19 | 7274.4 | 10094.0 | 13159.0 | 11638.0 | 9952.0 | 8930.0 | 8372.1 | 9731.1 | 10839.1 | 12251.0 | 7249.9 | 4442.4 |
| 20 | 6548.0 | 7566.1 | 9258.1 | 10473.0 | 8855.0 | 7921.0 | 8002.1 | 8692.1 | 7998.1 | 5604.0 | 4768.9 | 4659.3 |
| 21 | 6914.0 | 7934.4 | 9463.2 | 8352.5 | 6742.0 | 6914.1 | 5841.7 | 6078.7 | 10041.1 | 7988.0 | 4706.7 | 4473.6 |
| 22 | 6600.7 | 7454.8 | 8771.8 | 8099.2 | 7036.0 | 7379.0 | 8307.1 | 8601.1 | 10935.1 | 7078.0 | 5137.9 | 4466.1 |
| 23 | 6589.9 | 7576.9 | 11681.9 | 11823.0 | 10009.0 | 8811.0 | 8146.1 | 11379.1 | 11559.1 | 13455.0 | 9992.3 | 5118.1 |
| 24 | 6442.4 | 9888.8 | 12616.0 | 10926.0 | 9301.0 | 8106.0 | 7811.1 | 8187.1 | 9659.1 | 5909.0 | 4768.9 | 4583.8 |
| 25 | 6817.9 | 7862.3 | 9263.0 | 7812.3 | 8766.4 | 7841.0 | 7816.1 | 9694.1 | 8943.1 | 6550.0 | 4719.2 | 4532.6 |
| 26 | 6683.4 | 7694.5 | 9187.6 | 8120.0 | 6386.4 | 7444.9 | 8037.1 | 9940.1 | 10703.1 | 13158.0 | 8065.3 | 8143.2 |
| 27 | 8895.2 | 9744.0 | 12237.0 | 10683.0 | 9049.0 | 7976.0 | 7938.1 | 9943.1 | 9930.1 | 5947.0 | 4768.9 | 4652.0 |
| 28 | 6872.5 | 7916.9 | 9461.2 | 8019.1 | 8011.9 | 8512.0 | 8090.1 | 10218.1 | 11366.1 | 10688.0 | 8965.3 | 5136.9 |
| 29 | 8596.4 | 11102.0 | 13601.0 | 11654.0 | 9698.0 | 8632.0 | 8178.1 | 8038.1 | 8232.1 | 6575.0 | 4713.6 | 4544.6 |
| 30 | 6736.6 | 7740.7 | 9217.7 | 8033.0 | 6915.4 | 8316.0 | 7983.1 | 8540.1 | 8232.1 | 11674.0 | 9817.3 | 4426.1 |
| 31 | 7527.2 | 11846.0 | 13508.0 | 11436.0 | 9556.0 | 8472.0 | 8156.1 | 8813.1 | 9956.1 | 12453.0 | 10916.3 | 5388.0 |
| 32 | 9081.3 | 11590.0 | 12783.0 | 11074.0 | 9262.0 | 8148.0 | 7871.1 | 8846.1 | 9212.1 | 8785.0 | 13763.2 | 13763.2 |

SPILL CFS

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 321.6 | 0.0 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | 0.0 | 0.0 | 364.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1390.5 | 0.0 |
| 14 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1149.8 | 0.0 |
| 19 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 20 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 21 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 22 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 23 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 24 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 26 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 27 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 28 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 29 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 30 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 31 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 32 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3138.8 | 0.0 |

OUTFLOW CFS

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7159.0 | 8895.0 | 12572.0 | 10738.0 | 8909.0 | 7821.0 | 7863.1 | 9415.1 | 9045.1 | 7121.0 | 4713.4 | 4555.6 |
| 2 | 6771.0 | 7805.7 | 9344.3 | 8286.1 | 6561.6 | 6561.5 | 6242.6 | 9144.1 | 8550.1 | 6656.0 | 4971.4 | 11077.0 |
| 3 | 7114.2 | 10430.0 | 12987.0 | 11270.0 | 9116.0 | 7979.0 | 7814.1 | 8408.1 | 11396.1 | 7683.0 | 6754.4 | 5653.1 |
| 4 | 9409.2 | 11124.0 | 12780.0 | 10786.0 | 8918.0 | 7918.0 | 8112.1 | 10297.1 | 10826.1 | 6626.0 | 8050.3 | 6806.2 |
| 5 | 7001.2 | 9812.0 | 12616.0 | 11011.0 | 9103.0 | 7881.0 | 7926.1 | 11167.1 | 10804.1 | 6854.0 | 7599.9 | 4768.3 |
| 6 | 6466.3 | 9821.1 | 13097.0 | 11436.0 | 9448.0 | 8175.0 | 7905.1 | 9250.1 | 10331.1 | 7511.0 | 13763.2 | 7858.3 |
| 7 | 6540.2 | 9680.0 | 12436.0 | 10708.0 | 9066.0 | 8004.0 | 7889.1 | 10606.1 | 11052.1 | 13763.2 | 14084.8 | 12782.5 |
| 8 | 7127.2 | 10665.0 | 13216.0 | 11370.0 | 9562.0 | 8257.0 | 7902.1 | 9875.1 | 10244.1 | 7272.0 | 9092.3 | 11018.2 |
| 9 | 9326.2 | 11481.0 | 14127.4 | 11585.6 | 9385.0 | 8237.0 | 8018.1 | 9467.1 | 9417.1 | 6875.0 | 7937.3 | 4433.4 |
| 10 | 6563.7 | 7536.0 | 10087.3 | 11103.0 | 9352.0 | 8029.0 | 7973.1 | 11339.1 | 10313.1 | 7791.0 | 12016.3 | 8318.2 |
| 11 | 7953.2 | 10514.0 | 13241.0 | 11473.0 | 9513.0 | 8264.0 | 7885.1 | 9335.1 | 8439.1 | 7118.0 | 4887.4 | 9678.1 |
| 12 | 9063.2 | 10651.0 | 13666.0 | 11999.0 | 9766.0 | 8790.0 | 8986.1 | 9968.1 | 11360.1 | 9029.0 | 11095.3 | 5314.9 |
| 13 | 7243.4 | 10435.0 | 13208.0 | 11583.0 | 9586.0 | 8472.0 | 8194.1 | 8383.1 | 13763.2 | 13763.2 | 15153.7 | 11054.5 |
| 14 | 8200.2 | 10587.0 | 13125.0 | 11283.0 | 9560.0 | 8110.0 | 7774.1 | 9978.1 | 10500.1 | 13763.2 | 13763.2 | 7588.1 |
| 15 | 7890.2 | 9976.0 | 12616.0 | 10765.0 | 9073.0 | 7815.0 | 7829.1 | 8113.1 | 13760.1 | 13763.2 | 7627.9 | 4425.1 |
| 16 | 6534.5 | 8908.0 | 12390.0 | 10712.0 | 9002.0 | 8018.0 | 7895.1 | 8877.1 | 9992.1 | 8264.0 | 9537.3 | 11223.2 |
| 17 | 8388.2 | 9799.0 | 12708.0 | 11065.0 | 9360.0 | 8339.0 | 8200.1 | 9216.1 | 11630.1 | 7046.0 | 5826.7 | 4448.9 |
| 18 | 6556.6 | 7456.9 | 11599.5 | 11144.0 | 9441.0 | 8240.0 | 7943.1 | 9459.1 | 10172.1 | 11218.0 | 14913.0 | 13763.2 |
| 19 | 7274.4 | 10094.0 | 13159.0 | 11638.0 | 9952.0 | 8930.0 | 8372.1 | 9731.1 | 10839.1 | 12251.0 | 7249.9 | 4442.4 |
| 20 | 6548.0 | 7566.1 | 9258.1 | 10473.0 | 8855.0 | 7921.0 | 8002.1 | 8692.1 | 7998.1 | 5604.0 | 4768.9 | 4659.3 |
| 21 | 6914.0 | 7934.4 | 9463.2 | 8352.5 | 6742.0 | 6914.1 | 5841.7 | 6078.7 | 10041.1 | 7988.0 | 4706.7 | 4473.6 |
| 22 | 6600.7 | 7454.8 | 8771.8 | 8099.2 | 7036.0 | 7379.0 | 8307.1 | 8601.1 | 10935.1 | 7078.0 | 5137.9 | 4466.1 |
| 23 | 6589.9 | 7576.9 | 11681.9 | 11823.0 | 10009.0 | 8811.0 | 8146.1 | 11379.1 | 11559.1 | 13455.0 | 9992.3 | 5118.1 |
| 24 | 6442.4 | 9888.8 | 12616.0 | 10926.0 | 9301.0 | 8106.0 | 7811.1 | 8187.1 | 9659.1 | 5909.0 | 4768.9 | 4583.8 |
| 25 | 6817.9 | 7862.3 | 9263.0 | 7812.3 | 8766.4 | 7841.0 | 7816.1 | 9694.1 | 8943.1 | 6550.0 | 4719.2 | 4532.6 |
| 26 | 6683.4 | 7694.5 | 9187.6 | 8120.0 | 6386.4 | 7444.9 | 8037.1 | 9940.1 | 10703.1 | 13158.0 | 8065.3 | 8143.2 |
| 27 | 8895.2 | 9744.0 | 12237.0 | 10683.0 | 9049.0 | 7976.0 | 7938.1 | 9943.1 | 9930.1 | 5947.0 | 4768.9 | 4652.0 |
| 28 | 6872.5 | 7916.9 | 9461.2 | 8019.1 | 8011.9 | 8512.0 | 8090.1 | 10218.1 | 11366.1 | 10688.0 | 8965.3 | 5136.9 |
| 29 | 8596.4 | 11102.0 | 13601.0 | 11654.0 | 9698.0 | 8632.0 | 8178.1 | 8038.1 | 8232.1 | 6575.0 | 4713.6 | 4544.6 |
| 30 | 6736.6 | 7740.7 | 9217.7 | 8033.0 | 6915.4 | 8316.0 | 7983.1 | 8540.1 | 8232.1 | 11674.0 | 9817.3 | 4426.1 |
| 31 | 7527.2 | 11846.0 | 13508.0 | 11436.0 | 9556.0 | 8472.0 | 8156.1 | 8813.1 | 9956.1 | 12453.0 | 10916.3 | 5388.0 |
| 32 | 9081.3 | 11590.0 | 12783.0 | 11074.0 | 9262.0 | 8148.0 | 7871.1 | 8846.1 | 9212.1 | 8785.0 | 16902.0 | 13763.2 |

AVERAGE HEAD FT

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 556.7 | 564.5 |
| 2 | 564.5 | 561.4 | 557.1 | 556.3 | 568.2 | 584.4 | 590.1 | 580.0 | 560.0 | 550.0 | 560.3 | 583.6 |
| 3 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 562.4 | 585.7 |
| 4 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.6 | 586.9 |
| 5 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.4 | 584.5 |
| 6 | 596.6 | 603.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 567.5 | 590.8 |
| 7 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 563.2 | 590.8 | 600.8 |
| 8 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.6 | 586.9 |
| 9 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.6 | 580.4 |
| 10 | 584.7 | 585.1 | 594.6 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.6 | 586.9 |
| 11 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 560.2 | 583.5 |
| 12 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.6 | 586.5 |
| 13 | 600.3 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 564.7 | 573.1 | 595.9 | 600.8 |
| 14 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 560.2 | 586.1 | 599.2 |
| 15 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 551.8 | 565.2 | 581.4 |
| 16 | 589.0 | 598.5 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.6 | 586.9 |
| 17 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 561.3 | 578.3 |
| 18 | 584.5 | 591.3 | 601.3 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 577.5 | 603.9 |
| 19 | 603.9 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.0 | 579.2 |
| 20 | 582.4 | 582.0 | 593.3 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 551.7 | 554.4 |
| 21 | 555.4 | 554.3 | 552.7 | 552.4 | 553.9 | 556.8 | 560.8 | 566.5 | 560.0 | 550.0 | 560.0 | 575.1 |
| 22 | 584.2 | 591.5 | 598.4 | 603.5 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 560.5 | 576.1 |
| 23 | 581.6 | 586.0 | 597.5 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.6 | 585.9 |
| 24 | 599.2 | 604.5 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 555.1 | 561.0 |
| 25 | 560.5 | 556.6 | 567.0 | 592.0 | 604.5 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 556.0 | 567.5 |
| 26 | 572.7 | 571.0 | 568.5 | 568.8 | 583.9 | 601.4 | 597.5 | 580.0 | 560.0 | 550.0 | 563.6 | 586.9 |
| 27 | 600.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 552.6 | 556.2 |
| 28 | 556.6 | 554.5 | 557.3 | 576.8 | 598.5 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.6 | 585.9 |
| 29 | 599.8 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 556.7 | 565.9 |
| 30 | 569.3 | 569.1 | 566.9 | 575.2 | 594.8 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.6 | 581.3 |
| 31 | 595.2 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 563.6 | 586.7 |
| 32 | 600.5 | 605.0 | 605.0 | 605.0 | 605.0 | 605.0 | 597.5 | 580.0 | 560.0 | 550.0 | 577.5 | 604.1 |

TOTAL ENERGY GWH

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 227.7 | 282.9 | 399.9 | 341.5 | 283.4 | 248.8 | 247.0 | 287.1 | 266.3 | 205.9 | 138.0 | 135.2 |
| 2 | 201.0 | 230.4 | 273.7 | 242.3 | 196.0 | 201.6 | 193.6 | 278.8 | 251.7 | 192.5 | 146.4 | 339.9 |
| 3 | 224.7 | 331.7 | 413.1 | 358.5 | 289.9 | 253.8 | 245.5 | 256.4 | 335.5 | 222.2 | 199.7 | 174.1 |
| 4 | 297.2 | 353.8 | 406.5 | 343.1 | 283.7 | 251.8 | 254.8 | 314.0 | 318.7 | 191.6 | 238.6 | 210.0 |
| 5 | 221.1 | 312.1 | 401.3 | 350.2 | 289.5 | 250.7 | 249.0 | 340.5 | 318.1 | 198.2 | 225.1 | 146.5 |
| 6 | 202.8 | 311.3 | 416.6 | 363.7 | 300.5 | 260.0 | 248.3 | 282.1 | 304.2 | 217.2 | 410.7 | 244.1 |
| 7 | 206.6 | 307.9 | 395.5 | 340.6 | 288.4 | 254.6 | 247.8 | 323.4 | 325.4 | 407.5 | 427.5 | 403.8 |
| 8 | 225.1 | 339.2 | 420.4 | 361.6 | 304.1 | 262.6 | 248.2 | 301.1 | 301.6 | 210.3 | 269.4 | 340.0 |
| 9 | 294.6 | 365.2 | 437.8 | 368.5 | 298.5 | 262.0 | 251.9 | 288.7 | 277.2 | 198.8 | 235.2 | 135.3 |
| 10 | 201.8 | 231.8 | 315.3 | 353.1 | 297.5 | 255.4 | 250.5 | 345.8 | 303.6 | 225.3 | 356.1 | 256.7 |
| 11 | 251.2 | 334.4 | 421.2 | 364.9 | 302.6 | 262.8 | 247.7 | 284.6 | 248.5 | 205.8 | 143.9 | 296.9 |
| 12 | 286.3 | 338.8 | 434.7 | 381.6 | 310.6 | 279.6 | 282.3 | 304.0 | 334.5 | 261.1 | 328.8 | 163.9 |
| 13 | 228.6 | 331.9 | 420.1 | 368.4 | 304.9 | 269.5 | 257.4 | 255.6 | 408.6 | 414.7 | 431.2 | 349.2 |
| 14 | 259.0 | 336.7 | 417.5 | 358.9 | 304.1 | 258.0 | 244.2 | 304.3 | 309.1 | 405.4 | 424.1 | 239.0 |
| 15 | 249.2 | 317.3 | 401.3 | 342.4 | 288.6 | 248.6 | 245.9 | 247.4 | 405.1 | 399.3 | 226.7 | 135.3 |
| 16 | 202.4 | 280.3 | 394.1 | 340.7 | 286.3 | 255.0 | 248.0 | 270.7 | 294.2 | 239.0 | 282.6 | 346.3 |
| 17 | 264.9 | 311.7 | 404.2 | 351.9 | 297.7 | 265.2 | 257.6 | 281.0 | 342.4 | 203.7 | 171.9 | 135.3 |
| 18 | 201.5 | 231.8 | 366.7 | 354.5 | 300.3 | 262.1 | 249.5 | 288.4 | 299.5 | 324.4 | 417.9 | 437.0 |
| 19 | 231.0 | 321.1 | 418.5 | 370.2 | 316.5 | 284.0 | 263.0 | 296.7 | 319.1 | 354.2 | 214.6 | 135.3 |
| 20 | 200.5 | 231.5 | 288.8 | 333.1 | 281.6 | 251.9 | 251.4 | 265.0 | 235.5 | 162.0 | 138.3 | 135.8 |
| 21 | 201.9 | 231.2 | 275.0 | 242.6 | 196.3 | 202.4 | 172.2 | 181.1 | 295.6 | 231.0 | 138.6 | 135.3 |
| 22 | 202.7 | 231.8 | 275.9 | 257.0 | 223.8 | 234.7 | 260.9 | 262.3 | 321.9 | 204.7 | 151.4 | 135.3 |
| 23 | 201.5 | 233.4 | 366.9 | 376.0 | 318.4 | 280.2 | 255.9 | 347.0 | 340.3 | 389.1 | 296.1 | 157.6 |
| 24 | 202.9 | 314.2 | 401.3 | 347.5 | 295.8 | 257.8 | 245.4 | 249.6 | 284.4 | 170.9 | 139.2 | 135.2 |
| 25 | 200.9 | 230.1 | 276.1 | 243.2 | 278.6 | 249.4 | 245.5 | 295.6 | 263.3 | 189.4 | 137.9 | 135.2 |
| 26 | 201.2 | 231.0 | 274.6 | 242.8 | 196.1 | 235.4 | 252.5 | 303.1 | 315.1 | 380.5 | 239.0 | 251.3 |
| 27 | 281.0 | 309.9 | 389.2 | 339.8 | 287.8 | 253.7 | 249.4 | 303.2 | 292.4 | 172.0 | 138.5 | 136.0 |
| 28 | 201.1 | 230.8 | 277.2 | 243.2 | 252.1 | 270.7 | 254.1 | 311.6 | 334.6 | 309.0 | 265.7 | 158.2 |
| 29 | 271.1 | 353.1 | 432.6 | 370.7 | 308.5 | 274.6 | 256.9 | 245.1 | 242.4 | 190.1 | 138.0 | 135.2 |
| 30 | 201.6 | 231.6 | 274.7 | 242.9 | 216.3 | 264.5 | 250.8 | 260.4 | 242.4 | 337.6 | 290.9 | 135.3 |
| 31 | 235.5 | 376.8 | 429.6 | 363.7 | 303.9 | 269.5 | 256.2 | 268.7 | 293.1 | 360.1 | 323.5 | 166.2 |
| 32 | 286.7 | 368.6 | 406.6 | 352.2 | 294.6 | 259.2 | 247.3 | 269.7 | 271.2 | 254.0 | 417.9 | 437.1 |

STORAGE (MONTH END) AC-FT

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 798748.3 | 813181.9 |
| 2 | 798952.0 | 770511.0 | 740587.9 | 759515.3 | 902924.2 | 980498.1 | 979799.9 | 843400.0 | 707000.0 | 707000.0 | 847889.9 | 1024680.0 |
| 3 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843399.9 | 707000.0 | 707000.0 | 875992.8 | 1024680.0 |
| 4 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 893120.0 | 1024680.0 |
| 5 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 889283.1 | 994965.1 |
| 6 | 1056815.4 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 946188.2 | 1024680.0 |
| 7 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 887458.4 | 1092000.0 | 1024680.0 |
| 8 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 893119.9 | 1024680.0 |
| 9 | 1091600.0 | 1091600.0 | 1092000.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 893120.0 | 935004.6 |
| 10 | 952690.4 | 940510.8 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 893119.9 | 1024680.0 |
| 11 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 846564.5 | 1024680.0 |
| 12 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 893119.9 | 1018182.3 |
| 13 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843399.9 | 771754.4 | 957398.4 | 1092000.0 | 1024680.0 |
| 14 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 846637.0 | 1063273.9 | 1024680.0 |
| 15 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 731287.8 | 889938.3 | 952764.1 |
| 16 | 993433.3 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.1 | 707000.0 | 707000.0 | 893119.9 | 1024680.0 |
| 17 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 861377.1 | 939285.8 |
| 18 | 945638.9 | 1031632.1 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 1092000.0 | 1072753.0 |
| 19 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 883796.6 | 927968.3 |
| 20 | 927968.3 | 922293.1 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843399.9 | 707000.0 | 707000.0 | 729976.4 | 743585.6 |
| 21 | 743585.6 | 729630.2 | 721055.9 | 726211.2 | 740501.1 | 765760.8 | 796111.3 | 843400.0 | 707000.0 | 707000.0 | 843713.4 | 912720.6 |
| 22 | 967189.9 | 1012727.5 | 1064717.8 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 850515.4 | 919187.8 |
| 23 | 925465.5 | 979439.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 893119.9 | 1009907.4 |
| 24 | 1082118.8 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 777008.5 | 786666.3 |
| 25 | 770032.5 | 733837.0 | 912558.4 | 1082397.4 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 789051.7 | 863724.3 |
| 26 | 859659.1 | 840393.4 | 826188.9 | 843979.1 | 1032625.6 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 893120.0 | 1024680.0 |
| 27 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 741794.8 | 756206.3 |
| 28 | 747794.1 | 727000.2 | 786741.5 | 993251.7 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 893119.9 | 1010704.6 |
| 29 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843399.9 | 707000.0 | 707000.0 | 798372.8 | 832886.4 |
| 30 | 843885.8 | 830698.6 | 813952.9 | 943232.3 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 893119.9 | 948406.0 |
| 31 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.0 | 707000.0 | 707000.0 | 893119.8 | 1021249.4 |
| 32 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 1091600.0 | 979800.0 | 843400.1 | 707000.0 | 707000.0 | 1092000.0 | 1075707.6 |

$

```
SUSITNA HEP:
DEVIL CANYON 1455
600 MW (NO FLO REQ)
  384     1
   11     0         1000      707.0         1092.0            850.         .85        .01         1.00
    925.        0.        1000.         7.5       1050.          25.      1150.          85.
   1200.       132.       1250.        195.       1300.         292.      1350.         456.
   1400.       707.       1450.       1048.       1500.        1484.
    1455.
   600000.      2000.        00.0   32
   .73   .84   1.0   .88    .71    .73    .62    .56    .51    .53    .50    .49
   0.
  1000.0  1000.0  1000.0  1000.0  1000.0  1000.0  1000.0  1000.0  2000.0  2000.0  2000.0  2000.0
  1455.0  1455.0  1455.0  1455.0  1455.0  1455.0  1440.0  1420.0  1390.0  1390.0  1420.0  1440.0
   1.0   1.0    1.0    1.0    1.0    1.0    1.0    1.0    0.9   1.0    0.8    0.6
     7159.    8895.   12572.   10738.    8909.    7821.    6009.    7153.    6783.    7121.    6235.    4795.
     6535.    7334.    8848.    8600.    8940.    7848.    6231.    6882.    6288.    6656.    7308.   14009.
     8224.   10430.   12987.   11270.    9116.    7979.    5960.    6146.    9134.    7683.    9557.    8119.
    10519.   11124.   12780.   10786.    8918.    7918.    6258.    8035.    8564.    6626.   11137.    8988.
     8111.    9812.   12616.   11011.    9103.    7881.    6072.    8905.    8542.    6854.   10623.    6521.
     7492.   10398.   13097.   11436.    9448.    8175.    6051.    6988.    8069.    7511.   17730.    9160.
     7650.    9680.   12436.   10708.    9066.    8004.    6035.    8344.    8790.   16756.   17477.   11666.
     8237.   10665.   13216.   11370.    9562.    8257.    6048.    7613.    7982.    7272.   12179.   13200.
    10436.   11481.   14134.   11579.    9385.    8237.    6164.    7205.    7155.    6875.   11024.    5128.
     6857.    7334.   12593.   11103.    9352.    8029.    6119.    9077.    8051.    7791.   15103.   10500.
     9063.   10514.   13241.   11473.    9513.    8264.    6031.    7073.    6177.    7118.    7202.   12632.
    10173.   10651.   13666.   11999.    9766.    8790.    7132.    7706.    9098.    9029.   14182.    7389.
     8461.   10435.   13208.   11583.    9586.    8472.    6340.    6121.   12575.   16842.   17386.    9938.
     9310.   10587.   13125.   11283.    9560.    8110.    5920.    7716.    8238.   16079.   17356.    6948.
     9000.    9976.   12616.   10765.    9073.    7815.    5975.    5851.   11498.   14166.   10259.    5467.
     7209.   10536.   12390.   10712.    9002.    8018.    6041.    6615.    7730.    8264.   12624.   13405.
     9498.    9799.   12708.   11065.    9360.    8339.    6346.    6954.    9368.    7046.    8387.    5741.
     6662.    8883.   12594.   11144.    9441.    8240.    6089.    7197.    7910.   11218.   21298.   13444.
     7587.   10094.   13159.   11638.    9952.    8930.    6518.    7469.    8577.   12251.   10182.    5175.
     6548.    7472.   12066.   10473.    8855.    7921.    6148.    6430.    5736.    5604.    5150.    4885.
     6914.    7703.    9321.    8438.    6979.    7333.    6345.    6863.    7779.    7988.    6974.    5618.
     7504.    8210.    9634.    8545.    7036.    7379.    6453.    6339.    8673.    7078.    7518.    5605.
     6694.    8472.   13542.   11823.   10009.    8811.    6292.    9117.    9297.   13455.   13079.    7055.
     7640.   10046.   12616.   10926.    9301.    8106.    5957.    5925.    7397.    5909.    5930.    4744.
     6542.    7262.   12227.   10629.    8919.    7841.    5962.    7432.    6681.    6550.    6080.    5771.
     6616.    7375.    8952.    8415.    9515.    8423.    6183.    7678.    8441.   13158.   11152.   10325.
    10005.    9744.   12237.   10683.    9049.    7976.    6084.    7681.    7668.    5947.    5346.    4891.
     6733.    7572.   10452.   11444.    9643.    8512.    6236.    7956.    9104.   10688.   12052.    7087.
     9938.   11102.   13601.   11654.    9698.    8632.    6324.    5776.    5970.    6575.    6229.    5117.
     6919.    7522.    8940.   10177.    9376.    8316.    6129.    6278.    5970.   11674.   12904.    5343.
     9902.   11846.   13508.   11436.    9556.    8472.    6302.    6551.    7694.   12453.   14003.    7513.
    10248.   11590.   12783.   11074.    9262.    8148.    6017.    6584.    6950.    8785.   23287.   13493.
    5758.2   2404.7   1342.5    951.3    735.7    670.0    802.2 10490.7 18468.6 21383.4 18820.6  7950.8
    3652.0   1231.2   1030.8    905.7    767.5    697.1   1504.6 13218.5 19978.5 21575.9 18530.0 19799.1
    5221.7   2539.0   1757.5   1483.7    943.2    828.2    878.5  4989.5 30014.2 24861.7 19647.2 13441.1
    7517.6   3232.6   1550.4    999.6    745.6    766.7   1531.8 17758.3 25230.7 19184.0 19207.0 13928.4
    5109.3   1921.3   1387.1   1224.2    929.7    729.4   1130.6 15286.0 23188.1 19154.1 24071.6 11579.1
    4830.4   2506.8   1868.0   1649.1   1275.2   1023.6   1107.4  8390.1 28081.9 26212.8 24959.6 13989.2
    4647.9   1788.6   1206.6    921.7    893.1    852.3    867.3 15979.0 31137.1 29212.0 22609.8 16495.8
    5235.3   2773.8   1986.6   1583.2   1388.9   1105.4   1109.0 12473.6 28415.4 22109.6 19389.2 18029.0
    7434.5   3590.4   2904.9   1792.0   1212.2   1085.7   1437.4 11849.2 24413.5 21763.1 21219.8  6988.8
    4402.8   1999.8   1370.9   1316.9   1179.1    877.9   1119.9 13900.9 21537.7 23390.4 28594.4 15329.6
    6060.7   2622.7   2011.5   1686.2   1340.2   1112.8   1217.8 14802.9 14709.8 21739.3 22066.1 18929.9
    7170.9   2759.9   2436.6   2212.0   1593.6   1638.9   2405.4 16030.7 27069.3 22880.6 21164.4 12218.6
    5459.4   2544.1   1978.7   1796.0   1413.4   1320.3   1613.4 12141.2 40679.7 24990.6 22241.8 14767.2
    6307.7   2696.0   1896.0   1496.0   1387.4    958.4    810.9 17697.6 24094.1 32388.4 22720.5 11777.2
    5998.3   2085.4   1387.1    978.0    900.2    663.8    696.5  4046.9 47816.4 21926.0 15585.8  8840.0
    5744.0   2645.1   1160.8    925.3    828.8    866.9   1314.4 12267.1 24110.3 26195.7 19789.3 18234.2
    6496.5   1907.8   1478.4   1278.7   1187.4   1187.4   1619.1  8734.0 30446.3 18536.2 20244.6 10844.3
    3844.0   1457.9   1364.9   1357.9   1268.3   1089.1   1053.7 14435.5 27796.4 25081.2 30293.0 15726.2
    4585.3   2203.5   1929.7   1851.2   1778.7   1778.7   1791.0 14982.4 29462.1 24871.0 16090.5  8225.9
    3576.7   1531.8    836.3    686.6    681.8    769.6   1421.3 10429.9 14950.7 15651.2  8483.6  4795.5
    2866.5   1145.7    810.0    756.9    708.7    721.8   1046.6 10721.6 17118.9 21142.2 18652.8  8443.5
    4745.2   3081.8   2074.8   1318.8    943.6    866.8    986.2  3427.9 31031.0 22941.6 30315.9 13636.0
    5537.0   2912.3   2312.6   2036.1   1836.4   1659.8   1565.5 19776.8 31929.8 21716.5 18654.1 11884.2
    4638.6   2154.8   1387.0   1139.8   1128.6    955.0    986.7  7896.4 26392.6 17571.8 19478.1  8726.0
    3491.4   1462.9    997.4    842.7    745.9    689.5    949.1 15004.6 16766.7 17790.0 15257.0 11370.1
    3506.8   1619.4   1486.5   1408.8   1342.2   1271.9   1456.7 14036.5 30302.6 26188.0 17031.6 15154.7
    7003.3   1853.0   1007.9    896.8    876.2    825.2   1261.2 11305.3 22813.6 18252.6 19297.7  6463.3
    3552.4   2391.7   2147.5   1657.4   1469.7   1361.0   1509.8 11211.9 35606.7 21740.5 18371.2 11916.1
    6936.3   3210.8   2371.4   1867.9   1525.0   1480.6   1597.1 11693.4 18416.8 20079.0 15326.5  8080.4
    4502.3   2324.3   1549.4   1304.1   1203.6   1164.7   1402.8 13334.0 24052.4 27462.8 19106.7 10172.4
    1.
    1.
```

SUSITNA HEP
WATANA 2185
CASE A

| EL | STORAGE |
|---|---|
| 1900.0 | 2550000.0 |
| 1950.0 | 3330000.0 |
| 2000.0 | 4250000.0 |
| 2050.0 | 5340000.0 |
| 2100.0 | 6650000.0 |
| 2150.0 | 8189999.5 |
| 2200.0 | 10020000.0 |
| 2250.0 | 12210000.0 |

MINIMUM STORAGE= 5232000.0 MAXIMUM STORAGE 9652000.0

MAXIMUM P.H.Q = 17109.7 START WSEL=2185.0 TWEL=1455.0 PMAX=.90000E+06

MONTHLY BASELOAD DEMAND

0.321930E+06 0.370440E+06 0.441000E+06 0.388080E+06 0.313110E+06 0.321930E+06

0.273420E+06 0.246960E+06 0.224910E+06 0.233730E+06 0.220500E+06 0.216090E+06

MONTHLY DISCHARGE REQUIREMENT

1200.0 1200.0 1200.0 1200.0 1200.0 1200.0 1200.0 1200.0 1200.0 1200.0 1200.0 1200.0

MONTHLY WATER LEVEL

2185.0 2172.0 2153.5 2135.0 2119.0 2105.0 2095.0 2145.0 2160.0 2170.0 2180.0 2190.0

MONTHLY FLOW DISTRIBUTION

1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.9 0.9 0.8 0.8 0.7

MONTHLY L.F. = 0.490

NO. YEARS OF SIMULATION = 32

PDS= 0 NSEC= 323 NDEF= 61 NDEF1= 0 NDSFL= 0

| YEAR | TOTE | TOTSEC | TOTDEF |
|---|---|---|---|
| 1 | 0.30226E+10 | 0.41727E+09 | 0.92217E+06 |
| 2 | 0.30820E+10 | 0.47668E+09 | 0.84709E+06 |
| 3 | 0.33835E+10 | 0.77734E+09 | 0.57148E+05 |
| 4 | 0.35083E+10 | 0.90205E+09 | 0.00000E+00 |
| 5 | 0.32209E+10 | 0.61470E+09 | 0.38669E+05 |
| 6 | 0.37974E+10 | 0.11923E+10 | 0.10547E+07 |
| 7 | 0.39653E+10 | 0.13592E+10 | 0.39512E+05 |
| 8 | 0.36669E+10 | 0.10607E+10 | 0.60078E+05 |
| 9 | 0.34915E+10 | 0.88536E+09 | 0.22515E+05 |
| 10 | 0.33609E+10 | 0.75783E+09 | 0.31195E+07 |
| 11 | 0.34567E+10 | 0.85055E+09 | 0.38122E+05 |
| 12 | 0.37540E+10 | 0.11478E+10 | 0.00000E+00 |
| 13 | 0.43185E+10 | 0.17123E+10 | 0.00000E+00 |
| 14 | 0.40536E+10 | 0.14474E+10 | 0.39284E+05 |
| 15 | 0.36755E+10 | 0.10693E+10 | 0.60762E+05 |
| 16 | 0.36369E+10 | 0.10307E+10 | 0.00000E+00 |
| 17 | 0.32279E+10 | 0.62252E+09 | 0.82441E+06 |
| 18 | 0.39613E+10 | 0.13559E+10 | 0.78195E+06 |
| 19 | 0.35710E+10 | 0.96479E+09 | 0.00000E+00 |
| 20 | 0.29518E+10 | 0.34657E+09 | 0.98418E+06 |
| 21 | 0.26109E+10 | 0.69840E+07 | 0.22692E+07 |
| 22 | 0.26315E+10 | 0.26625E+08 | 0.13600E+07 |
| 23 | 0.37643E+10 | 0.11584E+10 | 0.30755E+06 |
| 24 | 0.31582E+10 | 0.55291E+09 | 0.88064E+06 |
| 25 | 0.29565E+10 | 0.35113E+09 | 0.84561E+06 |
| 26 | 0.33413E+10 | 0.73599E+09 | 0.91743E+06 |
| 27 | 0.31564E+10 | 0.55053E+09 | 0.36604E+06 |
| 28 | 0.33869E+10 | 0.78453E+09 | 0.38234E+07 |
| 29 | 0.33194E+10 | 0.71323E+09 | 0.00000E+00 |
| 30 | 0.32521E+10 | 0.64892E+09 | 0.30505E+07 |
| 31 | 0.38903E+10 | 0.12841E+10 | 0.00000E+00 |
| 32 | 0.41182E+10 | 0.15120E+10 | 0.38030E+05 |

AVERAGE MONTHLY ENERGY AND POWER

| MONTH | TOTAL POWER MW | PEAK POWER MW | OFFPEAK POWER MW | TOTAL ENERGY GWH | OFFPEAK ENERGY GWH | PEAK ENERGY GWH | DEFICIT MW | SEC MW |
|---|---|---|---|---|---|---|---|---|
| OCT | 384.944 | 384.944 | 384.944 | 280.855 | 280.855 | 0.000 | 0.387 | 63.401 |
| NOV | 476.498 | 476.498 | 476.498 | 347.653 | 347.653 | 0.000 | 0.318 | 106.377 |
| DEC | 609.614 | 609.614 | 609.614 | 444.775 | 444.775 | 0.000 | 0.014 | 168.629 |
| JAN | 525.629 | 525.629 | 525.629 | 383.499 | 383.499 | 0.000 | 0.008 | 137.558 |
| FEB | 435.888 | 435.888 | 435.888 | 318.024 | 318.024 | 0.000 | 0.006 | 127.783 |
| MAR | 378.048 | 378.048 | 378.048 | 275.824 | 275.824 | 0.000 | 0.006 | 56.124 |
| APR | 278.163 | 278.163 | 278.163 | 202.948 | 202.948 | 0.000 | 0.029 | 4.272 |
| MAY | 247.261 | 247.261 | 247.261 | 180.401 | 180.401 | 0.000 | 0.205 | 0.506 |
| JUN | 239.243 | 239.243 | 239.243 | 174.552 | 174.552 | 0.000 | 0.000 | 14.333 |
| JUL | 353.583 | 353.583 | 353.583 | 257.974 | 257.974 | 0.000 | 0.000 | 119.853 |
| AUG | 471.995 | 471.995 | 471.995 | 344.368 | 344.368 | 0.000 | 0.000 | 251.495 |
| SEP | 340.272 | 340.272 | 340.272 | 248.262 | 248.262 | 0.000 | 0.000 | 124.182 |

AVERAGE MONTHLY DISCHARGES AND HEAD

| MONTH | INFLOW | P.H.FLOW | PEAK | OFFPEAK | HEAD | SPILL | HLOSS |
|---|---|---|---|---|---|---|---|
| OCT | 4513.06 | 7338.21 | 7338.21 | 7338.21 | 727.30 | 0.00 | 0.00 |
| NOV | 2052.42 | 9186.44 | 9186.44 | 9186.44 | 719.01 | 0.00 | 0.00 |
| DEC | 1404.84 | 11998.66 | 11998.66 | 11998.66 | 704.27 | 0.00 | 0.00 |
| JAN | 1157.27 | 10617.16 | 10617.16 | 10617.16 | 686.46 | 0.00 | 0.00 |
| FEB | 978.88 | 9027.21 | 9027.21 | 9027.21 | 669.51 | 0.00 | 0.00 |
| MAR | 898.33 | 8012.69 | 8012.69 | 8012.69 | 654.54 | 0.00 | 0.00 |
| APR | 1112.57 | 6011.43 | 6011.43 | 6011.43 | 642.28 | 0.00 | 0.00 |
| MAY | 10397.55 | 5344.21 | 5344.21 | 5344.21 | 642.31 | 0.00 | 0.00 |
| JUN | 22922.44 | 4990.10 | 4990.10 | 4990.10 | 665.24 | 0.00 | 0.00 |
| JUL | 20778.01 | 7021.52 | 7021.52 | 7021.52 | 695.17 | 0.00 | 0.00 |
| AUG | 18431.45 | 9116.69 | 9116.69 | 9116.69 | 715.16 | 73.20 | 0.00 |
| SEP | 10670.41 | 6485.92 | 6485.92 | 6485.92 | 726.36 | 0.00 | 0.00 |

AVERAGE ANNUAL ENERGY = 0.345913E+10 KWH

DELMASS = 0.18098500E+06
STOREND = 0.96520000E+07
STORSTART = 0.96520000E+07
INFLOW MASS = 0.30501528E+07
OUTFL. MASS = 0.30471475E+07

INFLOW CFS

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4719.9 | 2083.6 | 1168.9 | 815.1 | 641.7 | 569.1 | 680.1 | 8655.9 | 16432.1 | 19193.4 | 16913.6 | 7320.4 |
| 2 | 3299.1 | 1107.3 | 906.2 | 808.0 | 673.0 | 619.8 | 1302.2 | 11649.8 | 18517.9 | 19786.6 | 16478.0 | 17205.5 |
| 3 | 4592.9 | 2170.1 | 1501.0 | 1274.5 | 841.0 | 735.0 | 803.9 | 4216.5 | 25773.4 | 22110.9 | 17356.3 | 11571.0 |
| 4 | 6285.7 | 2756.8 | 1281.2 | 818.9 | 611.7 | 670.7 | 1382.0 | 15037.2 | 21469.8 | 17355.3 | 16681.6 | 11513.5 |
| 5 | 4218.9 | 1599.6 | 1183.8 | 1087.8 | 803.1 | 638.2 | 942.6 | 11696.8 | 19476.7 | 16983.6 | 20420.6 | 9165.5 |
| 6 | 3859.2 | 2051.1 | 1549.5 | 1388.3 | 1050.5 | 886.1 | 940.8 | 6718.1 | 24881.4 | 23787.9 | 23537.0 | 13447.8 |
| 7 | 4102.3 | 1588.1 | 1038.6 | 816.9 | 754.8 | 694.4 | 718.3 | 12953.3 | 27171.8 | 25831.3 | 19153.4 | 13194.4 |
| 8 | 4208.0 | 2276.6 | 1707.0 | 1373.0 | 1189.0 | 935.0 | 945.1 | 10176.2 | 25275.0 | 19948.9 | 17317.7 | 14841.1 |
| 9 | 6034.9 | 2935.9 | 2258.5 | 1480.6 | 1041.7 | 973.5 | 1265.4 | 9957.8 | 22097.8 | 19752.7 | 18843.4 | 5978.7 |
| 10 | 3668.0 | 1729.5 | 1115.1 | 1081.0 | 949.0 | 694.0 | 885.7 | 10140.6 | 18329.6 | 20493.1 | 23940.4 | 12466.9 |
| 11 | 5165.5 | 2213.5 | 1672.3 | 1400.4 | 1138.9 | 961.1 | 1069.9 | 13044.2 | 13233.4 | 19506.1 | 19323.1 | 16085.6 |
| 12 | 6049.3 | 2327.8 | 1973.2 | 1779.9 | 1304.8 | 1331.0 | 1965.0 | 13637.9 | 22784.1 | 19839.8 | 19480.2 | 10146.2 |
| 13 | 4637.6 | 2263.4 | 1760.4 | 1608.9 | 1257.4 | 1176.8 | 1457.4 | 11333.5 | 36017.1 | 23443.7 | 19887.1 | 12746.2 |
| 14 | 5560.1 | 2508.9 | 1708.9 | 1308.9 | 1184.7 | 883.6 | 776.6 | 15299.2 | 20663.4 | 28767.4 | 21011.4 | 10800.0 |
| 15 | 5187.1 | 1789.1 | 1194.7 | 852.0 | 781.6 | 575.2 | 609.2 | 3578.8 | 42841.9 | 20082.8 | 14048.2 | 7524.2 |
| 16 | 4759.4 | 2368.2 | 1070.3 | 863.0 | 772.7 | 807.3 | 1232.4 | 10966.0 | 21213.0 | 23235.9 | 17394.1 | 16225.6 |
| 17 | 5221.2 | 1565.3 | 1203.6 | 1060.4 | 984.7 | 984.7 | 1338.4 | 7094.1 | 25939.6 | 16153.5 | 17390.9 | 9214.1 |
| 18 | 3269.8 | 1202.2 | 1121.6 | 1102.2 | 1031.3 | 889.5 | 849.7 | 12555.5 | 24711.9 | 21987.3 | 26104.5 | 13672.9 |
| 19 | 4019.0 | 1934.3 | 1704.2 | 1617.6 | 1560.4 | 1560.4 | 1576.7 | 12826.7 | 25704.0 | 22082.8 | 14147.5 | 7163.6 |
| 20 | 3135.0 | 1354.9 | 753.9 | 619.2 | 607.5 | 686.0 | 1261.6 | 9313.7 | 13962.1 | 14843.5 | 7771.9 | 4260.0 |
| 21 | 2403.1 | 1020.9 | 709.3 | 636.2 | 602.1 | 624.1 | 986.4 | 9536.4 | 14399.0 | 18410.1 | 16263.8 | 7224.1 |
| 22 | 3768.0 | 2496.4 | 1687.4 | 1097.1 | 777.4 | 717.1 | 813.7 | 2857.2 | 27612.8 | 21126.4 | 27446.6 | 12188.9 |
| 23 | 4979.1 | 2587.0 | 1957.4 | 1670.9 | 1491.4 | 1366.0 | 1305.4 | 15973.1 | 27429.3 | 19820.3 | 17509.5 | 10955.7 |
| 24 | 4301.2 | 1977.9 | 1246.5 | 1031.5 | 1000.2 | 873.9 | 914.1 | 7287.0 | 23859.3 | 16351.1 | 18016.7 | 8099.7 |
| 25 | 3056.5 | 1354.7 | 931.6 | 786.4 | 689.9 | 627.3 | 871.9 | 12889.0 | 14780.6 | 15971.9 | 13523.7 | 9786.2 |
| 26 | 3088.8 | 1474.4 | 1276.7 | 1215.8 | 1110.3 | 1041.4 | 1211.2 | 11672.2 | 26689.2 | 23430.4 | 15126.6 | 13075.3 |
| 27 | 5679.1 | 1601.1 | 876.2 | 757.8 | 743.2 | 690.7 | 1059.8 | 8938.8 | 19994.0 | 17015.3 | 18393.5 | 5711.5 |
| 28 | 2973.5 | 1926.7 | 1687.5 | 1348.7 | 1202.9 | 1110.8 | 1203.4 | 8569.4 | 31352.8 | 19707.3 | 16807.3 | 10613.1 |
| 29 | 5793.9 | 2645.3 | 1979.7 | 1577.9 | 1267.7 | 1256.7 | 1408.4 | 11231.5 | 17277.2 | 18385.2 | 13412.1 | 7132.6 |
| 30 | 3773.9 | 1944.9 | 1312.6 | 1136.8 | 1055.4 | 1101.2 | 1317.9 | 12369.3 | 22904.8 | 24911.7 | 16670.7 | 9096.7 |
| 31 | 6150.0 | 3525.0 | 2032.0 | 1470.0 | 1233.0 | 1177.0 | 1404.0 | 10140.0 | 23400.0 | 26740.0 | 18000.0 | 11000.0 |
| 32 | 6458.0 | 3297.0 | 1385.0 | 1147.0 | 971.0 | 889.0 | 1103.0 | 10406.0 | 17323.0 | 27840.0 | 31435.0 | 12026.0 |

POWERHOUSE FLOW CFS

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6120.2 | 8574.2 | 12398.2 | 10601.6 | 8814.5 | 7720.3 | 5886.8 | 5318.2 | 4746.0 | 4931.3 | 4328.0 | 4164.7 |
| 2 | 6181.7 | 7210.1 | 8723.0 | 8502.4 | 8845.8 | 7771.0 | 6028.8 | 5313.6 | 4827.4 | 4866.4 | 5255.9 | 11415.5 |
| 3 | 7594.7 | 10061.0 | 12730.3 | 11061.0 | 9013.8 | 7886.2 | 5885.5 | 5372.6 | 4893.4 | 4932.7 | 7266.6 | 6248.8 |
| 4 | 9287.5 | 10647.7 | 12510.5 | 10605.4 | 8784.5 | 7821.9 | 6108.6 | 5313.6 | 4802.8 | 4797.7 | 8611.8 | 6572.6 |
| 5 | 7220.7 | 9490.5 | 12413.1 | 10874.3 | 8975.9 | 7789.4 | 5884.1 | 5315.7 | 4830.5 | 4683.7 | 6972.1 | 4107.2 |
| 6 | 6521.1 | 9942.0 | 12778.8 | 11174.8 | 9223.3 | 8037.3 | 5884.1 | 5315.7 | 4868.5 | 5086.5 | 16307.3 | 8618.4 |
| 7 | 7104.1 | 9479.0 | 12267.9 | 10603.4 | 8927.6 | 7845.6 | 5886.4 | 5317.8 | 4824.9 | 13374.9 | 14021.0 | 8365.0 |
| 8 | 7209.8 | 10167.5 | 12936.3 | 11159.5 | 9361.8 | 8086.2 | 5884.0 | 5315.6 | 4841.6 | 5111.0 | 10107.6 | 10011.7 |
| 9 | 9036.7 | 10826.8 | 13487.8 | 11267.1 | 9214.5 | 8124.7 | 5992.0 | 5313.6 | 4839.8 | 4865.0 | 8647.1 | 4118.0 |
| 10 | 6121.7 | 7063.7 | 12337.1 | 10867.5 | 9121.8 | 7845.2 | 5884.6 | 5316.2 | 4842.8 | 4893.5 | 10449.2 | 7637.5 |
| 11 | 8167.3 | 10104.4 | 12901.6 | 11186.9 | 9311.7 | 8112.3 | 5882.7 | 5314.4 | 4701.1 | 4884.6 | 4459.1 | 9787.9 |
| 12 | 9051.1 | 10218.7 | 13202.5 | 11566.4 | 9477.6 | 8482.2 | 6691.6 | 5313.6 | 4812.9 | 5987.9 | 12497.9 | 5316.8 |
| 13 | 7639.4 | 10154.3 | 12989.7 | 11395.4 | 9430.2 | 8328.0 | 6184.0 | 5313.6 | 7912.0 | 15295.0 | 15031.2 | 7916.8 |
| 14 | 8561.9 | 10399.8 | 12938.2 | 11095.4 | 9357.5 | 8034.8 | 5885.8 | 5317.2 | 4806.9 | 12457.7 | 15647.3 | 5970.6 |
| 15 | 8188.9 | 9680.0 | 12424.0 | 10638.5 | 8954.4 | 7726.4 | 5887.6 | 5382.7 | 6523.7 | 12322.8 | 8721.7 | 4150.9 |
| 16 | 6224.6 | 10259.1 | 12299.6 | 10649.5 | 8945.5 | 7958.5 | 5959.0 | 5313.6 | 4832.4 | 5304.6 | 10228.8 | 11396.2 |
| 17 | 8223.0 | 9456.2 | 12432.9 | 10846.9 | 9157.5 | 8135.9 | 6065.0 | 5313.6 | 4861.4 | 4663.6 | 5533.5 | 4110.3 |
| 18 | 6087.8 | 8627.7 | 12350.9 | 10888.7 | 9204.1 | 8040.7 | 5885.0 | 5316.5 | 4825.7 | 8123.9 | 17109.7 | 11388.5 |
| 19 | 7020.8 | 9825.2 | 12933.5 | 11404.1 | 9733.2 | 8711.6 | 6303.3 | 5313.6 | 4818.8 | 9462.9 | 8238.8 | 4112.9 |
| 20 | 6106.1 | 7294.9 | 11983.2 | 10405.7 | 8780.3 | 7837.2 | 5988.2 | 5313.6 | 4747.2 | 4796.1 | 4438.3 | 4349.0 |
| 21 | 6450.3 | 7577.9 | 9220.7 | 8317.7 | 6872.2 | 7235.3 | 6284.9 | 5678.2 | 5059.0 | 5256.2 | 4584.8 | 4399.0 |
| 22 | 6526.3 | 7624.8 | 9246.4 | 8323.5 | 6870.0 | 7229.1 | 6280.2 | 5768.5 | 5254.6 | 5262.4 | 4649.0 | 4157.5 |
| 23 | 6136.4 | 8146.4 | 13186.7 | 11457.4 | 9664.2 | 8517.2 | 6032.0 | 5313.6 | 4796.0 | 11558.5 | 11934.4 | 6126.3 |
| 24 | 7303.0 | 9868.8 | 12475.8 | 10818.0 | 9173.0 | 8025.1 | 5884.4 | 5315.9 | 4864.0 | 4688.5 | 4468.1 | 4118.0 |
| 25 | 6106.9 | 7153.4 | 12160.9 | 10572.9 | 8862.7 | 7778.5 | 5884.8 | 5316.3 | 4695.4 | 4731.9 | 4347.0 | 4187.5 |
| 26 | 6198.1 | 7230.4 | 8741.9 | 8221.9 | 9283.1 | 8192.6 | 5937.8 | 5313.6 | 4827.2 | 10400.6 | 9247.3 | 8245.9 |
| 27 | 8680.9 | 9492.0 | 12105.5 | 10544.3 | 8916.0 | 7841.9 | 5882.8 | 5314.5 | 4848.8 | 4709.9 | 4442.3 | 4138.7 |
| 28 | 6154.2 | 7107.3 | 9991.5 | 11135.2 | 9375.7 | 8262.0 | 5930.0 | 5313.6 | 4850.0 | 8655.1 | 10488.4 | 5783.7 |
| 29 | 8795.7 | 10536.2 | 13209.0 | 11364.4 | 9440.5 | 8407.9 | 6135.0 | 5313.6 | 4830.5 | 4881.3 | 4314.6 | 4169.6 |
| 30 | 6190.4 | 7142.9 | 8703.5 | 10010.0 | 9228.2 | 8252.4 | 6044.5 | 5313.6 | 4822.1 | 9123.1 | 10468.0 | 4267.3 |
| 31 | 9151.8 | 11415.9 | 13261.3 | 11256.5 | 9405.8 | 8328.2 | 6130.6 | 5313.6 | 4838.5 | 9191.1 | 11807.2 | 6170.6 |
| 32 | 9459.8 | 11187.9 | 12614.3 | 10933.5 | 9143.8 | 8040.2 | 5882.4 | 5314.1 | 4837.4 | 5388.6 | 17109.7 | 12026.0 |

SPILL CFS

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 20 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 21 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 22 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 23 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 24 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 26 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 27 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 28 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 29 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 30 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 31 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 32 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2342.4 | 0.0 |

OUTFLOW CFS

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6120.2 | 8574.2 | 12398.2 | 10601.6 | 8814.5 | 7720.3 | 5886.8 | 5318.2 | 4746.0 | 4931.3 | 4328.0 | 4164.7 |
| 2 | 6181.7 | 7210.1 | 8723.0 | 8502.4 | 8845.8 | 7771.0 | 6028.8 | 5313.6 | 4827.4 | 4866.4 | 5255.9 | 11415.5 |
| 3 | 7594.7 | 10061.0 | 12730.3 | 11061.0 | 9013.8 | 7886.2 | 5885.5 | 5372.6 | 4893.4 | 4932.7 | 7266.6 | 6248.8 |
| 4 | 9287.5 | 10647.7 | 12510.5 | 10605.4 | 8784.5 | 7821.9 | 6108.6 | 5313.6 | 4802.8 | 4797.7 | 8611.8 | 6572.6 |
| 5 | 7220.7 | 9490.5 | 12413.1 | 10874.3 | 8975.9 | 7789.4 | 5884.1 | 5315.7 | 4830.5 | 4683.7 | 6972.1 | 4107.2 |
| 6 | 6521.1 | 9942.0 | 12778.8 | 11174.8 | 9223.3 | 8037.3 | 5884.1 | 5315.7 | 4868.5 | 5086.5 | 16307.3 | 8618.4 |
| 7 | 7104.1 | 9479.0 | 12267.9 | 10603.4 | 8927.6 | 7845.6 | 5886.4 | 5317.8 | 4824.9 | 13374.9 | 14021.0 | 8365.0 |
| 8 | 7209.8 | 10167.5 | 12936.3 | 11159.5 | 9361.8 | 8086.2 | 5884.0 | 5315.6 | 4841.6 | 5111.0 | 10107.6 | 10011.7 |
| 9 | 9036.7 | 10826.8 | 13487.8 | 11267.1 | 9214.5 | 8124.7 | 5992.0 | 5313.6 | 4839.8 | 4865.0 | 8647.1 | 4118.0 |
| 10 | 6121.7 | 7063.7 | 12337.1 | 10867.5 | 9121.8 | 7845.2 | 5884.6 | 5316.2 | 4842.8 | 4893.5 | 10449.2 | 7637.5 |
| 11 | 8167.3 | 10104.4 | 12901.6 | 11186.9 | 9311.7 | 8112.3 | 5882.7 | 5314.4 | 4701.1 | 4884.6 | 4459.1 | 9787.9 |
| 12 | 9051.1 | 10218.7 | 13202.5 | 11566.4 | 9477.6 | 8482.2 | 6691.6 | 5313.6 | 4812.9 | 5987.9 | 12497.9 | 5316.8 |
| 13 | 7639.4 | 10154.3 | 12989.7 | 11395.4 | 9430.2 | 8328.0 | 6184.0 | 5313.6 | 7912.0 | 15295.0 | 15031.2 | 7916.8 |
| 14 | 8561.9 | 10399.8 | 12938.2 | 11095.4 | 9357.5 | 8034.8 | 5885.8 | 5317.2 | 4806.9 | 12457.7 | 15647.3 | 5970.6 |
| 15 | 8188.9 | 9680.0 | 12424.0 | 10638.5 | 8954.4 | 7726.4 | 5887.6 | 5382.7 | 6523.7 | 12322.8 | 8721.7 | 4150.9 |
| 16 | 6224.6 | 10259.1 | 12299.6 | 10649.5 | 8945.5 | 7958.5 | 5959.0 | 5313.6 | 4832.4 | 5304.6 | 10228.8 | 11396.2 |
| 17 | 8223.0 | 9456.2 | 12432.9 | 10846.9 | 9157.5 | 8135.9 | 6065.0 | 5313.6 | 4861.4 | 4663.6 | 5533.5 | 4110.3 |
| 18 | 6087.8 | 8627.7 | 12350.9 | 10888.7 | 9204.1 | 8040.7 | 5885.0 | 5316.5 | 4825.7 | 8123.9 | 17109.7 | 11388.5 |
| 19 | 7020.8 | 9825.2 | 12933.5 | 11404.1 | 9733.2 | 8711.6 | 6303.3 | 5313.6 | 4818.8 | 9462.9 | 8238.8 | 4112.9 |
| 20 | 6106.1 | 7294.9 | 11983.2 | 10405.7 | 8780.3 | 7837.2 | 5988.2 | 5313.6 | 4747.2 | 4796.1 | 4438.3 | 4349.0 |
| 21 | 6450.3 | 7577.9 | 9220.7 | 8317.7 | 6872.2 | 7235.3 | 6284.9 | 5678.2 | 5059.0 | 5256.2 | 4584.8 | 4399.0 |
| 22 | 6526.3 | 7624.8 | 9246.4 | 8323.5 | 6870.0 | 7229.1 | 6280.2 | 5768.5 | 5254.6 | 5262.4 | 4649.0 | 4157.5 |
| 23 | 6136.4 | 8146.4 | 13186.7 | 11457.4 | 9664.2 | 8517.2 | 6032.0 | 5313.6 | 4796.0 | 11558.5 | 11934.4 | 6126.3 |
| 24 | 7303.0 | 9868.8 | 12475.8 | 10818.0 | 9173.0 | 8025.1 | 5884.4 | 5315.9 | 4864.0 | 4688.5 | 4468.1 | 4118.0 |
| 25 | 6106.9 | 7153.4 | 12160.9 | 10572.9 | 8862.7 | 7778.5 | 5884.8 | 5316.3 | 4695.4 | 4731.9 | 4347.0 | 4187.5 |
| 26 | 6198.1 | 7230.4 | 8741.9 | 8221.9 | 9283.1 | 8192.6 | 5937.8 | 5313.6 | 4827.2 | 10400.6 | 9247.3 | 8245.9 |
| 27 | 8680.9 | 9492.0 | 12105.5 | 10544.3 | 8916.0 | 7841.9 | 5882.8 | 5314.5 | 4848.8 | 4709.9 | 4442.3 | 4138.7 |
| 28 | 6154.2 | 7107.3 | 9991.5 | 11135.2 | 9375.7 | 8262.0 | 5930.0 | 5313.6 | 4850.0 | 8655.1 | 10488.4 | 5783.7 |
| 29 | 8795.7 | 10536.2 | 13209.0 | 11364.4 | 9440.5 | 8407.9 | 6135.0 | 5313.6 | 4830.5 | 4881.3 | 4314.6 | 4169.6 |
| 30 | 6190.4 | 7142.9 | 8703.5 | 10010.0 | 9228.2 | 8252.4 | 6044.5 | 5313.6 | 4822.1 | 9123.1 | 10468.0 | 4267.3 |
| 31 | 9151.8 | 11415.9 | 13261.3 | 11256.5 | 9405.8 | 8328.2 | 6130.6 | 5313.6 | 4838.5 | 9191.1 | 11807.2 | 6170.6 |
| 32 | 9459.8 | 11187.9 | 12614.3 | 10933.5 | 9143.8 | 8040.2 | 5882.4 | 5314.1 | 4837.4 | 5388.6 | 19452.1 | 12026.0 |

AVERAGE HEAD FT

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 728.8 | 722.3 | 707.8 | 689.3 | 672.0 | 657.0 | 644.4 | 642.6 | 657.8 | 683.0 | 707.2 | 720.1 |
| 2 | 720.4 | 713.0 | 701.5 | 687.5 | 672.0 | 657.0 | 645.0 | 646.6 | 666.6 | 693.4 | 716.2 | 730.2 |
| 3 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 644.6 | 637.9 | 657.6 | 694.1 | 717.9 | 730.6 |
| 4 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 645.0 | 649.9 | 676.1 | 703.0 | 720.2 | 730.9 |
| 5 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 644.8 | 646.2 | 667.2 | 692.7 | 715.0 | 730.2 |
| 6 | 732.2 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 644.8 | 641.1 | 662.5 | 698.7 | 721.0 | 731.0 |
| 7 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 644.5 | 646.9 | 676.4 | 708.3 | 722.8 | 731.0 |
| 8 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 644.8 | 644.7 | 669.8 | 702.5 | 721.0 | 731.0 |
| 9 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 645.0 | 644.9 | 666.7 | 696.8 | 718.4 | 728.3 |
| 10 | 727.8 | 721.4 | 707.7 | 689.3 | 672.0 | 657.0 | 644.7 | 644.5 | 662.9 | 690.4 | 715.9 | 731.0 |
| 11 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 644.9 | 647.8 | 664.1 | 686.2 | 712.3 | 729.8 |
| 12 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 645.0 | 648.5 | 674.6 | 703.9 | 721.2 | 731.0 |
| 13 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 645.0 | 646.3 | 679.0 | 712.3 | 723.0 | 731.0 |
| 14 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 644.6 | 649.3 | 675.1 | 704.4 | 722.6 | 731.0 |
| 15 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 644.4 | 636.7 | 669.9 | 711.7 | 722.5 | 729.6 |
| 16 | 731.2 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 645.0 | 645.9 | 667.8 | 699.5 | 721.1 | 731.0 |
| 17 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 645.0 | 642.0 | 664.8 | 695.7 | 715.7 | 729.7 |
| 18 | 731.6 | 723.1 | 707.8 | 689.3 | 672.0 | 657.0 | 644.6 | 646.8 | 673.8 | 704.8 | 723.8 | 733.1 |
| 19 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 645.0 | 647.7 | 675.8 | 706.5 | 721.8 | 729.2 |
| 20 | 729.2 | 721.9 | 707.8 | 689.3 | 672.0 | 657.0 | 645.0 | 644.3 | 657.6 | 676.5 | 689.6 | 692.7 |
| 21 | 688.7 | 678.3 | 663.5 | 647.3 | 632.1 | 617.3 | 603.6 | 601.9 | 617.1 | 642.0 | 667.6 | 681.8 |
| 22 | 681.9 | 674.2 | 661.7 | 646.8 | 632.3 | 617.8 | 604.0 | 594.0 | 616.4 | 658.2 | 694.4 | 721.4 |
| 23 | 727.1 | 721.6 | 707.8 | 689.3 | 672.0 | 657.0 | 645.0 | 650.8 | 682.9 | 711.0 | 722.4 | 731.0 |
| 24 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 644.7 | 641.7 | 662.6 | 692.0 | 713.9 | 728.3 |
| 25 | 729.1 | 721.8 | 707.8 | 689.3 | 672.0 | 657.0 | 644.7 | 647.2 | 664.9 | 685.6 | 704.0 | 716.2 |
| 26 | 718.3 | 711.0 | 700.0 | 686.9 | 672.0 | 657.0 | 645.0 | 646.6 | 674.5 | 706.6 | 722.1 | 731.0 |
| 27 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 644.9 | 643.7 | 662.5 | 688.8 | 711.9 | 724.7 |
| 28 | 723.3 | 716.4 | 705.3 | 689.3 | 672.0 | 657.0 | 645.0 | 643.6 | 672.7 | 707.5 | 721.8 | 731.0 |
| 29 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 645.0 | 646.2 | 664.5 | 689.3 | 709.3 | 719.3 |
| 30 | 719.7 | 713.5 | 703.1 | 688.5 | 672.0 | 657.0 | 645.0 | 647.3 | 672.3 | 703.4 | 721.9 | 731.0 |
| 31 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 645.0 | 645.1 | 668.4 | 701.7 | 721.9 | 731.0 |
| 32 | 732.5 | 723.5 | 707.8 | 689.3 | 672.0 | 657.0 | 644.9 | 645.2 | 662.8 | 695.1 | 725.1 | 734.9 |

TOTAL ENERGY GWH

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 234.5 | 325.6 | 461.3 | 384.2 | 311.4 | 266.7 | 199.4 | 179.7 | 164.1 | 177.1 | 160.9 | 157.7 |
| 2 | 234.1 | 270.3 | 321.7 | 307.3 | 312.5 | 268.4 | 204.4 | 180.6 | 169.2 | 177.4 | 197.9 | 438.2 |
| 3 | 292.5 | 382.7 | 473.7 | 400.8 | 318.4 | 272.4 | 199.4 | 180.2 | 169.2 | 180.0 | 274.2 | 240.0 |
| 4 | 357.6 | 405.0 | 465.5 | 384.3 | 310.3 | 270.2 | 207.1 | 181.5 | 170.7 | 177.3 | 326.0 | 252.5 |
| 5 | 278.1 | 361.0 | 461.9 | 394.0 | 317.1 | 269.0 | 199.4 | 180.6 | 169.4 | 170.6 | 262.1 | 157.7 |
| 6 | 251.0 | 378.2 | 475.5 | 404.9 | 325.8 | 277.6 | 199.4 | 179.2 | 169.6 | 186.8 | 618.2 | 331.2 |
| 7 | 273.6 | 360.5 | 456.5 | 384.2 | 315.4 | 271.0 | 199.4 | 180.9 | 171.6 | 498.0 | 532.8 | 321.5 |
| 8 | 277.6 | 386.7 | 481.3 | 404.4 | 330.7 | 279.3 | 199.4 | 180.2 | 170.5 | 188.8 | 383.2 | 384.7 |
| 9 | 348.0 | 411.8 | 501.9 | 408.3 | 325.5 | 280.6 | 203.2 | 180.2 | 169.6 | 178.2 | 326.6 | 157.7 |
| 10 | 234.2 | 267.9 | 459.0 | 393.8 | 322.3 | 271.0 | 199.4 | 180.1 | 168.8 | 177.6 | 393.3 | 293.5 |
| 11 | 314.5 | 384.3 | 480.0 | 405.4 | 329.0 | 280.2 | 199.4 | 181.0 | 164.1 | 176.2 | 167.0 | 375.5 |
| 12 | 348.5 | 388.7 | 491.2 | 419.1 | 334.8 | 293.0 | 226.9 | 181.2 | 170.7 | 221.6 | 473.9 | 204.3 |
| 13 | 294.2 | 386.2 | 483.3 | 412.9 | 333.2 | 287.7 | 209.7 | 180.5 | 282.5 | 572.7 | 571.3 | 304.2 |
| 14 | 329.7 | 395.6 | 481.4 | 402.0 | 330.6 | 277.5 | 199.4 | 181.5 | 170.6 | 461.3 | 594.4 | 229.4 |
| 15 | 315.3 | 368.2 | 462.3 | 385.5 | 316.3 | 266.9 | 199.4 | 180.2 | 229.8 | 461.1 | 331.3 | 159.2 |
| 16 | 239.3 | 390.2 | 457.6 | 385.9 | 316.0 | 274.9 | 202.1 | 180.4 | 169.7 | 195.1 | 387.8 | 437.9 |
| 17 | 316.7 | 359.7 | 462.6 | 393.0 | 323.5 | 281.0 | 205.7 | 179.4 | 169.9 | 170.6 | 208.2 | 157.7 |
| 18 | 234.1 | 328.0 | 459.6 | 394.6 | 325.2 | 277.7 | 199.4 | 180.8 | 170.9 | 301.0 | 651.0 | 438.9 |
| 19 | 270.4 | 373.7 | 481.2 | 413.2 | 343.9 | 300.9 | 213.7 | 180.9 | 171.2 | 351.5 | 312.6 | 157.7 |
| 20 | 234.1 | 276.9 | 445.9 | 377.1 | 310.2 | 270.7 | 203.1 | 180.0 | 164.1 | 170.6 | 160.9 | 158.4 |
| 21 | 233.5 | 270.2 | 321.7 | 283.0 | 228.4 | 234.8 | 199.4 | 179.7 | 164.1 | 177.4 | 160.9 | 157.7 |
| 22 | 234.0 | 270.2 | 321.7 | 283.1 | 228.4 | 234.8 | 199.4 | 180.1 | 170.3 | 182.1 | 169.7 | 157.7 |
| 23 | 234.6 | 309.0 | 490.7 | 415.2 | 341.4 | 294.2 | 204.5 | 181.8 | 172.2 | 432.0 | 453.3 | 235.4 |
| 24 | 281.2 | 375.4 | 464.2 | 392.0 | 324.1 | 277.2 | 199.4 | 179.3 | 169.4 | 170.6 | 167.7 | 157.7 |
| 25 | 234.1 | 271.4 | 452.5 | 383.1 | 313.1 | 268.7 | 199.4 | 180.9 | 164.1 | 170.6 | 160.9 | 157.7 |
| 26 | 234.0 | 270.3 | 321.7 | 296.9 | 328.0 | 283.0 | 201.3 | 180.6 | 171.2 | 386.3 | 351.1 | 316.9 |
| 27 | 334.3 | 361.0 | 450.4 | 382.1 | 315.0 | 270.9 | 199.4 | 179.9 | 168.9 | 170.6 | 166.3 | 157.7 |
| 28 | 234.0 | 267.7 | 370.5 | 403.5 | 331.2 | 285.4 | 201.1 | 179.8 | 171.5 | 321.9 | 398.0 | 222.3 |
| 29 | 338.7 | 400.8 | 491.5 | 411.8 | 333.5 | 290.4 | 208.0 | 180.5 | 168.8 | 176.9 | 160.9 | 157.7 |
| 30 | 234.2 | 267.9 | 321.7 | 362.3 | 326.0 | 285.0 | 205.0 | 180.8 | 170.4 | 337.4 | 397.3 | 164.0 |
| 31 | 352.4 | 434.2 | 493.4 | 407.9 | 332.3 | 287.7 | 207.9 | 180.2 | 170.0 | 339.0 | 448.1 | 237.1 |
| 32 | 364.3 | 425.5 | 469.4 | 396.2 | 323.0 | 277.7 | 199.4 | 180.3 | 168.6 | 196.9 | 652.2 | 464.7 |

STORAGE (MONTH END) AC-FT

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9386568.0 | 8995200.0 | 8318100.0 | 7727999.5 | 7235200.0 | 6804000.0 | 6490048.5 | 6691305.0 | 7395950.5 | 8255923.0 | 9014804.0 | 9205086.0 |
| 2 | 9031274.0 | 8663291.0 | 8191954.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6518999.5 | 6901055.5 | 7726559.0 | 8626213.0 | 9302880.0 | 9652000.0 |
| 3 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6497591.5 | 6427880.0 | 7686891.5 | 8722697.0 | 9331082.0 | 9652000.0 |
| 4 | 9471000.0 | 8995200.0 | 8318099.0 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 7105308.0 | 8110289.0 | 8867484.0 | 9354074.0 | 9652000.0 |
| 5 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6506042.5 | 6890809.5 | 7773940.0 | 8515594.0 | 9326506.0 | 9631508.0 |
| 6 | 9471000.0 | 8995200.0 | 8318099.0 | 7727999.5 | 7235200.0 | 6804000.0 | 6505933.0 | 6590496.0 | 7797223.5 | 8924869.0 | 9360799.0 | 9652000.0 |
| 7 | 9471000.0 | 8995200.0 | 8318100.0 | 7727999.5 | 7235200.0 | 6804000.0 | 6492376.0 | 6952777.0 | 8300238.5 | 9051331.0 | 9360800.0 | 9652000.0 |
| 8 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6506195.0 | 6799275.0 | 8031358.5 | 8926049.0 | 9360800.0 | 9652000.0 |
| 9 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 6799032.5 | 7839647.5 | 8737336.0 | 9352148.0 | 9464345.0 |
| 10 | 9316394.0 | 8994756.0 | 8318100.0 | 7727999.5 | 7235199.5 | 6804000.0 | 6502576.0 | 6793475.0 | 7606694.0 | 8547313.0 | 9360800.0 | 9652000.0 |
| 11 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6513799.0 | 6979884.5 | 7494361.5 | 8376001.5 | 9272262.0 | 9652000.0 |
| 12 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 7020933.5 | 8104551.5 | 8939785.0 | 9360800.0 | 9652000.0 |
| 13 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 6881984.0 | 8576651.0 | 9067999.0 | 9360800.0 | 9652000.0 |
| 14 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6495928.5 | 7097815.5 | 8053922.0 | 9037359.0 | 9360800.0 | 9652000.0 |
| 15 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6485728.5 | 6376960.5 | 8566860.0 | 9034771.0 | 9355946.0 | 9559350.0 |
| 16 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 6859824.5 | 7847534.0 | 8928748.0 | 9360800.0 | 9652000.0 |
| 17 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 6626358.5 | 7897320.0 | 8590135.0 | 9305109.0 | 9612858.0 |
| 18 | 9442938.0 | 8995200.0 | 8318100.0 | 7727999.5 | 7235200.0 | 6804000.0 | 6500382.5 | 6936873.5 | 8135961.5 | 8971892.0 | 9514254.0 | 9652000.0 |
| 19 | 9471000.0 | 8995200.0 | 8318099.0 | 7727999.0 | 7235200.0 | 6804000.0 | 6519000.0 | 6972020.0 | 8231345.0 | 8992293.0 | 9348570.0 | 9532518.0 |
| 20 | 9353369.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 6760195.0 | 7315832.5 | 7921667.0 | 8122674.0 | 8117306.0 |
| 21 | 7873272.0 | 7477900.0 | 6964685.0 | 6501512.5 | 6123440.0 | 5724800.5 | 5405315.0 | 5637957.0 | 6201135.5 | 6994285.5 | 7698497.5 | 7868844.0 |
| 22 | 7702527.0 | 7393296.5 | 6937510.0 | 6501776.0 | 6134408.5 | 5741750.0 | 5412136.0 | 5236590.5 | 6584733.0 | 7541290.0 | 8915929.0 | 9400203.0 |
| 23 | 9330420.0 | 8995200.0 | 8318100.0 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 7161740.5 | 8526472.0 | 9024637.0 | 9360800.0 | 9652000.0 |
| 24 | 9471000.0 | 8995200.0 | 8318100.0 | 7727999.5 | 7235200.0 | 6804000.0 | 6504306.5 | 6623157.0 | 7768525.5 | 8471751.0 | 9288695.0 | 9528780.0 |
| 25 | 9344846.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6501735.0 | 6958348.0 | 7566463.5 | 8244210.0 | 8797540.0 | 9135129.0 |
| 26 | 8947648.0 | 8600578.0 | 8150448.0 | 7727999.5 | 7235199.5 | 6804000.0 | 6519000.0 | 6902406.5 | 8220629.0 | 9006292.0 | 9360800.0 | 9652000.0 |
| 27 | 9471000.0 | 8995200.0 | 8318100.0 | 7727999.5 | 7235200.0 | 6804000.0 | 6513184.0 | 6731718.5 | 7644934.0 | 8386917.0 | 9228137.0 | 9322975.0 |
| 28 | 9131184.0 | 8818810.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 6715315.5 | 8313368.0 | 8979788.0 | 9360800.0 | 9652000.0 |
| 29 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 6875833.5 | 7626341.5 | 8440595.0 | 8989152.0 | 9167815.0 |
| 30 | 9022106.0 | 8708680.0 | 8263030.0 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 6944440.0 | 8034779.5 | 8986791.0 | 9360800.0 | 9652000.0 |
| 31 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235200.0 | 6804000.0 | 6519000.0 | 6810019.0 | 7929234.0 | 8987391.0 | 9360800.0 | 9652000.0 |
| 32 | 9471000.0 | 8995200.0 | 8318099.5 | 7727999.5 | 7235199.5 | 6804000.0 | 6515816.0 | 6822843.5 | 7575697.0 | 8929461.0 | 9652000.0 | 9652000.0 |

