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CLIMATIC AND STREAMFLOW ESTIMATES FOR NORTHEASTERN UTAH

By F. K. Fields and D. B. Adams

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ILLUSTRATIONS

TABLES

METRIC((SI) UNITS

Most numbers are given in this report in English units followed by metric units in parentheses. The conversion factors used are shown to four significant figures. In the text, however, the metric equivalents are shown only to the number of significant figures consistent with the accuracy of the number in English units.

English Units (Multiply)	English Abbreviation	(by)	Metric Units (to obtain)	Metric Abbreviation
Cubic feet per second	ft^3/s	0.02832	Cubic metres per second	m^3/s
Cubic feet per second per square mile	$(ft^3/s)/mi^2$		Cubic metres per second per square kilometre	$(m^3/s)/km^2$
Feet	ft	.3048	Metres	m
Inches	in	25.40	Millimetres	mm
Square miles	mi^2	2.590	Square kilometres	km^2

Air temperature is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation: $°C = \frac{(°F - 32)}{1.8}$ Differences in degrees Fahrenheit can be converted to differences in degrees Celsius by multiplying the value in degrees Fahrenheit by 0.55.

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ABSTRACT

This report shows how information from 44 air-temperature, 59 precipitation, and 86 streamflow sites was converted to a common-time base of 1941-70, and how general relations were developed to extend the converted point values to unsampled sites.

Two methods, regression and ratio, were used to convert the data to a common-time base. Both methods require a period of concurrent data at two sites. After an estimating equation has been defined from concurrent data, the regression method requires data at the independent site only during the record voids of the dependent site. The independent site must have a complete record, however, if the ratio method is to be used.

Regression techniques were used to fill voids in the air-temperature data base and to determine the correlation of monthly and annual averages, the average annual distribution, and equations that can be used to estimate average monthly and seasonal air temperature, precipitation, and streamflow. Incomplete precipitation and streamflow records were adjusted to the 1941-70 average on the assumption that the ratio of concurrent data is directly proportional to the ratio of the respective 1941-70 average annual values at nearby sites.

The average monthly air temperature at a short-term collection site generally can be approximated with a standard error of estimate of less than 2 degrees Fahrenheit (1.1 degrees Celsius). The standard deviation of the precipitation residuals, about the averages of the estimates for all incomplete-record sites, is 0.42 inch (11 millimetres). The average annual precipitation at the 59 sites used in this analysis is 16.2 inches (411 millimetres). Two-thirds of the streamflow estimates are within 13.0 cubic feet per second (0.37 cubic metres per second) of the averages of the site estimates, which is about 10 percent of the sample average.

Altitude and location can be used to estimate the average annual temperature and precipitation. Schematic diagrams, plotted by computer, were prepared to show variations of altitude, temperature, and precipitation. Maps, also plotted by computer, show lines of equal altitude, precipitation, and temperature.

Average annual streamflow can be estimated on the basis of drainage area and the average annual precipitation. Equations for these estimates have standard errors of estimate ranging from 30 to 125 percent.

INTRODUCTION

As part of a detailed hydrologic appraisal in northeastern Utah (fig. 1), done in cooperation with the Utah Department of Natural Resources, Division of Water Rights, climatic and streamflow records of variable length were converted to a common-time base, point-sample information was extended to unsampled sites, and estimates of lines of equal precipitation and temperature were expressed through computer graphics. The purpose of this report is to describe the methods used to carry out these procedures.

The conversion of data samples of variable length to a common-time base eliminates many of the subjective considerations that would otherwise be required. For instance, one 5-year average for a given point can be quite different from another, and neither may express a long-term average.

Monthly averages of air temperature for 44 sites and precipitation for 59 sites were compiled from summaries published by the U.S. National Weather Service. Sites in Colorado and Wyoming were included in order to obtain an enlarged sample and a greater diversification of parameter values.

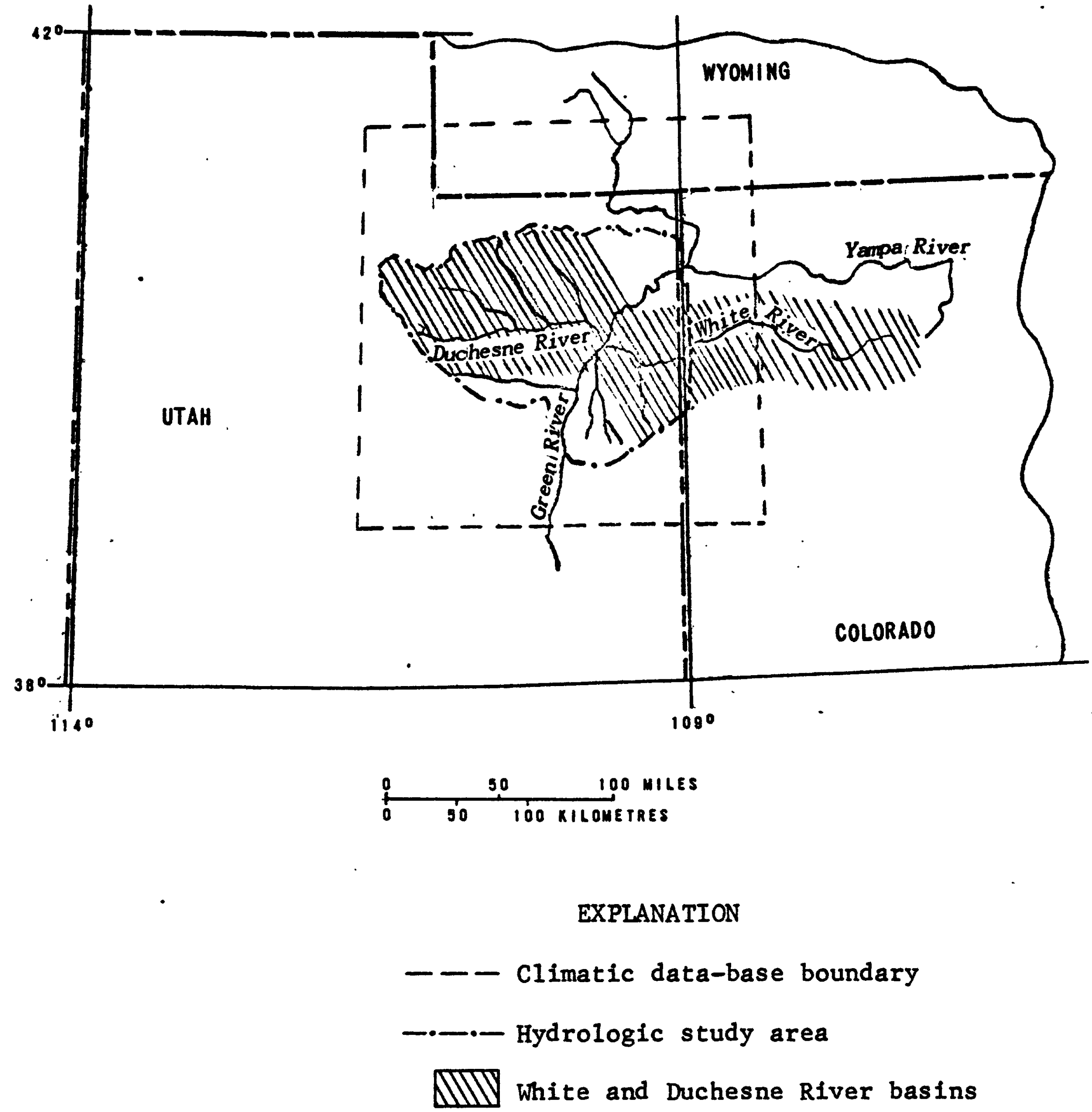

Figure 1.--Location of study area.

Annual discharges of streamflow based on measurements by the U.S. Geological Survey at 86 gaging sites are used in this report. Most of these sites are in an area of about 10,000 mi^2 (26,000 km^2), of which about 80 percent is drained by the Duchesne and White Rivers, which are tributary to the Green River. Several gaging sites outside the study area are included to account for changes in the flow of the Green River as it enters and leaves the area. Site locations and other descriptive information concerning the gaging sites are given in summaries of streamflow data published by the Geological Survey.

CONVERTING THE DATA TO A COMMON-TIME BASE

Two methods, regression and ratio, were used to convert the climatic and streamflow data to the common-time base of 1941-70. Both methods require a period of concurrent data at two sites. After an estimating equation has been defined from concurrent records, if the regression method is to be used, data are required at the independent site only during the record voids of the dependent site. The independent site must have a complete record, however, if the ratio method is to be used.

Changes in average monthly air temperatures at a single site reflect a general change of air temperature within the area. Because of the excellent correlation of temperature data, therefore, regression techniques were used to fill all data voids in the temperature-sample base.

The site-to-site comparisons of precipitation and streamflow records revealed an extreme variability for month-to-month and year-to-year comparisons. This irregular distribution eliminates the use of regression techniques. The incomplete-record sites ($\underline{SR}$) were adjusted to the 1941-70 average ($\underline{SR}(\underline{E})$) on the assumption that the ratio of concurrent annual averages ($\underline{SR}(\underline{K})/\underline{CR}(\underline{K})$) is directly proportional to the ratio of the respective 1941-70 average annual values ($\underline{SR}(\underline{E})/\underline{CR}(\underline{I})$). Only complete calendar year values were used in the ratios, which are expressed as:

$$\underline{SR}(\underline{K})/\underline{CR}(\underline{K}) = \underline{SR}(\underline{E})/\underline{CR}(\underline{I})$$

with the estimated average precipitation for 1941-70 is:

$$\underline{SR}(\underline{E}) = \underline{CR}(\underline{I})\cdot\underline{SR}(\underline{K})/\underline{CR}(\underline{K})$$

where,

$\underline{SR}$ = short-record site,

$\underline{CR}$ = complete-record site,

$\underline{K}$ = average annual precipitation (or streamflow) for the concurrent period of record,

$\underline{I}$ = observed average annual precipitation (or streamflow) during 1941-70, and

$\underline{E}$ = estimated average annual precipitation (or streamflow) during 1941-70.

DATA ESTIMATES

Two methods used to estimate the average temperature, precipitation, and streamflow for 1941-70 are described in this section. Also, because many hydrologic investigations require monthly or seasonal estimates, a series of regressions were made to determine (1) the correlation of monthly and annual averages, (2) the average annual distribution, and (3) equations that can be used to estimate average monthly and seasonal values.

Data voids for monthly air temperature were filled by estimate prior to the calculation of the 1941-70 averages because only small estimate errors were involved. Then the monthly values, actual and estimated, were used to determine the monthly and seasonal characteristics. Data voids for monthly precipitation and streamflow were not filled, however, because precipitation and streamflow information is too poorly correlated to make reliable monthly estimates. Therefore, monthly and annual characteristics were first determined from existing information, and then the 1941-70 averages were estimated for those sites with incomplete data.

The correlation coefficient ($\underline{R}$) describes the extend to which one variable accounts for the variance of another. A value of 1.00 indicates perfect correlation, and 0.00 describes a complete absence of correlation.

Two equation forms are used for the development of equations that can be used for monthly or seasonal estimates.

The rectangular-coordinate equations have the form:

$$\underline{Y} = \underline{A} + \underline{B} \cdot \underline{X} \; . \; . \; . \; \underline{E} \cdot \underline{Z} \qquad (1)$$

The power, or exponential, equations have the form:

$$\underline{Y} = \underline{A} \cdot \underline{X}^{\underline{B}} \; . \; . \; . \; \underline{Z}^{\underline{E}} \qquad (2)$$

where $\underline{Y}$ is the dependent variable, the letters $\underline{A}$, $\underline{B}$, and $\underline{E}$ represent constants, and the letters $\underline{X}$ and $\underline{Z}$ represent independent variables. Most of the equations used for monthly and seasonal estimates contain only one independent variable and none contain more than two.

The standard error of estimate ($\underline{Ss}$) was used to judge the accuracy of estimates made by regression techniques. This term is normally expressed in units of the dependent variable for arithmetic relations and in percentage for logarithmetic equations. If the standard error of estimate equals "x" units, then two-thirds of the observed dependent variable values fall within "x" units above and below the defined relation.

Air temperature

Common-time base estimates.--Air temperatures in northeastern Utah follow a predictable cycle each year. The lowest average monthly temperatures generally are in January, the highest are in July or August, and orderly changes occur during the transition periods. Because these changes are reflected over large areas, the temperature data are highly correlated and suitable for regression analyses. The 44 temperature-data sites used in this study are listed in table 1. A bar graph shows the period of actual data collection at each site during the 1941-70 period. The concurrent monthly average temperatures for each incomplete-record site and several nearby complete-record sites were regressed to obtain estimating equations. The equations with the smallest standard error of estimate and largest correlation coefficients were used to fill the data voids.

The equation constants and a nearby temperature record that can be used to estimate monthly air temperature at each of the 44 sites are given in table 2. Estimates were required to complete the 1941-70 records at 34 of these sites. The most reliable nearby site was used for estimates of data voids. If the record was still incomplete, however, the next most reliable record was used to complete the estimates.

