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RELATION OF HYDROLOGY PAPER NO. 36 TO RESEARCH PROGRAM: "HYDROLOGY OF WEATHER MODIFICATION"

The present study is part of a more comprehensive project which has as one of its objectives the development of methods of evaluation of atmospheric water resources programs. Correlatively the application of the methods to a variety of basins forms a basis for selection of suitable watersheds, basins or regions.

Several approaches are possible and are pursued. One approach was the subject of a previous hydrology paper, No. 34 (see inside back cover for complete reference). Another approach will be discussed in a forthcoming paper entitled, "Regional Discrimination of Change in Runoff."

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ABSTRACT

The purpose of this study was the determination of suitable watersheds or combinations of watersheds for precipitation management programs in the Upper Colorado River Basin in general and for two special zones: the San Juan Mountains and the Upper Basin of the Colorado River.

The study shows that the introduction of optimal weight factors in the linear combination of runoff from several basins will reduce significantly the number of years necessary for evaluation of the operations. Assuming a uniform 10% increase in winter precipitation throughout the Upper Colorado River Basin, the calculations show that three years of operations would be needed in the Upper Basin of the Colorado versus six years in the San Juan mountains.

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Hiroshi Nakamichi* and Hubert J. Morel-Seytoux**

Chapter I

INTRODUCTION

1. Water needs of the basin. The Colorado River system is the largest in the United States that flows mainly through lands having a chronic water deficiency for cultivation of crops [1]. Since the 1940's, the basin's population has increased rapidly with an accompanying growth in demand upon the region's water resources for irrigation, industrial, and domestic uses [2]. Over the decade from 1951 through 1960, the population of the five states comprising the Upper Colorado River Basin has increased by 40 percent, while over the same period the population of the nation as a whole has increased only by 20 percent [3].

2. Precipitation management program. In an effort to reduce the severity of these demands, an atmospheric water resource project is currently pursued by the United States Department of the Interior, Bureau of Reclamation, Office of Atmospheric Water Resources. The goal of this project is to induce more precipitation from the atmosphere by winter cloud seeding operations over certain high altitude watersheds in the Upper Colorado River Basin. In the past, there was some controversy as to whether man could economically increase precipitation in worthwhile amounts. There now exists evidence that this is possible at least in high mountain areas [4]. As of February 1969, plans of the Bureau of Reclamation called for a concentrated experimental effort in two pilot areas of the Upper Colorado River Basin, to start in the fall of 1969 [5]. This study was undertaken in connection with the Bureau's overall program in general and in connection with this pilot program in particular.***

3. Criteria of suitability. In the experimental or large-scale operational stage of the project, a site should be selected. At this point, one needs certain criteria in order to select suitable basins. These criteria should be considered both from a water resource and an evaluation standpoint [6]. The first standpoint requires a criterion of suitability for optimal water yield, and the second, a criterion of suitability for minimum time evaluation.

Ideally the criteria should be objective and simple. That is, they should be derived easily from available data rather than from theory. Though various aspects of research on cloud modification have been conducted sucessfully, it is still difficult to determine its quantitative effect. Indeed, one of the purposes of the pilot project is to determine the exact magnitude of the increase in precipitation on a large areal scale. Following this experiment, it may be possible to isolate the major factors that determine the magnitude of the increase in precipitation. Once precipitation is induced, the increase in runoff, (ΔQ), caused by the increase of precipitation, (ΔP), is estimated by a statistical relationship between precipitation and runoff, $(Q = f(P))$, often used when forecasting runoff:

$$\Delta Q = (Q+\Delta Q) - Q = f(P+\Delta P) - f(P) \ . \qquad (1)$$

Marginal criteria are defined in order to determine the relative suitability of many potential basins for minimum time evaluation, even if the type of statistical test and the design of the experiment are not known [6]. One such criterion is derived from the "two-sample u-test."

The two-sample u-test is a test of the hypothesis that assumes that the mean of a statistical population (the values of annual runoff for a given basin over many years) has not changed significantly even though there were reasons to suspect it had. As the name implies, the application of the test requires the availability of two samples of data, one sample collected prior to the suspected change and one collected afterward. If the suspected change is real but small, the records of many years may be necessary to determine its significance. If the change is large and the spread of the distribution is narrow, only a few years may be required.

No statistical test is free of assumptions. The two-sample u-test assumes that only the mean of the population may have changed whereas the shape and the spread of the distribution have not. Assuming a normal distribution, the explicit expression [6] for the number of years, N, necessary to guarantee the statistical significance of the observed or expected increase at the 95 percent confidence level is given by:

$$N = \frac{(1.96)^2 \times \sigma_Q^2}{(\Delta Q)^2} = \frac{3.84\ \sigma_Q^2}{(\Delta Q)^2} \qquad (2)$$

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***Since the initiation of this study the plans of the Bureau were modified. Currently (45) only one area is considered: the San Juan Mountains region.

where σ_Q^2 is the standard deviation of runoff, and

ΔQ is the increase in runoff.

One of the purposes of this study is to determine the relative suitability of individual basins within the Upper Colorado River Basin by calculating the expected increase in runoff for each, i.e., ΔQ , from equation (1) and the number of years needed for evaluation, i.e., N , from equation (2).

On the other hand, the pilot program involves many sub-basins within major ones. In this case, it is advisable to choose a favorable combination of sub-basins for evaluation. For this purpose, a new variable, Q^*, is constructed by a linear combination of n runoff variables, Q_i $(i=1, 2, \ldots, n)$, i.e.,

$$Q^* = \alpha_1 Q_1 + \alpha_2 Q_2 + \ldots + \alpha_n Q_n = \sum_{i=1}^{n} \alpha_i Q_i \qquad (3)$$

where Q_i is the runoff from an individual sub-basin. Much freedom is gained from a combination of runoff variables from various basins such as (3) compared to the use of a single basin runoff. The freedom gained is twofold. First, there is freedom gained in the process of selection of n basins among many. For example, where there are 15 ways of selecting one basin out of 15, there are 3003 ways of selecting five basins out of 15. Second, there is freedom gained in the process of selection of the parameters α_i once n sub-basins have been chosen.

However, for hydrologic reasons, two restrictions were imposed on the choice of the parameters α:

(a) The mean of Q^*, $\overline{Q}^*$, must be equal to the sum of the means of the Q_i, $\overline{Q}_i$, symbolically:

$$\overline{Q}^* = \sum_{i=1}^{n} \alpha_i \overline{Q}_i = \sum_{i=1}^{n} \overline{Q}_i \qquad (4)$$

and

(b) The expected increase of Q^*, $\overline{\Delta Q}^*$, must be equal to the sum of the expected increases in Q_i, $\overline{\Delta Q}_i$, i.e., symbolically:

$$\overline{\Delta Q}^* = \sum_{i=1}^{n} \alpha_i \overline{\Delta Q}_i = \sum_{i=1}^{n} \overline{\Delta Q}_i \ . \qquad (5)$$

The hydrologic interpretation of equation (4) is that the expectation of the random variable Q^* is the mean of the total runoff for the group of n basins. The interpretation of equation (5) is that the expected increase of the mean of Q^* is that of the total runoff for the group of n basins.

As for a single basin the number of years, N^*, needed for evaluation of grouped basins is given by:

$$N^* = \frac{3.84\, \sigma_{Q^*}^2}{(\Delta Q^*)^2} \ . \qquad (6)$$

Another purpose of this study is to develop systematic methods to obtain the most favorable combinations of sub-basins in the pilot areas by determining the α_i's such that the number of years, N^*, in equation (6), is kept to a minimum.

4. General plan of paper. In Chapter II, the hydrologic characteristics of the Upper Colorado River Basin are reviewed. In the same chapter, the potential for weather modification in this region is also discussed. Chapter III treats the question of definition of a criterion of suitability and its calculations. Chapters IV and V discuss the data used in the study, the techniques of data processing, and most importantly, the results. Chapter VI concludes the study.

5. Select basic terms used in this study.

(a) Water Year

"Water year" begins October 1 and ends September 30 of the calendar year. The term, "annual," refers to water year. In the text the words "year" and "water year" are used synonymously.

(b) Precipitation

"Precipitation" refers to rainfall and the water content of snow. Winter precipitation includes precipitation from September 1 through April 30 and spring precipitation from May 1 through July 31. Winter precipitation generally falls in the form of snow in the high mountain watersheds. Precipitation is measured in inches.

(c) Runoff

"Runoff" refers to the river flow measured at a gaging station. In this study, unit yield is used, i. e., the depth, in inches, of the cumulative volume of flow during a given period, when volume is spread uniformly over the whole watershed. Spring runoff includes runoff from April 1 through July 31.

(d) Upper Colorado River Basin

By this expression the drainage basin of the Colorado River above Lee's Ferry is meant (see Figure 1).

(e) Upper Basin of the Colorado River

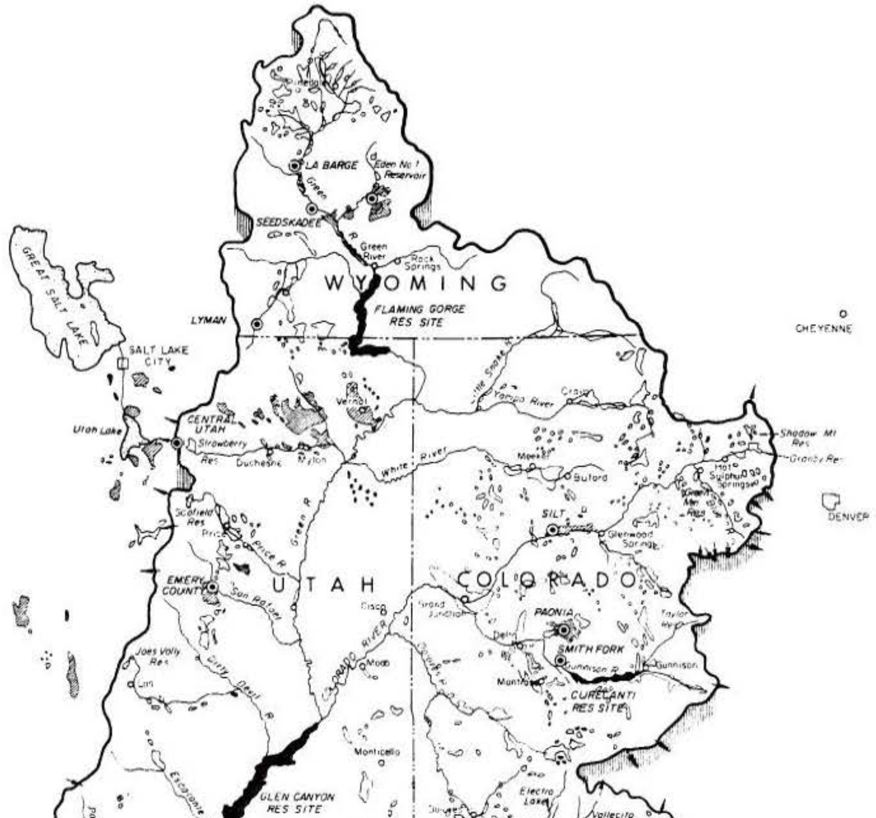
A much smaller drainage basin is meant by this expression. The Upper Basin of the Colorado River is defined in this study as the drainage basin of the main stem of the Colorado, close to its source, and of a few tributaries. The limits of this basin are shown on Figure 6(b).

Chapter II

THE HYDROLOGIC AND HISTORIC SETTING

The hydrologic characteristics of the Upper Colorado River Basin are reviewed. They explain in part the interest in and the potential for weather modification in this area. Certain aspects of the precipitation management program in the Upper Colorado River Basin are discussed briefly.

1. The Upper Colorado River Basin. The Upper Colorado River Basin (Fig. 1) covers parts of the states of Colorado, Wyoming, Utah, New Mexico, and Arizona. It comprises 109,500 square miles above Lees Ferry, Arizona, its boundaries extending along the continental divide in the east and the north and along the divide of the mountain range through Utah in the west. The Colorado River, which is the third longest river in the United States, has a length of 1,450 miles. It has its source in the high, snow-capped mountains in northwestern Colorado. It is also fed by major tributaries originating in other parts



EXPLANATION

- Irrigated Land
- ▨ Irrigated Land, To be Furnished Supplemental Water
- New Land
- Existing Reservoir and Lakes
- ⊙ Initial Participating Projects
- ○ Other Participating Projects

Fig. 1. The Upper Colorado River Basin (after Upper Colorado River Commission [7])

of Colorado; by the Green River originating in Wyoming and flowing into the Colorado River in southern Utah; by the San Juan River originating in southern Colorado, flowing through northern New Mexico and joining the Colorado River in southern Utah. In the northern portion of the basin, there are hundreds of peaks of more than 13,000 feet in elevation. A highly smoothed topography of the basin is shown in Fig. 2.

In high mountain regions, much of the annual runoff occurs as a result of melting snow. Hence, runoff is often characterized by a peak flood season in late spring followed by low water flow in summer, fall, and winter. This holds true for the Colorado River and its tributaries [2].

The annual virgin runoff at Lees Ferry, Arizona, is noted for its large fluctuation, as shown in Fig. 3. Virgin runoff is that runoff which takes place without the interference of man. Virgin runoff is reconstructed from the actual flow, from data on transmountain diversions, on regulation by dams, and from estimates of irrigation diversions and uses. The fluctuation of annual virgin runoff ranges from a low of 1.08 inches to a high of 4.10, as measured in the last 51 years [9].