$

```
  TY WA.DAT
SUSITNA HEP
WATANA 2185
CASE A
  384
   8    0       1000000      5.232      9.652     1455.         .85        .01       1.00
     1900.      2.55     1950.      3.33     2000.      4.25     2050.      5.34
     2100.      6.65     2150.      8.19     2200.     10.02     2250.     12.21
     2185.
   900000.     2000.       00.0   32
   .73   .84   1.0   .88   .71   .73   .62   .56   .51   .53   .50   .49
   0.
  1200.0  1200.0  1200.0  1200.0  1200.0  1200.0  1200.0  1200.0  1200.0  1200.0  1200.0  1200.0
  2185.0  2172.0  2153.5  2135.0  2119.0  2105.0  2095.0  2145.0  2160.0  2170.0  2180.0  2190.0
   1.0   1.0   1.0   1.0   1.0   1.0   1.0   0.9   0.9   0.8   0.8   0.7
    4719.9  2083.6  1168.9   815.1   641.7   569.1   680.1  8655.9 16432.1 19193.4 16913.6  7320.4
    3299.1  1107.3   906.2   808.0   673.0   619.8  1302.2 11649.8 18517.9 19786.6 16478.0 17205.5
    4592.9  2170.1  1501.0  1274.5   841.0   735.0   803.9  4216.5 25773.4 22110.9 17356.3 11571.0
    6285.7  2756.8  1281.2   818.9   611.7   670.7  1382.0 15037.2 21469.8 17355.3 16681.6 11513.5
    4218.9  1599.6  1183.8  1087.8   803.1   638.2   942.6 11696.8 19476.7 16983.6 20420.6  9165.5
    3859.2  2051.1  1549.5  1388.3  1050.5   886.1   940.8  6718.1 24881.4 23787.9 23537.0 13447.8
    4102.3  1588.1  1038.6   816.9   754.8   694.4   718.3 12953.3 27171.8 25831.3 19153.4 13194.4
    4208.0  2276.6  1707.0  1373.0  1189.0   935.0   945.1 10176.2 25275.0 19948.9 17317.7 14841.1
    6034.9  2935.9  2258.5  1480.6  1041.7   973.5  1265.4  9957.8 22097.8 19752.7 18843.4  5978.7
    3668.0  1729.5  1115.1  1081.0   949.0   694.0   885.7 10140.6 18329.6 20493.1 23940.4 12466.9
    5165.5  2213.5  1672.3  1400.4  1138.9   961.1  1069.9 13044.2 13233.4 19506.1 19323.1 16085.6
    6049.3  2327.8  1973.2  1779.9  1304.8  1331.0  1965.0 13637.9 22784.1 19839.8 19480.2 10146.2
    4637.6  2263.4  1760.4  1608.9  1257.4  1176.8  1457.4 11333.5 36017.1 23443.7 19887.1 12746.2
    5560.1  2508.9  1708.9  1308.9  1184.7   883.6   776.6 15299.2 20663.4 28767.4 21011.4 10800.0
    5187.1  1789.1  1194.7   852.0   781.6   575.2   609.2  3578.8 42841.9 20082.8 14048.2  7524.2
    4759.4  2368.2  1070.3   863.0   772.7   807.3  1232.4 10966.0 21213.0 23235.9 17394.1 16225.6
    5221.2  1565.3  1203.6  1060.4   984.7   984.7  1338.4  7094.1 25939.6 16153.5 17390.9  9214.1
    3269.8  1202.2  1121.6  1102.2  1031.3   889.5   849.7 12555.5 24711.9 21987.3 26104.5 13672.9
    4019.0  1934.3  1704.2  1617.6  1560.4  1560.4  1576.7 12826.7 25704.0 22082.8 14147.5  7163.6
    3135.0  1354.9   753.9   619.2   607.5   686.0  1261.6  9313.7 13962.1 14843.5  7771.9  4260.0
    2403.1  1020.9   709.3   636.2   602.1   624.1   986.4  9536.4 14399.0 18410.1 16263.8  7224.1
    3768.0  2496.4  1687.4  1097.1   777.4   717.1   813.7  2857.2 27612.8 21126.4 27446.6 12188.9
    4979.1  2587.0  1957.4  1670.9  1491.4  1366.0  1305.4 15973.1 27429.3 19820.3 17509.5 10955.7
    4301.2  1977.9  1246.5  1031.5  1000.2   873.9   914.1  7287.0 23859.3 16351.1 18016.7  8099.7
    3056.5  1354.7   931.6   786.4   689.9   627.3   871.9 12889.0 14780.6 15971.9 13523.7  9786.2
    3088.8  1474.4  1276.7  1215.8  1110.3  1041.4  1211.2 11672.2 26689.2 23430.4 15126.6 13075.3
    5679.1  1601.1   876.2   757.8   743.2   690.7  1059.8  8938.8 19994.0 17015.3 18393.5  5711.5
    2973.5  1926.7  1687.5  1348.7  1202.9  1110.8  1203.4  8569.4 31352.8 19707.3 16807.3 10613.1
    5793.9  2645.3  1979.7  1577.9  1267.7  1256.7  1408.4 11231.5 17277.2 18385.2 13412.1  7132.6
    3773.9  1944.9  1312.6  1136.8  1055.4  1101.2  1317.9 12369.3 22904.8 24911.7 16670.7  9096.7
    6150.0  3525.0  2032.0  1470.0  1233.0  1177.0  1404.0 10140.0 23400.0 26740.0 18000.0 11000.0
    6458.0  3297.0  1385.0  1147.0   971.0   889.0  1103.0 10406.0 17323.0 27840.0 31435.0 12026.0
$
```

FORCAST ENERGY 2000

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 416.0 | 490.0 | 535.0 | 485.0 | 462.0 | 412.0 | 371.0 | 331.0 | 321.0 | 307.0 | 329.0 | 364.0 | 4823.0 |

TOTAL ENERGY

| YR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | TOTAL | WAT | DC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 462.2 | 608.5 | 861.2 | 725.7 | 594.8 | 515.5 | 446.4 | 466.8 | 430.4 | 383.0 | 298.9 | 292.9 | 6086.3 | 3022.6 | 3063.7 |
| 2 | 435.1 | 500.7 | 595.4 | 549.6 | 508.5 | 470.0 | 398.0 | 459.4 | 420.9 | 369.9 | 344.3 | 778.1 | 5829.9 | 3082.0 | 2747.9 |
| 3 | 517.2 | 714.4 | 886.8 | 759.3 | 608.3 | 526.2 | 444.9 | 436.6 | 504.7 | 402.2 | 473.9 | 414.1 | 6688.6 | 3383.5 | 3305.1 |
| 4 | 654.8 | 758.8 | 872.0 | 727.4 | 594.0 | 522.0 | 461.9 | 495.5 | 489.4 | 368.9 | 564.6 | 462.5 | 6971.8 | 3508.0 | 3463.8 |
| 5 | 499.2 | 673.1 | 863.2 | 744.2 | 606.6 | 519.7 | 448.4 | 521.1 | 487.5 | 368.8 | 487.2 | 304.2 | 6523.2 | 3220.9 | 3302.3 |
| 6 | 453.8 | 689.5 | 892.1 | 768.6 | 626.3 | 537.6 | 447.7 | 461.3 | 473.8 | 404.0 | 1028.9 | 575.3 | 7358.9 | 3797.4 | 3561.5 |
| 7 | 480.2 | 668.4 | 852.0 | 724.8 | 603.8 | 525.6 | 447.2 | 504.3 | 497.0 | 905.5 | 960.3 | 725.3 | 7894.4 | 3965.4 | 3929.0 |
| 8 | 502.7 | 725.9 | 901.7 | 766.0 | 634.8 | 541.9 | 447.6 | 481.3 | 472.1 | 399.1 | 652.6 | 724.7 | 7250.4 | 3666.8 | 3583.6 |
| 9 | 642.6 | 777.0 | 939.7 | 776.8 | 624.0 | 542.6 | 455.1 | 468.9 | 446.8 | 377.0 | 561.8 | 293.0 | 6905.3 | 3491.6 | 3413.7 |
| 10 | 436.0 | 499.7 | 774.3 | 746.9 | 619.8 | 526.4 | 449.9 | 525.9 | 472.4 | 402.9 | 749.4 | 550.2 | 6753.8 | 3360.9 | 3392.9 |
| 11 | 565.7 | 718.7 | 901.2 | 770.3 | 631.6 | 543.0 | 447.1 | 465.6 | 412.6 | 382.0 | 310.9 | 672.4 | 6821.1 | 3456.6 | 3364.5 |
| 12 | 634.8 | 727.5 | 925.9 | 800.7 | 645.4 | 572.6 | 509.2 | 485.2 | 505.2 | 482.7 | 802.7 | 368.2 | 7460.1 | 3753.9 | 3706.2 |
| 13 | 522.8 | 718.1 | 903.4 | 781.3 | 638.1 | 557.2 | 467.1 | 436.1 | 691.1 | 987.4 | 1002.5 | 653.4 | 8358.5 | 4318.4 | 4040.1 |
| 14 | 588.7 | 732.3 | 898.9 | 760.9 | 634.7 | 535.5 | 443.6 | 485.8 | 479.7 | 866.7 | 1018.5 | 468.4 | 7913.7 | 4053.4 | 3860.3 |
| 15 | 564.5 | 685.5 | 863.6 | 727.9 | 604.9 | 515.5 | 445.3 | 427.6 | 634.9 | 860.4 | 558.0 | 294.5 | 7182.6 | 3675.5 | 3507.1 |
| 16 | 441.7 | 670.5 | 851.7 | 726.6 | 602.3 | 529.9 | 450.1 | 451.1 | 463.9 | 434.1 | 670.4 | 784.2 | 7076.5 | 3636.9 | 3439.6 |
| 17 | 581.6 | 671.4 | 866.8 | 744.9 | 621.2 | 546.2 | 463.3 | 460.4 | 512.3 | 374.3 | 380.1 | 293.0 | 6515.5 | 3228.0 | 3287.5 |
| 18 | 435.6 | 559.8 | 826.3 | 749.1 | 625.5 | 539.8 | 448.9 | 469.2 | 470.4 | 625.4 | 1068.9 | 875.9 | 7694.8 | 3961.2 | 3733.6 |
| 19 | 501.4 | 694.8 | 899.7 | 783.4 | 660.4 | 584.9 | 476.7 | 477.6 | 490.3 | 705.7 | 527.2 | 293.0 | 7095.1 | 3570.9 | 3524.2 |
| 20 | 434.6 | 508.4 | 734.7 | 710.2 | 591.8 | 522.6 | 454.5 | 445.0 | 399.6 | 332.6 | 299.2 | 294.2 | 5727.4 | 2952.0 | 2775.4 |
| 21 | 435.4 | 501.4 | 596.7 | 525.6 | 424.7 | 437.2 | 371.6 | 360.8 | 459.7 | 408.4 | 299.5 | 293.0 | 5114.0 | 2610.8 | 2503.2 |
| 22 | 436.7 | 502.0 | 597.6 | 540.1 | 452.2 | 469.5 | 460.3 | 442.4 | 492.2 | 386.8 | 321.1 | 293.0 | 5393.9 | 2631.5 | 2762.4 |
| 23 | 436.1 | 542.4 | 857.6 | 791.2 | 659.8 | 574.4 | 460.4 | 528.8 | 512.5 | 821.1 | 749.4 | 393.0 | 7326.7 | 3764.3 | 3562.4 |
| 24 | 484.1 | 689.6 | 865.5 | 739.5 | 619.9 | 535.0 | 444.8 | 428.9 | 453.8 | 341.5 | 306.9 | 292.9 | 6202.4 | 3158.2 | 3044.2 |
| 25 | 435.0 | 501.5 | 728.6 | 626.3 | 591.7 | 518.1 | 444.9 | 476.5 | 427.4 | 360.0 | 298.8 | 292.9 | 5701.7 | 2956.5 | 2745.2 |
| 26 | 435.2 | 501.3 | 596.3 | 539.7 | 524.1 | 518.4 | 453.8 | 483.7 | 486.3 | 766.8 | 590.1 | 568.2 | 6463.9 | 3341.3 | 3122.6 |
| 27 | 615.3 | 670.9 | 839.6 | 721.9 | 602.8 | 524.6 | 448.8 | 483.1 | 461.3 | 342.6 | 304.8 | 293.7 | 6309.4 | 3156.5 | 3152.9 |
| 28 | 435.1 | 498.5 | 647.7 | 646.7 | 583.3 | 556.1 | 455.2 | 491.4 | 506.1 | 630.9 | 663.7 | 380.5 | 6495.2 | 3386.9 | 3108.3 |
| 29 | 609.8 | 753.9 | 924.1 | 782.5 | 642.0 | 565.0 | 464.9 | 425.6 | 411.2 | 367.0 | 298.9 | 292.9 | 6537.8 | 3319.5 | 3218.3 |
| 30 | 435.8 | 499.5 | 596.4 | 605.2 | 542.3 | 549.5 | 455.8 | 441.2 | 412.8 | 675.0 | 688.2 | 299.3 | 6201.0 | 3252.0 | 2949.0 |
| 31 | 587.9 | 811.0 | 923.0 | 771.6 | 636.2 | 557.2 | 464.1 | 448.9 | 463.1 | 699.1 | 771.6 | 403.3 | 7537.0 | 3890.2 | 3646.8 |
| 32 | 651.0 | 794.1 | 876.0 | 748.4 | 617.6 | 536.9 | 446.7 | 450.0 | 439.8 | 450.9 | 1070.1 | 901.8 | 7983.3 | 4118.2 | 3865.1 |
| ANN | 511.0 | 642.8 | 817.5 | 715.1 | 599.2 | 531.8 | 450.8 | 465.2 | 477.5 | 521.3 | 597.6 | 463.2 | 6792.9 | 3459.1 | 3333.8 |

# APPENDIX A2

## PROBABLE MAXIMUM FLOOD

### 1 - INTRODUCTION

This report presents the results of the studies conducted to determine a probable maximum flood (PMF) at Watana and Devil Canyon damsites appropriate for use in design of project spillways and related facilities.

As part of the Acres' Plan of Study for the Susitna Hydroelectric Project dated February 1980 and revised September 1980, Subtask 3.05 (ii) was undertaken. The main objectives of this subtask were to review and determine the adequacy of the PMF estimate reported by the U.S. Army Corps of Engineers (1). The primary conclusions of the review was that further analysis of the PMF was warranted because of its sensitivity to snowpack and probable maximum precipitation (PMP) estimates. This further evaluation was authorized by the Alaska Power Authority in April, 1981 and the results are presented in this report. Subtask 3.05 (ii) closeout report is included here as Attachment 1.

This report covers the work performed by Acres in re-estimating the PMF. The study estimated new values for the Probable Maximum Precipitation and temperature sequences based on more complete data and elaborate procedures. The study has relied heavily on the work of the U.S. Army Corps of Engineers (COE) and that reported in Attachment 1 in calibrating the watershed computer model of the basin.

### 2 - REVIEW OF PREVIOUS ESTIMATES

The U.S. Army Corps of Engineers (COE) reported on their studies of the estimate of the PMF (1). The COE estimate of flood peaks are 233,000 cfs for Watana and 226,000 cfs for Devil Canyon. Watana reservoir provides some flood peak attenuation for Devil Canyon. The COE calibrated the SSARR watershed model by estimating basin snowmelt, runoff and other parameters for historical floods. Based on this calibration, any estimates of the PMP determined by the National Weather Service, the COE derived likely estimates of the PMF peak and volume.

Acres reviewed the watershed model developed by the COE and input parameters particularly the probable maximum precipitation (PMP), temperature sequences and snowpack depths. Generally, the watershed model was found to be adequate given the amount of information available on the watershed characteristics. Several apparent typographical errors in basin parameters were corrected.

The estimates of PMP and snowpack depths were reviewed and a sensitivity analysis was performed using the SSARR Model and input data supplied by the COE. The range of PMF peaks are given in Tables A2.1 and A2.2 for Watana and Devil Canyon, respectively. It was found that a change of 30 percent in precipitation results in a 47 percent change in flood peak at Watana. Snowpack amounts at the start and temperatures before and during the PMP storm also proved significant with respect to PMF peak. Due to the relatively large change in PMF peaks for moderate increases in PMP or temperature maximums, it was recommended to further study the PMF. More details and further discussion of the sensitivity analysis and review of the COE study are given in Attachment 1.

Attachment 1 provides the necessary intermation and data on the watershed characteristics and the SSARR Model of the basin on which this study is based.

## 3 - CLIMATE AND HYDROLOGY

The following section gives a brief description of the climate and hydrology of the Upper Susitna Basin. It is important to point out that variations within the basin of both climate and hydrology may be significant. Local climatic influences of glaciers and mountain ranges are expected to be important but are currently insufficiently documented to enable a proper analysis of these influences. The continuation of data collection at the weather stations established within the Susitna Basin will improve the watershed model as time proceeds. However, it is believed that the general patterns of precipitation, snowmelt and hydrological parameters are adequate for this feasibility study and will yield acceptable results.

### 3.1 - Climate

The climate of Alaska in general is dictated mostly by its latitude. The character of the surrounding land or water, physical relief and their interaction with global circulation patterns also play an important part in determining climate. The Susitna Basin in particular lies between the moderating influence of the Pacific currents and the more severe continental influences.

The climate of the Susitna Basin upstream from Talkeetna is generally characterized by cold, dry winters and warm, moderately moist summers. The upper basin is dominated by continental climatic conditions while the lower basin falls within a zone of transition between maritime and continental climatic influences.

#### (a) Climatic Data Records

Data on precipitation, temperature and other climatic parameters have been collected by NOAA at several stations in the south central region of Alaska since 1941. Prior to the current studies, there were no stations located within the Susitna Basin upstream from Talkeetna.

The closest stations where long-term climate data is available are at Talkeetna to the south and Summit to the north. A summary of the precipitation and temperature data available in the vicinity of the basin is presented in Table A2.3.

Six automatic climate stations were established in the upper basin during 1980 (Figure A2.1). The data currently being collected at these stations includes air temperature, average wind speed, wind direction, peak wind gust, relative humidity, precipitation, and solar radiation. Snowfall amounts are being measured in a heated precipitation bucket at the Watana station. Data are recorded at thirty minute intervals at the Susitna Glacier station and at fifteen minute intervals at all other stations.

(b) Precipitation

Precipitation in the basin varies from low to moderate amounts in the lower elevations to heavy in the mountains. Mean annual precipitation of over 80 inches is estimated to occur at elevations above 3000 in the Talkeetna Mountains and the Alaskan Range whereas at Talkeetna station, at elevation 345, the average annual precipitation recorded is about 28 inches. The average precipitation reduces in a northerly direction as the continental climate starts to predominate. At Summit station, at elevation 2397, the average annual precipitation is only 18 inches.

The seasonal distribution of precipitation is similar for all the stations in and surrounding the basin. At Talkeetna, records show that 68 percent of the total precipitation occurs during the warmer months of May through October, while only 32 percent is recorded in the winter months. Average recorded snowfall at Talkeetna is about 106 inches. Generally, snowfall is restricted to the months of October through April with about 82 percent snowfall recorded in the period November to March.

The U.S. Soil Conservation Services (SCS) operates a network of snow course stations in the basin and records of snow depths and water content are available from 1964. The stations within the Upper Susitna Basin are generally located at elevations below 3000 and indicate that annual snow accumulations are around 20 to 40 inches and that peak depths occur in late March. There are no historical data for the higher elevations. The basic network was expanded during 1980 with the addition of three new snow courses on the Susitna glacier (Figure A2.1). Arrangements have been made with SCS for continuing the collection of information from the expanded network during the study period.

(c) Temperature

Typical temperatures observed from historical records at the Talkeetna and Summit stations are presented in Table A2.4. It is expected that the temperatures at the damsites will be somewhere between the values observed at these stations.

3.2 - Hydrology

(a) Water Resources

Streamflow data has been recorded by the USGS at a total of 12 gaging stations on the Susitna River and its tributaries (Figure A2.1). The length of these records varies from 30 years at Gold Creek to about five years at the Susitna station. There were no historical records of streamflow at any of the proposed damsite before this study. A gaging station was established at the Watana damsite in June 1980 and continuous river stage data is being collected.

Seasonal variation of flows is extreme and ranges from very low values in winter (October to April) to high summer values (May to September). For the Susitna River at Gold Creek, the average winter and summer flows are 2100 and 20,250 cfs, respectively, a 1 to 10 ratio. On the average, approximately 88 percent of the streamflow recorded at Gold Creek station occurs during the summer months. Figure A2.2 shows the average monthly flow distribution for the wettest average and driest year flow for streamflow recorded at Gold Creek. At higher elevations in the basin, the distribution of flows is concentrated even more in the summer months. For the Maclaren River near Paxson (El 4520) the average winter and summer flows are 144 and 2100 cfs, respectively, a 1 to 15 ratio.

The Susitna River above the confluence with the Chulitna River contributes only approximately 20 percent of the mean annual flow near Cook Inlet (measured at Susitna station).

(b) Floods

The most common causes of flood peaks in the Susitna River Basin are snowmelt or a combination of snowmelt and rainfall over a large area. Annual maximum peak discharges generally occur between May and October with the majority, approximately 60 percent, occuring in June. Some of the annual maximum flood peaks have also occurred in August or later and are the result of heavy rains over large areas augmented by significant snowmelt from higher elevations and glacial runoff.

A regional flood frequency analysis has been carried out using the recorded floods in the Susitna River and its principal tributaries, as well as the Copper, Matanuska and Tosina rivers. These analyses have been conducted for two different time periods within the year. The first period selected is the open water period, i.e., after the ice breakup and before freezeup. This period contains the largest floods which must be accommodated by the project. The second period represents that portion of time during which ice conditions occur in the river. These floods, although smaller, can be accompanied by ice jamming, and must be considered during the construction phase of the project in planning and design of cofferdams for river diversion. The results of these frequency analyses are given in greater detail in Appendix A3.

## 4 - HISTORICAL STORMS

In any evaluation of design floods using a watershed model, it is essential to review past experience of floods in the basin and to attempt to reconstruct storm patterns and other meteorological and hydrological conditions before and during the event in question. To this end, a review of past floods and an attempt to reconstruct from available meteorological records, the storms causing these floods has been made. Due to the masking effect of large spring snowmelt, only flood flows thought to be only as a result of significant rainfall with some high elevation snowmelt are investigated in this section.

The rainfall storms will be transposed in time to occur in conjunction with appropriate probable maximum snowmelt quantities to produce the PMF event. This transposition is discussed further in Section 6.

Five major flood flows (measured at Gold Creek) were selected for detailed analysis. These flood flows were the result of documented storms during the following periods:

August 4 - 10, 1971
August 2 - 17, 1967
August 19 - 25, 1959
July 28 - August 3, 1958
August 22 - 28, 1955

A sixth storm, July 25-31, 1980, was also examined. This storm was used as a base since it had the most data available, including those from the four Weather Wizards installed at Devil Canyon, Watana, Denali and Susitna Glacier.

Since the Susitna River basin is mountainous, and hence orographic factors are significant, it was necessary to develop appropriate isohyetal maps for each storm which would reflect the variation of relief in the basin. This was necessary to model the various sub-basins and their precipitation patterns, volumes, and intensities adequately.

The paucity of data and sparse distribution of precipitation gages within the Susitna Basin and vicinity necessitated the use of the isopercental techniques to obtain valid isohyetal maps. This method requires a base chart of either mean annual precipitation, or preferably, mean precipitation for the season of the storm. The July 1980 storm provided such a base chart since it was from the same season as the other storms, and had additional precipitation stations within the basin. The isohyetal map for the July 1980 storm was also based on the precipitation chart for the State of Alaska during this storm event.

The isopercental technique involves taking the ratio of the total storm precipitation (of a given storm) to the July 1980 storm precipitation and plotting this ratio at each station. Isopercental lines are drawn based on the ratios at the stations. The ratios on these isopercental lines are then multiplied by the original base chart precipitation values to yield the storm isohyetal chart (Figures A2.3 to A2.8). The storm isohyetal gradients and locations of centers tend to resemble the features of the base chart, which in turn reflects the orographic influences of the terrain.

The accuracy of the isopercental technique relies on the accuracy of the base chart (that is, July 1980 storm event) and the similarity between the individual storms and the base storm. In general, most storms of significant precipitation develop from weak depressions and are fed by a flow of relatively moist air from the Pacific Ocean. This moisture is carried into the basin and precipitated primarily due to orographic lifting. This results in a isohyetal pattern of high precipitation on windward sides of significant relief and lower precipitation amounts of the lee side. This general pattern is reflected in the base storm. The other storms, based on a cursory review of synoptic information available, developed from the same general storm pattern are believed to be represented by the basic isohyetal pattern of the 1980 storm.

## 5 - HISTORICAL FLOOD SIMULATION

The simulation of past floods recorded in the watershed under study is the accepted technique for calibration and verification of computer mathematical models. Generally, basin parameters are determined by surveys of the basin and by comparison with other basin with similar topographical and vegetal characteristics. Calibration proceeds by adjusting critical basin parameters, such as rainfall runoff and snowmelt run off relationships until acceptable modelling of streamflow is obtained. A verification of the model is made by a final model run using a storm not used in calibration and without changing basin parameters.

This process of calibration and verification was performed for the SSARR model of the Susitna Basin above Gold Creek. Basin parameters derived by the COE (1,2) and updates by Acres (Attachment 1) were used as the base from which the model was calibrated. In most cases, only minor adjustments to parameters were made except in the cases of typographical errors in data files which were corrected (Attachment 1).

The SSARR model is believed to be an acceptable model of the Susitna Basin's rainfall runoff relationships, routing characteristics and other physical and hydrological responses. The details of the SSARR model are given in the COE publication "Program Description and User Manual for SSARR Model," and where an elaborate discussion of the merits of the model can be found. Consequently, this discussion is limited to model results and characteristics specific to the Susitna Basin. Guidelines established in the SSARR manual have been followed both by the COE in their earlier studies and by Acres.

The most significant input variables to the SSARR model are storm precipitation, temperature sequence and antecedent conditions. By far, the most significant is storm precipitation and antecedent snowpack amounts. The assessment of these parameters and the results of the historical flood simulation or reconstitution are presented below.

## 5.1 - Historical Storm Precipitation

The significant storms used in the reconstitution of large floods on the Susitna Basin were derived from precipitation records at stations located either within or close to the basin. Isohyetal charts of the area were determined using storm precipitation amounts from the recording stations of that storm (as described in Section 4). The isohyetal charts for the following storms are given in Figures A2.3 to A2.8.

August 22 - 28, 1955
July 28 - August 3, 1958
August 19 - 25, 1959
August 9 - 17, 1967
August 4 - 10, 1971
July 25 - 31, 1980

The Susitna Basin has been divided into eight sub-basins to reflect variations in the principal hydrological and topographic characteristics.

The precipitation in each storm for each sub-basin uniformly distributed was determined by the Thieson Polygon method. The method considered orographic and other relevant effects. The stations affecting a given sub-basin were weighted with respect to sub-basin area and multiplied by the daily storm precipitation for that station. This yielded a daily storm distribution for each sub-basin and for each storm.

Temporal distribution of the precipitation within each sub-basin was derived from observed rainfall intensities recorded during the storm at the stations. This distribution was adjusted to reflect the general storm track and possible modifications to this track because of orographic effects.

### 5.2 - Flood Reconstitution

The results of calibration and verification studies are provided to indicate, in as objective a fashion as possible, the level of accuracy that can be expected from the use of the derived model. Consequently, the level of accuracy is a direct function of the degree of detail that is available on the physical parameters and input variables. Unfortunately, due to the remoteness of most of the Upper Susitna Basin information is generally sparse. However, from transposition of data collected at experimental watersheds with similar features and the use of data available on the basin, a reasonable model is believed to have been constructed.

The floods of August 1967 and June 1972 were used to calibrate the SSARR model. The August 1967 flood was chosen because it represented a major rainfall event similar in nature to the PMP. The June 1972 flood was chosen since it consisted of significant snowmelt. The hydrographs showing observed and calculated flows on the Susitna River near Cantwell, at Gold Creek and the Maclaren River near Paxson are given on Figures A2.9 to A2.11 and Figures A2.12 to A2.14 for the floods of August 1967 and June 1972, respectively. Verification of the model was with the 1971 flood season which had both a significant spring snowmelt flood and a late summer rainfall flood. The 1971 results are shown in Figures A2.15 to A2.17.

Calibration of the model was hindered by the paucity of information on the physical characteristics of the basin. This was particularly true with respect to the relationship between soil moisture index and runoff percent. This relationship has probably the most significant effect on the rainfall snowmelt-runoff regime. Attempts were made during the calibration to accurately assess the impact of changes in the soil moisture index-runoff relationship at peak outflows. The relationships given by Figure A2.18 are believed to be the best that can be achieved under the constraints of time and information available. These relationships represent the average conditions expected in each of the model subbasins (Figure A2.19). Minor errors in flow estimates are therefore expected due to the variation of runoff characteristics (soil types, vegetation, etc.).

To a lesser extent, the other basin modelling studies of Baseflow Infiltration Index (Figure A2.20), surface component input rate (Figure A2.21), evapotranspiration index (Figure A2.22), snowmelt rate (Figure A2.23), generated runoff (Figure A2.24) and evapotranspiration rate reduction (Figure A2.25), played a part in deviations in the observed versus calculated streamflow.

## 6 - PROBABLE MAXIMUM FLOOD SIMULATION

### 6.1 - Probable Maximum Precipitation

The Probable Maximum Precipitation (PMP) must be developed before any flood simulations are undertaken. The PMP was derived from the six storms discussed in Section 5 by maximizing each storm with respect to available moisture. The maximization factor for each storm was applied to that storm's total precipitation to give the maximum precipitation from that storm given moisture content and recorded precipitation. The storm yielding the largest total precipitation for its period was determined to be the Probable Maximum Precipitation.

(a) Precipitation Maximization

The maximization factor for a particular storm is defined as the ratio between the maximum precipitable water which could have existed in the air which flowed into the storm, and the precipitable water which actually did exist in the air flowing into the storm.

The maximum precipitable water which could have existed in the area was derived from dew point temperatures recorded at Anchorage. Maximum recorded 12-hour persisting dew point temperatures for the months of May through September were abstracted from the 27 year record at Anchorage and a frequency curve for each month determined and fitted to the data. The fifty-year return period maximum 12-hour persisting dew point temperature was determined from the frequency curves for each month and a plot of month versus 50-year dew point temperature was developed (Figure A2.26). A similar exercise was undertaken for Talkeetna to correlate data and check lapse rates. As shown on Figure A2.26, the correlation between the two stations is very good. From Figure A2.26, the appropriate dew point temperature for each storm period was determined and the maximum precipitable water determined.

The actual storm dew point temperature for each storm was derived by examining the temperature prior to the storm occurrence. The highest 12-hour dew point temperature in the air mass flowing into the storm was identified, and the actual precipitable water flowing into the storm system was based on this temperature. The ratio between the actual precipitable water and the maximum precipitable water yields the maximization factor for the storm.

The results of the precipitation maximization are shown in Table A2.5. As shown, the storm occurring on August 8-17, 1967 has a maximization factor of 2.0, yielding the largest total precipitation (12.5 inches). This storm comprises the summer PMP and was also assumed to occur under spring conditions but with a lower maximization factor due to lower dew point temperatures. The storm was centered on June 15 and similar maximization procedures were followed. The maximization factor for the August 1967 storm occurring in June was 1.4, yielding a total precipitation of 8.9 inches. This concurs with the National Weather Service Memorandum to the COE (1,2) which showed similar transposition of the summer storm and a spring to summer total precipitation ratio of 0.7.

(b) Temporal Precipitation Pattern

The temporal pattern of the PMP was maximized to yield the maximum precipitation pattern. The general pattern derived indicated that the maximum precipitation effect is observed when the maximum 24-hour precipitation occurred later in the storm period. This would sufficiently prime the basin, ultimately yielding maximum runoff. The derived pattern had the largest 24-hour precipitation occurring on the eighth day of the storm.

The second largest 24-hour precipitation occurs on the seventh, and the third largest precipitation occurs on the ninth day. The pattern is continued as shown on Table A2.6.

The daily precipitation was further divided into 6-hour periods. After examining data collected at several stations, no conclusive 6-hour pattern was found. Therefore, the 6-hour distribution recommended by the National Weather Service (1) was used. The NWS recommended the 24-hour precipitation be distributed into 50 percent, 20 percent, 15 percent and 15 percent values for each respective 6-hour period. Within the storm period, the 6-hour precipitation was ranked similar to the 24-hour precipitation ranking. The 6-hour precipitation was distributed in ascending order for each day up to the ninth day, while the ninth and tenth day's 6-hourly precipitation was distributed in descending order.

### 6.2 - Antecedent Conditions

It is important to ensure that the antecedent conditions before occurrence of the PMP are suitable to yielding the PMF. The condition of soil moisture, snowpack, and the temperature sequence and other basin parameters help determine the ultimate PMF value.

Snowmelt is a major part of the PMF peak and volume. Adequate snow must therefore be available to ensure snowmelt throughout the occurrence of the PMP. This was ensured by assuming that the snowpack for glacial sub-basins was unlimited and the snowpack for the other sub-basins was large enough to ensure a residual snowpack during the storm period. These snowpack values were based on maximum recorded data at stations in and around the Susitna Basin. Table A2.7 lists the initial snowpack values for each sub-basin of the model in equivalent inches of water.

The amount of soil moisture initially present will control the amount of water available for runoff and subsequent rate of runoff, and the distribution of runoff to baseflow, subsurface and surface components of runoff. Relatively moist soil conditions were assumed for each sub-basin. These initial conditions were based on past soil conditions and maximizing where indicated by the calibration and verification studies.

The temperature sequence prior to and during the PMP and the snowpack quantities are two of the major components in the estimation of the PMF event. The temperature rise just prior to the PMP storm should be great enough to yield significant snowmelt; during the PMP the temperatures should be sufficient to maintain significant snowmelt but be representative of temperatures during an event of the nature of the PMP. The temperature sequence for the PMF simulation is shown on Figure A2.27. Temperatures through May are at 32°F to ensure the snowpack is ripening but yielding little or no snowmelt runoff; following that, a significant temperature rise occurs. This temperature gradient is based on maximum one to seven day temperature rises observed for records at Anchorage and Talkeetna.

During the PMP storm, temperatures are depressed from the previous peak reached to reflect the meteorological conditions at the time. After the most significant precipitation has fallen, temperatures are again increased to ensure continuation of significant snowmelt and to maintain runoff at levels representative of a probable maximum event.

## 6.3 - Probable Maximum Flood Estimates

The calibrated SSARR model of the upper Susitna Basin has been utilized to evaluate the peak discharge and volume of a PMF. The value of daily precipitation during the PMP derived from maximization of historical storms has been transposed in time to coincide with maximum snowmelt. This simultaneous occurrence of the most critical elements which contribute to the flood follows the generally accepted rationale behind PMF evaluation.

Generally, basin parameters derived during SSARR model calibration and verification studies have been unchanged during the PMF estimation. Sufficient snowpack quantities have been assumed to ensure that adequate snowmelt is occurring during the PMP storm to ensure that the general philosophy of simultaneous occurrence of severe precipitation and snowmelt is maintained. Temperature sequences before and during the PMP storm are based on the studies conducted in reevaluation of the COE storm (Attachment 1).

The model, given the above conditions, estimates the PMF peak at Watana to be 325,000 cfs. With routing through the storage at Watana and the assumed discharge facility operation, the peak outflow from Watana is 310,000 cfs. Consequently, the peak inflow to Devil Canyon reservoir is 365,000 cfs, and the maximum outflow is 365,000 cfs.

## REFERENCES

1. Corps of Engineers, Interim Feasibility Report, Southcentral Railbelt Area, Alaska, Appendix 1, Part 1, 1975.

## LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

TABLE A2.1: SUMMARY OF SENSITIVITY RUNS - WATANA INFLOW AND OUTFLOW

| | Watana | | | |
|---|---|---|---|---|
| Run Description | Maximum Inflow (cfs) | % Increase From Base | Maximum Outflow (cfs) | % Increase From Base |
| COE - Base Run | 233,000 | 0.0 | 192,000 | 0.0 |
| Storm Timing Sensitivity | 239,000 | 2.6 | 194,000 | 1.0 |
| Temperature Sensitivity | 243,000 | 4.3 | 198,000 | 3.1 |
| COE Snow Pack Sensitivity | 254,000 | 9.0 | 232,000 | 20.8 |
| Increased Temperature Gradient Sensitivity | 302,000 | 29.6 | 243,000 | 26.6 |
| Precipitation/Snow Pack Sensitivity | 342,000 | 46.8 | 250,000 | 30.2 |
| Combined Case Sensitivity | 430,000 | 84.5 | 270,000 | 40.6 |

TABLE A2.2: SUMMARY OF SENSITIVITY RUNS - DEVIL CANYON

| Run Description | Devil Canyon Maximum Inflow $ft^3/s$ | % Increase From Base | Maximum Outflow $ft^3/s$ | % Increase From Base |
|---|---|---|---|---|
| COE - Base Run | 226,000 | 0.0 | 222,000 | 0.0 |
| Storm Timing Sensitivity | 229,000 | 1.3 | 224,000 | 0.9 |
| Temperature Sensitivity Run | 233,000 | 3.1 | 229,000 | 3.2 |
| COE Snow Pack Sensitivity | 272,000 | 20.4 | 262,000 | 18.0 |
| Increased Temperature Gradient Sensitivity | 282,000 | 24.8 | 275,000 | 23.9 |
| Precipitation/Snow Pack Sensitivity | 302,000 | 33.6 | 290,000 | 30.6 |
| Combined Case Sensitivity | 330,000 | 46.0 | 332,000 | 45.1 |

## TABLE A2.3: SUMMARY OF CLIMATOLOGICAL DATA

| | MEAN MONTHLY PRECIPITATION IN INCHES | | | | | | | | | | | | | PERIOD OF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATION | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC | ANNUAL | RECORD |
| Anchorage | 0.84 | 0.56 | 0.56 | 0.56 | 0.59 | 1.07 | 2.07 | 2.32 | 2.37 | 1.43 | 1.02 | 1.07 | | |
| Big Delta | 0.36 | 0.27 | 0.33 | 0.31 | 0.94 | 2.20 | 2.49 | 1.92 | 1.23 | 0.56 | 0.41 | 0.42 | 11.44 | 1941 - 70 |
| Fairbanks | 0.60 | 0.53 | 0.48 | 0.33 | 0.65 | 1.42 | 1.90 | 2.19 | 1.08 | 0.73 | 0.66 | 0.65 | 11.22 | 1941 - 70 |
| Gulkana | 0.58 | 0.47 | 0.34 | 0.22 | 0.63 | 1.34 | 1.84 | 1.58 | 1.72 | 0.88 | 0.75 | 0.76 | 11.11 | 1941 - 70 |
| Matanuska Agr. Exp. Station | 0.79 | 0.63 | 0.52 | 0.62 | 0.75 | 1.61 | 2.40 | 2.62 | 2.31 | 1.39 | 0.93 | 0.93 | 15.49 | 1951 - 75 |
| McKinley Park | 0.68 | 0.61 | 0.60 | 0.38 | 0.82 | 2.51 | 3.25 | 2.48 | 1.43 | 0.42 | 0.90 | 0.96 | 15.54 | 1951 - 75 |
| Summit WSO | 0.89 | 1.19 | 0.86 | 0.72 | 0.60 | 2.18 | 2.97 | 3.09 | 2.56 | 1.57 | 1.29 | 1.11 | 19.03 | 1951 - 75 |
| Talkeetna | 1.63 | 1.79 | 1.54 | 1.12 | 1.46 | 2.17 | 3.48 | 4.89 | 4.52 | 2.54 | 1.79 | 1.71 | 28.64 | 1941 - 70 |
| | MEAN MONTHLY TEMPERATURES | | | | | | | | | | | | | |
| Anchorage | 11.8 | 17.8 | 23.7 | 35.3 | 46.2 | 54.6 | 57.9 | 55.9 | 48.1 | 34.8 | 21.1 | 13.0 | | 1941 - 70 |
| Big Delta | - 4.9 | 4.3 | 12.3 | 29.4 | 46.3 | 57.1 | 59.4 | 54.8 | 43.6 | 25.2 | 6.9 | - 4.2 | 27.5 | 1941 - 70 |
| Fairbanks | -11.9 | - 2.5 | 9.5 | 28.9 | 47.3 | 59.0 | 60.7 | 55.4 | 44.4 | 25.2 | 2.8 | -10.4 | 25.7 | 1941 - 70 |
| Gulkana | - 7.3 | 3.9 | 14.5 | 30.2 | 43.8 | 54.2 | 56.9 | 53.2 | 43.6 | 26.8 | 6.1 | - 5.1 | 26.8 | 1941 - 70 |
| Matanuska Agr. Exp. Station | 9.9 | 17.8 | 23.6 | 36.2 | 46.8 | 54.8 | 57.8 | 55.3 | 47.6 | 33.8 | 20.3 | 12.5 | 34.7 | 1951 - 75 |
| McKinley Park | - 2.7 | 4.8 | 11.5 | 26.4 | 40.8 | 51.5 | 54.2 | 50.2 | 40.8 | 23.0 | 8.9 | - 0.10 | 25.8 | 1951 - 75 |
| Summit WSO | - 0.6 | 5.5 | 9.7 | 23.5 | 37.5 | 48.7 | 52.1 | 48.7 | 39.6 | 23.0 | 9.8 | 3.0 | 25.0 | 1951 - 75 |
| Talkeetna | 9.4 | 15.3 | 20.0 | 32.6 | 44.7 | 55.0 | 57.9 | 54.6 | 46.1 | 32.1 | 17.5 | 9.0 | 32.8 | 1941 - 70 |

TABLE A2.4: RECORDED AIR TEMPERATURES AT TALKEETNA AND SUMMIT IN °F

| | STATION | | | | | |
|---|---|---|---|---|---|---|
| | Talkeetna | | | Summit | | |
| Month | Daily Max. | Daily Min. | Monthly Average | Daily Max. | Daily Min. | Monthly Average |
| Jan | 19.1 | - 0.4 | 9.4 | 5.7 | - 6.8 | - 0.6 |
| Feb | 25.8 | 4.7 | 15.3 | 12.5 | - 1.4 | 5.5 |
| Mar | 32.8 | 7.1 | 20.0 | 18.0 | 1.3 | 9.7 |
| Apr | 44.0 | 21.2 | 32.6 | 32.5 | 14.4 | 23.5 |
| May | 56.1 | 33.2 | 44.7 | 45.6 | 29.3 | 37.5 |
| June | 65.7 | 44.3 | 55.0 | 52.4 | 39.8 | 48.7 |
| Jul | 67.5 | 48.2 | 57.9 | 60.2 | 43.4 | 52.1 |
| Aug | 64.1 | 45.0 | 54.6 | 56.0 | 41.2 | 48.7 |
| Sept | 55.6 | 36.6 | 46.1 | 46.9 | 32.2 | 39.6 |
| Oct | 40.6 | 23.6 | 32.1 | 29.4 | 16.5 | 23.0 |
| Nov | 26.1 | 8.8 | 17.5 | 15.6 | 4.0 | 9.8 |
| Dec | 18.0 | - 0.1 | 9.0 | 9.2 | - 3.3 | 3.0 |
| Annual Average | | | 32.8 | | | 25.0 |

TABLE A2.5: PRECIPITATION MAXIMIZATION RESULTS

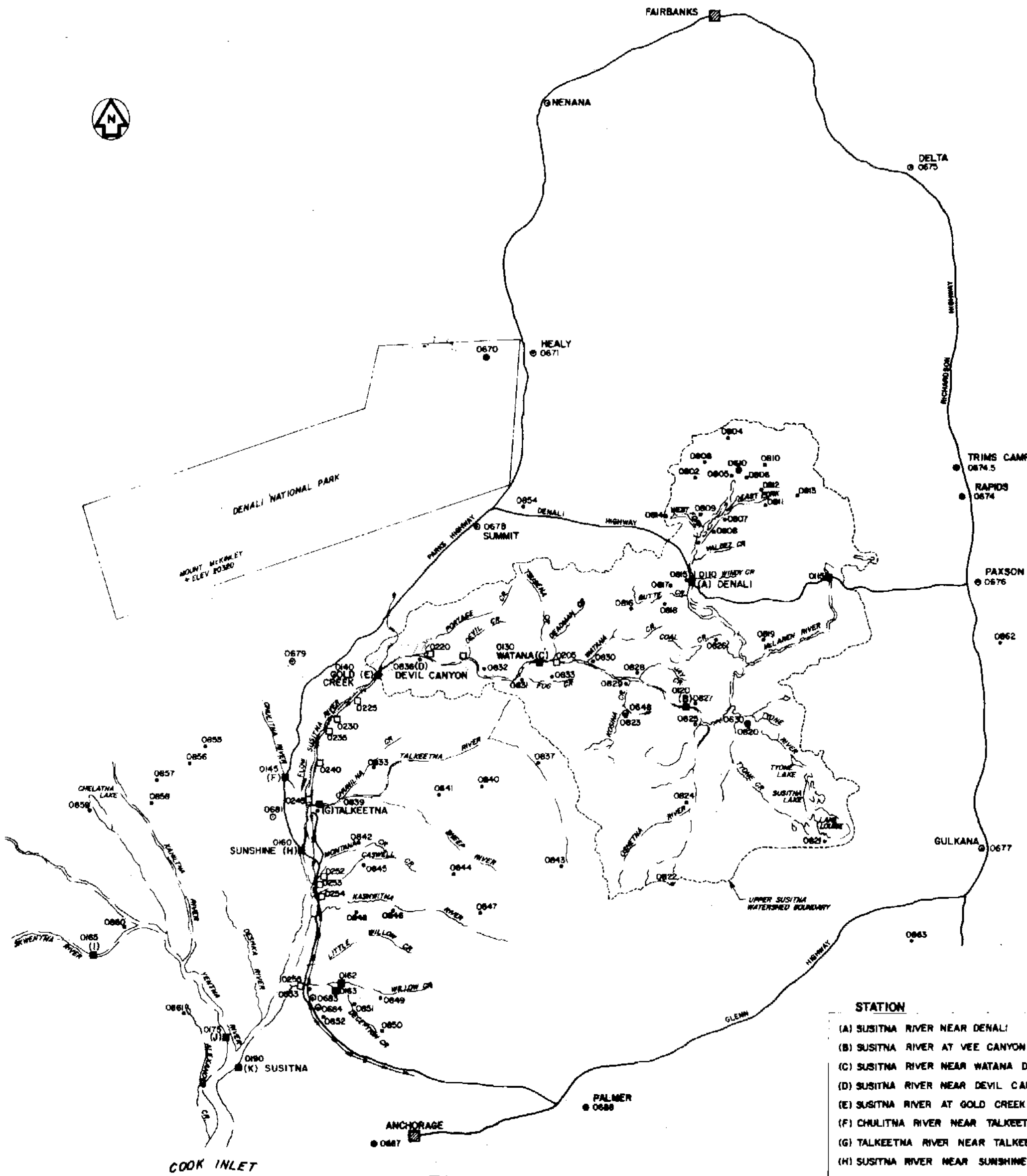
| Storm | Maximization Factor | Maximized Total Precipitation (inches) |
|---|---|---|
| August 1971 | 1.77 | 9.04 |
| August 1967 | 2.00 | 12.54 |
| August 1959 | 1.80 | 6.82 |
| July - August 1958 | 1.66 | 4.96 |
| August 1955 | 1.86 | 7.03 |

TABLE A2.6: TEMPORAL PATTERN OF AUGUST 1967 STORM

| | STORM DURATION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Daily Precipitation Ranking | 10 | 9 | 8 | 7 | 6 | 4 | 2 | 1 | 3 | 5 |

TABLE A2.7: SSARR MODEL INITIAL SNOWPACK FOR PMF

| Sub-Basin Number | Initial Snowpack Water Equivalent (inches) |
|---|---|
| 10 | 99 |
| 20 | 81 |
| 80 | 35 |
| 180 | 32 |
| 210 | 99 |
| 220 | 62 |
| 280 | 30 |
| 330 | 33 |
| 340 | 27 |
| 380 | 59 |
| 480 | 57 |
| 580 | 48 |
| 680 | 48 |




## DATA COLLECTED

| | | INDEX NUMBERING |
|---|---|---|
| ■ | STREAMFLOW - CONTINUOUS RECORD | 0100 |
| □ | STREAMFLOW - PARTIAL RECORD | 0200 |
| ● | WATER QUALITY | 0300 |
| T | WATER TEMPERATURE | 0400 |
| ▲ | SEDIMENT DISCHARGE | 0500 |
| ⊖ | CLIMATE | 0600 |
| ⟼ | FREEZING RAIN AND INCLOUD ICING | 0700 |
| * | SNOW COURSE | 0800 |
| ^ | SNOW CREEP | 0900 |

## NOTES

1. PARAMETERS MEASURED LISTED IN APPENDIX B1
2. CONTINUOUS WATER QUALITY MONITOR INSTALLED
3. DATA COLLECTION 1981 SEASON
4. THE LETTER BEFORE EACH STATION NAME IN THE TABLE IS USED ON THE MAP TO MARK THE APPROXIMATE LOCATION OF THE STATIONS.

SCALE 0 10 20 MILES (APPROX.)

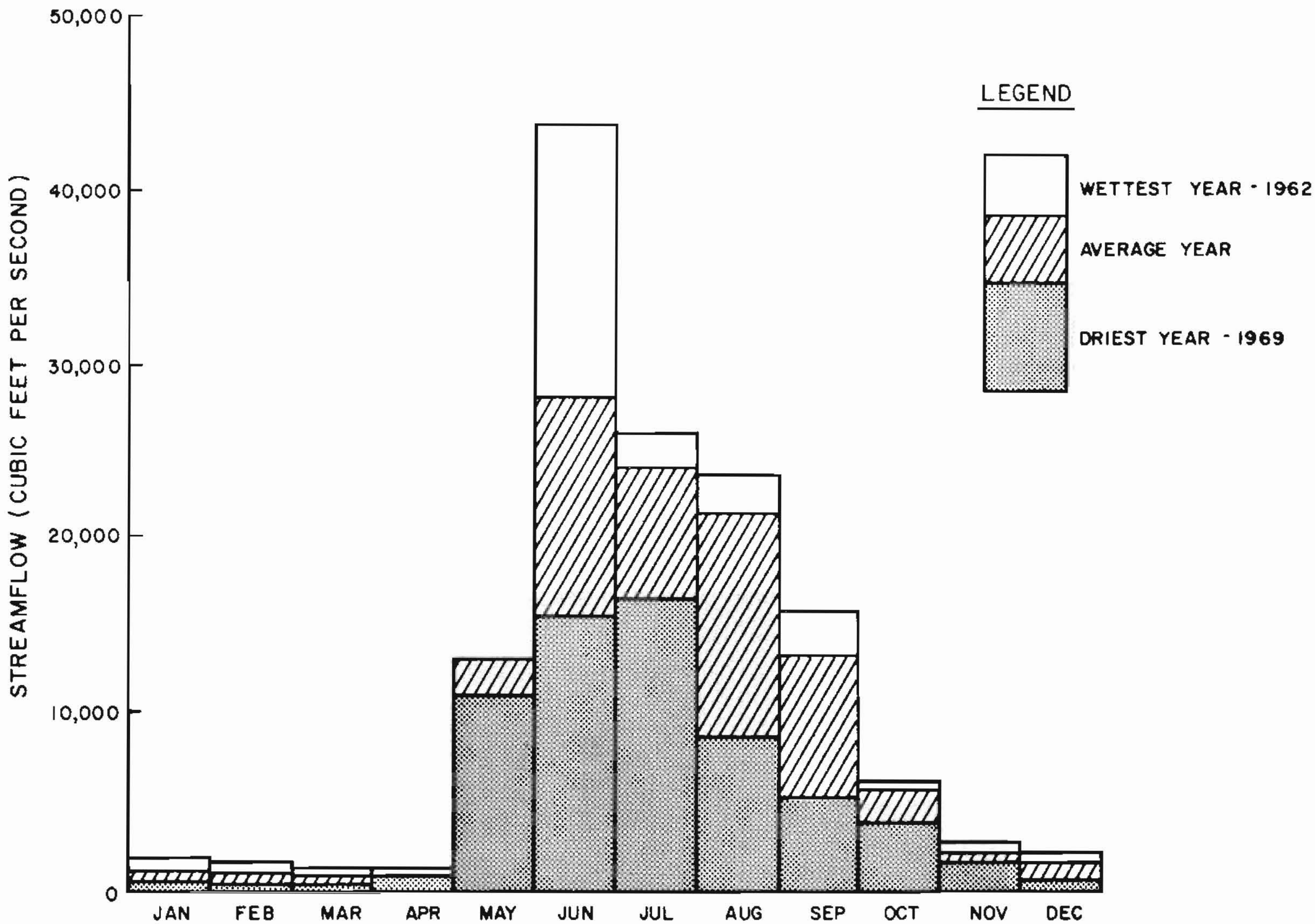
| STATION | STREAMFLOW GAGING | CREST STAGE GAGE | STAFF GAGE | WATER QUALITY (1) | WATER TEMPERATURE | SEDIMENT DISCHARGE | BEDLOAD SAMPLING (3) | CLIMATE | IN-CLOUD ICING | FREEZING RAIN | SNOW CREEP | PERIOD OF RECORD OF STREAMFLOW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (A) SUSITNA RIVER NEAR DENALI | X | | X | | X | X | | X | X | X | | 1957 - PRESENT |
| (B) SUSITNA RIVER AT VEE CANYON | X | | X | X | X | X | | | | | | 1961 - 1972 & 1980 - PRESENT |
| (C) SUSITNA RIVER NEAR WATANA DAMSITE | X | X | | $X^2$ | X | | | X | X | X | X | 1980 - PRESENT |
| (D) SUSITNA RIVER NEAR DEVIL CANYON | | X | X | | | | | X | | | X | |
| (E) SUSITNA RIVER AT GOLD CREEK | X | | | X | X | X | X | | | | | 1949 - PRESENT |
| (F) CHULITNA RIVER NEAR TALKEETNA | X | | | | X | X | X | | | | | 1958 - 1972 & 1980 - PRESENT |
| (G) TALKEETNA RIVER NEAR TALKEETNA | X | | | X | X | X | X | | | | | 1964 - PRESENT |
| (H) SUSITNA RIVER NEAR SUNSHINE | X | | | | X | X | X | | | | | 1981 - PRESENT |
| (I) SKWENTNA RIVER NEAR SKWENTNA | X | | | X | X | X | - | X | | | | 1959 - 1980 |
| (J) YENTNA RIVER NEAR SUSITNA STATION | X | | | | X | X | | | | | | 1980 - PRESENT |
| (K) SUSITNA RIVER AT SUSITNA STATION | X | | | X | X | X | | | | | | 1974 - PRESENT |