The average monthly temperature at a short-term collection site generally is related to that at another site with a standard error of estimate of less than 2°F (1.1°C) and only one correlation coefficient was less than 0.98. (See table 2.)

Table 2.--Equations to estimate average monthly air temperature

See page 7 for an explanation of equation (1).

Station numbers of variables		Constants for equation (1), $Y = A + BX$		Standard error of estimate	Correlation coefficient
Dependent (Y)	Independent (X)	A	B	Ss (in)	R
0050	2484	1.25	0.997	1.83	0.994
0074	9111	2.94	.914	1.85	.994
0802	5969	3.47	.985	2.18	.994
0810	5969	4.00	.966	1.42	.997
1214	7015	-.26	.983	1.50	.996
1440	1772	-5.01	1.101	2.41	.992
1772	2484	.16	1.110	1.94	.994
2150	2996	10.20	.956	2.51	.991
2173	2996	.87	1.039	.99	.999
2253	9111	1.75	.978	1.39	.997
2385	7909	.49	1.026	1.46	.996
2484	1214	1.62	.928	1.41	.996
2798	2484	-3.17	1.102	1.23	.998
2864	7909	-2.33	1.075	1.51	.996
2996	7395	-2.01	1.009	1.41	.997
3056	7015	3.29	.872	2.49	.987
3146	6832	9.80	.877	2.56	.989
3413	7015	-.73	1.085	2.10	.994
3418	7015	-.47	1.061	2.53	.990
3624	3896	-.72	.946	1.67	.994
3896	7724	8.82	.975	1.99	.993
4065	5377	-4.47	1.054	2.32	.991
4342	2996	-.05	1.013	1.54	.997
4467	2864	3.38	.908	1.76	.993
5377	7909	-.89	1.065	2.16	.991
5446	9111	2.91	.883	1.92	.994
5815	3896	-5.35	.950	2.45	.985
5969	2253	-2.64	1.073	1.61	.996
6123	9111	1.52	.944	1.36	.997
6340	9111	6.11	.898	1.42	.996
6568	2996	-.47	1.059	1.87	.996
6832	2996	1.75	.993	1.75	.996
7015	2484	-1.46	1.106	1.74	.995
7395	9111	.49	1.033	1.24	.998
7720	2484	-10.47	1.021	1.70	.995
7724	7909	-8.97	1.075	1.89	.994
7909	2385	-.11	.966	1.41	.996
7955	2484	-12.75	.985	4.11	.970

Table 1-page 9

Table 2.--Equations to estimate average monthly air temperature--Continued

Station numbers of variables		Constants for equation (1), $Y = A + BX$		Standard error of estimate S_s (in)	Correlation coefficient R
Dependent (Y)	Independent (X)	A	B		
7959	3896	-4.30	0.945	2.02	0.991
8370	7909	-8.25	1.017	2.33	.989
8376	2484	-4.13	.910	1.36	.985
8474	2484	-.42	1.035	1.96	.993
8705	7015	2.30	1.029	1.96	.994
9111	7395	-.29	.964	1.20	.998

The average monthly and annual air temperatures (measured and/or estimated) for 1941-70 at each of the sampling sites are shown in table 3. The variation of annual mean temperatures with altitude approximates the typical adiabatic cooling rate. This rate is about 5.3°F per 1,000 ft or 1.0°C per 100 m change in altitude (Blair, 1942, p. 104). A value frequently used for an average saturated condition is 3.2°F change per 1,000 ft or 0.6°C per 100 m. The computed slope for the equation fit to these data per 1,000 ft or 100 m of altitude change is 3.12°F and 0.6°C, respectively. The relation is: annual average temperature, in °F, = 63.95 - 3.12x (altitude in thousands of feet above mean sea level).

Air-temperature characteristics.--Correlation coefficients are shown in table 4 for all possible combinations of average annual and monthly air temperatures. The annual and monthly temperatures of March-November correlate the best, with correlation coefficients ranging from 0.973 to 0.997. The coefficients for December, January, and February reflect a lesser degree of correlation, being 0.872, 0.700, and 0.908, respectively. Because of the overall good correlation, estimates of monthly and seasonal air temperature were made from the average annual temperature. The monthly value, expressed as a percentage of the average annual air temperature (fig. 2), shows an orderly transition of temperature during the year.

The rectangular-coordinate or power-equation forms appear to serve equally well for these estimates (table 5) with only the December, January, and February estimates expected to have a standard error of estimate of 2.0°F (1.1°C) or greater.

Table 4.--Correlation of average annual and monthly air temperatures, 1941-70

	Annual	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Annual	1.000	0.700	0.908	0.986	0.976	0.973	0.974	0.975	0.977	0.990	0.997	0.988	0.872
Jan.		1.000	.922	.649	.542	.520	.531	.545	.550	.608	.666	.759	.946
Feb.			1.000	.884	.810	.794	.800	.806	.809	.847	.822	.931	.974
Mar.				1.000	.985	.973	.966	.957	.961	.973	.981	.976	.832
Apr.					1.000	.996	.989	.982	.984	.984	.980	.952	.762
May						1.000	.996	.992	.993	.989	.979	.940	.743
June							1.000	.997	.996	.993	.979	.935	.742
July								1.000	.999	.994	.980	.935	.754
Aug.									1.000	.995	.983	.940	.762
Sept.										1.000	.994	.962	.805
Oct.											1.000	.984	.853
Nov.												1.000	.918
Dec.													1.000
Mean	45.2	20.0	25.6	33.8	44.4	53.7	61.4	69.1	66.9	58.6	49.3	34.8	24.6
Annual average (percent)	100.0	44.2	56.8	74.7	98.1	119	136	153	148	130	109	77.0	54.4

Table 3 - page 13

Table 5--Equations to estimate average monthly and seasonal air temperatures from a known 1941-70 average annual temperature

See page 7 for an explanation of equations (1) and (2).

Dependent variable Mean monthly temperature	Tm[1] = A + B(Ta)[2], equation (1)				Tm = A(Ta)^B, equation (2)			
	Equation constants		Correlation coefficient	Standard error of estimate	Equation constants		Correlation coefficient	Standard error of estimate
Y	A	B	R	Ss (°F)	A	B	R	Ss (percent)
Jan.	-6.91	0.60	0.70	3.1	0.115	1.35	0.70	16
Feb.	-12.18	.84	.91	2.0	.079	1.48	.92	8
Mar.	-12.54	1.02	.99	.9	.162	1.40	.99	3
Apr.	-4.85	1.09	.98	1.2	.615	1.12	.98	3
May	1.93	1.15	.97	1.4	1.363	.96	.98	3
June	.63	1.22	.97	1.5	2.084	.89	.98	2
July	13.91	1.22	.98	1.4	3.422	.79	.98	2
Aug.	13.49	1.18	.98	1.3	3.303	.79	.98	2
Sept.	8.23	1.11	.99	.8	2.255	.85	.99	1
Oct.	.41	1.00	.99	.4	1.500	.92	.99	1
Nov.	-4.16	.86	.99	.7	.451	1.14	.99	2
Dec.	-7.67	.71	.87	2.0	.137	1.36	.88	9
May-Sept.	8.78	1.18	.98	1.2	2.418	.85	.98	2
Oct.-Apr.	-6.32	.87	.98	.9	.336	1.20	.98	3

1/ Tm = monthly or seasonal estimate. 2/ Ta = average annual temperature.

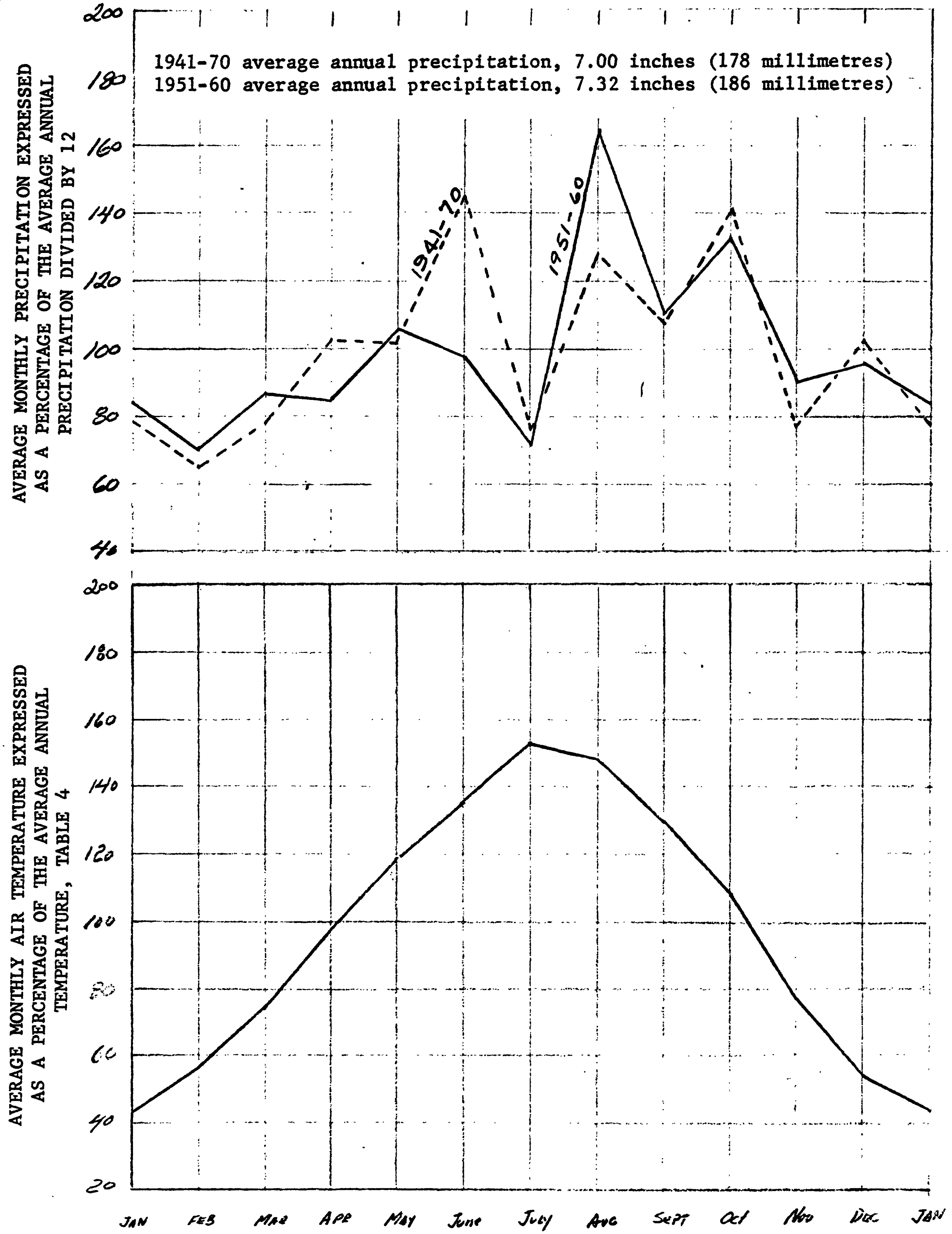

Figure 2.--Annual distribution of average monthly air temperature, 1941-70, and average monthly precipitation at Duchesne, Fort Duchesne, Jensen, Roosevelt, and Vernal, 1941-70 and 1951-60.

Precipitation

Precipitation characteristics.--Precipitation in northeastern Utah is derived primarily from two types of airmass movements. Storms enter the area from the northwest during the cool season (October to April), and airmass movements from the south provide moisture during the warm season (May to September). During the transition between the seasons, large low-pressure systems, which may be almost stationary for several days, result in widespread low-intensity rainfall over large areas.

The monthly distribution of precipitation, averaged over five sites for two different time periods, is shown in figure 2. The monthly averages for two time periods are significantly different, although the average annual precipitation for each time period is almost the same. The monthly averages differ largely because of the erratic distribution of thunderstorms, making June the month of highest rainfall for one time period, whereas August has the greatest rainfall for the other period.

Regression techniques were used to examine the existing precipitation information in order to obtain a better understanding of the characteristics of monthly and seasonal distribution. Reliable monthly values could not be calculated for missing data voids, and only 9 of the 59 sampling sites had complete records for 1941-70 (table 9). Therefore, the monthly means were determined for the 10-year period from 1951 to 1960 for which complete records were available for 40 sampling sites.

The average annual precipitation for these 40 sites (table 6) is more than twice that of those sites used in figure 2. The wider sampling indicates that the periods of highest precipitation are August and the snowfall season from December to May. The monthly values, except for the period from June to September, correlate well with the annual value and each of the other monthly precipitation averages (table 6). Although none of the monthly means for the period from June to September correlate well with means for other months, means for these months have a moderate correlation with one another, with coefficients ranging from 0.69 to 0.87.