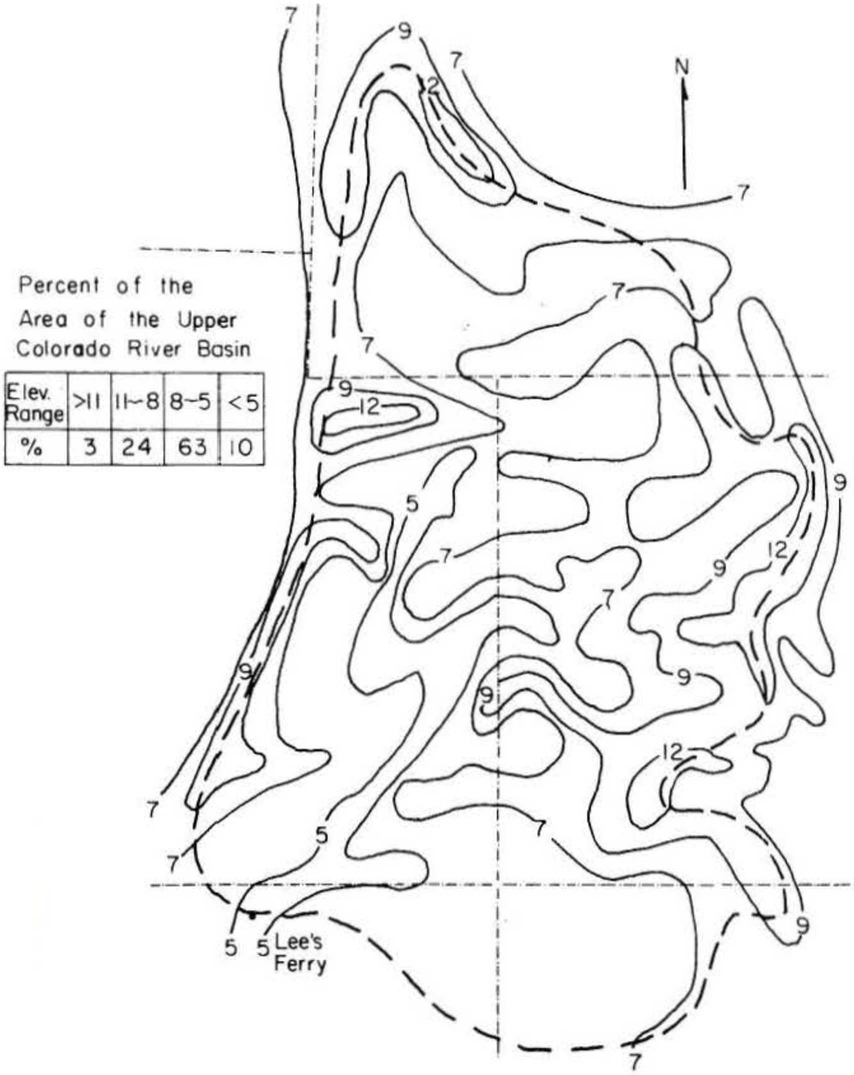
2. Precipitation management in the Upper Colorado River Basin. The precipitation management project, currently planned by the United States Bureau of Reclamation, Office of Atmospheric Water Resources, concerns winter cloud seeding operations above certain high elevation watersheds of the Upper Colorado River Basin. The precipitation due to cloud seeding which falls as snow in winter, is expected to increase the runoff in spring.

The following characteristics of the Upper Colorado River Basin are favorable for weather modification:

(a) High mountain ranges in this region are favorable for orographic precipitation and in addition, the northwest wind brings large supplies of moisture in winter [10].

(b) Water from snowmelt in early spring through early summer can be stored and made available when needed for various kinds of use.

Figures 4 and 5 illustrate the typical variation of precipitation and runoff in this region. The distribution of monthly precipitation is, on the average,


Percent of the Area of the Upper Colorado River Basin

Elev. Range	>11	11–8	8–5	<5
%	3	24	63	10

Fig. 2 The highly smoothed topography of the Upper Colorado River Basin (in units of 1000's of feet). (After Rasmussen, J.L. [8])

uniform. However, the major part of the runoff occurs during the spring and early summer months, which is due primarily to snowmelt.

The design of a moderate scale pilot program of operational seeding is in progress, serving as a bridge between experimental programs and the large-scale operation of the Colorado River Basin [5,11]. The following two areas were selected by the Bureau of Reclamation* for a pilot program.

(1) The San Juan Mountains including drainage areas from Lake Fork, Colorado, to the New Mexico border, and

(2) The Upper Basin of the Colorado River including drainage from Williams Fork, Colorado, to Troublesome Creek, Colorado.

These regions are shown in Fig. 6. The suitability of grouped basins from these regions for weather modification is discussed in Chapter V, Section 5.

The next chapter discusses the question of definition and calculation of suitability criteria. Based on these criteria, the overall suitability of the Upper Colorado River Basin is assessed in general and for the pilot areas in particular in Chapter V, Section 5.

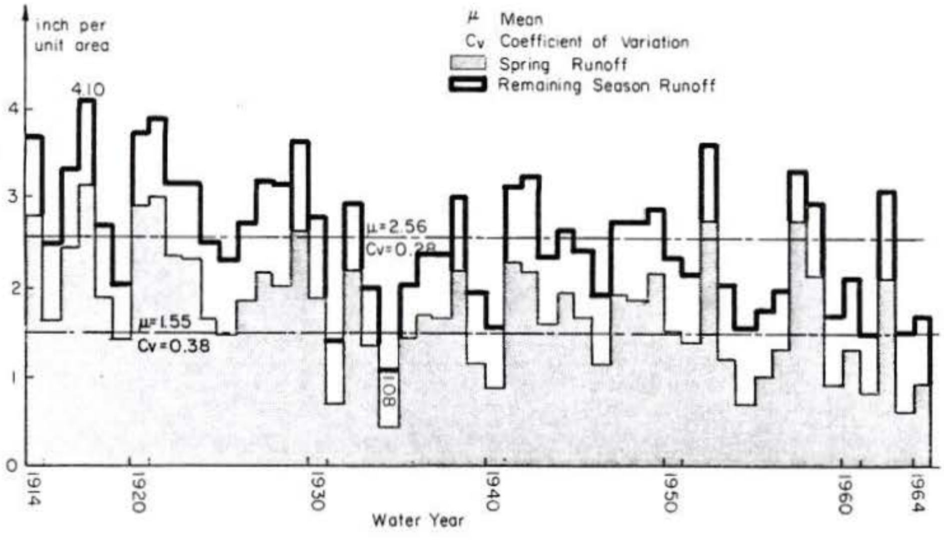


Fig. 3 Annual and spring runoff at Lees Ferry, Arizona

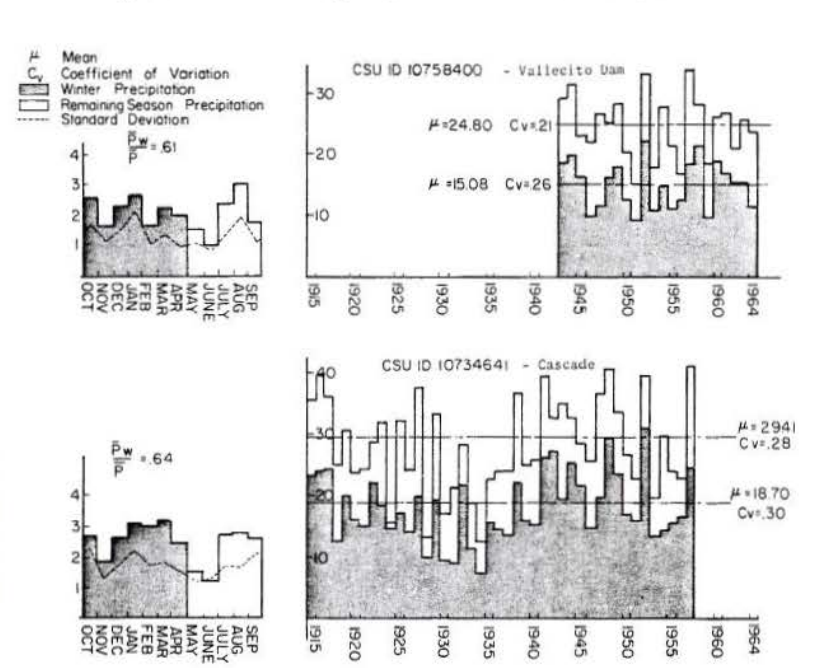


Fig. 4(a) Annual, winter, and monthly precipitation (in inches) for stations Vallecito Dam and Cascade. P_w/P represents the ratio of mean winter precipitation to mean annual precipitation.

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* Since the initiation of this study the plans of the Bureau were modified. Currently (45) only one area is considered: the San Juan Mountains region.

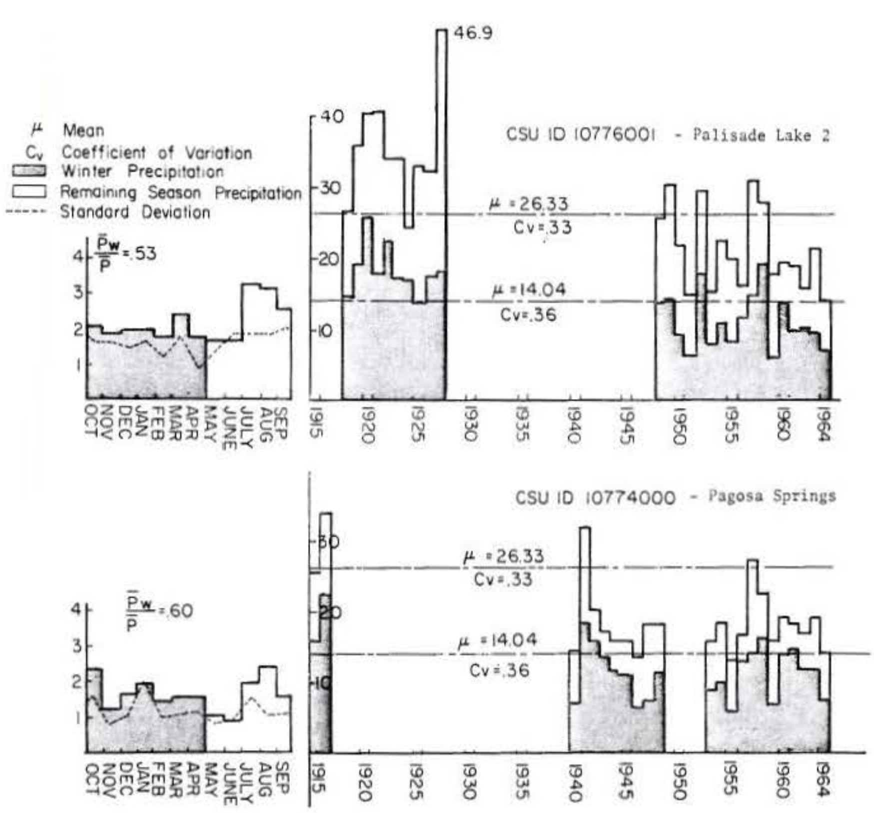

Fig. 4(b) Annual, winter, and monthly precipitation (in inches) for stations Palisade Lake 2 and Pagosa Springs. P_w/P represents the ratio of mean winter precipitation to mean annual precipitation.

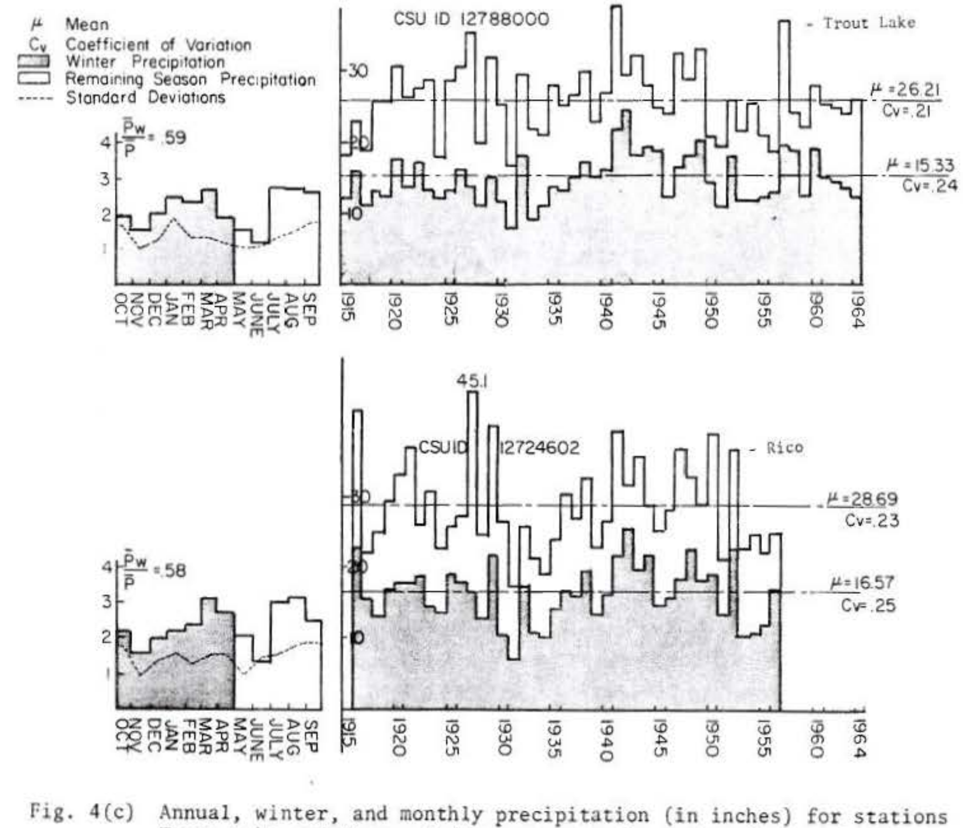

Fig. 4(c) Annual, winter, and monthly precipitation (in inches) for stations Trout Lake and Rico. P_w/P represents the ratio of mean winter precipitation to mean annual precipitation.