**DATA COLLECTION STATIONS**

USED IN PMF STUDY

ACRES

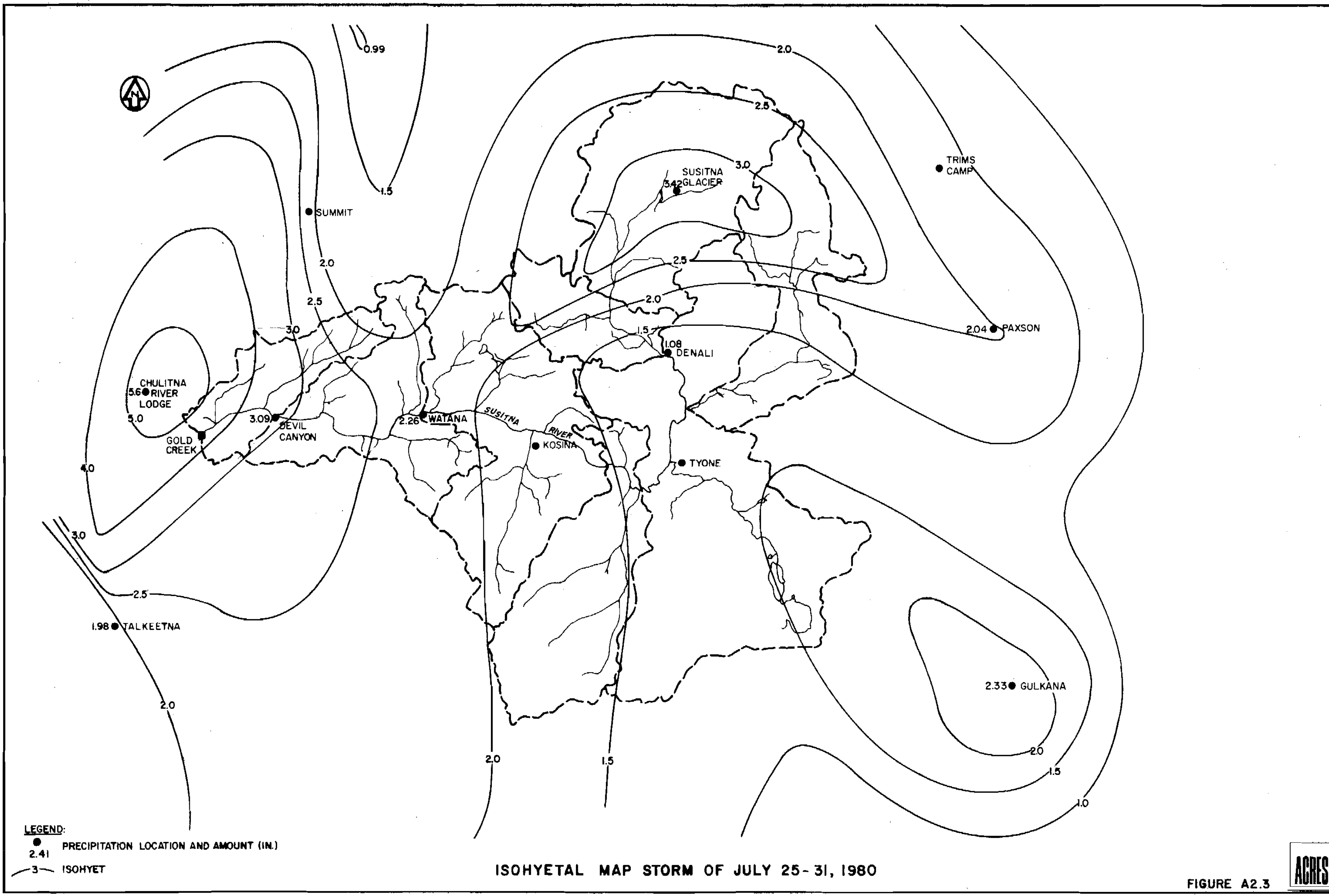
**FIGURE A2.1**




MONTHLY AVERAGE FLOWS IN
THE SUSITNA RIVER AT GOLD CREEK

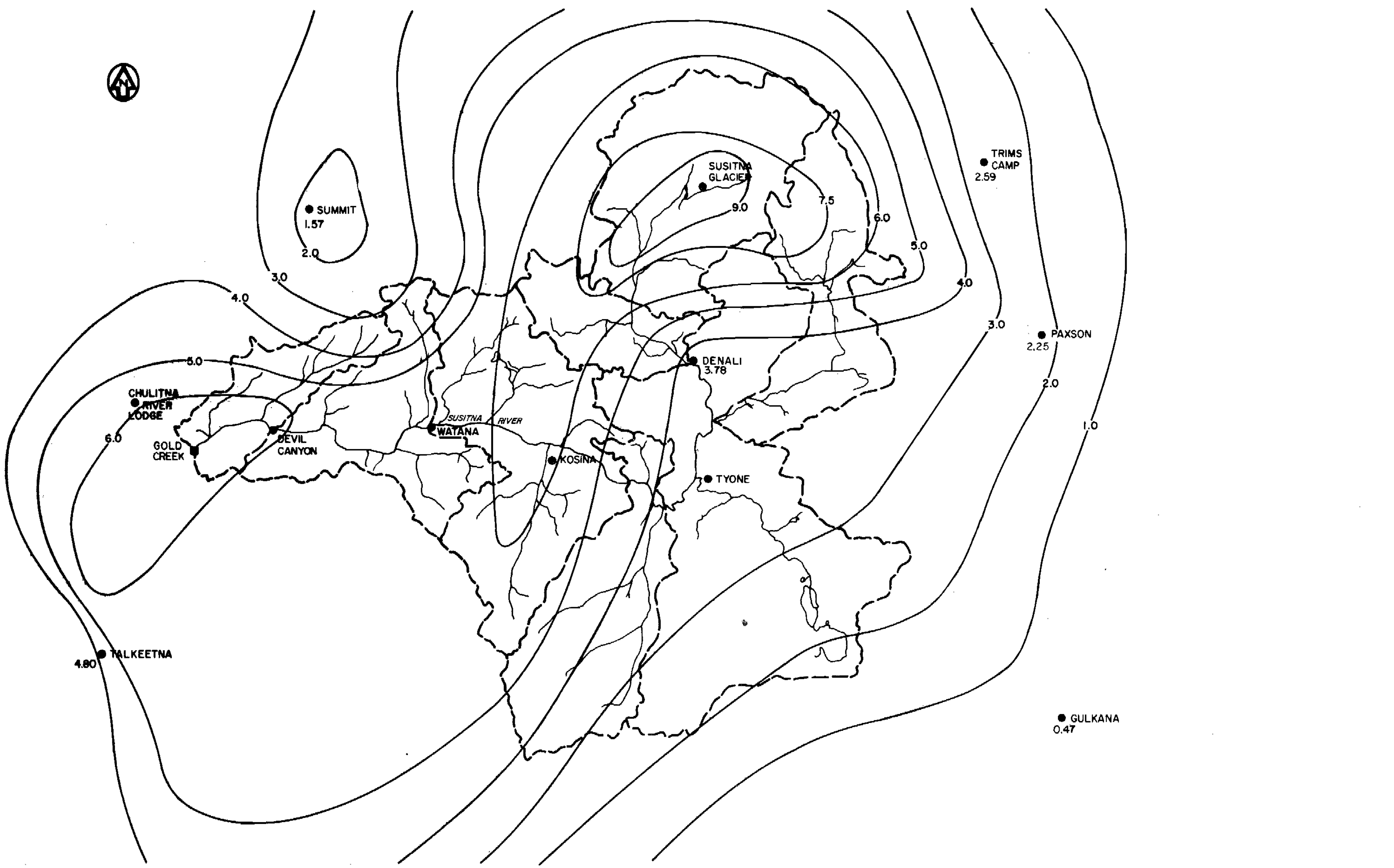
FIGURE A2.2

ACRES




ISOHYETAL MAP STORM OF JULY 25-31, 1980

FIGURE A2.3

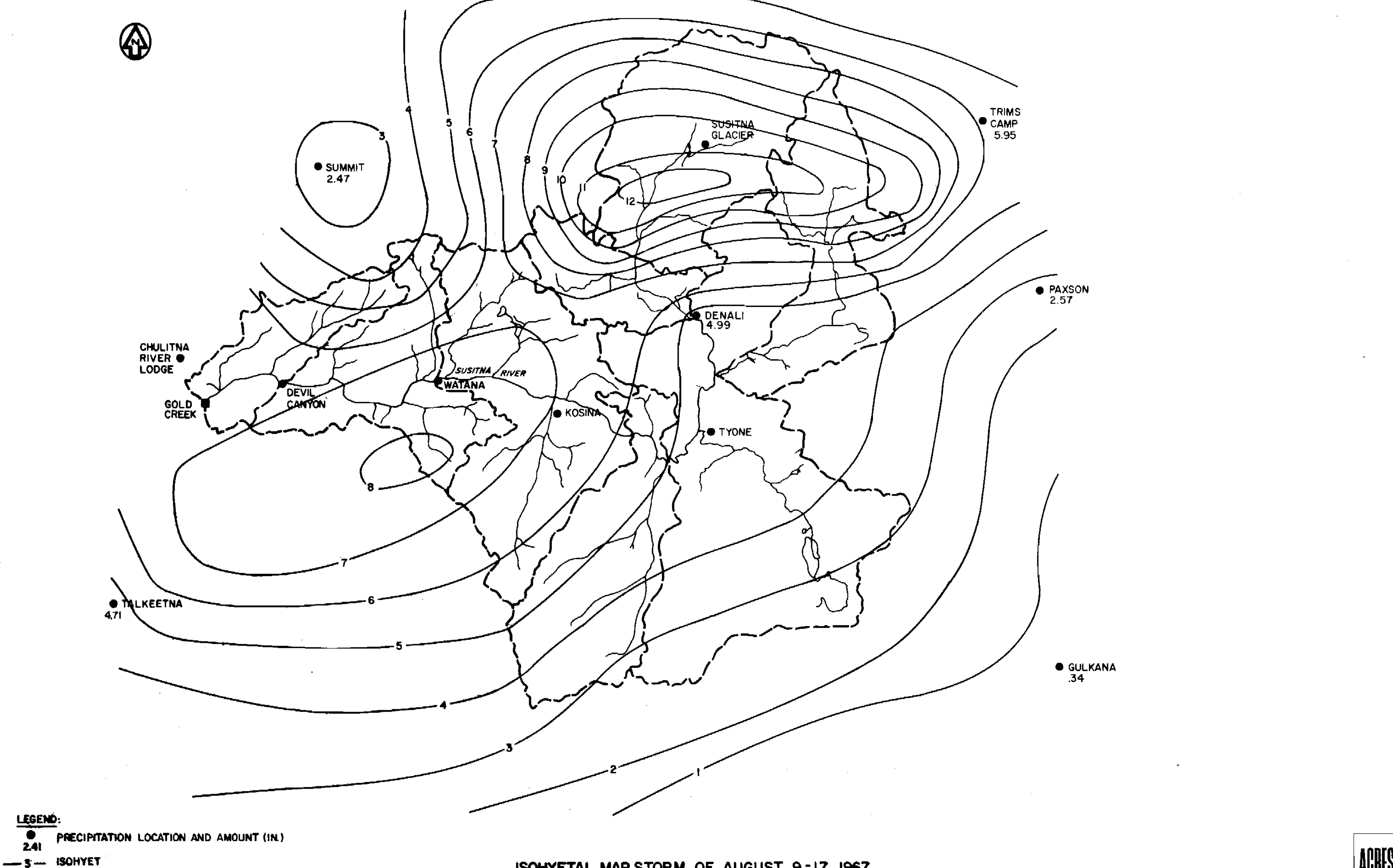



LEGEND:
PRECIPITATION LOCATION AND AMOUNT (IN.)
ISOHYET

ISOHYETAL MAP STORM OF AUGUST 4-10, 1971

FIGURE A2.4

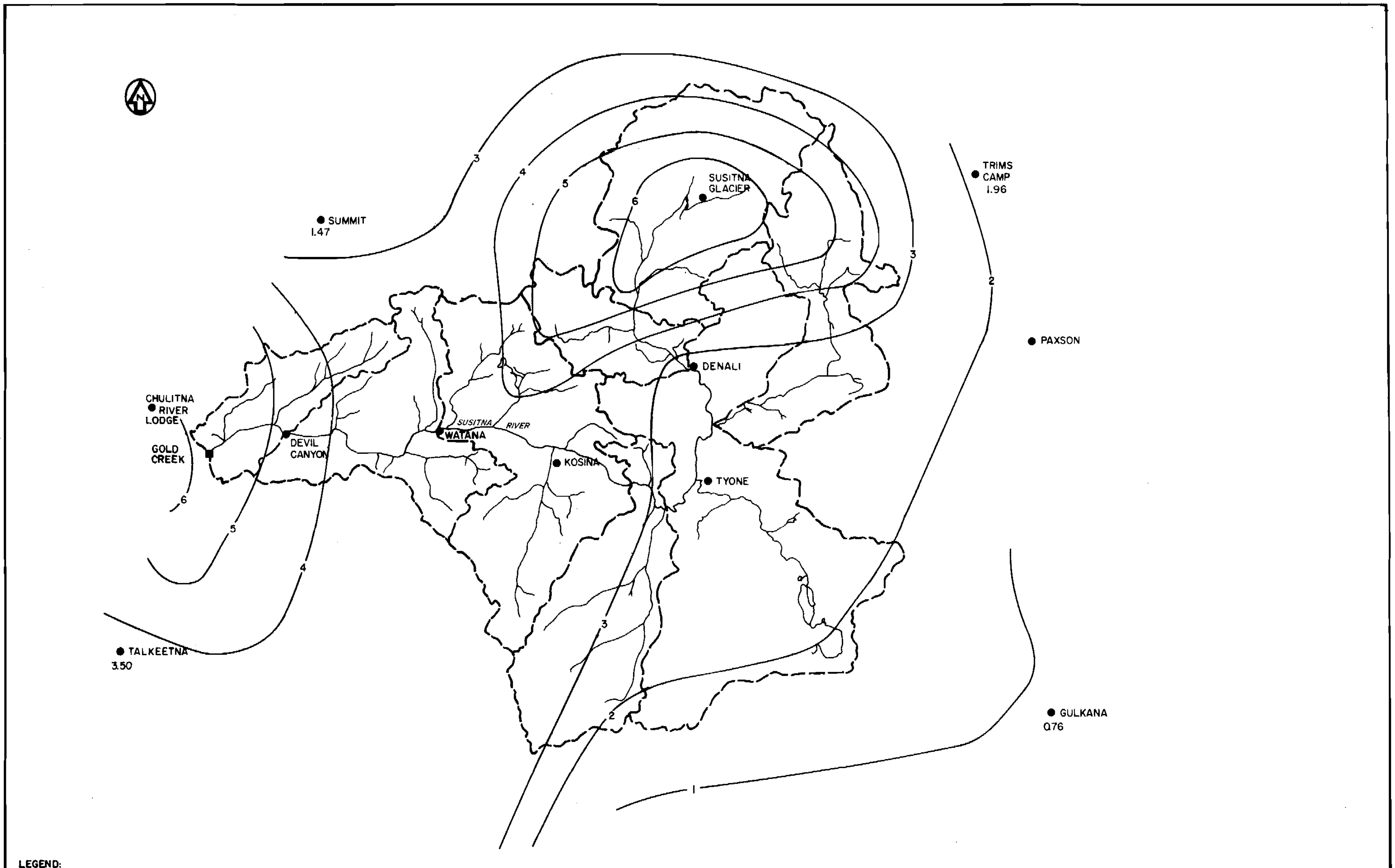
ACRES




ISOHYETAL MAP STORM OF AUGUST 9-17, 1967

FIGURE A2.5

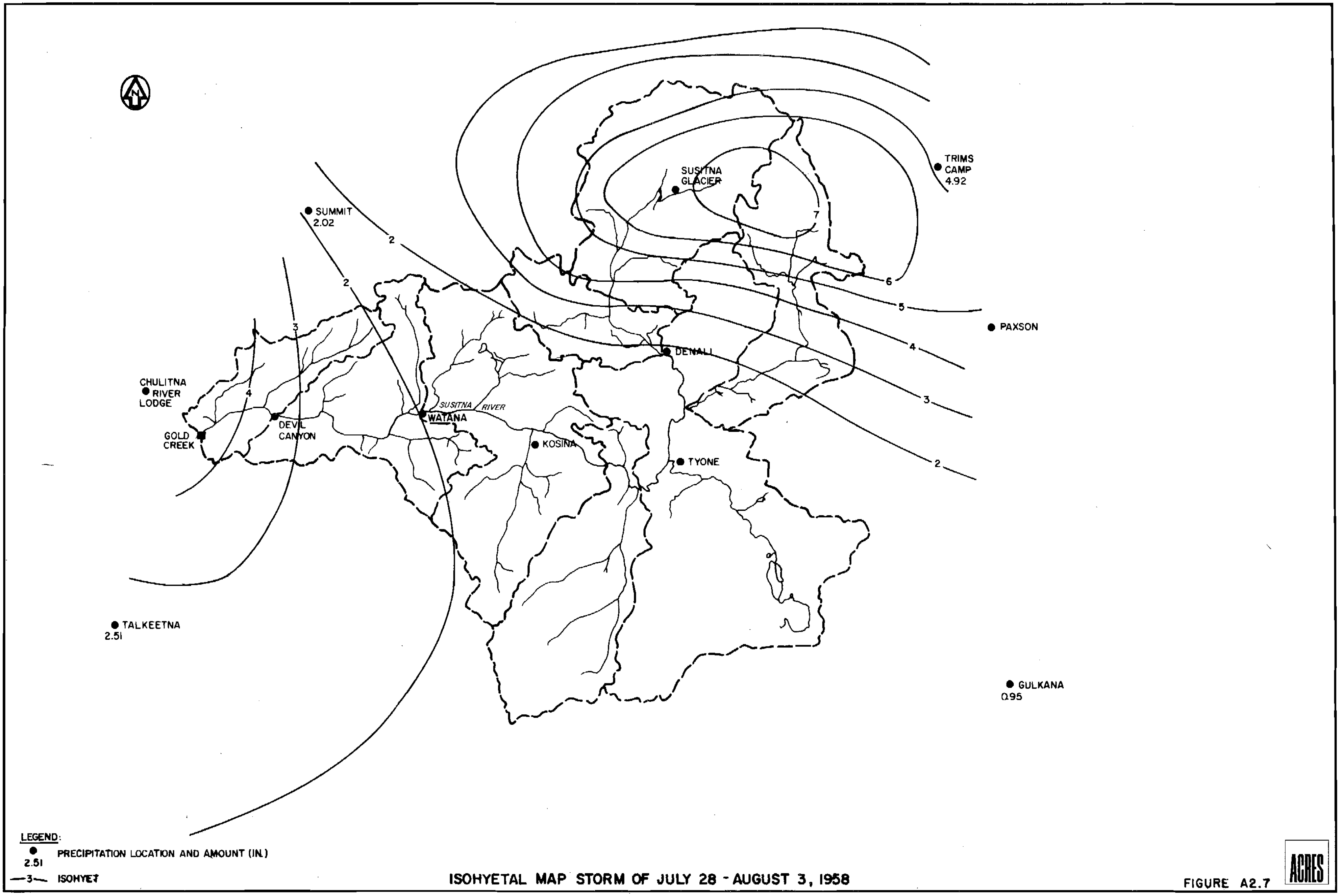
ACRES




ISOHYETAL MAP STORM OF AUGUST 19-25, 1959

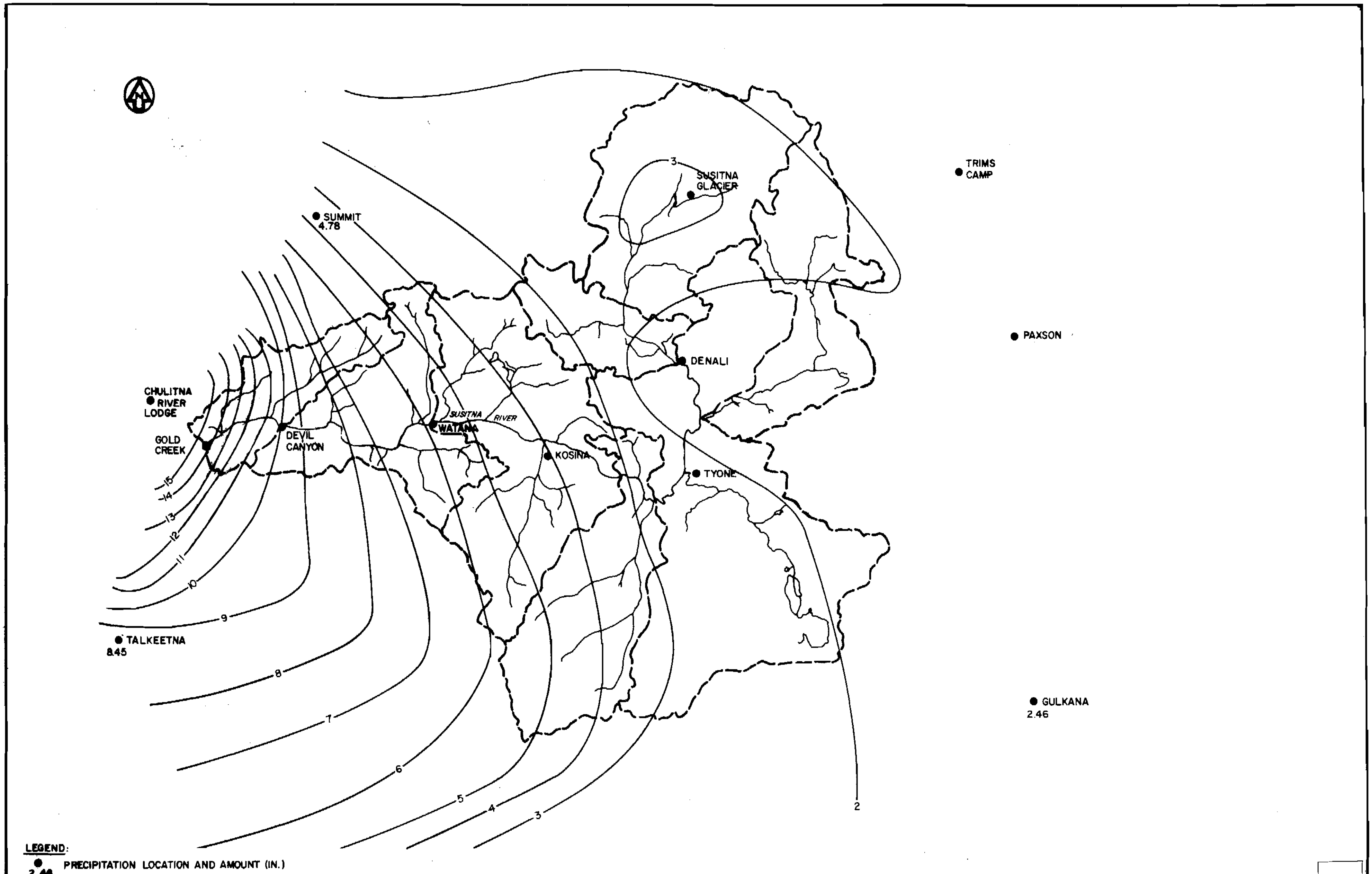
FIGURE A2.6

ACRES



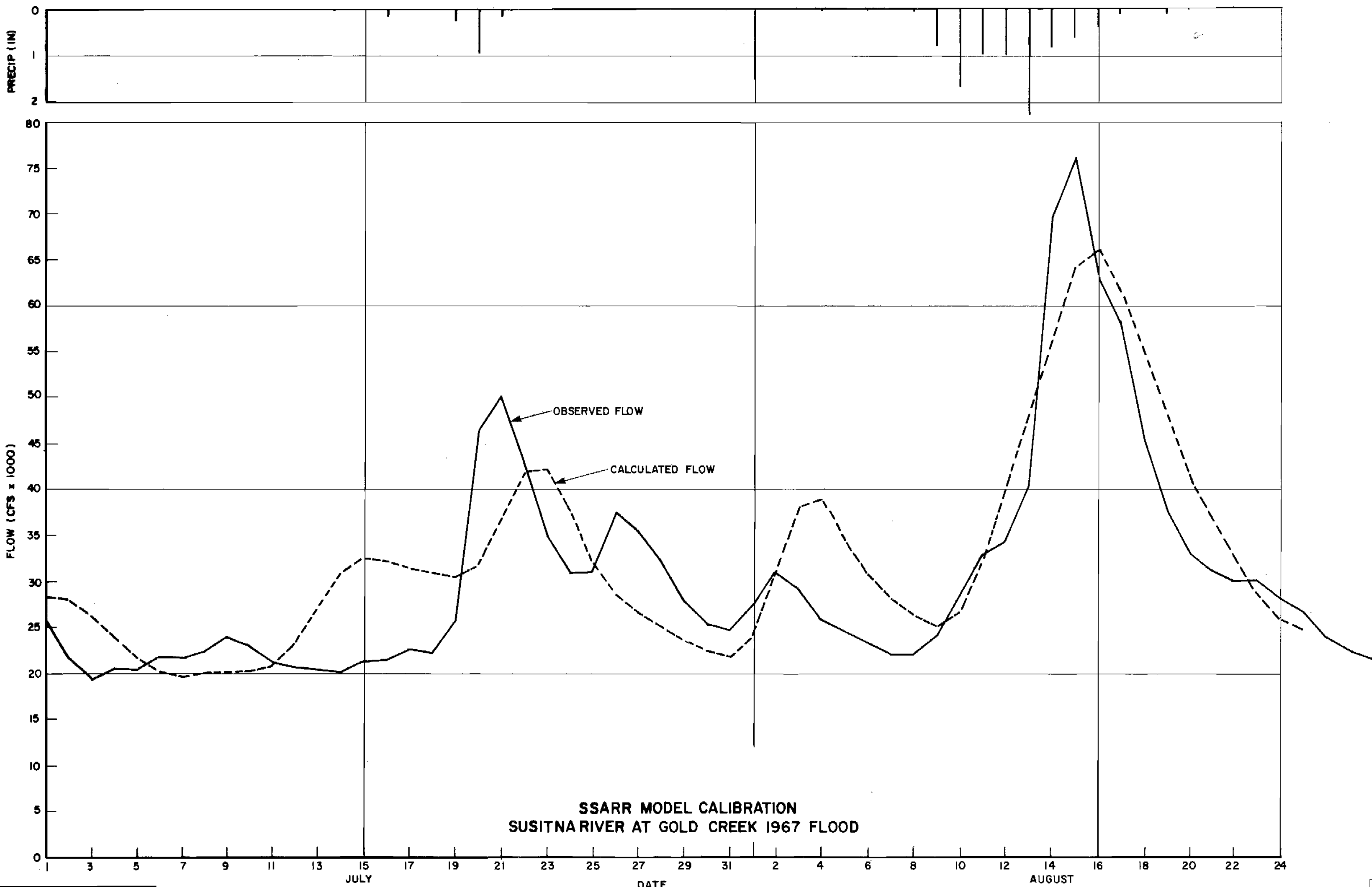

ISOHYETAL MAP STORM OF JULY 28 - AUGUST 3, 1958

FIGURE A2.7




ISOHYETAL MAP STORM OF AUGUST 22-28, 1955

FIGURE A2.8

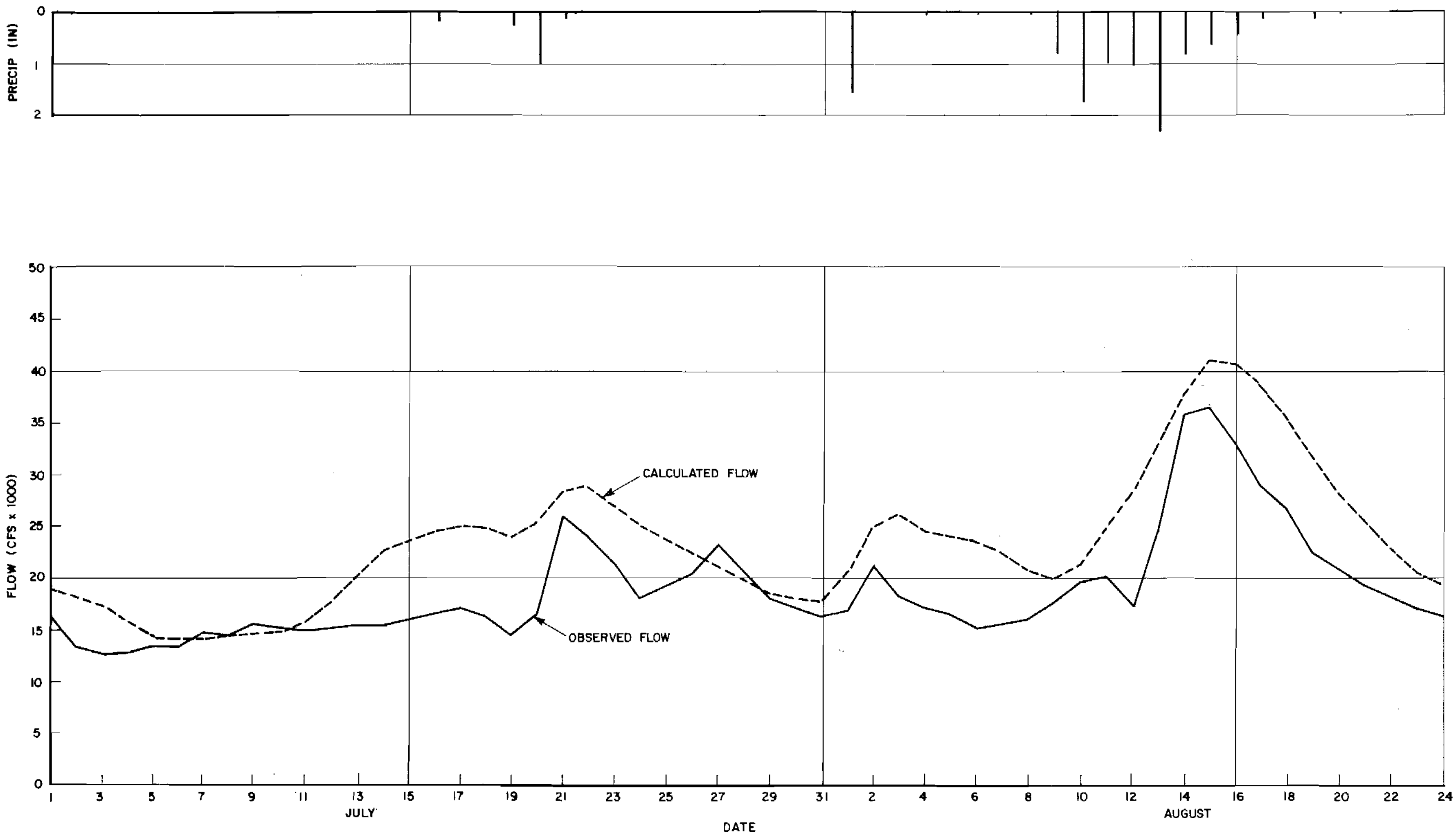



SSARR MODEL CALIBRATION
SUSITNA RIVER AT GOLD CREEK 1967 FLOOD

| DESIGNED BY | | |
|---|---|---|
| DRAWN BY | | |
| CHECKED BY | | |

ACRES

FIGURE A2.9

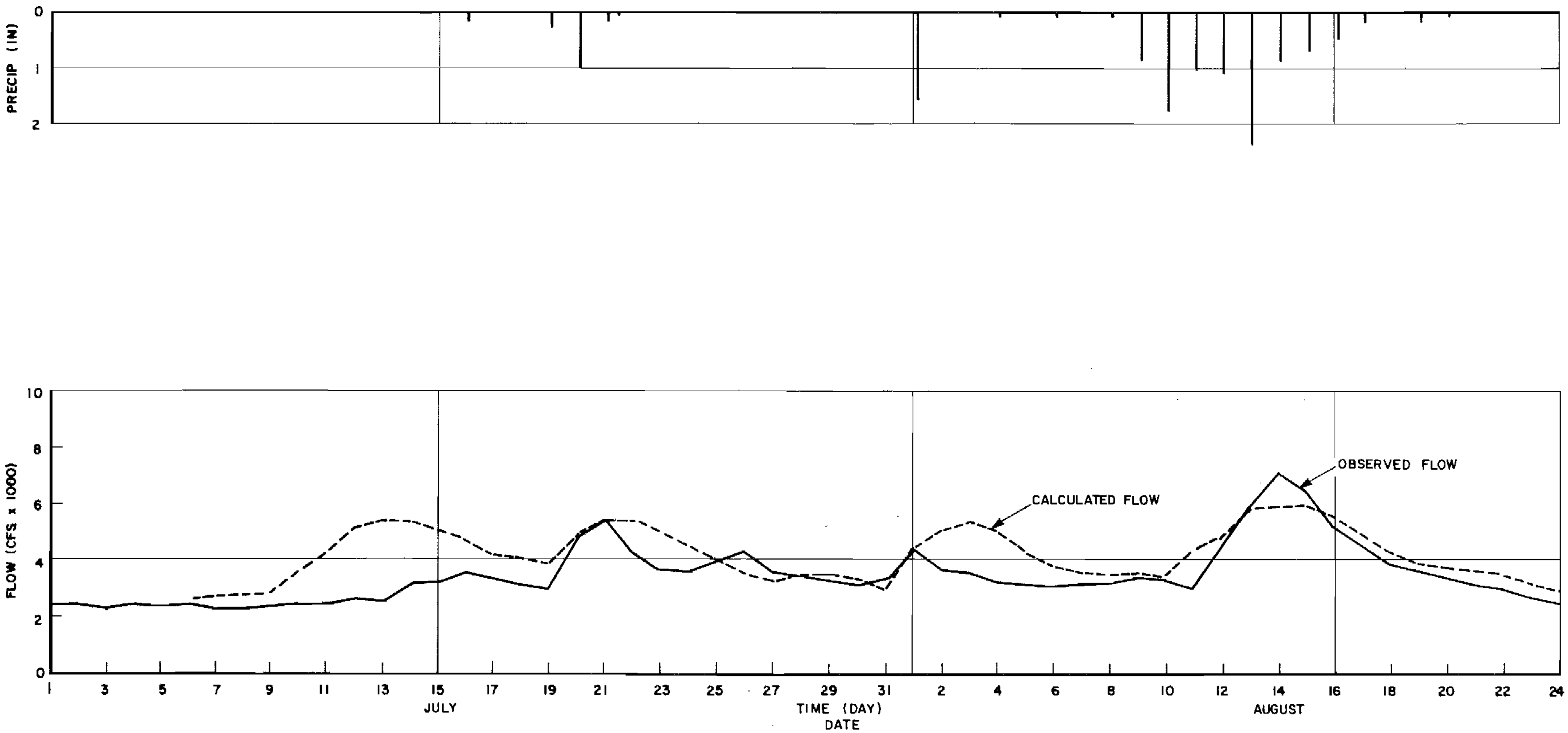



| DESIGNED BY | | |
|---|---|---|
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL CALIBRATION
SUSITNA RIVER NEAR CANTWELL 1967 FLOOD

FIGURE A2.10

ACRES

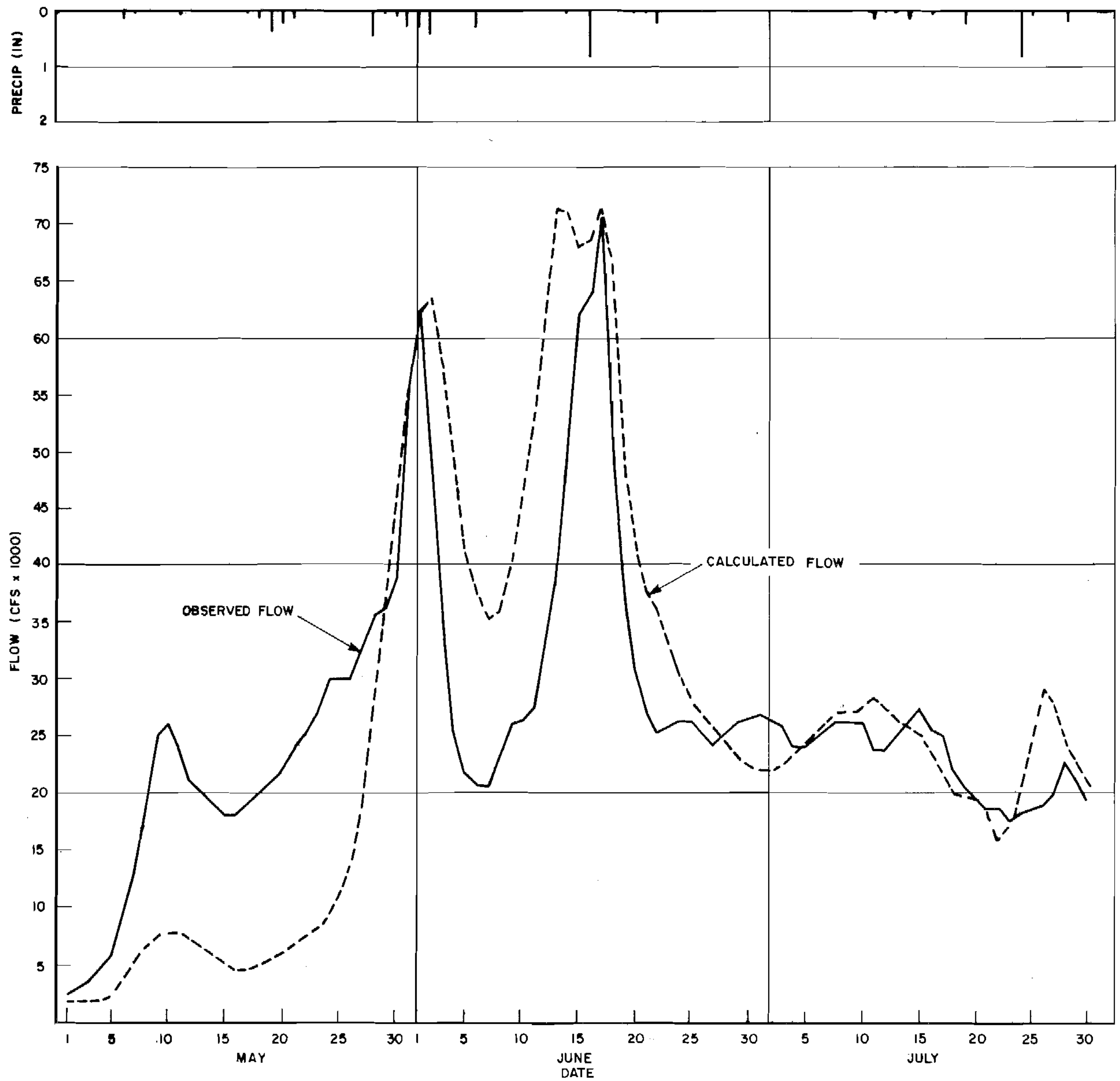



| DESIGNED BY | | |
|---|---|---|
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL CALIBRATION
MACLAREN RIVER NEAR PAXSON 1967 FLOOD

FIGURE A2.11

ACRES

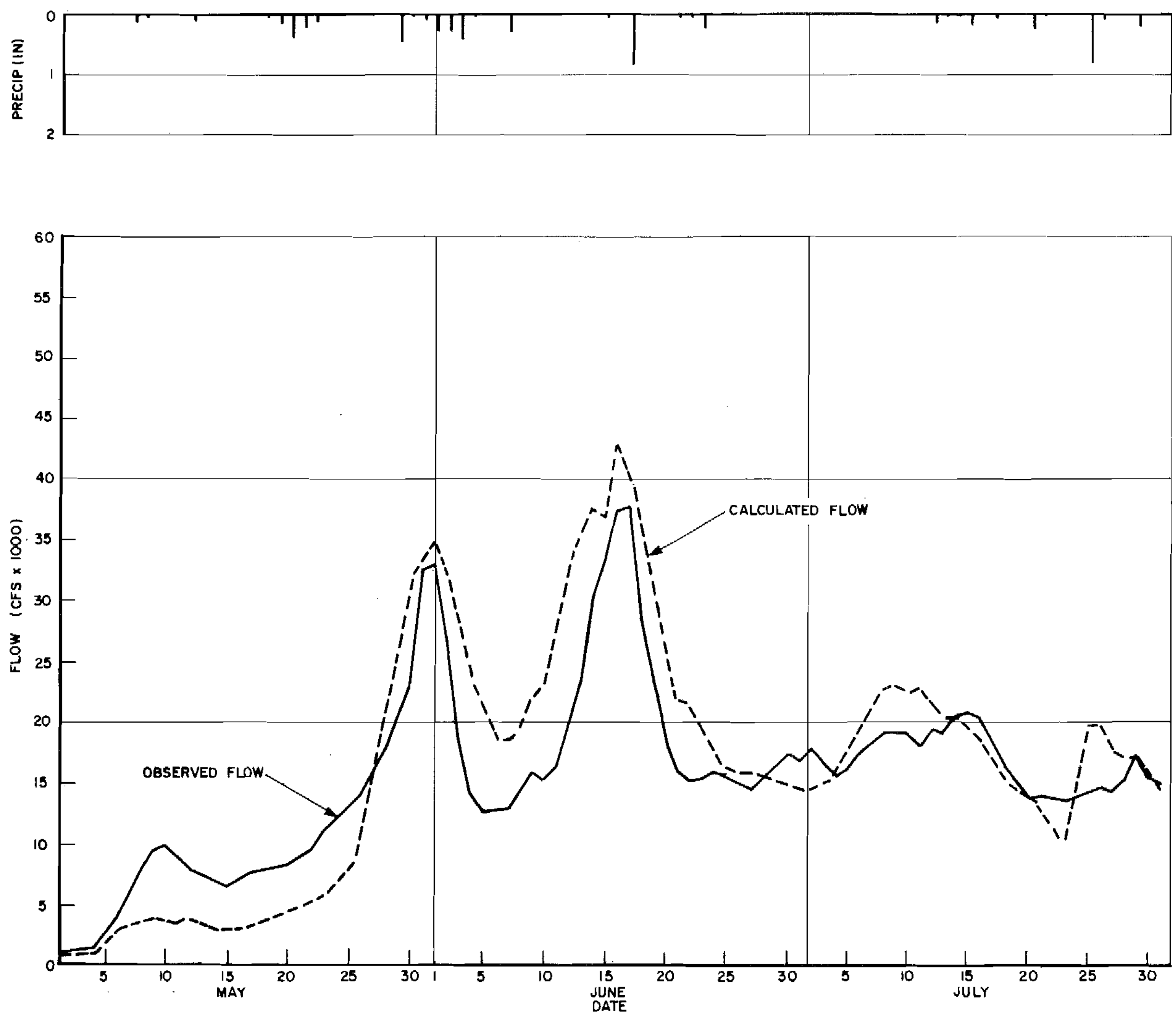



| | | |
|---|---|---|
| DESIGNED BY | | |
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL CALIBRATION
SUSITNA RIVER AT GOLD CREEK 1972 FLOOD

FIGURE A2.12

ACRES

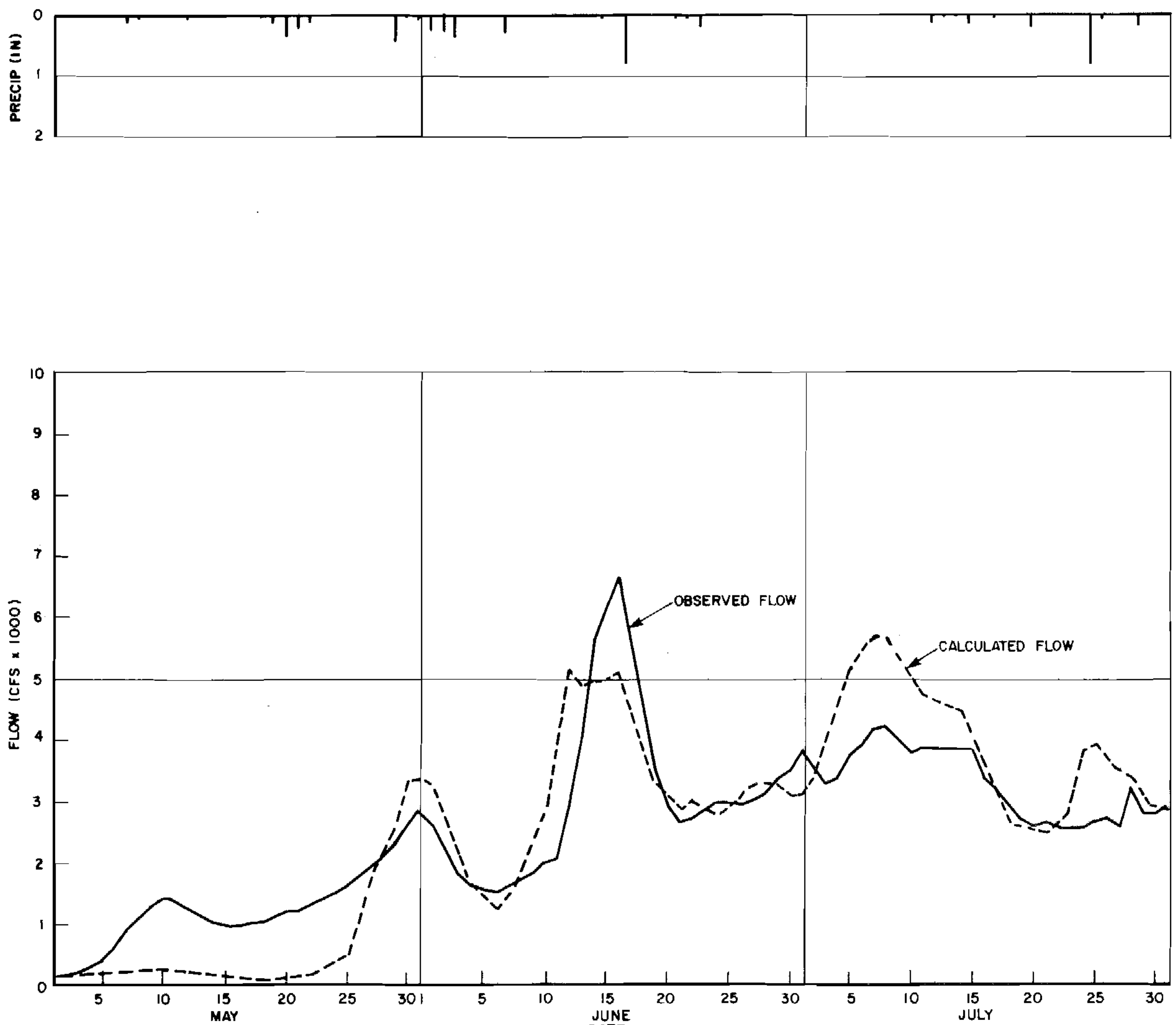



| DESIGNED BY | | |
|---|---|---|
| DRAWN BY | | |
| CHECKED BY | | |

**SSARR MODEL CALIBRATION**
**SUSITNA RIVER NEAR CANTWELL 1972 FLOOD**

FIGURE A2.13

ACRES

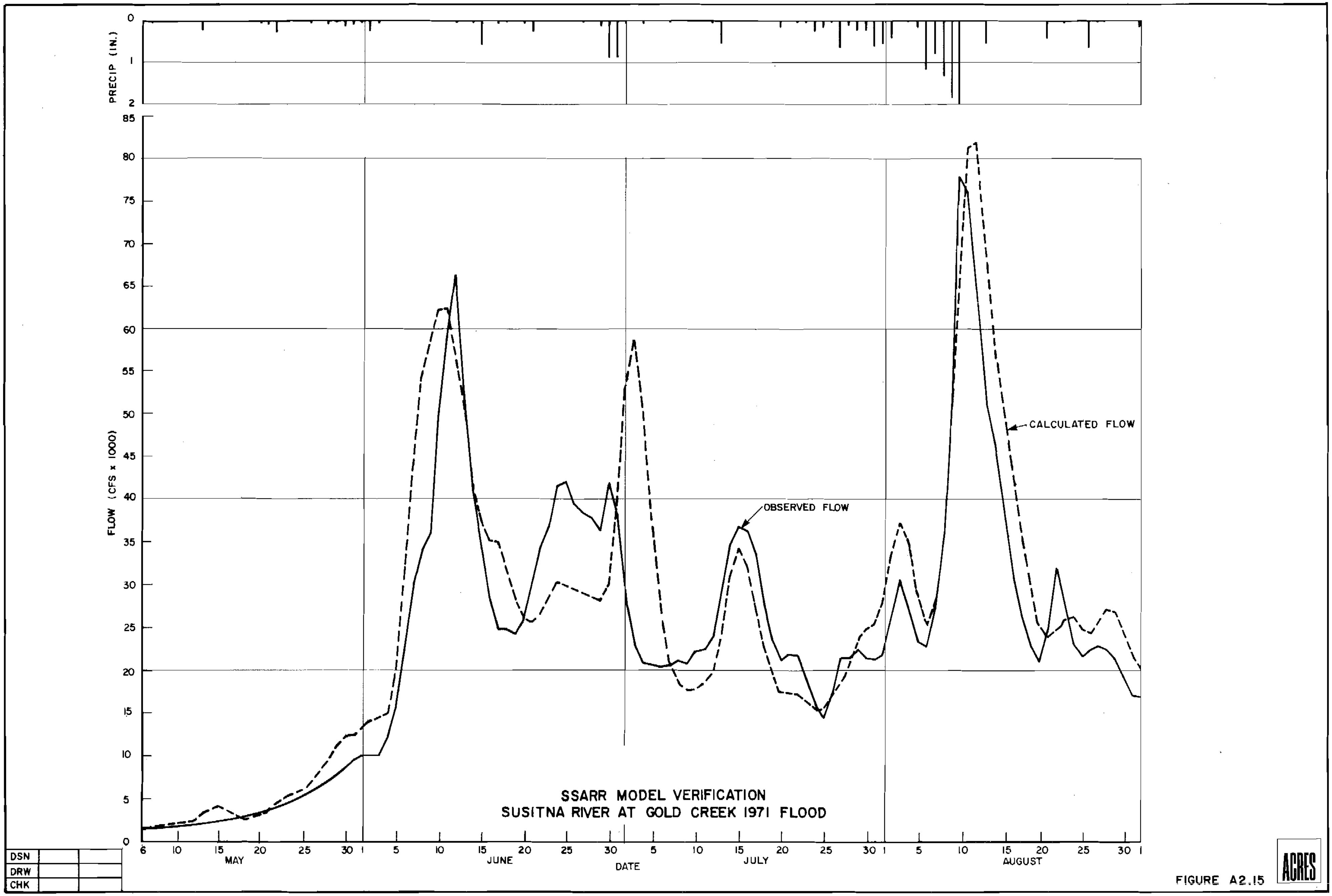



| DESIGNED BY | | |
|---|---|---|
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL CALIBRATION
MACLAREN RIVER NEAR PAXSON 1972 FLOOD

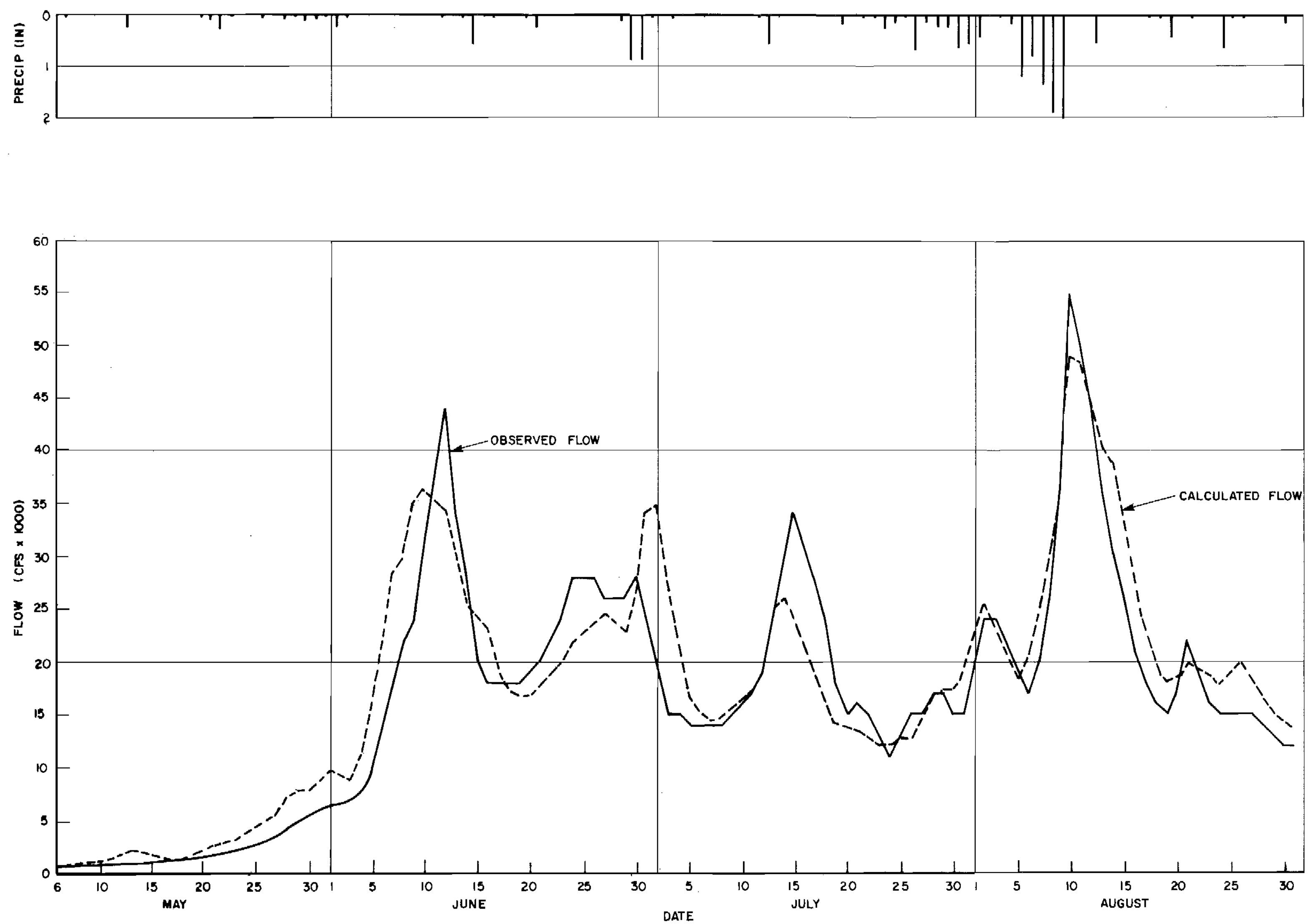
FIGURE A2.14

ACRES



PRECIP (IN.)
0
1
2
FLOW (CFS x 1000)
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
CALCULATED FLOW
OBSERVED FLOW
SSARR MODEL VERIFICATION
SUSITNA RIVER AT GOLD CREEK 1971 FLOOD
6 10 15 20 25 30 1 5 10 15 20 25 30 5 10 15 20 25 30 1 5 10 15 20 25 30 1
MAY
JUNE
DATE
JULY
AUGUST
DSN
DRW
CHK
ACRES


FIGURE A2.15

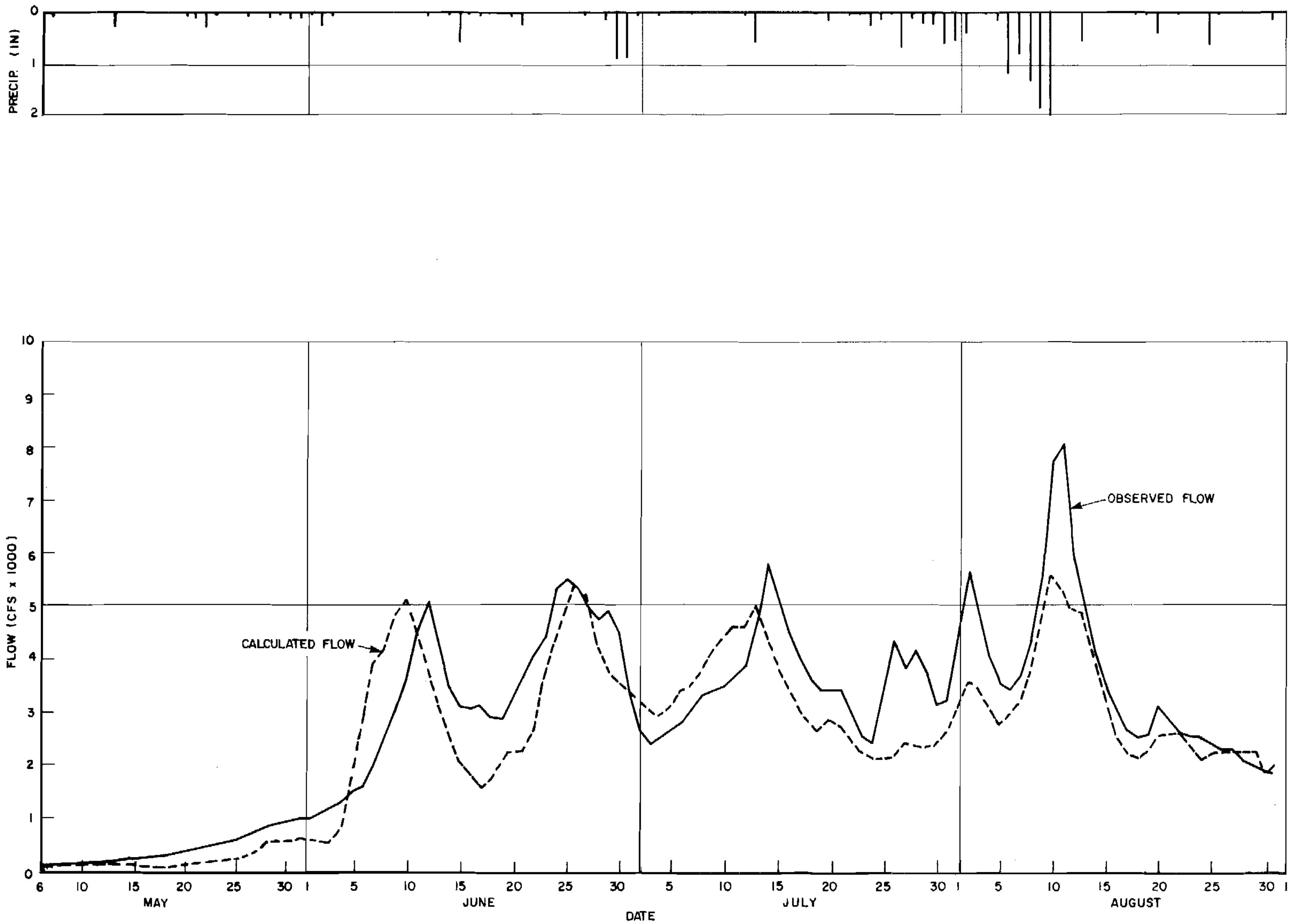



| DESIGNED BY | | |
|---|---|---|
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL VERIFICATION
SUSITNA RIVER NEAR CANTWELL 1971 FLOOD

FIGURE A2.16

ACRES

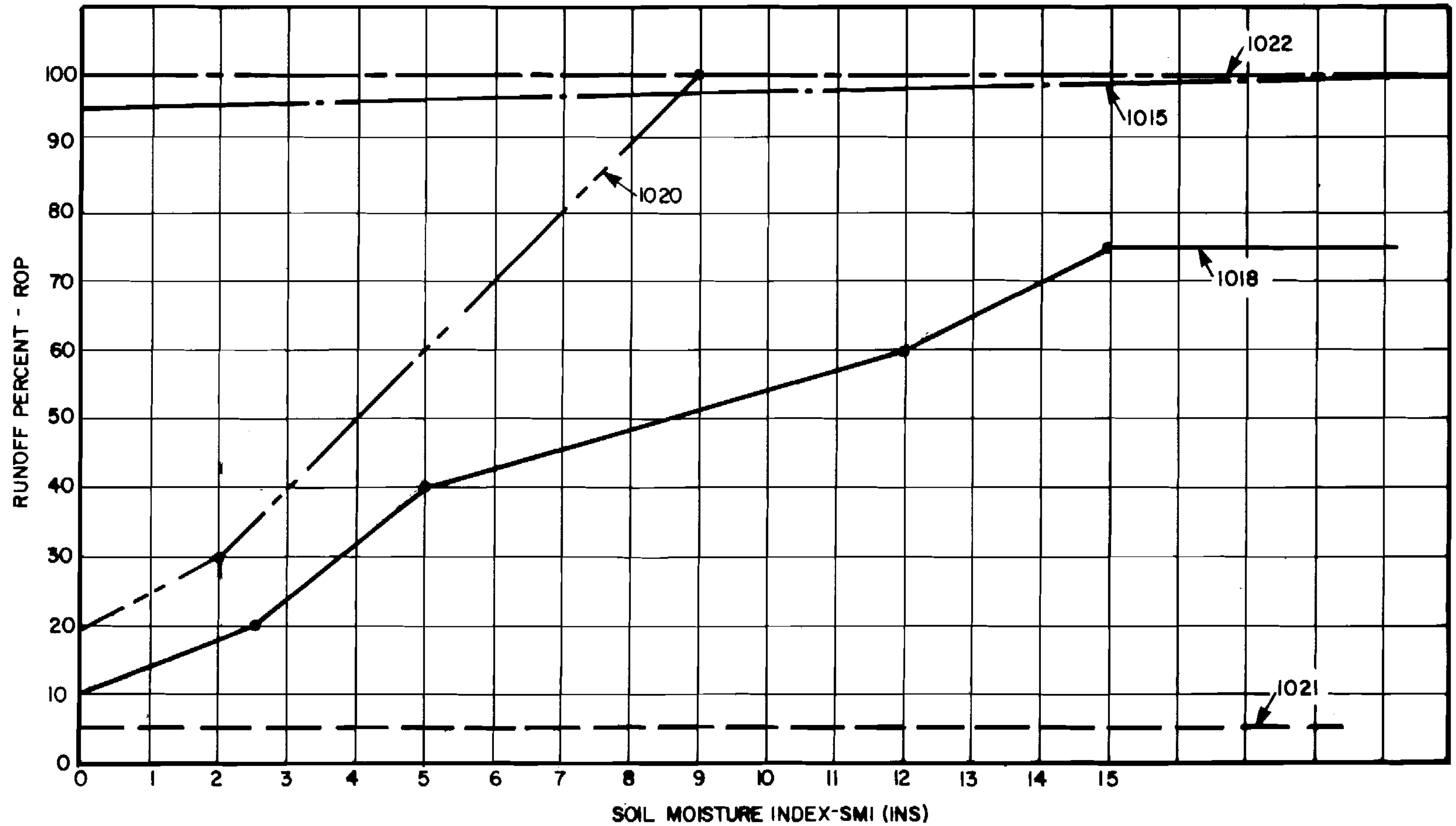



| DESIGNED BY | | |
|---|---|---|
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL VERIFICATION
MACLAREN RIVER NEAR PAXSON 1971 FLOOD

FIGURE A2.17

ACRES



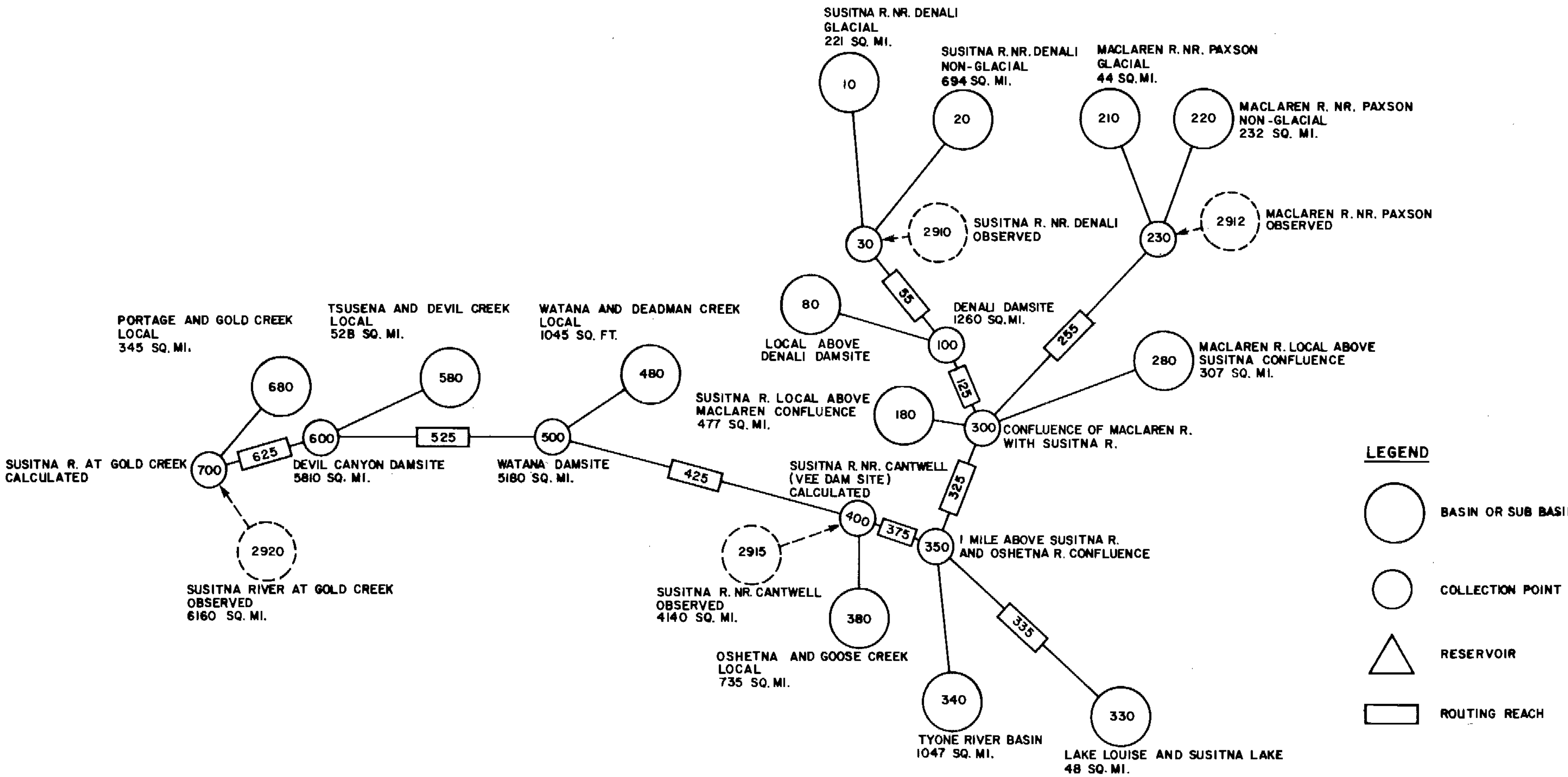

LEGEND:
1018 - TABLE NUMBER IN SSARR MODEL

| DESIGNED BY | | |
|---|---|---|
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL SMI VS ROP

FIGURE A2.18

ACRES

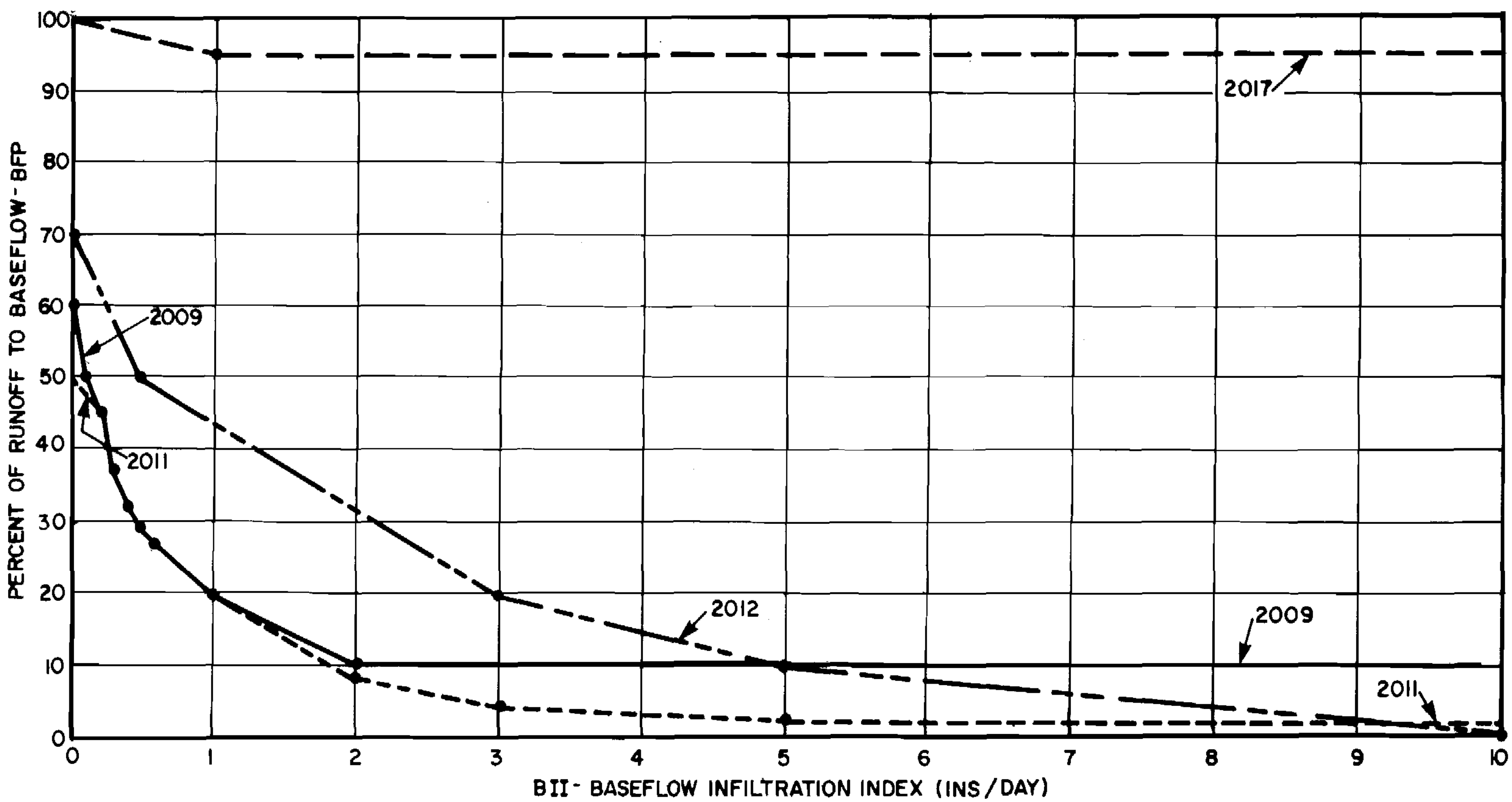



SCHEMATIC DIAGRAM OF SSARR COMPUTER MODEL

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

FIGURE A2.19

ACRES



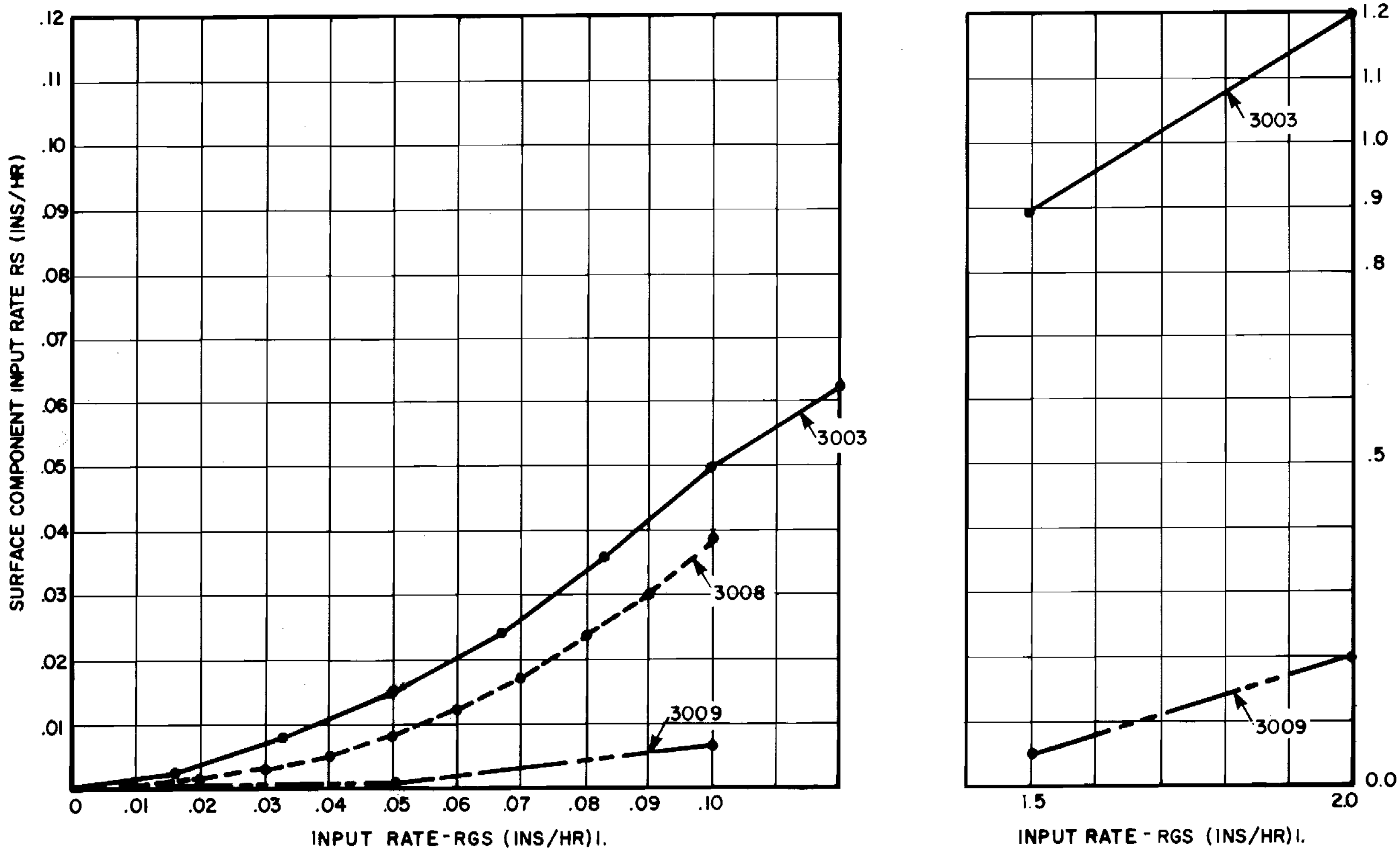

LEGEND:
2011 - TABLE NUMBER IN SSARR MODEL

| DESIGNED BY | | |
|---|---|---|
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL B II VS BFP

FIGURE A2.20

ACRES



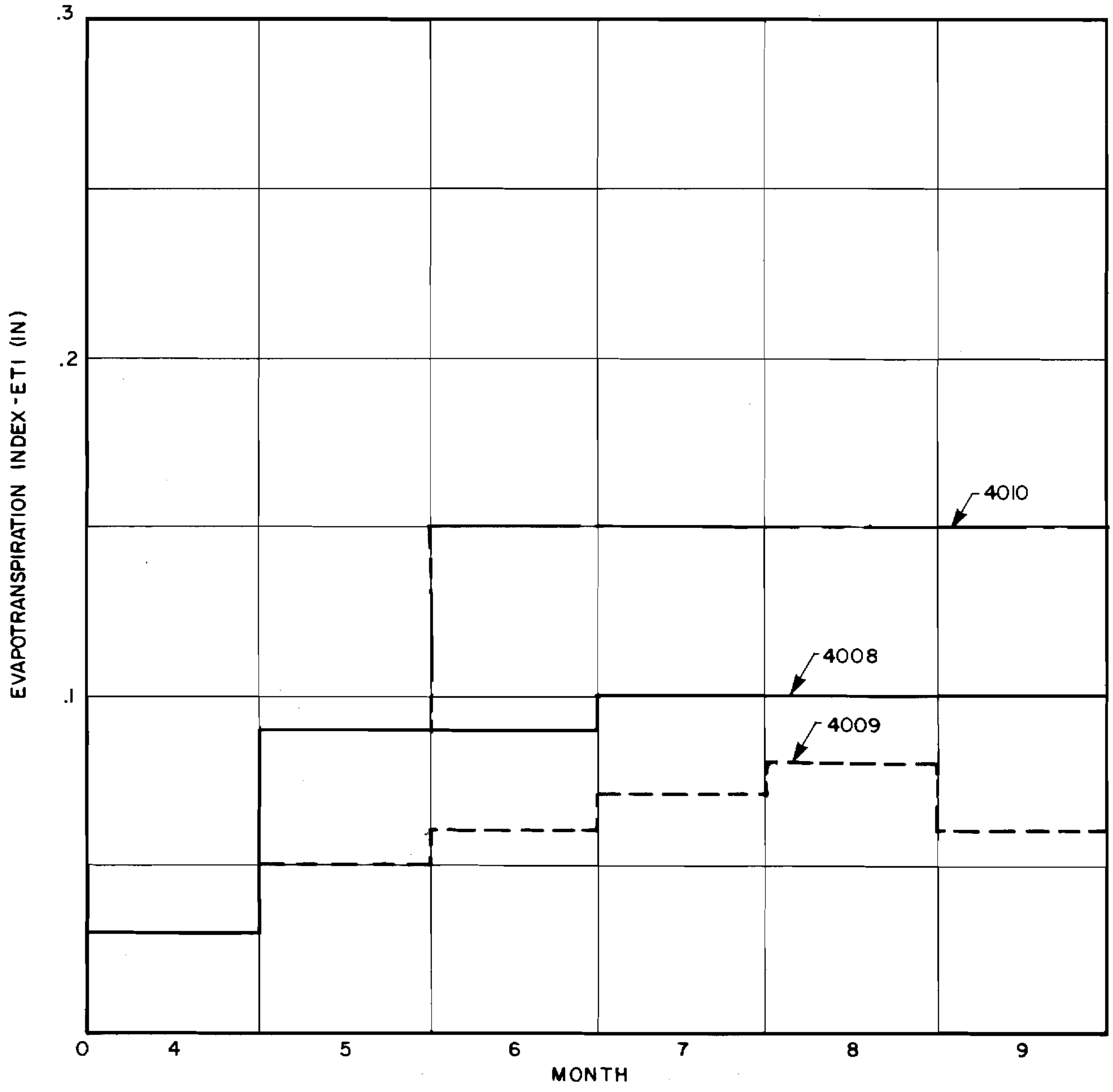

LEGEND:
3008 - TABLE NUMBER IN SSARR MODEL

| | | |
|---|---|---|
| DESIGNED BY | | |
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL RGS VS RS

FIGURE A2.21

ACRES



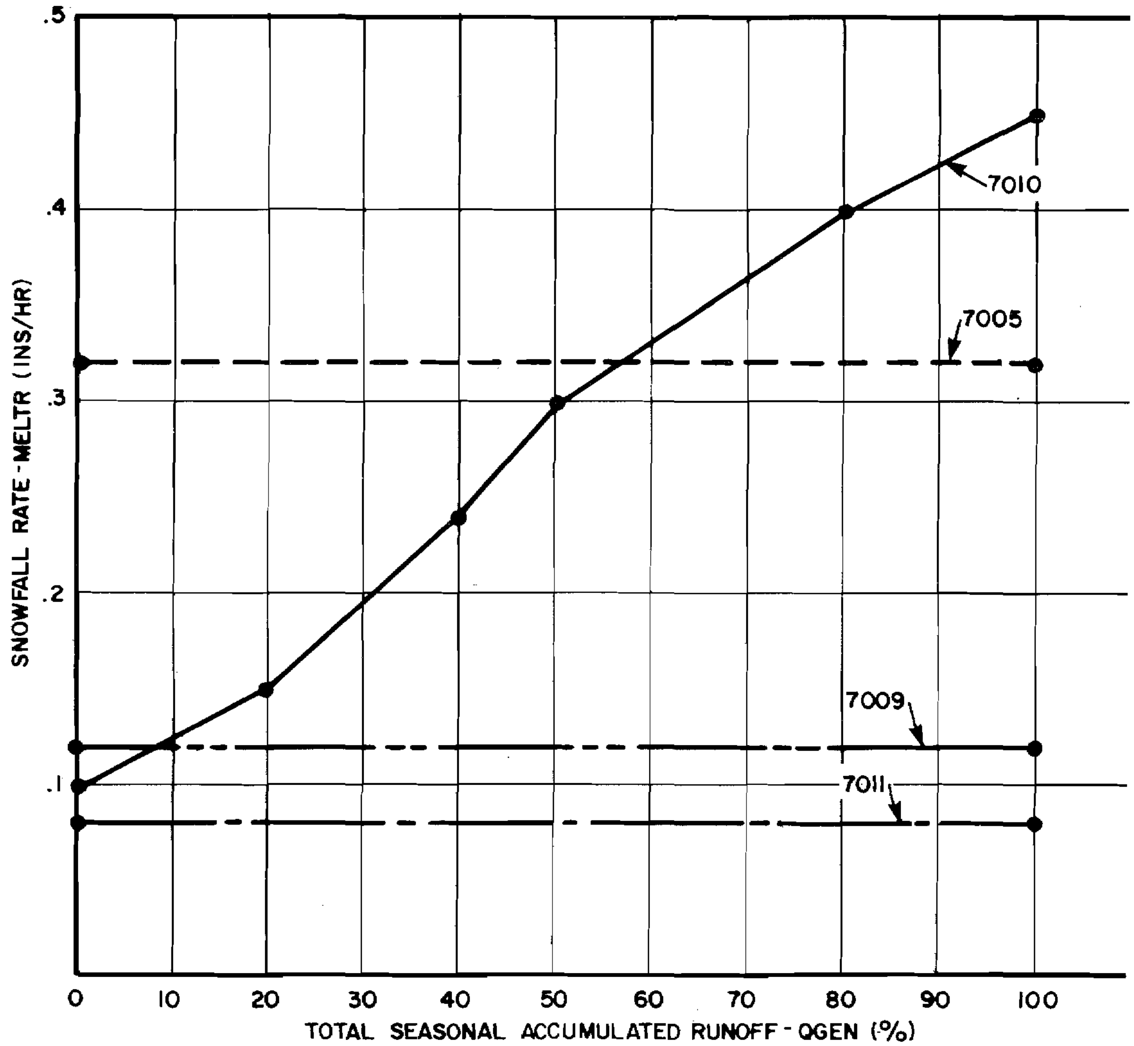

LEGEND:
4009 - TABLE NUMBER IN SSARR MODEL

MONTHLY EVAPOTRANSPIRATION INDEX

| DESIGNED BY | | |
|---|---|---|
| DRAWN BY | | |
| CHECKED BY | | |

FIGURE A2.22

ACRES

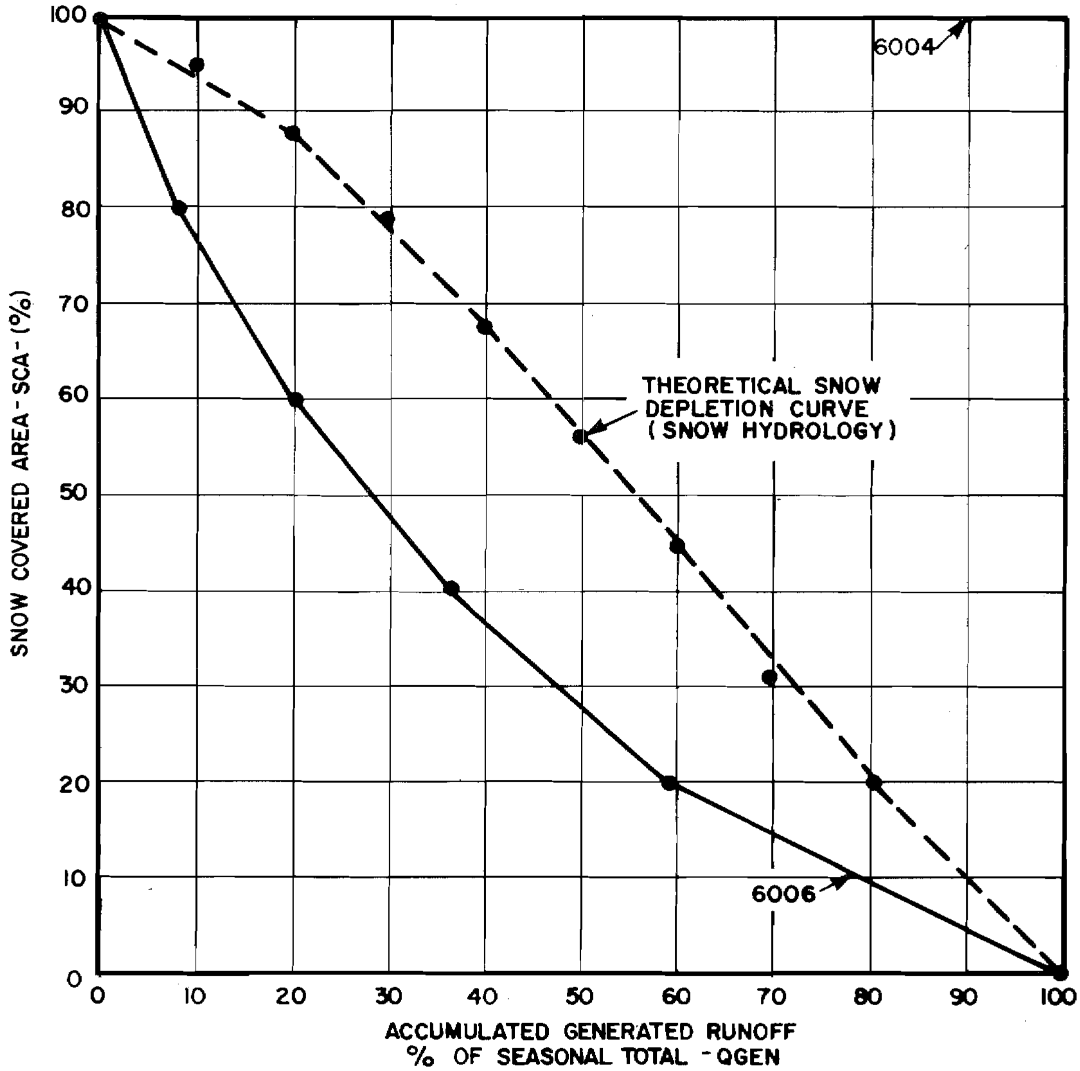



| | | |
|---|---|---|
| DESIGNED BY | | |
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL QGEN VS MELTR

FIGURE A2.23

ACRES

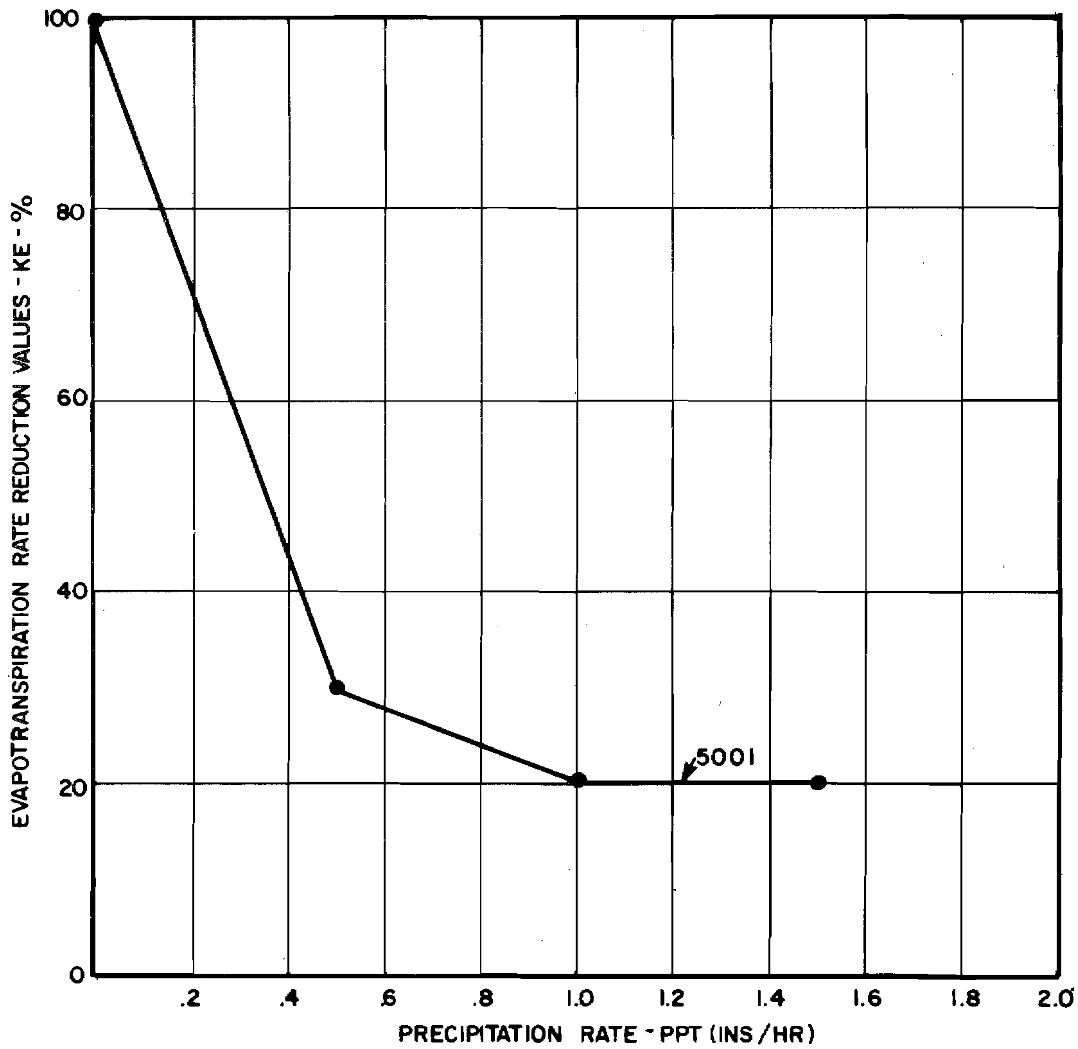



| | | |
|---|---|---|
| DESIGNED BY | | |
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL QGEN VS SCA

FIGURE A2.24

ACRES

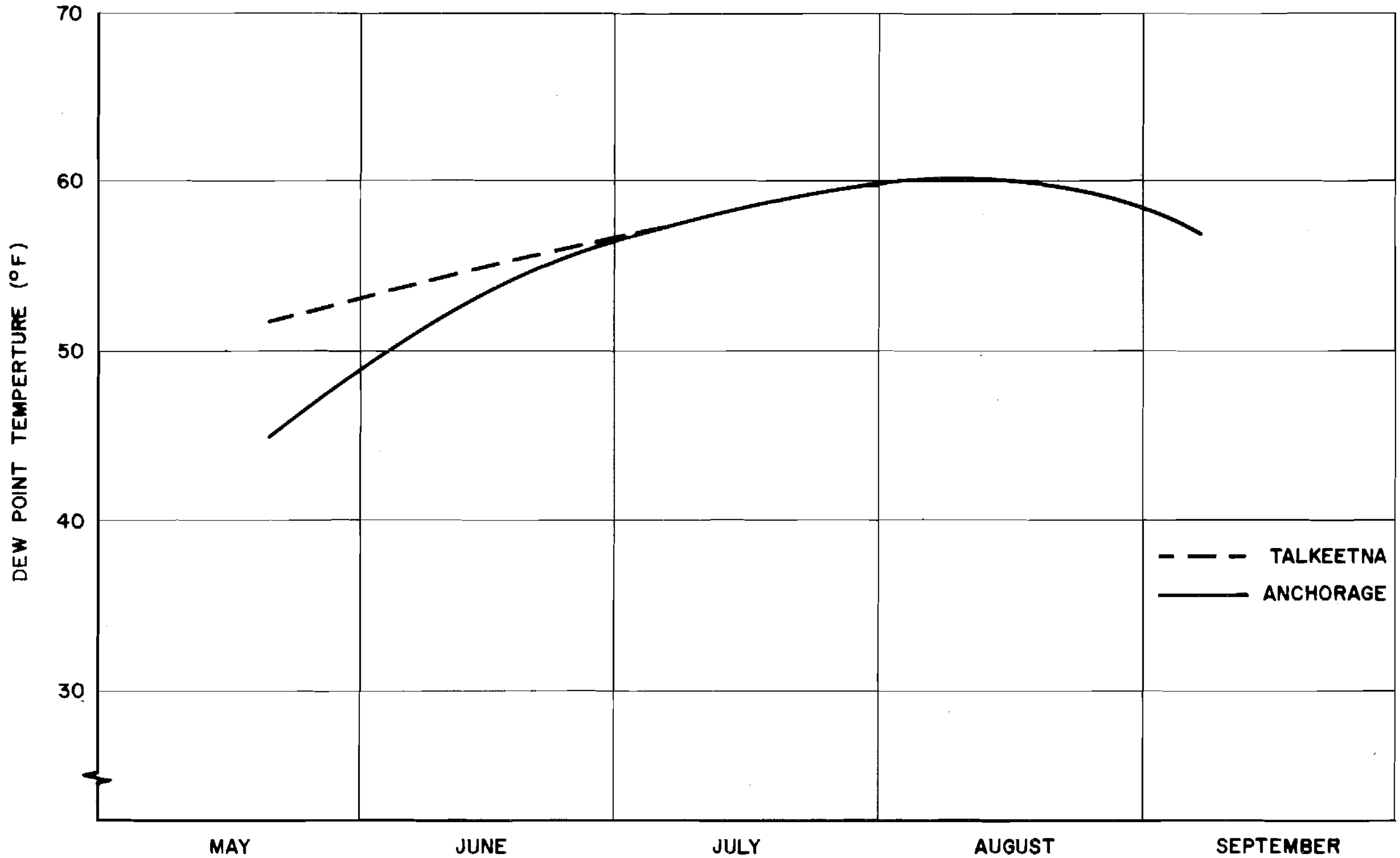



| DESIGNED BY | | |
|---|---|---|
| DRAWN BY | | |
| CHECKED BY | | |

SSARR MODEL PPT VS KE

FIGURE A2.25

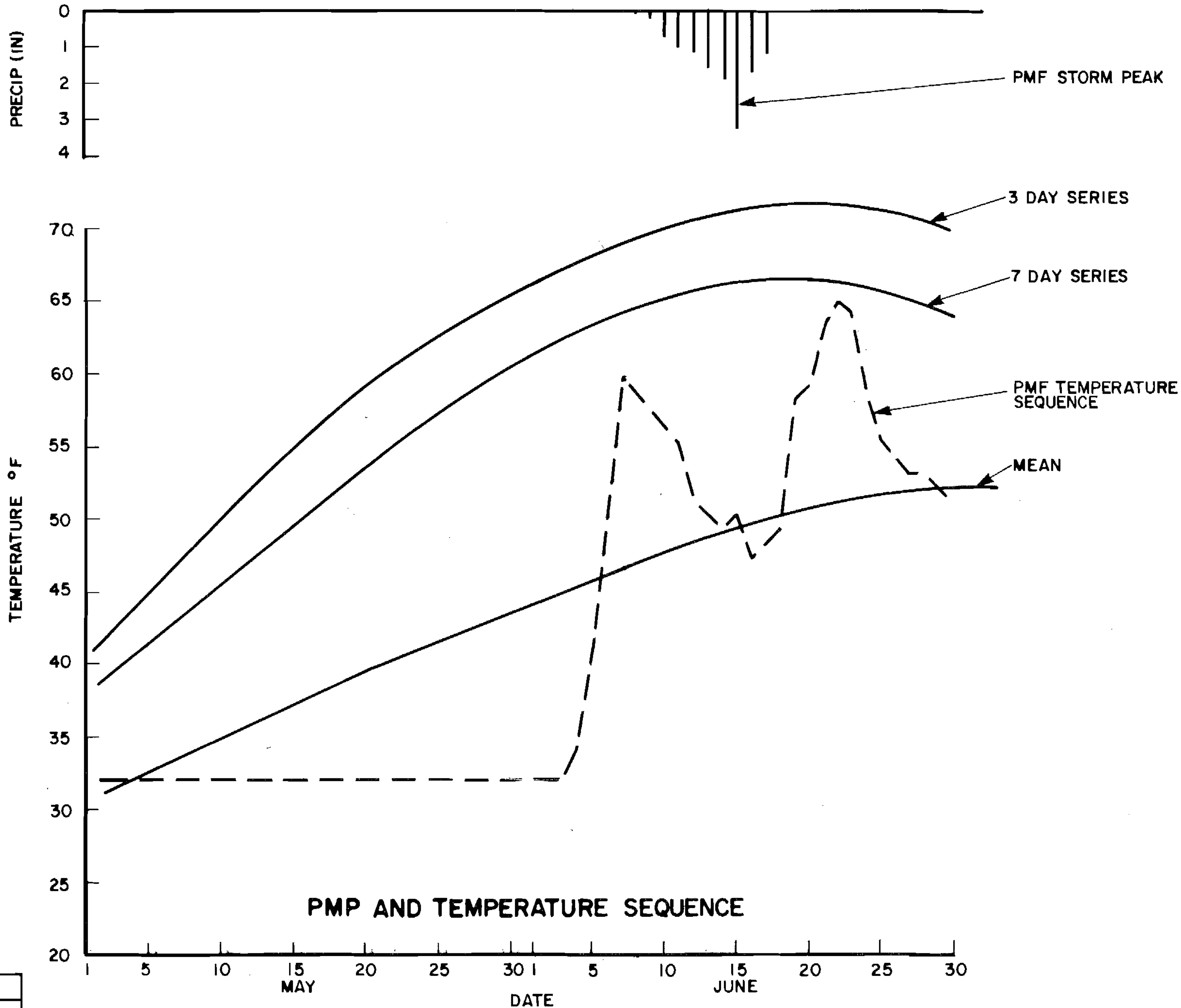
ACRES




50 YEAR MAXIMUM 12 HOUR PERSISTING DEW POINT TEMPERATURES

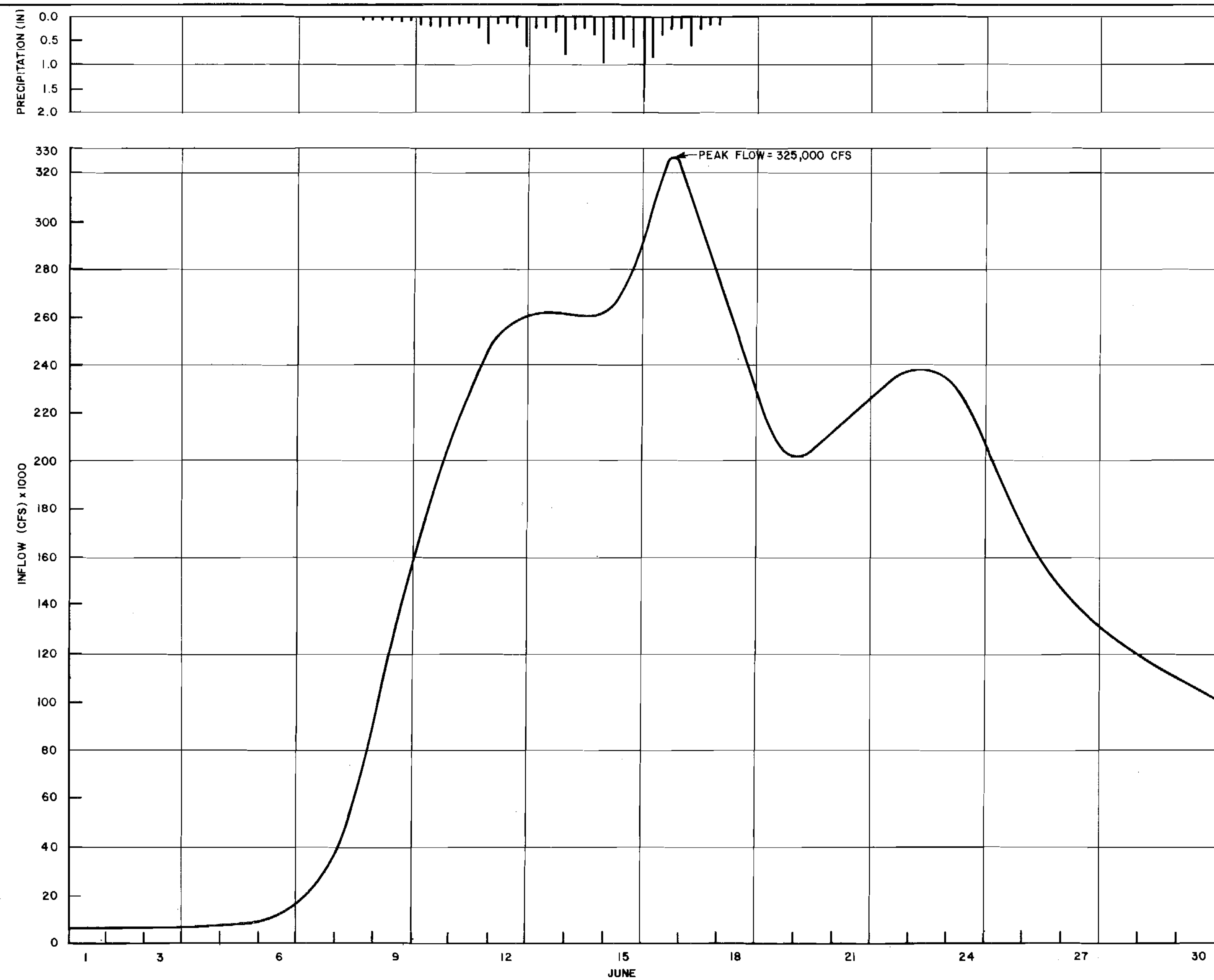
FIGURE A2.26

ACRES




| | | |
|---|---|---|
| DESIGNED BY | | |
| DRAWN BY | | |
| CHECKED BY | | |

FIGURE A2.27




WATANA PMF INFLOW HYDROGRAPH

FIGURE A2.28

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ATTACHMENT 1
SUBTASK 3.05 (ii) - CLOSEOUT REPORT
PROBABLE MAXIMUM FLOOD DETERMINATION

## TABLE OF CONTENTS

# 1 - INTRODUCTION

Results of feasibility studies undertaken by the U.S. Army, Corps of Engineers (COE) for the Susitna Hydroelectric Project were reported in 1975 (1) and 1979 (2). These studies included determination of a Probable Maximum Flood (PMF) peak for the Watana and Devil Canyon dam sites appropriate for use in design of project spillway and related facilities. The location of the dam sites and main tributaries to the Susitna River are given in Figure 1.1.