The equations in table 7 also can be used to estimate average monthly or seasonal values at ungaged sites for the 1951-60 period. The error that would result in attempting to use these equations to obtain average monthly estimates for 1941-70 is not known. However, in comparing the error of estimate for equation (2) in tables 5 and 7, the precipitation estimate errors are about 10 times greater than the air-temperature estimates.

Four variables--altitude, longitude, latitude, and average annual precipitation--were tested for use in the equations to estimate monthly and annual precipitation. Only the two most significant variables were retained. The average annual precipitation is a significant variable for all months except July and August. Altitude is the next most frequently used independent variable.

Table 6.--Correlation of average annual and monthly precipitation, 1951-60

	Annual	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Annual	1.00	0.92	0.95	0.97	0.95	0.93	0.84	0.75	0.84	0.85	0.91	0.97	0.92
Jan.		1.00	.93	.93	.81	.81	.70	.60	.66	.62	.80	.94	.97
Feb.			1.00	.95	.92	.81	.66	.58	.71	.78	.82	.94	.91
Mar.				1.00	.94	.90	.75	.66	.75	.77	.89	.96	.89
Apr.					1.00	.89	.79	.65	.81	.89	.87	.93	.81
May						1.00	.88	.83	.78	.79	.87	.89	.78
June							1.00	.83	.78	.74	.75	.77	.76
July								1.00	.75	.69	.78	.62	.61
Aug.									1.00	.87	.83	.72	.73
Sept.										1.00	.79	.76	.66
Oct.											1.00	.86	.77
Nov.												1.00	.91
Dec.													1.00
Average precipitation, in inches:													
	15.00	1.37	1.29	1.41	1.39	1.32	1.05	.85	1.50	1.14	1.17	1.21	1.30
Average monthly precipitation expressed as a percentage of the average annual precipitation divided by 12:													
		110	103	113	111	106	84.0	68.0	120	91.2	93.6	96.8	104

Table 7.--Equations to estimate monthly and seasonal precipitation values for the period 1951-60

Variables (X and Y): 1, altitude above mean sea level, in thousands of feet; 2, longitude 108°, in minutes; 3, latitude 38°, in minutes; 4, average annual precipitation, in inches.
See page 7 for an explanation of equations (1) and (2).

Month	Precipitation (IM) = A + B(X) + C(Y), equation (1)						Precipitation (IM) = $A(X)^{B}(Y)^{C}$, equation (2)					
	A	X	B	Y	C	Standard error of estimate (inches)	A	X	B	Y	C	Standard error of estimate (percent)
Jan.	1.39	4	0.18	1	-0.41	0.30	0.163	4	1.71	1	-1.33	23
Feb.	.70	4	.17	1	-.28	.31	.049	4	1.64	1	-.66	26
Mar.	.28	4	.15	1	-.17	.25	.073	4	1.71	1	-.91	23
Apr.	-.11	4	.12	2	-.0046	.29	.084	4	1.32	2	-.19	18
May	-.38	4	.068	3	.0077	.23	.038	4	.81	3	.31	18
June	-.44	4	.024	1	.17	.30	.056	4	.58	1	.69	29
July	-.66	1	.21	2	.0010	.26	.027	4	.22	1	1.45	30
Aug.	-.45	1	.41	3	-.0097	.25	.340	1	1.74	3	-.43	19
Sept.	-.75	4	.017	1	.24	.30	.048	4	.33	1	1.17	24
Oct.	-.05	4	.031	1	.11	.20	.085	4	.60	3	.23	19
Nov.	.35	4	.12	1	-.14	.22	.021	4	1.07	3	.25	18
Dec.	1.12	4	.15	1	-.32	.30	.219	4	1.93	1	-1.82	36
Seasonal precipitation, expressed in percent of annual average precipitation:												
May-Sept.	27.93	4	-1.50	1	5.39		30.76	4	-.60	1	.96	11
Oct.-Apr.	72.07	4	1.50	1	-5.39		67.45	4	.37	1	-.58	8

Comparisons of monthly and seasonal precipitation (table 8) show that individual monthly differences for the two time periods range from 6 to 42 percent but the seasonal differences are only 1 percent. The 1 percent seasonal difference indicates that reliable seasonal estimates can be made if the average annual precipitation is known. The seasonal estimates are of particular interest since, for instance, precipitation during the nonevaporation season has a much more significant effect upon the hydrologic system than does precipitation during the evaporation season.

Common-time base estimates.--Conversion of the precipitation records to a common-time base was done by the ratio method described on page 6 rather than through the use of regression techniques. It was assumed that the ratio of short-term concurrent average annual precipitation at two sites would be equal to the ratio of the average annual precipitation during 1941-70. This assumption enables rapid conversion of the sample base to a compatable timespan.

For ease of application, the equation given on page 6 becomes:

$$\underline{SR}_{(E)} = \underline{CR}_{(I)} \cdot \underline{SR}_{(K)} / \underline{CR}_{(K)}$$

where,

$\underline{SR}$ = short-record site,

$\underline{CR}$ = complete-record site,

$\underline{K}$ = average annual precipitation (or streamflow) for the concurrent period of record,

$\underline{I}$ = observed average annual precipitation (or streamflow) during 1941-70, and

$\underline{E}$ = estimated average annual precipitation (or streamflow) during 1941-70.

Table 8.--Comparison of the averages for monthly precipitation for the periods 1951-60 and 1941-70 for nine sites in northeastern Utah

The nine sites are Duchesne, Echo Dam, Fort Duchesne, Jensen, Price Warehouse, Roosevelt, Snake Creek Powerhouse, Thompson, and Vernal.

Month	Average monthly precipitation 1941-70 (in)	Percentage of annual average divided by 12	Average monthly precipitation 1951-60 (in)	Percentage of annual average divided by 12	Departure 1941-70 less 1951-60 (percent)
Jan.	0.94	106	0.99	117	-11
Feb.	.75	84	.81	95	-11
Mar.	.83	93	.86	101	-8
Apr.	.90	101	.78	92	+9
May	.82	92	.85	100	-8
June	1.01	113	.60	71	+42
July	.62	70	.55	64	+6
Aug.	1.07	120	1.19	140	-20
Sept.	.81	91	.84	99	-8
Oct.	1.10	123	.96	113	+10
Nov.	.79	89	.81	95	-6
Dec.	1.05	118	.94	111	+7
Seasonal precipitation, expressed as cumulative totals and percentage of average annual total:					
May-Sept.	4.33	41	4.03	40	+1
Oct.-Apr.	6.36	59	6.15	60	-1

An example of this calculation follows:

For National Weather Service station (2864) at Flaming Gorge. The period of record at this site is from 1958 to 1970, for which the average annual precipitation, $\underline{SR}_{(\underline{K})}$, was 12.25 in.

Comparing stations	1958-70 average annual precipitation (in) $\underline{CR}_{(\underline{K})}$	1941-70 average annual precipitation (in) $\underline{CR}_{(\underline{I})}$	Estimated 1941-70 average annual precipitation (in) $\underline{SR}_{(\underline{E})}$	Residual (in)	Absolute residual
Vernal (9111)	7.34	7.66	12.78	-0.02	0.02
Roosevelt (7395)	7.10	7.44	12.84	+.04	.04
Jensen (4342)	7.61	7.95	12.80	0	0
Fort Duchesne (2996)	6.92	7.22	12.78	-.02	.02

Average of 1941-70 precipitation estimates for Flaming Gorge 12.80 in.

The last column in table 9 gives the 1941-70 average annual precipitation for each of the 59 sampling sites used in this study. If the period of data collection shown by the bar graph does not cover the entire 1941-70 period, the entry for average annual precipitation is an average of estimates made in conjunction with complete precipitation record at four sites, as shown in the example above. Each complete record was tested by means of double-mass curves prior to use in these calculations. The consistency of the 1941-70 estimates is indicated by the low standard deviation of the absolute residual values--0.42 in (11 mm).

The accuracy of an estimate made by a ratio calculation is difficult to appraise. The accuracy level is primarily dependent upon the length of the concurrent records; the longer the period, the more reliable the estimate. This relation is shown in figure 3 and is generated from the comparison of over 300 estimates with actual values for eight complete-record precipitation sites. These estimates are calculated for periods of concurrent records of 1, 2, 5, 10, and 20 years for about 40 different time intervals within 1941-70. The median timespan for the individual precipitation sites requiring estimates is 14 years.

Streamflow

Streamflow characteristics.--Streamflow is dependent upon several factors, the most important of which is precipitation. At high-altitude perennial streams, snowmelt runoff during the period May to July accounts for the greatest part of the average annual flow (fig. 4). This monthly distribution was calculated from the flow parameters for 26 gaging sites in the area that were compiled by Whitaker (1971). The May-July period is above average in runoff, and the remainder of the year is below. Ephemeral streams in this area generally have no flow except during the thunderstorm period, July-October.

The correlation matrix (table 10) produced from these streamflow averages shows that each of the monthly values is closely related to the annual average. March has the lowest coefficient, 0.90. The months of October-April and May-September form two groups of closely related discharges. The first period is the "low-flow" or "base-flow" period, and the second is the "runoff season." The monthly averages from table 10 can be used to show that, on the average, 80 percent of the annual streamflow is in the period from May to September each year.

Table 9-page 24

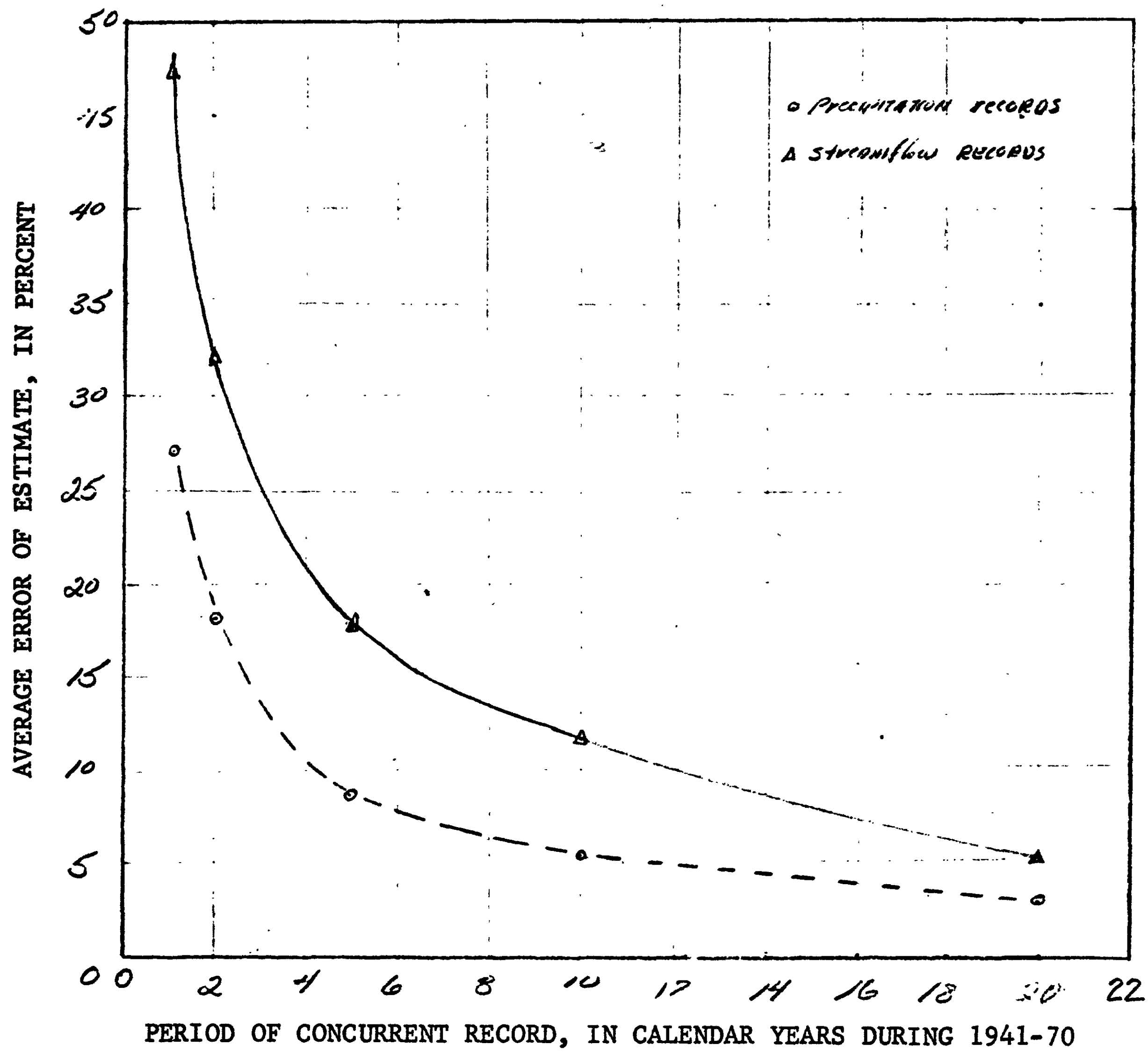

Figure 3.--Relation of the standard errors of estimate for precipitation and streamflow, made by the ratio method, to the length of concurrent record.