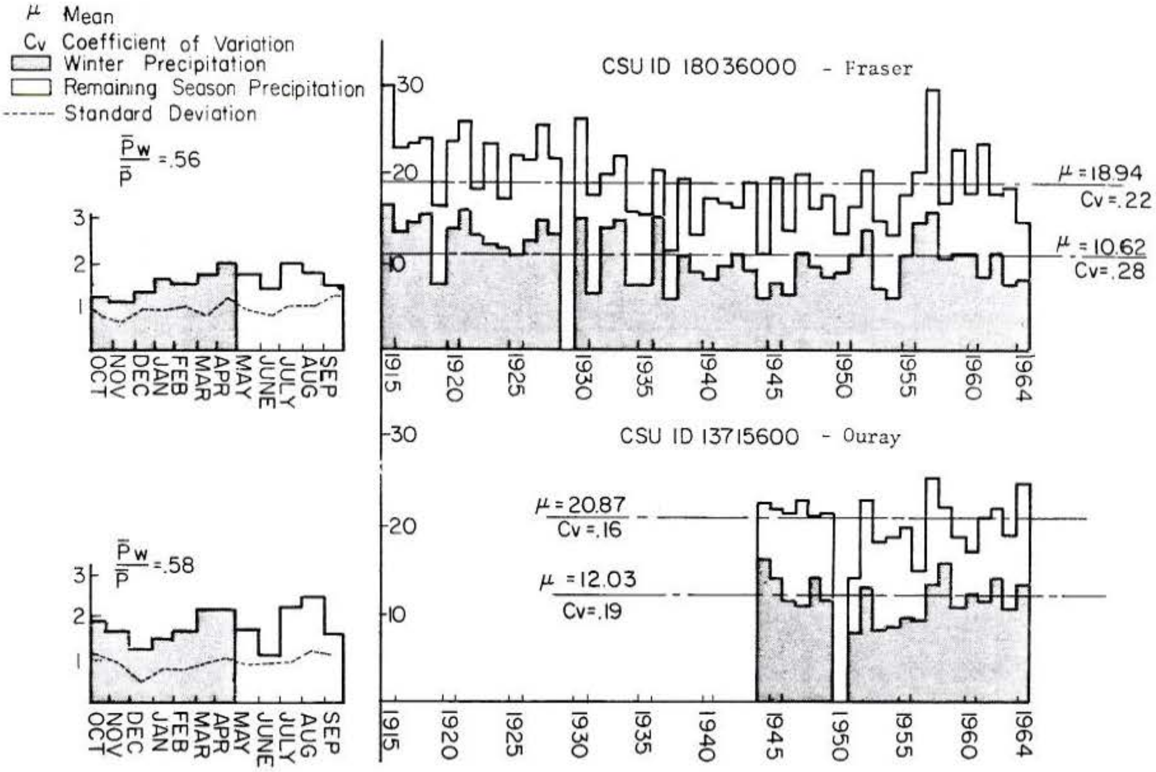

Fig. 4(d) Annual, winter, and monthly precipitation (in inches) for stations Fraser and Ouray. P_w/P represents the ratio of mean winter precipitation to mean annual precipitation.

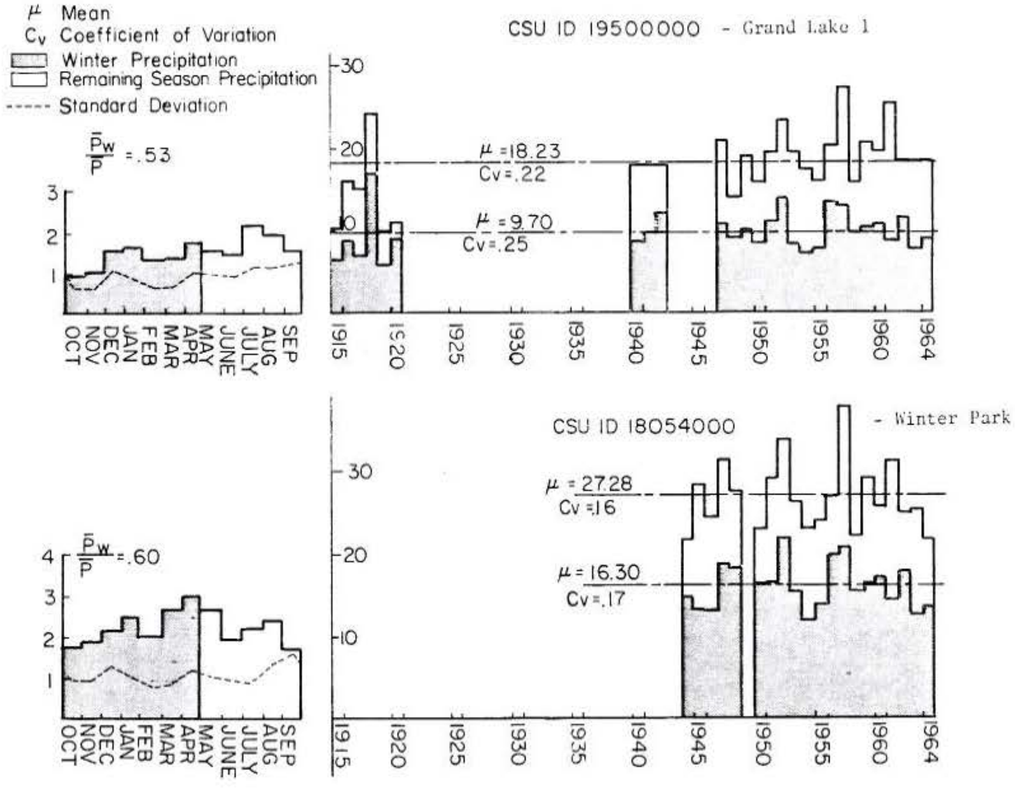

Fig. 4(e) Annual, winter, and monthly precipitation (in inches) for stations Grand Lake 1 and Winter Park. P_w/P represents the ratio of mean winter precipitation to mean annual precipitation.

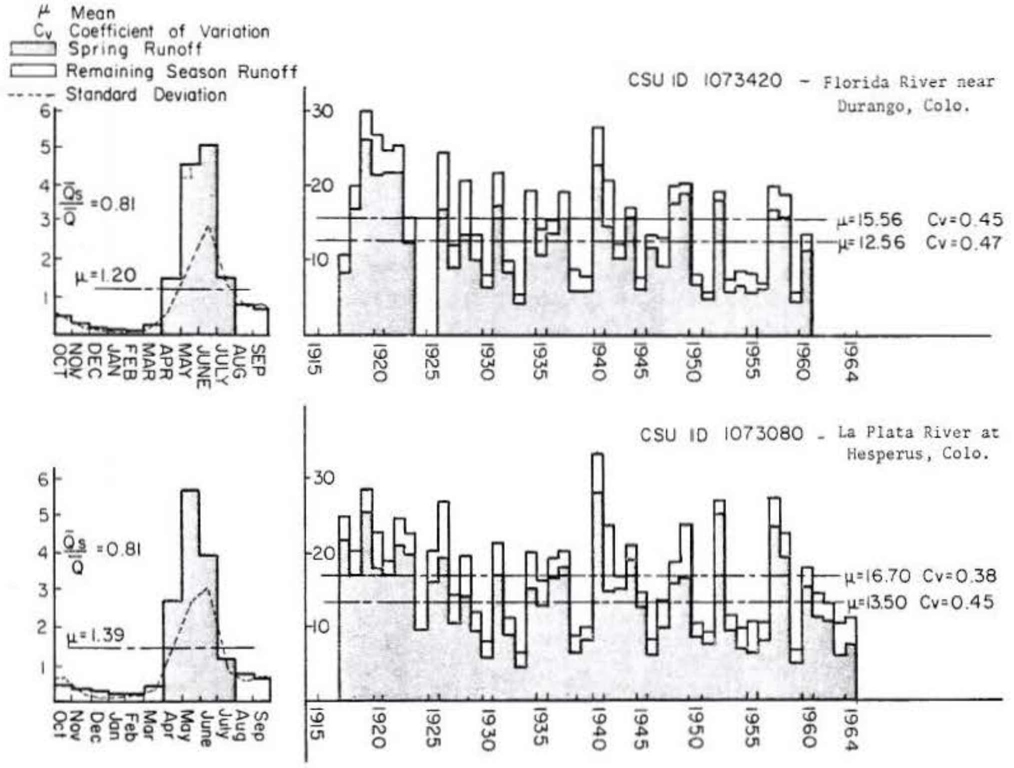

Fig. 5(a) Annual, spring, and monthly runoff (in inches) for stations Florida River near Durango, Colo. and La Plata River at Hesperus, Colo. $\overline{Q}_s/\overline{Q}$ represents the ratio of mean spring runoff to mean annual runoff.

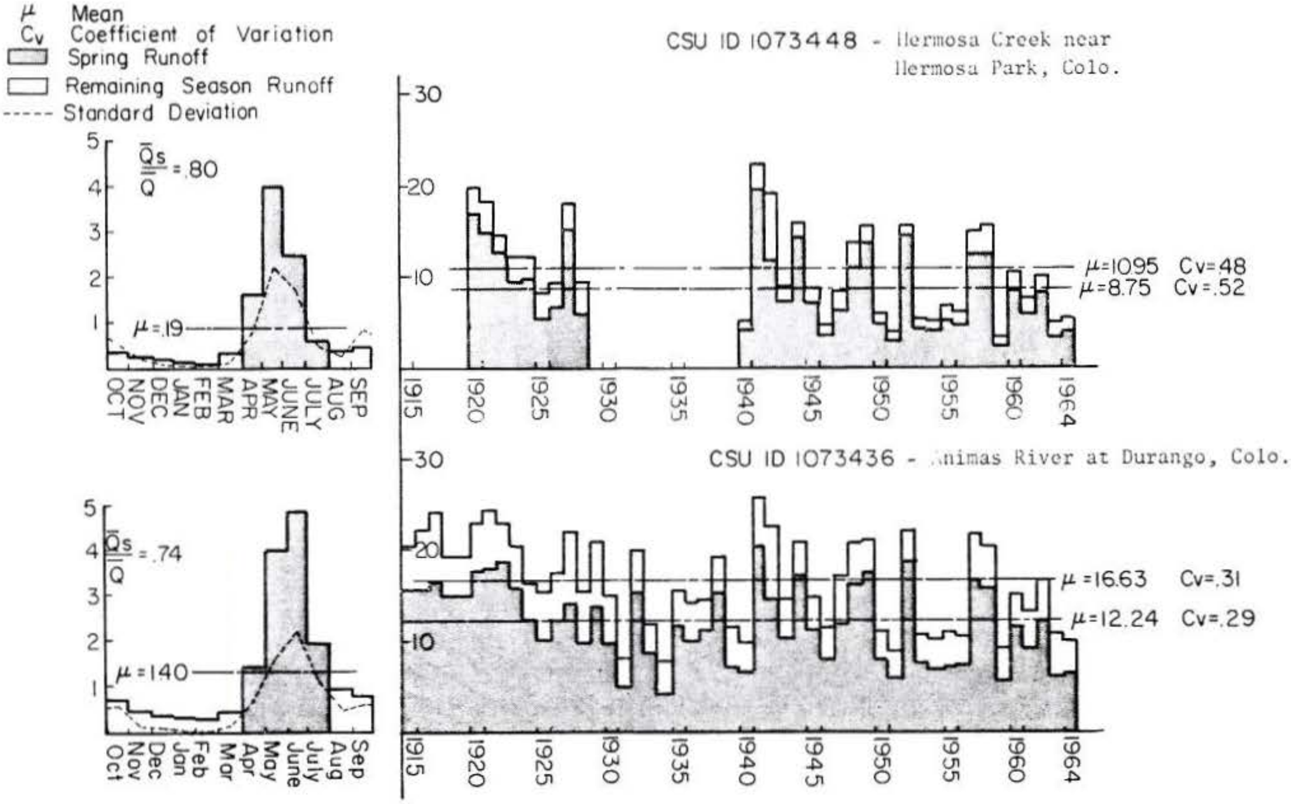

Fig. 5(b) Annual, spring, and monthly runoff (in inches) for stations Hermosa Creek near Hermosa Park, Colo. and Animas River at Durango, Colo. $\overline{Q}_s/\overline{Q}$ represents the ratio of mean spring runoff to mean annual runoff.

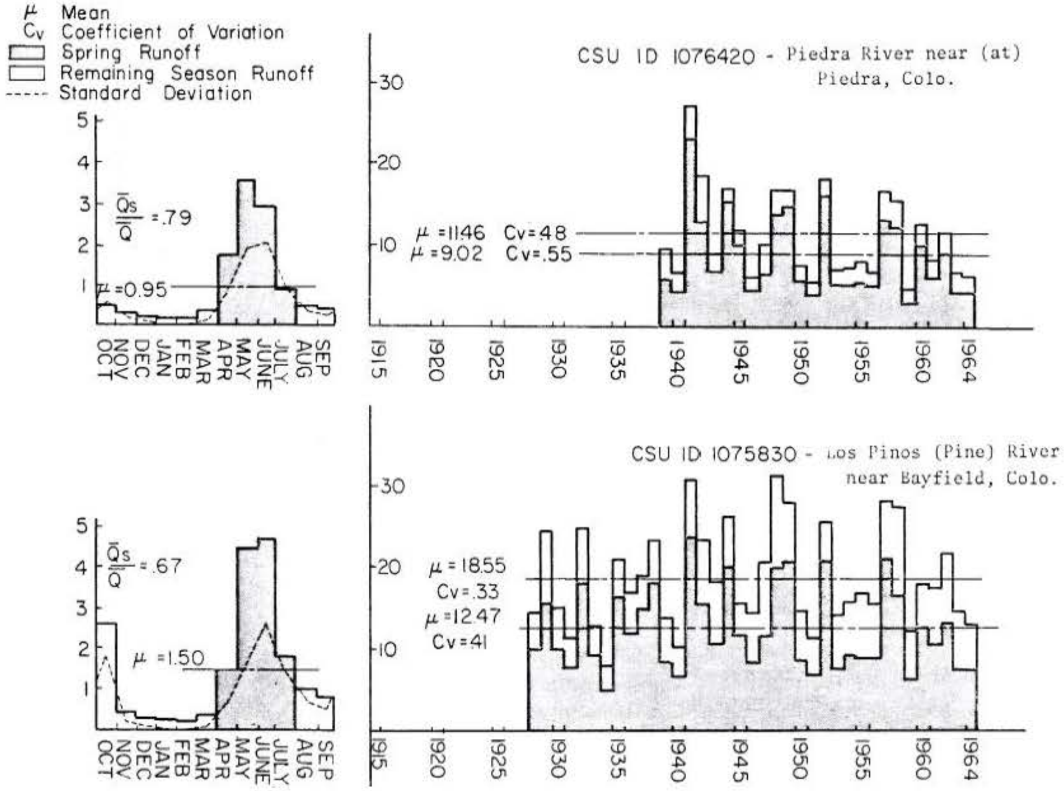

Fig. 5(c) Annual, spring, and monthly runoff (in inches) for stations Piedra River near (at) Piedra, Colo. and Los Pinos (Pine) River near Bayfield, Colo. $\bar{Q}_s/\bar{Q}$ represents the ratio of mean spring runoff to mean annual runoff.