As part of the Acres American Plan of Study (POS) for the Susitna Hydroelectric Project dated February 1980 and revised in September 1980, Subtask 3.05(ii) has been undertaken with the following objectives:

- To review the input parameters used in determining PMF peaks;
- To determine the sensitivity of PMF peaks to changes in critical input parameters; and
- To determine if the results are appropriate for use in the current study and if not, to outline steps required to re-evaluate the PMF.

The results of these studies are reported in this document. Section 2 is a summary of the work undertaken and the results obtained. In Section 3 there is a description of the scope of work performed and in Section 4 the results of the review of the COE evaluation are discussed. Sensitivity analyses are described in Section 5 and in Section 6 are the necessary steps required to re-evaluate the PMF for use in Phase 1 Susitna Design Studies.

# 2 - SUMMARY

## 2.1 - Review of COE Evaluations

The COE evaluated the PMF by means of a calibrated river basin computer model which simulates streamflow in response to specified temperature and precipitation.

The study includes a detailed review of the COE model, 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 entailed systematic plausible changes to the snowpack, temperature and precipitation values to determine the relative importance of these parameters to the peak flood.

These studies indicate the following:

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

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

- Both the magnitude of the probable maximum precipitation and the temperature sequences were based on tentative estimates made by NWS. In their report, the NWS noted the need for a more detailed analysis (Appendix A).

## 2.2 - Sensitivity Analyses

Sensitivity analyses indicated that the peak flow associated with the PMF event could be considerably higher than that previously estimated by the COE. Further re-evaluation of the PMF on the basis of more comprehensive climatological data and study using an appropriate modeling procedure is therefore considered to be essential as input to the current feasibility studies. This re-evaluation is further justified by the fact that the Susitna project is large, involving large capital outlays and is very important to the future development of Alaska.

## 2.3 - 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. We consider that 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 difficulty in acceptance of the model results is further compounded by the lack of any verification runs. We conclude, therefore, that the procedures of calibration should be repeated and several verification runs be made to prove the acceptability of model parameters and accuracy limits that can be applied to PMF estimates.

The sensitivity runs indicate that the estimates of peak inflow to Watana Reservoir and discharges at any other location are particularly sensitive to variations in snowpack water equivalents, temperature gradient and temperature maximums and precipitation volumes and intensity. Sensitivity to changes in subbasin parameters are small relative to the sensitivity of the basin to the three main input parameters given above. Table 2.1 summarizes each sensitivity run and gives the percent change from the COE estimate for inflow and outflow into Watana Reservoir. Percent changes to inflow and outflow for Devil Canyon Reservoir are summarized in Table 2.2.

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 back-up computations are available or information on which form of storm maximization procedure used. No comment can be made on the validity of these precipitation analyses. It is therefore concluded that due to the sensitivity of the PMF estimate to precipitation, further analyses should be performed under established guidelines and with reliable procedures.

It is also concluded that, 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.

### 2.4 - 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 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 conjunction to re-evaluate the PMF.

## 3 - SCOPE OF WORK

### 3.1 - Probable Maximum Flood Evaluation

The 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 Probable Maximum Precipitation (PMP). The timing of these maximum events is usually assumed to be such that the resultant peak is maximized. 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 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.

A computer simulation model of the basin is usually 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 ease 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 of spring and summer PMF events. In undetaking this work, the following review steps were performed:

(a) Review of COE Work

(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 sections.

## 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 has 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 aspects.

The assumed values are then "fine tuned" to obtain 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 considered to be acceptable at this stage.

### (b) Data Discrepancies

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

(i) For Maclaren Glacier a table, Number 4006 is specified for the 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 accurancy 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.

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

(iii) 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 2.6 percent, with peak flows occurring approximately twelve hours earlier.

(iv) Total drainage basin area at Gold Creek determined by summing individual sub-basins equals 6,135 square miles. Actual drainage at Gold Creek is 6,160 square miles.

In Acres sensitivity runs, the discrepancies noted above have been revised. The revision of discrepancies given in (i) and (ii) do not seriously effect streamflow estimates as they only effect flows from Maclaren Glacier subbasin which represents approximately 0.7 percent of the drainage basin area at Gold Creek station. Effects of revision to temperature sequence are discussed in (iii) above. The drainage area difference does not seriously effect PMF estimates.

## 4.2 - Calibration and Verification Studies

The results of calibration and verification studies are provided to indicate in as 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 that 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.

Review of the COE studies has found no evidence that verification of the model was undertaken; only calibration runs were apparently made. Consequently, it is likely that the accuracy of the modeling approach adopted has not been adequately 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 tributaties 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 (1) appear to be in error as they do not agree with the computer output values. Tables 4.2 to 4.4 also show 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 percent and 14 percent for 1964 and 1972 floods respectively. However, snowmelt floods peaks at the next upstream gage (Cantwell) are consistently over-estimated by 4.1 percent and 0.5 percent for 1964 and 1972 respectively. No conclusive pattern was found for Denali and Maclaren gages. Rainfall flood peak estimation for 1971 is 4.6 percent less than the observed value at Gold Creek gage and is 22.2 percent greater than the observed value at the Cantwell gate. 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 some 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 the PMF estimates has been made and the accuracy of the model has not been assessed.

## 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.

### 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 the 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 on June 11 due to snowmelt 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 sequence during the PMP and for the four preceeding days was obtained by the COE from the National Weather Service (NWS). The temperature and PMP storm are given in a memo from the NWS to COE and is attached in Appendix A. 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 consits of two storms, one 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.

## 5.3 - Sensitivity Studies

Three main groups of sensitivity runs were performed to determine the effect on the flood peak due to 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 from as much as 60 percent of the available area. In the base run, approximately 1270 sq. miles or 20 percent 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 juxtaposition 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 percent increase in peak inflow. The hydrograph is given in Figure 5.5. The above result 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 one 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 being 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 appraisel 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 assumed. 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 to Watana Reservoir of 302,000 cfs an increase of 29.6 percent, 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 give 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 station 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 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 Nay 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 percent. 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 percent 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 for the COE by the NWS involved only a summer rainfall envent. The NWS recommended that 70 percent of the summer PMP be used as the PMP storm for spring PMF estimates. No basis for this decision to use 70 percent 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 percent 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 percent 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 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 percent. Outflow from Watana Reservoir obtained from the above sensitivity runs are shown on Figure 5.6.

### 5.4 - Reservoir Storage

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 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 attentuate the flood peak significantly.

For the summer PMF, reservoir levels are close to maximum so no significant flood storage is likely. 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.

## 6 - RE-EVALUATION OF PMF

### 6.1 - Introduction

The work discussed above shows that no high degree of confidence can be given to the present estimate of the PMF peak. Consequently it is concluded that a more comprehensive PMF study should be undertaken to re-evaluate the PMF peak estimates. The steps required in this re-evaluation are given below.

### 6.2 - Objectives

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

### 6.3 - Approach

The approach will entail reassessing 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 techniques. The calibration will start with assuming that the basin's meteorological and hydrological parameters used in the COE PMF estimates are the most representative. These parameters may be adjusted as analysis proceeds.

When a 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.

## 6.4 - Discussion

The motivation of 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 Tables 2.1 and 2.2.

The meteorological data used in the COE estimates were developed by the NWS in a preliminary study which given 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 increses to the PMF peak found in the sensitivity analysis.

LIST OF REFERENCES

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

(2) U.S. Army Corps of Engineers, "Supplemental Feasibility Report, South-central Railbelt Area, Alaska", 1979.

TABLE 4.1: COE CALIBRATION STUDY RESULTS: SUSITNA RIVER AT GOLD CREEK
USGS GAGE NO. 15292000 DRAINAGE AREA 6160 $mi^2$

| Period | Flood Event | Maximum Discharge | | | | % Difference | Observed Peak Return Period - tp (years) |
|---|---|---|---|---|---|---|---|
| | | Observed | Date | Calculated | Date | | |
| 1964<br>19 May to 25 June | Snowmelt | 85,900 | 7 Jun | 80,500 | 5 Jun | -6.3 | 16.0 |
| 1967<br>1 Jul to 31 Aug | Rainfall | 76,000 | 15 Aug | 78,800 | 16 Aug | +3.7 | 8.8 |
| 1971<br>6 May to 30 Sep | Snowmelt | 66,300 | 12 Jun | 53,000 | 11 Jun | -20.1 | - |
| | Rainfall | 77,700 | 10 Aug | 74,100 | 12 Aug | -4.6 | 9.5 |
| 1972<br>2 May to 30 Sep | Snowmelt | 70,700 | 17 Jun | 60,800 | 17 Jun | -14.0 | 6.5 |
| | Rainfall | 26,400 | 14 Sep | 32,300 | 15 Sep | +22.4 | - |

TABLE 4.2: COE CALIBRATION STUDY RESULTS: SUSITNA RIVER NEAR CANTWELL
USGS GAGE NO. 15291500 DRAINAGE AREA 4140 $mi^2$

| Period | Flood Event | Maximum Discharge | | | | % Difference | Observed Peak Return Period - tp (years) |
|---|---|---|---|---|---|---|---|
| | | Observed | Date | Calculated | Date | | |
| 1964<br>19 May to 25 June | Snowmelt | 49,100 | 7 Jun | 51,100 | 4 Jun | -4.1 | 11.1 |
| 1967<br>1 Jul to 31 Aug | Rainfall | 36,400 | 15 Aug | 36,600 | 16 Aug | +0.1 | 3.2 |
| 1971<br>6 May to 30 Sep | Snowmelt | 24,000 | 23 Jun | 32,600 | 23 Jun | +35.8 | - |
| | Rainfall | 36,000 | 9 Aug | 44,000 | 11 Aug | +22.2 | 3.1 |
| 1972<br>2 May to 30 Sep | Snowmelt | 37,600 | 17 Jun | 37,800 | 17 Jun | +0.5 | 3.6 |
| | Rainfall | 21,000 | 14 Sep | 22,800 | 15 Sep | +8.6 | - |

TABLE 4.3: COE CALIBRATION STUDY RESULTS: MACLAREN RIVER NEAR PAXSON
USGS GAGE NO. 15291200 DRAINAGE AREA 280 $mi^2$

| Period | Flood Event | Maximum Discharge | | | | % Difference |
|---|---|---|---|---|---|---|
| | | Observed | Date | Calculated | Date | |
| 1964<br>19 May to 25 June | Snowmelt | 6,400 | 7 Jun | 6,230 | 4 Jun | -2.7 |
| 1967<br>1 Jul to 31 Aug | Rainfall | 7,280 | 14 Aug | 7,290 | 15 Aug | 0.0 |
| 1971<br>6 May to 30 Sep | Snowmelt | 5,520 | 25 Jun | 5,430 | 25 Jun | -1.6 |
| | Rainfall | 8,100 | 11 Aug | 7,980 | 10 Aug | -1.5 |
| 1972<br>2 May to 30 Sep | Snowmelt | 6,680 | 16 Jun | 7,780 | 16 Jun | +16.5 |
| | Rainfall | 3,980 | 13 Sep | 2,950 | 12 Sep | -25.9 |

TABLE 4.4: COE CALIBRATION STUDY RESULTS: SUSITNA RIVER NEAR DENALI USGS GAGE NO. 15291000 DRAINAGE AREA 950 $mi^2$

| Period | Flood Event | Maximum Discharge | | | | % Difference | Observed Peak Return Period - tp (years) |
|---|---|---|---|---|---|---|---|
| | | Observed | Date | Calculated | Date | | |
| 1964<br>19 May to 25 June | Snowmelt | 16,000 | 7 Jun | 17,200 | 4 Jun | +7.5 | 2.0 |
| 1967<br>1 Jul to 31 Aug | Rainfall | * | - | 16,000 | 16 Aug | - | - |
| 1971<br>6 May to 30 Sep | Snowmelt | 17,600 | 27 Jun | 17,300 | 24 Jun | -1.7 | - |
| | Rainfall | 33,400 | 10 Aug | 31,500 | 11 Aug | -5.7 | 37.6 |
| 1972<br>2 May to 30 Sep | Snowmelt | 14,700 | 16 Jun | 20,300 | 17 Jun | +38.1 | 1.5 |
| | Rainfall | 5,690 | 13 Sep | 15,300 | 13 Sep | +169 | - |

*No Record

TABLE 5.1: PRECIPITATION - 1:100 YR STORM (inches)

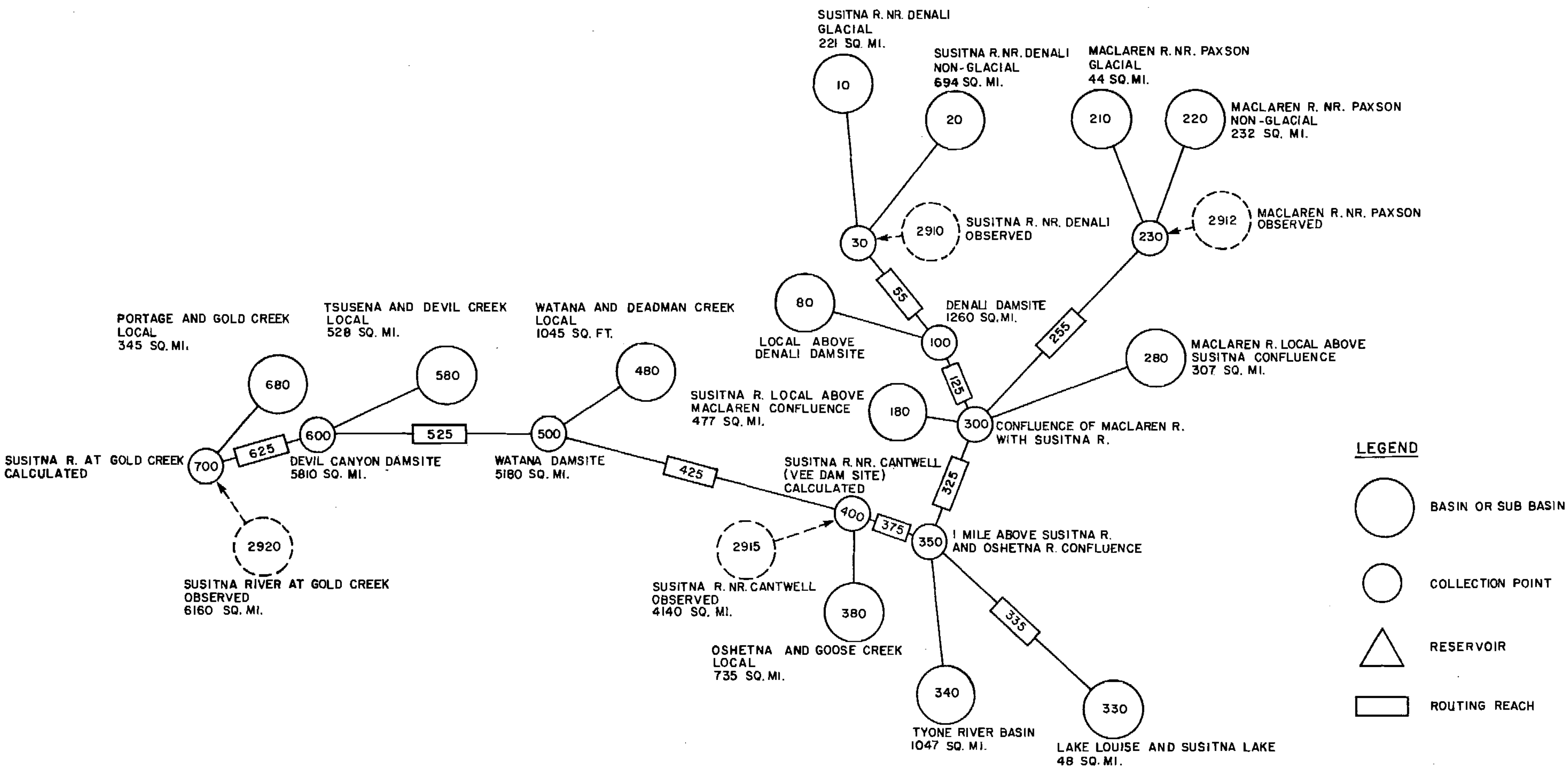
| Hour | 1st Day | 2nd Day | 3rd Day | |
|---|---|---|---|---|
| 0-6 | .04 | .14 | .04 | |
| 6-12 | .07 | .29 | .09 | |
| 12-18 | .17 | .65 | .21 | |
| 18-24 | .06 | .22 | .07 | |
| TOTAL | .34 | 1.30 | .41 | 3.05 ins |

TABLE 5.2: PRECIPITATION - PROBABLE MAXIMUM PRECIPITAITON (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 | |
| TOTAL | 2.25 | 5.40 | 1.35 | 9.0 ins. |

TABLE 5.3: SNOWPACK WATER EQUIVALENTS (inches) ON MAY 1

| Sub-basin | | 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 |

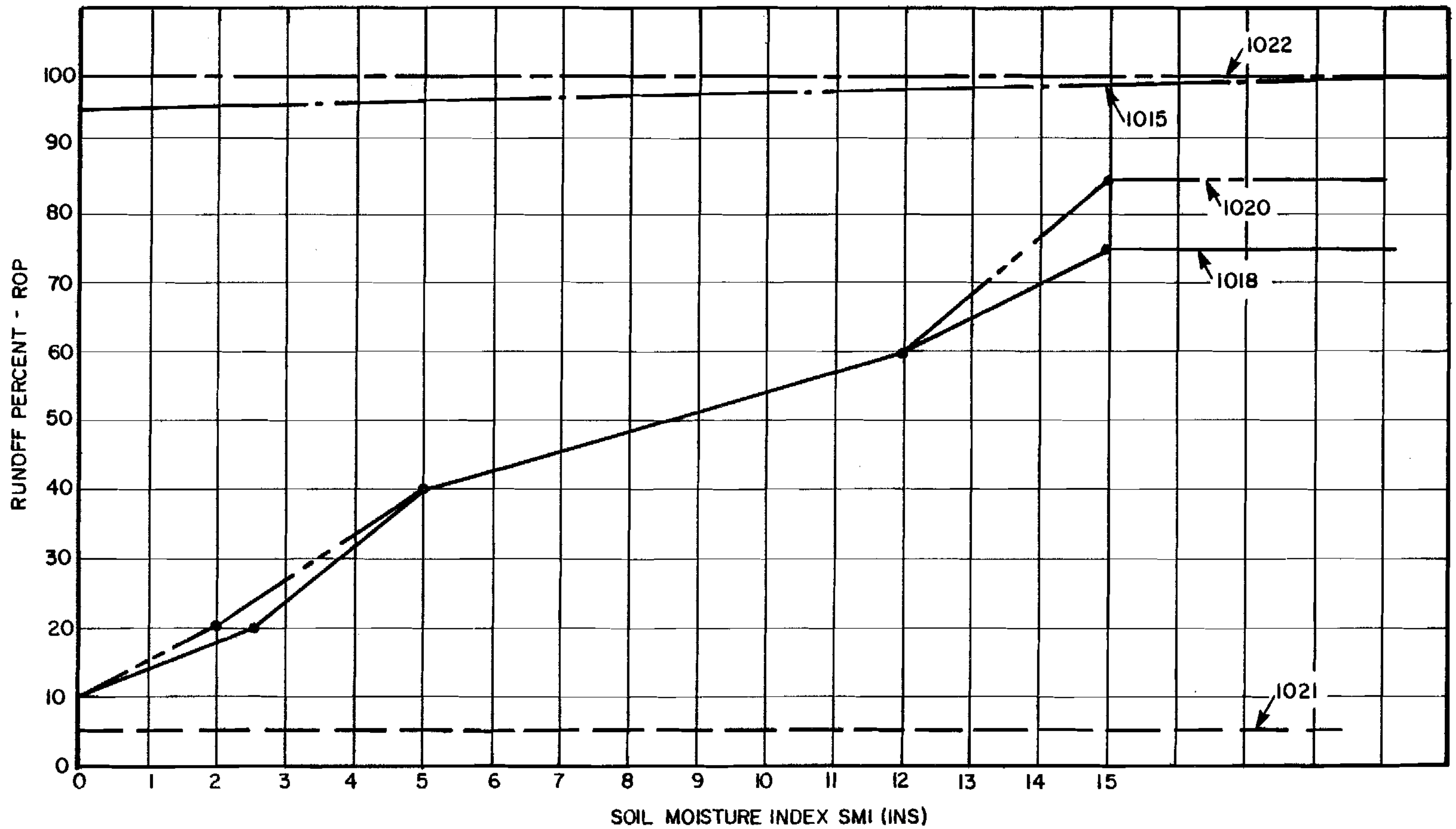



SCHEMATIC DIAGRAM OF SSARR COMPUTER MODEL

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

FIGURE 4.1

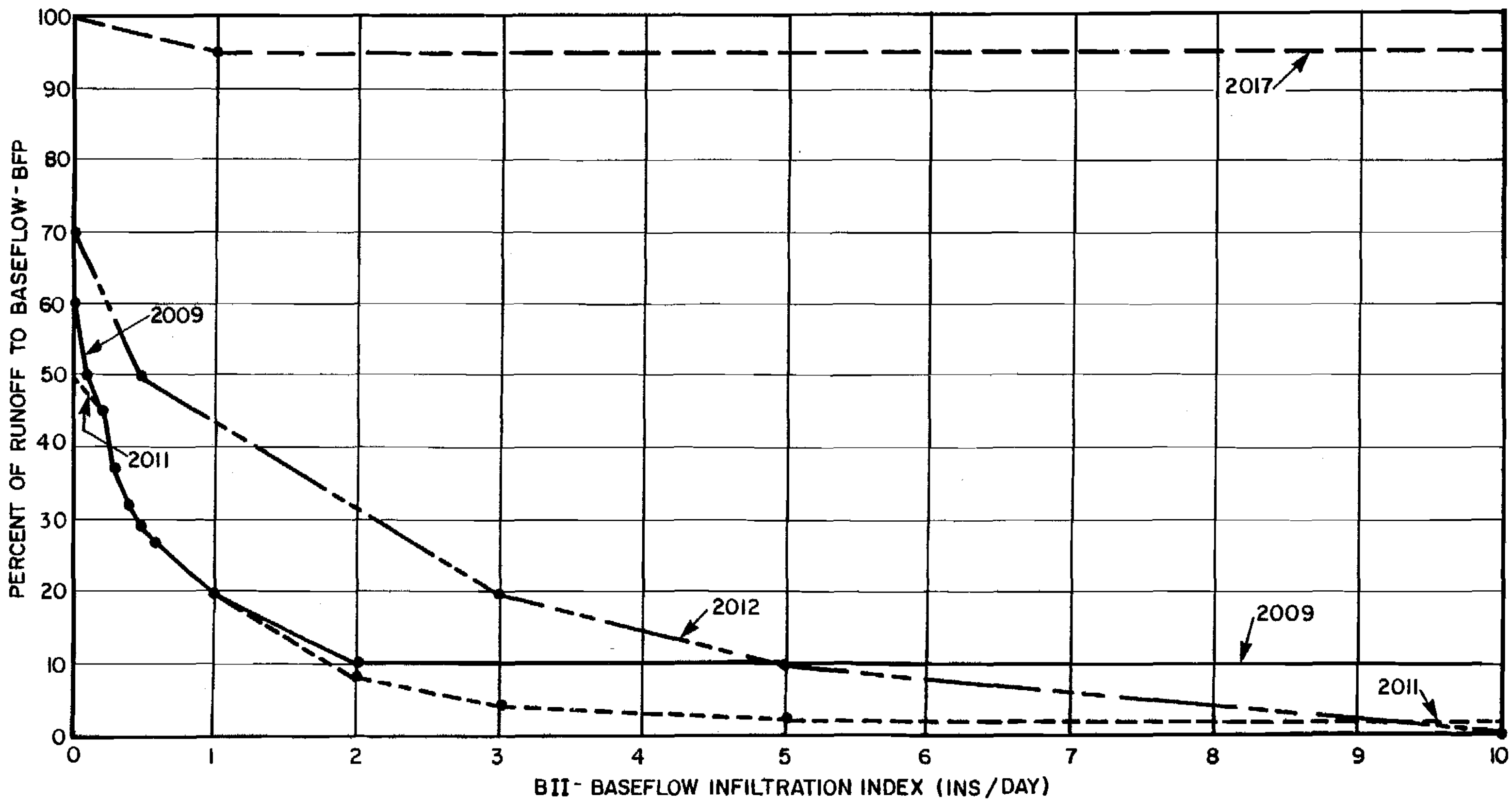
ACRES




## SSARR MODEL SMI VS ROP

FIGURE 4.2

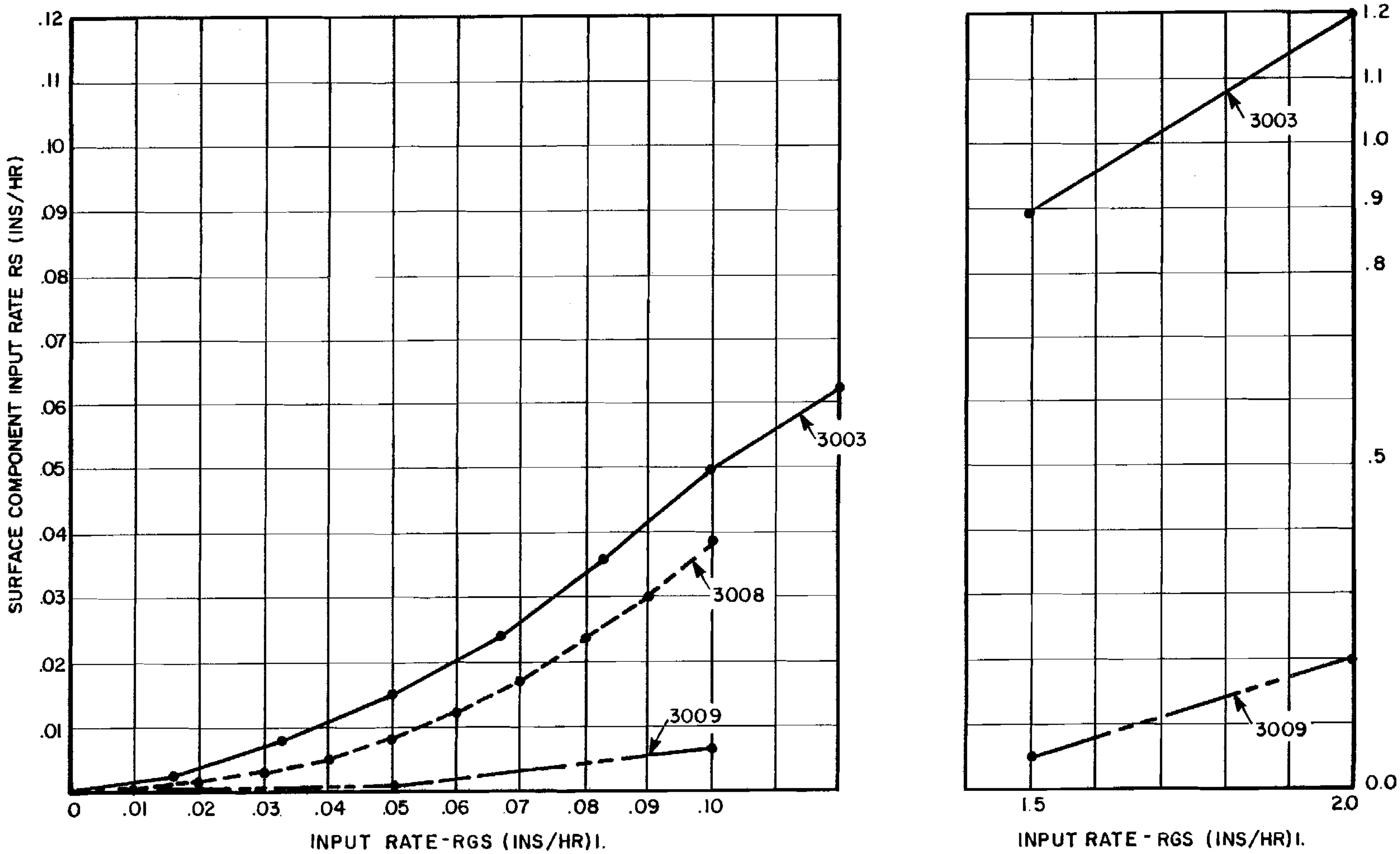
ACRES




# SSARR MODEL BII VS BFP

FIGURE 4.3

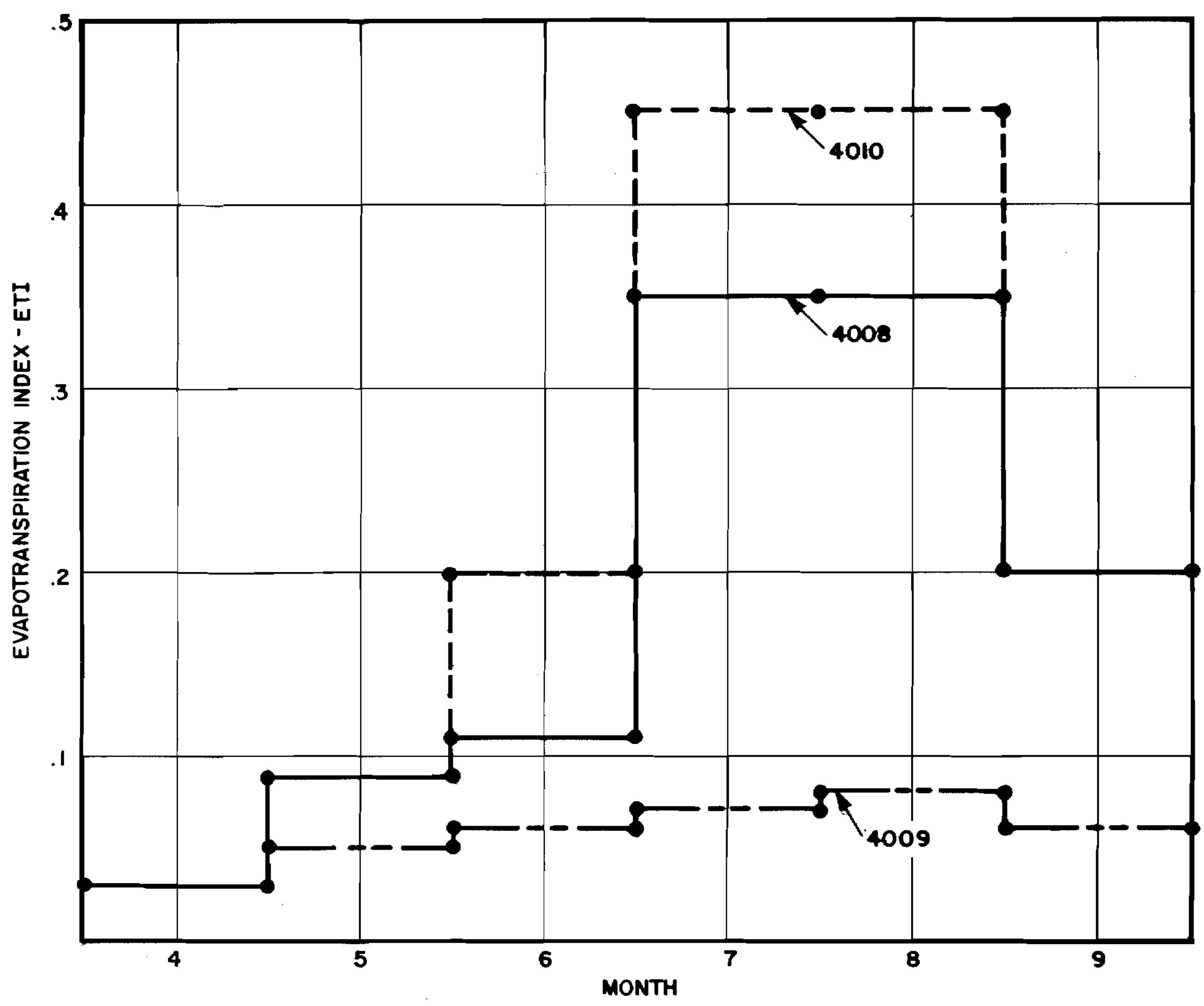
ACRES




## SSARR MODEL RGS VS RS

FIGURE 4.4

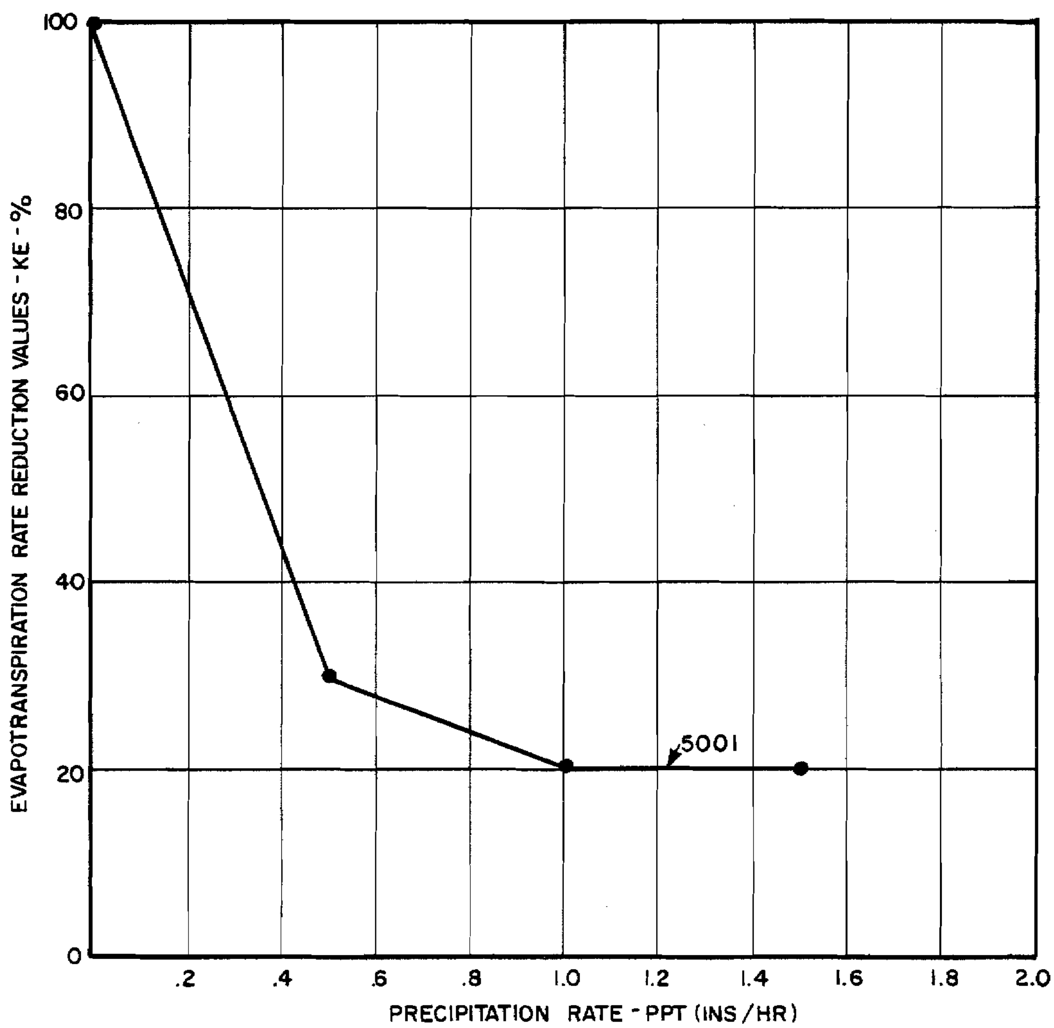
ACRES




SSARR MODEL MONTH VS ETI

ACRES

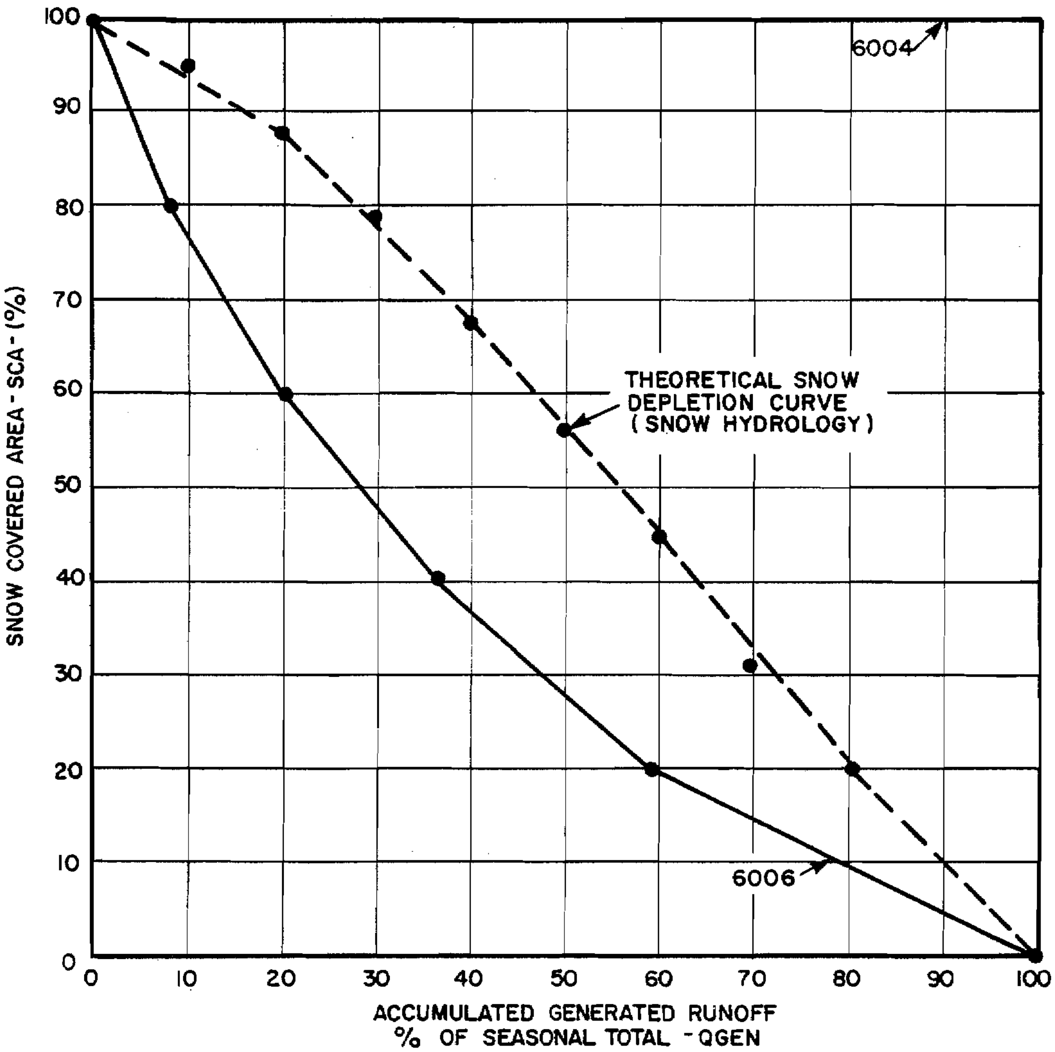
FIGURE 4.5




SSARR MODEL PPT VS KE

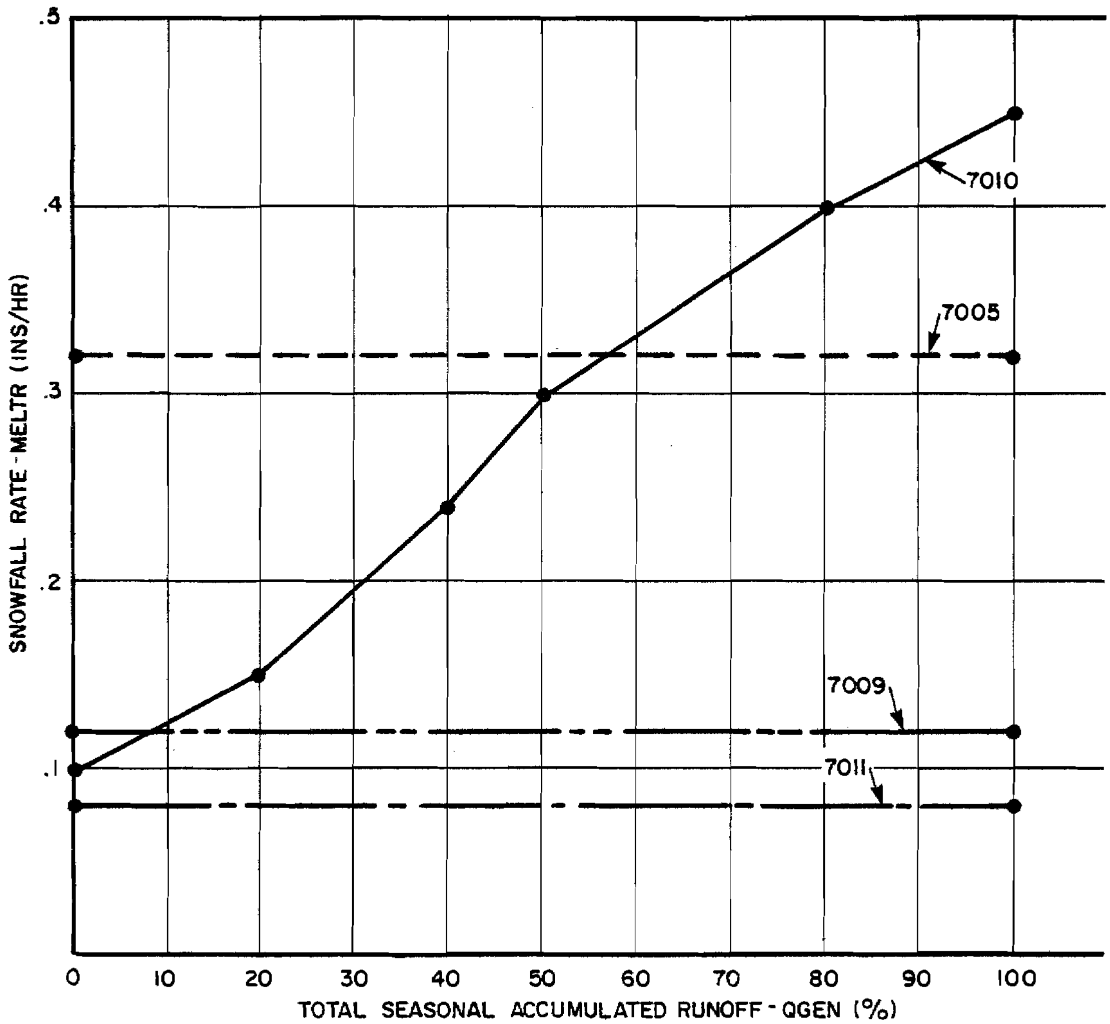
FIGURE 4.6

ACRES




# SSARR MODEL QGEN VS SCA

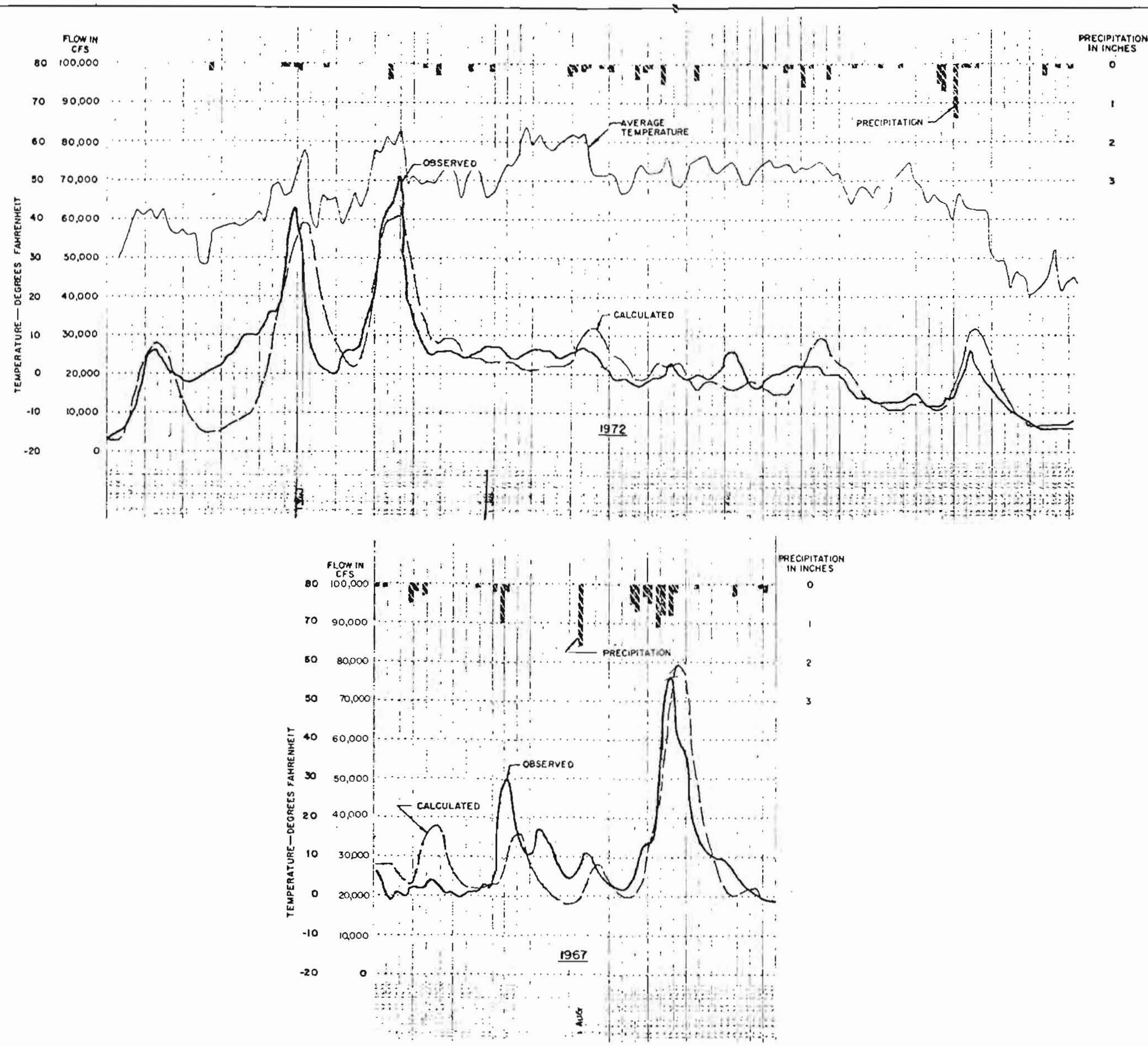
FIGURE 4.7




SSARR MODEL QGEN VS MELTR

FIGURE 4.8

ACRES

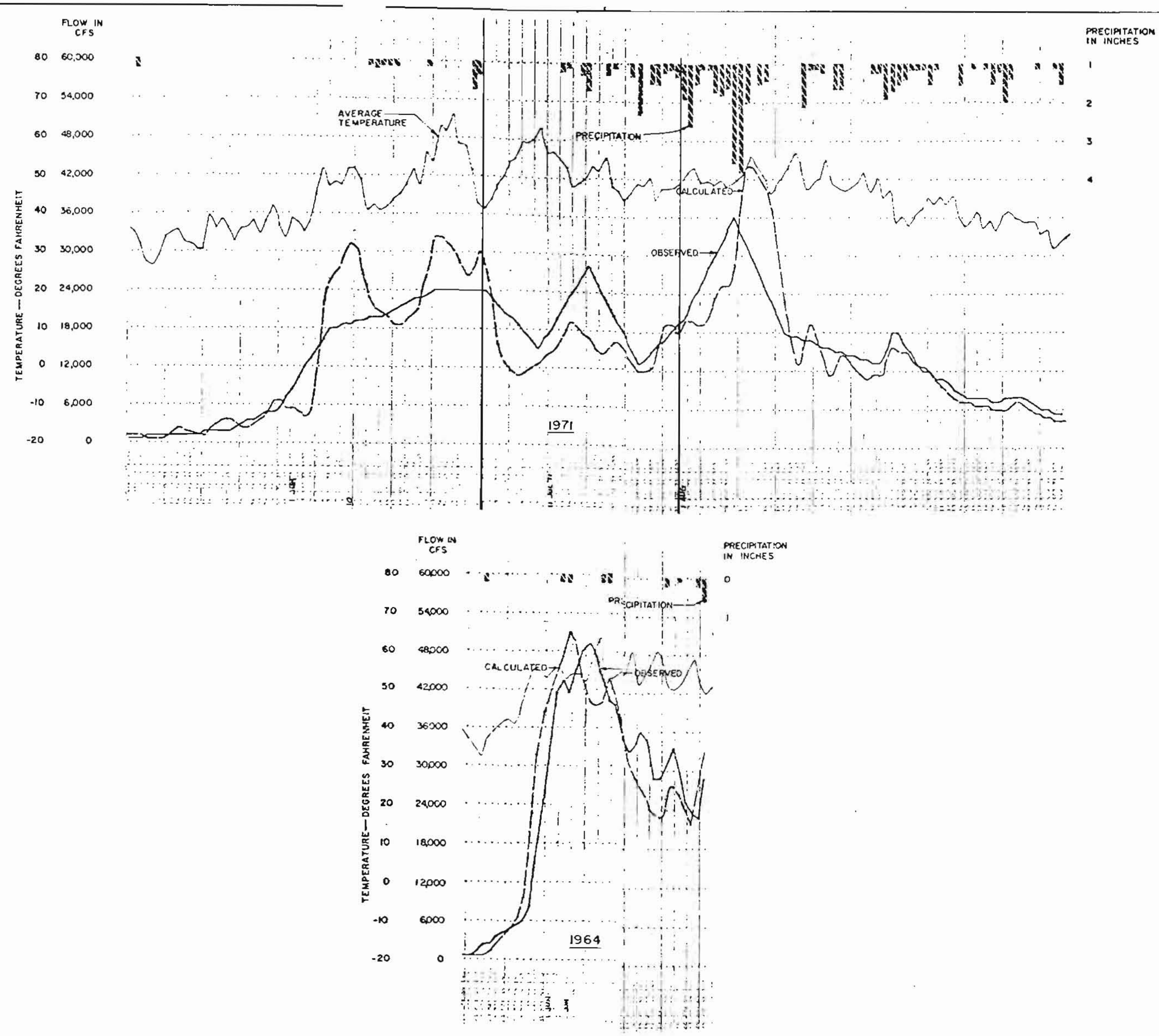



REFERENCE:
U.S. ARMY CORPS OF ENGINEERS INTERIM FEASIBILITY REPORT, 1975 APPENDIX I PART I

HYDROGRAPH : SUSITNA RIVER AT GOLD CREEK, 1967, 1972

FIGURE 4.9

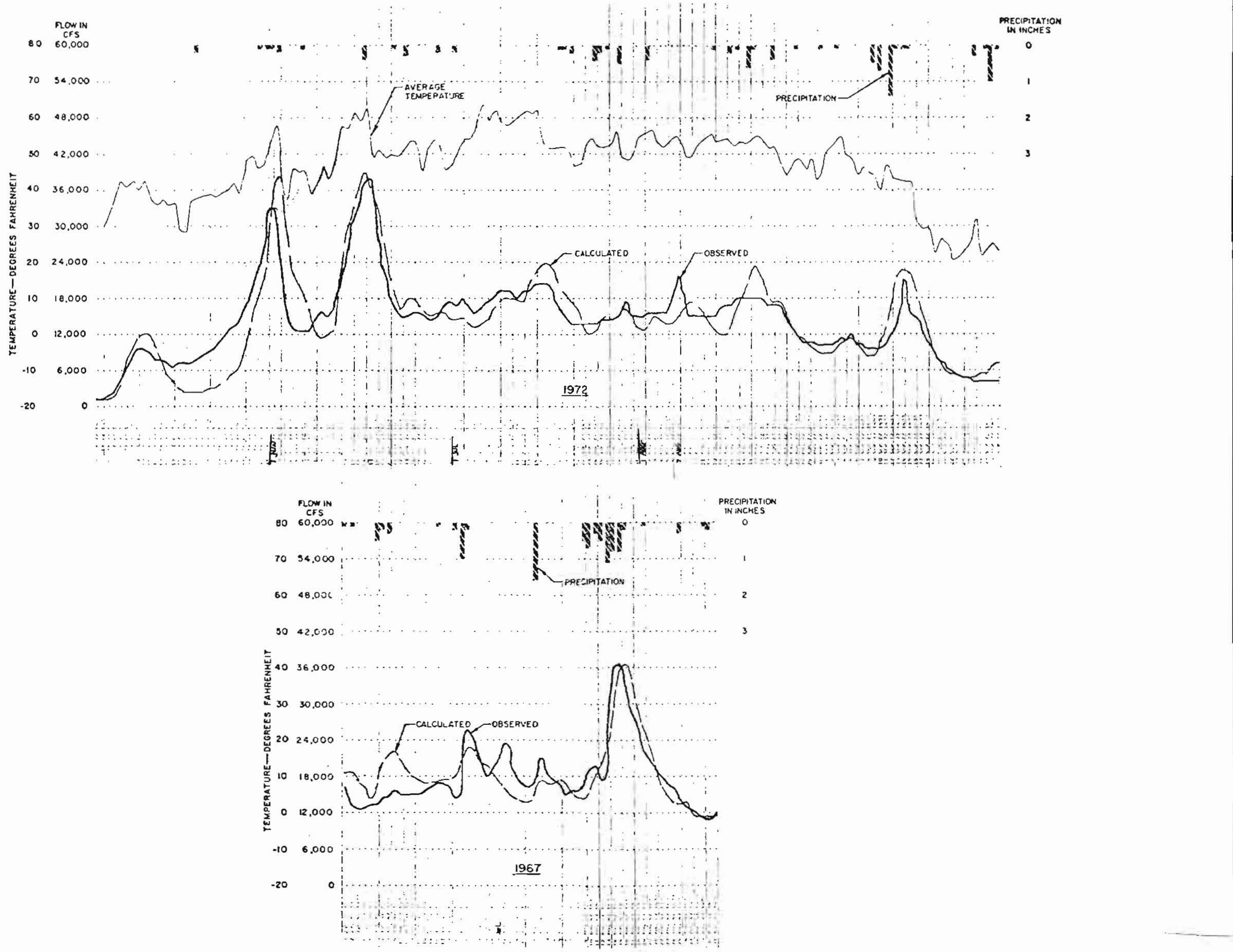
ACRES




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

HYDROGRAPH : SUSITNA RIVER NEAR CANTWELL, 1964, 1971

FIGURE 4.10 ACRES

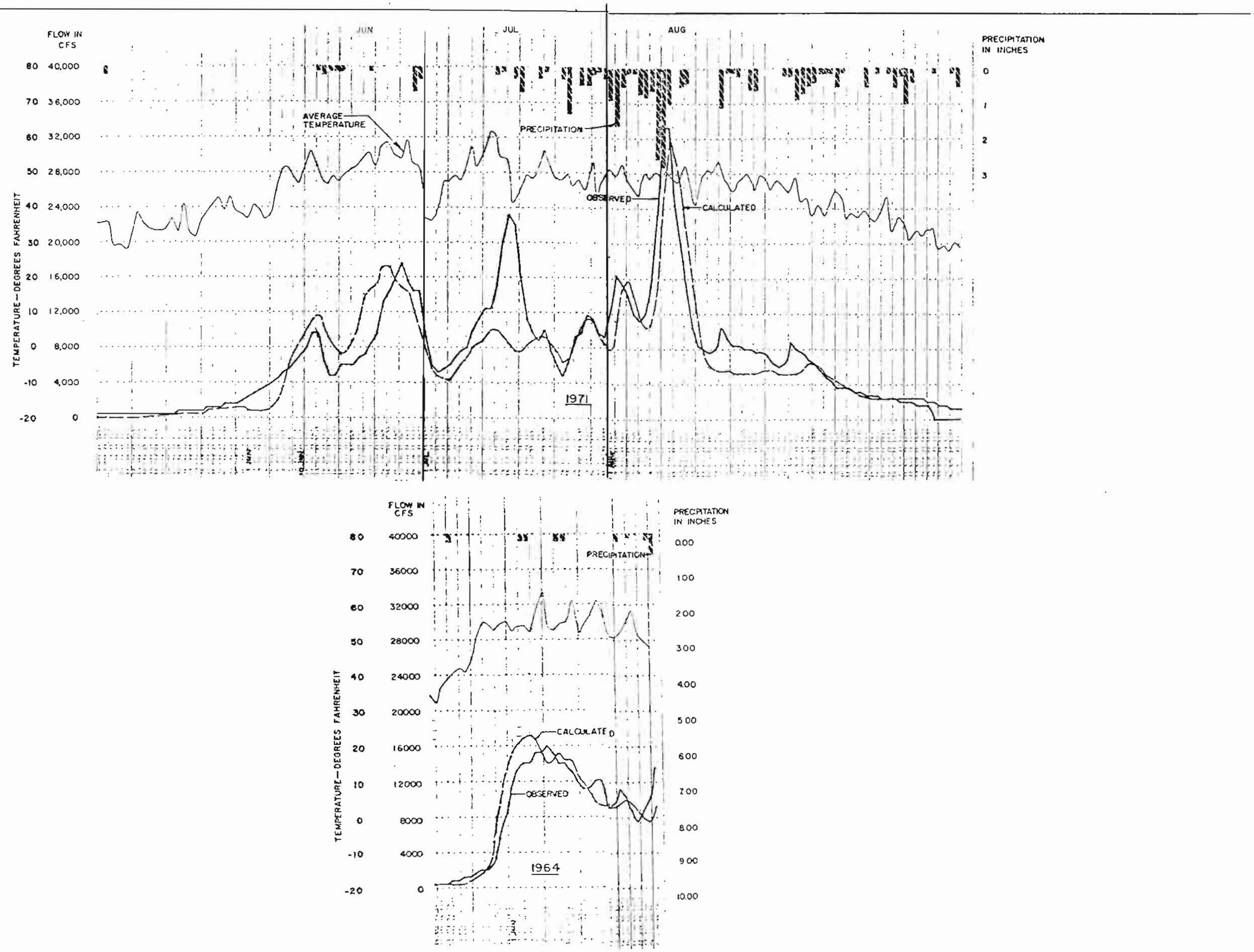



# HYDROGRAPH : SUSITNA RIVER NEAR CANTWELL, 1967, 1972

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

FIGURE 4.11

ACRES

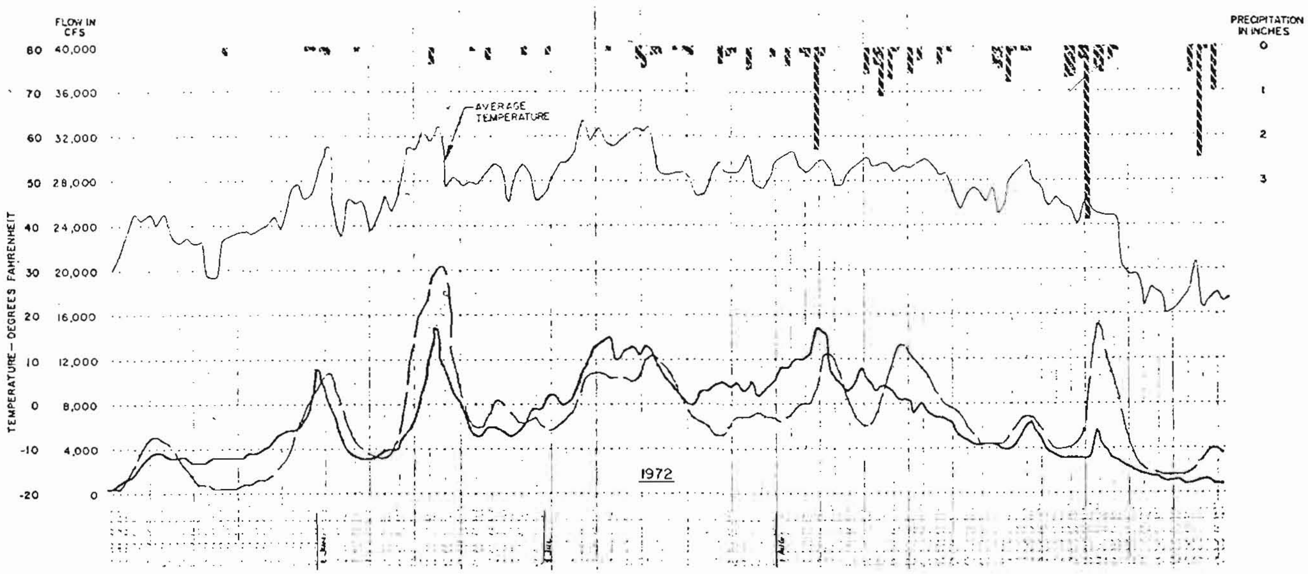



REFERENCE:
U.S. ARMY CORPS OF ENGINEERS INTERIM FEASIBILITY REPORT, 1975 APPENDIX I PART I

HYDROGRAPH SUSITNA RIVER NEAR DENALI, 1964, 1971

FIGURE 4.12

ACRES

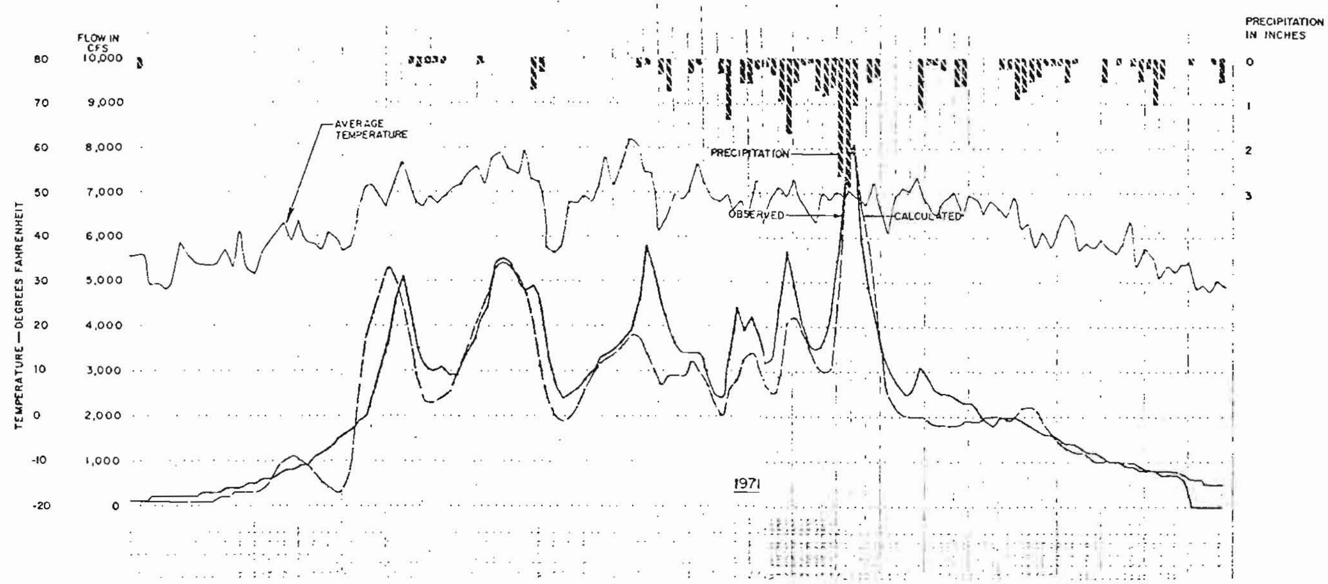


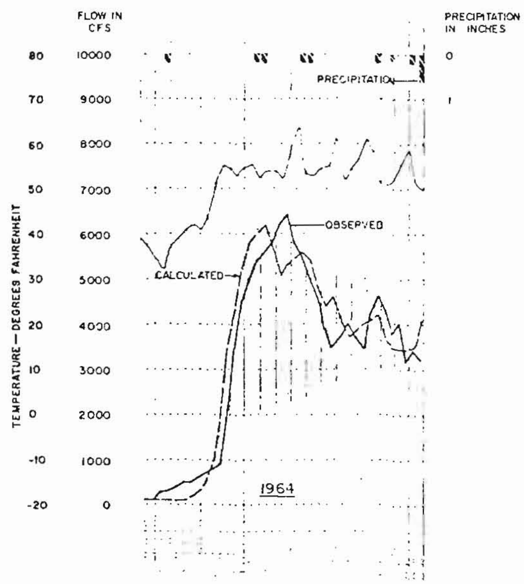

REFERENCE:
U.S. ARMY CORPS OF ENGINEERS INTERIM FEASIBILITY REPORT, 1975 APPENDIX I PART I

HYDROGRAPH SUSITNA RIVER NEAR DENALI, 1972

FIGURE 4.13

ACRES



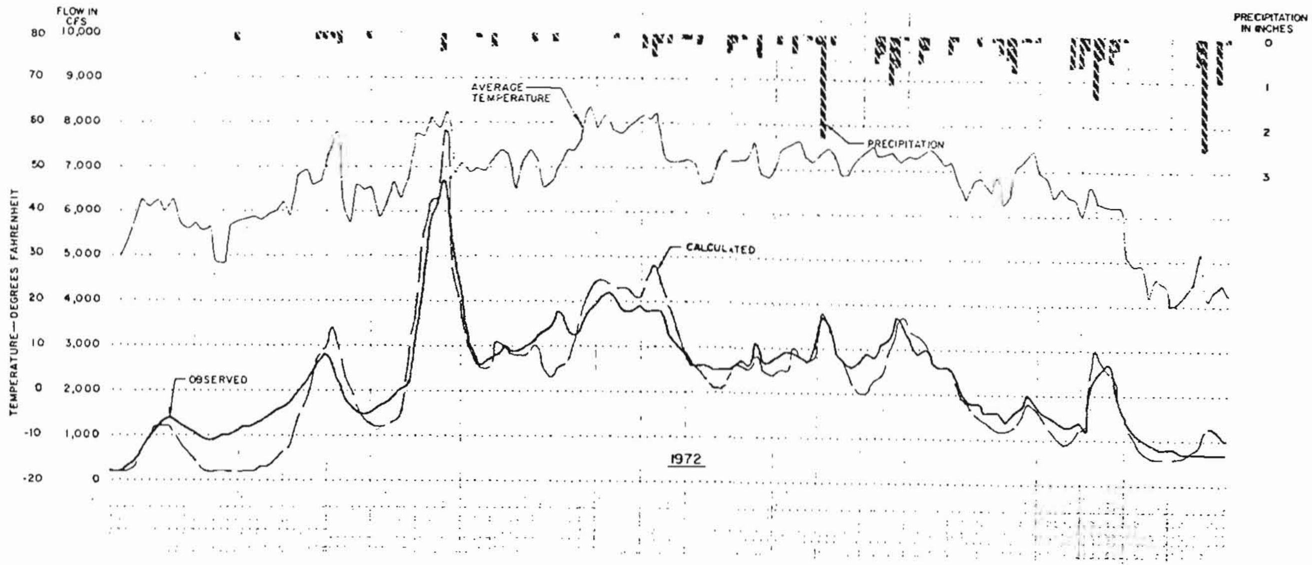



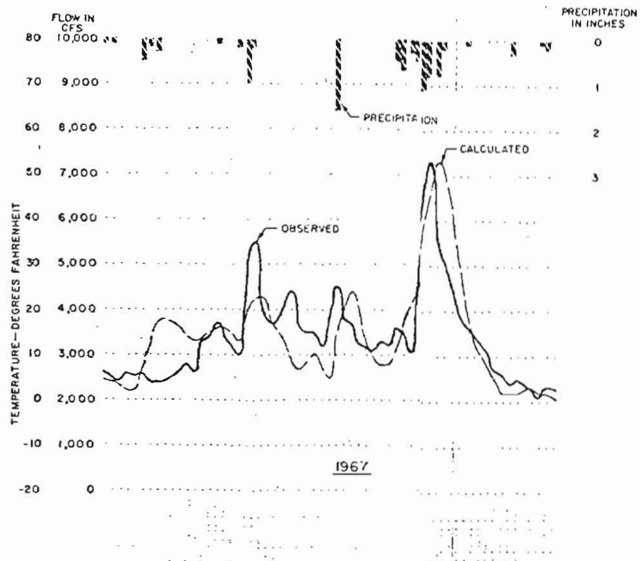

REFERENCE:
U.S. ARMY CORPS OF ENGINEERS INTERIM FEASIBILITY REPORT, 1975 APPENDIX I PART I

# HYDROGRAPH: MACLAREN RIVER NEAR PAXSON, 1964, 1971

FIGURE 4.14

ACRES

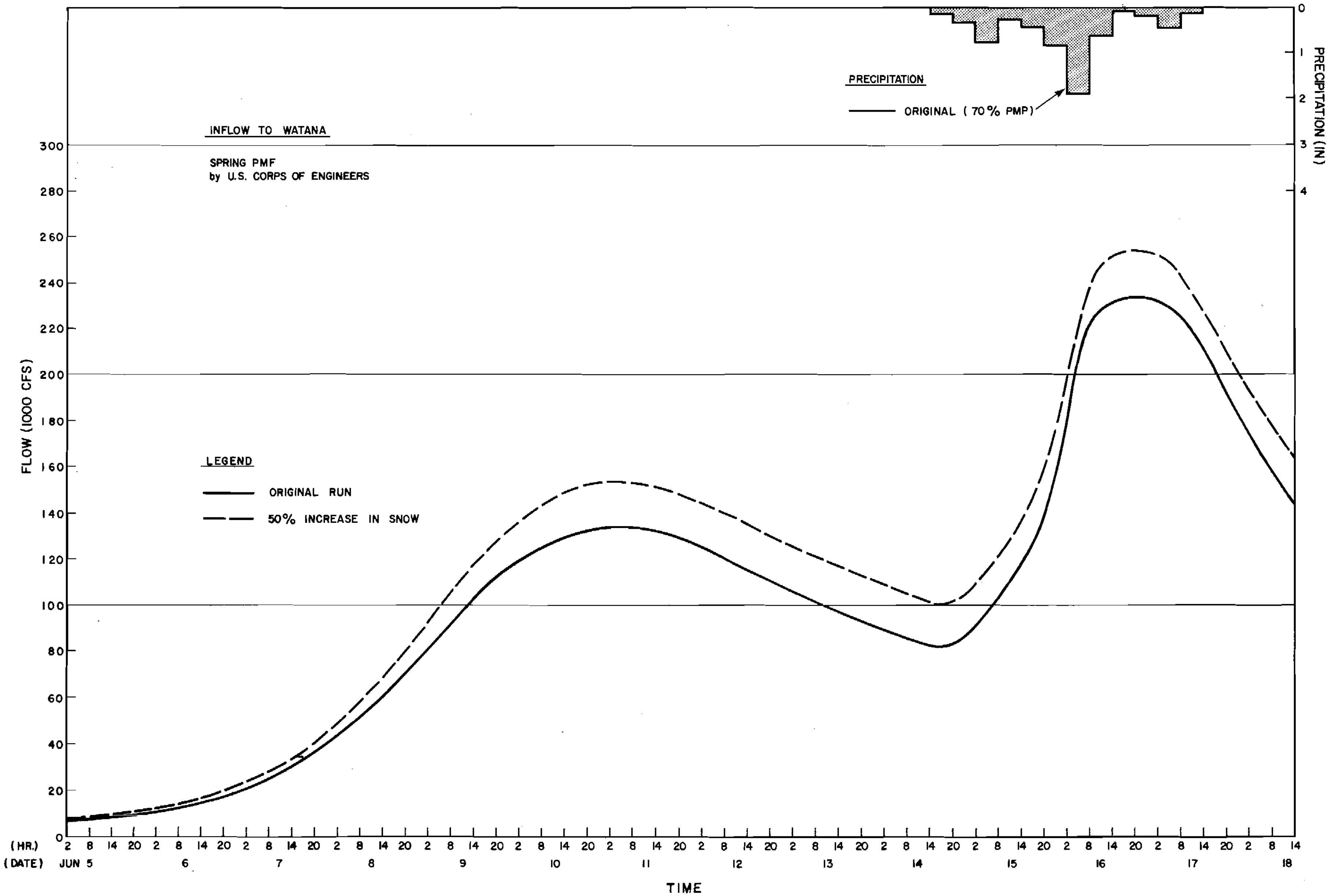



REFERENCE:
U.S. ARMY CORPS OF ENGINEERS INTERIM FEASIBILITY REPORT, 1975 APPENDIX I PART I

# HYDROGRAPH MACLAREN RIVER NEAR PAXSON, 1967, 1972

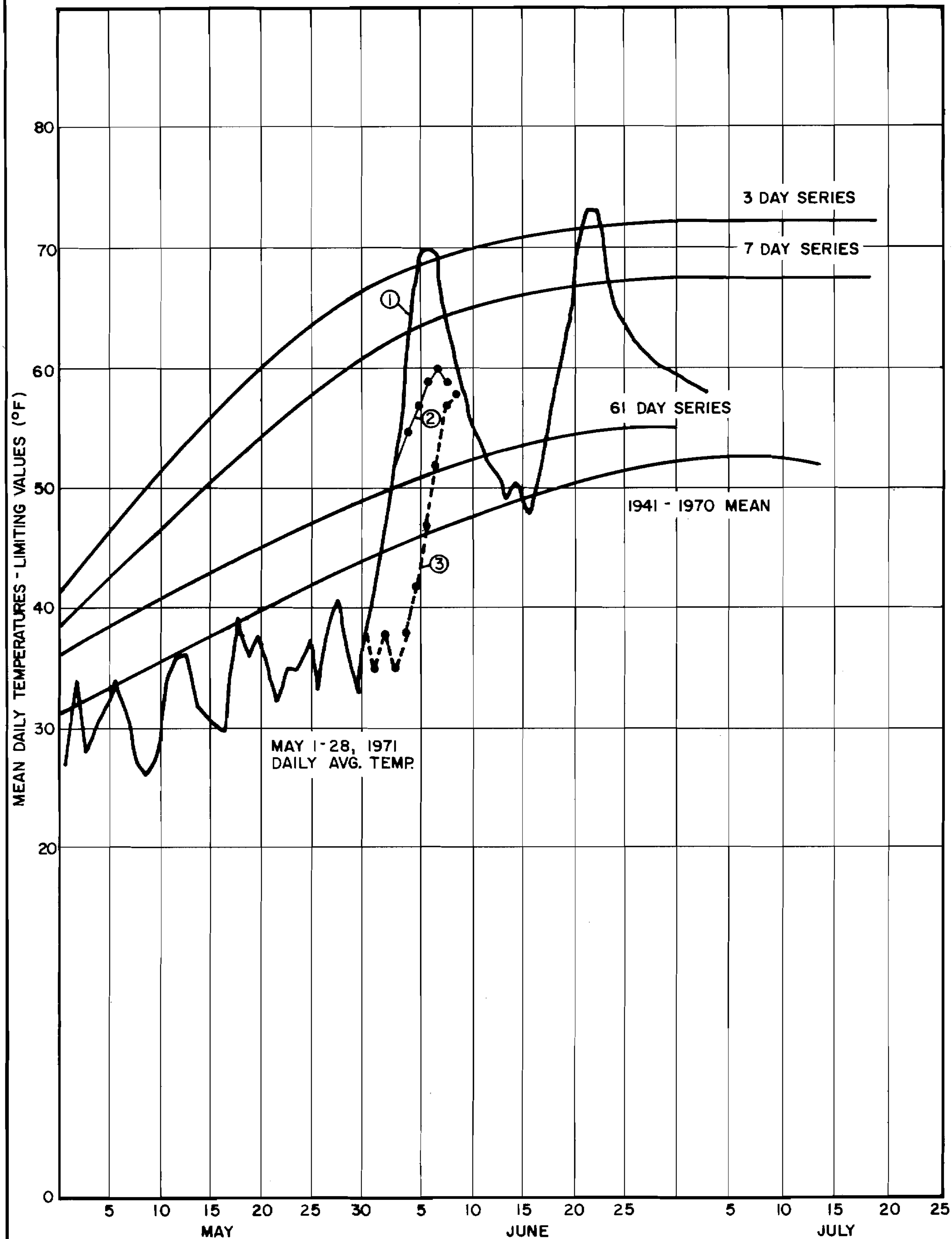
FIGURE 4.15




INFLOW TO WATANA (COE)