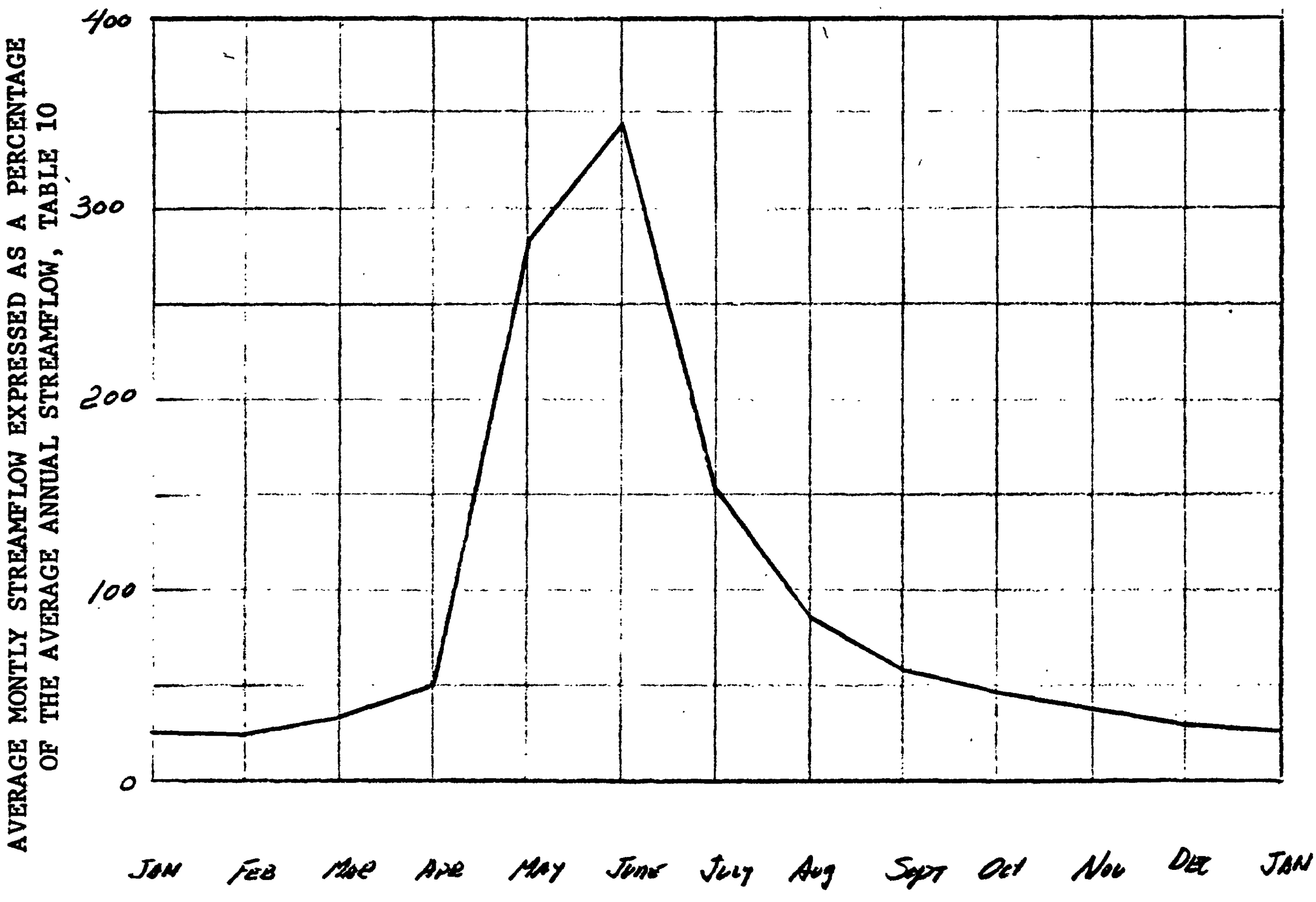

Figure 4.--Annual distribution of average monthly streamflow at 26 gaging sites in the study area, 1941-70.

Table 10.--Correlation of average annual and monthly streamflow, 1941-70

	Annual	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Annual	1.00	0.95	0.95	0.90	0.94	0.97	0.97	0.99	0.94	0.94	0.95	0.96	0.95
Jan.		1.00	.99	.97	.94	.88	.87	.95	.96	.98	.99	.99	.99
Feb.			1.00	.98	.95	.87	.86	.94	.95	.97	.98	.99	.99
Mar.				1.00	.96	.83	.82	.88	.89	.92	.94	.96	.96
Apr.					1.00	.91	.88	.90	.87	.89	.92	.93	.94
May						1.00	.97	.93	.86	.85	.88	.88	.88
June							1.00	.96	.84	.84	.86	.87	.87
July								1.00	.94	.94	.95	.95	.95
Aug.									1.00	.99	.99	.97	.97
Sept.										1.00	.99	.99	.98
Oct.											1.00	.99	.99
Nov.												1.00	.99
Dec.													1.00
Average streamflow (cubic feet per second):													
	54.0	14.2	13.4	14.2	28.3	144	210	82.3	47.0	32.0	25.8	19.8	16.2
Average monthly streamflow expressed as a percentage of the annual average (54.0):													
	100	26.3	24.8	26.3	52.4	267	388	152	87	59.3	47.8	36.7	30.0

The same data were used to define a series of estimating equations for monthly and seasonal estimates, which have standard errors of estimate ranging from 5.0 to 54.8 ft^3/s (0.1 to 1.6 m^3/s) (table 11). Although individual monthly estimates may be or poor reliability, the seasonal estimates have a small error of estimate. This is significant because a relatively large part of the annual flow is expected during the May-September season.

Common-time base estimates.--The estimates of average annual streamflow were made in the same manner as the precipitation estimates. The streamflow estimates are given in table 12, and the location of each site is shown in figure 5. The average annual discharge given in the last column of table 12 is either the actual discharge based on the full period of record or an estimated discharge if a data void exists during the 1941-70 period. Each estimated discharge is the average of calculations made from concurrent records at four long-term stations.

Table 11.--Equations to estimate average monthly and seasonal streamflow for the period 1941-70

Equation form: $Q_{month}(ft^3/s) = A + B\ (Q_{annual}(ft^3/s))$, equation (1).

See page 7 for an explanation of equation (1).

Month	Equation constants A	Equation constants B	Correlation coefficient R	Sample average (ft^3/s)	Standard error of estimate Ss (ft^3/s)
Jan.	-0.375	0.270	0.95	14.2	5.0
Feb.	-.060	.249	.95	13.4	5.0
Mar.	1.257	.239	.90	14.2	6.8
Apr.	6.112	.411	.94	28.3	9.2
May	19.220	2.316	.97	144	34.1
June	-6.752	4.004	.97	209	54.8
July	-8.510	1.682	.99	82.3	15.2
Aug.	-3.974	.943	.94	47.0	21.2
Sept.	-3.179	.652	.94	32.0	14.6
Oct.	-2.125	.516	.95	25.8	9.8
Nov.	-1.038	.385	.96	19.8	7.0
Dec.	-.654	.311	.95	16.2	5.8
Seasonal average:					
Oct.-Apr.	.445	.340	.96	19.8	6.1
May-Sept.	-.639	1.919	.99	103.0	8.6

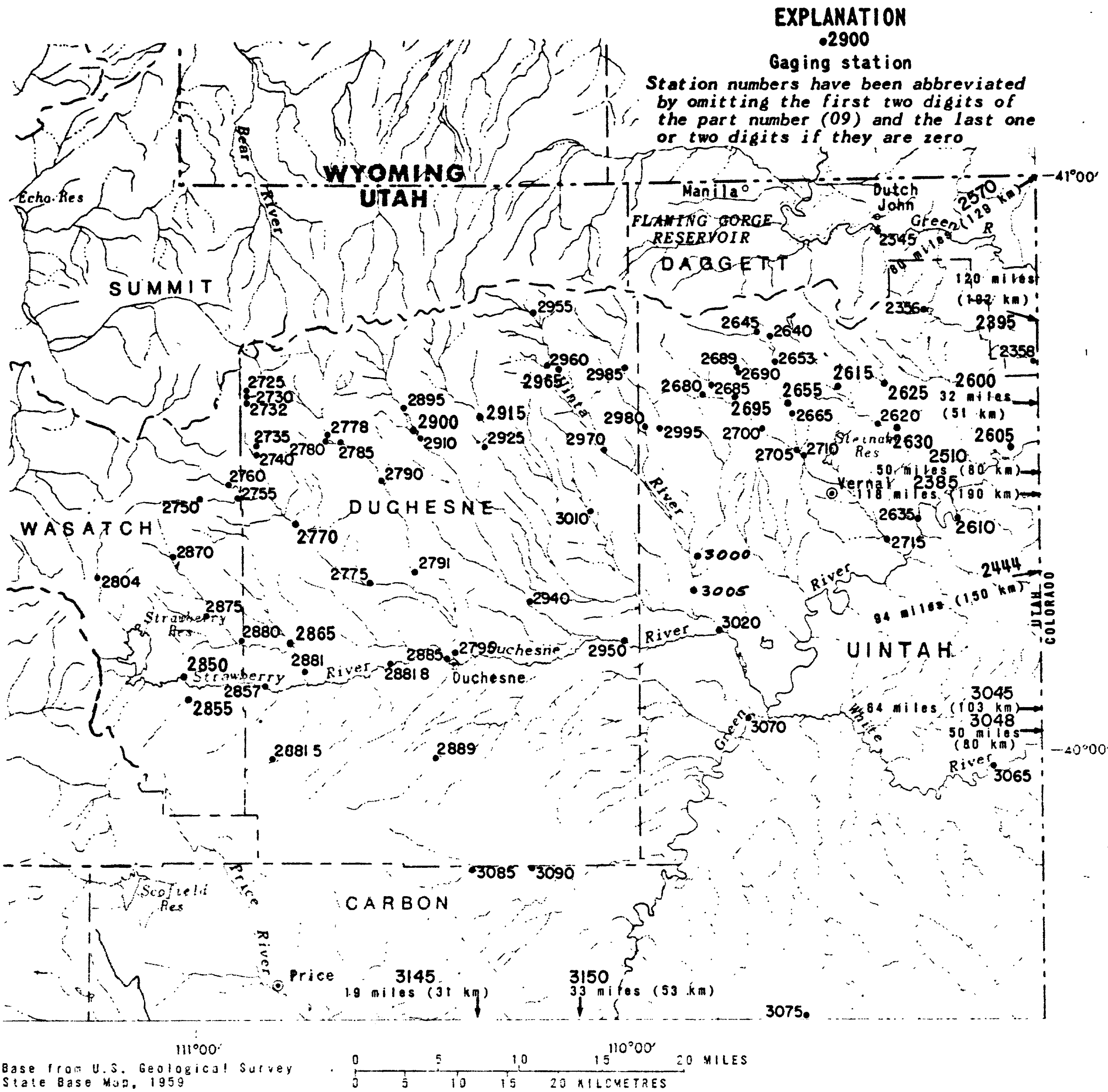

Figure 5.--Locations of streamflow-gaging sites.

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The standard deviation of the absolute residual values obtained by the ratio method are within 13 ft^3/s (0.37 m^3/s) or 10 percent of the sample average.

The estimate errors for periods of 1, 2, 5, 10, and 20 years of concurrent record were calculated on the basis of eight complete-record sites, similar to the precipitation analysis (fig. 3).

The median timespan for the individual streamflow records requiring estimates is 14 years.

These particular sample sites indicate that the streamflow error will be about twice that of the precipitation estimate for records of the same timespan. Each of the samples indicates that the accuracy of an estimate can be substantially increased by the addition of an expanded sampling-time base up to about 8 years. Beyond this point, the reduction in the error of estimate is small and practically constant for each incremental increase in the data-base timespan.

EXTENSION OF POINT-SAMPLE INFORMATION TO UNSAMPLED SITES

The individual site averages for the 1941-70 period are point samples or estimates. Optimum use of these data requires an objective method to distribute or transfer the information to ungaged sites within the study area. Through the computer program KWIKR8 (Esler, Smith, and Davis, 1968), equations were developed that accounted for the variance of temperature and precipitation with the parameters of location ($\underline{A}$ and $\underline{B}$) and altitude ($\underline{C}$). These parameters are expressed as:

$\underline{A}$ = minutes north of 38 degrees latitude,

$\underline{B}$ = minutes west of 108 degrees longitude, and

$\underline{C}$ = altitude, in thousands of feet.