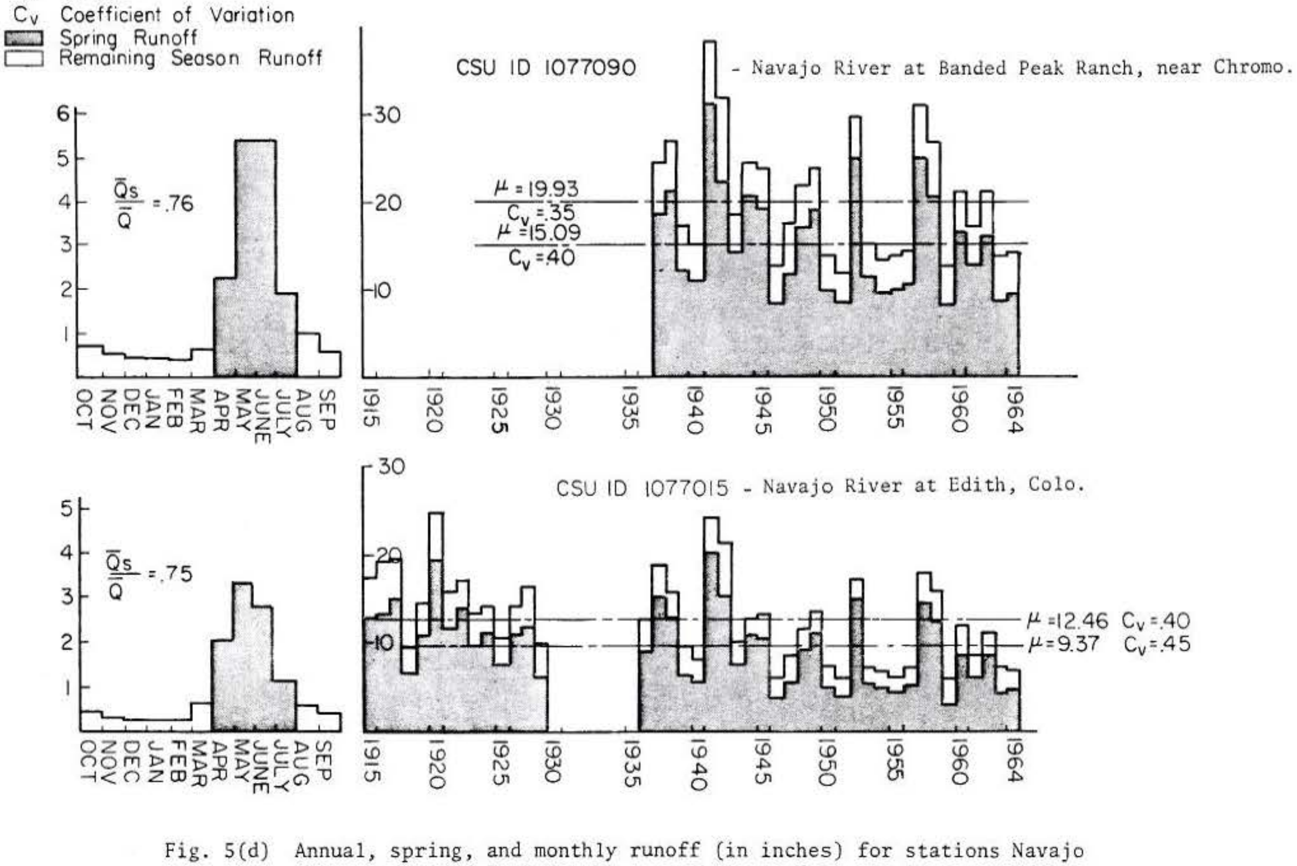

Fig. 5(d) Annual, spring, and monthly runoff (in inches) for stations Navajo River at Banded Peak Ranch, near Chromo and Navajo River at Edith, Colo. $\bar{Q}_s/\bar{Q}$ represents the ratio of mean spring runoff to mean annual runoff.

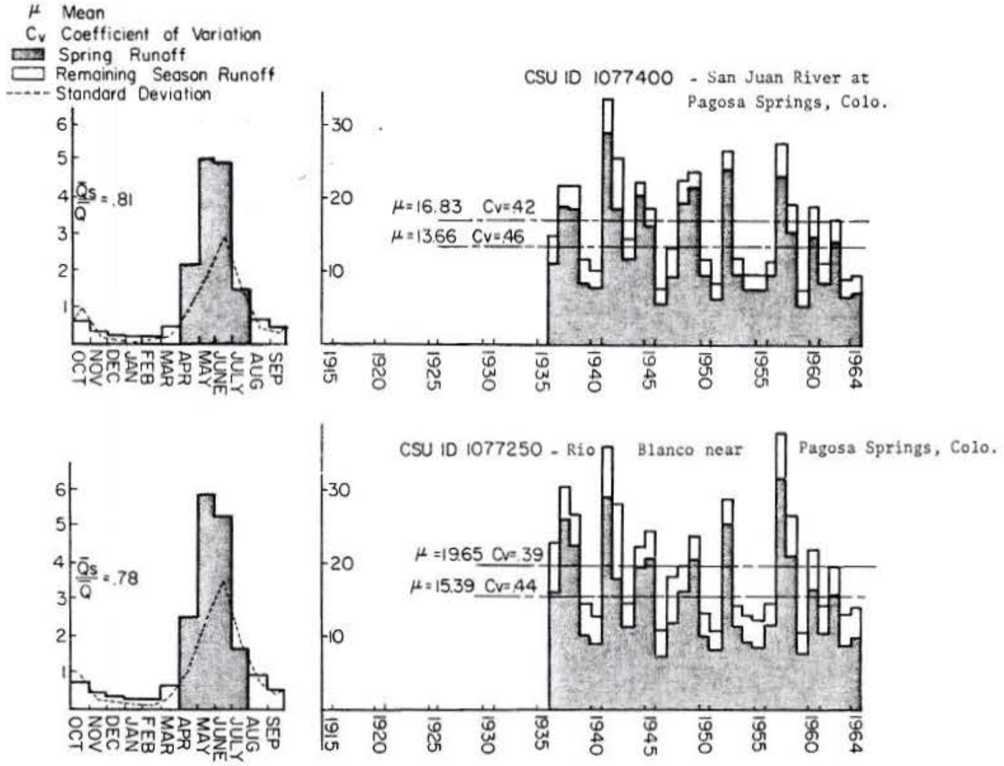

Fig. 5(e) Annual, spring, and monthly runoff (in inches) for stations San Juan River at Pagosa Springs, Colo. and Rio Blanco near Pagosa Springs, Colo. $\overline{Q}_s/\overline{Q}$ represents the ratio of mean spring runoff to mean annual runoff.

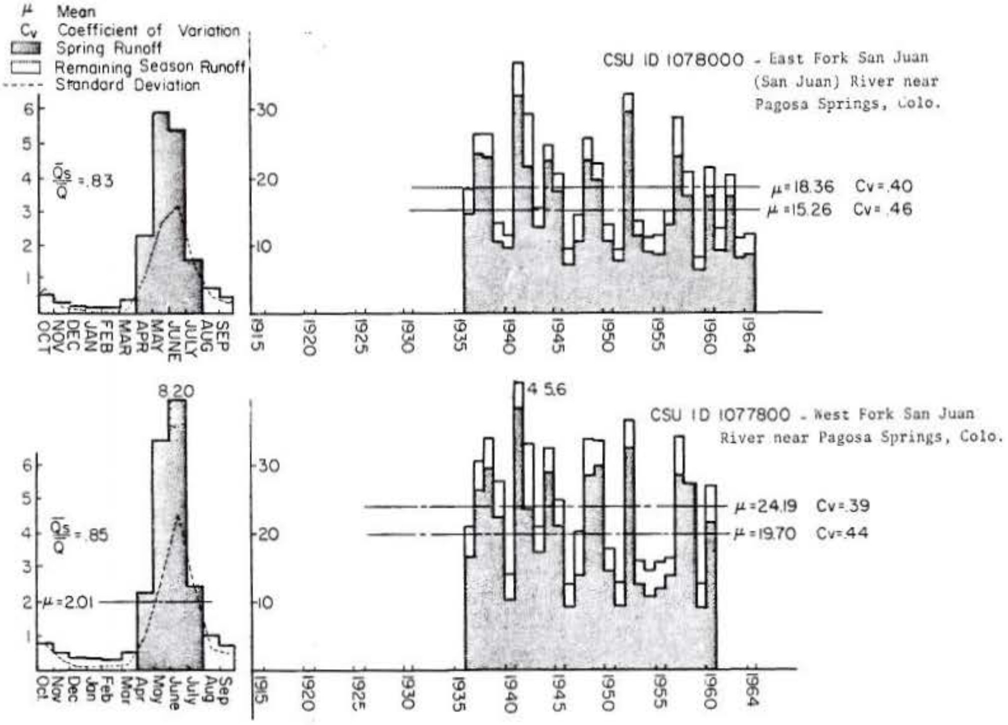

Fig. 5(f) Annual, spring, and monthly runoff (in inches) for stations East Fork San Juan (San Juan) River near Pagosa Springs, Colo. and West Fork San Juan River near Pagosa Springs, Colo. $\overline{Q}_s/\overline{Q}$ represents the ratio of mean spring runoff to mean annual runoff.

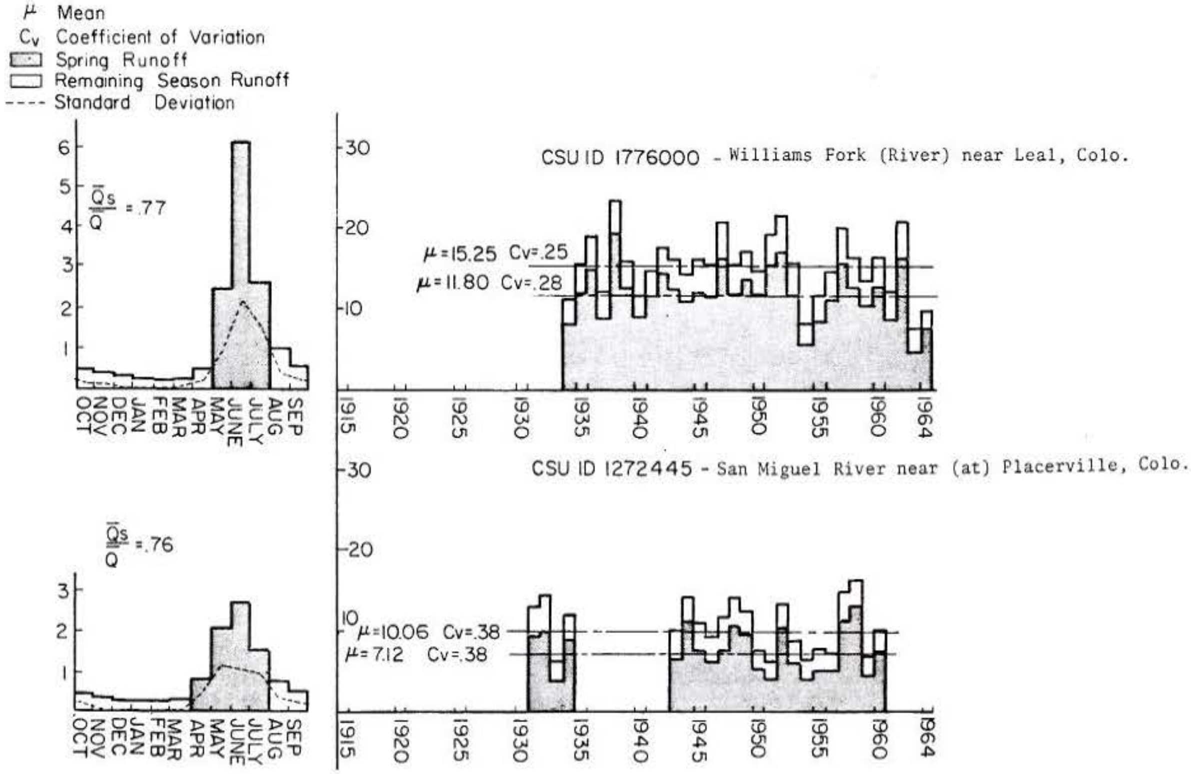

Fig. 5(g) Annual, spring, and monthly runoff (in inches) for stations Williams Fork (River) near Leal, Colo. and San Miguel River near (at) Placerville, Colo. $\bar{Q}_s/\bar{Q}$ represents the ratio of mean spring runoff to mean annual runoff.