ACRES

FIGURE 5.1

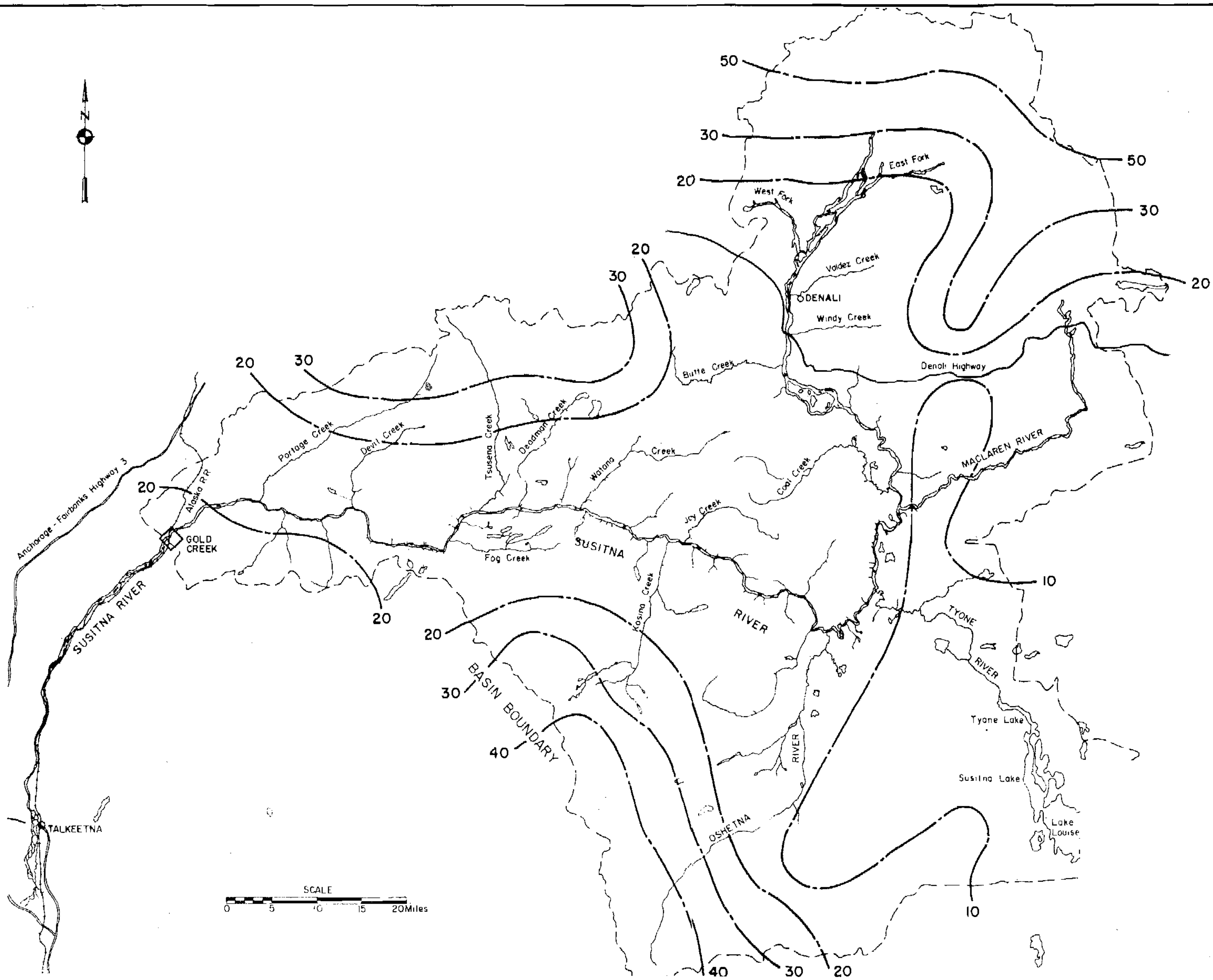



# SPRING PMF TEMPERATURE REGIME (COE)

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

ACRES

FIGURE 5.2

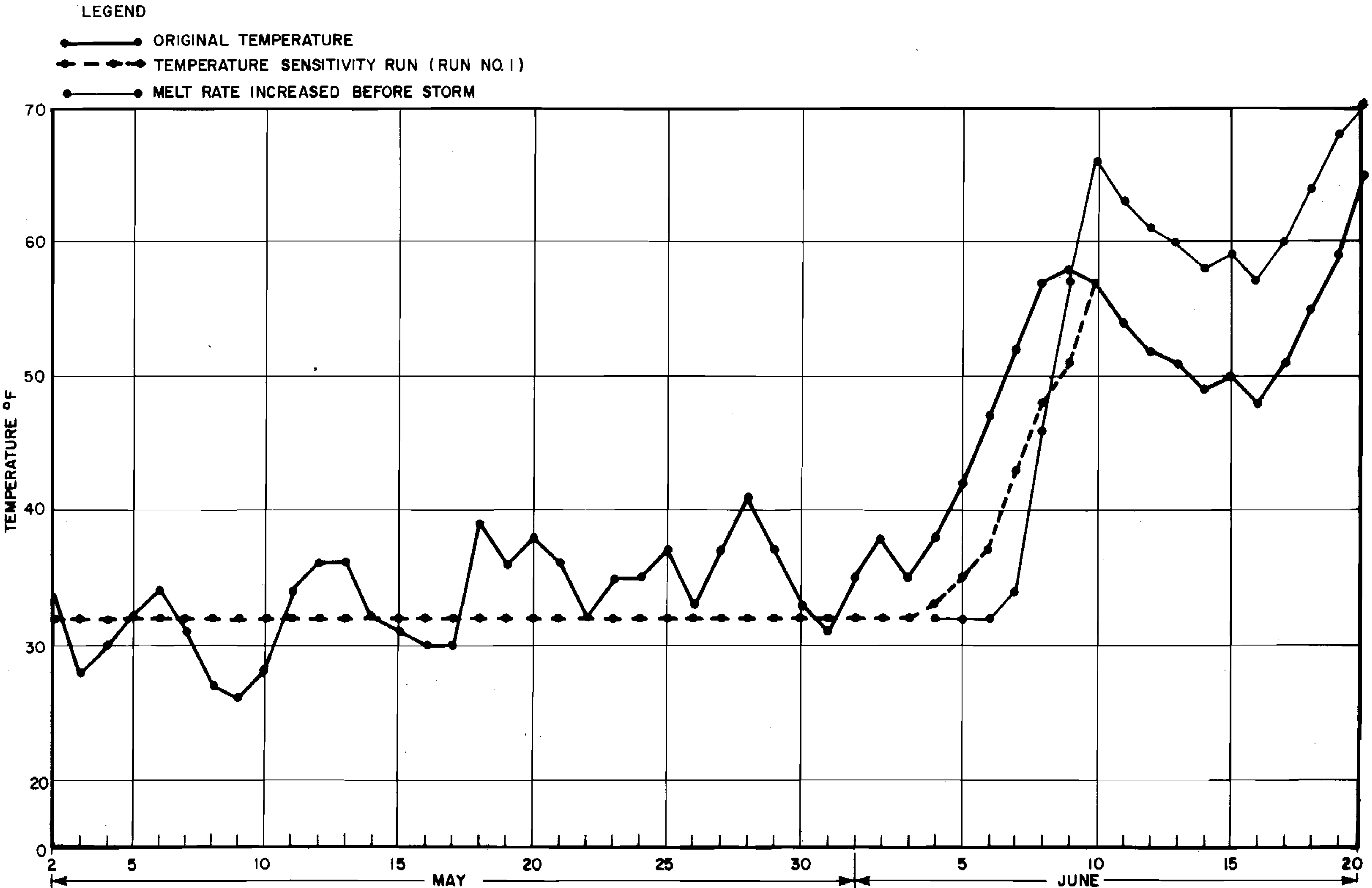



REFERENCE:
U.S. ARMY CORPS OF ENGINEERS
INTERIM FEASIBILITY REPORT, 1975
APPENDIX I, PART I

ASSUMED SNOW PACK

FIGURE 5.3

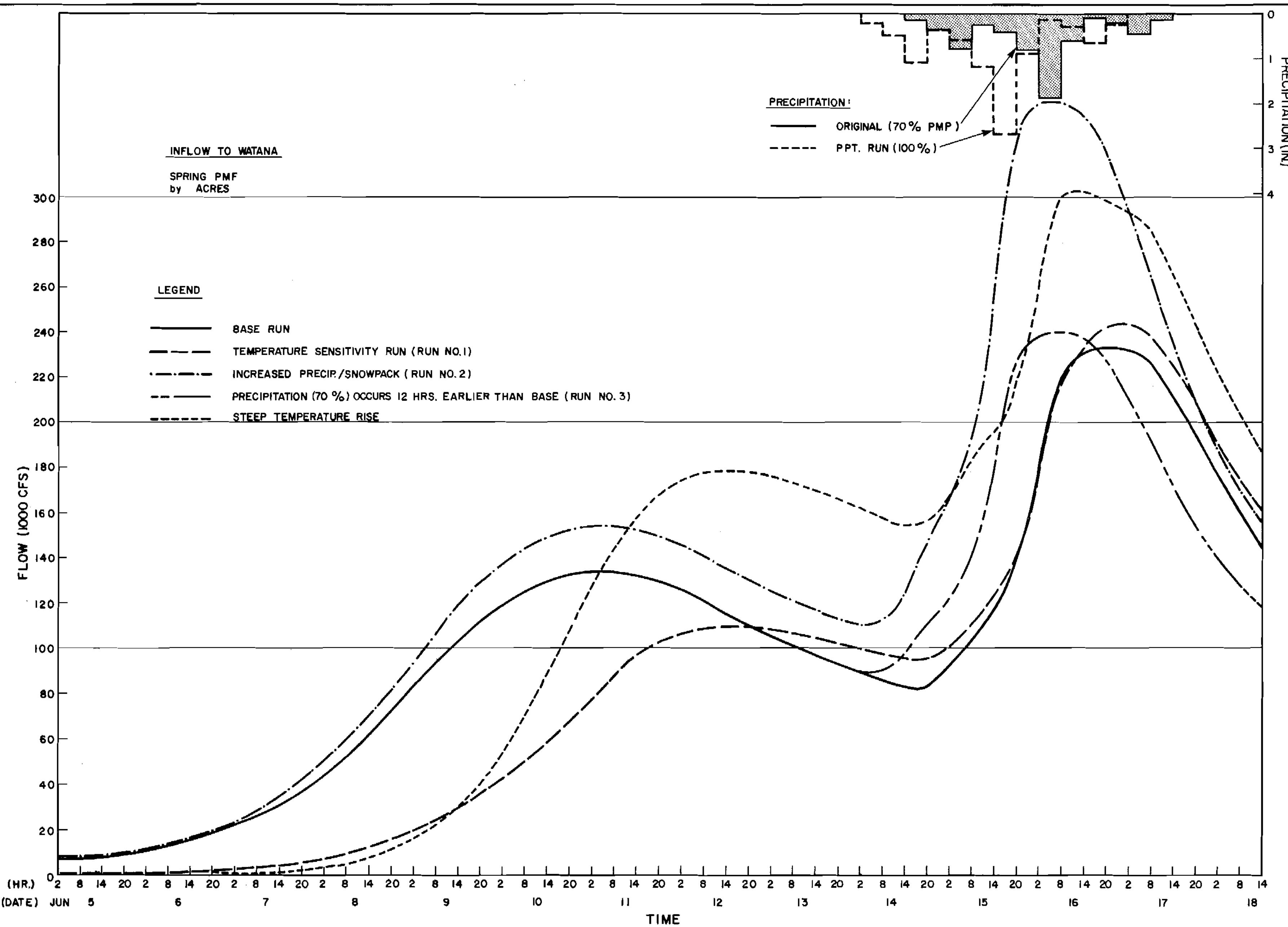
ACRES




SPRING PMF TEMPERATURE SEQUENCE 2 MAY - 20 JUNE

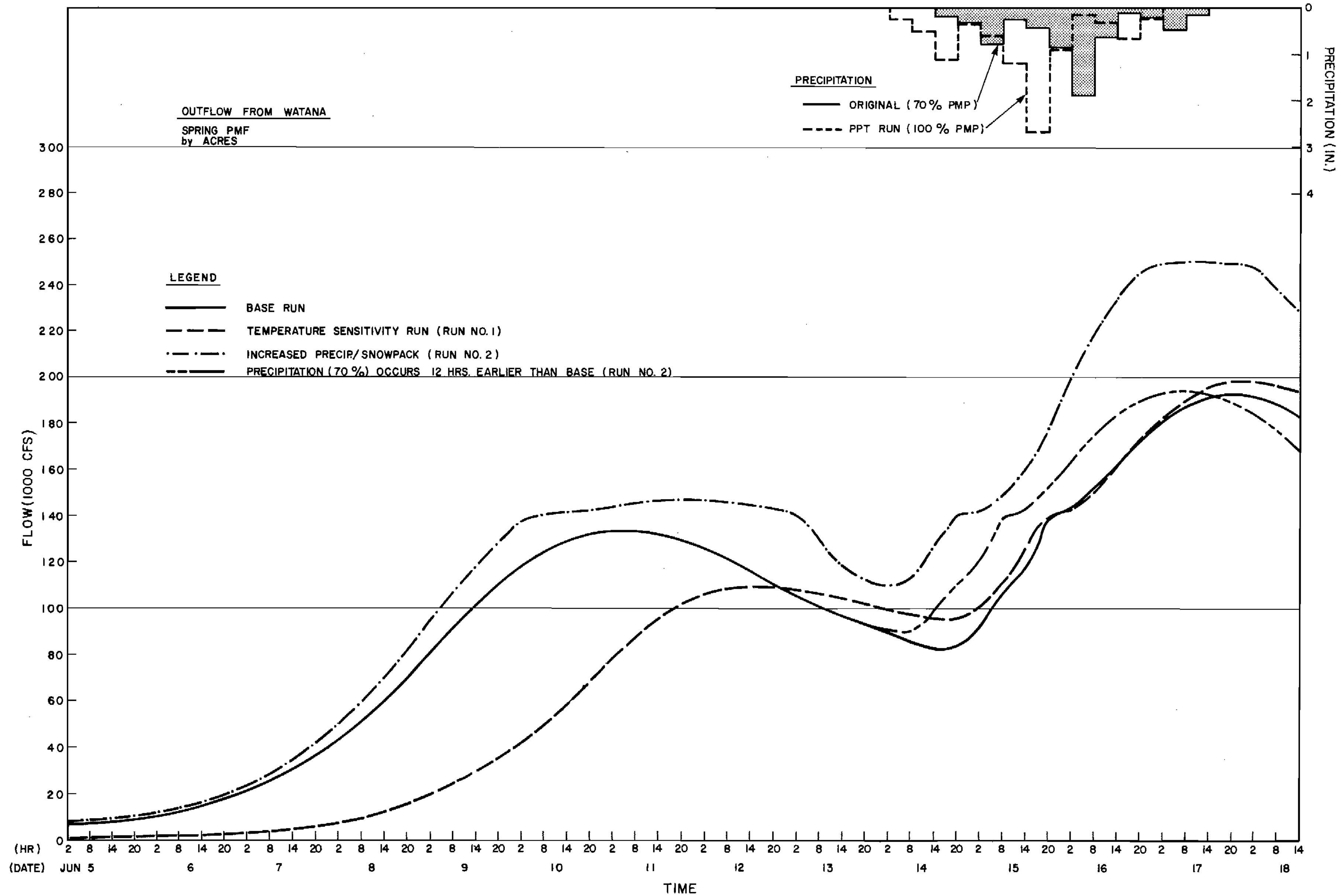
FIGURE 5.4

ACRES




INFLOW TO WATANA (ACRES)

FIGURE 5.5




OUTFLOW FROM WATANA (ACRES)

FIGURE 5.6

ACRES

SUPPLEMENT 1

DRAFT

TO: Mr. Vernon K. Hagen
Office of Chief of Engineers
Corps of Engineers
Forrestal Bldg., Rm. 5-F-039
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 Oshetna 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 |

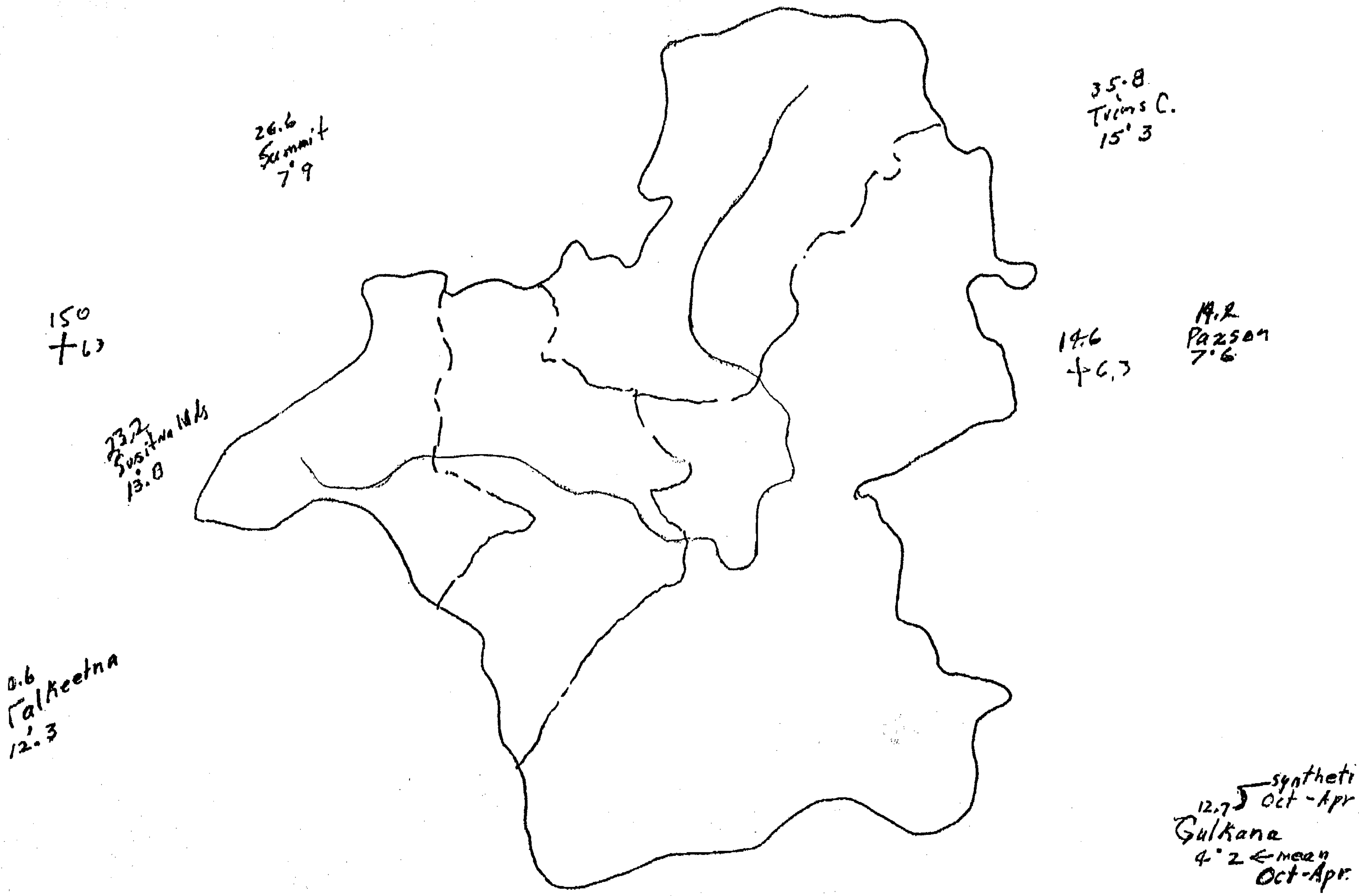



**Figure 1.--Drainage outlines and October-April precipitation in inches.
(Upper values = synthetic October-April precipitation;
Lower = mean October-April precipitation.)**

Sheep Mtn

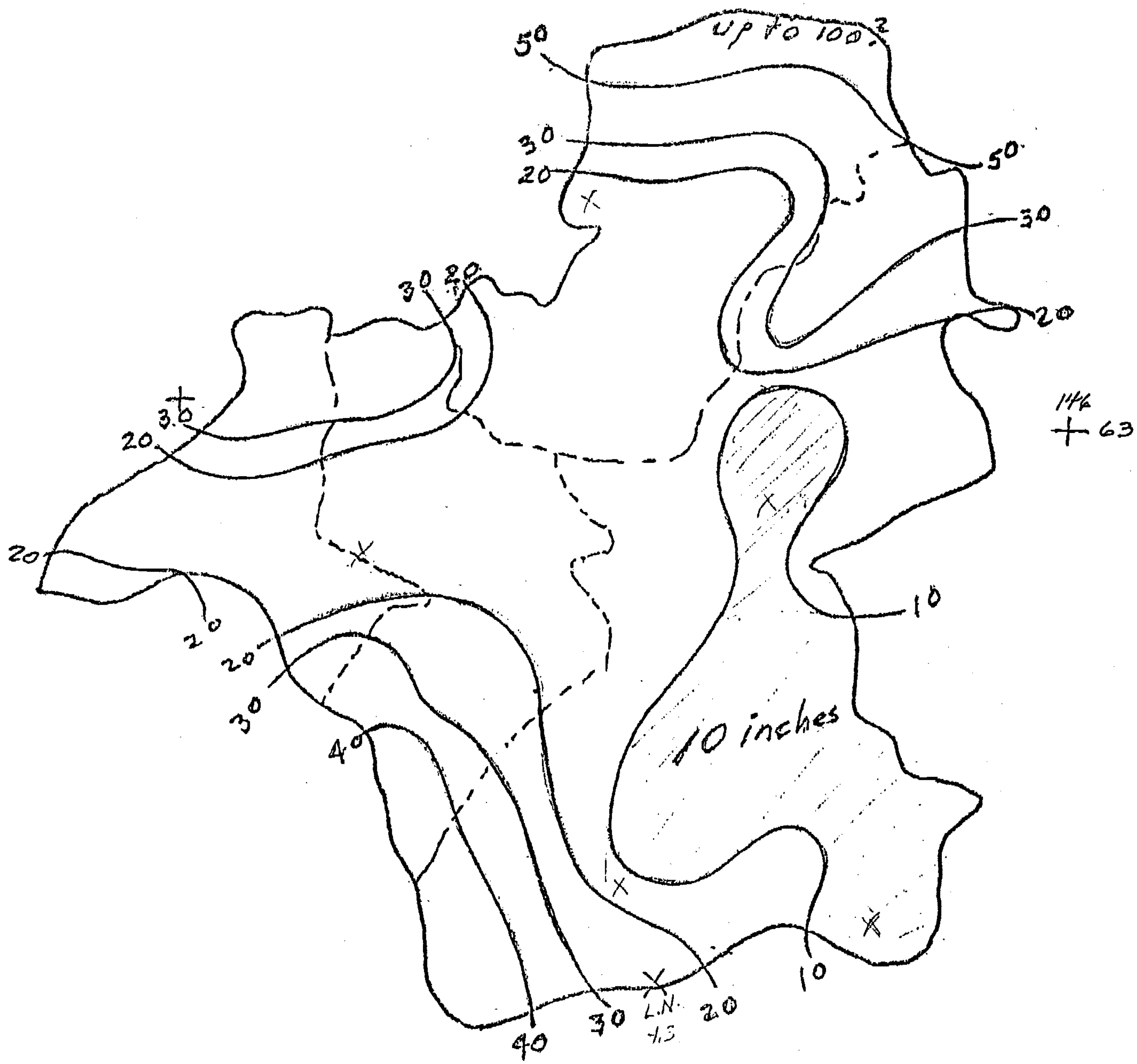



Figure 2.--Minimum water equivalents of snow pack in inches (based on gross smoothing of maximum snow course measurements.)

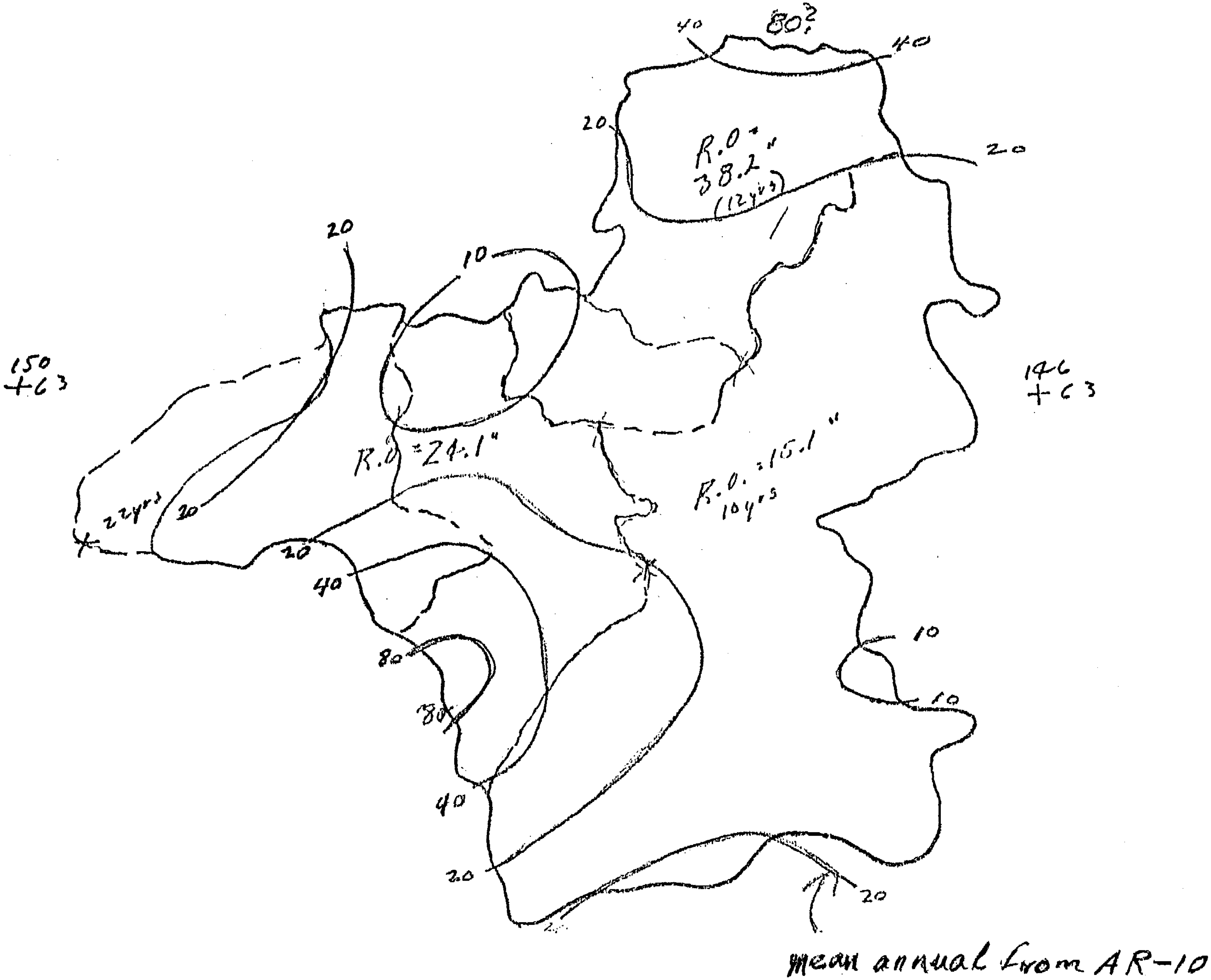



Figure 3.--Mean annual precipitation and stream runoff (in inches).

# APPENDIX A3

## RESERVOIR HYDRAULIC STUDIES

This appendix presents hydraulic studies undertaken to design and check reservoir safety structures including outlet and spillway facilities, river diversion facilities during construction, emergency reservoir drawdown facilities, and reservoir freeboard requirements. Section 1 presents the flood routing analyses performed for selection of capacity of river diversion, outlet facilities, and spillways for Watana and Devil Canyon developments. Reservoir freeboard requirements under operation and extreme flood conditions are presented in Section 2. Section 3 describes studies conducted to assess the effects of potential landslides into the reservoirs.

## 1 - FLOOD ROUTING STUDIES TO DETERMINE SPILLWAY, OUTLET WORKS AND DIVERSION CAPACITIES

This section presents the results of the flood routing analyses performed for design of outlet facilities, spillways for Watana and Devil Canyon, and the required diversion capacity for the two damsites during construction.

### 1.1 - Spillway and Outlet Works

Selection of the discharge capacity and types of spillway and outlet facilities has been based on project safety, environmental, and economic criteria. These are described in detail in Sections 12 and 13 of the main report. In brief, at each of the developments a set of fixed-cone valves is provided in the outlet works to discharge floods up to 1:50-year recurrence interval. This facility would reduce the potential of supersaturation of spill water with gases, especially nitrogen, and will facilitate avoiding unacceptable levels of supersaturation for downstream fisheries. The main spillway comprises a gated-control structure and a chute with a flip bucket at its end. The facility has a capacity to discharge in combination with the outlet works, the routed design flood which has a return period of 1:10,000 years. A fuse plug with an associated rock cut channel is provided to cater for discharges above the design flood and up to the estimated probable maximum flood (see Appendix A2).

### 1.2 - Design Flood Hydrographs

A regional flood peak and volume analysis for the Susitna and surrounding basins has been carried out (1). Peak discharge, flood volume and hydrograph shape of design floods for different return periods (1:50 years, 1:10,000 years, etc.) have been derived based on the above analysis. Generally, results from the regional flood peak frequency curve (Figure A3.1) and single station frequency curve for Gold Creek (Figure A3.2) agree well (within 10 percent) for flood peak estimates. The station frequency curve yields somewhat higher estimate of flood peaks and has been used to conservatively estimate design flood peaks (1:10,000 years). This estimate of flood peak at Gold Creek station has been transferred to the damsites using the regional expression to calculate mean annual flood peak at the damsites (Reference Report 1). For smaller floods, the regional frequency curve (Figure A3.1) has been used. Estimated flood peaks at the damsites in the natural river regime are presented in Table A3.1.

Proposed reservoir operations (see Appendix A1) indicate that substantial storage will be available in the Watana reservoir to route spring floods in the river. In the summer months (August to October), comparatively less storage will be available to route the floods. To take this aspect into account, spring and summer flood peaks were estimated at the damsites based on similar analyses of Gold Creek floods (1). Table A3.1 lists the flood peaks in spring and summer at the damsites. Plate A3.1 presents the design flood hydrographs for Watana damsite.

In all the analyses for Devil Canyon development, it has been assumed that the Watana development would already exist and floods would be routed through the Watana reservoir. Plate A3.2 shows the inflow hydrographs at Devil Canyon which are composed of flood outflow from Watana and the natural flood flow in the intermediate catchment.

## 1.3 - Spillway Valves and Gates Operation

For the purpose of flood routing, assumptions have been made as to the time of opening of the fixed cone valves and spillway gates. Theoretically, these facilities can be operated when the water level in the reservoir reaches its normal maximum operating level. However, to allow for operational ease, a minimum surcharge of 0.5 foot will be provided before the valves and gates are opened to pass floods. The fixed cone valves at Watana would open when water level rises to 2186 feet and main spillway gates open at 2191.5 feet. The reservoir would surcharge to Elevation 2191 while discharging a 1:50-year flood through the fixed cone valves with normal power operation.

At Devil Canyon, no allowance of surcharge has been made on the assumption that the Watana operation would be known in advance and valves and gates could be opened at the normal maximum operating level to cope with a flood discharge.

## 1.4 - Capacity of Fixed Cone Valves

Physical size and capacity of these valves are restricted and their operational experience limited. A review of existing facilities was made to determine the sizes that can be used in the Watana and Devil Canyon developments with an assurance of quality and performance. The selection of the number of valves at each development has been restricted by the project layout and size. A detailed description of the type of valves selected and the reasons therefore may be found in Sections 12 and 13 of the main report.

Six 78-inch diameter fixed cone valves, each with a capacity of 4000 cfs at the design head, are provided at Watana. Seven valves (3 of 90-inch and 4 of 102-inch diameter) with a total capacity of 38,500 cfs, are provided at Devil Canyon as outlet facilities.

1.5 - Main Spillway Gates

Vertical lift gates are provided at the two developments to control discharges over the main spillway with a free overflow ogee-type crest. Standard discharge-head relationship has been used to calculate spillway capacity at different heads.

$$Q = CLH^{1.5}$$

where $Q$ = spillway discharge in cfs
$C$ = coefficient of discharge
$L$ = effective spillway length in feet
and $H$ = head above spillway crest in feet

Value of the coefficient "C" is calculated from the physical dimension of the structures. Procedures to calculate C may be found in standard treatises on the subject.

1.6 - Availability of Power Flow

Generally, the power flow of the developments is small compared to peak flood discharges. It is essentially a philosophical question whether power flow should be considered in determining spillway capacities. In keeping with general practice (USBR, COE, etc.), it has been assumed that power flow will not be available in discharging the design 1:10,000-year flow or the probable maximum flood. However, a power flow consistent with system power demand during the flood season (May through October) was used in routing smaller floods through the reservoirs.

1.7 - Probable Maximum Flood and Fuse Plug Provision

To ensure safety of main structures of the development, the probable maximum flood (PMF) discharge has been considered in the design of discharge facilities (see Sections 12 and 13 of main report). A fuse plug has been provided at each of the developments to cater for floods above the design 1:10,000-year flood and up to the PMF. The fuse plug is designed to fail at an overtopping water depth of around one foot. For details of the fuse plug, refer to Sections 12 and 13 of the main report.

1.8 - Results of Flood Routing Analyses

A modified Puls method of routing has been used in these analyses. Reservoir outflows have been restricted to peak inflows until the capacity of the outlet spillway facilities are exceeded when the reservoir is allowed to surcharge.

Results of the analysis are presented on Plates A3.1 and A3.2, and summarized in Tables A3.2 to A3.3. Spillway and diversion capacities, as calculated, are provided in the design of the structures (see Sections 12 and 13 of main report).

### 1.9 - River Diversion During Construction

#### (a) Watana Development

Based on the dam construction schedule and acceptable level of risk of flooding the construction site, it has been decided that the diversion facilities will be designed to discharge a 1:50-year flood flow without any flooding of the construction site (see Section 12 of main report).

The selected discharge facility comprises two 38-foot diameter tunnels and has a total capacity of 80,000 cfs which is the peak outflow of a 1:50-year flood routed through the cofferdam. Discharge capacity of the tunnels is presented in Figures A3.3 to A3.5. The flood routing analysis is shown in Figure A3.6.

For details of method of selection of the facility, see Section 12 of the main report.

#### (b) Devil Canyon Development

Design flood for the diversion facility at Devil Canyon development was selected as 1:25-year flood due to significant regulation of floods by the Watana reservoir and due to lower risk and damage to the proposed concrete dam in the event of a flooding during construction (see Section 12 of the main report).

The selected facility comprises a single modified horseshoe tunnel 30 feet in diameter with a discharge capacity of 36,000 cfs. Figure A3.7 presents the rating curve of the facility, and Figure A3.8 shows results of the flood-routing analysis.

## 2 - RESERVOIR FREEBOARD FOR WIND WAVES

This section describes studies undertaken to determine freeboard requirements for wind-induced waves for the developments at Watana and Devil Canyon damsites. Two effects of wind conditions are considered: wave run-up and wind setup. The wave freeboard is only a portion of the total freeboard required and must be combined with those determined for seismic slump of the dam crest, etc.

### 2.1 - Analysis

Standard design procedures as detailed in the U.S. Army Corps of Engineers (COE) Shore Protection Manual (2) and outlined specifically for inland reservoirs in the COE Engineer Technical Letter No. 1110-2-221 (3) have been used in the analysis.

The wind data recorded at Summit Station have been used in this analysis. Although somewhat limited, these data are believed to be the most representative of wind conditions at the damsites. More extensive wind data will be required for final design and will be available from the climatic stations at Watana and Devil Canyon.

Wind speeds and durations are shown in Table A3.4. Wind speeds were converted to equivalent speeds over water using a wind velocity ratio (3). Wind-velocity duration curves for Watana and Devil Canyon reservoirs were then developed (Figure A3.9). A straight line relationship on log-log paper was assumed for the curves. Based on these, the effective fetch for wave generation was determined for Watana and Devil Canyon damsites (Figures A3.10 and A3.11). The lengths of radial lines extending 45° on each side of a central radial located at the damsite are weighted and summed to estimate an average effective fetch (2). The design wind direction yields the longest fetch length at the damsite. Calculated effective fetch for wave generation is 3.4 miles for Watana and 1.0 miles for Devil Canyon.

Curves of critical duration versus wind speed for a given effective fetch were developed using Figure A3.12. Table A3.5 lists wind speeds and duration for the Watana reservoir along with the resulting significant wave and the limiting factor. This table shows the maximum significant wave and, hence, the design wind characteristics. Figure A3.9 gives a graphic representation of Table A3.5.

The design wind velocity was found by determining the intersection of the wind velocity duration curve with the critical duration versus wind speed curve for a given effective fetch length. The design wind velocity for Watana is 40 miles per hour with a 44-minute duration. The Devil Canyon design wind velocity is 40 miles per hour with a 19-minute duration.

The significant wave found from Figure A3.12 (4) is 3.1 feet for Watana and 1.7 feet for Devil Canyon. The significant wave represents the average wave height of the top one-third wave heights in a stable wave chain.

Wave run-up is dependent on wave and embankment characteristics. Wave run-up for Watana is determined using the following relationship:

$$\frac{Rs}{Hs} = \frac{1}{0.4 + (H_s/L_o)^{1/2} \text{ COT } \theta}$$

where: $H_s$ = significant wave height, feet
$R_s$ = wave run-up caused by the significant wave, feet
$L_o$ = wave length, feet
$\theta$ = angle embankment makes with horizontal, degrees

The wave length ($L_o$) is determined from the relationship:

$$L_o = 5.12 \ T^2$$

where: T = represents the wave periods and is determined from Figure A3.13 (4).

This run-up relationship is appropriate for earthfill embankments armored with riprap (3). Assuming a 2.25H:1.0V slope yields a significant wave run-up of 3.4 feet. For design purposes, maximum wave run-up is taken as 1.5 times the run-up due to the significant wave, yielding 5.1 feet. Wave run-up for Devil Canyon was determined using Figure A3.14 (4). For vertical walls in deep water, Figure A3.14 yields a significant wave run-up of 2.2 feet. Similar to Watana, Devil Canyon's maximum wave run-up is 3.3 feet.

Wind set-up is produced from wind shear stress on the reservoir surface which results in increased water levels at the leeward end. Wind set-up is found by the following relationship (5):

$$S = \frac{U^2F}{1,400\ D}$$

where: U = design wind velocity, miles per hour
F = fetch, miles
D - average reservoir depth, feet.

In contrast to the fetch determined for wave generation, the wind fetch for wind set-up is assumed to extend the length of the reservoir. This is a standard assumption since wind set-up is not seriously affected by the presence of curves or discontinuities such as islands in a reservoir. The wind set-up fetch for both Watana and Devil Canyon is 28 miles. The average depth of both reservoirs is taken as 450 feet. The corresponding wind set-ups are .07 feet for both Watana and Devil Canyon and are rounded to 0.1 feet.

The freeboard required for wind-induced effects is the sum of the maximum wave run-up and wind set-up, resulting in 5.2 feet for Watana and 3.4 feet for Devil Canyon, see Table A3.4.

### 2.2 - Conclusions

Wave heights in both Watana and Devil Canyon reservoirs are governed by the respective fetch lengths. The narrowness and bends in the reservoirs reduce the effective fetch, and thus reduce wind-induced waves. The wind set-up for both reservoirs is 0.1 feet. Set-up is not significant considering the degree of accuracy inherent in the wave height and run-up calculations. However, set-up is included in wind-induced freeboard requirements.

Wind-induced freeboard requirements of 5.2 feet for a Watana rockfill dam and 3.4 feet for a Devil Canyon arch dam are included in the total freeboard requirements. When data of wind direction, duration, and speed become available, it will be appropriate to redefine wind speed duration-relationships for relevant directions.

## 3 - SLIDE-INDUCED SURGES

A study of wave surges that may be induced by potential landslides into the proposed reservoirs was undertaken to evaluate the magnitude of such waves and associated problems. Published works on recorded slides and associated predictive empirical models were reviewed to get an insight into the potential magnitude of such problems and engineering analyses. An empirical approach defining generic relationships among impact velocity and kinetic energy of the slides, induced wave heights, and their attenuation with passage along the reservoir was then selected to develop standard monographs.

A set of field data on potential slides in the reservoir areas developed under separate studies (refer to Appendix K of Task 5 - 1980-81 Geotechnical Report) was incorporated in these monographs to estimate potential wave heights and their impact on design parameters. The following sections describe the analyses carried out and results of the studies.

## 3.1 - Generic Relationships

Figure A3.15 presents a definition sketch for the terms and variables used in describing the generic relationships.

The velocity of a slide impact is a function of the downslope distance (to the reservoir), slope angle of the slide plane, and angle of dynamic sliding function. Figure A3.16 shows a plot of this relationship. In the present analysis, the angle of dynamic sliding was assumed as a constant due to relatively little variation in its value. Any slide velocity may be calculated from this figure when other variables are known. The dimensionless kinetic energy of the slide may then be estimated from the slide velocity, volume, and density.

Figure A3.17 presents the relationship between the dimensionless kinetic energy of slide and the maximum potential height of the wave that could be generated as a ratio of average depth of water at impact location. From this, the maximum wave height generated at the point of impact may be calculated.

Attentuation of the wave height as it progresses in a radial direction along the surface of the reservoir is presented in Figure A3.18. This relationship may be used to determine effective wave heights at various points of interest in the reservoir and especially at the dam to evaluate potential overtopping due to such waves.

## 3.2 - Analyses and Results

Field investigations have estimated that the potential for the largest block slide exists about two miles above the Watana damsite on the south bank. The maximum volume of this slide is estimated to be about 18 million cubic yards (see Appendix K mentioned in Section 3). The likelihood of occurrence of such a slide is extremely remote. However, for such a case, the wave height that may be generated is estimated at 64 feet which will attenuate to approximately 10 feet at the Watana dam. Thus, with some 20 feet freeboard available over the normal maximum reservoir operating level of 2185 feet, the effect of such a slide, should it occur at all, will be minimal.

Field investigations have also identified a solifluction flow and retrogressive slide located approximately 8 miles downstream from the Watana damsite. Initial investigations show this slide to have an approximate volume of 3.4 million cubic yards. A slide of this volume will cause impedence to the flow; however, it will have little effect on the tailwater at Watana. Further assessment of this slide mass will be necessary in subsequent phases of the project since an increased mass may cause tailwater problems at Watana development.

Several potential landslides of much smaller volumes have been identified along the two reservoirs, especially in the area of reservoir drawdown and along the lakes that will be created behind construction cofferdams at the two developments. In general, the study indicates that no major impact is likely on the proposed structures due to landslides. Table A3.6 presents the theoretical volume of slides that should be dislodged and dumped into the reservoirs at their normal maximum operating levels to cause waves of heights greater than the freeboard provided at the dams. This table is essentially presented to illustrate the order of magnitude of slides that would be significant in affecting design parameters.

### 3.3 - Conclusions

It does not appear that potentially serious problems of slide-induced surges exist in the proposed reservoir areas. Minor slides could occur during construction and operation of the developments and could be handled without difficulty.

## LIST OF REFERENCES


1. R&M Consultants, Susitna Hydroelectric Project, Regional Flood Studies, December 1981.

2. U.S. Department of the Army, Coastal Engineering Research Center, Shore Protection Manual, Volumes 1, 2, 3, Fort Belvoir, Virginia, 1973.

3. U.S. Department of the Army, Corps of Engineers, Engineer Technical Letter No. 1110-2-221, Washington, D.C., November 29, 1976.

4. U.S. Department of the Army, Corps of Engineers, Engineer Technical Letter No. 1110-2-8, Washington, D.C., August 1, 1966.

5. Thorndike Saville, Jr., M. ASCE, Elmo W. McClendon, Albert L. Cochran, F. ASCE, Freeboard Allowances for Waves in Inland Reservoirs, Paper No. 3465, Vol. 128, 1963, Part IV.

## LIST OF TABLES

## LIST OF FIGURES

TABLE A3.1: ESTIMATED NATURAL FLOOD PEAKS AT WATANA AND DEVIL CANYON

| | WATANA FLOOD PEAKS | | |
|---|---|---|---|
| Flood Return Period (Years) | Annual (cfs) | Spring (cfs) | Summer (cfs) |
| 1:25 | 71,800 | 51,000 | 54,500 |
| 1:50 | 80,000 | 73,000 | 60,500 |
| 1:10,000 | 156,100 | - | - |

| | DEVIL CANYON FLOOD PEAKS | | |
|---|---|---|---|
| Flood Return Period (Years) | Annual (cfs) | Spring (cfs) | Summer (cfs) |
| 1:25 | 74,200 | 52,700 | 56,300 |
| 1:50 | 82,700 | 75,500 | 62,600 |
| 1:10,000 | 161,400 | - | - |

TABLE A3.2: FLOOD ROUTING RESULTS - WATANA

| Flood | Maximum Flow During Flood (cfs) | | | | | Max WSEL (ft) |
|---|---|---|---|---|---|---|
| | Powerhouse | Service | Secondary | Emergency | Total | |
| 1:50-year | 7,000 | 24,000 | 0 | 0 | 31,000 | 2191.6 |
| 1:10,000-year | 7,000 | 24,000 | 114,000 | 0 | 145,000 | 2193.0 |
| PMF | 7,000 | 24,000 | 147,000[1] | 140,000 | 311,000 | 2202.0 |

[1] At Elevation 2201.2.

TABLE A3.3: FLOOD ROUTING RESULTS - DEVIL CANYON

| | Maximum Flow During Flood (cfs) | | | | | |
|---|---|---|---|---|---|---|
| Flood | Powerhouse | Outlet Works | Main Spillway | Emergency | Total | Max WSEL (ft) |
| 1:50-year | 3,500 | 38,500 | 0 | 0 | 42,000 | 1455 |
| 1:10,000-year | 3,500 | 38,500 | 123,000 | 0 | 165,000 | 1455 |
| PMF | 3,500 | 38,500 | 160,500 | 160,500 | 366,000 | 2466 |

TABLE A3.4: FREEBOARD ANALYSIS SUMMARY

| | WATANA | DEVIL CANYON |
|---|---|---|
| Effective Fetch (miles) | 3.4 | 1.0 |
| Wind Speed (mph): | | |
| Fastest Mile* | 48 | 48 |
| Monthly Mean** | 15.1 | 15.1 |
| Fastest Mile Over Water | 60.5 | 54.2 |
| Monthly Mean Over Water | 19.0 | 17.1 |
| Design Wind | 40 | 40 |
| Design Wind Duration (min) | 44 | 19 |
| Significant Wave (feet) | 3.1 | 1.7 |
| Significant Wave Run-Up (feet) | 3.4 | 2.2 |
| Maximum Design Wave Run-Up (feet) | 5.1 | 3.3 |
| Wind Set-Up (feet) | 0.1 | 0.1 |
| Wind Effects Freeboard Requirement (feet) | 5.2 | 3.4 |

*Equivalant to 1 minute duration
**Equivalent to 43,800 minute duration

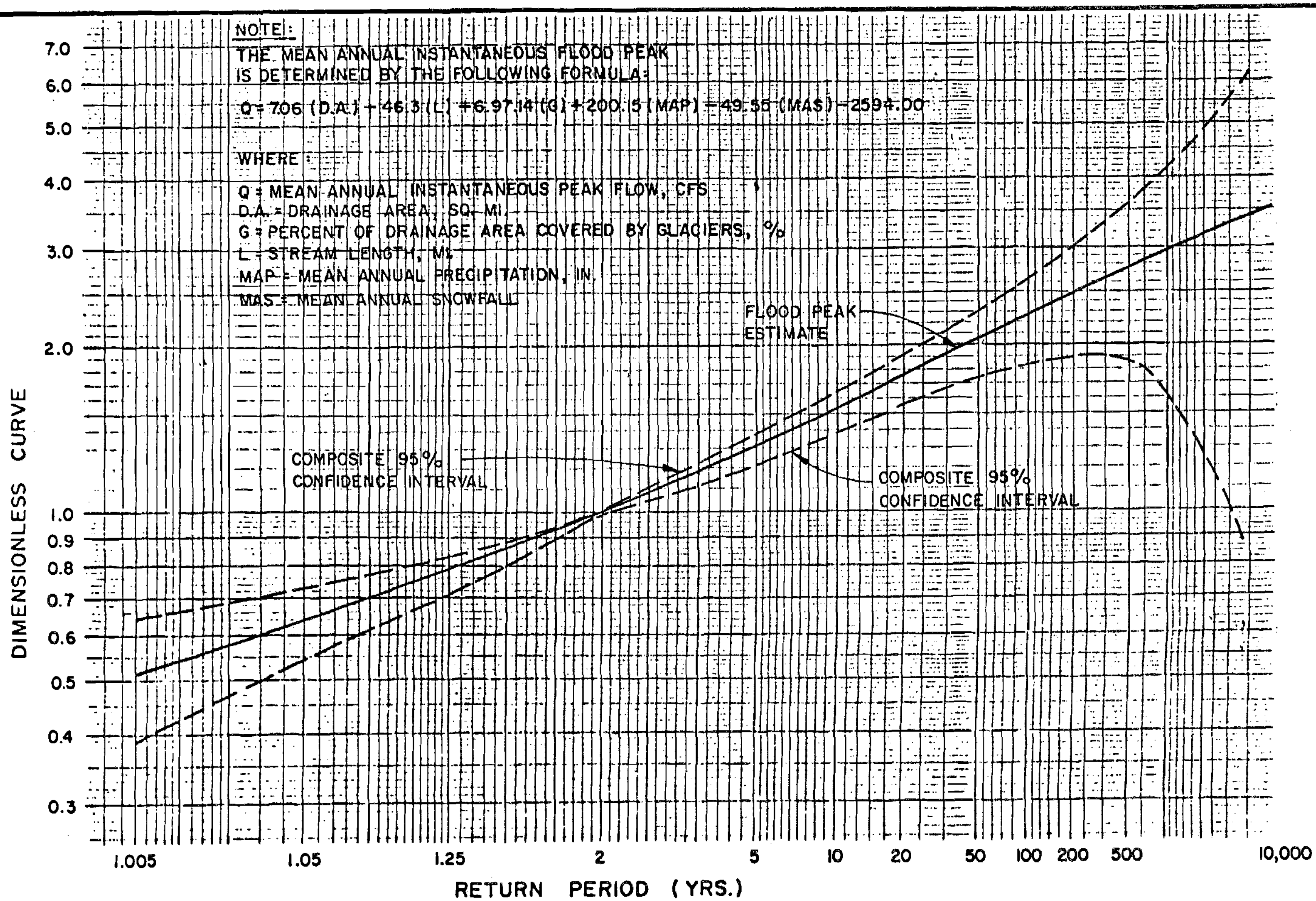
TABLE A3.5: WATANA DESIGN WIND

| Wind Velocity (mph) | Wind Duration (min) | Forecast Hs (ft) | Comments |
|---|---|---|---|
| 37 | 90 | 2.95 | Fetch Limits |
| 38 | 70 | 2.9 | Fetch Limits |
| 39 | 50 | 3.0 | Fetch Limits |
| 40 | 44 | 3.1 | Design Wave |
| 41 | 37 | 2.8 | Duration Limits |
| 42 | 20 | 1.95 | Duration Limits |
| 46 | 4.5 | .82 | Duration Limits |

TABLE A3.6: VOLUME OF SLIDE REQUIRED TO CAUSE WAVE HEIGHTS IN EXCESS OF FREEBOARDS PROVIDED AT THE DAMS (in million cu. yds.)

| Location<br>Mean Water Depth | Impact<br>Velocity | Distance from Dam | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | x = 1640 ft. | x = 3280 ft. | x = 6560 ft. | x = 9840 ft. | x = 13120 ft. | x = 16400 ft. | x = 32800 ft. |
| Watana Main Dam*<br>D = 150 m. | 90 ft/s | 3.35 | 10.71 | 28.12 | 48.67 | 67.60 | 97.34 | 264.96 |
| Watana Main Dam*<br>D = 150 m. | 30 ft/s | 30.36 | 96.96 | 254.65 | 440.73 | 612.12 | 881.45 | 2399.51 |
| Devil Canyon Arch Dam**<br>D = 150 m. | 90 ft/s | 1.96 | 5.99 | 16.32 | 28.29 | 42.44 | 57.68 | 149.63 |
| Devil Canyon Arch Dam**<br>D = 150 m. | 30 ft/s | 17.63 | 53.87 | 147.58 | 254.67 | 382.00 | 519.13 | 1346.78 |

* Watana water level assumed at 2185 feet.
** Devil Canyon water level assumed at 1455 feet.




Prepared by:

R&M CONSULTANTS, INC.

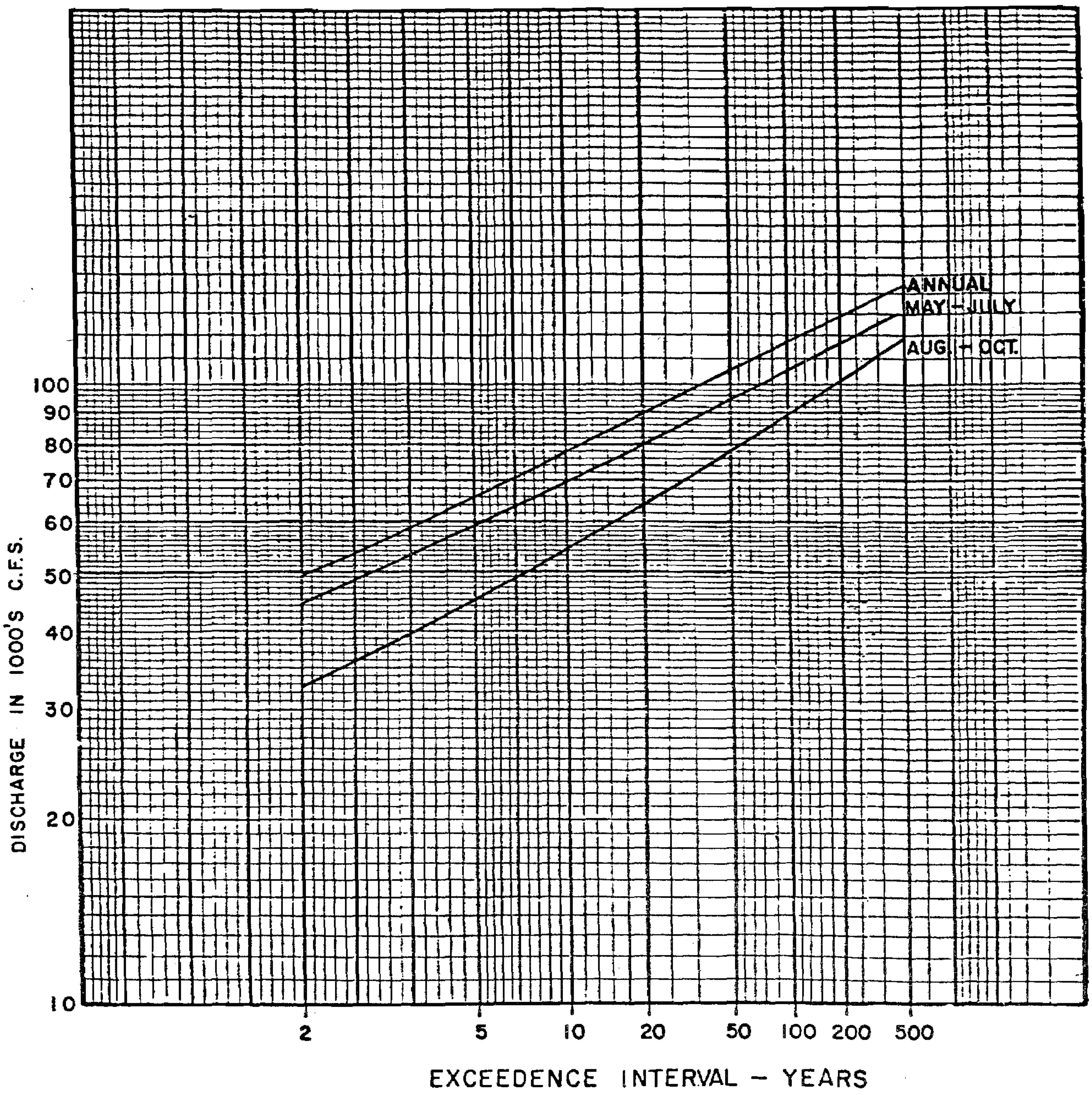
DESIGN DIMENSIONLESS REGIONAL FREQUENCY CURVE

ANNUAL INSTANTANEOUS FLOOD PEAKS

FIGURE A3.1

Prepared for:

ACRES




SUSITNA RIVER AT GOLD CREEK

PERIOD OF RECORD - 1950 - 1980

ANNUAL SKEW IS 0.6830

MAY - JULY SKEW IS 1.130

AUG - OCT SKEW IS 1.134

Prepared by:

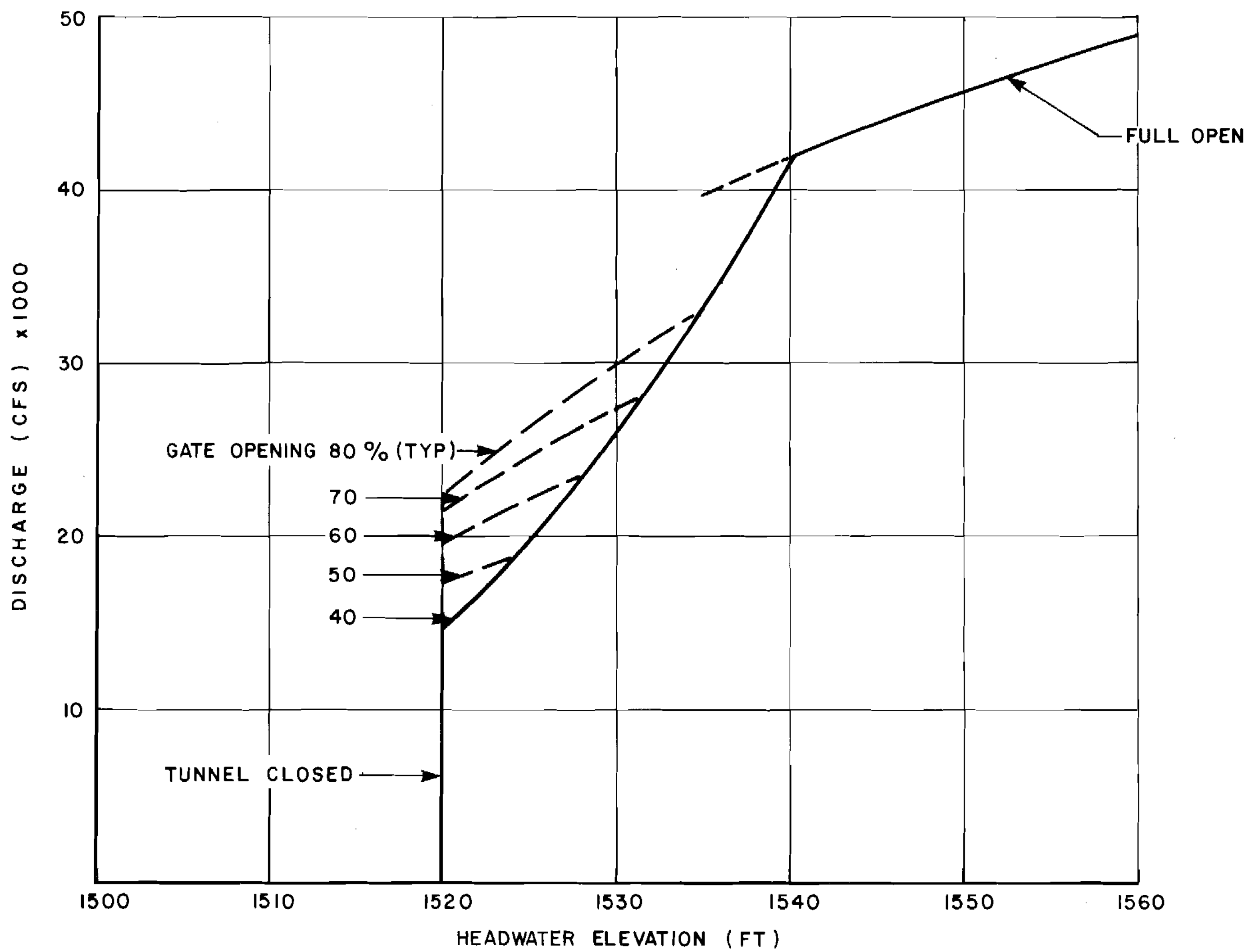
R&M CONSULTANTS, INC.