The equations include a series of coefficients that are expressed in scientific notation when followed by the letter E. Each coefficient is multiplied by 10 raised to the exponent shown after the letter E. For example, a coefficient shown as 4E-02 is 4 x 10^{-2}, or 0.04. These equations are used to transfer the existing data-base values and estimates to ungaged sites; but no rational explanation for the variance, relative to location, has been explored. The equations are:

Average annual temperature, in degrees Fahrenheit, for the period

$$1941\text{-}70 = 24.61 - 18.59E\text{-}02(A) + 16.38E\text{-}02(B) + 10.99(C) + 24.63E\text{-}05(A)^2 + 32.62E\text{-}05(A)(B) - 41.05E\text{-}06(B)^2 + 41.80E\text{-}04(A)(C) - 36.88E\text{-}03(B)(C) - 68.30E\text{-}02(C)^2 \quad (3)$$

where the correlation coefficient is 0.95, the standard error of estimate is 1.5°F (1.0°C), and the sample mean is 45.2°F (7.5°C).

Average annual precipitation, in inches, for the period 1941-70 =

$$33.04 - 17.53E\text{-}02(A) + 10.13E\text{-}01(B) + 23.26E\text{-}01(C) + 28.36E\text{-}04(A)^2 - 49.70E\text{-}04(A)(B) - 45.16E\text{-}04(B)^2 + 42.06E\text{-}03(A)(C) - 85.19E\text{-}03(B)(C) + 22.13E\text{-}02(C)^2 + 12.03E\text{-}07(A)^3 + 12.42E\text{-}06(A)^2(B) - 81.54E\text{-}05(A)^2(C) + 34.19E\text{-}07(A)(B)^2 + 25.01E\text{-}07(B)^3 + 58.50E\text{-}05(B)^2(C) + 11.52E\text{-}03(A)(C)^2 - 60.76E\text{-}04(B)(C)^2 - 35.73E\text{-}03(C)^3 + 20.41E\text{-}05(A)(B)(C) \quad (4)$$

where the correlation coefficient is 0.96, the standard error of estimate is 2.08 in (53 mm), and the sample mean is 14.9 in (378 mm).

Two-thirds of the observed and estimated average annual temperatures are within ±1.5°F (1.0°C) of the defined relation, whereas two-thirds of the precipitation values and estimates are within ±2.08 in (53 mm) of the expression.

The empirical equations (3) and (4) are difficult to use; therefore, the distribution of the climatic variables were expressed in graphical form. A grid with a 6-minute latitude and longitude interval was superimposed upon a topographic map of the area. The altitude was determined at each grid intersection or node point, and a computer solution of the value of temperature and precipitation for each node was made by the previously developed equations. These values provided parameter estimates for more than 800 unsampled points. Then, using the measured altitudes and the estimated climatic values, figures 6, 7, and 8 were plotted on a drum plotter using the computer program THREE-D (California Computer Products, Inc., 1969).

Figures 6-8 effectively portray the distribution of altitude, temperature, and precipitation. It is not practicable, however, to obtain quantitative values from these figures. For this reason, the parameter values were converted to contours, lines of equal temperature, and lines of equal precipitation in figures 9, 10, and 11, which were plotted on a drum plotter by means of the computer program GPCP (California Computer Products, Inc., 1971).

The distributions in figures 6-8 are shown for an area within a range of 2 degrees of latitude and 3.8 degrees of longitude. However, the east and west boundary values are poorly defined. Figures 9-11 show the lines of equal value within a range of 1.9 degrees latitude and 2.7 degrees longitude, after the removal of the poorly defined fringe areas.

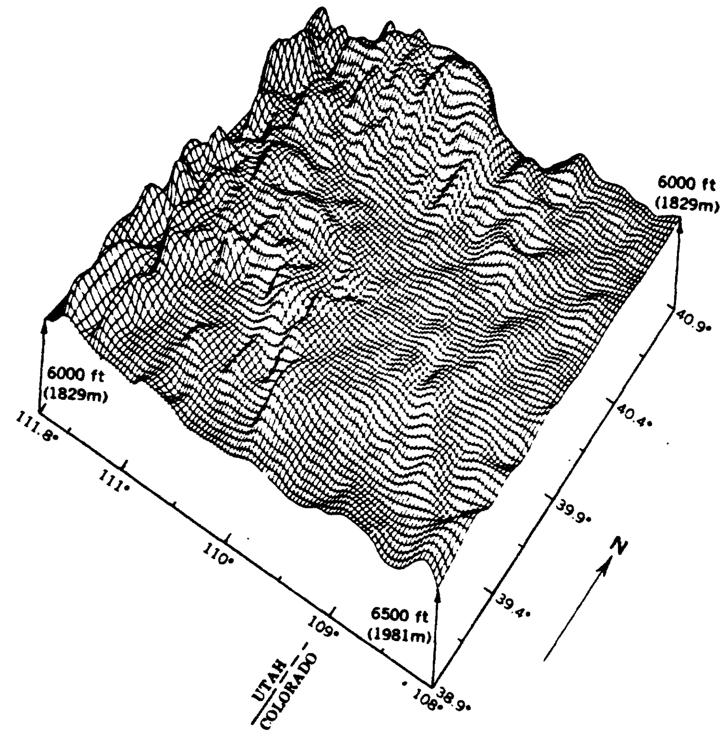


Figure 6.--Distribution of land-surface altitude.

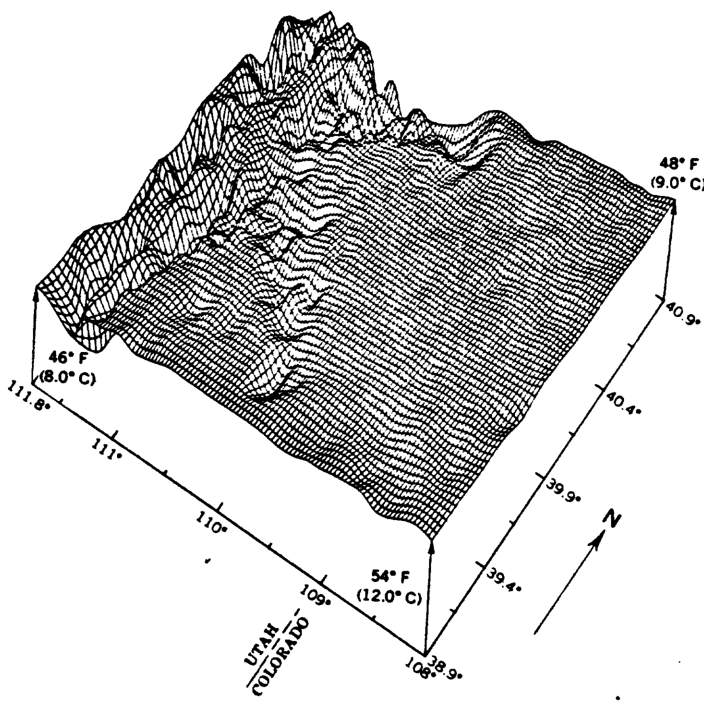


Figure 7.--Distribution of average annual air temperature, 1941-70.

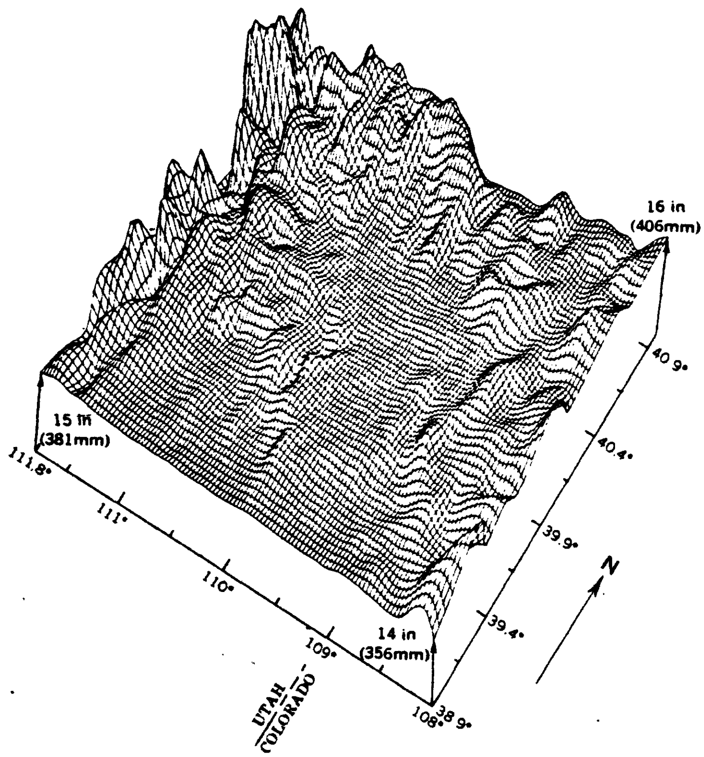


Figure 8.--Distribution of average annual precipitation, 1941-70.

Each vector base is equal to 9 inches (229 millimetres).

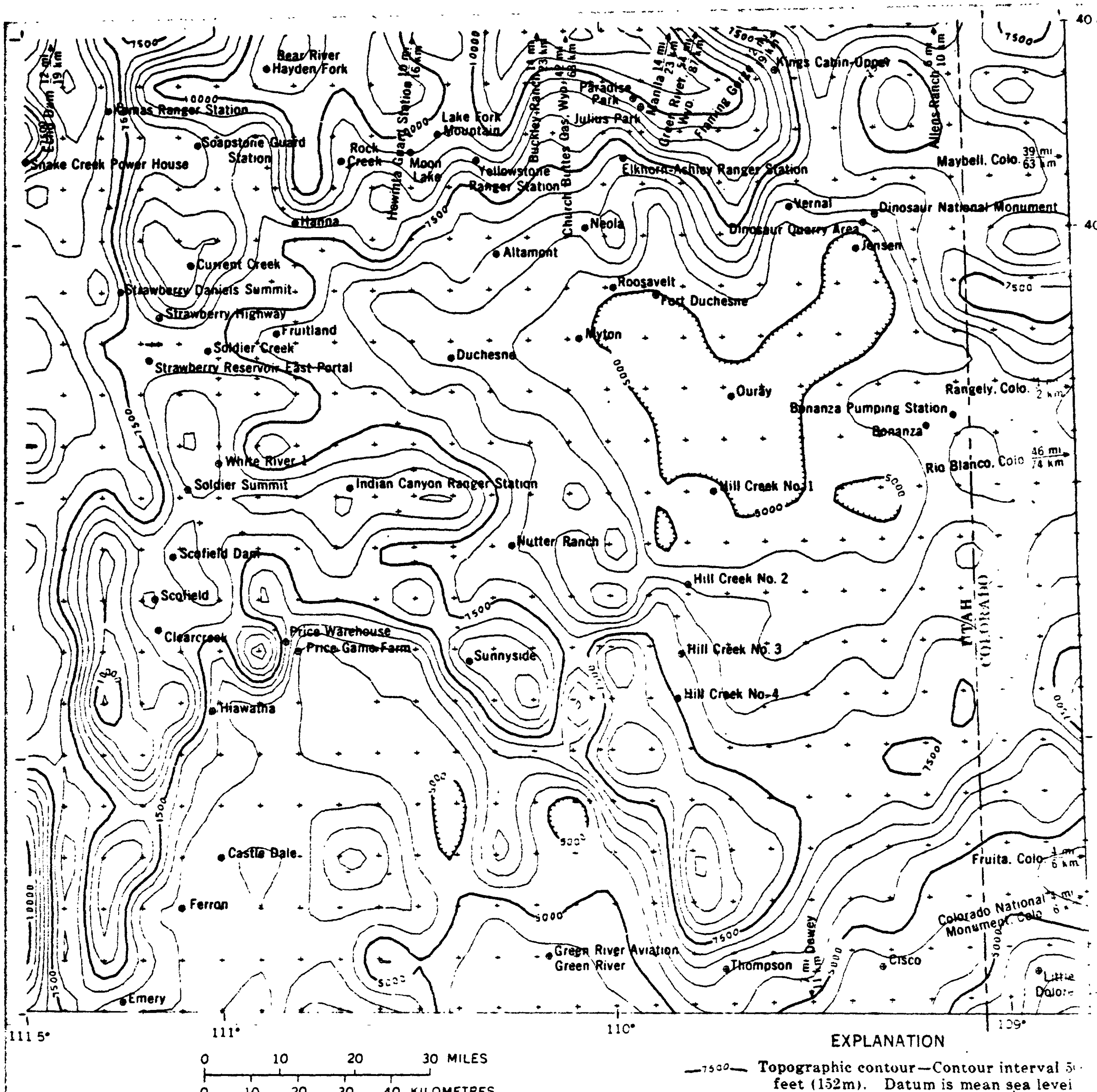


Figure 9 .--Topographic map.