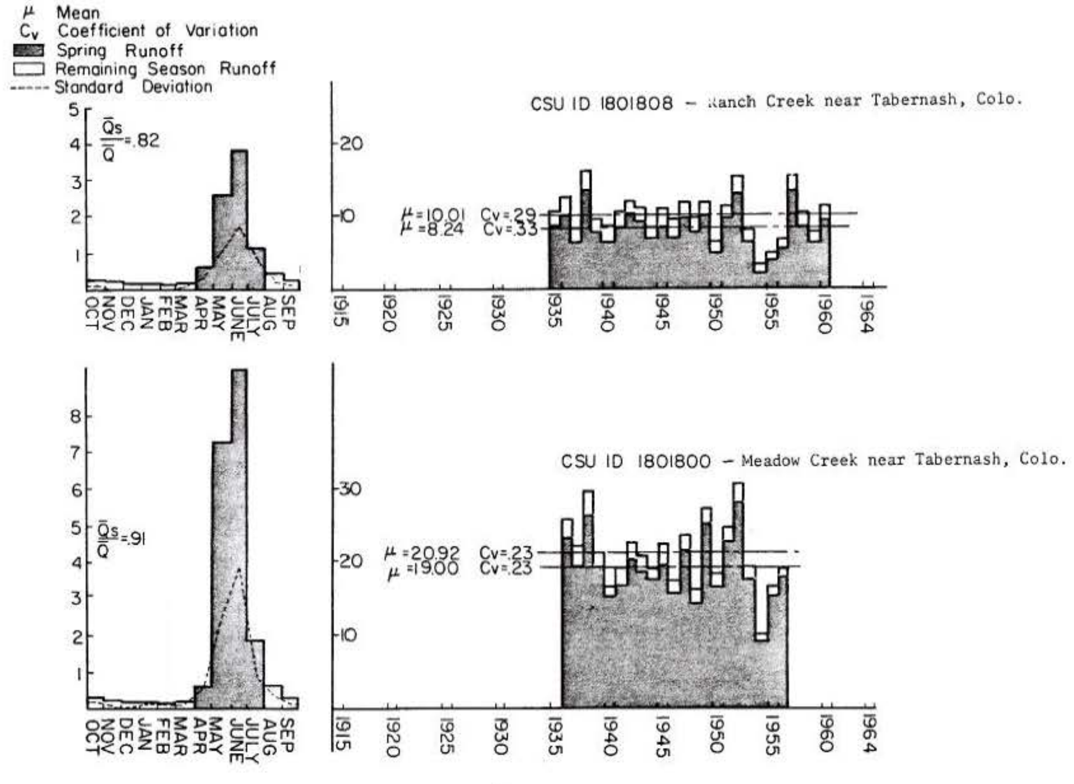

Fig. 5(h) Annual, spring, and monthly runoff (in inches) for stations Ranch Creek near Tabernash, Colo. and Meadow Creek near Tabernash, Colo. $\bar{Q}_s/\bar{Q}$ represents the ratio of mean spring runoff to mean annual runoff.

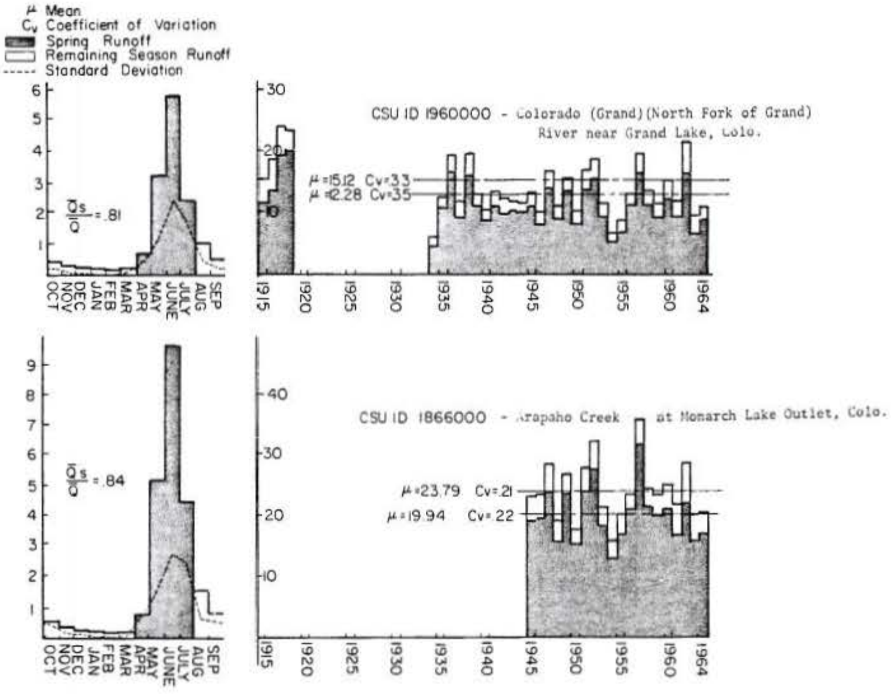

Fig. 5(i) Annual, spring, and monthly runoff (in inches) for stations Colorado (Grand)(North Fork of Grand) River near Grand Lake, Colo. and Arapaho Creek at Monarch Lake Outlet, Colo. $\overline{Q}_S/\overline{Q}$ represents the ratio of mean spring runoff to mean annual runoff.

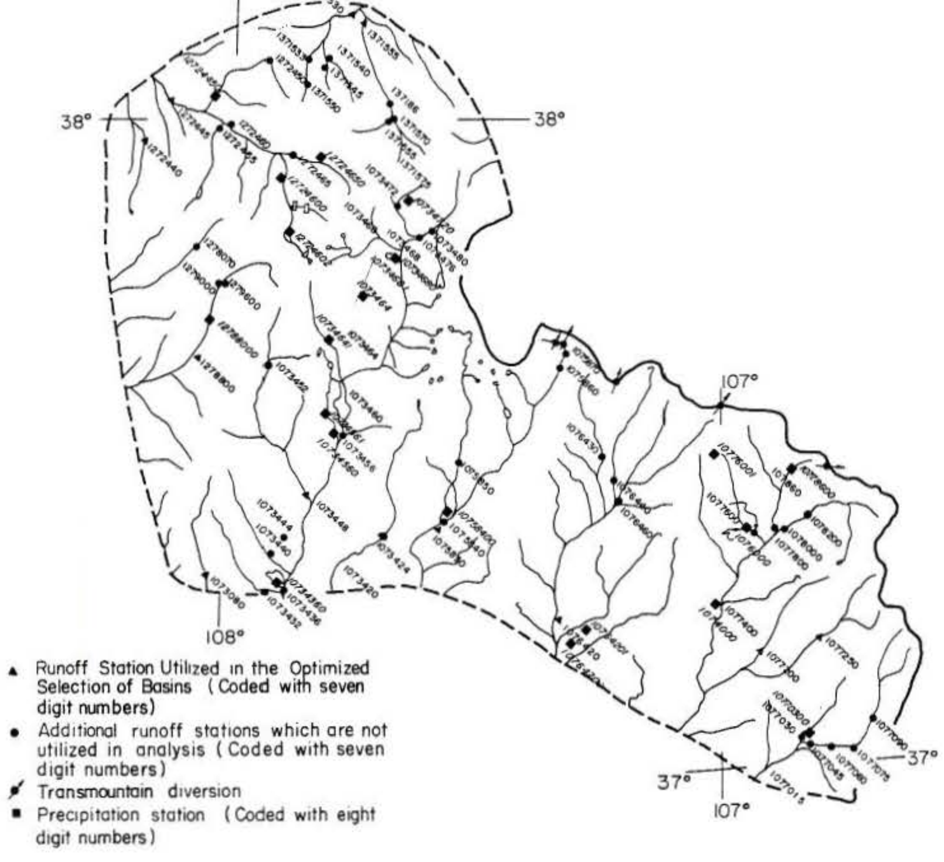

Fig. 6(a) General configuration of and location of gages within the Colorado River Basin Pilot Project area (San Juan Mountains region).

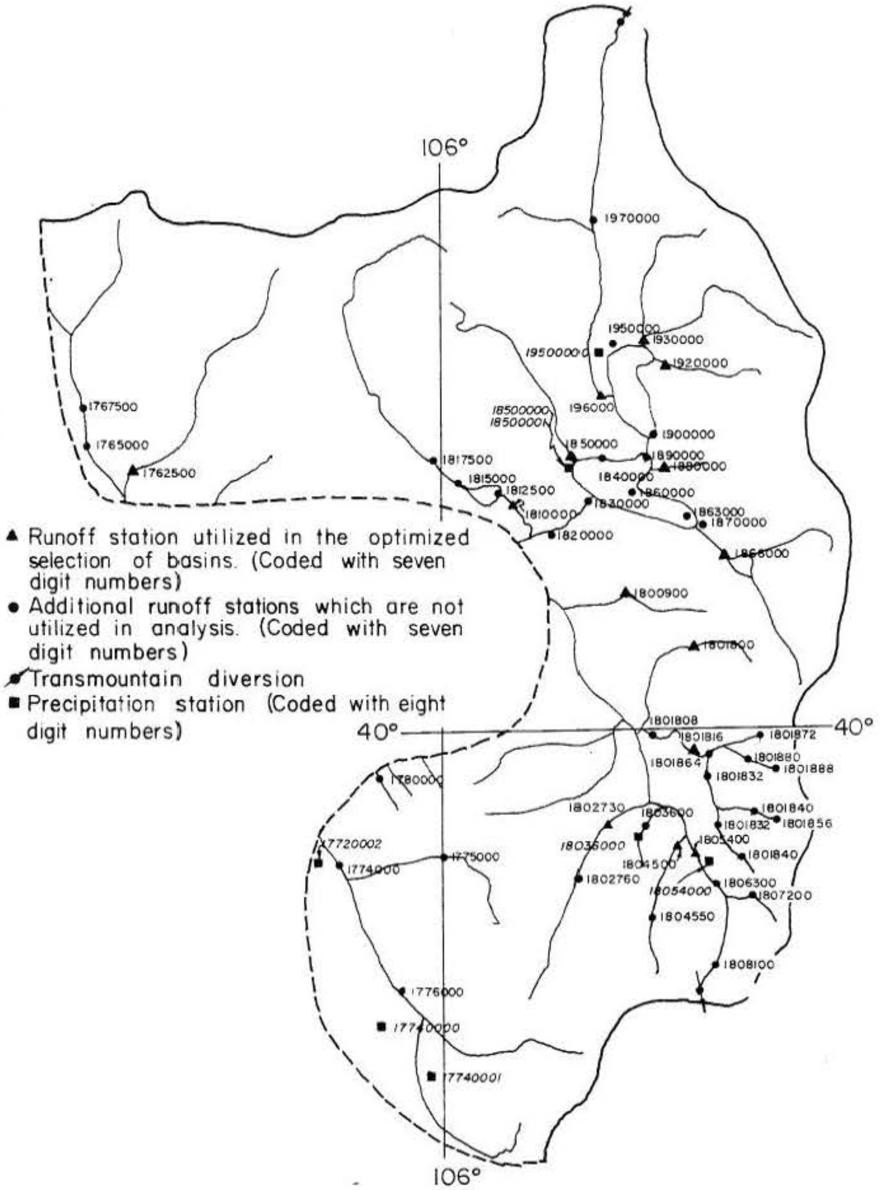

Fig. 6(b) General configuration of the Upper Basin of the Colorado River.

Chapter III

SUITABILITY OF BASINS FOR PRECIPITATION MANAGEMENT

1. Criteria of suitability of basins for precipitation management. Whether it be an experimental or a large-scale operation, the proper selection of basins for weather modification is important. Simply put, the question to be answered is: What makes one basin more suitable than another for a precipitation management operation [6]?

From a water resource point of view, the largest amount of runoff that can be brought about by cloud seeding is one of the criteria of suitability. But at the present time, cloud seeding is in the preliminary stages, and its success still has to be measured and discussed. One needs another criterion for evaluation. The smallest number of years needed for significance at a given level and power is the criterion from the evaluation standpoint.

Both of the criteria above are not necessarily the same and, of course, they are not absolute. In addition, meteorologic and economic conditions must be considered. However, these criteria are beyond the objective of this study, which is confined to hydrologic suitability.

2. Suitability of basins for optimal water yield.

a. Increase of precipitation by cloud seeding. Cloud seeding operations have been carried out on the following assumptions [12]:

(1) That some cloud systems precipitate inefficiently or not at all because of a deficiency of ice crystals in their super-cooled regions;

(2) That by seeding these clouds with silver iodide to increase the concentration of ice crystals, it might be possible to produce a detectable increase in precipitation or, alternatively, change its distribution or character;

(3) That nuclei leaving a ground generator and carried up by convection and turbulent diffusion will provide the proper concentration of ice crystals, at least somewhere in the supercooled parts of the cloud system;

(4) That the silver iodide nuclei will retain their ice nucleating ability during their travel from the generator to the supercooled regions of the cloud.

Because cloud physics and physical meteorology in general have received vigorous impetus only during the past decade principally from interest in cloud seeding, it is still difficult to predict the extent of man-made precipitation in the future. But it seems to be the consensus of opinion that present technology is not sufficiently developed to induce an additional amount of precipitation above a small percentage (10-20 percent) that occurs naturally.

At present it is a somewhat accepted opinion that the increase of precipitation by cloud seeding is proportional to the natural precipitation, i.e.,

$$\Delta P_w = k\ P_w \qquad (7)$$

where

ΔP_w is the expected increase of winter precipitation by cloud seeding,

P_w is the natural winter precipitation, and

k is the ratio of increase of precipitation to the natural value or relative increase.

In equation (7) the average value of k might be determined physically, for various meteorological and geographical conditions.

b. Relationship between runoff and precipitation. In order to implement a plan for the best use of the total manageable water supply, it is necessary to understand the relationship between climate, water losses, and water yield from watersheds. For this purpose, various methods have been developed indirectly or from data at hand, which are classified in the following two categories:

(1) Prediction equation for specific yield [13-16] and

(2) Runoff forecasting analysis [17-24].

The first approach is to relate the specific yield with climatologic and/or basin characteristics known to influence precipitation amounts, as well as their disposition. However, most available climatologic and basin data are only indices of the combined effects of several physical factors. Hence, the more complex statistical approaches have been applied. General effects of climatologic and basin characteristics are more clearly defined on an annual basis than for shorter periods.