SEASONAL DISCHARGE FREQUENCY CURVES

Prepared for;

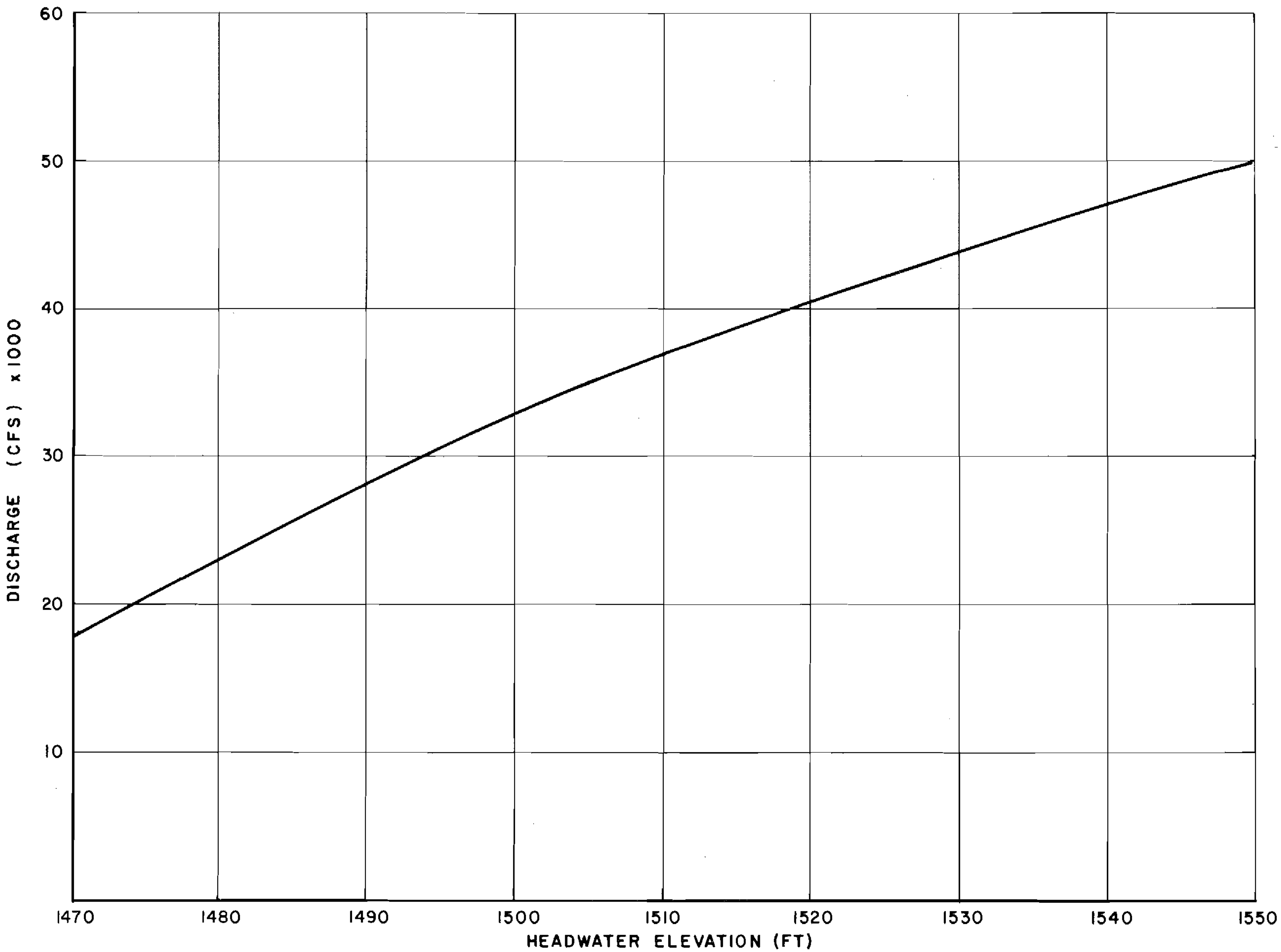
ACRES

FIGURE A3.2




**WATANA DIVERSION**
**"FREE" FLOW TUNNEL RATING**

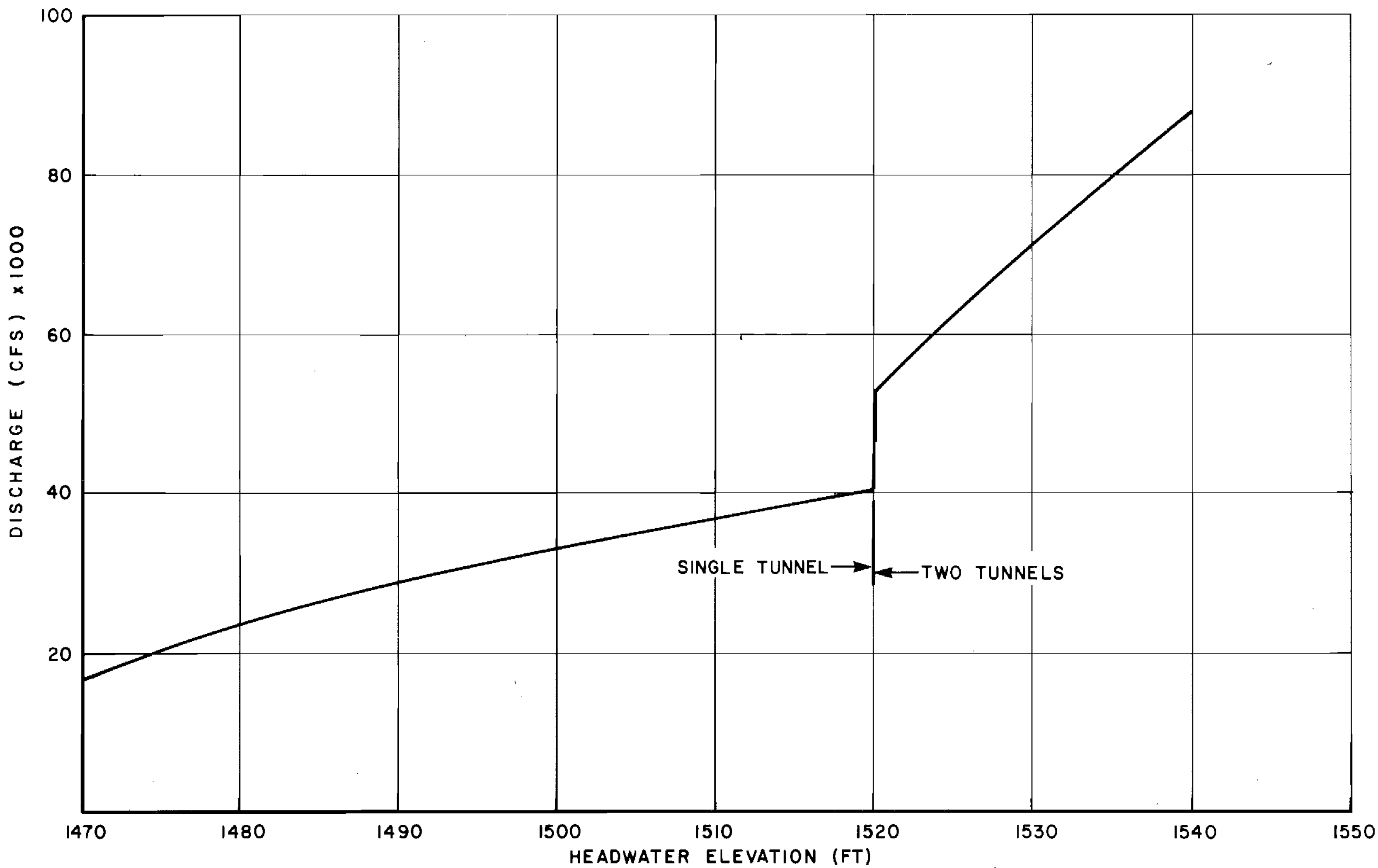
FIGURE A3.3




WATANA DIVERSION
PRESSURE TUNNEL RATING CURVE

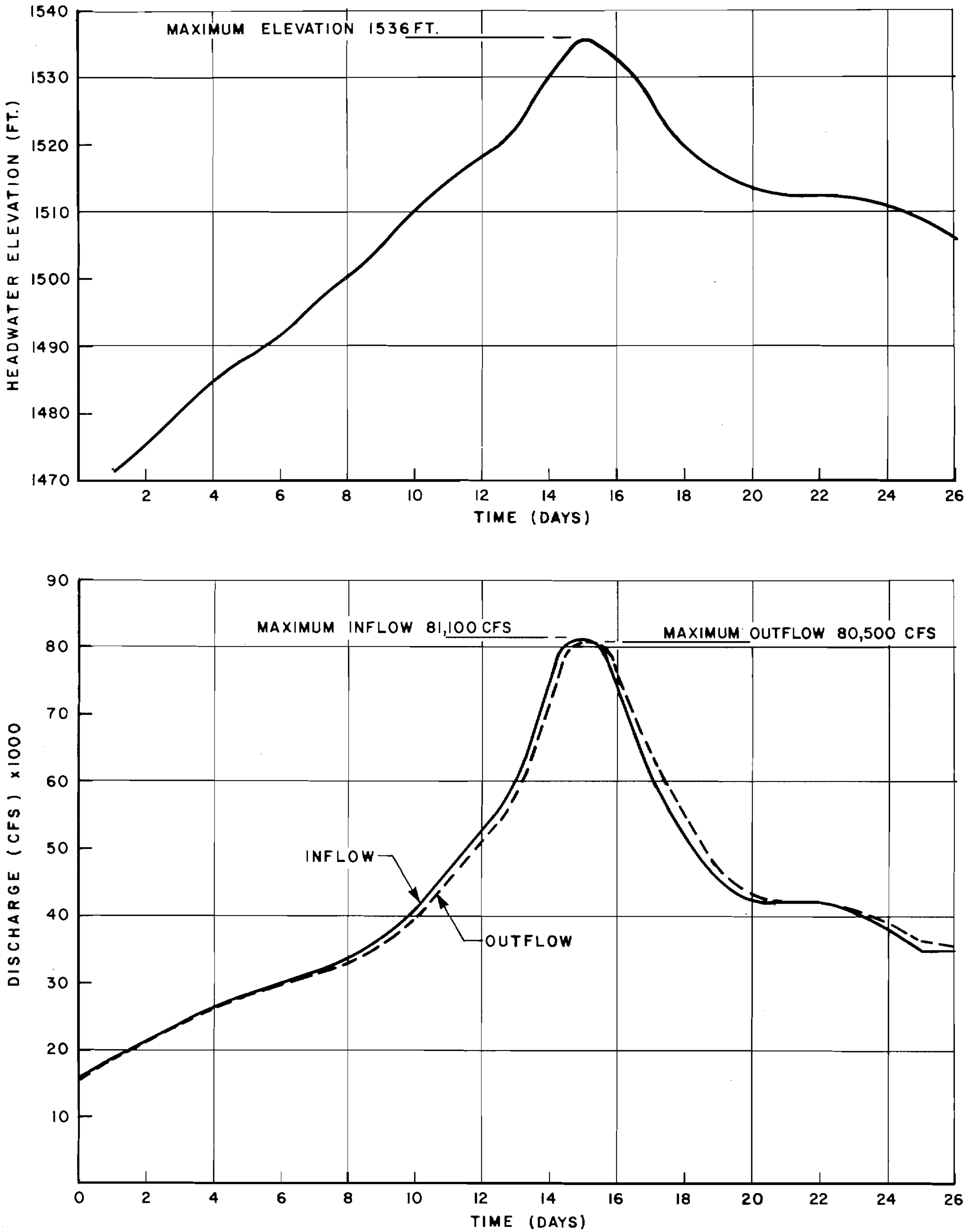
FIGURE A3.4

ACRES




WATANA DIVERSION
TOTAL FACILITY RATING CURVE

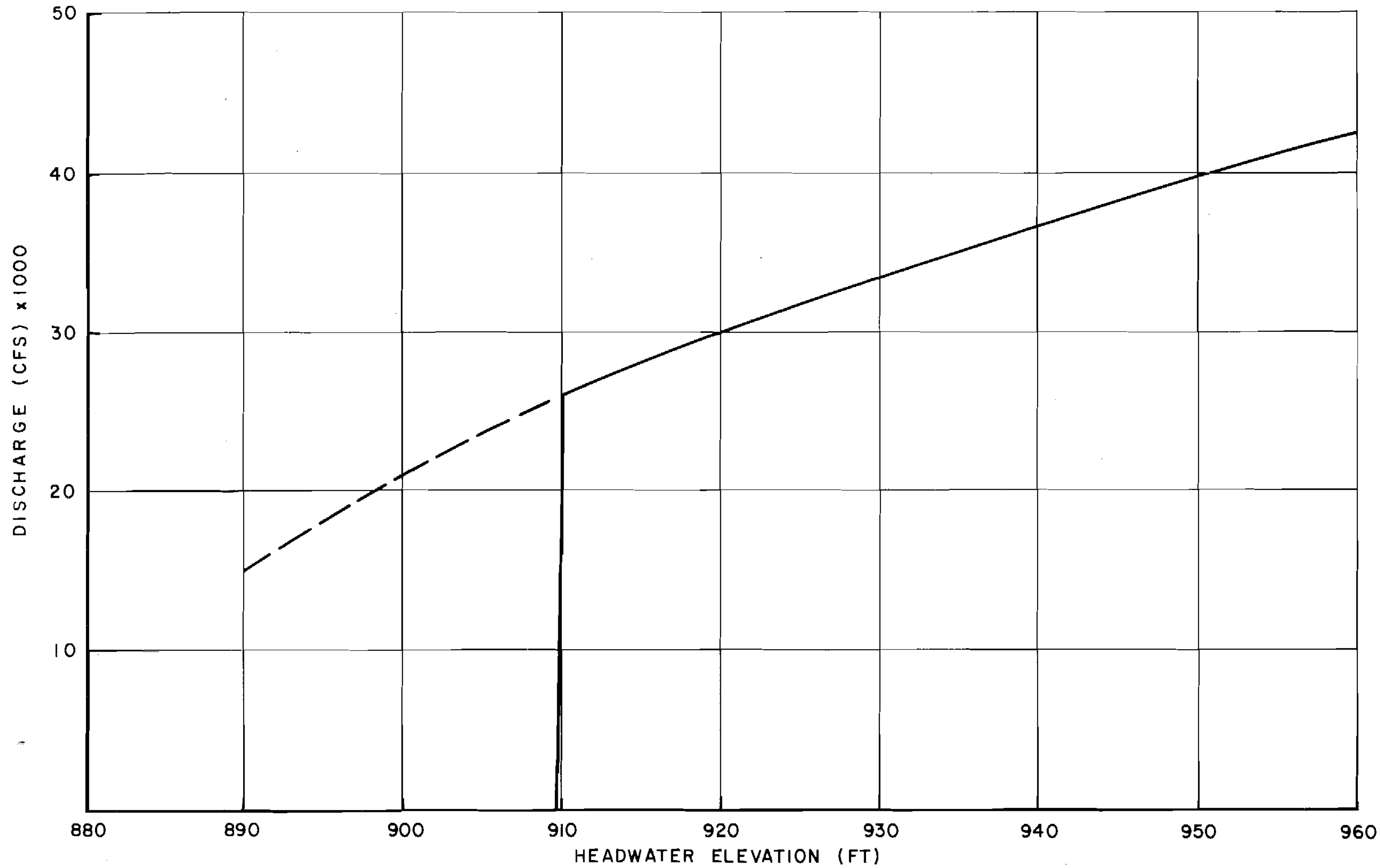
FIGURE A3.5




WATANA DIVERSION
50 YR. FLOOD ROUTING

FIGURE A3.6

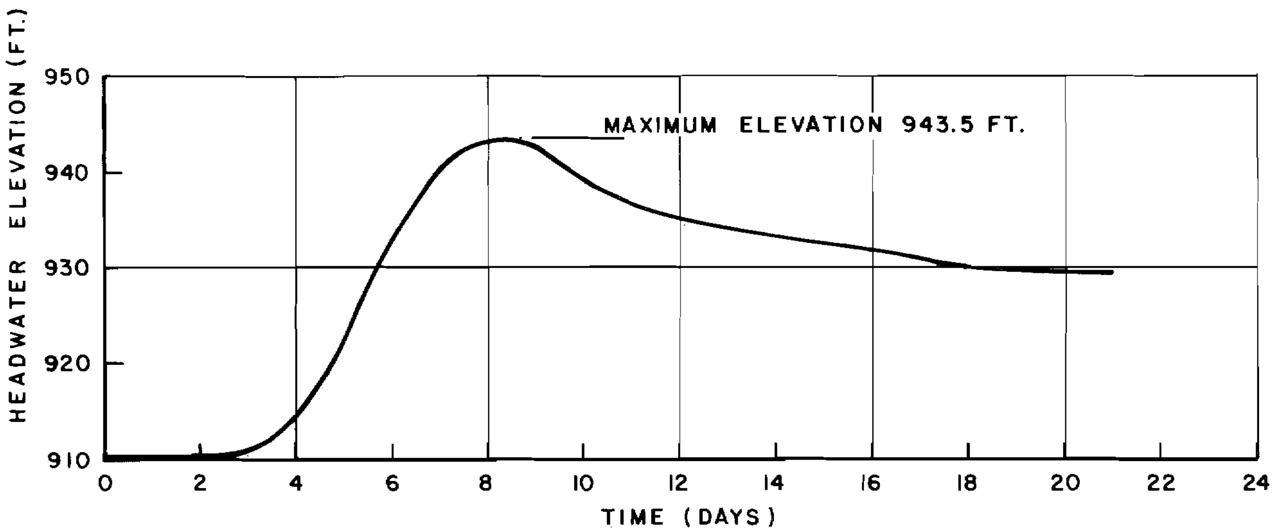
ACRES

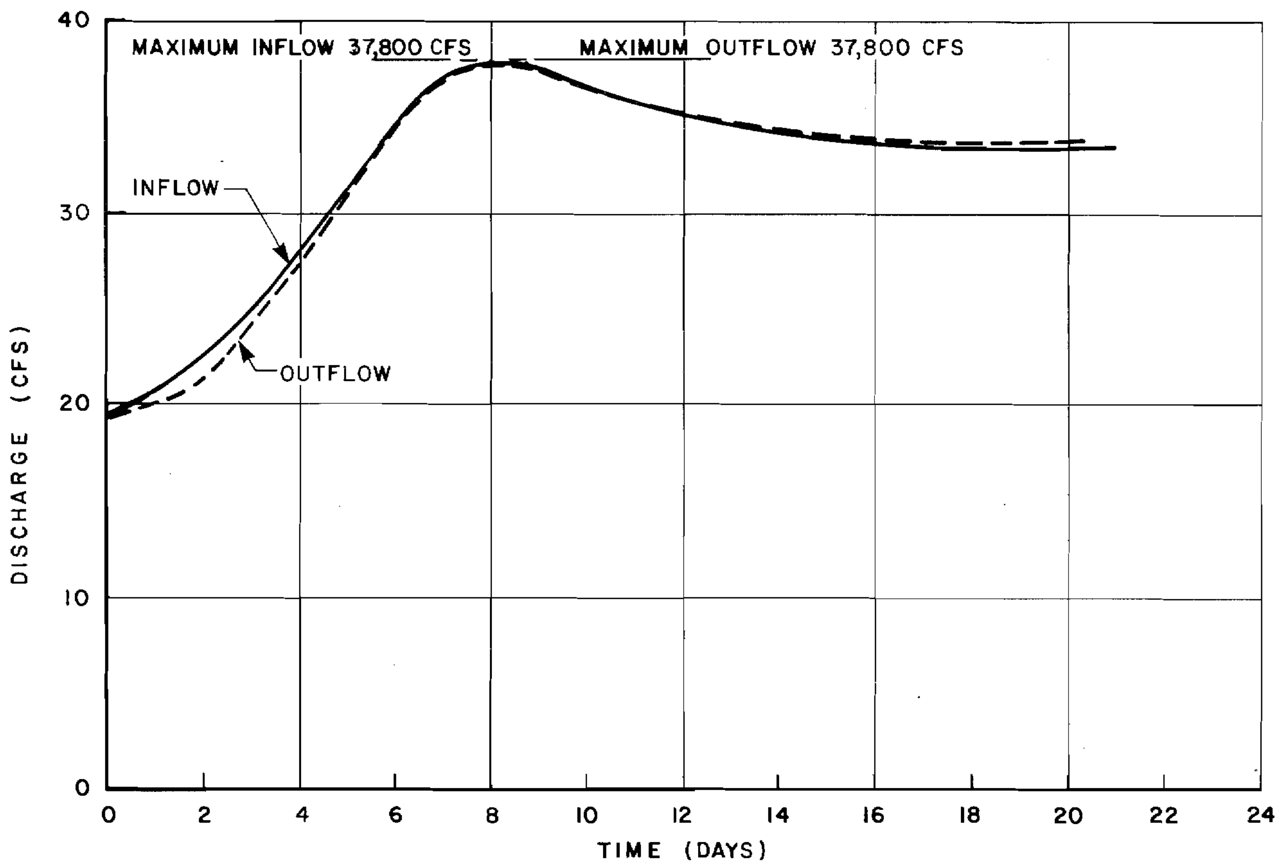



**DEVIL CANYON DIVERSION RATING CURVE**

FIGURE A3.7

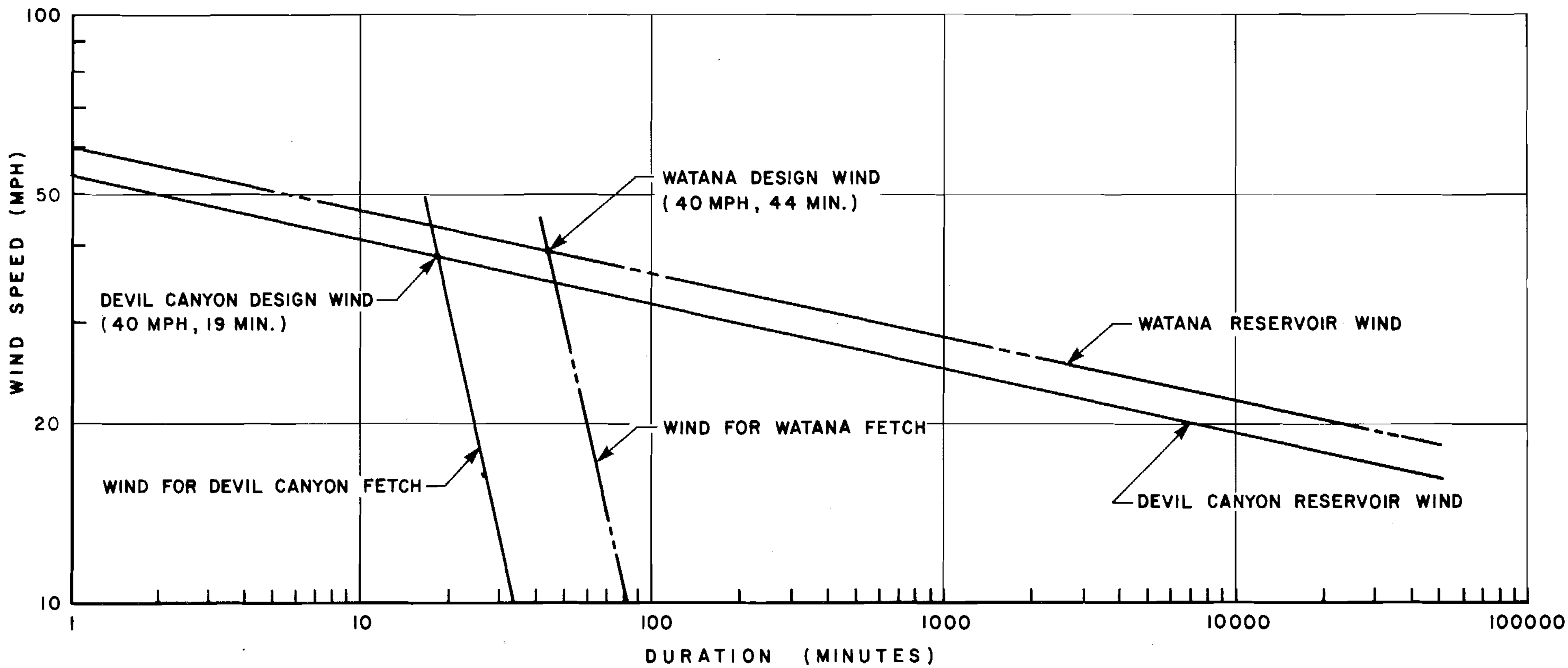
ACRES




DEVIL CANYON DIVERSION
25 YR. FLOOD ROUTING

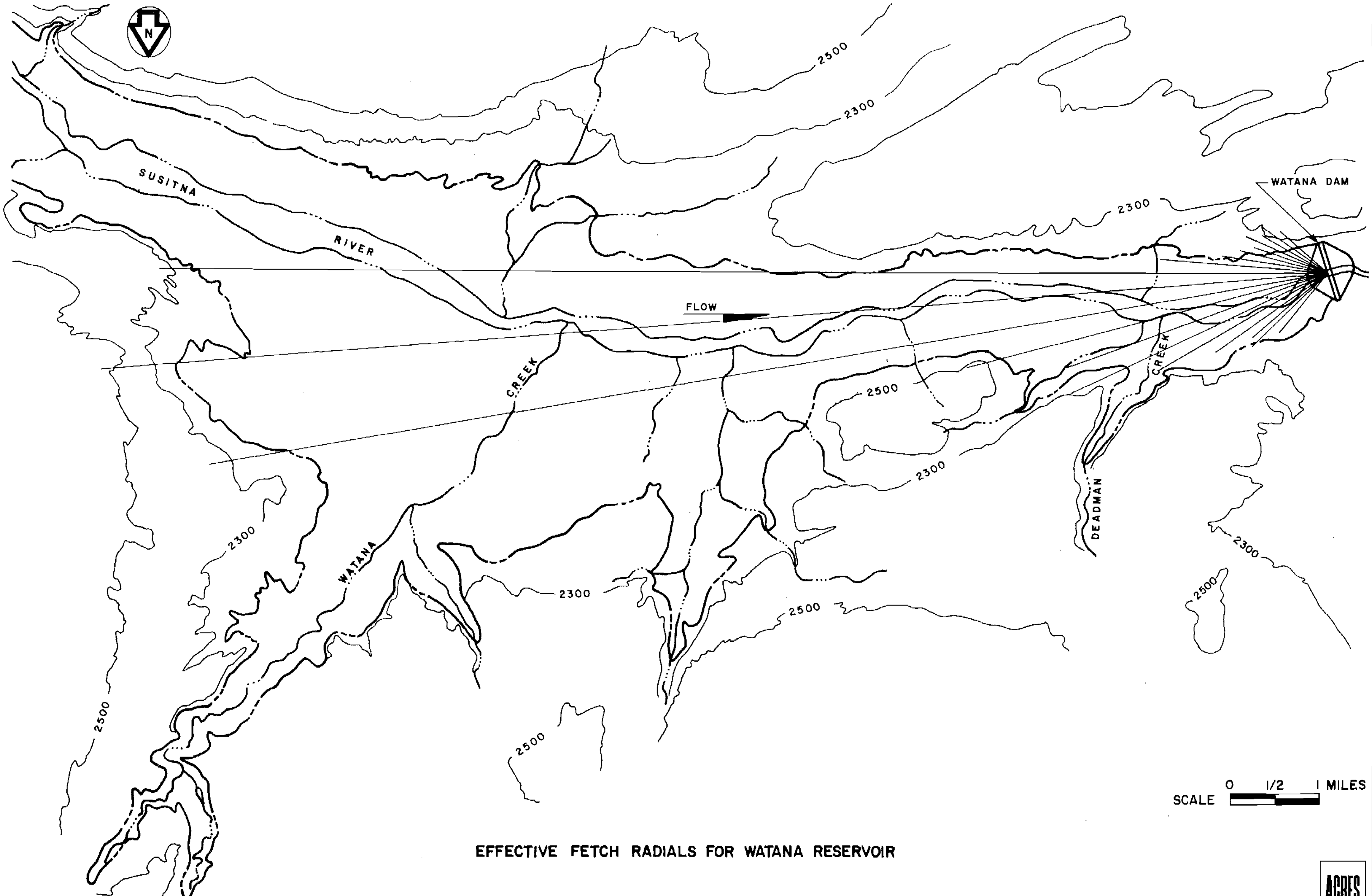
FIGURE A3.8




WIND SPEED-DURATION CURVES

FIGURE A3.9

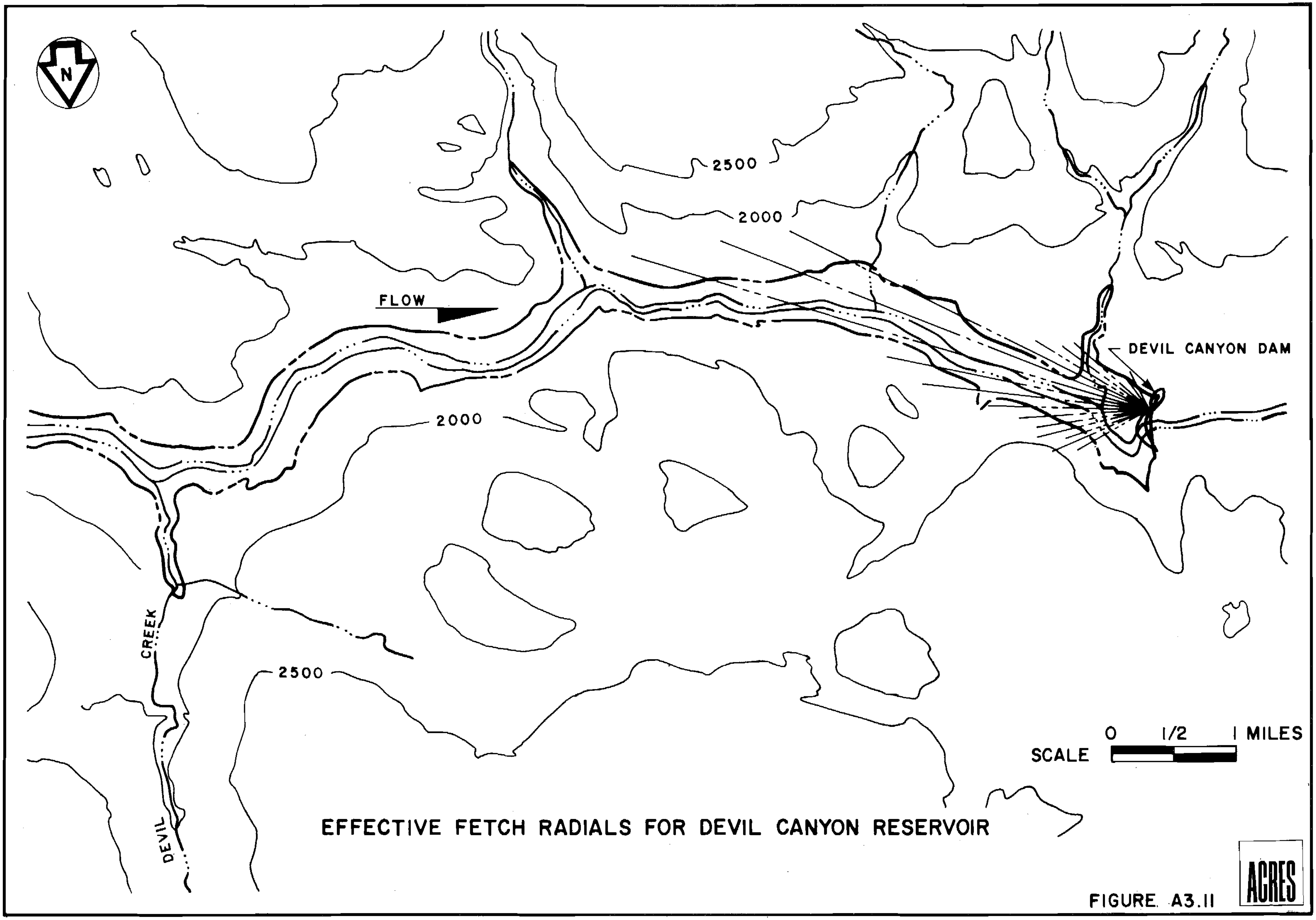
ACRES




EFFECTIVE FETCH RADIALS FOR WATANA RESERVOIR

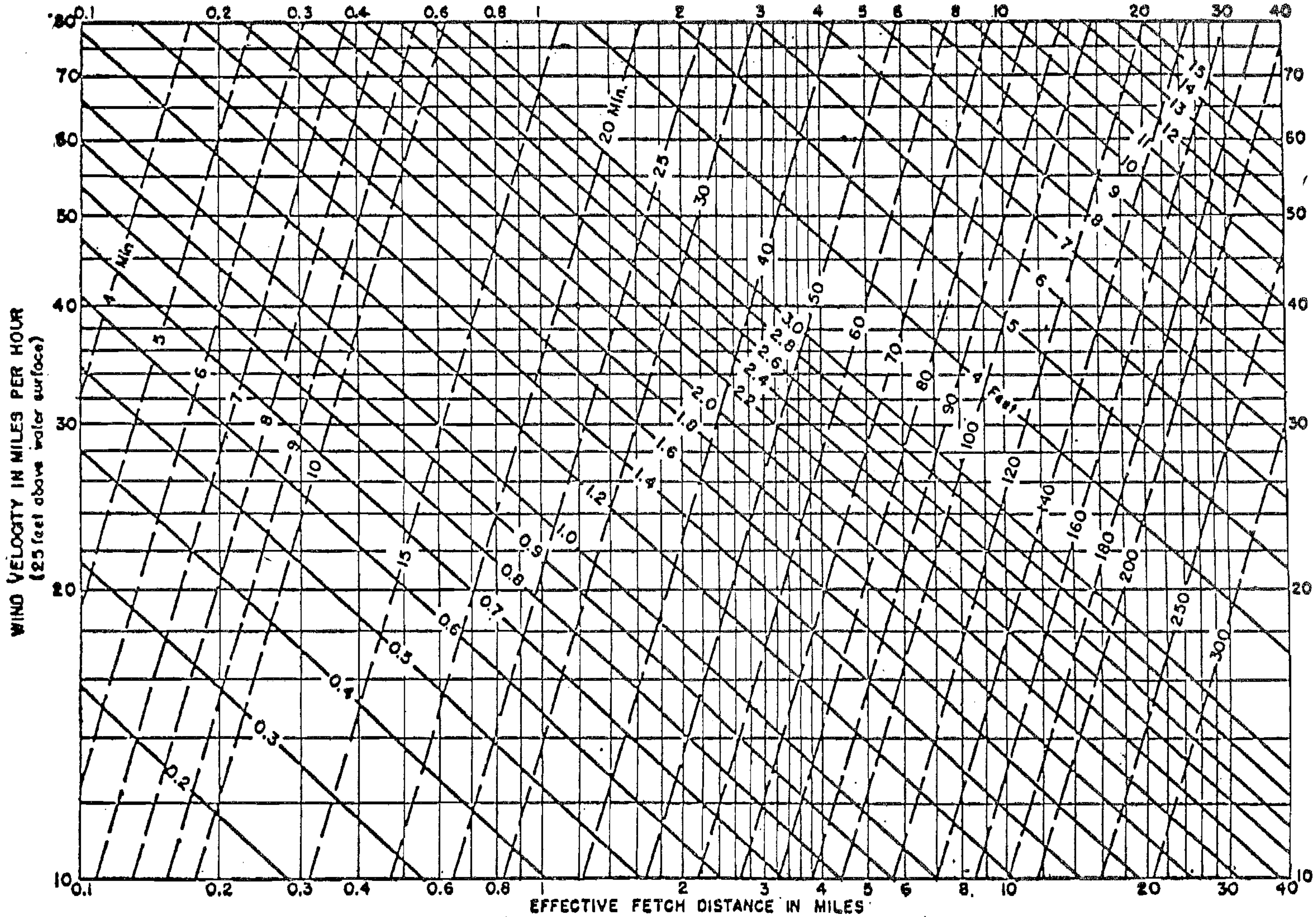
ACRES

FIGURE A3.10




EFFECTIVE FETCH RADIALS FOR DEVIL CANYON RESERVOIR

FIGURE A3.11

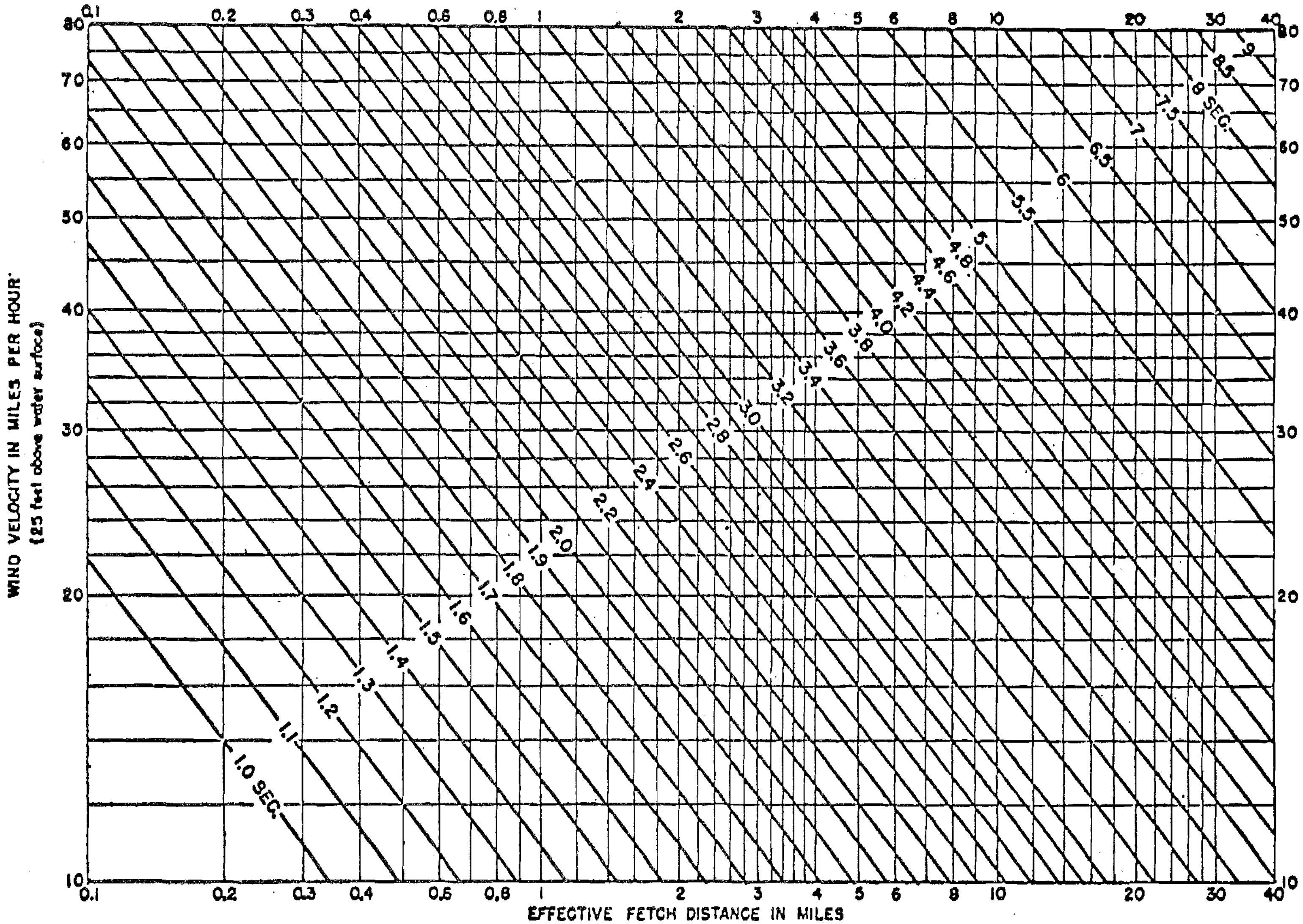



GENERALIZED CORRELATIONS OF SIGNIFICANT WAVE HEIGHTS ($H_s$) WITH RELATED FACTORS
(DEEP WATER CONDITIONS)

LEGEND:
Solid Lines represent significant wave heights, in feet.

Dashed Lines represent minimum wind duration, in minutes, required for generation of wave heights indicated for corresponding wind velocities and fetch distance

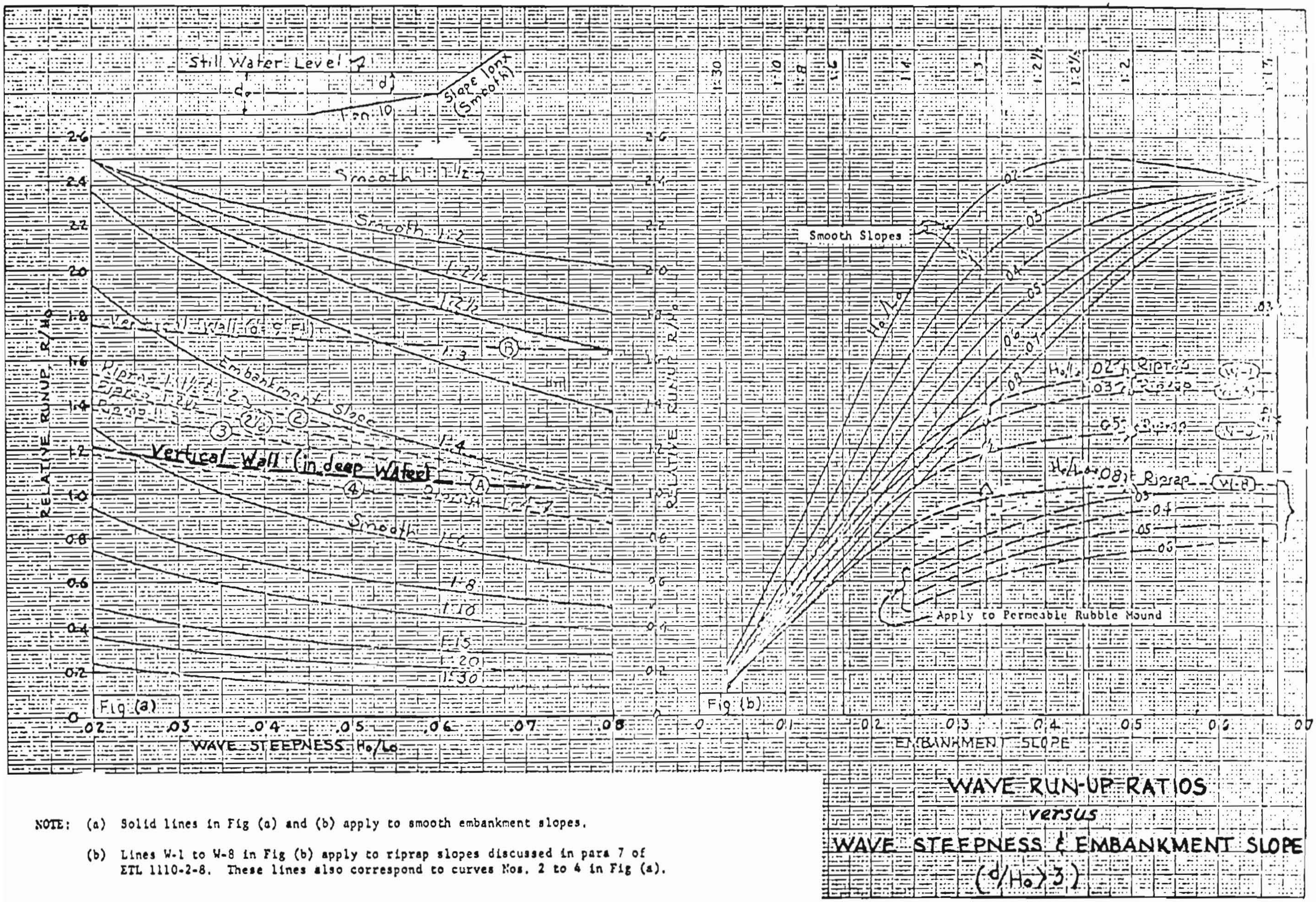
FIGURE A3.12
SOURCE: REF. 4




**GENERALIZED RELATIONS BETWEEN WAVE PERIODS AND RELATED FACTORS**

**(DEEP WATER CONDITIONS)**

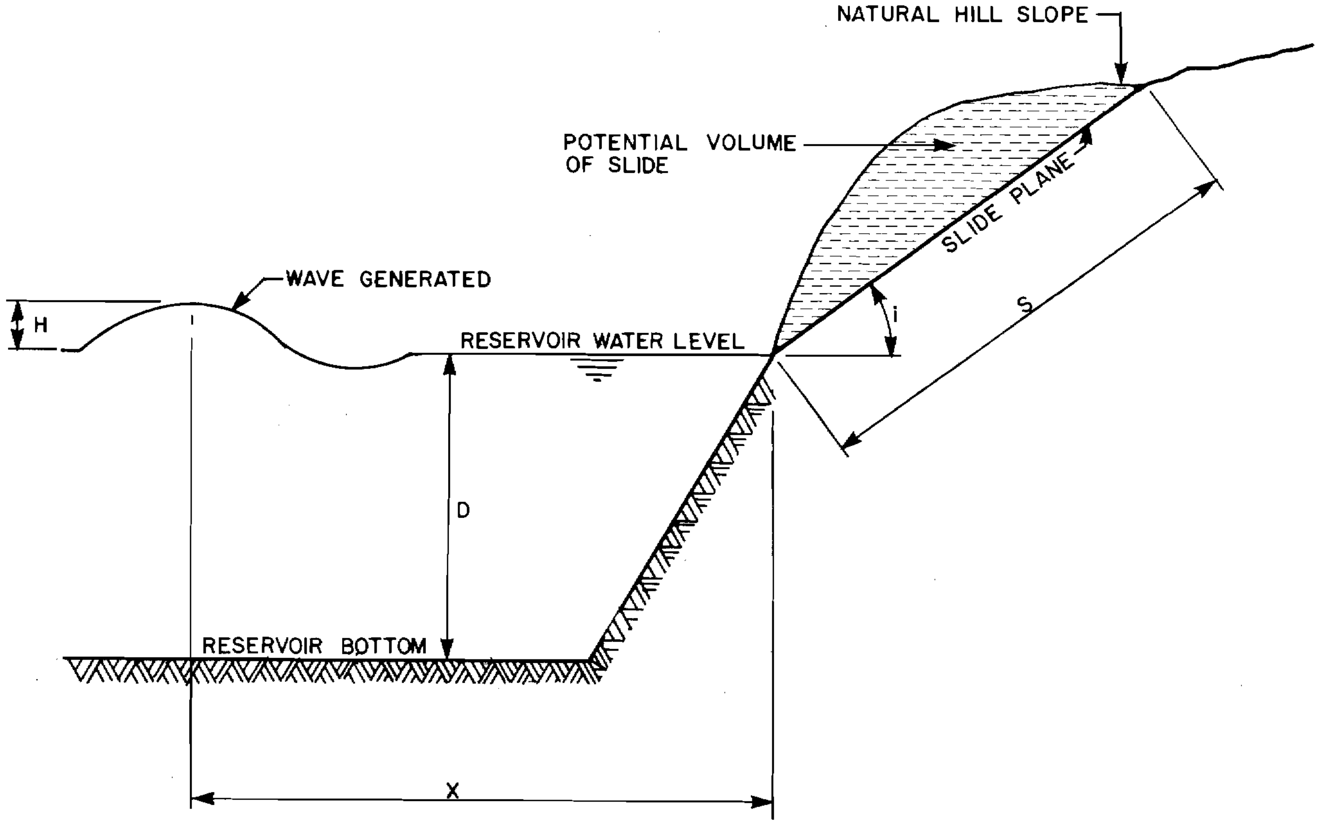
FIGURE A3.13
SOURCE: REF. 4




NOTE: (a) Solid lines in Fig (a) and (b) apply to smooth embankment slopes.

(b) Lines W-1 to W-8 in Fig (b) apply to riprap slopes discussed in para 7 of ETL 1110-2-8. These lines also correspond to curves Nos. 2 to 4 in Fig (a).

FIGURE A3.14
SOURCE: REF. 4



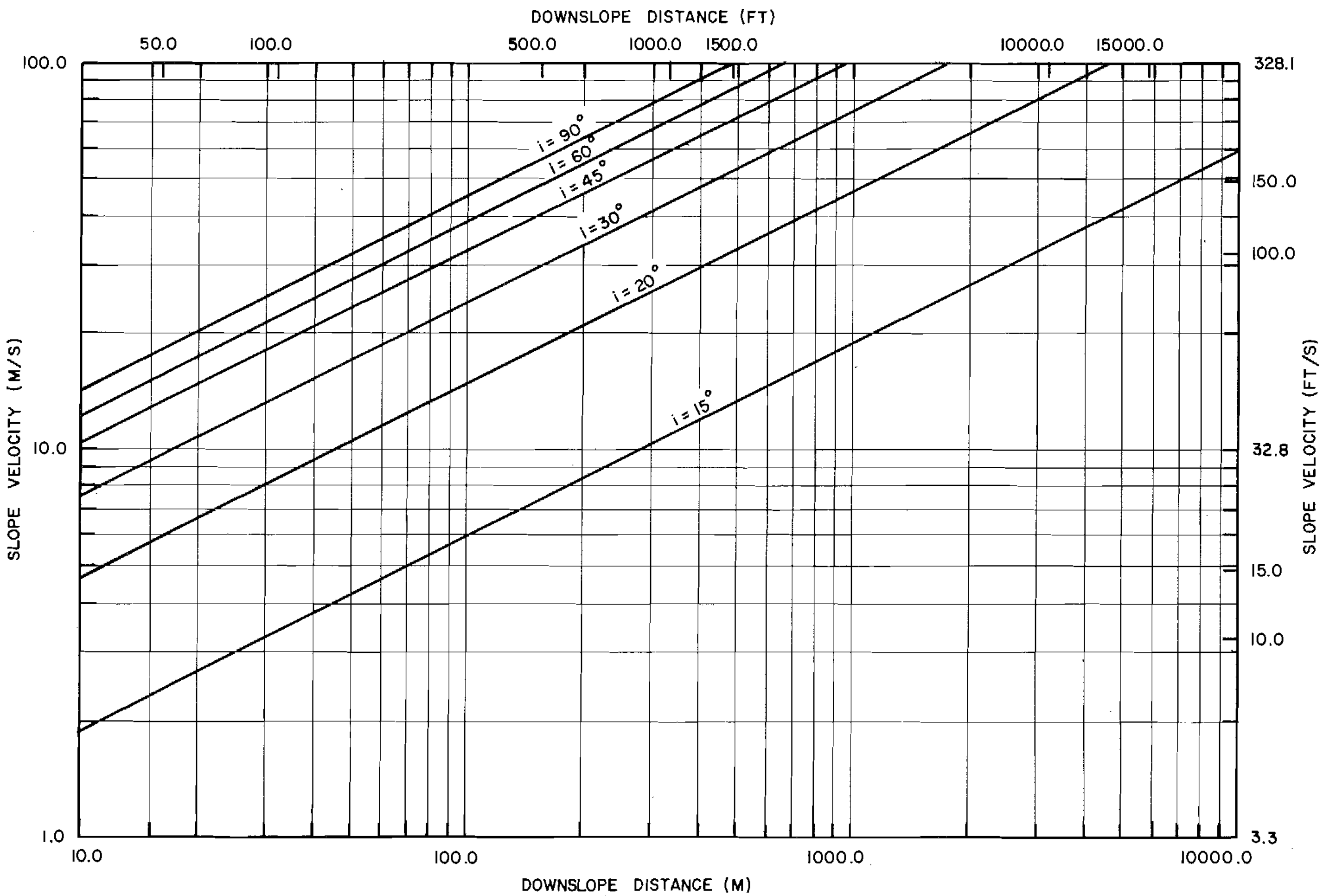

VARIABLES:

- Vim = SLIDE IMPACT VELOCITY WITH WATER
- g = GRAVITATIONAL CONSTANT
- S = DOWNSLOPE DISTANCE
- i = SLOPE ANGLE OF THE SLIDE PLANE
- $\phi$S = ANGLE OF DYNAMIC SLIDING FUNCTION
- Vo = INITIAL SLIDE VELOCITY (ASSUME = 0)
- Vol = VOLUME OF THE SLIDE
- D = MEAN WATER DEPTH
- $\rho_s$ = DENSITY OF SLIDE
- $\rho$ = DENSITY OF WATER
- KE = KINETIC ENERGY (DIMENSIONLESS)
- $\eta$ MAX = MAXIMUM WAVE HEIGHT
- X RADIAL DISTANCE FROM SLIDE
- H = WAVE HEIGHT AT DISTANCE X

DEFINITION SKETCH

FIGURE A3.15

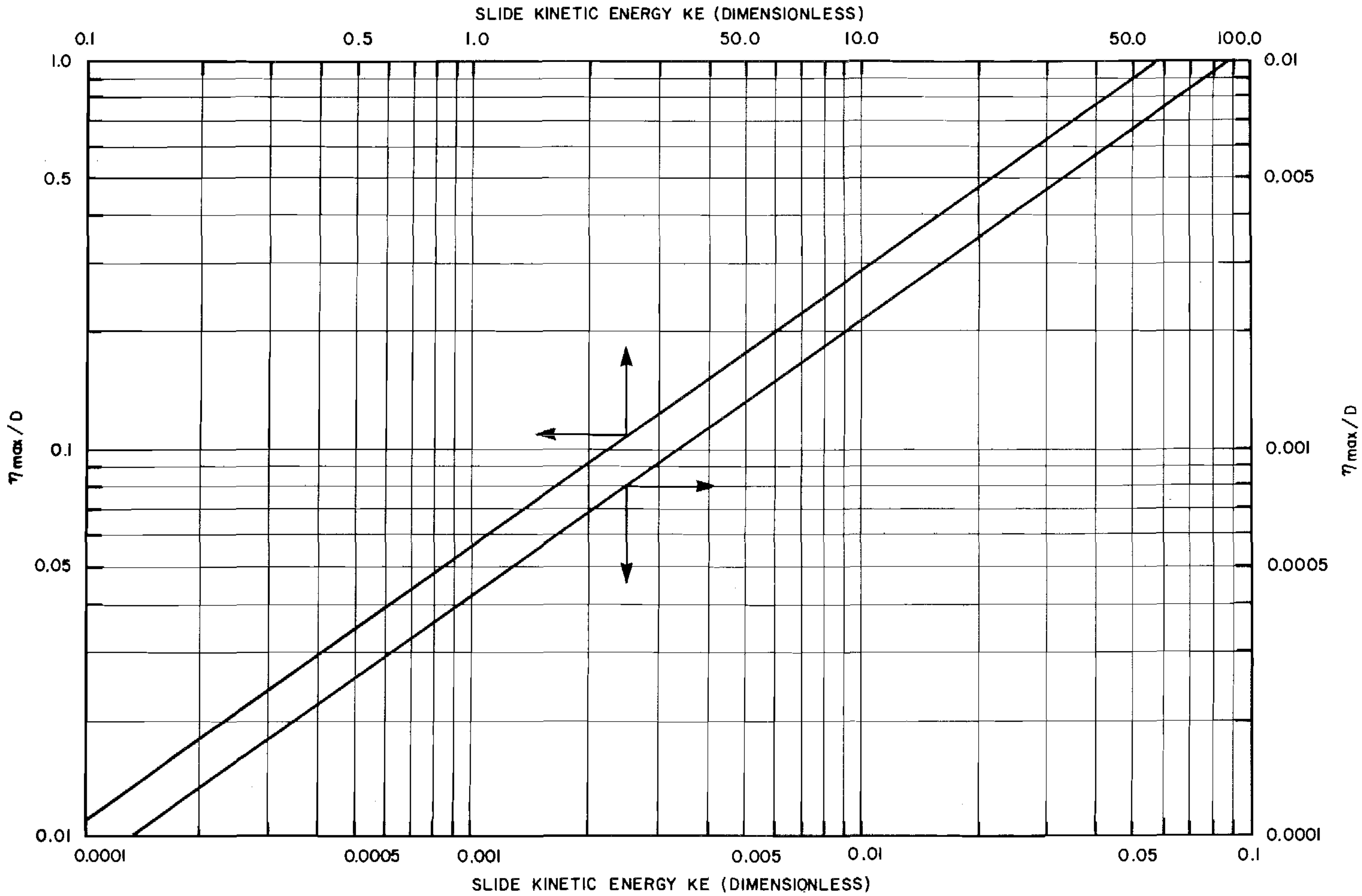
ACRES




SLIDE IMPACT VELOCITY

FIGURE A3.16

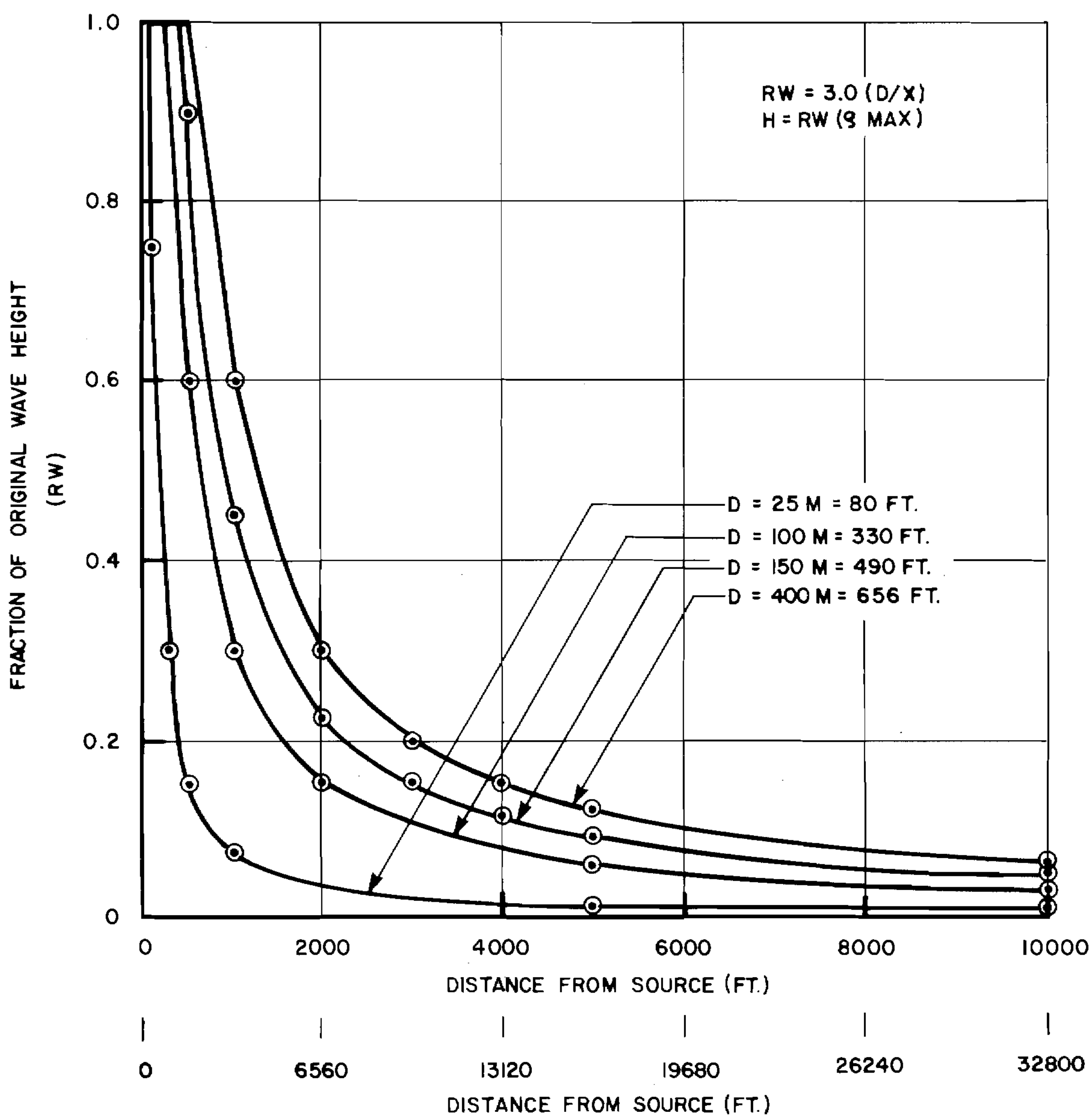
ACRES




**SLIDE KINETIC ENERGY**
**VS**
**MAXIMUM WAVE HEIGHT/AVERAGE DEPTH**

FIGURE A3.17

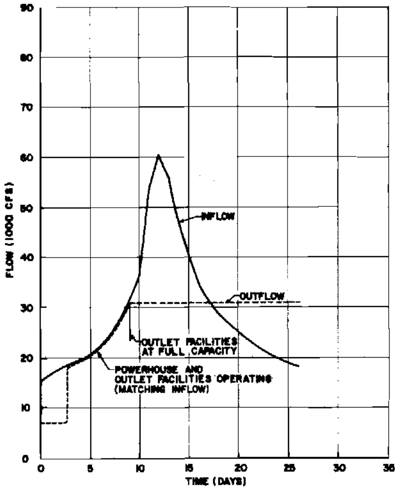
ACRES



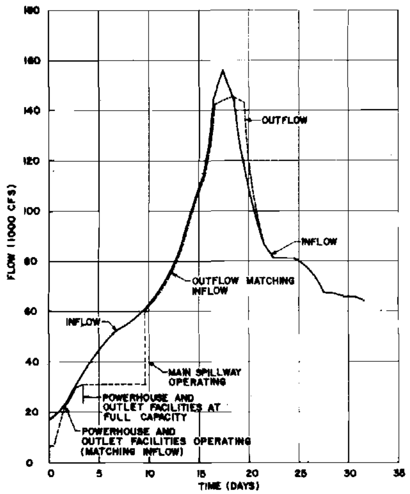

## WAVE ATTENUATION

FIGURE A3.18

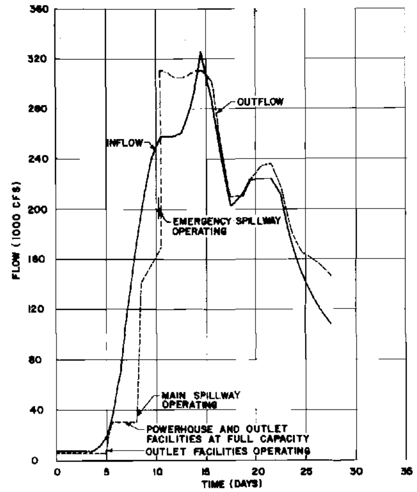
ACRES



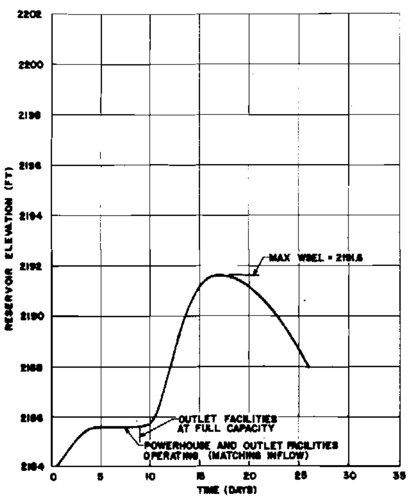

**1:50 YEAR FLOOD**
(SUMMER)



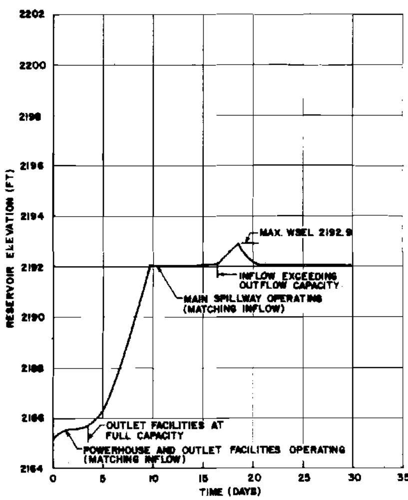

**1:10,000 YEAR FLOOD**



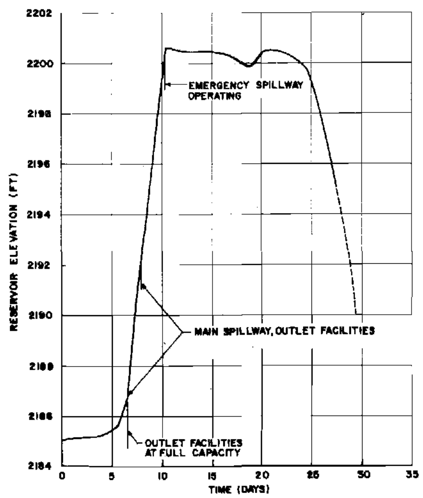

**PROBABLE MAXIMUM FLOOD**




**1:50 YEAR FLOOD**
(SUMMER)




**1:10,000 YEAR FLOOD**




**PROBABLE MAXIMUM FLOOD**

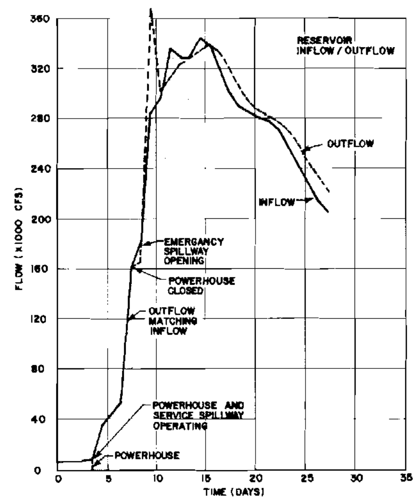
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

WATANA
HYDROLOGICAL DATA

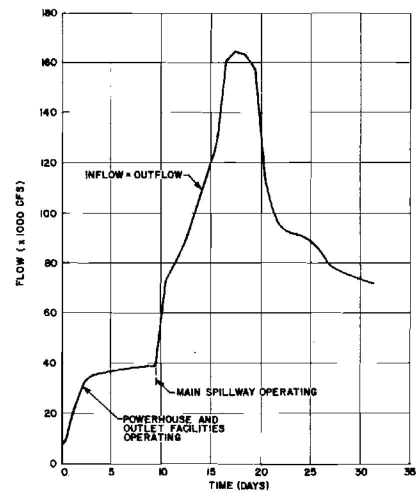
ACRES
ACRES AMERICAN INCORPORATED

MARCH 1982

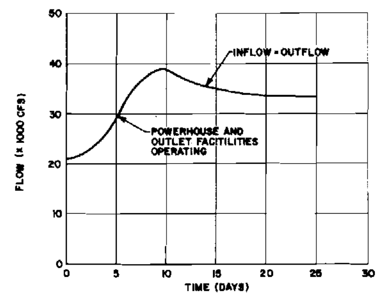
PLATE A3.1



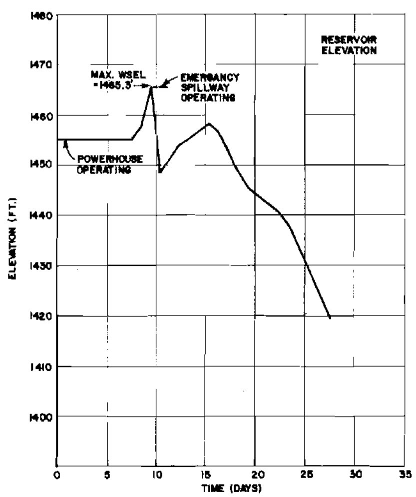

PROBABLE MAXIMUM FLOOD



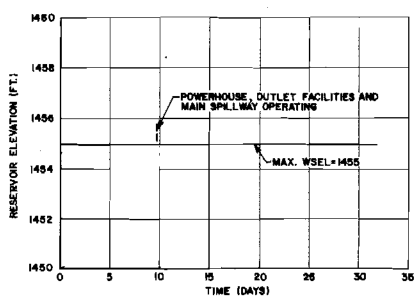

RESERVOIR ROUTING
1:10,000 YR. FLOOD



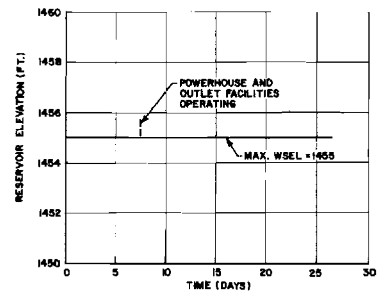

RESERVOIR ROUTING
1:50 YR. FLOOD




PROBABLE MAXIMUM FLOOD




RESERVOIR ROUTING
1:10,000 YR. FLOOD




RESERVOIR ROUTING
1:50 YR. FLOOD

| | |
|---|---|
| ALASKA POWER AUTHORITY | |
| SUSITNA HYDROELECTRIC PROJECT | |
| DEVIL CANYON HYDROLOGICAL DATA | |
| ACRES AMERICAN INCORPORATED | MARCH 1982 |
| PLATE | A32 |

ACRES

# APPENDIX A4

## RESERVOIR AND RIVER THERMAL STUDIES

## 1 - INTRODUCTION

Temperature regime of the Susitna River below the dam will be greatly altered from its natural state after impoundment of the proposed reservoirs at Watana and Devil Canyon. The reservoirs will act as heat traps during summer, resulting in the river water temperature being lower in summer and higher in winter when compared to natural conditions. River water temperature is of paramount importance to the fisheries, and changes in water temperatures could have serious effects on the fisheries unless controlled carefully.

This appendix describes the studies conducted to analyze natural and post-project temperature regime of the Susitna River in the reach from the Watana damsite to the confluence of the Chulitna River with the Susitna River. Studies were carried out in two parts. First, a simulation of the monthly temperature regime of the proposed reservoirs was made to determine typical temperature profiles within the reservoirs and temperature of outflows. A heat balance in a series of river reaches below the dams up to the Chulitna confluence was then made to estimate river water temperatures. The process was iterated several times by modifying power outlet levels until water temperatures in the reaches below the dams reach environmentally acceptable levels.

Section 2 describes the reservoir temperature studies and Section 3 details temperature regime analysis for the river below the dams. Microclimatic effects due to post-project temperatures in the reservoirs and the lower river are outlined in Section 4.

## 2 - RESERVOIR TEMPERATURE STUDIES

### 2.1 - Introduction

The objective of the reservoir temperature studies was to determine, for representative years, the possible temperature profile within the reservoir of the selected development plan.

The results from this study are used to determine the best configuration of outlet works and power intakes to achieve environmentally acceptable temperature levels in the river below the dams and maintain, to the extent possible, downstream ice cover growth and stability.

The model used for this study was the Reservoir Temperature Stratification of the Corps of Engineers developed by the Hydrologic Engineering Center (1). The model simulates the vertical distribution of water temperature within a reservoir on a monthly basis using data on initial conditions, inflows, outflows, evaporation, precipitation, radiation, and average air temperature. Outflow requirements can be specified in terms of releases or target outflow temperatures. The model is based on the energy budget approach schematically represented in Figure A4.1.

The Reservoir Temperature Stratification model is not the most precise model available in the field for such analysis. Other models, such as the MIT model, could perhaps give more detailed and precise results. However, the amount of information required to produce this higher order of accuracy is substantial and is not available for the study area. Information that is available on climatic conditions and water temperatures for the Susitna Basin essentially dictates the level of analyses most effective in both cost and in results. Analyses performed on other lakes and reservoirs indicates that the model used here provides reasonable indication of reservoir stratification and temperatures. Also, temperature measurements of Garibaldi Lake, in British Columbia and Bradley Lake in Alaska indicate that the general pattern of reservoir temperatures estimated by the model is similar to these observed patterns. Figures A4.2 and A4.3 show observed temperatures in Garibaldi Lake and Bradley Lake, respectively.

In the model, the reservoir is divided into horizontal layers of uniform thickness and an energy balance between the individual layers, the atmosphere, and the inflow is performed. Outlets, at specified levels, release water to meet a given total discharge. The selection of the outlet level from which water is released is determined such that the outlet temperature is as close as possible to prescribed target temperatures.

Temperature modeling of Devil Canyon reservoir assumes Watana is on-line and operating under normal power operation.

## 2.2 - Model Description

### (a) Model Characteristics

The Reservoir Temperature Stratification model is based on an energy budget approach as represented in Figure A4.1. The principal energy balance relationships of conduction, mixing, diffusion, evaporation, and insolation are represented by standard equations containing the hydrological and meteorological variables required to estimate the relationship. In each equation, a regional coefficient is used to describe site specific conditions. These coefficients are briefly described below:

- Air Temperature Coefficient is an index of energy transferred by conduction due to the difference between the air and water surface temperature;

- Inflow Mixing Coefficient is an index of energy transferred to the inflow due to the difference between the modified inflow temperature and the temperature of each layer as the inflow descends through the reservoir;

- Vertical Diffusion Coefficient is an index of energy transferred between adjacent layers due to the difference in temperature between layers;

- Evaporation Coefficient is an index of energy lost from the reservoir water surface due to evaporation. The remaining energy required for the heat of vaporization is obtained by cooling the air; and

- Insolation Coefficient is an index of energy transferred to the reservoir due to solar radiation. The solar radiation energy that is not effective in warming the reservoir is lost because of the absorption and reflection with the atmosphere and reflection at the water surface.

The values chosen for these coefficients are from a similar reservoir study undertaken in Oregon. These were assumed to be the best available since no regional coefficients have as yet been determined for Southcentral Alaska. These coefficients are listed in Table A4.1.

In the model, Watana and Devil Canyon reservoirs have been divided into horizontal layers of uniform thickness of five feet. This is believed to give a reasonable degree of profile definition and models approximately 500 feet in depth of the reservoir.

(b) Initial Conditions

Initial reservoir elevations and storage volumes are taken from the reservoir power simulation studies performed by Acres (Appendix A1). These studies simulate average monthly elevations and storage volumes for specified reservoir operation.

September was initially considered as the starting month for modeling, since it appeared to have the most stable water surface elevations given normal power operation. However, the initial temperature profile was difficult to define because of the possible large variation in heat inflow to the reservoir during the summer months and the consequent likelihood of a wide range of temperature profiles. After several trials, May was selected as the starting month, since it proved to have the most stable temperature profiles due to the depletion of the storage for power generation and low inflow volumes (hence low heat flux into the reservoir). It was found that if the model was started in September, after two years of simulation May was again in an almost isothermal condition of 39°F. Water at this temperature is at its maximum density, and therefore is believed to be a reasonable starting temperature based on similar studies in cold regions.

(c) Inflow

Watana and Devil Canyon reservoir inflow, outflow, and maximum and minimum storages were obtained from the reservoir simulation studies for reservoir operation cases (see Appendix A1) and are presented in Table A4.2. Two additional sets of inflow and outflow corresponding to wet and dry year streamflows for Case A were used in the analyses to determine the range of operating temperatures (see Table A4.3).

(d) Meteorological Variables

The determination of representative meteorological periods was based on the number of degree days of heating. It was assumed that the cold, mild, and average conditions were represented by the highest, lowest, and average number of degree days of heating. The cumulative degree days of heating for Talkeetna and Summit Stations are given in Figures A4.4 and A4.5, respectively. A review of this data indicated that average conditions may be used to determine typical reservoir conditions. Average air temperatures are based on recorded temperatures at Summit and Talkeetna Stations.

Average monthly precipitation figures, based on 35 years of record, for the Summit Stations were used in the analysis in the absence of good records at the damsites. Similarly, monthly evaporation data from Matanuska Valley Agricultural Experimental Stations were initially used in the model. A correlation was established between the evaporation estimates at Watana and Matanuska Station (Appendix A1) based on one-year observations at Watana. The differences between the values were small to cause any significant change in the model results, and the Matanuska data has ben retained in the model (Table A4.4). Solar radiation values were estimated from Corps of Engineers model data (Figure A4.6).

(e) Inflow Water Temperatures and Calibration of Model

Occasional water temperature data recorded by the USGS are available for the Gold Creek and Cantwell gaging stations. The data is limited and not continuous over any period of time. Cantwell records were averaged to obtain mean monthly inflow water temperatures at Watana. Where such data was unavailable, temperatures were interpolated between available monthly values. All the modeling of Watana reservoir were carried out with these synthesised monthly inflow water temperatures (see Table A4.5).

During 1981 actual water temperature measurements were made near to Watana damsite as part of water quality monitoring program (2). This data, along with simultaneous stream discharges at Watana and climatological data at Watana and Talkeetna, were used to rerun the model to assess the sensitivity of the outflow water temperatures using synthetic inflow temperature data as discussed above. The results compare very closely (Table A4.5) indicating the reasonableness of synthesised data in evaluating post-project conditions.

Inflow temperature into Devil Canyon reservoir was assumed as that of the Watana outflow temperature with minor modifications to account for intermediate catchment discharge and heat exchange with atmosphere in the intermediate shallow reaches of the reservoir.

(f) Model Analyses and Results

With the streamflow, water temperature and other climatological data, the model was run to determine the temperature profiles in the two reservoirs for several power intake configurations. The anlyses covered different operations (Cases A and D, see Appendix A1 for details) and Watana reservoir filling sequence to define the range of downstream conditions that could be expected during construction and operation of the projects. Outflow temperature as modeled are input to the downstream river temperature simulation model (Section 3) to determine the temperature regime in the low river because of the reservoir operations.

Model results generally confirmed that single power intakes capable of drawing water at the lowest operating levels of the reservoirs would be unable to meet the minimum downstream temperature requirements of 42.5°F during summer (Section 3). In most months, draw off nearest to the reservoir surface yielded outflow temperatures closest to natural temperatures. An intake structure design with such capability to draw water at or close to the surface over the entire drawdown range of the reservoir at Watana was developed but not found to be cost-effective when compared to a relatively simple multi-level structure with four discrete opening levels. The latter configuration in combination with a single power intake at 70 feet below the reservoir operating level of 1455 feet generally provided downstream flow temperatures well above the minimum required during the summer months June through September.

In winter, the two reservoirs reach fairly close to isothermal conditions with water temperature around 39°F. The model is relatively crude in its representation of ice formation in the reservoir and the anamodous expansion of water between 39°F and 32°F. This results in the inability of the model to define winter temperature profile clearly in this range (see Figures A4.8 and A4.10). If thus appears that winter and outflow temperature will be close to 39°F no matter where the water is drawn. It is, however, logical to assume that somewhat cooler water may be drawn from close the surface below the ice cover when formed. Figures A4.7 and A4.10 present monthly temperature profiles in the two reservoirs. Plates A4.1 shows general arrangement of the selected intake facility at Watana.

Typical computer output for Watana and Devil Canyon temperature modeling are presented in Attachment 1.

## 3 - TEMPERATURE REGIME OF SUSITNA RIVER BELOW DAMS

### 3.1 - Introduction

An in-house computer model was used to study the temperature regime of the river below the dams. The Susitna River between the damsites and the confluence of the Chulitna River is divided into representative reaches. These reaches are selected to model effectively the hydraulic characteristics of the river. A daily heat balance in this series of river reaches is simulated in the model to determine the water temperature at the downstream end of each reach. The components of heat exchange used in the balance, determined from empirical relationships presented by Michel (3) are shown in Figure A4.11. Several other possible sources of heat such as the conduction of heat from within the ground and heat gained or lost from ground water flows have been neglected because of their relatively small magnitude.

The procedure involves a daily heat balance to be made stepwise starting from the upstream section of the first reach to the downstream section of the reach. The water temperature, calculated from the net exchange at the end of the first reach, is then used as the starting temperature of the second reach. This process was continued until water temperatures in all the reaches had been calculated. At each step, the net heat exchange was added to the volume of water passing through the sections.

### 3.2 - Data Input

The coefficients required for the computation of the components of heat balance are insolation, emissivity and albedo. These coefficients are described below:

- Insolation Coefficient is an index of energy transferred to the water due to solar radiation;
- Emissivity Coefficient is a measure of the radiation emitted by a surface. For water, the emissivity has a very small variation with temperature; and
- Albedo for Water is an index of the amount of the atmospheric radiation absorbed by the body of water.

The values of the insolation, emissivity and albedo coefficients adopted for the analysis are 0.97, 0.97, and 0.1, respectively. These values are the generally accepted values for water (3).

Long-term climatic records at Talkeetna and Summit collected by NOAA have been used as input in the analysis. The principal climatic parameters used in the model are average daily air temperature, ratio of recorded sunshine to maximum possible sunshine, wind speed, precipitation, barometric pressure, and relative humidity. Air temperature and the sunshine ratio are the two most important parameters of this set.

In the analysis, the average daily air temperature has been assumed to be the average for the period of record (1941-70) for Talkeetna and Summit Stations. The average temperatures of the two stations are used for the upper reaches (above Devil Canyon), since this portion of the river is at an intermediate elevation and latitude. Average Talkeetna daily air temperatures are used in the lower river reach. The ratio of bright sunshine to maximum possible sunshine is taken from the average number of clear, partly cloudy, and cloudy days for each month over the period of record for Summit, and have been given values of 0.9, 0.5, and 0.2, respectively.

The other climatological parameters such as wind speed, rainfall, snowfall, barometric pressure, and relative humidity are taken as the average monthly values at Summit for the period of record. The average monthly values of these variables were determined to be adequate due to their relatively small impact on the estimation of the change in water temperature.

The model in this analysis does not reflect the diurnal variations in water temperatures. In winter, this diurnal change in the water temperature may have a significant variation about the daily mean due to the normal range in air temperatures.

### 3.3 - River Characteristics

In computing the heat balance of a river system, the model requires specific inputs which describe the hydraulic characteristics of the river and the flow conditions. The study section of Susitna River has been divided into 20 reaches from the Watana damsite to Talkeetna. Each of these reaches comprises several sub-reaches which have been surveyed (see Hydrographic Survey Report, Subtask 2.16) and is evaluated to determine relationships which would describe the mean velocity and average depth for a given discharge. The U.S. Army Corps of Engineers backwater program (HEC-2) has been used to obtain average depths and velocities at various discharges (4). A power curve fitting routine is then used to determine the relationship between mean velocity and depth flows.