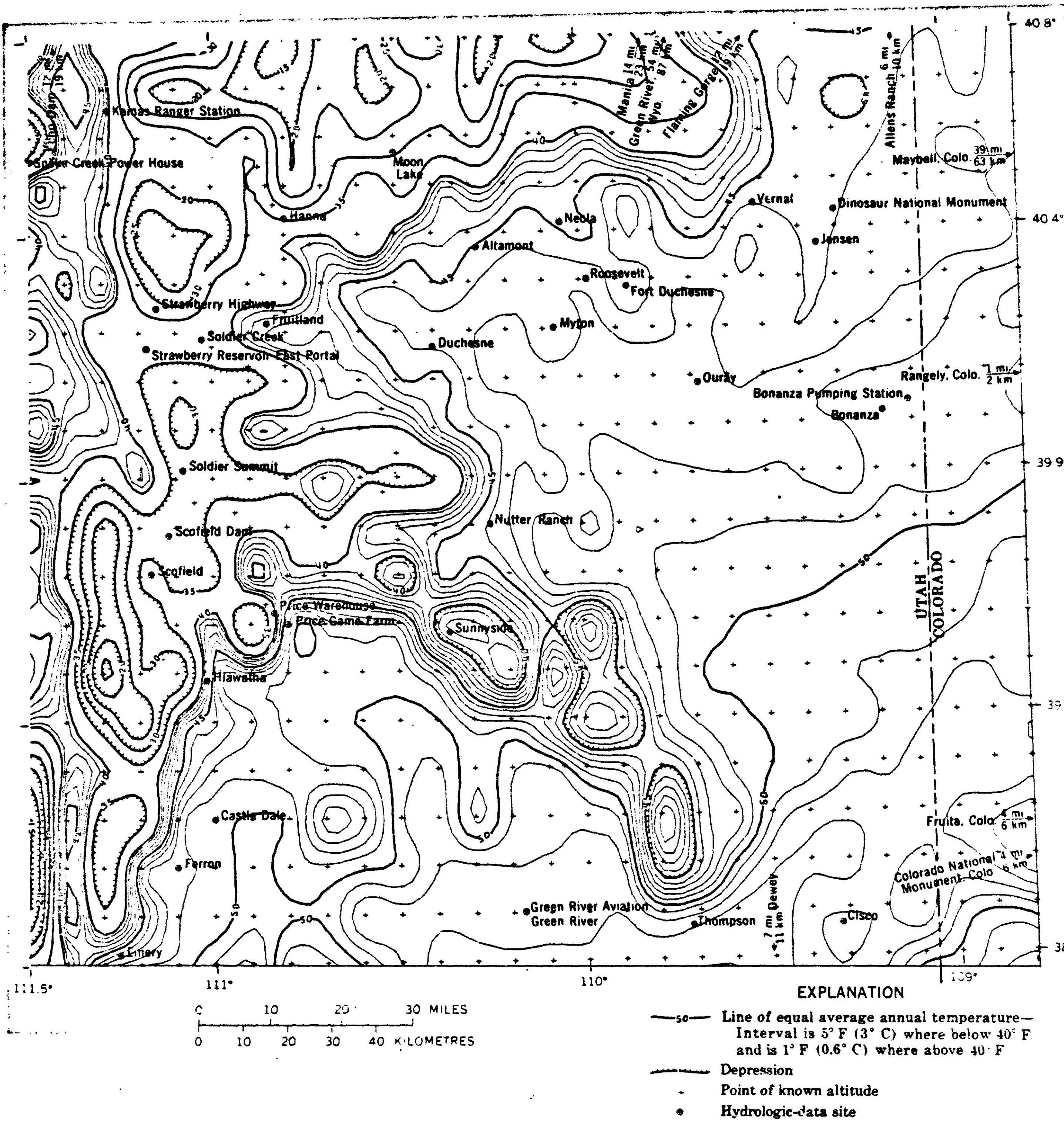


Figure 10.--Lines of equal average annual air temperature, 1941-70.

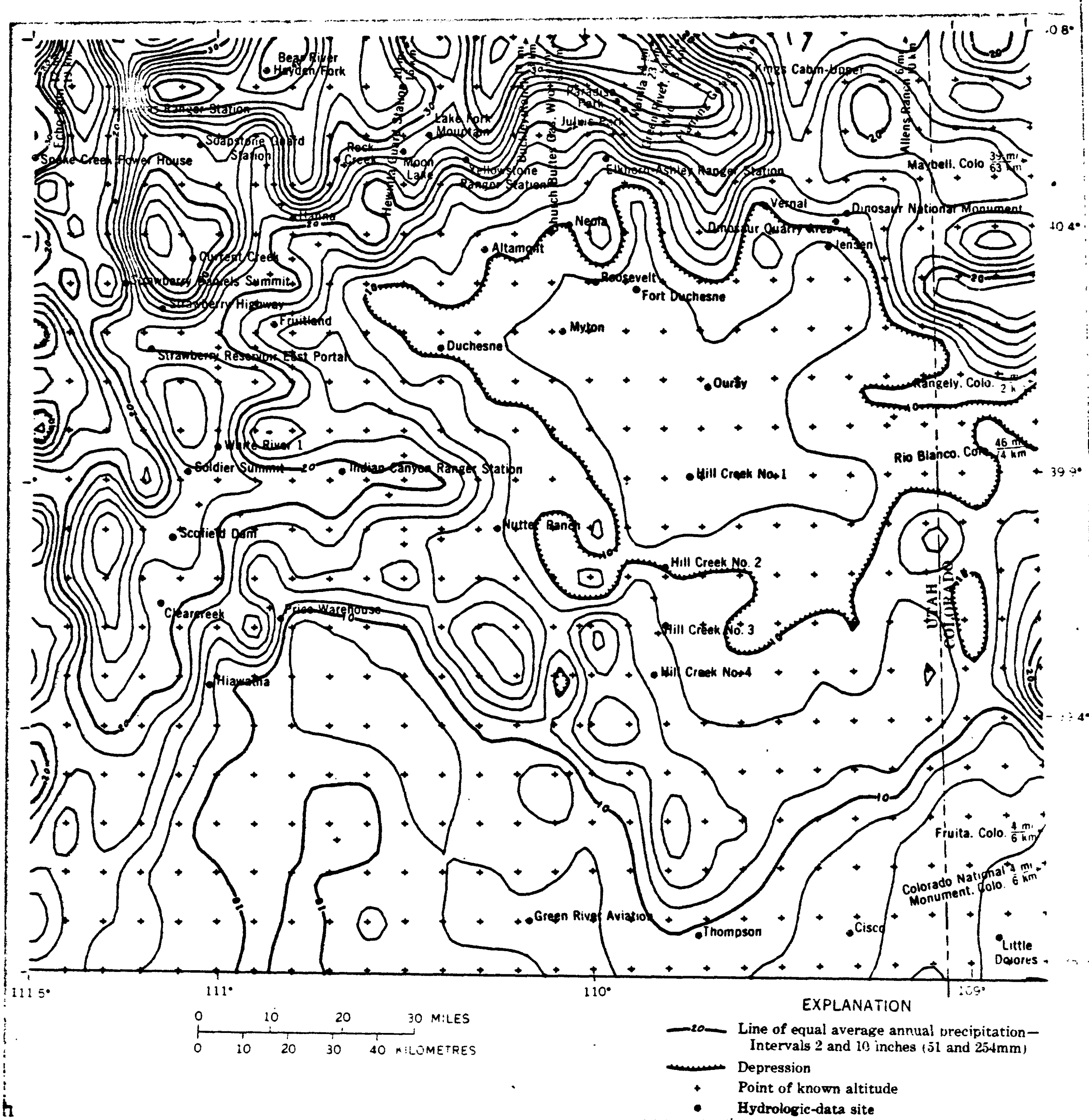


Figure 11.--Lines of equal average annual precipitation, 1941-70.

The lines of equal value in figures 9-11 were plotted on the basis of an analysis of eight neighboring values surrounding each grid intersection. The effect of the neighboring points is inversely related to the square of their distances from the node point, and the smoothness of the contours is directly related to the number of neighboring points considered (a user's option) in the grid analysis.

Monthly and seasonal estimates of temperature and precipitation can be made for any site within the study area with the estimating equations in tables 5 and 7 and the information from figures 10 and 11.

The average streamflow information can be used to make estimates at ungaged sites. Whitaker (1971) used multiple-regression techniques to relate the average flow to basin characteristics for high-altitude perennial streams in part of the area. Drainage area was the most significant variable tested. The standard error of estimate dropped from 58 to 31 percent, however, when average annual precipitation was used in conjunction with drainage area to estimate average streamflow. The addition of 10 other basins characteristics for estimating purposes resulted in only a 10 percent decrease in the standard error of estimate.

Drainage area and average precipitation are used to estimate average streamflow for the study area (table 13), but only drainage area is used for the smaller river basins (fig. 12). The estimating equations in table 13 have a wide range in accuracy--30 to 125 percent. The average unit runoff rate varies from 0.47 to 0.95 $(ft^3/s)/mi^2$ [0.0051 to 0.010 $(m^2/s)/km^2$] in the data sets used to define the equations.

SUMMARY

Information from 67 climatic and 86 streamflow sites was converted to the common-time base of 1941-70. This information was then used to define equations to estimate monthly, seasonal, and annual average precipitation, air temperature, and streamflow.

Regression techniques used to fill voids in the temperature-data base generally have a standard error of estimate of less than 2.0°F (1.1°C). Regression techniques were also used to determine the correlation of monthly and annual averages, the average annual distribution, and equations that can be used to estimate average monthly and seasonal temperature, precipitation, and streamflow. Incomplete precipitation and streamflow records were adjusted to the 1941-70 average on the assumption that the ratio of concurrent data is directly proportional to the ratio of the respective 1941-70 average annual values at nearby sites. The accuracy of a ratio estimate is dependent upon the length of concurrent record with the nearby sites.

Table 13.--Relation of average streamflow to drainage area and average annual precipitation for 1941-70

Parameter ranges: $\bar{Q}$ is average annual streamflow, in cubic feet per second; DA is drainage area, in square miles; P is average annual precipitation, in inches.

See page 7 for explanation of equation (2).

Area shown in figure 12	Equation	Standard error (percent)	Average unit runoff rate ((ft³/s)/mi²)	Parameter ranges $\bar{Q}$	Parameter ranges DA	Parameter ranges P
For unregulated streams in the study area						
-	$\bar{Q} = 0.95\ DA^{0.81}$	120	0.65	0.84-604	1.4-3,920	-
	$\bar{Q} = 0.000093\ DA^{0.88}P^{2.76}$	88	.65	.84-604	1.4-3,920	11.00-33.71
For the Ashley Creek area; stations 09262500-09269500						
A	$\bar{Q} = 0.54\ DA^{1.11}$	38	0.67	5.76-96.0	8.80- 101	-
For the upper Duchesne River basin; stations 09273000-09279500						
B	$\bar{Q} = 1.31\ DA^{0.92}$	30	0.95	6.65-352	7.5- 660	-
For the Strawberry River and lower Duchesne River basins; stations 09280400-092889, 09295000						
C	$\bar{Q} = 0.64\ DA^{0.80}$	125	0.47	1.58-440	1.4-2,750	-
For the Uinta River basin; stations 09291500-0929500, 09295500-09299500						
D	$\bar{Q} = 0.71\ DA^{1.76}$	45	0.91	1.12-189	9.5- 160	-

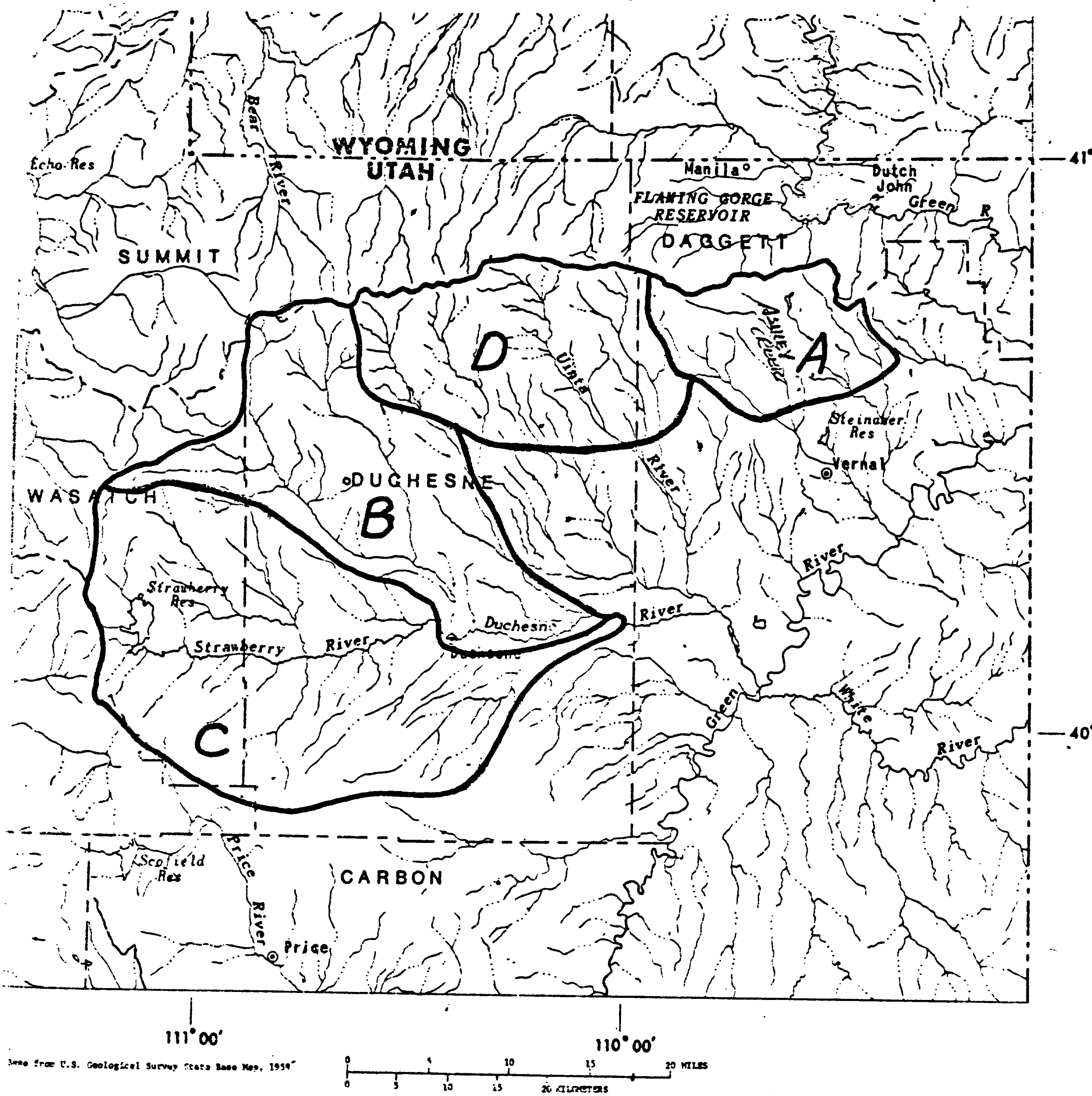


Figure 12.--Locations of areas referred to in table 13.