The second approach is to find a solution to the water-budget equation which serves for water supply forecasting. This approach is based largely on the existence of a time lag between winter precipitation stored as snow pack and spring runoff and on the greater effectiveness of the winter precipitation in producing runoff as compared to that which occurs during the summer.

The atmospheric water resource project in the Upper Colorado River Basin aims to increase winter precipitation as snow, which is followed by an increase of runoff in the spring. Hence, the second approach is helpful in finding the relationship between spring runoff and winter precipitation and in estimating the increase of runoff.

c. Increase of runoff. The effect of cloud seeding is measured by the increase of usable runoff. It is assumed that runoff (Q) is a function of a representative precipitation (P). Then, in the general form,

$$Q = f(P) \quad . \qquad (8)$$

But is is hard to find an integrated precipitation that represents the whole basin. Suppose that the precipitation data P_j's corresponding to Q are collected, as many as possible, in the basin in question. Equation (8) is then modified as

$$Q = f(P_1, P_2, \ldots) \quad . \tag{9}$$

In the case of precipitation management in the Upper Colorado River Basin, it is the spring runoff, (Q_s), caused mainly by winter precipitation, (P_{wj}), and partially by spring precipitation, (P_{sj}), which is of concern. The relationship is represented more precisely by the following equation:

$$Q_s = f(P_{w1}, P_{s1}, P_{w2}, P_{s2}, \ldots) \quad . \tag{10}$$

Multiple linear regression analysis is applied to find the approximate relationship. Finally,

$$Q_s = a + b_1P_{w1} + c_1P_{s1} + b_2P_{w2} + c_2P_{s2} + \ldots \tag{11}$$

where the a, b_j, c_j are coefficients determined from available data.

Then, the increase of spring runoff, (ΔQ_s), caused by the increase of winter precipitation, (ΔP_w), is given by

$$\begin{aligned} \Delta Q_s &= (Q_s + \Delta Q_s) - Q_s \\ &= \{a + b_1(P_{w1} + \Delta P_{w1}) + c_1P_{s1} + b_2(P_{w2} + \Delta P_{w2}) + c_2P_{s2} + ..\} \\ &= \{a + b_1P_{w1} + c_1P_{s1} + b_2P_{w2} + c_2P_{s2} + ..\} \\ &= b_1\Delta P_{w1} + b_2\Delta P_{w2} + \ldots \end{aligned} \tag{12}$$

Substituting equation (7) into (12), and averaging

$$\overline{\Delta Q}_s = b_1k_1\overline{P}_{w1} + b_2k_2\overline{P}_{w2} + \ldots . \tag{13}$$

From a water resource point of view, the greater the $\overline{\Delta Q}_s$ calculated from equation (13), the more suitable the basin.

3. Suitability of basins for evaluation.

a. Two-sample u-test. One of the goals of the precipitation management program has been the rigorous establishment of the statistical significance of its attainment. For this purpose, various methods of evaluation were devised. Indeed, a great deal is already known about methods of evaluation of attainment [6].

Of course, the criteria of suitability of basins for evaluation depend upon the choice of the variable selected to test the hypothesis or the type of statistical test and upon the design of the experiments.

Assuming that the end result of seeding is to increase the natural mean, but that everything else stays the same, the criteria are derived from the two-sample u-test [6] in the following way. The two-sample u-test is a test of the hypothesis that assumes that the population mean is equal to a given value while the population standard deviation is known and stationary [25]. The statistic used in testing this hypothesis is

$$u = \frac{\overline{x} - \mu}{\sigma/\sqrt{n}} \tag{14}$$

where $\overline{x}$ is the sample mean,

μ is the population mean,

σ is the standard deviation, and

n is the sample size

with the critical region $|u| > 1.96$ if the 5 percent significance level is used. The significance of the increase in spring runoff is achieved if the observed statistic u, in equation (15), is greater than 1.96 at the 95 percent confidence level, i.e.,

$$u = \frac{\overline{\Delta Q}_s}{\sigma_{Q_s}/\sqrt{N}} \geq 1.96 \tag{15}$$

where $\overline{\Delta Q}_s$ is the expected increase in spring runoff,

N is the number of years necessary to establish the significance of the increase with a 50% power, and

σ_{Q_s} is the standard deviation of the natural spring runoff.

b. A criterion to determine the relative suitability of an individual basin. The number of years, N, necessary for evaluation is derived from equation (15)

$$N = \frac{3.84\,\sigma_{Q_s}^2}{(\overline{\Delta Q}_s)^2} \quad . \tag{16}$$

A low value of N in equation (16) provides a criterion to determine the relative suitability of many potential basins.

c. A criterion to determine the suitability of grouped basins. In the major basins there are sets of gaged sub-basins that are not, in part or in full, a tributary of any other member sub-basin of the set. Suppose that in a major basin there exist m such sub-basins. The spring runoff for each of these individual sub-basins is denoted $Q_{si}(i=1,2,\ldots m)$. Now suppose one wants to choose n of the m sub-basins for a pilot program $(n < m)$. Construct a linear combination of Q_{si}'s, i.e.,

$$Q_s^* = \alpha_1Q_{s1} + \alpha_2Q_{s2} + \ldots + \alpha_nQ_{sn} = \sum_{i=1}^{n} \alpha_iQ_{si} \quad . \tag{17}$$

The variance of Q_s^* is given by

$$\sigma_{Q_s^*}^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij}\alpha_i\alpha_j \tag{18}$$

where

$$a_{ij} = \begin{cases} \sigma^2_{Q_{si}} & \text{for } i=j \\ \mathrm{Cov}(Q_{si}, Q_{sj}) & \text{otherwise.} \end{cases} \qquad (19)$$

The increase of spring runoff from grouped basins, ΔQ^*_s, is given by

$$\Delta Q^*_s = \alpha_1 \Delta Q_{s1} + \alpha_2 \Delta Q_{s2} + \ldots + \alpha_n Q_{sn} = \sum_{i=1}^{n} \alpha_i \Delta Q_{si}, \qquad (20)$$

where $\Delta Q_{si}(i=1,2,\ldots,n)$ represents the increase in spring runoff from an individual basin. Now impose the restriction that

$$\overline{Q}^*_s = \sum_{i=1}^{n} \alpha_i \overline{Q}_{si} = \sum_{i=1}^{n} \overline{Q}_{si} \qquad (21)$$

where $\overline{Q}^*_s$ is the mean of the Q^*_s values and $\overline{Q}_{si}$ is the mean of the Q_{si} values. Also impose the restriction that $\overline{\Delta Q}^*_s$ is equal to the sum of the $\overline{\Delta Q}_{si}$ values, i.e.,

$$\overline{\Delta Q}^*_s = \sum_{i=1}^{n} \alpha_i \overline{\Delta Q}_{si} = \sum_{i=1}^{n} \overline{\Delta Q}_{si} \ . \qquad (22)$$

Finally the number of years, N*, for evaluation of grouped basins is given by the following expression:

$$N^* = \frac{3.84\sigma^2_{Q^*_s}}{(\overline{\Delta Q}^*_s)^2} = \frac{3.84 \sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij}\alpha_i\alpha_j}{(\overline{\Delta Q}^*_s)^2} \propto \sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij}\alpha_i\alpha_j \qquad (23)$$

where the α_i and α_j are as yet arbitrary but subject to the constraints expressed by equations (21) and (22). Choose the α_i's such that the number of years, N*, is kept to a minimum value. Setting

$$f(\alpha_1, \alpha_2, \ldots, \alpha_n) = \sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij}\alpha_i\alpha_j$$

$$g_1(\alpha_1, \alpha_2, \ldots, \alpha_n) = \sum_{i=1}^{n} (\overline{Q}_{si}\alpha_i) - (\sum_{i=1}^{n} \overline{Q}_{si})$$

$$g_2(\alpha_1, \alpha_2, \ldots, \alpha_n) = \sum_{i=1}^{n} (\overline{\Delta Q}_{si}\alpha_i) - (\sum_{i=1}^{n} \overline{\Delta Q}_{si})$$

a new function is defined

$$F(\alpha_1, \alpha_2 \ldots, \alpha_n, \lambda_1, \lambda_2) = f(\alpha_1, \alpha_2, \ldots, \alpha_n) - \lambda_1 g_1(\alpha_1, \alpha_2, \ldots, \alpha_n) - \lambda_2 g_2(\alpha_1, \alpha_2, \ldots \alpha_n) \ . \qquad (24)$$

The α_i's that make the objective function $F(\alpha_1, \alpha_2, \ldots, \alpha_n)$ in equation (24) minimum give the minimum value for N* in equation (23).

By taking the partial derivative of $F(\alpha_1, \alpha_2, \ldots \alpha_n, \lambda_1, \lambda_2)$ with respect to the α_i's, λ_1, and λ_2 and setting each derivative equal to zero, one obtains the system of equations:

$$\frac{\partial F}{\partial \alpha_k} = \sum_{j=1}^{n} a_{kj}\alpha_j + \sum_{i=1}^{n} a_{ik}\alpha_i - \lambda_1 \overline{Q}_{sk} - \lambda_2 \overline{\Delta Q}_{sk}$$

$$= 2 \sum_{i=1}^{n} a_{ki}\alpha_i - \overline{Q}_{sk}\lambda_1 - \overline{\Delta Q}_{sk}\lambda_2 = 0$$

for k = 1,2,..,n

$$\frac{\partial F}{\partial \lambda_1} = - \sum_{i=1}^{n} \overline{Q}_{si}\alpha_i + (\sum_{i=1}^{n} \overline{Q}_{si}) = 0$$

$$\frac{\partial F}{\partial \lambda_2} = - \sum_{i=1}^{n} \overline{\Delta Q}_{si}\alpha_i + (\sum_{i=1}^{n} \overline{\Delta Q}_{si}) = 0$$

or in matrix notation

$$\begin{bmatrix} 2a_{11} & 2a_{12} & \cdots\cdots & 2a_{1n} & -\overline{Q}_{s1} & -\overline{\Delta Q}_{s1} \\ 2a_{21} & 2a_{22} & \cdots\cdots & 2a_{2n} & -\overline{Q}_{s2} & -\overline{\Delta Q}_{s2} \\ \cdot & \cdot & & \cdot & \cdot & \cdot \\ \cdot & \cdot & & \cdot & \cdot & \cdot \\ \cdot & \cdot & & \cdot & \cdot & \cdot \\ 2a_{n1} & 2a_{n2} & \cdots\cdots & 2a_{nn} & -\overline{Q}_{sn} & -\overline{\Delta Q}_{sn} \\ \overline{Q}_{s1} & \overline{Q}_{s2} & \cdots\cdots & \overline{Q}_{sn} & 0 & 0 \\ \overline{\Delta Q}_{s1} & \overline{\Delta Q}_{s2} & \cdots\cdots & \overline{\Delta Q}_{sn} & 0 & 0 \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \cdot \\ \cdot \\ \cdot \\ \alpha_n \\ \lambda_1 \\ \lambda_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \\ (\sum_{i=1}^{n} \overline{Q}_{si}) \\ (\sum_{i=1}^{n} \overline{\Delta Q}_{si}) \end{bmatrix} \qquad (25)$$

The system of equation (25) is linear and its resolution for the unknown α_i's is obtained by the Gaussian elimination procedure. Thus a procedure is described that objectively selects the optimal group of basins of a given size among a larger set. The procedure also determined the optimal parameters of the combination of runoff variables for minimum time evaluation.

It remains to apply this technique in practice to the Upper Colorado River Basin. Before doing so, Chapter IV describes the data used in the analysis.

Chapter IV

DATA USED FOR THIS STUDY

The data used in this study are winter and spring precipitation and spring runoff. They have to be collected in a certain order and have to satisfy specific criteria. These conditions are discussed in this chapter.

1. Precipitation and runoff in the Upper Colorado Basin.

a. Precipitation records. According to the United States Weather Bureau's "Substation History" (26-30), about 400 stations are found in the Upper Colorado River Basin, including stations with records of storage gage and stations not now in operation. For 312 of these stations, monthly precipitation data were collected from the following sources and recorded on magnetic tapes.

(1) The United States Weather Bureau, "Climatological Data" [31,35]

(2) The United States Weather Bureau, "Climatic Summary of the United States" [36-37]

(3) The United States Weather Bureau, "Climatography of the United States" [38]

(4) The United States Weather Bureau, "Monthly Weather Review" [39]

(5) The United States Department of Agriculture, "Report of the Chief of Weather Bureau" [40]

The characteristics of the precipitation stations are tabulated in Appendix A.

b. Runoff records. As a part of Colorado State University hydrology data system, monthly runoff records have been collected and recorded on magnetic tapes [6,9]. The source of the data is the United States Geological Survey, "Water Supply Papers" [41]. The total number of stations from which data were collected is 749.

c. Hydrologic data system. There is no relationship between the numbering system of runoff stations of the United States Geological Survey and that of precipitation stations of the United States Weather Bureau. For fast data processing and particularly for ease of correlation between precipitation and runoff, it is desirable to have identical or almost identical identification numbers for neighboring precipitation and runoff stations for the entire Upper Colorado River Basin. The Colorado State University numbering system was developed for this purpose:

(1) Runoff stations are coded with seven digit numbers.Runoff stations within the same drainage have an intermediate number between two limiting numbers that characterize the downstream and upstream reach of the drainage area [6].

(2) Precipitation stations are coded with eight digit numbers. The first seven digits are identical to the Colorado State University identification number of the nearest downstream runoff station. However, in some areas there may be several precipitation gages close to a single runoff station. The eighth digit in the station number makes it possible to distinguish between the gages in this situation. The precipitation station closest to the associated runoff station is assigned a zero for its eighth digit. The precipitation station next in proximity is assigned one for its eight digit, and so forth.