As explained in Section 2, monthly water temperatures at Watana were synthesized from Gold Creek and Cantwell data. These data have been used to generally calibrate the model to simulate natural temperature regime in the reach above the Chulitna confluence and Watana damsite.

### 3.4 - Model Verification

During the summer of 1981, several thermographs were installed along the river by the Alaska Department of Fish and Game (ADF&G) as part of fisheries habitat studies (see Volume 2 of main report). Processed data from selected stations are now available (Table A4.5). Simultaneous data collected at Watana is also presented in Table A4.5.

No water temperature data at Watana is available for July 1981 due to a malfunction of the instrument. Difficulties with monitoring equipment at Watana and Devil Canyon resulted in poor data recovery in the months July through September 1981. Thus it was decided to use the observed water temperature at river Section 61 upstream of Portage Creek for the period of July 17 to September 30, 1981 along with simultaneous flows at Gold Creek and Talkeetna climatic parameters as input to the HEATSIM model and formulate the river stretch for over 20 miles to generate water temperatures at cross-sections 54, 47 and 34. These temperatures were compared with the observed water temperatures during this period. Table A4.6 shows that on the average monthly temperatures simulated and observed compare favorably ($\pm$ 1°F) except for the river Section 54 which may be due to local floods, lack of tributary flow and temperature data or gross averaging effects of the model procedures. However, the closeness of results suggest that the physical heat exchange processes are modeled reasonably and that the model may be used to estimate post-project river conditions.

### 3.5 - Environmental Considerations

In order to establish target water temperatures to be achieved in the river reaches below the dams, extensive discussions were held with the fisheries study team and ADF&G. It was decided that a minimum temperature of around 42.5°F should be reached in the river below the dams during the predominant salmon runs between early June and mid September. Higher temperatures would, however, be advantageous during the months of July and August. To take account of model accuracy as interpreted from the calibration and verification procedures, a minimum summer outflow temperature of 45° was set as target temperature below the dams and several iterations for power intake levels were made until target temperatures were achieved. The winter temperatures of 39°F will be somewhat detrimental to the fisheries, but lower water temperatures as one progresses further downstream from the dams reduces such adverse impacts. Impacts of fisheries of the temperature regime in the river under post-project conditions are discussed in Volume 2 of the main report.

### 3.6 - Model Analyses and Results

The calibrated model was used to determine the temperature regime of the river below the dams for the following phases of development:

- Filling sequence of the Watana reservoir;
- Operation of the Watana development only; and
- Operation of both Watana and Devil Canyon developments.

The chief concern during the filling sequence of the Watana reservoir lasting over three summers is that the minimum flow releases from the reservoir will be made through the low level discharge facilities (Section 15, Volume 1 of the main report). Temperature of this discharge is estimated to be close to 39°F all through the year. HEATSIM modeling of the river reach below the dam up to the confluence of Chultina was made and results presented in Table A4.7. A river reach of over 10 miles in the Devil Canyon area between Devil Creek and just above Portage Creek are not modeled due to lack of river cross-section and inability to model the rapids. It is estimated that the temperature regime presented in Table A4.7 would be somewhat conservative.

Results of the model runs are presented in Tables A4.8 to A4.11 for reservoir operations in average, wet and dry years of record as well as for Case A and D operations. Figures A4.12 to A4.17 present these results along with simulated natural water temperatures at selected rivers sections below the dams.

It should be emphasized that the temperature modeling though performed on a daily basis is only a tool to predict average monthly conditions due essentially to gross discretion of all input parameters. The results are believed adequate to picture the post-project effects on the river thermal regime to assess environmental impacts. More detailed data collection program should be initiated to enable use of sophisticated modeling of the reservoir operations and river characteristics in later phases of work.

## 4 - MICROCLIMATIC CHANGES DUE TO THE IMPOUNDMENTS

A preliminary assessment of the microclimatic changes at and downstream of the proposed impoundments was made and the following sesctions discuss the findings.

### 4.1 - Temperature

On the average the reservoir will be ice covered during the period from October through April and, although shoreline cracking may occur as a result of drawdown, the area of exposed water will be insufficient to cause any significant temperature change.

During the period from May through September when the reservoir is expected to be ice free, the surface water temperature will range from 15°F below the average daily maximum to some 5°F above the average daily minimum air temperatures.

Temperature changes of approximately 70 percent of the difference between reservoir surface temperature and undisturbed air temperature are expected at the shoreline, gradually diminishing to zero change at a downwind inland distance of about one mile. This means lower shoreline maximums of about 10°F and higher shoreline minimums of about 4°F, with a lower mean daily temperature of about 3°F or 4°F in the direction of the wind on any particular day. Accuracy of these temperature projections is of the order of $\pm$2°F.

From May through August, the regional prevailing wind directions are from west to southwest, and in 1980 at Watana ranged from over 40 percent of time in May, over 60 percent in June and July, to 90 percent in August. By September, the reserve flow characteristic of winter conditions sets in with winds from north to east about 55 percent of the time.

The inland areas most frequently affected by these temperature changes will lie to the east and northeast of the east-west oriented reservoir from May through August, shifting to the west and southwest in September, although all other inland directions will occasionally be affected.

The date of the latest frost in May will likely be earlier by some 10 days, and the date of the earliest frost in September will likely be delayed by about 7 days.

### 4.2 - Relative Humidity

As with temperatures, no change in atmospheric moisture content is expected from October through April when the reservoir will be ice covered. However, in the open season, the high minimum temperatures should decrease the frequency of nighttime radiation fog occurrences in the downwind nearshore areas. This would be particularly true during August and September when the average relative humidity at Talkeetna exceeds 80 percent at 10 p.m. and 8 a.m. Alaskan Standard Time and is undoubtedly at or near 100 percent occasionally between those hours.

### 4.3 - Precipitation

Again, no change to the existing precipitation regime is expected when the reservoir is ice covered. A significant change to the distribution of snow in the area over and downwind of the reservoir will occur. Because reduced frictional drag over the ice-covered reservoir surface as compared with the existing irregular land surface which will be flooded (even though snow covered during the colder months), snow will tend to blow and drift into large accumulations to the west and southwest of the reservoir, extending in alternating drifts and hollows a few miles downwind. Snow will also tend to blow and drift into the transmission line corridor(s) regardless of wind direction.

During the open reservoir season, no change in the existing overall precipitation regime is expected. Changes on the micro-scale extending up to about a mile inland are expected, but these will have no effect on the hydrology of the drainage basin. As discussed in Section 1, air cooled by up to 10°F blowing inland off the reservoir in the afternoon may extend about a mile inland before being destroyed by insolation. The effect of this will be to suppress convective cloud development and hence reduce the frequency of showers in that very limited area.

## 4.4 - Wind

During the ice-covered reservoir period, prevailing north to east winds will tend to sweep the reservoir clear of snow or at least to maintain a smooth flat surface that will reduce frictional drag, as mentioned in Section 3. Increased wind speeds from those directions could be in the order of 15 to 20 percent, but that energy is likely to dissipate downwind of the dam and may be imperceptible to 5 percent stronger at Gold Creek.

During the open-reservoir period, prevailing west to southwest winds will again have less frictional drag in passage over the reservoir and hence could be stronger by 15 to 20 percent at the east and northeast ends of the reservoir. Again, this energy is likely to dissipate within a few miles after the air leaves the reservoir.

## 4.5 - Winter Ice Fog

Downstream of the dam, the river is expected to remain largely ice-free up to Talkeetna when both Watana and Devil Canyon developments are operational. When air temperatures are in the approximate range of +10°F to -10°F, so-called "steam fog" is likely to form over the wider expansions of the river. This fog consists of small supercooled water drops typically in a size range of 10 to 50 microns which freeze on contact with vegetation or structures to form rime ice having a density of about 0.6. Typically, the ice thickness in such deposits is only in the order of 1/4 inch and exerts loads only sufficient to break twigs on vegetation. At temperatures colder than about -10°F, ice crystals are likely rather than supercooled water drops.

Of more concern is the potential for icing roadways, railways and runways. Based on our experience in observing this type of fog formation on Lake St. Louis, a widening of the St. Lawrence River near Montreal, it is very unlikely that these fog occurrences will extend inland more than one mile and are unlikely to affect Talkeetna airport. The railway and road systems closer to the river would be affected, possibly requiring additional salt and/or sand treatment, although this seems unlikely for the railway. Estimated frequencies of such occurrences are presented below:

| Winter Temperature | Total Fog Days | Maximum Consecutive Days |
|---|---|---|
| Average | 50 | 15 |
| Warm | 20 | 7 |
| Cold | 75 | 20 |

## LIST OF REFERENCES

1. R&M Consultants, Susitna Hydroelectric Project, Field Data Collection and Processing, December 1981.

2. U.S. Army Corps of Engineers, Hydrologic Engineering Center (1972) - Reservoirs Temperature Stratification User Manual.

3. Michel, B. (1977) Winter Regime of Rivers and Lakes Cold Regions Science and Engineering Monograph III - Bla U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory; Hanover, New Hampshire.

4. Acres/R&M Consultants, Susitna Hydroelectric Project, Hydraulic and Ice Studies, March 1982.

LIST OF TABLES

## LIST OF FIGURES

TABLE A4.1: RESERVOIR TEMPERATURE STRATIFICATION MODEL COEFFICIENTS

| Coefficient | Value |
|---|---|
| Air Temperature | 0.816 |
| Inflow Mixing | 0.114 |
| Vertical Diffusion | 0.043 |
| Evaporation | 0.637 |
| Insolation | 0.193 |

TABLE A4.2: WATANA AND DEVIL CANYON RESERVOIR AVERAGE YEAR FLOWS (CFS)

| Month | Watana | | | Devil Canyon | | | |
|---|---|---|---|---|---|---|---|
| | Inflow | Outflow | | Inflow | | Outflow | |
| | Case A | Case A | Case D | Case A | Case D | Case A | Case D |
| Jan | 1157 | 10617 | 7989 | 10812 | 8184 | 10514 | 7670 |
| Feb | 979 | 9027 | 6743 | 9195 | 6911 | 8883 | 6670 |
| Mar | 898 | 8013 | 6856 | 8156 | 6999 | 8072 | 6771 |
| Apr | 1113 | 6011 | 5723 | 6180 | 5892 | 7903 | 5735 |
| May | 10398 | 5344 | 5286 | 7177 | 7119 | 9344 | 7031 |
| Jun | 22922 | 4990 | 4599 | 8059 | 7668 | 10288 | 7608 |
| Jul | 20778 | 7022 | 10350 | 9344 | 12672 | 9070 | 13786 |
| Aug | 18431 | 9190 | 13933 | 11467 | 16210 | 8478 | 18685 |
| Sep | 10670 | 6486 | 10105 | 8115 | 11734 | 6972 | 11458 |
| Oct | 4513 | 7338 | 6324 | 8137 | 7123 | 7403 | 6456 |
| Nov | 2052 | 9186 | 7485 | 9517 | 7816 | 9425 | 7200 |
| Dec | 1405 | 11999 | 8909 | 12246 | 9156 | 11864 | 8457 |

TABLE A4.3: WATANA AND DEVIL CANYON RESERVOIRS - WET AND DRY YEAR FLOWS

| | WATANA | | | | DEVIL CANYON | | | |
|---|---|---|---|---|---|---|---|---|
| | Wet Year | | Dry Year | | Wet Year | | Dry Year | |
| Month | Inflow | Outflow | Inflow | Outflow | Inflow | Outflow | Inflow | Outflow |
| Jan | 817 | 10603 | 636 | 8318 | 10708 | 10708 | 8437 | 8353 |
| Feb | 755 | 8928 | 602 | 6872 | 9066 | 9066 | 6979 | 6742 |
| Mar | 694 | 7846 | 624 | 7235 | 8004 | 8004 | 7333 | 6914 |
| Apr | 718 | 5886 | 986 | 6285 | 6035 | 7889 | 6345 | 5842 |
| May | 12953 | 5318 | 9536 | 5678 | 8344 | 10606 | 6863 | 6079 |
| Jun | 27172 | 4825 | 14399 | 5059 | 8790 | 11052 | 7779 | 10041 |
| Jul | 25831 | 13375 | 18410 | 5256 | 16756 | 13763 | 7988 | 7988 |
| Aug | 19153 | 14021 | 16264 | 4585 | 17477 | 14085 | 6974 | 4707 |
| Sep | 13194 | 8365 | 7224 | 4399 | 11666 | 12783 | 5618 | 4474 |
| Oct | 4102 | 7104 | 2043 | 6450 | 7650 | 6540 | 6914 | 6914 |
| Nov | 1588 | 9479 | 1021 | 7579 | 9680 | 9680 | 7703 | 7934 |
| Dec | 1039 | 12268 | 709 | 9221 | 12436 | 12436 | 9321 | 9463 |

TABLE A4.4: AVERAGE MONTHLY EVAPORATION DATA (INCHES)

| Month | Evaporation[1] | Years of Record |
|---|---|---|
| May | 4.63 | 15 |
| June | 4.58 | 24 |
| July | 4.09 | 29 |
| August | 2.99 | 29 |
| September | 1.83 | 26 |

(1) Data recorded at Matanuska Valley Agricultural Experiment Station

TABLE A4.5: COMPARISON OF SYNTHETIC AND OBSERVED MONTHLY WATER TEMPERATURES AT WATANA

| Month | Inflow Temperatures | | Calculated Power Outflow Temperatures | |
|---|---|---|---|---|
| | Synthetic (°F) | Recorded 1981 (°F) | Synthetic (°F) | Recorded 1981 (°F) |
| Jan | 32.0 | 32.0[3] | 39.0 | 39.0 |
| Feb | 32.0 | 32.0[3] | 39.0 | 39.0 |
| Mar | 32.0 | 32.0[3] | 39.0 | 39.0 |
| Apr | 32.0 | 32.0[3] | 39.0 | 39.0 |
| May | 41.9 | 41.9[3] | 39.1 | 43.1 |
| Jun | 45.5 | 50.4[1] | 43.9 | 51.6 |
| Jul | 50.9 | 48.8[2] | 49.1 | 50.4 |
| Aug | 49.6 | 47.1[1] | 48.8 | 48.4 |
| Sep | 42.3 | 41.3[1] | 45.4 | 47.9 |
| Oct | 35.2 | 33.1[1] | 39.9 | 42.8 |
| Nov | 32.0 | 32.0[3] | 39.0 | 39.6 |
| Dec | 32.0 | 32.0[3] | 39.0 | 39.0 |

Notes:

(1) Average Monthly Data Recorded at Watana
(2) No Data Available - Linear Interpolation
(3) No Recorded Data Available - Same as "Average"

TABLE A4.6: COMPARISON OF RECORDED AND CALCULATED WATER TEMPERATURES BELOW DEVIL CANYON DAMSITE FOR NATURAL CONDITIONS (°F)

| Months | Water Temperature | LR x 61 | | LR x 54 | | LR x 47 | | LR x 34 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Recorded | Calculated | Recorded | Calculated | Recorded | Calculated | Recorded | Calculated |
| Jul '81[1] | Mean | 50.1 | 49.7 | 48.3 | 49.8 | 49.3 | 50.0 | 50.5 | 50.1 |
| | Std. Dev. | 0.4 | 0.4 | 0.9 | 0.5 | 0.9 | 0.4 | 0.4 | 0.4 |
| Aug '81 | Mean | 47.7 | 47.3 | 45.8 | 47.3 | 47.4 | 47.7 | 47.5 | 47.7 |
| | Std. Dev. | 2.6 | 2.6 | 2.3 | 2.6 | 2.4 | 2.6 | 3.3 | 2.6 |
| Sep '81 | Mean | 42.7 | 42.3 | 41.8 | 42.6 | 41.3 | 42.9 | 43.6 | 43.0 |
| | Std. Dev. | 4.3 | 4.3 | 5.0 | 5.3 | 4.4 | 4.1 | 3.6 | 3.9 |

(1) Partial records averaged

TABLE A4.7: AVERAGE MONTHY STREAM TEMPERATURES (°F) - "CASE A OR D" OPERATION DURING WATANA RESERVOIR FILLING SEQUENCE

| | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Watana Flow cfs | 900 | 900 | 900 | 900 | 4000 | 4000 | 6000 | 6000 | 6000/3200 avg=4600 | 3200/900 avg=2050 | 900 | 900 |
| Watana Outflow Temp | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| LRX 68 | 32.0 | 32 | 32 | 42.1 | 44.1 | 47.5 | 45.1 | 44.8 | 40.8 | 37.0 | 32.0 | 32.0 |
| LRX 61 Flow cfs | 1110 | 1070 | 1045 | 1070 | 5870 | 7180 | 8256 | 8228 | 7644 | 4000 | 1225 | 1150 |
| Temp | 32.0 | 32.0 | 32.0 | 42.1 | 44.1 | 47.5 | 45.5 | 44.8 | 40.8 | 36.5 | 32.0 | 32.0 |
| LRX 54 | 32.0 | 32.0 | 32.0 | 43.5 | 44.8 | 48.6 | 46.0 | 45.7 | 41.2 | 36.3 | 32.0 | 32.0 |
| LRX 47 | 32.0 | 32.0 | 32.0 | 43.3 | 45.3 | 49.1 | 46.4 | 46.2 | 41.4 | 36.3 | 32.0 | 32.0 |
| LRX 41 | 32.0 | 32.0 | 32.0 | 43.5 | 45.5 | 49.3 | 46.4 | 46.4 | 41.5 | 36.3 | 32.0 | 32.0 |
| LRX 34 | 32.0 | 32.0 | 32.0 | 43.9 | 45.9 | 49.8 | 47.1 | 46.9 | 41.7 | 36.3 | 32.0 | 32.0 |
| LRX 24 | 32.0 | 32.0 | 32.0 | 44.2 | 46.6 | 50.7 | 47.7 | 47.8 | 41.9 | 36.1 | 32.0 | 32.0 |
| LRX 21 | 32.0 | 32.0 | 32.0 | 44.4 | 46.9 | 51.4 | 48.0 | 48.4 | 42.3 | 36.1 | 32.0 | 32.0 |
| LRX 15 | 32.0 | 32.0 | 32.0 | 45.0 | 47.8 | 52.5 | 48.7 | 49.5 | 42.6 | 36.0 | 32.0 | 32.0 |
| LRX 9 | 32.0 | 32.0 | 32.0 | 45.1 | 48.6 | 53.4 | 49.5 | 50.4 | 43.0 | 36.0 | 32.0 | 32.0 |
| LRX 3 | 32.0 | 32.0 | 32.0 | 45.3 | 51.3 | 54.1 | 60.0 | 51.1 | 43.2 | 36.0 | 32.0 | 32.0 |
| Alternative | | | | | | | | | | | | |
| Watana FLow cfs | 900 | 900 | 900 | 900 | 4000 | 4000 | 16000 | 16000 | 4600 | 2050 | 900 | 900 |
| Temp at LRX 68 | 32.0 | 32.0 | 32.0 | 39.7 | 43.7 | 47.1 | 40.8 | 41.4 | 40.5 | 36.5 | 32.0 | 32.0 |

TABLE A4.8: STREAM WATER TEMPERATURE FOR AVERAGE YEAR (°F) - "CASE A" OPERATION
MULTILEVEL INTAKE AT WATANA AND SINGLE LEVEL AT DEVIL CANYON

| Cross Section | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LRX 68 | 39.0 | 39.0 | 39.0 | 39.0 | 42.3 | 44.8 | 49.6 | 49.3 | 45.7 | 39.7 | 39.0 | 39.0 |
| LRX 61 | 38.8 | 38.8 | 39.0 | 39.0 | 42.4 | 44.8 | 49.6 | 49.5 | 45.7 | 39.7 | 39.0 | 38.8 |
| LRX 54 | 37.9 | 38.3 | 38.7 | 39.2 | 43.0 | 45.5 | 50.2 | 50.2 | 45.9 | 39.6 | 38.3 | 38.3 |
| LRX 47 | 37.4 | 37.8 | 38.5 | 39.4 | 43.2 | 46.0 | 50.4 | 50.5 | 46.0 | 39.6 | 38.1 | 37.9 |
| LRX 41 | 37.2 | 37.8 | 38.5 | 39.4 | 43.3 | 46.2 | 50.5 | 50.7 | 46.0 | 39.6 | 37.9 | 37.8 |
| LRX 34 | 36.7 | 37.2 | 38.1 | 39.6 | 43.7 | 46.8 | 50.9 | 51.3 | 46.2 | 39.4 | 37.4 | 37.2 |
| LRX 27 | 35.8 | 36.5 | 37.9 | 39.7 | 44.2 | 47.5 | 51.3 | 51.8 | 46.4 | 39.4 | 36.9 | 36.5 |
| LRX 21 | 35.1 | 36.1 | 37.8 | 39.9 | 44.6 | 8.08 | 51.6 | 52.3 | 46.6 | 39.2 | 36.5 | 36.0 |
| LRX 15 | 34.0 | 35.2 | 37.4 | 40.1 | 45.1 | 48.9 | 52.2 | 53.2 | 46.8 | 39.0 | 35.8 | 35.1 |
| LRX 9 | 32.9 | 34.5 | 37.0 | 40.5 | 45.9 | 49.8 | 52.7 | 54.0 | 46.9 | 38.8 | 35.1 | 34.3 |
| LRX 3 | 32.2 | 34.0 | 36.7 | 40.6 | 46.2 | 50.5 | 53.1 | 54.7 | 47.1 | 38.8 | 34.5 | 33.6 |
| Discharge Below Devil Canyon (cfs) | 10514.0 | 8883.0 | 8072.0 | 7903.0 | 9344.0 | 10288.0 | 9070.0 | 8665.0 | 6972.0 | 7403.0 | 9425.0 | 11864.0 |

TABLE A4.9: STREAM WATER TEMPERATURE FOR WET YEAR (°F) - "CASE A" OPERATION
MULTILEVEL INTAKE AT WATANA AND SINGLE LEVEL AT DEVIL CANYON

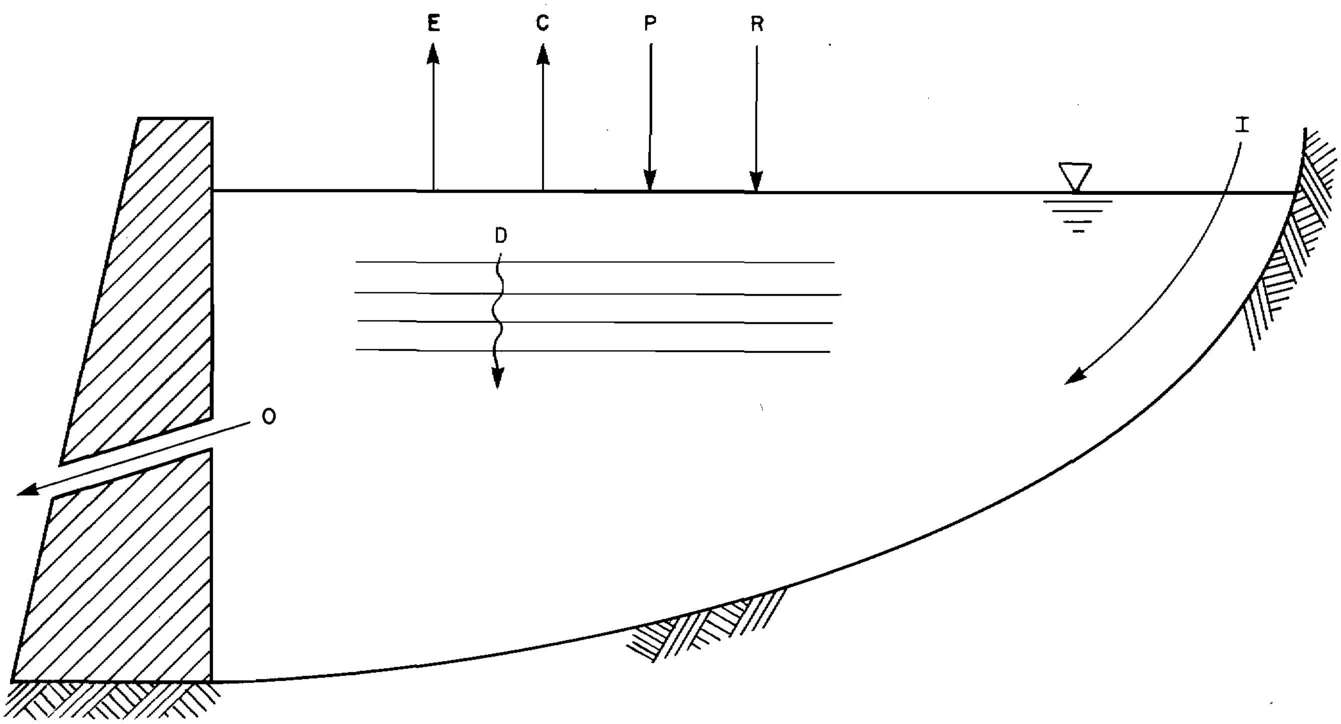
| Cross Section | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LRX 68 | 39.0 | 39.0 | 39.0 | 39.0 | 42.3 | 44.8 | 50.2 | 49.5 | 45.1 | 39.6 | 39.0 | 39.0 |
| LRX 61 | 38.8 | 38.8 | 39.0 | 39.0 | 42.4 | 45.0 | 50.2 | 49.6 | 45.1 | 39.6 | 39.0 | 38.8 |
| LRX 54 | 37.9 | 38.3 | 38.7 | 39.2 | 42.8 | 45.5 | 50.5 | 50.0 | 45.3 | 39.4 | 38.3 | 38.3 |
| LRX 47 | 37.4 | 37.9 | 38.5 | 39.4 | 43.2 | 46.0 | 50.7 | 50.4 | 45.5 | 39.4 | 37.9 | 37.9 |
| LRX 41 | 37.2 | 37.8 | 38.5 | 39.4 | 43.2 | 46.2 | 50.9 | 50.4 | 45.5 | 39.4 | 37.9 | 37.8 |
| LRX 34 | 36.7 | 37.2 | 38.1 | 39.6 | 43.5 | 46.6 | 51.1 | 50.7 | 45.5 | 39.2 | 37.6 | 37.2 |
| LRX 27 | 35.8 | 36.7 | 37.9 | 39.7 | 44.1 | 47.3 | 51.4 | 51.3 | 45.7 | 39.0 | 36.9 | 36.7 |
| LRX 21 | 35.2 | 36.1 | 37.8 | 39.9 | 44.4 | 47.8 | 51.6 | 51.6 | 45.9 | 39.0 | 36.5 | 36.1 |
| LRX 15 | 34.0 | 35.4 | 37.4 | 40.1 | 45.0 | 48.7 | 52.0 | 52.2 | 46.0 | 38.8 | 35.8 | 35.2 |
| LRX 9 | 33.1 | 34.7 | 37.0 | 40.5 | 45.5 | 49.6 | 52.3 | 52.9 | 46.2 | 38.7 | 35.1 | 34.5 |
| LRX 3 | 32.2 | 34.2 | 36.7 | 40.6 | 46.0 | 50.4 | 52.7 | 53.2 | 46.2 | 38.5 | 34.7 | 33.8 |
| Discharge Below Devil Canyon (cfs) | 10708.0 | 9066.0 | 8004.0 | 7889.0 | 10606.0 | 11052.0 | 13763.0 | 14085.0 | 12783.0 | 6540.0 | 9680.0 | 12436.0 |

TABLE A4.10: STREAM WATER TEMPERATURE FOR DRY YEAR (°F) - "CASE A" OPERATION MULTILEVEL INTAKE AT WATANA AND SINGLE LEVEL AT DEVIL CANYON

| Cross Section | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LRX 68 | 39.0 | 39.0 | 39.0 | 39.0 | 42.3 | 44.4 | 48.9 | 48.6 | 45.3 | 39.7 | 39.0 | 39.0 |
| LRX 61 | 38.8 | 38.8 | 39.0 | 39.0 | 42.4 | 44.4 | 48.9 | 48.7 | 45.3 | 39.7 | 38.8 | 38.8 |
| LRX 54 | 37.8 | 37.9 | 38.7 | 39.4 | 43.2 | 45.3 | 49.5 | 50.0 | 45.7 | 39.6 | 38.3 | 38.1 |
| LRX 47 | 37.0 | 37.6 | 38.3 | 39.6 | 43.7 | 45.7 | 49.8 | 50.7 | 45.9 | 39.4 | 37.8 | 37.6 |
| LRX 41 | 36.9 | 37.4 | 38.3 | 39.6 | 43.9 | 45.9 | 50.0 | 50.9 | 45.9 | 39.4 | 37.6 | 37.4 |
| LRX 34 | 36.1 | 36.7 | 38.1 | 39.7 | 44.2 | 46.4 | 50.4 | 51.8 | 46.0 | 39.4 | 37.2 | 36.9 |
| LRX 27 | 35.1 | 36.0 | 37.8 | 39.9 | 45.0 | 47.3 | 50.9 | 52.9 | 46.4 | 39.2 | 36.5 | 36.0 |
| LRX 21 | 34.3 | 35.4 | 37.6 | 40.1 | 45.5 | 47.7 | 51.3 | 53.6 | 46.6 | 39.0 | 36.1 | 35.4 |
| LRX 15 | 33.1 | 34.5 | 37.0 | 40.5 | 46.4 | 48.7 | 51.8 | 54.9 | 46.9 | 38.8 | 35.2 | 34.3 |
| LRX 9 | 32.0 | 33.6 | 36.7 | 40.6 | 47.1 | 49.6 | 52.3 | 55.9 | 47.1 | 38.7 | 34.5 | 33.4 |
| LRX 3 | 32.0 | 33.1 | 36.5 | 41.0 | 47.7 | 50.4 | 52.9 | 56.7 | 47.3 | 38.7 | 34.0 | 32.7 |
| Average Discharge Below Devil Canyon (cfs) | 8353.0 | 6742.0 | 6914.0 | 5842.0 | 6079.0 | 10041.0 | 7988.0 | 4707.0 | 4474.0 | 6914.0 | 7934.0 | 9463.0 |

TABLE A4.11: STREAM WATER TEMPERATURE FOR AVERAGE YEAR (°F) - "CASE D" OPERATION
MULTILEVEL INTAKE AT WATANA AND SINGLE LEVEL AT DEVIL CANYON

| Cross Section | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LRX 68 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 48.6 | 52.7 | 50.4 | 44.6 | 39.0 | 39.0 | 39.0 |
| LRX 61 | 38.8 | 38.8 | 39.0 | 39.0 | 39.0 | 48.6 | 52.7 | 50.4 | 44.6 | 39.0 | 38.8 | 38.8 |
| LRX 54 | 37.6 | 37.9 | 38.7 | 39.4 | 39.9 | 49.5 | 52.9 | 50.7 | 44.8 | 38.8 | 38.1 | 37.9 |
| LRX 47 | 36.9 | 37.4 | 38.3 | 39.6 | 40.3 | 50.0 | 53.1 | 50.9 | 45.0 | 38.8 | 37.8 | 37.4 |
| LRX 41 | 36.7 | 37.2 | 38.3 | 39.6 | 40.5 | 50.2 | 53.1 | 51.1 | 45.0 | 38.7 | 37.6 | 37.2 |
| LRX 34 | 36.0 | 36.7 | 38.1 | 39.7 | 41.0 | 50.7 | 53.2 | 51.3 | 45.0 | 38.7 | 37.0 | 36.7 |
| LRX 27 | 34.7 | 36.0 | 37.8 | 39.9 | 41.7 | 51.6 | 53.6 | 51.6 | 45.1 | 38.5 | 36.3 | 35.8 |
| LRX 21 | 34.0 | 35.4 | 37.6 | 40.1 | 42.3 | 52.2 | 53.8 | 52.0 | 45.3 | 38.5 | 36.0 | 35.1 |
| LRX 15 | 32.7 | 34.3 | 37.0 | 40.5 | 43.2 | 53.2 | 54.1 | 52.3 | 45.5 | 38.3 | 35.1 | 34.0 |
| LRX 9 | 32.0 | 33.6 | 36.7 | 40.8 | 43.9 | 54.1 | 54.5 | 52.9 | 45.7 | 38.1 | 34.2 | 33.1 |
| LRX 3 | 32.0 | 32.9 | 36.5 | 41.0 | 44.4 | 54.7 | 54.9 | 53.2 | 45.9 | 38.1 | 33.8 | 32.4 |
| Average Discharge Below Devil Canyon (cfs) | 7670.0 | 6670.0 | 6771.0 | 5735.0 | 7031.0 | 7608.0 | 13786.0 | 18685.0 | 11458.0 | 6456.0 | 7200.0 | 8457.0 |




LEGEND

C = AIR-WATER CONDUCTION

R = EFFECTIVE RADIATION

E = EVAPORATION

I = INFLOW

D = DIFFUSION BETWEEN LAYERS

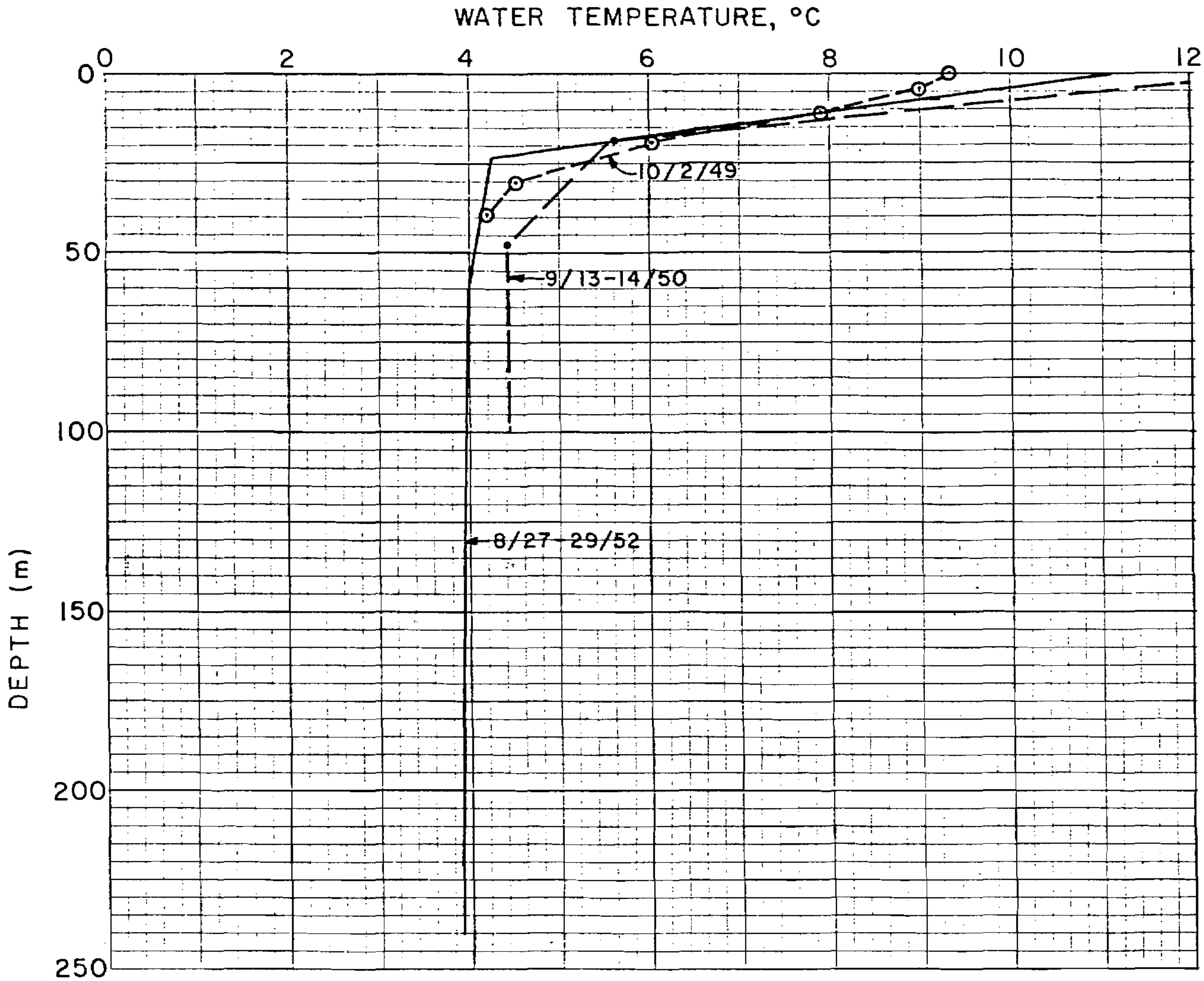
O = OUTFLOW

P = PRECIPITATION

RESERVOIR ENERGY BUDGET

ACRES

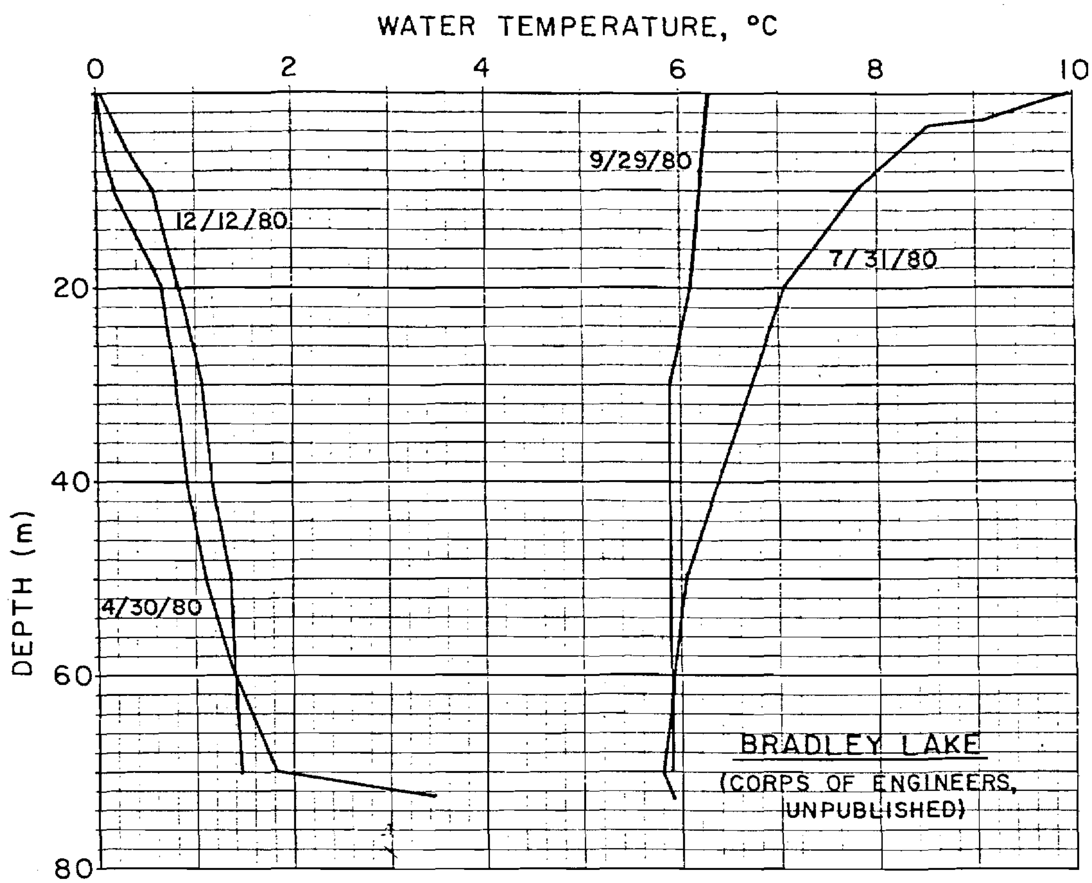
FIGURE A4.1




WATER TEMPERATURE PROFILES
GARIBALDI LAKE, BRITISH COLUMBIA

FIGURE A4.2

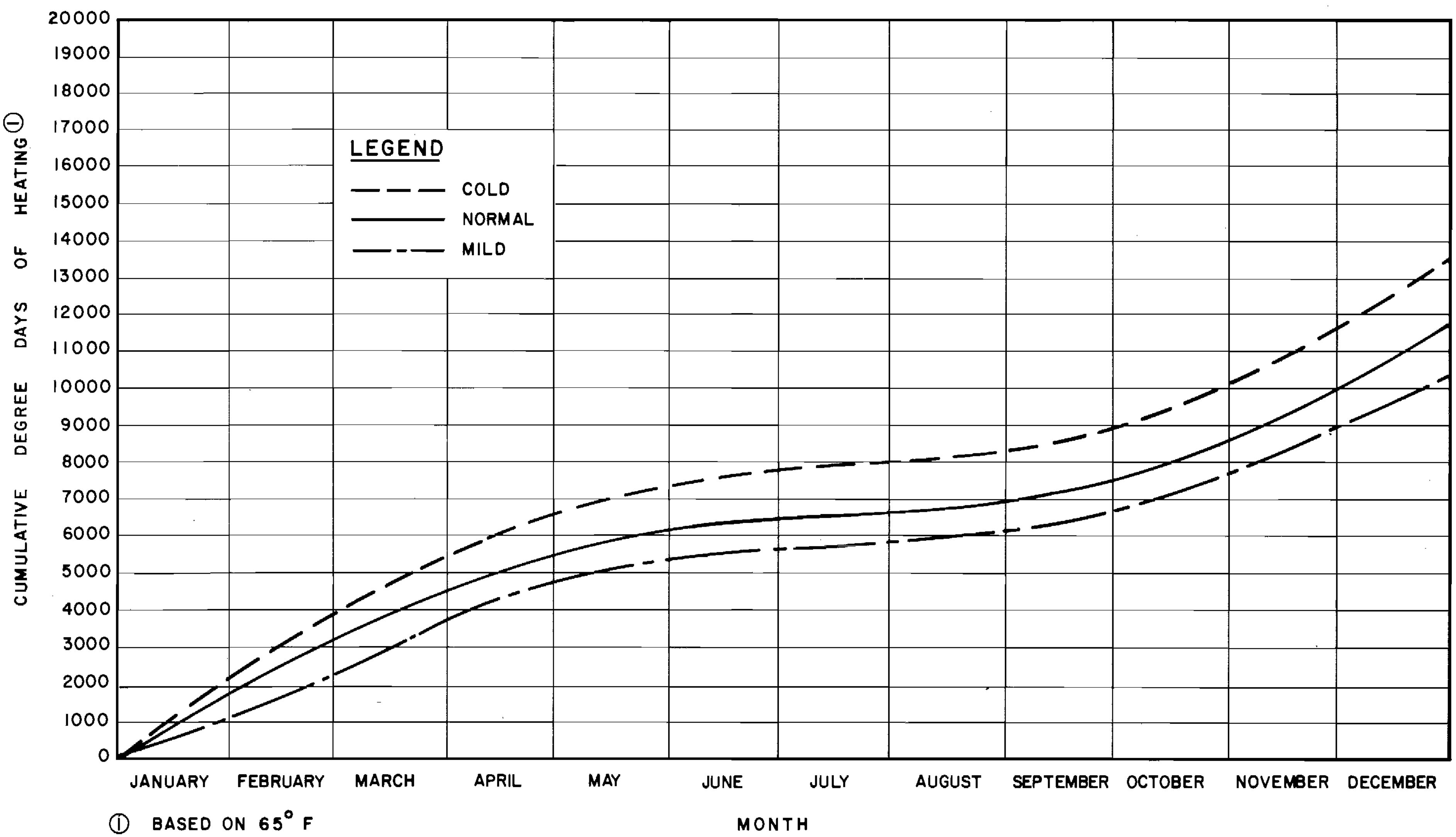
ACRES




**WATER TEMPERATURE PROFILES**
**BRADLEY LAKE, ALASKA**

ACRES

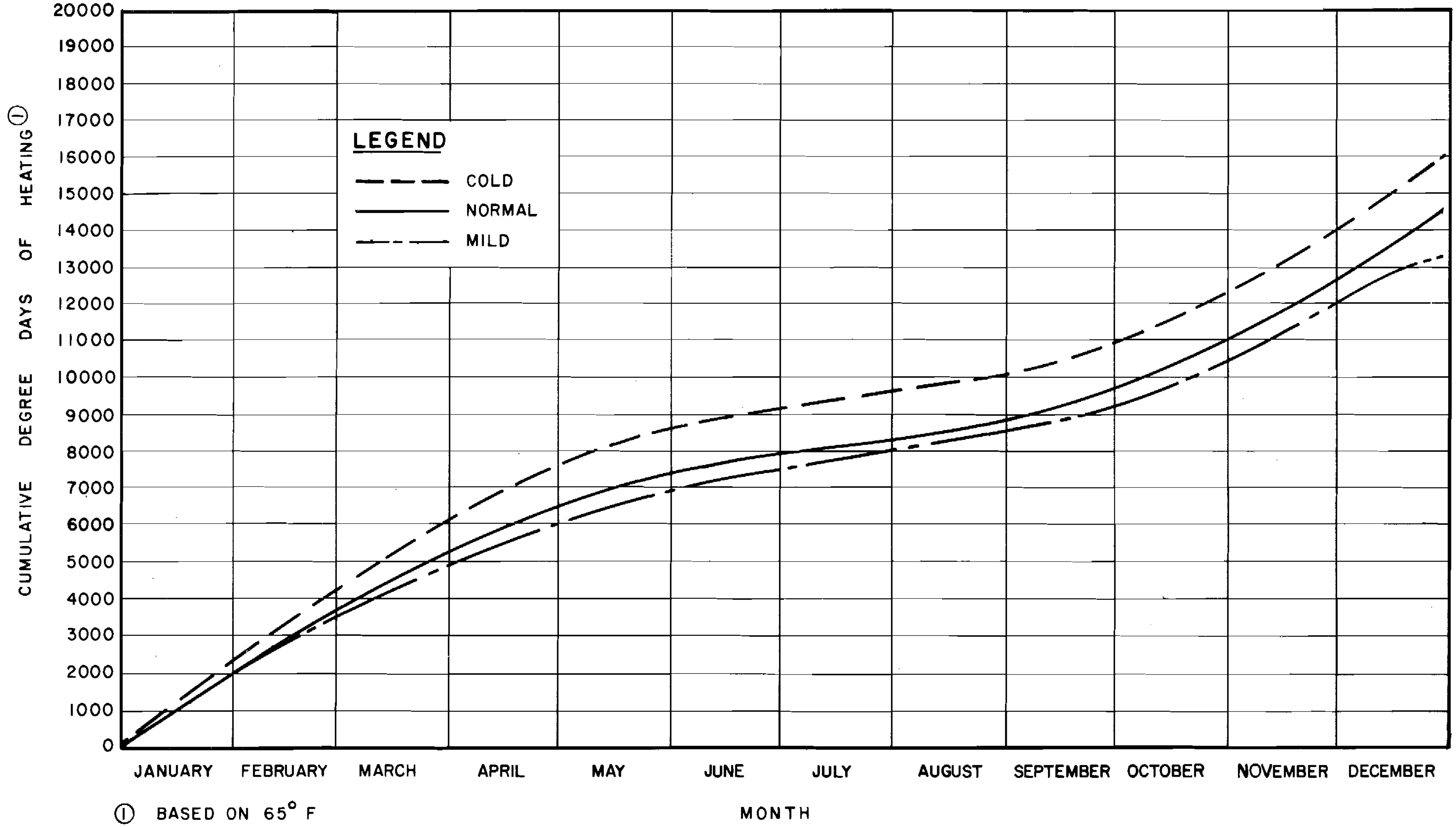
FIGURE A4.3




CUMULATIVE DEGREE DAYS OF HEATING AT TALKEETNA STATION

FIGURE A4.4

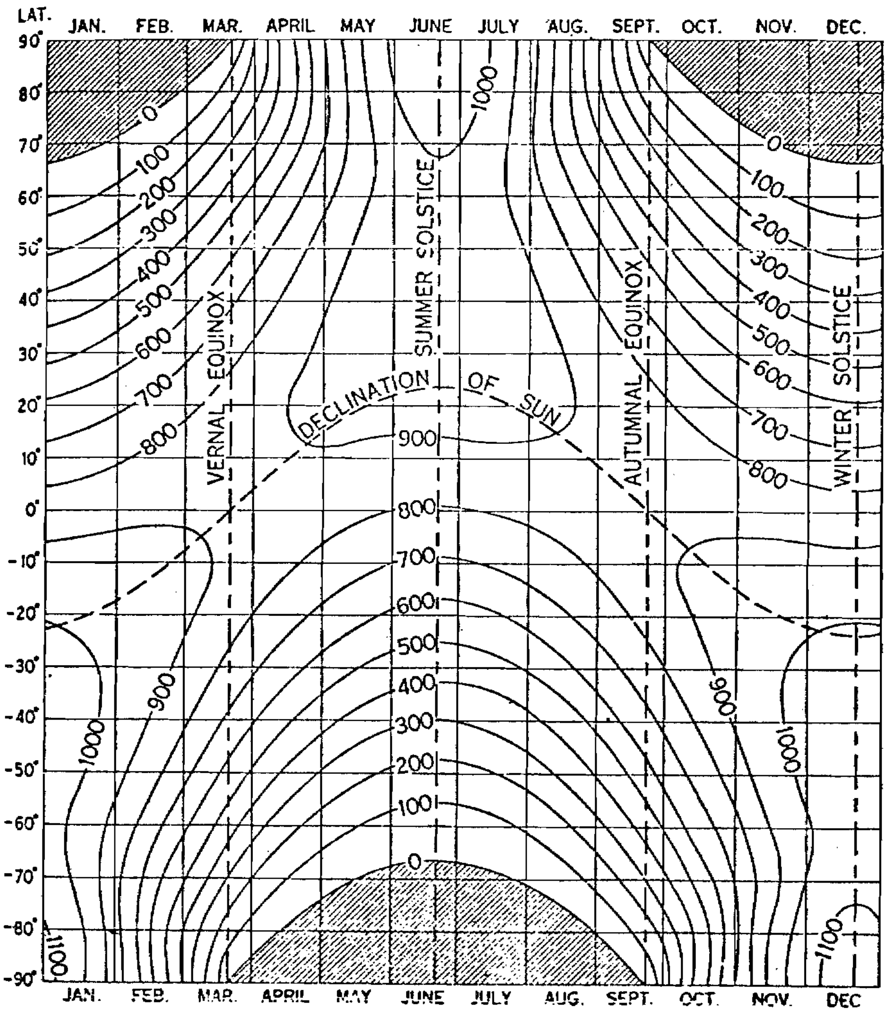
ACRES




CUMULATIVE DEGREE DAYS OF HEATING AT SUMMIT STATION

FIGURE A4.5

The solid curves represent total daily solar radiation on a horizontal surface at the top of the atmosphere, measured in cal. cm.$^{-2}$ Shaded areas represent regions of continuous darkness.

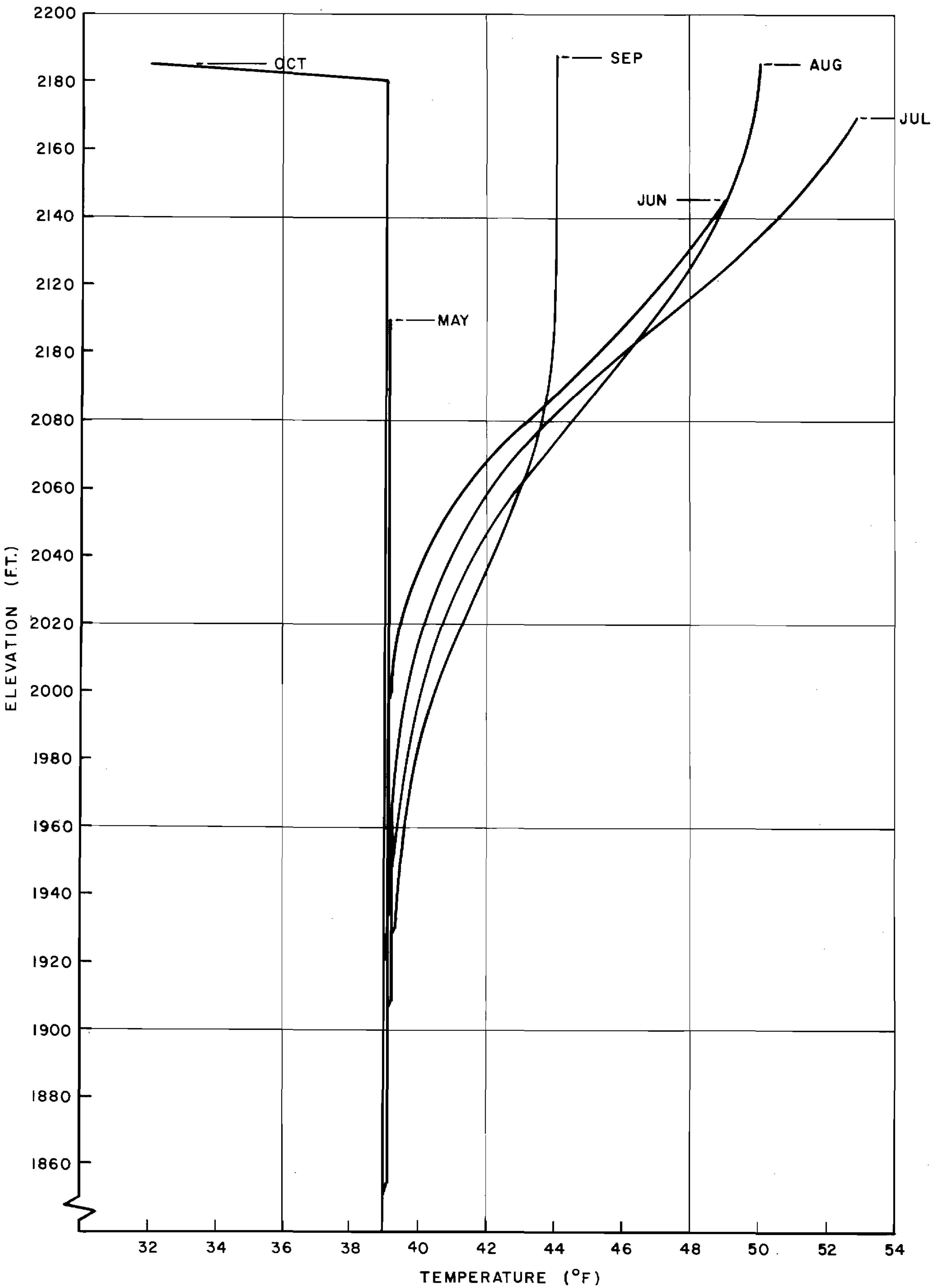



The above data was obtained from the Smithsonian Meteorological Tables, by Robert J. List, 6th revised edition, 1949.

## CHART OF THE TOTAL DAILY SOLAR RADIATION AT THE TOP OF THE ATMOSPHERE

FIGURE A4.6

ACRES

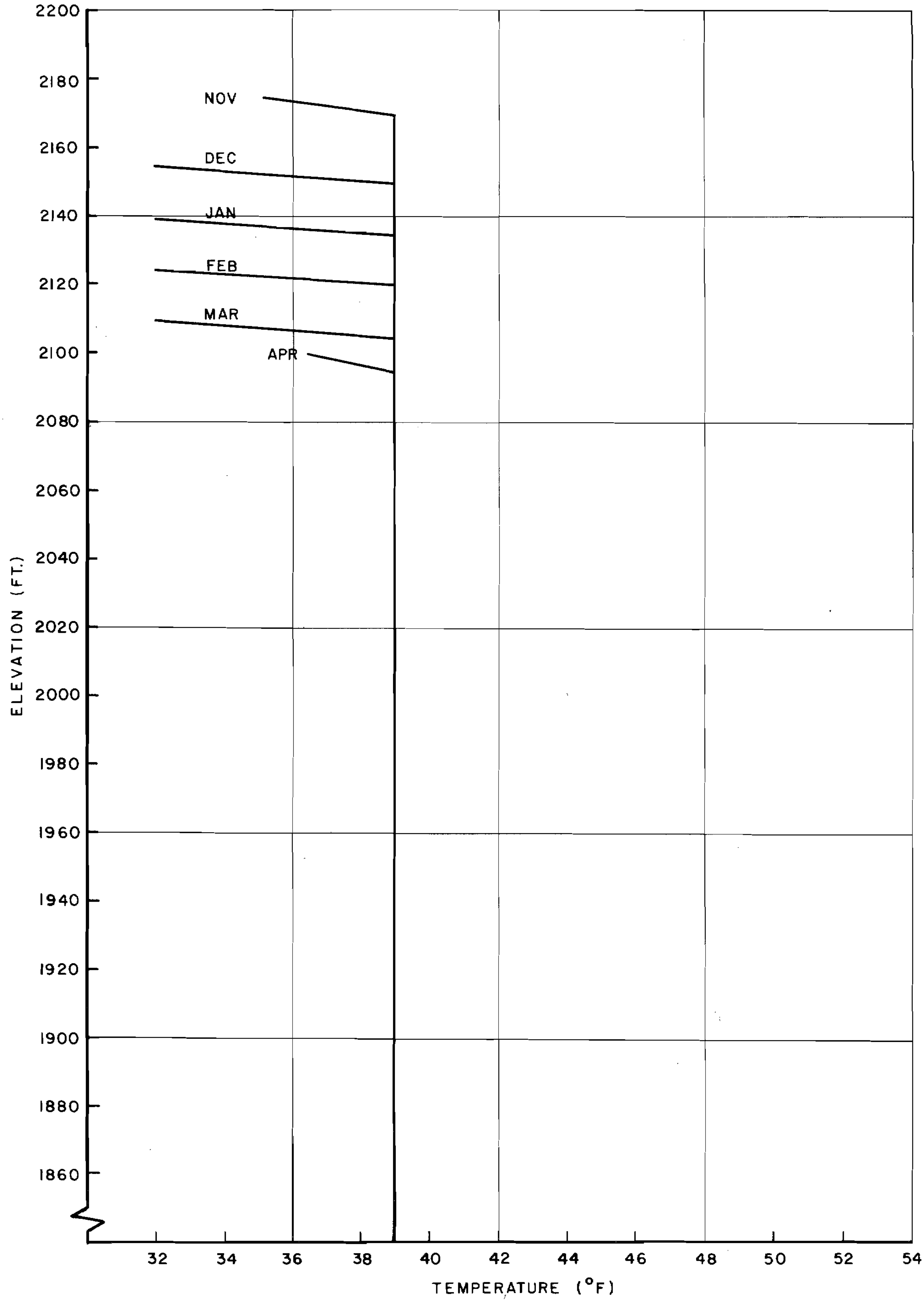



## WATANA RESERVOIR TEMPERATURE PROFILE

AVERAGE YEAR CONDITIONS MAY THROUGH OCTOBER

FIGURE A4.7

ACRES

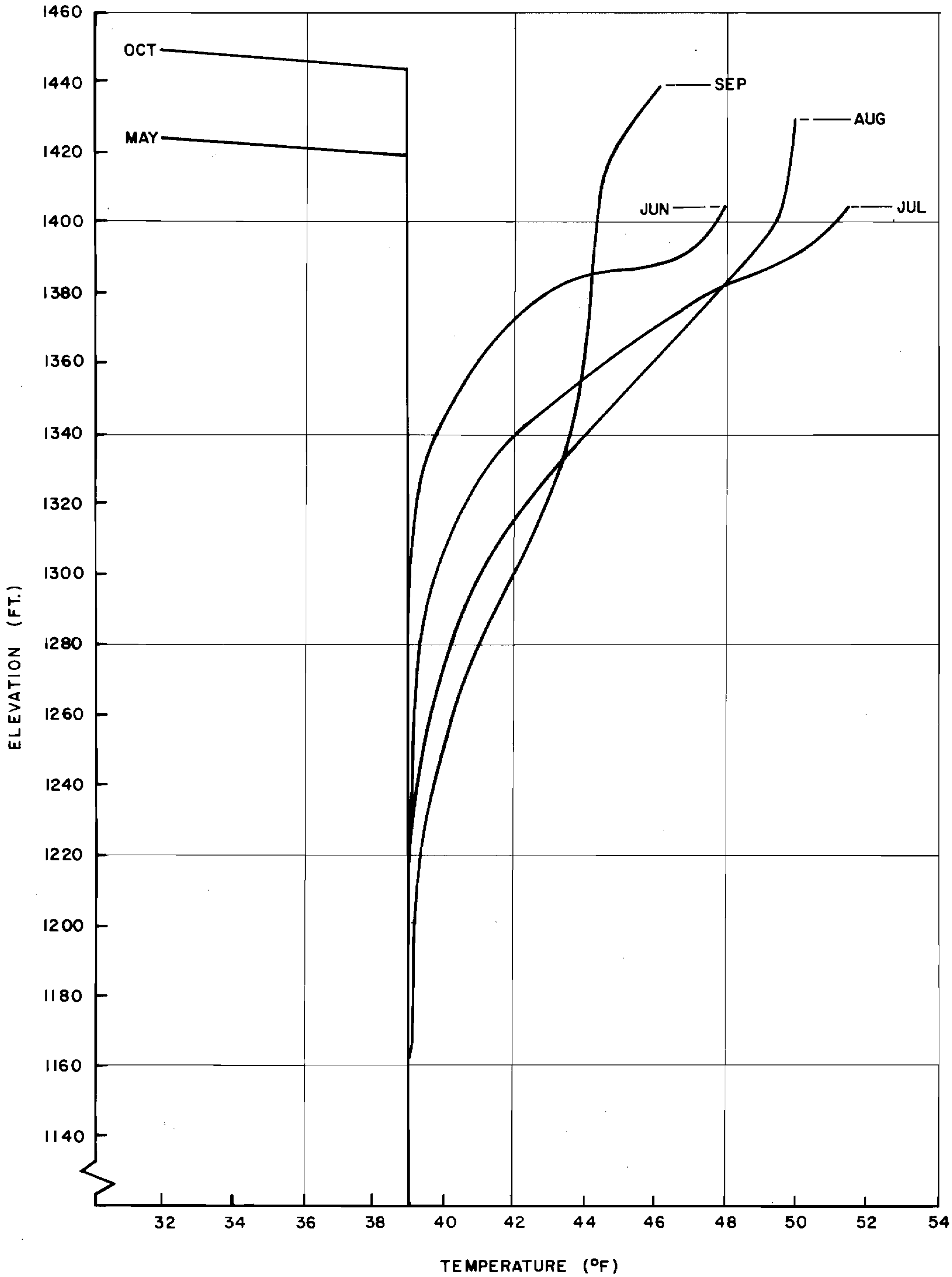



# WATANA RESERVOIR TEMPERATURE PROFILE

AVERAGE YEAR CONDITIONS NOVEMBER THROUGH APRIL

ACRES

FIGURE A4.8

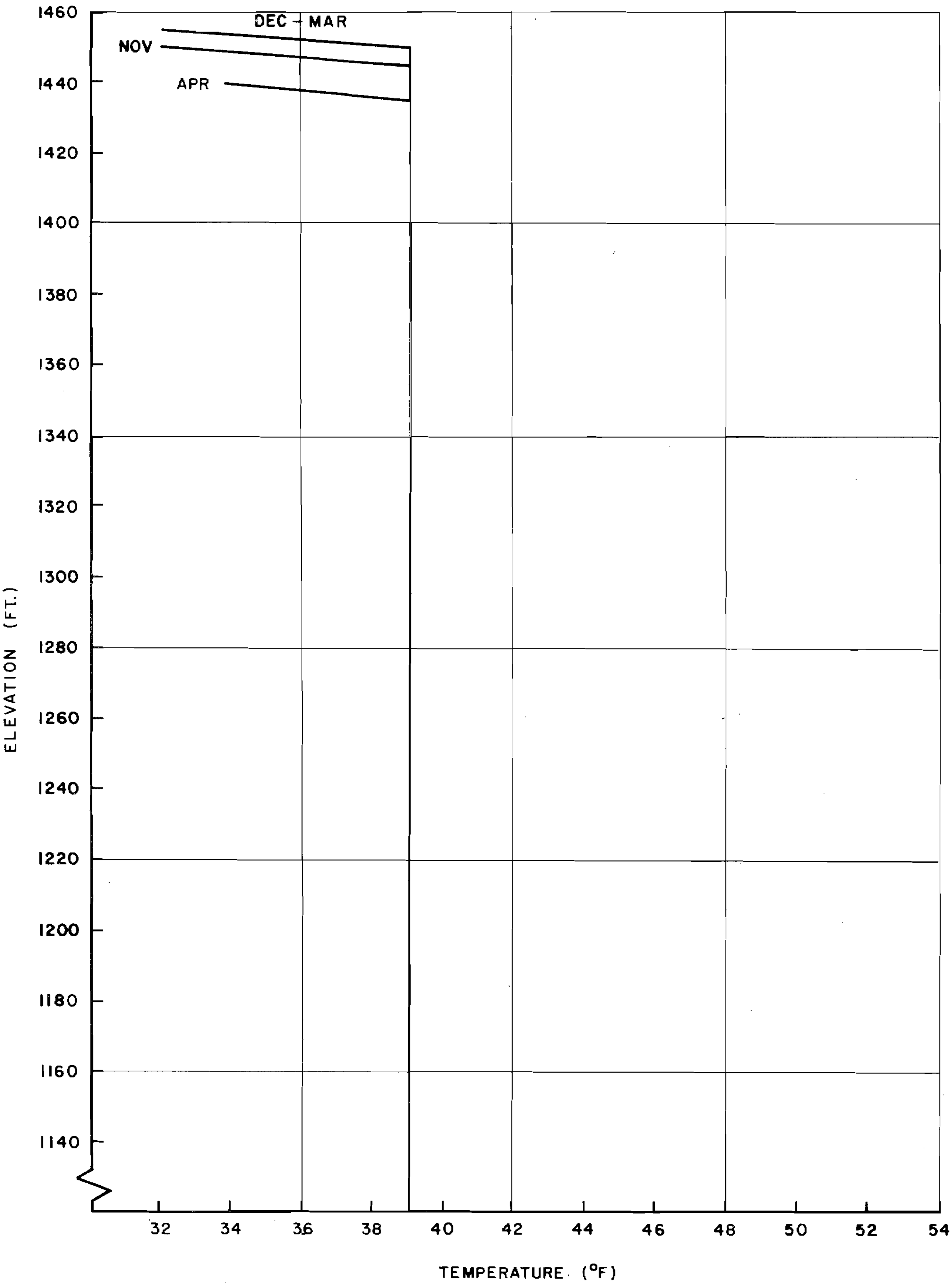



DEVIL CANYON RESERVOIR TEMPERATURE PROFILE

AVERAGE YEAR CONDITIONS MAY THROUGH OCTOBER

FIGURE A4.9

ACRES

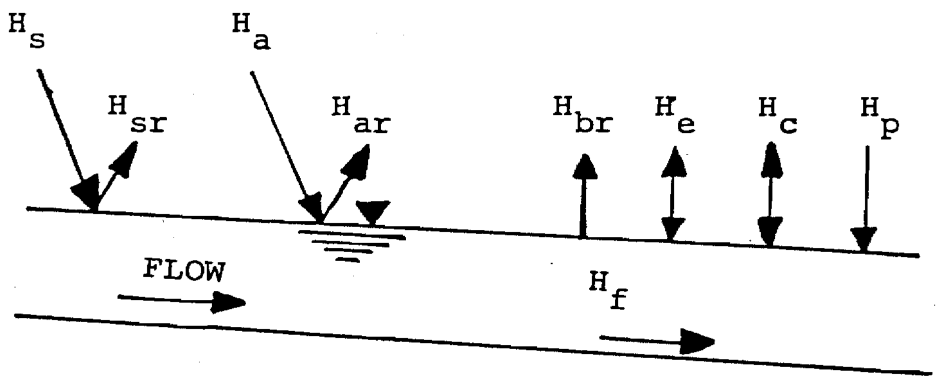



## DEVIL CANYON RESERVOIR TEMPERATURE PROFILE

AVERAGE YEAR CONDITIONS NOVEMBER THROUGH APRIL

FIGURE A4.10

ACRES




$$H_{net} = H_s - H_{sr} + H_a - H_{ar} - H_{br} \pm H_e \pm H_c \pm H_p + H_f$$

where

$H_{net}$ is the net heat transfer at the water surfaces

$H_s$ is the solar radiation incident to the water surface

$H_{sr}$ is the reflected solar radiation

$H_a$ is the atmospheric radiation incident to the water surface

$H_{ar}$ is the reflected atmospheric radiation

$H_{br}$ is the back radiation or the net energy lost by the body of water through the exchange of long-wave radiation between the body of water and the atmosphere

$H_e$ is the evaporative heat exchange

$H_c$ is the conductive heat exchange

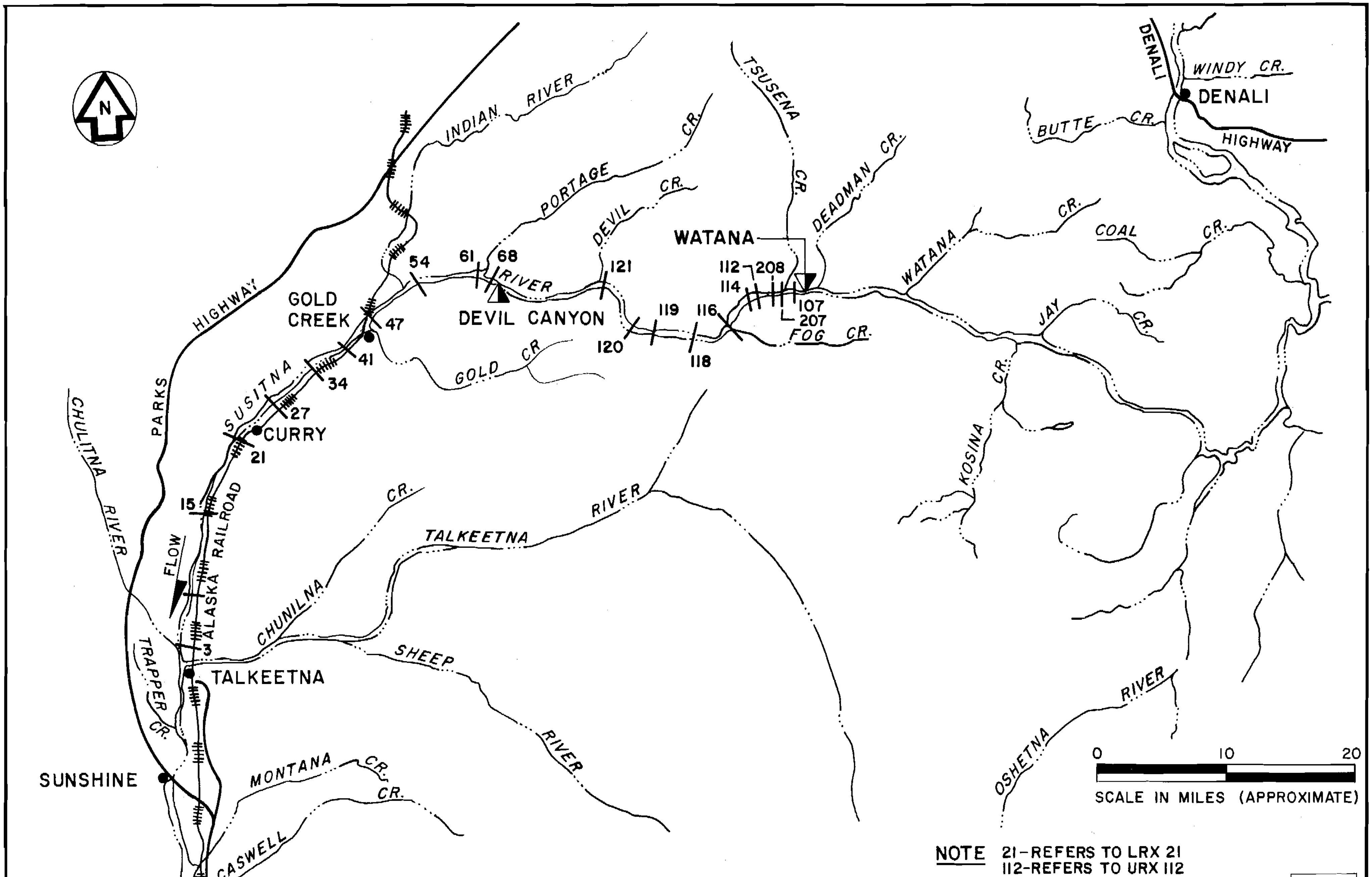
$H_p$ is the heat required to supply the latent heat of fusion of snow falling into the water <u>or</u> the heat gain from rainfall