The areal variations of average annual temperature and precipitation are related to altitude and location. These variations are shown graphically in three-dimensional form and as lines of equal value. The standard error of estimates of these distributions are 1.5°F (1.0°C) and 2.08 in (53 mm).

Drainage area and average annual precipitation can be used to estimate average annual streamflow in the study area with standard errors of estimate ranging from 30 to 125 percent for areas with average unit runoff rate ranging from 0.47 to 0.95 $(ft^3/s)/mi^2$ [0.0051 to 0.010 $(m^3/s)/km^2$].

Monthly and seasonal estimates of average temperature, precipitation, and streamflow can be made from equations or on the basis of the average monthly values expressed as a percentage of the 1941-70 average.

REFERENCES CITED

Blair, T. A., 1942. Weather elements: New York, Prentice-Hall, Inc., 401 p.

California Computer Products, Inc., 1969, THREE-D, a prospective drawing software system: Anaheim, Calif., California Computer Products, Inc., 45 p.

_______1971, GPCP, a general purpose contouring program: Anaheim, Calif., California Computer Products, Inc., 129 p.

Esler, J. E., Smith, P. F., and Davis, J. C., 1968, KWIKR8, A Fortran IV program for multiple regression and geologic trend analysis: Kansas State Geol. Survey, 31 p.

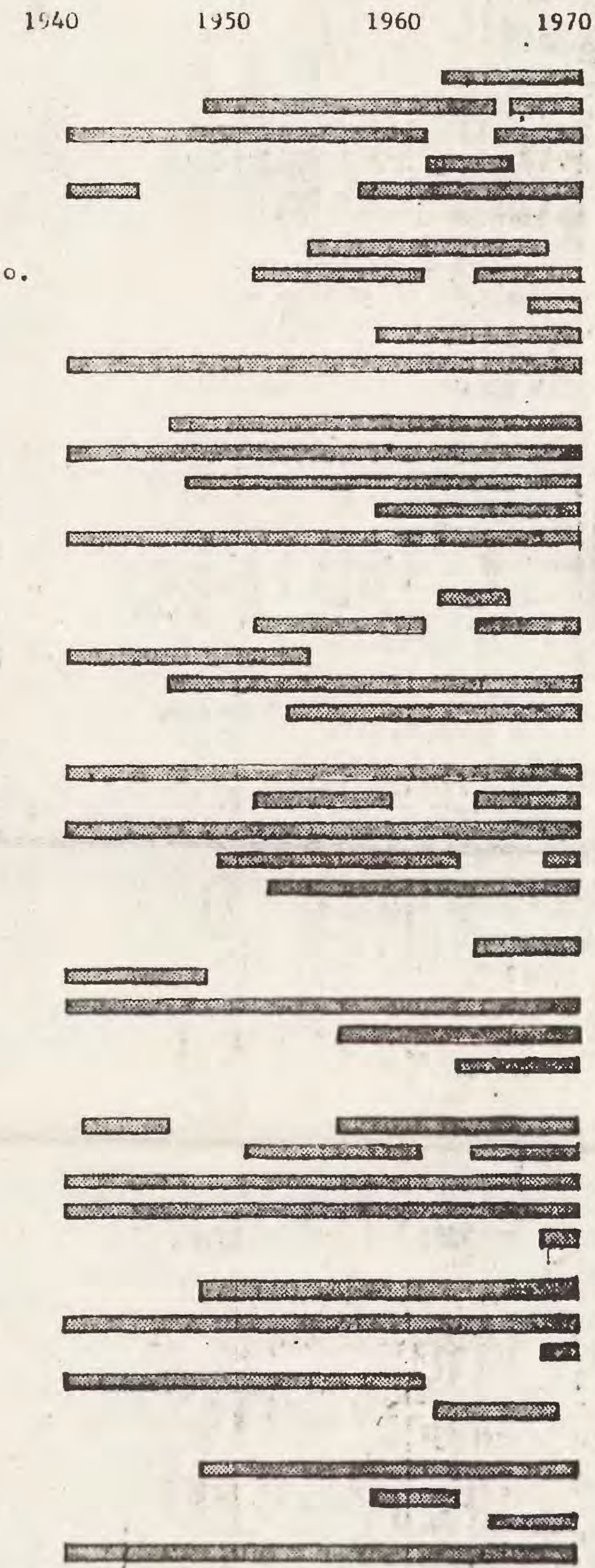
Whitaker, G. L., 1971, A proposed streamflow data program for Utah: U.S. Geol. Survey open-file report, 46 p.

7395	17.00	24.31	36.26	47.69	57.24	64.74	72.48	70.05	61.00	50.91	35.76	23.17	46.72
7720	14.38	18.91	25.78	35.18	44.08	51.81	59.11	56.98	49.34	40.50	26.90	17.12	36.67
7724	14.30	18.22	24.99	35.64	45.50	53.06	60.64	58.96	51.19	42.30	28.41	18.56	37.65
7909	22.11	25.73	31.95	42.00	50.75	57.61	65.29	63.66	55.76	47.50	34.09	26.13	43.55
7955	11.21	15.53	22.02	31.26	39.96	47.43	54.48	52.45	44.42	36.33	23.28	13.82	32.68
7959	17.93	20.97	26.73	36.43	45.92	53.17	61.07	59.30	51.53	43.12	29.12	21.15	38.87
8370	14.31	17.64	23.91	34.36	43.18	50.29	58.14	56.52	48.38	40.08	26.59	18.23	35.97
8376	17.98	22.14	28.17	36.56	44.38	50.80	57.94	56.66	49.40	41.39	29.23	20.72	37.95
8474	25.02	29.80	36.04	45.19	54.67	62.68	70.58	68.17	60.35	51.57	37.67	28.16	47.49
8705	27.07	34.36	41.56	51.79	61.74	70.50	78.50	75.85	67.60	57.88	42.23	31.70	53.40
9111	16.16	23.24	34.09	45.48	54.79	62.18	69.63	67.39	58.75	48.94	34.09	21.96	44.73

Table 1.--Air-temperature data base

Name: Site is in Utah unless noted otherwise.

National Weather Service station number	Name
0050	Allens Ranch
0074	Altamont
0802	Bonanza
0810	Bonanza pumping
1214	Castle Dale
1440	Cisco
1772	Colorado National Monument, Colo.
2150	Dewey
2173	Dinosaur National Monument[1/]
2253	Duchesne
2385	Echo Dam
2484	Emery
2798	Ferron
2864	Flaming Gorge
2996	Fort Duchesne
3056	Fruitland
3146	Fruita, Colo.
3413	Green River
3418	Green River Aviation
3624	Hanna
3896	Hiawatha
4065	Green River, Wyo.
4342	Jensen
4467	Kamas
5377	Manila
5446	Maybell, Colo.
5815	Moon Lake
5969	Myton
6123	Neola
6340	Nutters Ranch
6568	Ouray
6832	Rangely, Colo.
7015	Price Game Farm
7395	Roosevelt
7720	Scofield
7724	Scofield Dam
7909	Snake Creek
7955	Soldier Creek
7959	Soldier Summit
8370	Strawberry Highway
8376	Strawberry Reservoir[1/]
8474	Sunnyside
8705	Thompson
9111	Vernal



1/ Summers only.

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Table 12.--Streamflow-data base and average annual discharge for the period 1941-70

Name: Site is in Utah unless otherwise noted.

Drainage area: a, approximate.

U.S. Geological Survey station number	Name	Drainage area (mi^2)	Average annual discharge (ft^3/s)
09234500	Green River near Greendale	15,100	2,080
09235600	Pot Creek above diversions, near Vernal	a25	2.18
09235800	Pot Creek near Vernal	106	.84
09238500	Walton Creek near Steamboat Springs, Colo.	42.4	66.2
09239500	Yampa River at Steamboat Springs, Colo.	604	437
09244400	Yampa River near Hayden, Colo.	1,430	1,080
09251000	Yampa River near Maybell, Colo.	3,410	1,440
09257000	Little Snake River near Dixon, Wyo.	988	462
09260000	Little Snake River near Lily, Colo.	a3,730	527
09260500	Jones Hole Creek near Jensen	a120	41.9
09261000	Green River near Jensen	a25,400	4,270
1/09261500	Brush Creek above cave, near Vernal	a23	8.35
1/09262000	Big Brush Creek near Vernal	a82	34.2
09262500	Little Brush Creek below East Park Reservoir, near Vernal	a20	13.5
1/09263000	Little Brush Creek near Vernal	a28	16.8
1/09263500	Brush Creek near Jensen	255	18.5
09264000	Ashley Creek below Trout Creek, near Vernal	a27	22.2
09264500	South Fork Ashley Creek near Vernal	a20	18.6
09265300	Ashley Creek above Red Pine Creek, near Vernal	a58	60.9
09265500	Ashley Creek above springs, near Vernal	a100	59.9
09266500	Ashley Creek near Vernal	101	96.0
09268000	Dry Fork above sinks, near Dry Fork	a48	35.5
09268500	North Fork of Dry Fork near Dry Fork	a12	5.76
09268900	East Fork of Dry Fork above sinks, near Dry Fork	8.8	12.2
09269000	East Fork of Dry Fork near Dry Fork	a12	7.59
09269500	East Fork of Dry Fork at mouth, near Dry Fork	a18	7.51
09270000	Dry Fork below springs, near Dry Fork	102	31.8
09270500	Dry Fork at mouth, near Dry Fork	118	27.3
09271000	Ashley Creek near Vernal	241	123
1/09271500	Ashley Creek near Jensen	386	55.2
1/09272500	Duchesne tunnel near Kamas	--	52.0
09273000	Duchesne River at Provo River Trail, near Hanna	a39	55.6
09273200	Duchesne River below Little Deer Creek, near Hanna	a39	24.6
09273500	Hades Creek near Hanna	a7.5	8.18
09274000	Duchesne River near Hanna	a78	77.8
09275000	West Fork Duchesne River below Dry Hollow, near Hanna	a47	37.9
09275500	West Fork Duchesne River near Hanna	a61	47.4
09276000	Wolf Creek above Rhoades Canyon, near Hanna	a9	6.65
09277000	Duchesne River at Hanna	[illegible]30	193
09277500	Duchesne River near Tabiona	[illegible]52	196
09277800	Rock Creek above South Fork, near Hanna	a98	132
09278000	South Fork Rock Creek near Hanna	a14	13.2
09278500	Rock Creek near Hanna	a120	157
09279000	Rock Creek near Mountain Home	149	174
09279100	Rock Creek near Talmage	a240	181
09279500	Duchesne River at Duchesne	a660	351
09280400	Hobble Creek near Wallsburg	a1.4	1.58
1/09285000	Strawberry River near Soldier Springs	a212	29.3
09285500	Willow Creek near Soldier Springs	44	4.51
1/09285700	Strawberry River near Fruitland	a360	59.8
1/09286500	Red Creek near Fruitland	a89	6.79
1/09287000	Currant Creek below Red Ledge Hollow, near Fruitland	a48	27.0
1/09287500	Water Hollow near Fruitland	a15	4.78
09288000	Currant Creek near Fruitland	142	46.7
1/09288100	Red Creek below Currant Creek, near Fruitland	a300	56.4
09288150	Cottonwood Creek near Fruitland	a56	11.3
1/09288180	Strawberry River near Duchesne	a770	151
1/09288500	Strawberry River at Duchesne	a950	136
09288900	Sowers Creek near Duchesne	a43	3.29
09289500	Lake Fork near Mountain Home	a78	101
1/09290000	Brown Duck Creek near Mountain Home	a15	9.02
1/09291000	Lake Fork near Mountain Home	a110	128
1/09291500	Yellowstone Creek below Swift Creek, near Altonah	a99	119
09292500	Yellowstone River (Creek) near Altonah	131	142
09294000	Lake Fork near Upalco	418	59.2
09295000	Duchesne River at Myton	a2,730	440
09295500	Uinta River below Gilbert Creek, near Neola	a33.0	39.5
09296000	Uinta River above Clover Creek, near Neola	132	142
09296500	Clover Creek near Neola	a9.5	1.12
09297000	Uinta River near Neola	160	189
09298000	Farm Creek near Whiterocks	a22	5.35
09298500	Whiterocks River above Paradise Creek, near Whiterocks	a90	99.1
09299500	Whiterocks River near Whiterocks	115	117
1/09300000	Deep Creek near Lapoint	a75	4.83
09300500	Uinta River near Fort Duchesne	672	76.7
09301000	Dry Gulch near Neola	a67	1.84
09302000	Duchesne River near Randlett	a3,920	604
09304500	White River near Meeker, Colo.	762	601
09304800	White River below Meeker, Colo.	a1,040	621
09306500	White River near Watson	a4,020	673
09307000	Green River near Ouray	a35,500	5,520
09307500	Willow Creek above diversions, near Ouray	a310	17.4
09308500	Minnie Maud Creek near Myton	a30	4.54
09309000	Minnie Maud Creek at Nutter Ranch, near Myton	231	21.0
1/09314500	Price River at Woodside	a1,500	102
09315000	Green River at Green River	40,600	5,720

1/Regulated.