2. The accuracy of data measurements. It is well known that the observed precipitation does not necessarily represent the true amount of water that falls over a station or over the surrounding area [42]. However, the precipitation data that correlate highly with runoff data are still useful indices in this study.

3. Non-homogeneity and inconsistency of records. Non-homogeneity and inconsistency of precipitation data are introduced when there is a change in location, exposure, or instrument. Substation History [26-30] and Climatological Data [31-35], both published by the Weather Bureau, show horizontal movement and elevation change. However, the environment and local orography cannot be shown.

Most of the drainage area in the Upper Colorado River Basin has been subjected to transmountain diversion, transbasin diversion, interbasin diversion, regulation by reservoir, and irrigation diversion that causes a non-homogeneity in the runoff data. The information about the first four cases is given in the Water Supply Papers [41] and is used for correction of runoff data on the monthly level [9]. As to irrigation diversion, there is no available record. Furthermore, it is very difficult to estimate seasonable consumptive use and return rate to river. In the high mountain regions, the irrigation allotment is small in amount and is diverted mainly in summer. Correction for irrigation diversion is not done for this reason.

4. Filling missing data. It is necessary to establish a reliable connection between stations having incomplete records and those that are complete. This is done by estimating the missing data from nearby stations with records covering the missing months and having a sufficiently long record which coincides with that of the station with incomplete records. In this study, a simple linear regression method is applied for this purpose.

DATA PROCESSING AND RESULTS

The techniques described in Chapter III are applied by using the data discussed in Chapter IV. The goal of this chapter is to determine the relative suitability of individual basins within the Upper Colorado River Basin and to select the favorable combinations of sub-basins in the two pilot areas.

1. Mean winter precipitation and mean spring runoff.

a. Seasonal and yearly variability of precipitation. The mean and standard deviations of monthly precipitation are computed for 10 stations in the pilot area and are plotted on Fig. 4. The annual and winter precipitation time series are also shown in the same figures. The distribution of monthly precipitation is roughly uniform, on the average, though there are peaks in July and August and a low in June. The coefficients of variation of monthly precipitation are very large though those of annual precipitation are relatively small. The ratios of winter to annual precipitation are around 0.6.

b. Seasonal and annual variability of runoff. The mean and standard deviations of monthly runoff were computed for 18 stations in the pilot areas and are plotted on Fig. 5. The annual and spring runoff time series are also shown in the same figures. These figures illustrate the typical behavior of stations located at a high altitude. An outstanding rise during April through June, a decline in July and August, and steady flow in fall and winter are common to all the watersheds.

Precipitation appears as snow during October through April. During this season, the watersheds are covered with snow and the streams are frozen. As the weather warms up in the spring, the snow pack on the high mountains begins to melt and pours into the streams along with the runoff from spring precipitation. The precipitation that falls during the summer season is stored in the soil, but strong evapotranspiration takes place and summer precipitation does not contribute to runoff to a great extent. This is why runoff displays an extreme seasonal variability compared to the nearly uniform distribution of seasonal precipitation. For this reason, the coefficients of variations of both annual and spring runoff are high for all the stations.

c. Mean winter precipitation. As far as precipitation management in the Upper Colorado River Basin is concerned, mostly the winter precipitation is significant in the application of artificial techniques. As discussed in Section 2 of Chapter III the increase of precipitation is roughly proportional to the natural precipitation. The establishment of zones of equal winter precipitation was attempted over the Upper Colorado River Basin. Though it is desirable to obtain recording years common to all the stations, all those having records of five years or more were used. Figure 7 shows isohyets of 5, 7.5 and 10 inches (very rough and uncorrected for topography).

The names of the watersheds that have a great amount of winter precipitation follow in order:

(1) San Juan Mountains

(2) Upper basin of the Colorado River

(3) Upper reach of the Yampa River and its tributaries

(4) Headwaters of the Rafael River

(5) Upper basins of Uinta River, Lake Fork, and Rock Creek.

d. Mean spring runoff. The increase of precipitation in winter appears as spring runoff. The spring runoff might be a rough indicator for optimal water yield.

Lines of equal spring runoff were drawn and are depicted in Fig. 8. The streams having a great amount of spring runoff, of course, correspond to the watersheds with a large amount of winter precipitation.

2. Relation between precipitation and runoff.

a. Stepwise multiple regression. To determine the coefficients a, b_i, and c_i in equation (11), stepwise multiple regression was used. Its chief advantage is to produce an equation that uses only a small number of prediction variables and that has a comparatively high coefficient of determination [43].

b. Correlation between winter and spring precipitation. For all precipitation stations in the pilot areas the correlation coefficient between winter and spring precipitation was calculated. Table 1 shows no correlation.

TABLE 1 CORRELATION COEFFICIENT, (r), BETWEEN WINTER AND SPRING PRECIPITATION

CSU ID	r
10734360	.04
10734560	.12
10734641	.17
10774000	.30
10778600	.01
12724450	-.04
12724602	-.32
13715600	.58
18036000	-.24
18054000	-.06
18500000	.26
19500000	.24

c. Watershed without precipitation station data available. Though it would be of interest to study the watersheds in the high altitudes, generally there are few, if any, stations there. In this case data from one of the precipitation stations nearby were used to compute the coefficients in equation (11). As long as a good correlation exists, a sufficient forecasting equation can be found.

d. Computation and results. Computation was done for all possible sets of precipitation and runoff having

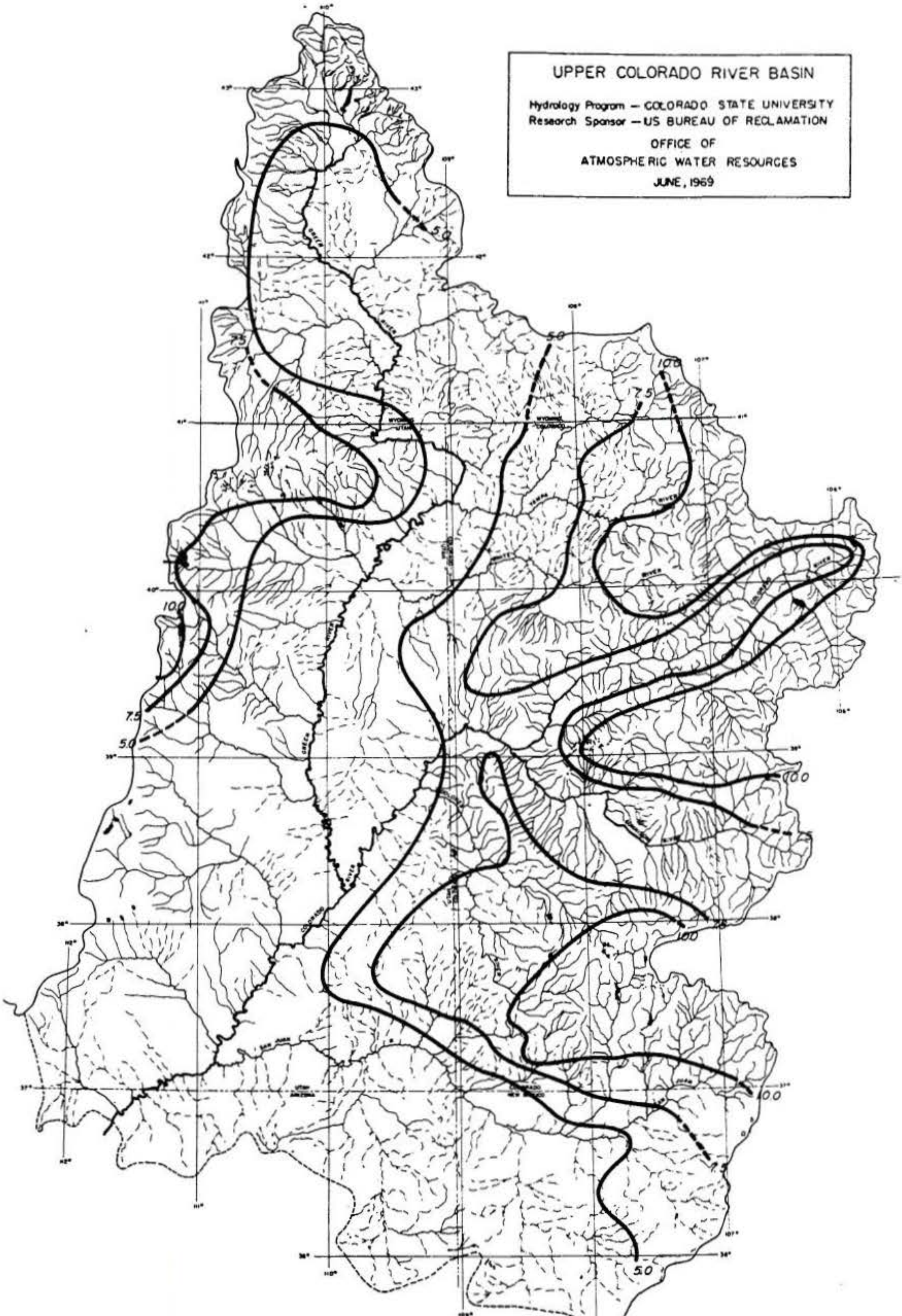

Fig. 7 Mean winter precipitation (in inches)

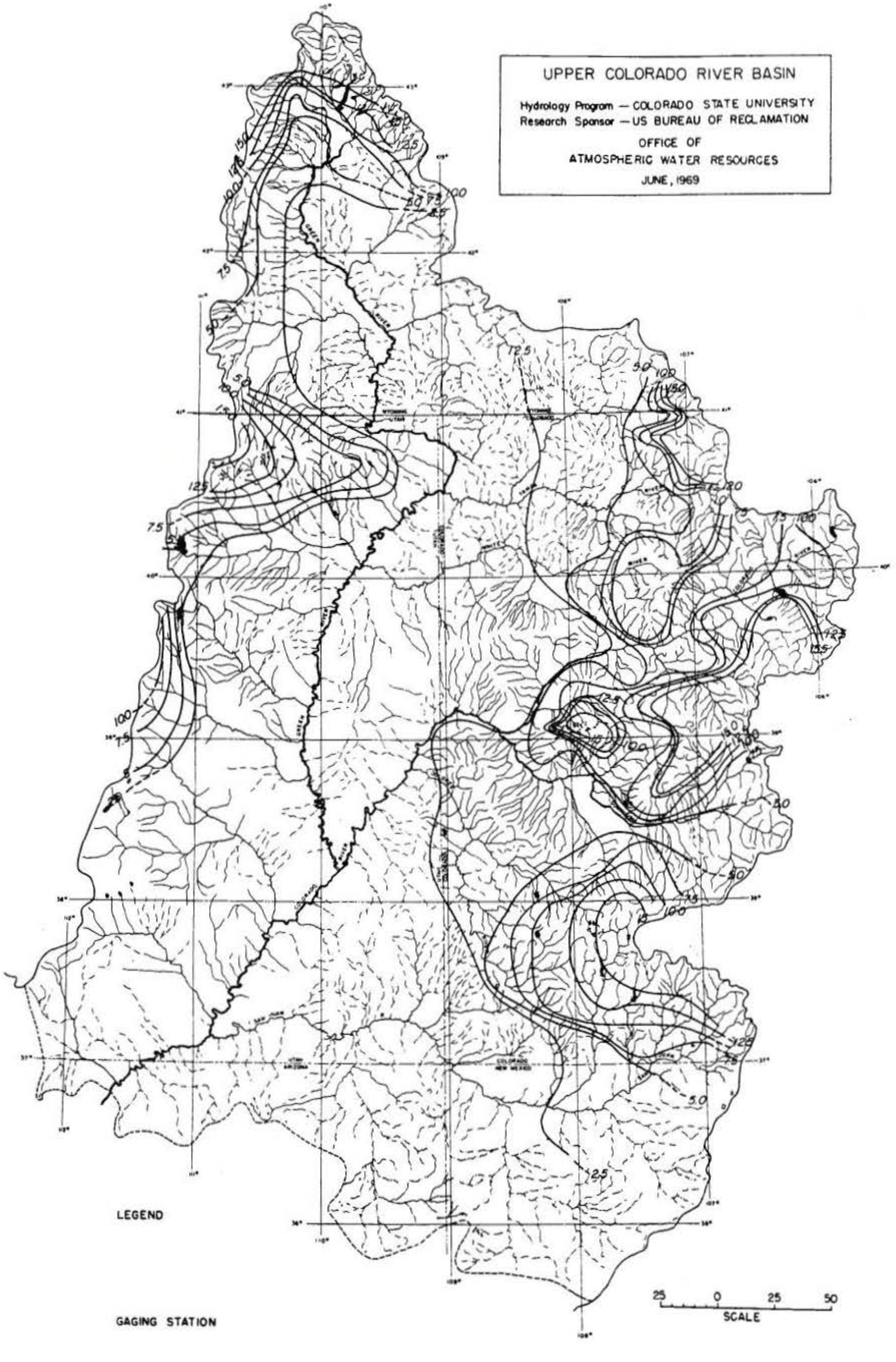

Fig. 8 Mean spring runoff (in inches)

a common recording length. Three hundred and sixty-five sets of these with greater than 0.90 correlation coefficient were used for the calculation of the increase in runoff and of the number of years needed for evaluation (see Appendix B).

3. Increase of runoff. At the present stage, it is impossible to assign scientifically a reasonable value to the relative increase in precipitation, k_i, in equation (7), for each station. A uniform 10 percent increase of winter precipitation over its natural value is assumed for further computation. Then the increase of spring runoff induced by an increase of winter precipitation is, on the average, found from equation (13) in Section 2 of Chapter III.

Here the $\overline{P}_{wi}$ were calculated, not for the common recording length, which was used to find the regression line, but for the whole recording length of each station (see Appendix B).

The computed value of $\overline{\Delta Q_s}$ for every station is plotted on Fig. 9 and rough contour lines of equal increase of spring runoff are shown there.