$H_f$ is the heat gain from flow friction losses in a river reach

**DEFINITION SKETCH**
**HEAT BALANCE**

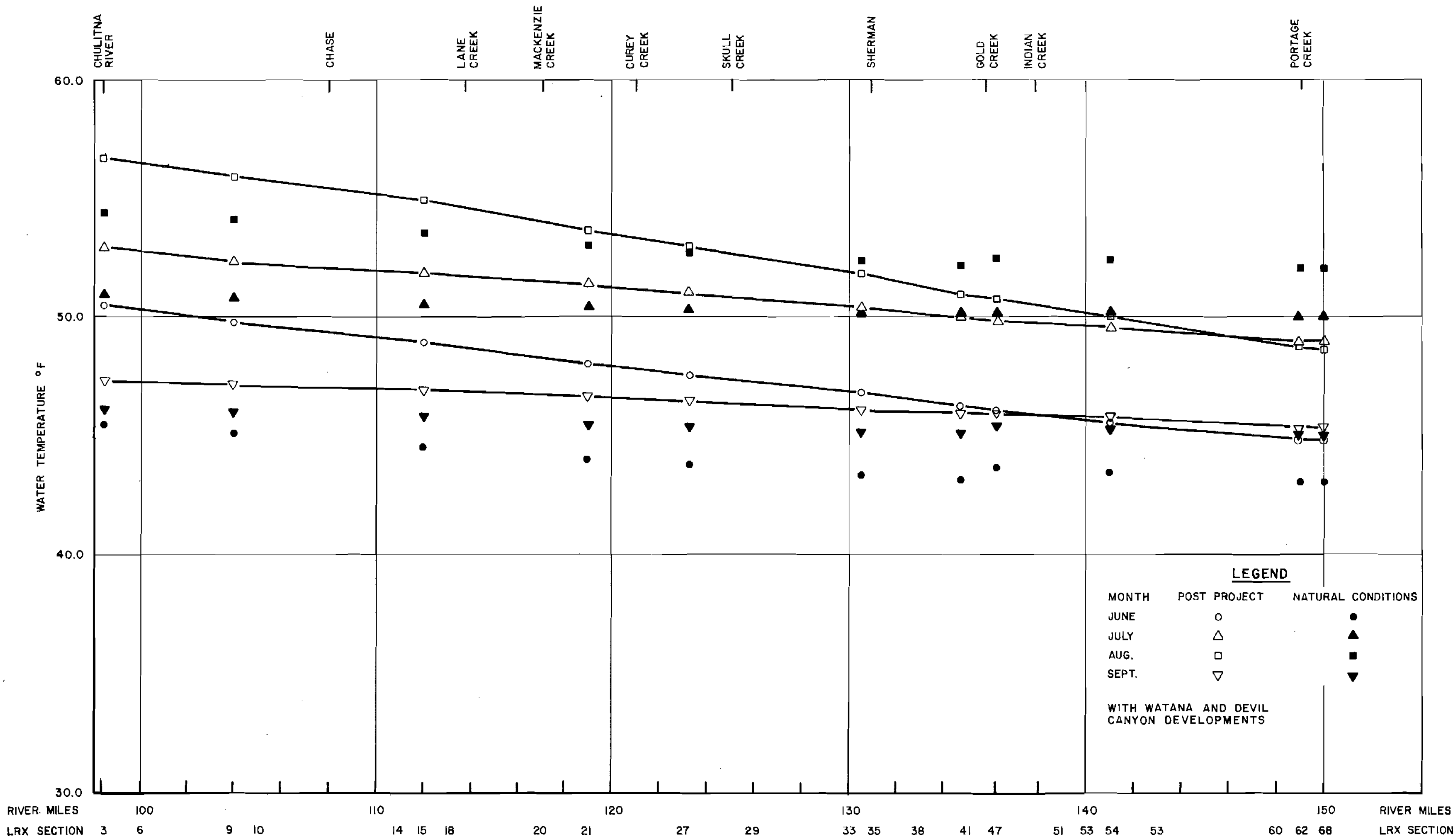
ACRES

FIGURE A4.11




MAP SHOWING RIVER CROSS SECTIONS

FIGURE A4.12



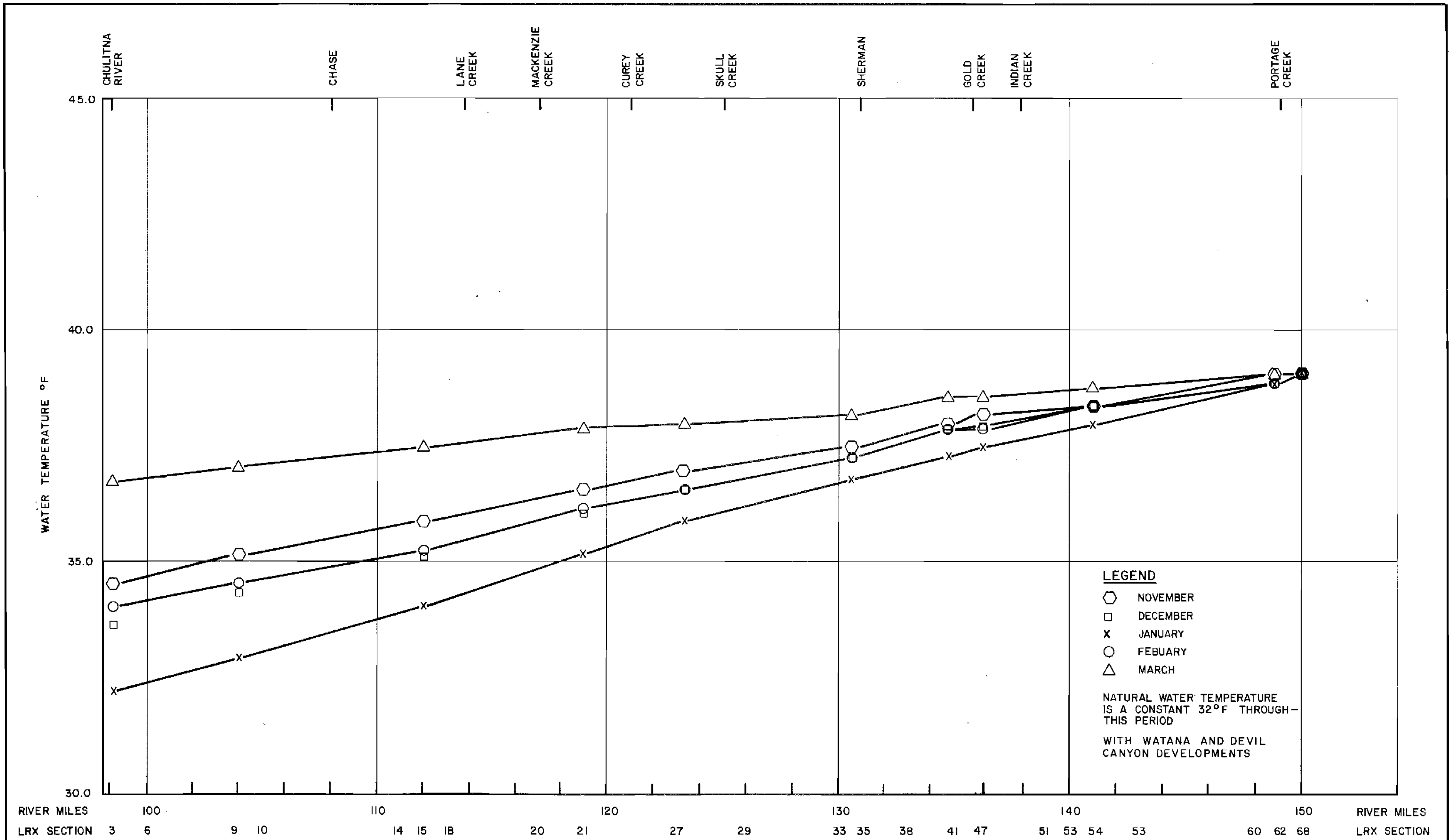

## LONGITUDINAL THERMAL PROFILES

POST PROJECT AND NATURAL CONDITIONS

SHEET 1 OF 2

FIGURE A4.13

ACRES



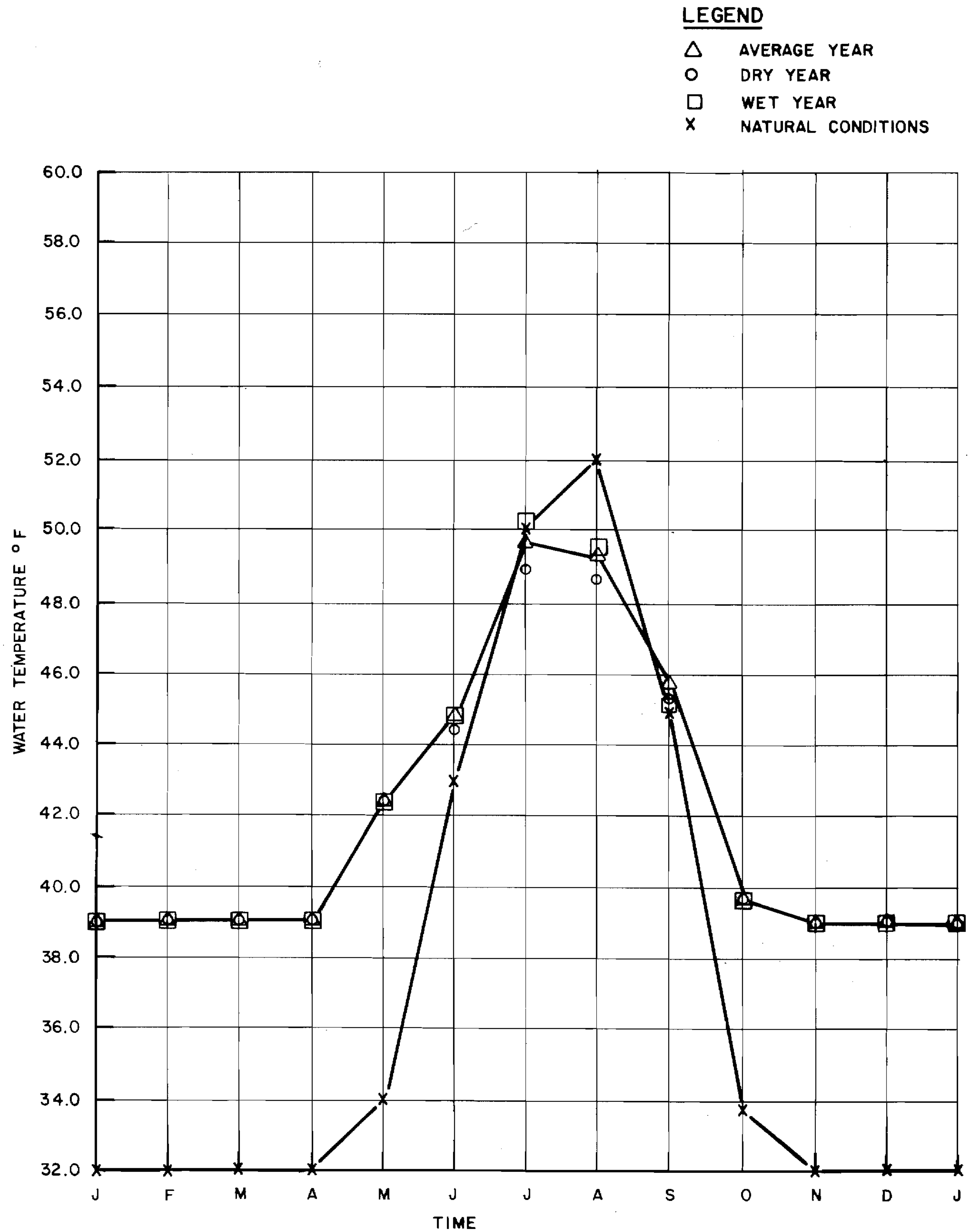

LONGITUDINAL THERMAL PROFILES

POST PROJECT AND NATURAL CONDITIONS

SHEET 2 OF 2

FIGURE A 4.13

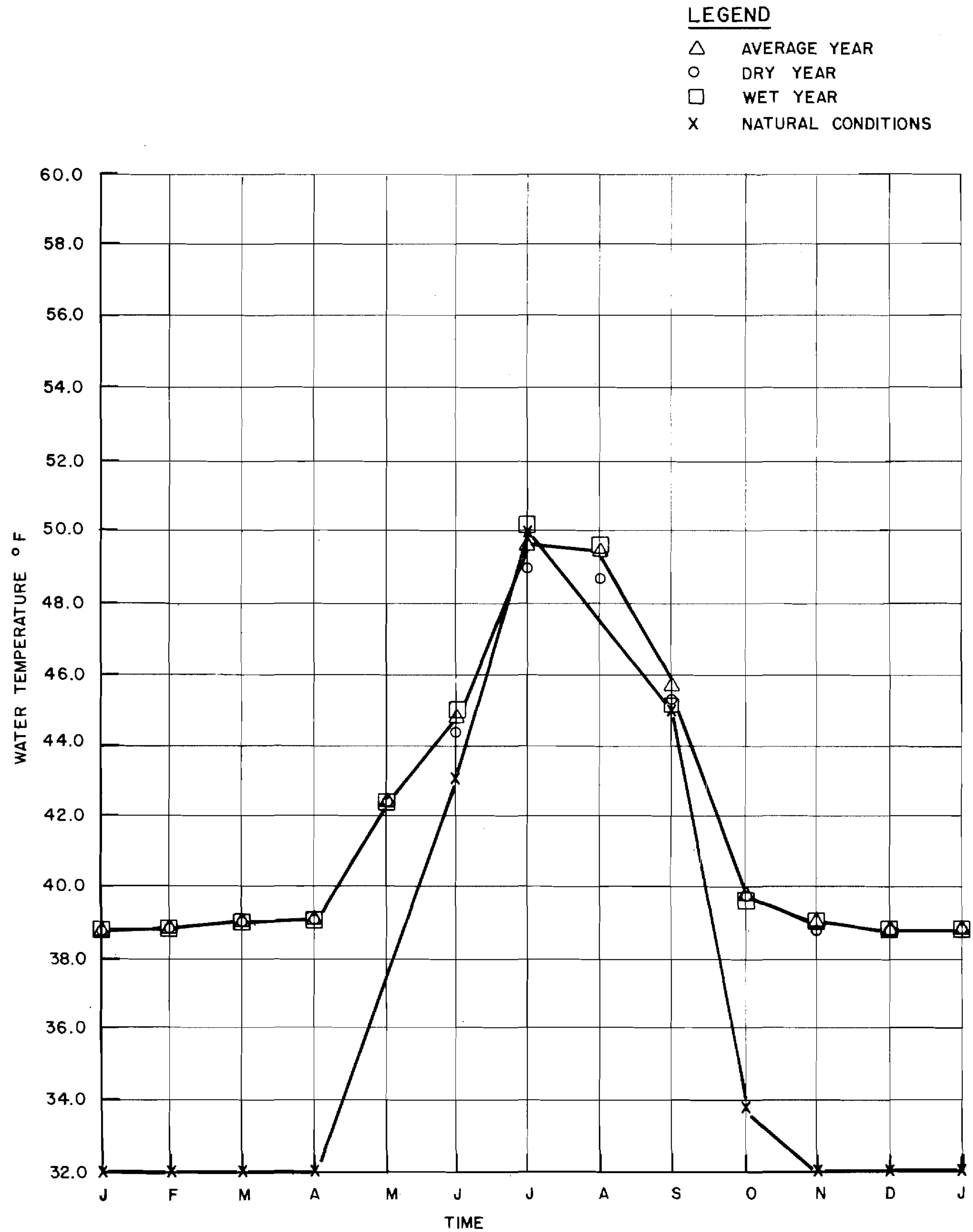
ACRES




AVERAGE MONTHLY TEMPERATURES
CROSS SECTION LRX 68
DOWNSTREAM OF DEVIL CANYON DAM SITE

ACRES

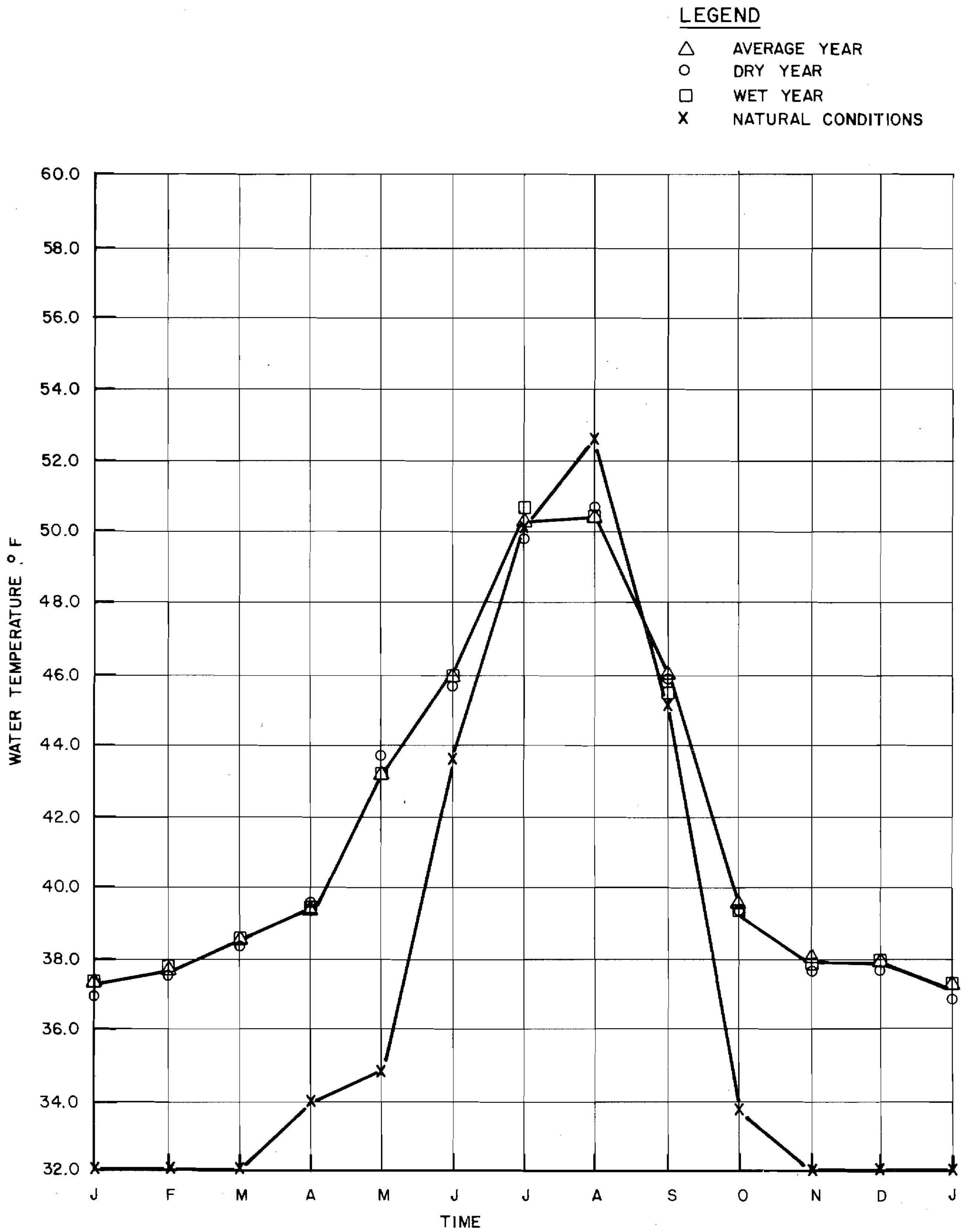
FIGURE A4.14




AVERAGE MONTHLY TEMPERATURES
CROSS SECTION LRX 61
DOWNSTREAM OF PORTAGE CREEK

ACRES

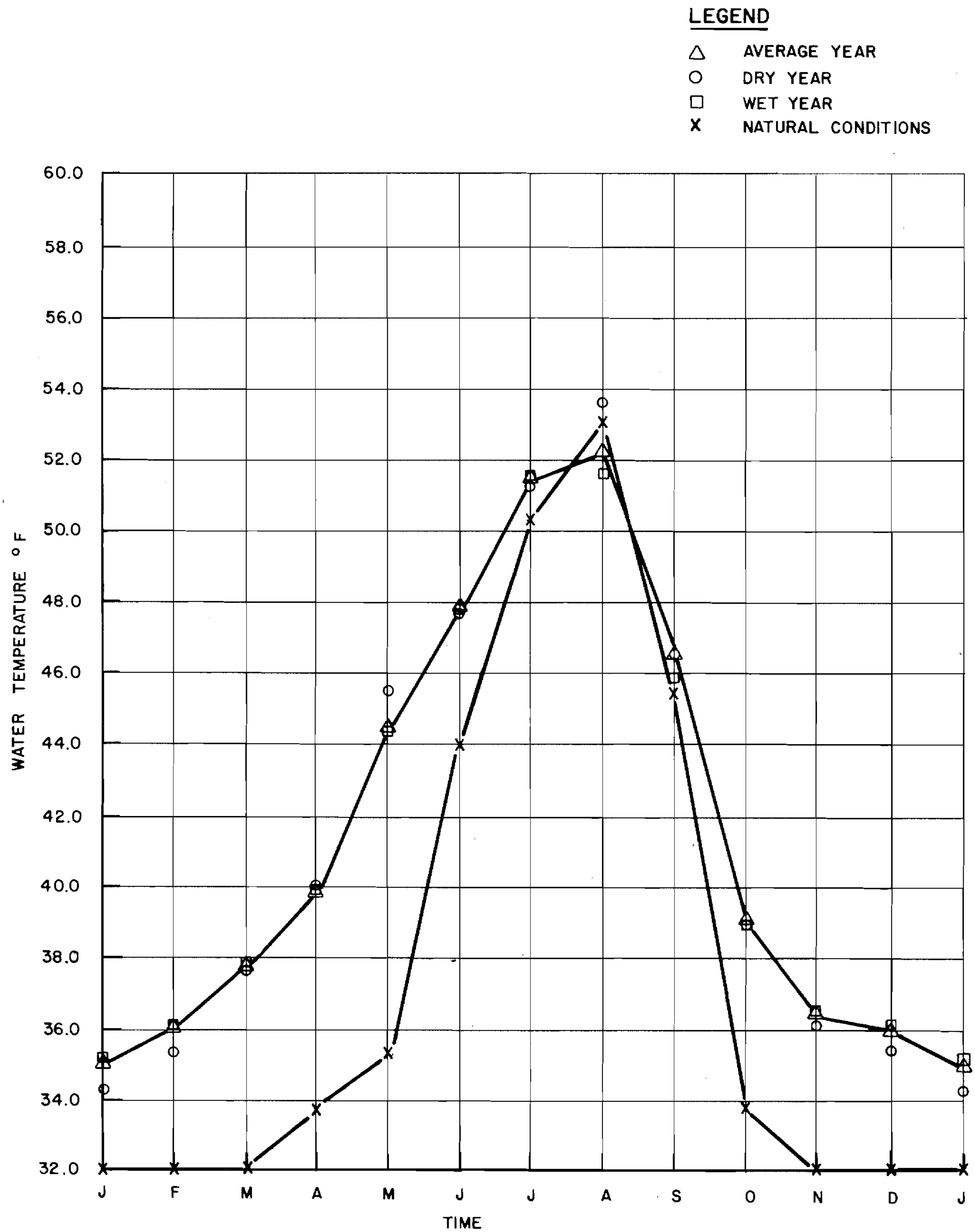
FIGURE A4.15




AVERAGE MONTHLY TEMPERATURES
CROSS SECTION LRX 47
NEAR GOLD CREEK

ACRES

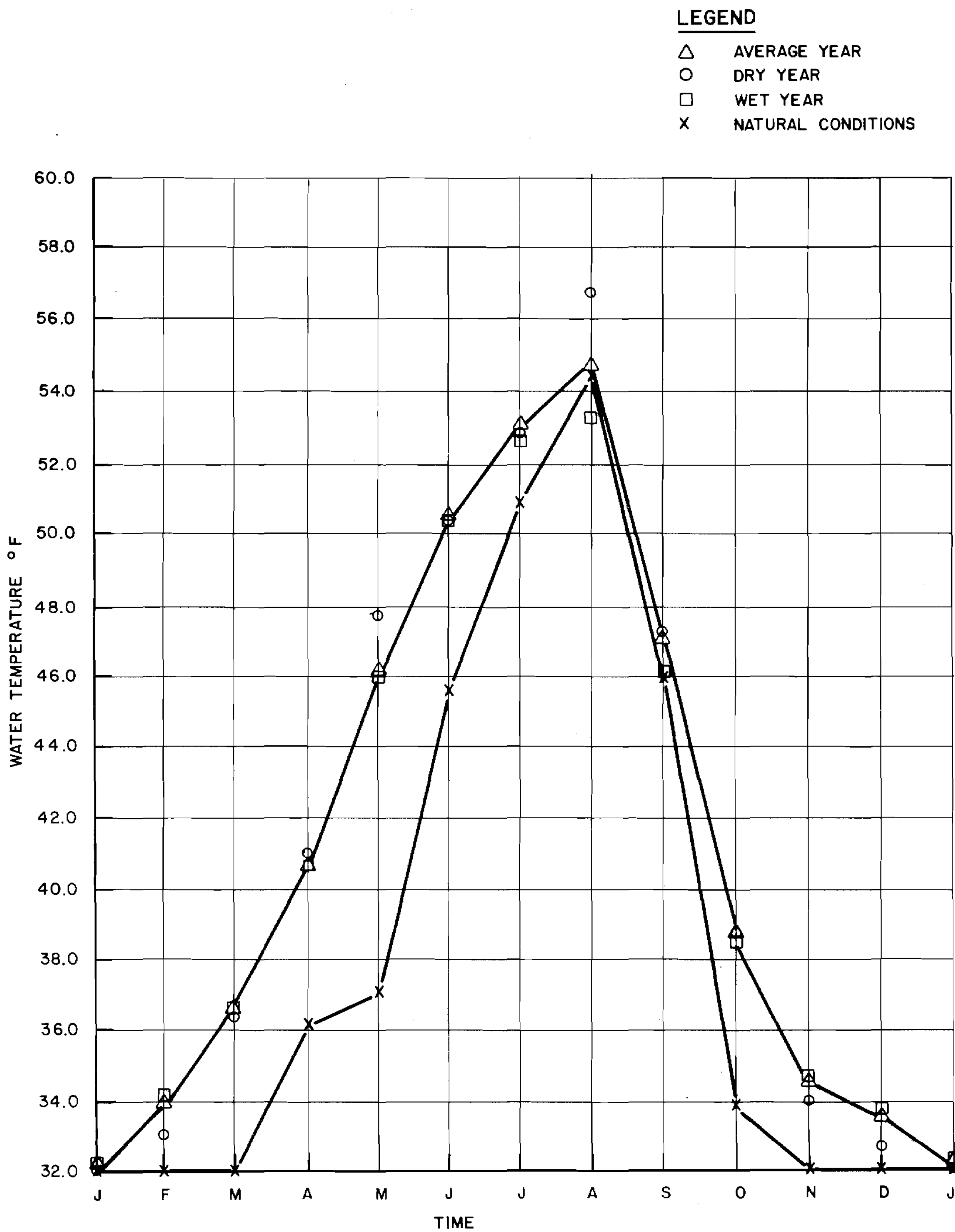
FIGURE A4.16




AVERAGE MONTHLY TEMPERATURES
CROSS SECTION LRX 21
BETWEEN CURRY CREEK AND MACKENZIE CREEK

FIGURE A4.17

ACRES

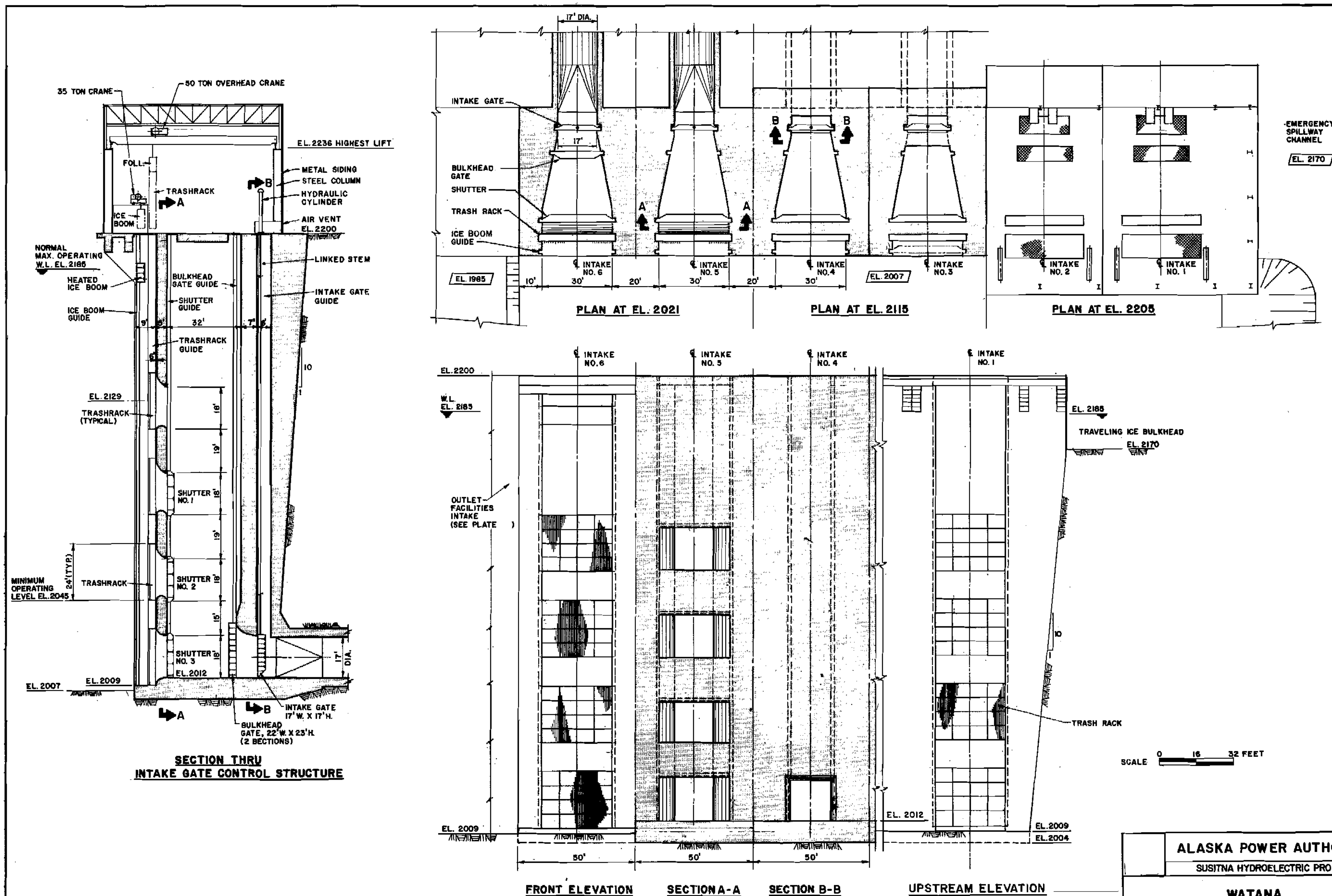



## AVERAGE MONTHLY TEMPERATURES
## CROSS SECTION LRX 3

NEAR THE CONFLUENCE OF THE
CHULITNA AND SUSITNA RIVERS

FIGURE A4.18

ACRES




ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

**WATANA POWER INTAKE SECTIONS**

ACRES

ACRES AMERICAN INCORPORATED

MARCH 1982

PLATE A4.1

ATTACHMENT 1

GUIDE TO VARIABLES USED IN ATTACHMENT 1

| | |
|---|---|
| STORA: | Initial Storage Capacity, (Ac-Ft) |
| STRMX: | Maximum Storage Capacity, (Ac-Ft) |
| STRMN: | Minimum Storage Capacity, (Ac-Ft) |
| STCAP: | Storage Capacity Below Each Layer (Ac-Ft) |
| NLAYER: | Number of Layers |
| LAYER: | Layer Thickness, (Feet) |
| TSTRT: | Initial Temperature of Each Layer, (°F) |
| RESERVOIR TEMPERATURES: | Month End Water Temperatures of Each Layer, (°F) |
| TA: | Air Temperature, (°F) |
| TMPIN: | Inflow Water Temperature, (°F) |
| TEMPERATURES: | (°F) |
| TPOUT: | Outflow Temperature, (°F) |
| RELEASES THROUGH OUTLET: | Flow Through Each Outlet and Corresponding Temperature |

WATANA RESERVOIR
TEMPERATURE STRATIFICATION STUDY
DATES: AVERAGE YEAR 4 OUTLETS:2021,2057,2093,2129

THE OUTPUT UNITS ON INFLOW AND OUTFLOW ARE IN CFS, EVAP AND PRECIP IN INCHES, STORAGE IN AF, AND TEMPERATURE IN DEGREES F

| NYR | IYR | NPER | IPER | MSTRT | NLAYR | LAYER | NOUTL | NMINQ | IDERV | METRC | IDGST | NIC | NIT | NOTL | INTER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1981 | 12 | 5 | 5 | 100 | 5 | 3 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 4 |

| MREL | NMO |
|---|---|
| 0 | 3 |

| STORA | CISA | COSA | STRMX | STRMN | TIN | TAIR | EVAP | PRCP | QMIN | TMAX | TMIN | CSOUT | SOLR | DEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6560000. | 1.983 | 1.983 | 9652000. | 5230000. | -1. | -1. | -1.00 | -1.00 | -1. | -1. | -1. | 0.504 | -1. | 32.81 |

| AIR TEMP COEF | INFLO MIXING COEF | DIFFUSION COEF | EVAP HEAT COEF | INSOLATION COEF |
|---|---|---|---|---|
| 0.816 | 0.114 | 0.043 | 0.637 | 0.193 |

QDMIN= -2.0 -2.0 -2.0

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STCAP= | 518960. | 548736. | 579824. | 611104. | 643920. | 676912. | 710560. | 746320. | 782384. | 817728. |
| | 855712. | 894528. | 933328. | 972864. | 1015472. | 1056576. | 1099344. | 1143776. | 1188256. | 1233664. |
| | 1280448. | 1328688. | 1377216. | 1426640. | 1477536. | 1528992. | 1580416. | 1636224. | 1690240. | 1746144. |
| | 1803840. | 1861792. | 1921216. | 1981248. | 2041824. | 2104832. | 2168800. | 2233472. | 2300960. | 2369472. |
| | 2437600. | 2506752. | 2577824. | 2652352. | 2724672. | 2800800. | 2879072. | 2957504. | 3036224. | 3117344. |
| | 3201344. | 3284192. | 3371584. | 3457888. | 3547328. | 3637664. | 3729792. | 3823488. | 3918624. | 4015296. |
| | 4113760. | 4214880. | 4317440. | 4422496. | 4525664. | 4635936. | 4744448. | 4855712. | 4969984. | 5084704. |
| | 5203232. | 5353424. | 5466992. | 5583536. | 5703008. | 5825456. | 5950864. | 6079184. | 6210496. | 6344720. |
| | 6481920. | 6622080. | 6765168. | 6911216. | 7060208. | 7212176. | 7367088. | 7524912. | 7685744. | 7849520. |
| | 8016208. | 8185872. | 8358448. | 8534032. | 8712560. | 8893984. | 9078400. | 9265760. | 9456096. | 9649376. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| TSTRT= | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 |
| | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 |

STOUT= 5253752. 6337988. 7262580.

WATANA RESERVOIR TEMPERATURES

| YEAR | PER | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.1 | 39.1 | 39.1 | 39.1 |
| | | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 |
| | | 39.1 | 39.1 | 39.1 | 39.1 | | | | | | | | | | | | | | | | |
| 1 | 6 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 |
| | | 39.1 | 39.1 | 39.2 | 39.2 | 39.3 | 39.3 | 39.4 | 39.5 | 39.7 | 39.9 | 40.1 | 40.3 | 40.6 | 40.9 | 41.3 | 41.8 | 42.3 | 42.8 | 43.3 | 43.9 |
| | | 44.7 | 45.2 | 45.6 | 46.0 | 46.4 | 46.6 | 47.0 | 47.5 | 48.1 | 48.7 | 49.1 | | | | | | | | | |
| 1 | 7 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.2 | 39.2 | 39.2 | 39.3 | 39.3 | 39.4 |
| | | 39.4 | 39.5 | 39.6 | 39.7 | 39.9 | 40.0 | 40.2 | 40.4 | 40.6 | 40.9 | 41.1 | 41.4 | 41.8 | 42.1 | 42.6 | 43.0 | 43.5 | 44.0 | 44.5 | 45.1 |
| | | 45.6 | 46.2 | 46.8 | 47.5 | 48.1 | 48.6 | 49.6 | 50.2 | 50.6 | 50.9 | 51.1 | 51.4 | 51.8 | 52.2 | 52.7 | 52.9 | | | | |
| 1 | 8 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.1 |
| | | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.2 | 39.2 | 39.2 | 39.3 | 39.3 | 39.4 | 39.4 | 39.5 | 39.6 | 39.7 | 39.8 |
| | | 39.9 | 40.0 | 40.2 | 40.3 | 40.5 | 40.7 | 40.9 | 41.2 | 41.4 | 41.7 | 42.0 | 42.3 | 42.7 | 43.0 | 43.4 | 43.9 | 44.3 | 44.7 | 45.2 | 45.6 |
| | | 46.1 | 46.5 | 46.9 | 47.3 | 47.7 | 48.1 | 48.7 | 49.0 | 49.2 | 49.4 | 49.5 | 49.6 | 49.7 | 49.8 | 49.8 | 49.9 | 50.0 | 50.0 | 50.0 | |
| 1 | 9 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 |
| | | 39.1 | 39.1 | 39.1 | 39.2 | 39.2 | 39.2 | 39.2 | 39.3 | 39.3 | 39.3 | 39.4 | 39.5 | 39.5 | 39.6 | 39.7 | 39.8 | 39.9 | 40.0 | 40.1 | 40.2 |
| | | 40.4 | 40.5 | 40.7 | 40.9 | 41.1 | 41.3 | 41.5 | 41.7 | 42.0 | 42.2 | 42.4 | 42.6 | 42.9 | 43.1 | 43.3 | 43.5 | 43.6 | 43.7 | 43.8 | 43.9 |
| | | 44.0 | 44.0 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 |
| 1 | 10 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | -12.9 | |
| 1 | 11 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 35.2 | | | |
| 1 | 12 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 31.5 | | | | | | | |
| 1 | 1 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 32.1 | | | | | | | | | | |
| 1 | 2 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 22.4 | | | | | | | | | | | | | |
| 1 | 3 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 22.7 | | | | | | | | | | | | | | | | |
| 1 | 4 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 36.5 | | | | | | | | | | | | | | | | | | |

WATANA FLOWS AND TEMPERATURES FOR YEAR 1

| | YEAR | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INFLO | 7943.0 | 10398.0 | 22922.0 | 20778.0 | 18431.0 | 10670.0 | 4513.0 | 2052.0 | 1405.0 | 1157.0 | 979.0 | 898.0 | 1113.0 |
| EVAP | 2.3 | 4.6 | 4.6 | 4.1 | 3.0 | 1.8 | 0.8 | 0.2 | 0.4 | 0.5 | 1.3 | 2.4 | 3.5 |
| PRCP | 1.7 | 0.8 | 2.2 | 3.1 | 3.3 | 2.8 | 1.6 | 1.2 | 1.2 | 0.9 | 1.2 | 1.0 | 0.7 |
| OUTFL | 7935.3 | 5344.0 | 4990.0 | 7022.0 | 9190.0 | 6486.0 | 7338.0 | 9186.0 | 11999.0 | 10617.0 | 9027.0 | 8013.0 | 6011.0 |
| REQDQ | 7935.3 | 5344.0 | 4990.0 | 7022.0 | 9190.0 | 6486.0 | 7338.0 | 9186.0 | 11999.0 | 10617.0 | 9027.0 | 8013.0 | 6011.0 |
| STMX | | 9652000. | 9652000. | 9652000. | 9652000. | 9652000. | 9652000. | 9652000. | 9652000. | 9652000. | 9652000. | 9652000. | 9652000. |
| STOR | | 6861553. | 7922295. | 8765243. | 9334403. | 9586525. | 9415367. | 8993987. | 8345057. | 7764515. | 7317498. | 6876671. | 6578542. |
| STMN | | 5230000. | 5230000. | 5230000. | 5230000. | 5230000. | 5230000. | 5230000. | 5230000. | 5230000. | 5230000. | 5230000. | 5230000. |
| TA | 25.5 | 37.4 | 49.0 | 52.0 | 48.6 | 39.9 | 24.0 | 9.7 | 2.9 | 1.6 | 6.6 | 11.2 | 23.5 |
| TMPIN | 45.2 | 41.9 | 45.5 | 50.9 | 49.6 | 42.3 | 35.2 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 37.0 |
| TMPMX | 41.8 | 45.9 | 49.5 | 54.9 | 53.6 | 46.3 | 39.2 | 37.6 | 36.0 | 36.0 | 36.0 | 36.0 | 41.0 |
| TPOUT | 41.5 | 39.0 | 43.9 | 49.1 | 48.8 | 45.4 | 39.9 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| TMPMN | 38.6 | 44.9 | 48.5 | 53.9 | 52.6 | 45.3 | 38.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 33.0 |
| RELEASES THRU OUTLET 2057 | | | | | | | | | | | | | |
| QQMN | | 5344.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8013.0 | 6011.0 |
| QOUTL | | 5344.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8013.0 | 6011.0 |
| TOUTL | | 39.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 39.0 | 39.0 |
| RELEASES THRU OUTLET 2093 | | | | | | | | | | | | | |
| QQMN | | 0.0 | 4990.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9027.0 | 0.0 | 0.0 |
| QOUTL | | 0.0 | 4990.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9027.0 | 0.0 | 0.0 |
| TOUTL | | 0.0 | 43.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 39.0 | 0.0 | 0.0 |
| RELEASES THRU OUTLET 2129 | | | | | | | | | | | | | |
| QQMN | | 0.0 | 0.0 | 7022.0 | 9190.0 | 6486.0 | 7338.0 | 9186.0 | 11999.0 | 10617.0 | 0.0 | 0.0 | 0.0 |
| QOUTL | | 0.0 | 0.0 | 7022.0 | 9190.0 | 6486.0 | 7338.0 | 9186.0 | 11999.0 | 10617.0 | 0.0 | 0.0 | 0.0 |
| TOUTL | | 0.0 | 0.0 | 49.1 | 48.8 | 45.4 | 39.9 | 39.0 | 39.0 | 39.0 | 0.0 | 0.0 | 0.0 |

DEVIL CANYON RESERVOIR ( TWO LEVEL INTAKE AT 70 AND 200 )
TEMPERATURE STRATIFICATION STUDY
DATES:AVE. YEAR, WATANA INTAKES:2021,2057,2129

THE OUTPUT UNITS ON INFLOW AND OUTFLOW ARE IN CFS, EVAP AND PRECIP IN INCHES, STORAGE IN AF, AND TEMPERATURE IN DEGREES F

| NYR | IYR | NPER | IPER | MSTRT | NLAYR | LAYER | NOUTL | NMINQ | IDERV | METRC | IDGST | NIC | NIT | NOTL | INTER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1981 | 12 | 5 | 5 | 71 | 5 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 4 |

| MREL | NMO |
|---|---|
| 0 | 3 |

| STORA | CISA | COSA | STRMX | STRMN | TIN | TAIR | EVAP | PRCP | QMIN | TMAX | TMIN | CSOUT | SOLR | DEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 979800. | 1.983 | 1.983 | 1082000. | 292000. | -1. | -1. | -1.00 | -1.00 | -1. | -1. | -1. | 0.504 | -1. | 32.81 |

| AIR TEMP COEF | INFLO MIXING COEF | DIFFUSION COEF | EVAP HEAT COEF | INSOLATION COEF |
|---|---|---|---|---|
| 0.816 | 0.114 | 0.043 | 0.637 | 0.193 |

QOMIN= -1.0 -3.0

| STCAP= | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 52500. | 56000. | 59500. | 63000. | 66500. | 70000. | 73500. | 77000. | 80500. | 84000. |
| | 88800. | 93600. | 98400. | 103200. | 108000. | 112800. | 117600. | 122400. | 127200. | 132000. |
| | 138300. | 144600. | 150900. | 157200. | 163500. | 169800. | 176100. | 182400. | 188700. | 195000. |
| | 204600. | 214200. | 223800. | 233400. | 243000. | 252600. | 262200. | 271800. | 281400. | 291000. |
| | 307500. | 324000. | 340500. | 357000. | 373500. | 390000. | 406500. | 423000. | 439500. | 456000. |
| | 481100. | 506200. | 531300. | 556400. | 581500. | 606600. | 631700. | 656800. | 681900. | 707000. |
| | 741100. | 775200. | 809300. | 843400. | 877500. | 911600. | 945700. | 979800. | 1013900. | 1048000. |
| | 1082100. | | | | | | | | | |

| TSTRT= | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | -1.0 | -1.0 |
| | -1.0 | | | | | | | | | |

STOUT= 204600. 631700.

## DEVIL CANYON RESERVOIR TEMPERATURES

| YEAR | PER | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | -36.3 | | | | | | | | | | | | | | | |
| 1 | 6 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.1 | 39.1 |
| | | 39.1 | 39.1 | 39.2 | 39.2 | 39.3 | 39.4 | 39.6 | 39.8 | 40.0 | 40.3 | 40.6 | 40.9 | 41.3 | 41.8 | 42.3 | 42.9 | 43.6 | 46.6 | 47.3 | 47.8 |
| | | 48.0 | | | | | | | | | | | | | | | | | | | |
| 1 | 7 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.2 | 39.2 | 39.3 | 39.4 | 39.5 | 39.6 | 39.7 |
| | | 39.9 | 40.0 | 40.2 | 40.5 | 40.8 | 41.2 | 41.6 | 42.1 | 42.7 | 43.2 | 43.9 | 44.5 | 45.2 | 45.9 | 46.6 | 47.4 | 48.1 | 50.3 | 50.6 | 51.0 |
| | | 51.5 | | | | | | | | | | | | | | | | | | | |
| 1 | 8 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.2 | 39.2 | 39.3 | 39.3 | 39.4 | 39.5 | 39.6 | 39.7 | 39.8 | 40.0 | 40.2 | 40.4 | 40.6 | 40.8 | 41.1 |
| | | 41.3 | 41.6 | 41.9 | 42.3 | 42.6 | 43.1 | 43.5 | 44.0 | 44.5 | 45.0 | 45.4 | 45.9 | 46.3 | 46.8 | 47.3 | 47.7 | 48.2 | 49.5 | 49.5 | 49.6 |
| | | 49.6 | 49.7 | 49.7 | 49.8 | 49.9 | 50.0 | | | | | | | | | | | | | | |
| 1 | 9 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.1 | 39.2 |
| | | 39.2 | 39.2 | 39.3 | 39.4 | 39.4 | 39.5 | 39.6 | 39.7 | 39.8 | 39.9 | 40.1 | 40.2 | 40.4 | 40.5 | 40.7 | 40.9 | 41.2 | 41.4 | 41.7 | 41.9 |
| | | 42.2 | 42.4 | 42.7 | 42.9 | 43.1 | 43.3 | 43.5 | 43.7 | 43.8 | 43.9 | 44.0 | 44.1 | 44.1 | 44.1 | 44.1 | 44.2 | 44.2 | 44.3 | 44.3 | 44.4 |
| | | 44.5 | 44.6 | 44.6 | 44.6 | 45.1 | 45.7 | 46.0 | 46.2 | | | | | | | | | | | | |
| 1 | 10 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | -90.6 | | | | | | | | | | |
| 1 | 11 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 16.8 | | | | | | | | | | |
| 1 | 12 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 25.4 | | | | | | | | | |
| 1 | 1 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 14.1 | | | | | | | | | |
| 1 | 2 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 14.3 | | | | | | | | | |
| 1 | 3 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 16.4 | | | | | | | | | |
| 1 | 4 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| | | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 33.8 | | | | | | | | | | | | |

FLOWS AND TEMPERATURES FOR YEAR 1

| | YEAR | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INFLO | 9033.8 | 7177.0 | 8059.0 | 9344.0 | 11467.0 | 8115.0 | 8137.0 | 9517.0 | 12246.0 | 10612.0 | 9195.0 | 8156.0 | 6180.0 |
| EVAP | 2.3 | 4.6 | 4.6 | 4.1 | 3.0 | 1.8 | 0.8 | 0.2 | 0.4 | 0.5 | 1.3 | 2.4 | 3.5 |
| PRCP | 1.7 | 0.8 | 2.2 | 3.1 | 3.3 | 2.8 | 1.6 | 1.2 | 1.2 | 0.9 | 1.2 | 1.0 | 0.7 |
| OUTFL | 9036.9 | 9344.0 | 10288.0 | 9070.0 | 8478.0 | 6972.0 | 7403.0 | 9425.0 | 11864.0 | 10514.0 | 9038.4 | 8143.8 | 7903.0 |
| REQDQ | 9018.0 | 9344.0 | 10288.0 | 9070.0 | 8478.0 | 6972.0 | 7403.0 | 9425.0 | 11864.0 | 10514.0 | 8883.0 | 8072.0 | 7903.0 |
| STMX | | 1082000. | 1082000. | 1082000. | 1082000. | 1082000. | 1082000. | 1082000. | 1082000. | 1082000. | 1082000. | 1082000. | 1082000. |
| STOR | | 844363. | 710370. | 726649. | 910612. | 979182. | 1024763. | 1030805. | 1054766. | 1073316. | 1082000. | 1082000. | 977883. |
| STMN | | 292000. | 292000. | 292000. | 292000. | 292000. | 292000. | 292000. | 292000. | 292000. | 292000. | 292000. | 292000. |
| TA | 25.5 | 37.4 | 49.0 | 52.0 | 48.6 | 39.9 | 24.0 | 9.7 | 2.9 | 1.6 | 6.6 | 11.2 | 23.5 |
| TMPIN | 42.0 | 39.1 | 44.2 | 49.4 | 49.6 | 46.5 | 39.9 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| TMPMX | 42.5 | 45.9 | 49.5 | 54.9 | 53.6 | 46.3 | 39.2 | 37.6 | 36.0 | 36.0 | 36.0 | 36.0 | 41.0 |
| TPOUT | 41.5 | 39.0 | 44.0 | 48.8 | 48.8 | 45.3 | 39.7 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| TMPMN | 36.2 | 37.9 | 41.5 | 46.9 | 45.6 | 38.3 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 33.0 |
| RELEASES THRU OUTLET 1 | | | | | | | | | | | | | |
| QOMN | | 0.0 | 0.0 | 0.0 | 188.0 | 0.0 | 0.0 | 0.0 | 11.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| QOUTL | | 0.0 | 0.0 | 0.0 | 188.0 | 0.0 | 0.0 | 0.0 | 11.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOUTL | | 0.0 | 0.0 | 0.0 | 39.4 | 0.0 | 0.0 | 0.0 | 39.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RELEASES THRU OUTLET 2 | | | | | | | | | | | | | |
| QOMN | | -3.0 | -3.0 | -3.0 | -3.0 | -3.0 | -3.0 | -3.0 | -3.0 | -3.0 | -3.0 | -3.0 | -3.0 |
| QOUTL | | 9344.0 | 10288.0 | 9070.0 | 8290.0 | 6972.0 | 7403.0 | 9425.0 | 11853.0 | 10514.0 | 9038.4 | 8143.8 | 7903.0 |
| TOUTL | | 39.0 | 44.0 | 48.8 | 49.0 | 45.3 | 39.7 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |

APPENDIX A5

CLIMATIC STUDIES FOR TRANSMISSION LINES

Climatic studies were carried out to determine likely wind and ice loads for preliminary design of transmission lines. Historical data and those collected in the field during the study period were used to assess potential wind and ice conditions along the selected transmission corridor. The following sections present details of the analysis undertaken and recommended loads for design.

## 1 - WIND LOADS

### 1.1 - Available Data

Daily climatological data summaries were obtained from the National Oceanographic and Atmospheric Administration (NOAA) for the 10-year period 1969 to 1978 for recording stations at Anchorage, Fairbanks, and Talkeetna along with monthly summaries of all available records (extending over 30 years). Partial records (1969 - 1973) for Gulkana and Big Delta stations. Data for Summit station and Healy power station were collected by the project team in Anchorage. For a general description of climatological data availability in the basin, refer to the Field Data Index.

The NOAA records report the fastest mile of wind, which is the maximum wind speed averaged over a 1 minute duration. Within this interval, instantaneous gust speeds can be significantly above the average value. Instantaneous gusts usually are recorded as averages over a few seconds, since this is the lower limit of response time of most measuring anemometers. NOAA does not routinely report gust speeds.

Wind speed, direction, and gust speeds were recorded at six climate stations located in the Upper Susitna Basin during 1980-81 as part of the field data collection program. Wind and gust values were recorded every 15 minutes as averages of 15 second readings. Peak gusts and values around the peak were also recorded to enable estimate gust speeds of few seconds duration. Figure A5.1 to A5.3 presents selected peak gust values and estimated duration for Watana, Devil Canyon, and Susitna Glacier stations.

### 1.2 - Analyses

Table A5.1 presents a summary of the length of records and fastest mile speed recorded at the different stations. The highest wind speed of 75 mph was recorded at Big Delta. At the Healy power plant, a high of 70 mph was observed in a 1.5 year period of record. Several records between 50 and 60 mph were also observed in this short period at Healy.

It has not been possible to carry out a regional frequency analysis to estimate wind speeds along the transmission corridor because of limited records at representative stations along the corridor. However, from a review of the available data, a wind speed (1 minute value) of about 100 mph along the corridor was estimated to have a return period of 1 in 30 years. Corresponding gust speed was estimated around 150 mph. These values are considered appropriate for use in preliminary transmission line design.

## 2 - ICE LOADS

### 2.1 - Freezing Precipitation

#### (a) Available Data

Data collected from NOAA on freezing precipitation amount included 3 hourly records for the period 1969 - 1978 for Anchorage and Fairbanks. Records at Gulkana, Bid Delta, and Talkeetna stations were available for shorter durations between 1969 and 1972.

Standard freezing precipitation equipment consisting of 8-inch square steel plates mounted on steel pipes were installed at Watana and Denali climate stations to record such precipitation amounts (1). The winter of 1980 - 1981 was unusually mild and no freezing precipitation was recorded at these stations. While some icing may have occurred but gone unrecorded because of limited site visits by the data recording team, from discussion with the Watana camp residents, it is gathered that no icing actually occurred during the season.

#### (b) Analyses

Short records at the Gulkana, Big Delta, and Talkeetna stations could not be used in any analyses except as check values. A frequency plot of Fairbanks and Anchorage records is presented in Figure A5.4. This indicates that an average 1-inch ice accumulation may be expected as a 1 in 15-year event.

### 2.2 - In-Cloud Icing

In-cloud ice accretion on transmission lines is a function of supercooling of the cloud moisture, cloud type, wind speed temperatures, etc. Based on previous experience in northern climate, a typical combination of climatic conditions conducive to in-cloud icing was identified. Such data were available from NOAA only for Anchorage and Fairbanks stations, and were obtained for a 10-year period (1969 to 1978).

In order to measure in-cloud icing in the field, two methods were used. The first consisted of a 12-foot length of 1-inch diameter aluminum (steel core) cables mounted about 8 to 10 feet above ground between upright posts. As in-cloud icing caused rime to build up on the cables, its thickness was to be measured. The second method continuously measured amounts of atmospheric icing. The set up consisted of a Rosemount ice detector which sensed the presence of ice (sensitivity = 0.025 inches) and produced an output electrical signal suitable for automatic recording in a counter. The unit contains a built-in heater which automatically de-ices the detector each time an ice warning signal is produced, thus preparing the detector for another ice-sensing cycle. This device is designed for use as an automatic control mechanism to de-ice fixed antenna installations. For our purposes, the unit was connected to a counter which totaled the number of times that the detector indicated an occurrence of icing. The counter was then read during regular monthly site visits.

As with the freezing rain measuring setup, no icing was observed on the sections of transmission line set up during the winter of 1980-81.

The ice detector unit was located near the Watana camp because it required ac power supply from the camp generator for operation. The system was planned to automatically record icing events. Unfortunately, the system could not perform satisfactorily because of frequent power outages at the camp for daily servicing or changeover. Each power interruption was recorded as a count in the ice detector, making initial observations useless. As a solution to this problem, an attempt was made to keep a count of the number of power interruptions at the camp. The intent was that these would then be subtracted from the counts recorded by the detector, with the balance of the counts being the number of icings occurring. The generator operator was enlisted to record the timing of each power outage.

Keeping accurate track of the number of power interruptions was a more difficult task than originally envisioned. Sometimes a shut-off might not be recorded, or during a shut-off the generator might kick on and off a few times, thus causing multiple icing counts to be recorded but not necessarily logged by the operator.

For this reason, the detector results are suspect. However, the winter of 1980-81 was a dry one, and judging by observation of the icing cable and plate, it is suspected that little if any icing actually did occur during the winter at the observation sites. This suspicion is supported by discussion with long-term residents of the Watana camp. When the camp maintenance men and/or cooks were asked at frequent intervals during visits to the camp, none reported any freezing rain or icing conditions.

Without field data, no analytical method or modeling could be applied to estimate in-cloud icing on the transmission corridor.

## 2.3 - Snow Creep

Snow creep is the slow movement of a snowpack downhill. It is most prevalent on slopes of 25° and 35°. Above this angle the movement of snow will more likely occur as an avalanche.

During 1973 in Southeast Alaska, several transmission line towers servicing the Snettisham Hydroelectric Project failed for a reason unknown but theorized to be high winds or snow creep pushing the tower off its base. In 1974 and 1975 the Corps of Engineers installed a system to evaluate the amount of force that snow creep could exert on a transmission line tower (Meyer, 1978,[2]). These tests measured a maximum pressure of 460 $lbs/ft^2$ with a 71-inch depth of 37 percent-density snow, but concluded that snow creep forces did not contribute to the failure of the tower.

Even though not judged to be a factor in the Snettisham failures, snow creep was considered to be a potentially large force in Alaska. To try to determine the magnitude for the transmission line servicing the Susitna Project, two installations were set up to measure snow creep forces. To simulate conditions at the actual transmission line towers as closely as possible, 24-inch diameter, 3/8-inch thick tubular steel sections were placed on the chosen slopes along the potential transmission corridor. These sections were allowed to slide over the ground and were held from sliding downhill by a cable attached to a dynamometer. The dynamometer measured the force in the cable which was needed to support the pipe section. If creep of the snowpack did occur, the force would have been transmitted to the pipe section, cable and dynamometer where its maximum would have been recorded by a maximum-recording gauge (1).

The two setups were installed in January 1981, one near Watana and the other near Devil Canyon damsites. During setup, the snowpack was unavoidably disturbed. Partly because of this and also because of the lack of abundant snow during the winter, no usable snow creep data were collected. Some readings were taken, however, which indicated the type of base readings that may occur on the instrument with no snow (because of thermal, wind, or other stresses). 1981 observations are summarized in Table A5.2.

## 3 - COMBINED LOADS

Where historical events are reported, only 3-hour average and 4-hour maximum wind speeds are reported. For Anchorage and Fairbanks, these values are as follows:

| | Maximum Wind Speed During Icing mph | |
|---|---|---|
| | 3-hour average | 1 hour average |
| Anchorage | 10 | 21 |
| Fairbanks | 12 | 25 |

These values are recorded over a 10-year period during occurrences of freezing precipitation. There is no reliable method to extrapolate wind speeds from 3-hour averages to shorter duration wind and gust speeds. A conservative approach would suggest using wind speed values in conjunction with 1-inch diameter ice buildup for preliminary designs. A specific gravity of 0.9 may be assigned to the ice (clear or glaze associated with freezing rain).

## 4 - DISCUSSION AND RECOMMENDED DESIGN LOADS

Discussions were held with Commonwealth Associates Incorporated, who are responsible for the detailed design of the transmission line interties between Willow and Healy, with the COE, Retherford Associates, and local utilities in the Railbelt on the general design parameters of the transmission lines. Based on these and the analyses discussed above, the following set of parameters were chosen for the preliminary design of the Susitna transmission lines:

- NESC heavy loading 1/2-inch with 40 mph wind; or
- Extreme wind of 140 mph without any ice; or
- Extreme ice of 1-inch with 40 mph wind.

## REFERENCES


1. R&M Consultants, Susitna Hydroelectric Project, Field Data Collection and Processing, December 1981.

2. Meyers, R., Snow Creep Investigations in Southeast Alaska, Cold Regions Specialty Conference, Anchorage, Alaska, May 1978, Published by American Society of Civil Engineers.

LIST OF TABLES

## LIST OF FIGURES

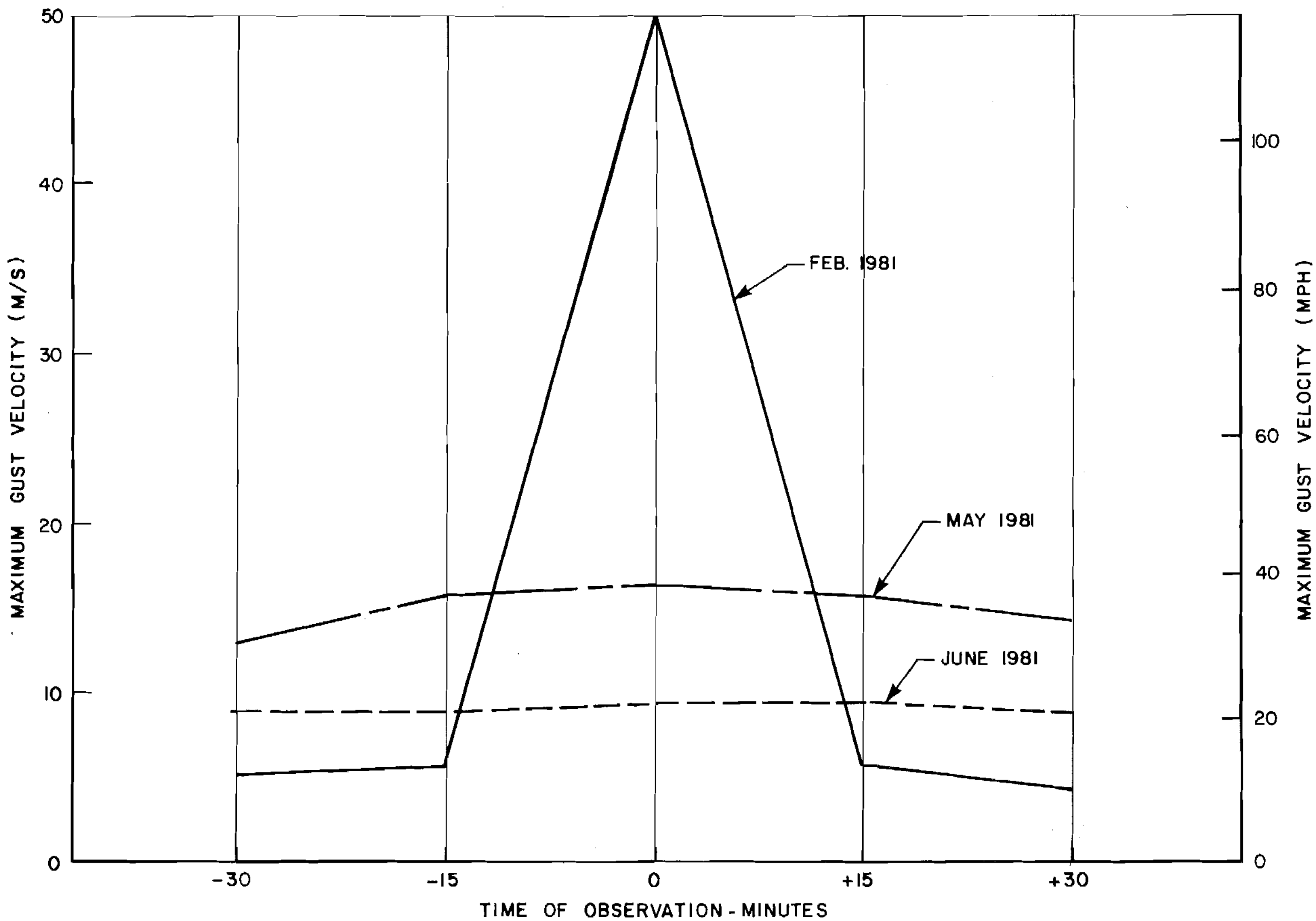
TABLE A5.1: RECORDED WIND DATA

| Station | Period of Record Years | Gust (15 min. avg.) | Month/Year | Maximum Wind Speed Recorded mph/min. avg | Month/Year |
|---|---|---|---|---|---|
| Anchorage | 24 | N/A | N/A | 61 | Jan 1971 |
| Big Delta | 23 | N/A | N/A | 74 | -- |
| Fairbanks | 26 | N/A | N/A | 40 | Jun 1974 |
| Gulkana | 15 | N/A | N/A | 52 | Jan 1971 |
| Healy Power Plant | 1-1/2 | N/A | N/A | 70 | Jan 1979 |
| Summit | 15 | N/A | N/A | 48 | Mar 1971 |
| Talkeetna | 10 | N/A | N/A | 38 | Jan 1972 |
| Watana | 1 | 37 | May 1980 | 35 | May 1980 |
| Devil Canyon | 1 | 31 | Apr 1980 | 19 | Nov 1981 |
| Susitna Glacier | 1 | 73 | Jan 1981 | 64 | Jan 1981 |

N/A - Not Available

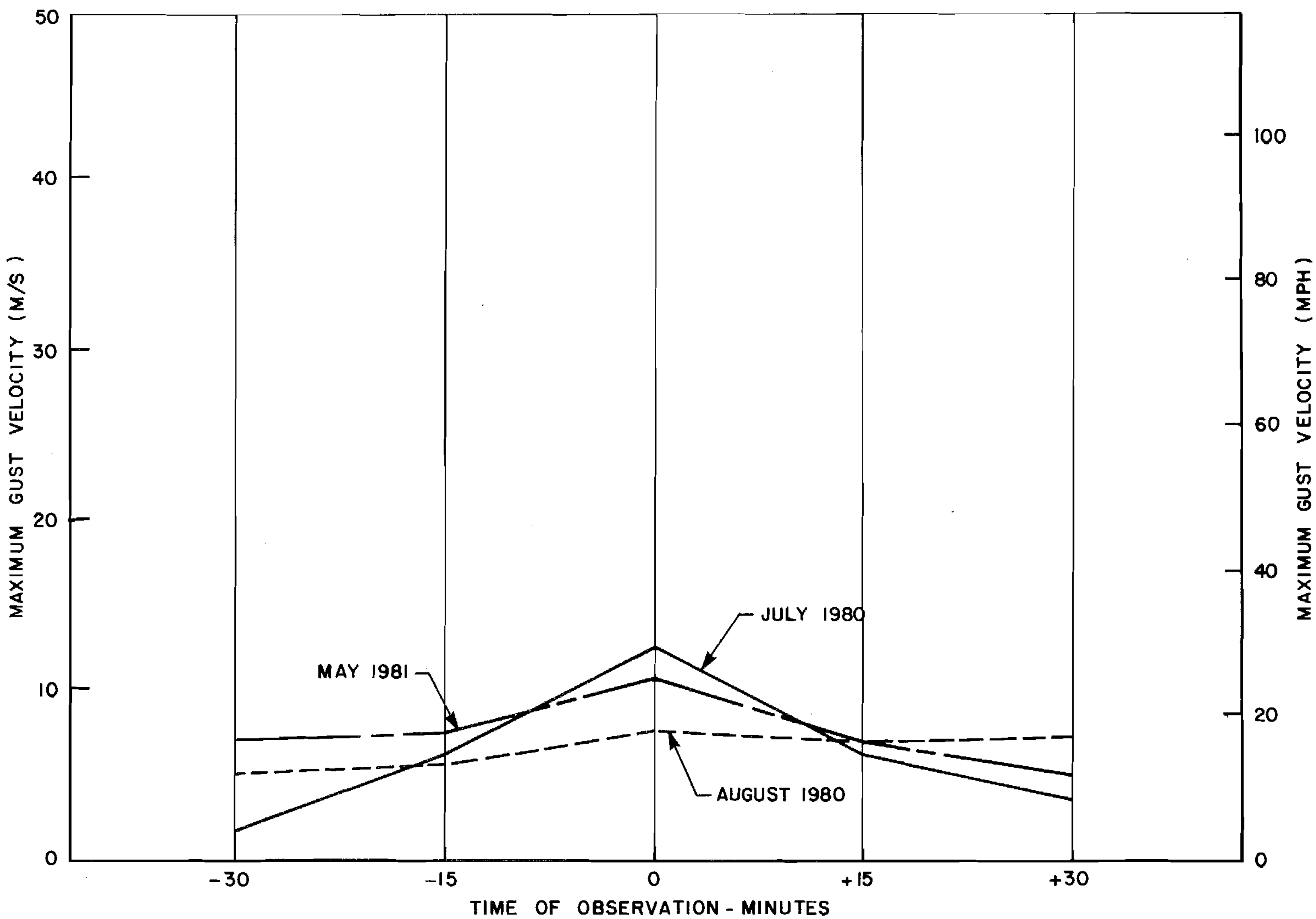
## TABLE A5.2: SNOW CREEP OBSERVATIONS 1981

| Date | Maximum Dynomometer Reading (lbs) | Snow Depth (feet) | Comments |
|---|---|---|---|
| Devil Canyon Site | | | |
| 2-25-81 | - | 1.5 | Installation date. Dyno reading 400 lbs. |
| 3-5-81 | 515 | 2.5 | |
| 3-31-81 | 605 | - | Last reading of season. |
| 10-2-81 | - | 0.0 | First visit of season. Dyno reads 340 lbs. |
| 11-3-81 | 400 | 1.0 | |
| 12-3-81 | 480 | 2.5 | Dry snow, no ice layers or depth hoar. |
| Tsusena Butte Site (Watana) | | | |
| 2-26-81 | - | 2.5 | Installation date. Dyno reading 440 lbs. |
| 4-2-81 | 500 | 0.0 | No snow around cylinder. Last reading of season. |
| 10-2-81 | - | 0.5 | First visit of season. Dyno reads 400 lbs. |
| 11-3-81 | 480 | 0.5 | Hard wind packed snow. |
| 12-2-81 | 520 | 2.0 | Dry snow. Eight inches of depth hoar. Ice crusts at eight inches and an surface. |




GUST VELOCITIES WATANA STATION

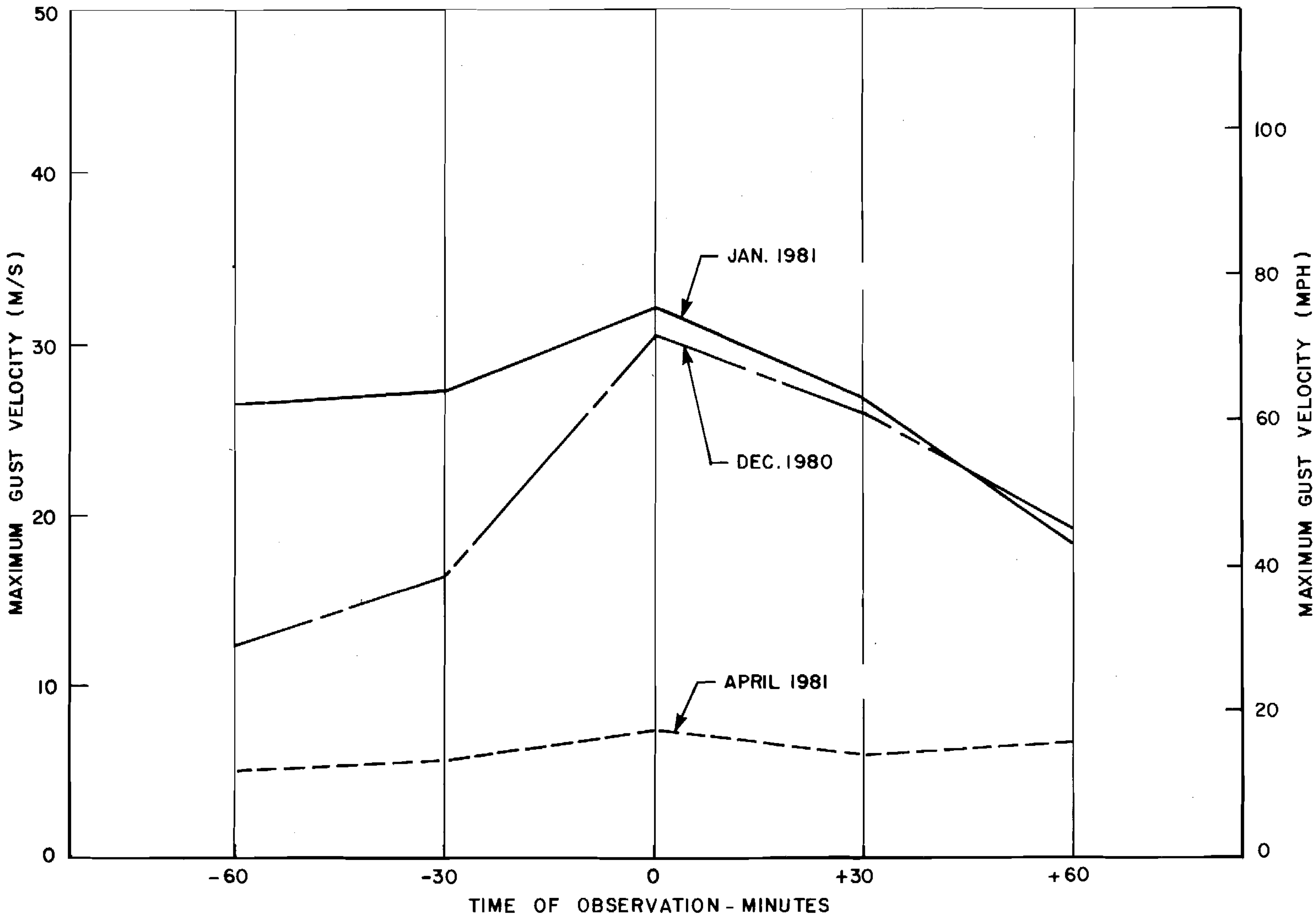
FIGURE A5.1




GUST VELOCITIES DEVIL CANYON STATION

FIGURE A5.2

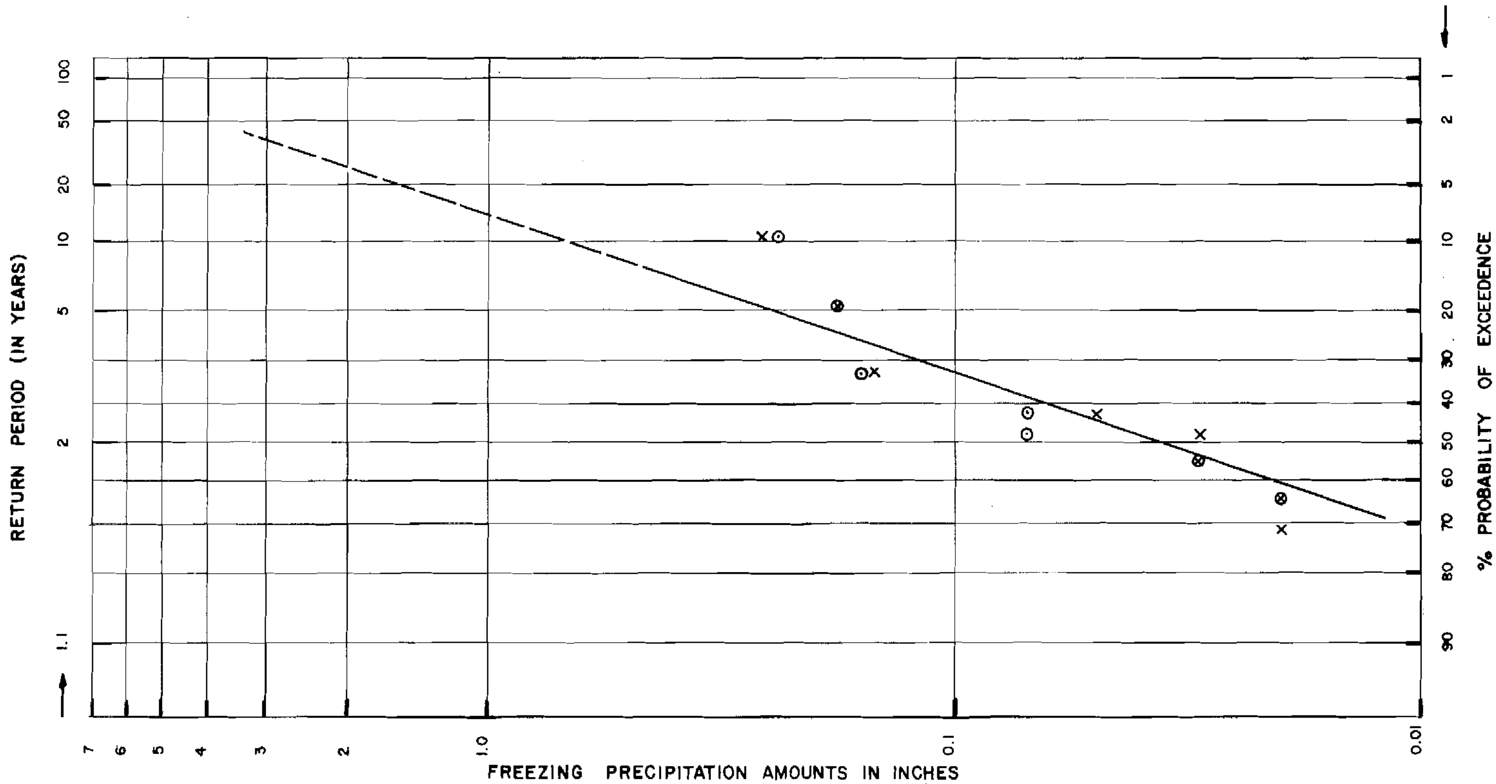
ACRES




GUST VELOCITIES SUSITNA GLACIER STATION

FIGURE A5.3

ACRES




## FREQUENCY CURVE FOR FREEZING PRECIPITATION AMOUNTS

LEGEND

× – ANCHORAGE

⊙ – FAIRBANKS

FIGURE A5.4 ACRES