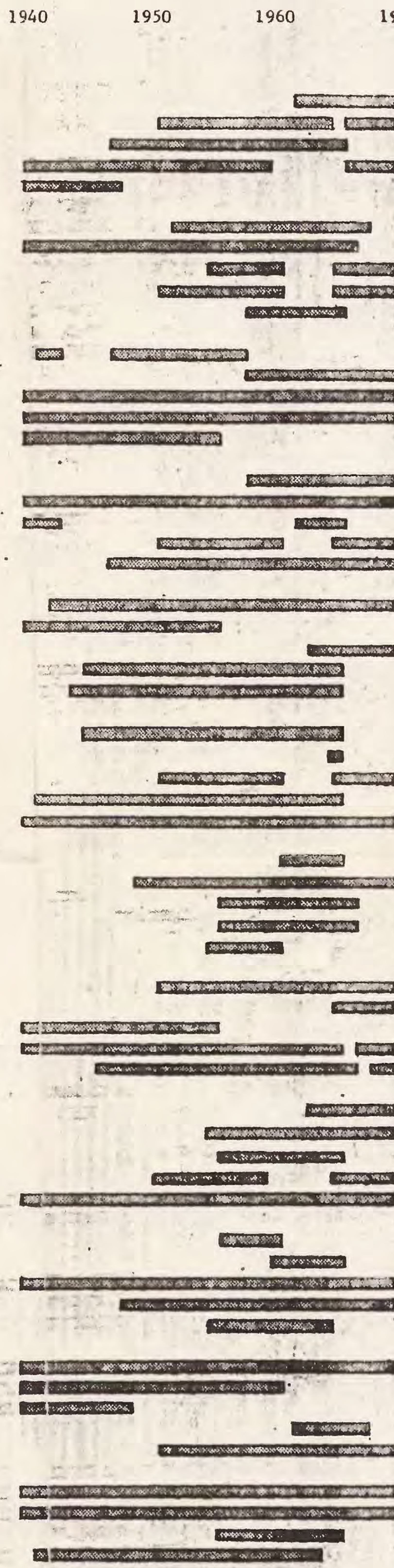
Table 3.--Average monthly and annual air temperatures, in degrees Fahrenheit, for the sites shown in table 1, 1941-70

National Weather Service station number	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
0050	25.44	30.29	36.50	45.77	54.0	62.22	69.55	67.13	59.76	49.11	36.57	27.94	47.02
0074	18.53	23.96	32.60	43.80	52.49	59.62	66.66	64.91	57.13	46.38	33.15	22.62	43.49
0802	19.66	26.56	36.85	49.23	59.16	67.00	75.00	72.80	63.70	51.71	40.39	24.85	48.91
0810	19.40	26.47	37.85	49.15	58.81	66.10	73.83	71.59	63.09	53.47	38.08	25.69	48.63
1214	23.62	29.97	37.85	47.61	56.94	64.84	72.33	69.91	62.03	50.53	36.57	26.91	48.26
1440	23.26	31.09	39.41	50.56	61.38	70.42	78.56	75.91	66.16	54.94	38.68	27.44	51.48
1772	27.36	32.32	39.37	49.71	59.82	68.64	76.10	73.41	65.34	55.25	40.29	30.76	51.53
2150	24.12	31.95	42.77	54.37	63.76	71.00	78.07	75.98	67.24	57.99	42.94	31.25	53.45
2173	16.09	24.12	36.38	49.01	59.11	66.92	74.50	72.34	62.92	52.52	36.37	23.25	47.79
2253	17.91	24.52	34.86	45.80	55.32	62.70	70.09	67.87	59.28	49.64	34.59	23.23	45.48
2385	22.82	27.13	33.27	43.38	52.26	59.29	67.83	66.38	57.57	49.04	35.75	27.32	45.17
2484	24.30	28.87	35.51	44.73	53.41	60.97	68.22	66.07	58.62	50.20	36.77	27.46	46.26
2798	23.15	28.67	36.01	46.27	56.01	64.21	71.91	69.42	61.59	51.97	37.17	27.13	47.79
2864	21.36	25.44	31.79	42.82	52.10	59.65	68.07	66.03	57.74	48.50	34.35	25.69	44.46
2996	14.60	22.38	34.13	46.23	56.01	63.49	70.82	68.75	59.73	49.82	34.21	21.56	45.14
3056	24.73	29.91	36.65	45.47	53.73	60.88	67.87	65.50	58.40	50.20	37.16	28.50	46.58
3146	25.90	32.03	39.15	49.23	58.82	66.89	73.92	71.52	63.12	53.47	38.87	29.14	50.17
3413	25.42	32.87	41.21	52.12	62.24	71.29	79.58	76.80	67.67	57.19	40.77	30.18	53.11
3418	23.92	33.29	41.65	51.93	61.77	70.04	77.86	75.43	66.12	55.48	39.64	29.17	52.19
3624	21.32	24.95	30.45	40.44	49.22	56.81	64.84	62.72	55.76	46.66	33.01	24.41	42.55
3896	23.68	27.44	32.96	43.24	52.56	61.20	69.21	66.88	59.56	50.06	35.16	26.91	45.74
4065	18.96	24.01	30.27	41.94	51.94	59.68	68.36	66.01	56.55	47.29	32.85	23.15	43.42
4342	14.66	22.22	34.98	47.06	57.03	64.35	72.07	69.17	60.29	49.98	34.77	21.75	45.69
4467	23.24	26.39	31.66	41.33	50.16	57.14	65.65	63.89	55.83	47.81	34.84	27.30	43.77
5377	22.59	26.82	32.90	43.50	52.99	60.46	69.00	66.95	58.60	49.49	35.32	26.95	45.46
5446	17.72	23.48	32.48	42.96	51.22	57.88	64.57	62.51	54.91	46.14	32.84	22.40	42.42
5815	16.87	20.16	25.40	35.80	45.24	52.49	60.68	58.11	50.74	42.49	28.51	20.41	38.07
5969	15.78	23.27	35.27	47.10	56.73	64.41	72.14	70.06	61.12	50.91	35.01	22.18	46.16
6123	17.08	23.51	33.35	44.01	53.06	59.96	67.57	65.22	57.20	48.05	33.62	22.42	43.75
6340	21.07	27.18	36.52	46.55	55.20	61.78	68.79	66.84	58.92	50.37	36.73	25.78	46.31
6568	14.66	23.41	36.45	48.85	58.81	67.15	74.36	71.96	62.54	52.27	35.48	21.96	47.32
6832	16.66	24.20	35.19	47.57	57.16	65.20	72.61	70.14	60.86	50.87	35.56	22.95	46.58
7015	24.40	30.65	38.24	48.38	57.68	66.10	73.86	71.38	63.36	53.65	38.95	28.73	49.62
7395	17.00	24.31	36.26	47.69	57.24	64.74	72.48	70.05	61.00	50.91	35.76	23.17	46.72
7720	14.38	18.91	25.78	35.18	44.08	51.81	59.11	56.98	49.34	40.50	26.90	17.12	36.67
7724	14.30	18.22	24.99	35.64	45.50	53.06	60.64	58.96	51.19	42.30	28.41	18.56	37.65
7909	22.11	25.73	31.95	42.00	50.75	57.61	65.29	63.66	55.76	47.50	34.09	26.13	43.55
7955	11.21	15.53	22.02	31.26	39.96	47.43	54.48	52.45	44.42	36.33	23.28	13.82	32.68
7959	17.93	20.97	26.73	36.43	45.92	53.17	61.07	59.30	51.53	43.12	29.12	21.15	38.87
8370	14.31	17.64	23.91	34.36	43.18	50.29	58.14	56.52	48.38	40.08	26.59	18.23	35.97
8376	17.98	22.14	28.17	36.56	44.38	50.80	57.94	56.66	49.40	41.39	29.23	20.72	37.95
8474	25.02	29.80	36.04	45.19	54.67	62.68	70.58	68.17	60.35	51.57	37.67	28.16	47.49
8705	27.07	34.36	41.56	51.79	61.74	70.50	78.50	75.85	67.60	57.88	42.23	31.70	53.40
9111	16.16	23.24	34.09	45.48	54.79	62.18	69.63	67.39	58.75	48.94	34.09	21.96	44.73

Table 9.--Precipitation-data base and average annual precipitation for the period 1941-70

Name: Site is in Utah unless noted otherwise.
Type: N, normal reporting station; S, storage gage.

National Weather Service station number	Name	Type	1941-70 average annual precipitation (in)
0050	Allens Ranch	N	9.25
0074	Altamont	N	9.07
0497	Bear River, Hayden Fork	S	39.84
0802	Bonanza	N	8.48
1017	Buckley Ranch	S	13.13
1440	Cisco	N	7.05
1472	Clear Creek	N	23.74
1738	Church Buttes Gas, Wyo.	N	8.09
1772	Colorado National Monument, Colo.	N	11.78
1903	Currant Creek	N	25.14
2172	Dinosaur National Monument	N	8.62
2173	Dinosaur Quarry area	N	8.31
2253	Duchesne	N	8.73
2385	Echo Dam	N	13.80
2429	Elkhorn-Ashley Ranger Station	N	13.11
2864	Flaming Gorge	N	12.79
2996	Fort Duchesne	N	7.22
3056	Fruitland	N	12.65
3146	Fruita, Colo.	N	8.82
3418	Green River Aviation	N	6.34
3624	Hanna	N	12.36
3886	Hewinta Guard Station	S	24.18
3896	Hiawatha	N	14.04
3939	Hill Creek No. 1	S	7.38
3944	Hill Creek No. 2	S	10.44
3949	Hill Creek No. 3	S	12.43
3954	Hill Creek No. 4	S	15.10
4065	Green River, Wyo.	N	8.10
4199	Indian Canyon Ranger Station	S	17.73
4342	Jensen	N	7.95
4413	Julius Park	S	27.72
4467	Kamas Ranger Station	N	16.79
4683	Kings Cabin - Upper	S	25.16
4808	Lake Fork Mountain	S	28.76
5040	Little Dolores, Colo.	S	14.84
5377	Manila	N	9.55
5446	Maybell, Colo.	N	11.02
5815	Moon Lake	N	18.88
5969	Myton	N	6.67
6123	Neola	N	[illegible].29
6340	Nutters Ranch	N	[illegible]
6568	Ouray	N	6.71
6620	Paradise Park	S	30.06
6832	Rangely, Colo.	N	9.53
7026	Price Warehouse	N	9.24
7045	Rio Blanco, Colo.	S	35.17
7368	Rock Creek	S	26.44
7395	Roosevelt	N	7.44
7724	Scofield Dam	N	18.00
7800	Soapstone Guard Station	N	28.33
7909	Snake Creek Powerhouse	N	23.30
7959	Soldier Summit	N	13.64
8369	Strawberry Daniels Summit	N	26.87
8370	Strawberry Highway	N	17.26
8376	Strawberry Reservoir East Portal	N	19.05
8705	Thompson	N	8.62
9111	Vernal	N	7.66
9484	White River No. 1	S	24.99
9679	Yellowstone Ranger Station	S	17.74
		Average	16.2



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