The names of the watersheds where the greatest increase in runoff is expected follow:

(1) San Juan Mountains,

(2) Upper reach of the Yampa River and its tributaries,

(3) Headwaters of the Green River,

(4) Upper basin of the Colorado River,

(5) Upper basins of Uinta River, Lake Fork, and Rock Creek, and

(6) Headwaters of the Rafael River basin.

These watersheds also have a large amount of natural precipitation and natural spring runoff.

4. Number of years needed for evaluation. Using $\overline{\Delta Q_s}$ calculated in the previous section, the number of years needed for evaluation was computed for each station by equation (16) in Section 3 of Chapter III.

The results are shown in Appendix B and on Fig. 10. The occurrence of aberrant values made it difficult to draw more precise contour lines. This is caused mainly by the fact that the common recording length was not used, and the variability of the data affects the value of N to the second power, compared to the case of $\overline{\Delta Q_s}$ in equation (13).

In general, the value of N are smaller in the high mountain watersheds where the large increase of spring runoff is expected. However, when the size of the watershed becomes quite small the trend sometimes reverses. This seems to occur to the watersheds consisting of sub-basins with different hydrological features and with a smaller variance. The names of the watersheds where the smaller number of years can be expected follow:

(1) Upper reach of the Yampa River and its tributaries,

(2) Headwaters of the Green River,

(3) Upper basin of the Colorado River,

(4) Upper basins of Uinta River, Lake Fork, and Rock Creek, and

(5) San Juan Mountains.

5. Optimized selection of basins in the pilot area.

(a) Runoff stations in the pilot area. Out of 53 stations in the San Juan Mountains and 49 stations in the upper basin of the Colorado River, 15 and 14 stations, respectively, were selected for the study. They gage representative sub-basins and have relatively long records. The locations of the stations and their characteristics are found in Table 2, and on Figs. 6 and 11. The covariance matrix was computed and is shown in Table 3.

(b) Optimized selection of basins. As discussed in Section 3 of Chapter III an attempt was made to find a combination of numbers of sub-basins giving the minimum number of years for evaluation. This was accomplished by solving equation (19) for all possible combinations of two through six stations out of 15 in the San Juan Mountains and out of 14 in the upper basin of the Colorado River. The number of all possible combinations is so large that only those combinations which yield the twenty lowest values of N* are plotted. In Fig. 12, N* is plotted versus the increase of spring runoff and also versus the drainage area. The minimum value in the San Juan Mountains is six and in the upper basin of the Colorado River it is three.

The same calculation was performed setting all the α_i's equal to 1 in equation (17) instead of optimizing the parameters. The results are shown on Fig. 12. The comparison of the results for the two cases demonstrate that the method is effective.

The analysis of the results indicates that several particular sub-basins play a particular important role in making N* small. They are in:

(a) the San Juan Mountains

1077015	Navajo River at Edith
1077250	Rio Blanco near Pagosa Springs
1371555	Uncompahgre River near Ridgway,

and in

(b) the upper basin of the Colorado River

1762500	East Fork Troublesome Creek near Troublesome
1810000	Willow Creek below Willow Creek Reservoir
1930000	North Inlet at Grand Lake.

These stations do not necessarily have a small value of N in Table 2. Table 4 list the optimal combination of gages for group sizes equal to 2, 3, 4, 5 and 6 selected from 15 stations in the San Juan Mountains and from 14 stations in the upper basin of the Colorado River.

The results are very encouraging for evaluation of the pilot projects. The method of optimized grouping of basins brings a very large reduction in the number of years needed to establish significance. One may nevertheless question the method. In other words how sensitive is the method? Could a slight variation in this or that parameter say double the calculated value of N*, quadruple it ... etc?

A complete theoretical answer to the question is not easy. One can however obtain an idea by varying various

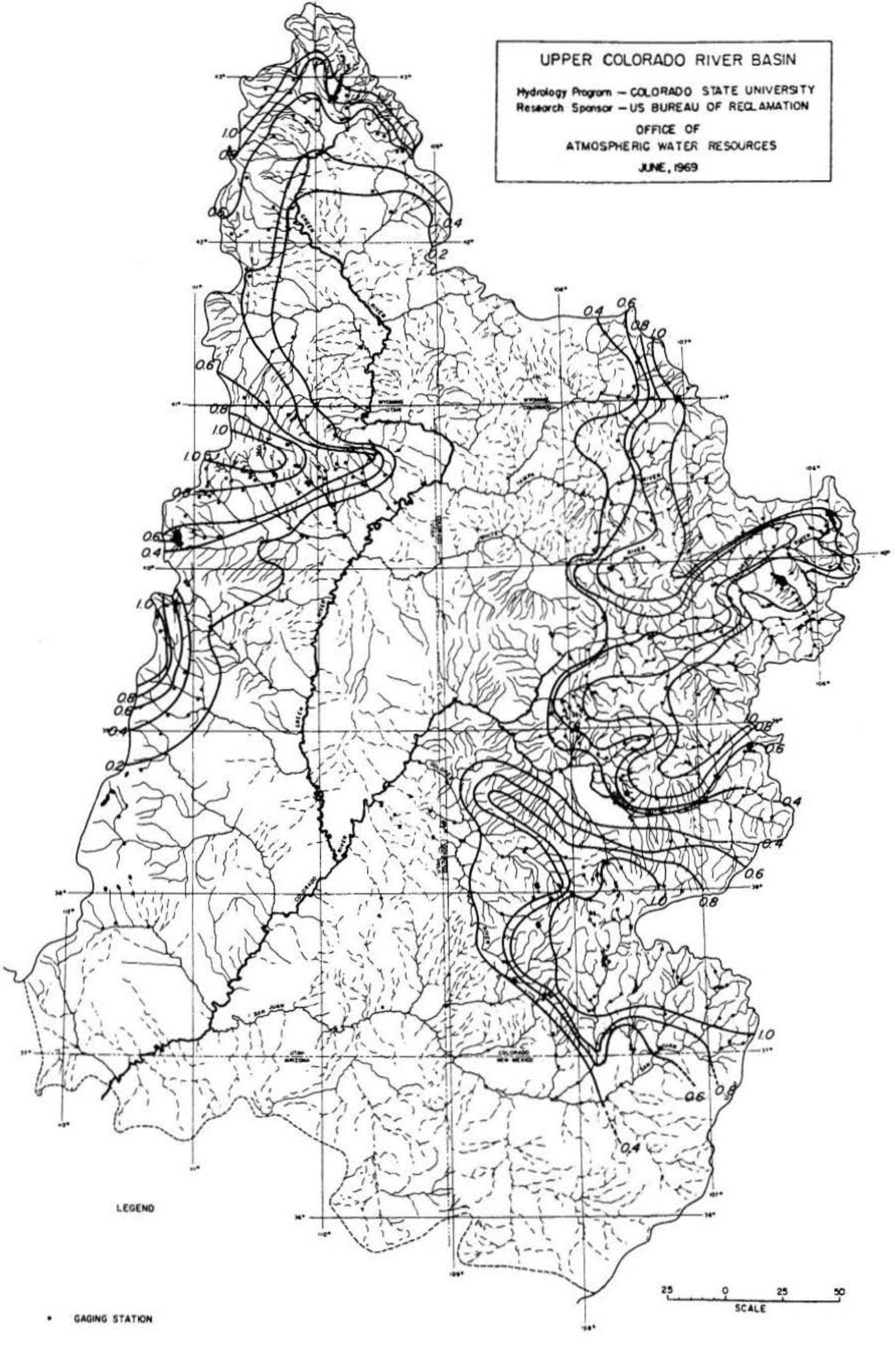

Fig. 9 Expected increase in spring runoff due to a uniform 10% increase in winter precipitation (in inches)

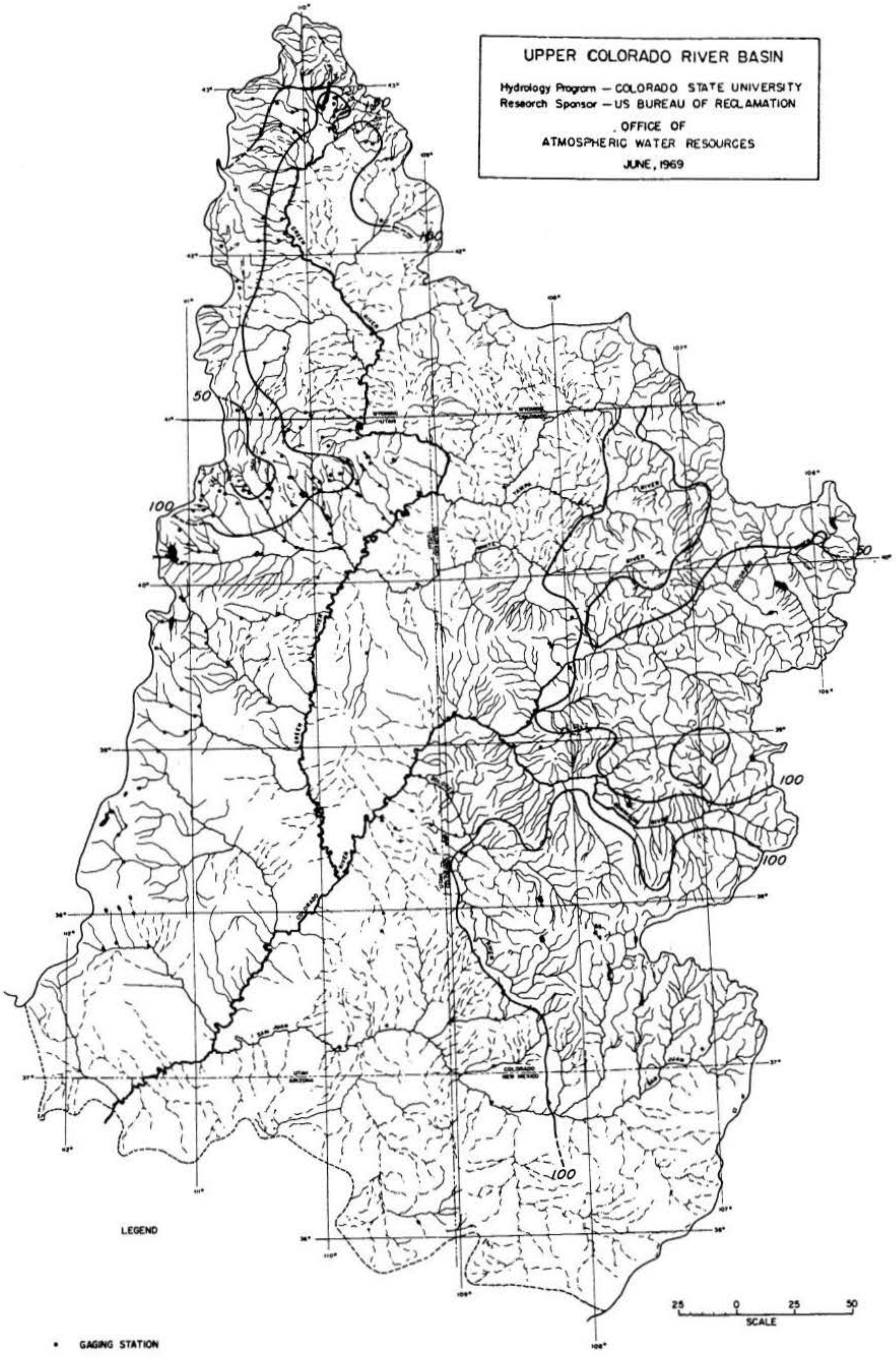

Fig. 10 Number of years needed for evaluation (based on the two-sample u-test)

parameters and observing the changes in the calculated values of N*. Given the value of N* for the optimal group of a given size, how different is the corresponding value for the next best grouping, etc. Tables 5 and 6 show that many combinations will actually give a value of N* close to the optimal.

How sensitive is N* to the values of the weight coefficients α_i? The best 10 ranking groups of size 6 were used for the sensitivity test.

The procedure was to modify 2 weight factors (those corresponding to the first 2 columns of Table 7) by 1, 5 and 10%, keeping these fixed and recalculating the remaining $4\alpha_i$ according to the optimization procedure. The results are shown in Table 7. They indicate that the weight factors can be rounded off without appreciable effects.

How sensitive is N* to the runoff data? The optimal group of size 6 in the Upper Basin of the Colorado was used for this test. It is a test of sensitivity of N* to the sample covariance matrix. The procedure was to select at random 7 years from the total record (1948-1964). The years turned out to be: 1948, 1951, 1954, 1956, 1958, 1960 and 1963. Then runoff data for 3 out of the 7 years were deleted from the entire record. This can be done in 35 ways. For each sample N* was calculated. Table 8 shows the results.

TABLE 2(a) STATION CHARACTERISTICS - THE SAN JUAN MOUNTAINS

CSU ID (U.S.G.S. No.)	Name	Location Latitude Longitude	Elevation feet	Drainage Area mile^2	Recording Length	Continuous Recording Length	Mean (inch) & variance (inch^2)		Ratio of spring to annual runoff	Increase in runoff (inch)	Percentage Increase	Number of years for Evaluation
							Annual	Spring				
1073080 (9.36550)	La Plata River at Hesperus	37 17 20 108 2 5	8105	37.0	1904-64	1917-64	16.70 45.03	13.50 42.81	.81	1.15	8.5	124
1073420 (9.3630)	Florida River near Durango	37 19 40 107 44 40	7302	96.0	1899-60	1927-60	15.13 46.03	12.21 27.39	.81	1.00	8.2	105
1073448 (9.36100)	Hermosa Creek near Hermosa	37 25 30 107 50 20	6706	172.0	1912-64	1940-64	10.95 28.25	8.91 17.53	.81	.98	11.0	70
1073460 (9.35950)	Animas River above Tacoma	37 34 10 107 46 40	7520	348.0	1946-56	1946-56	20.66 45.12	15.91 39.95	.77	1.50	9.4	68
1075830 (9.35350)	Los Pinos River near Bayfield	37 23 0 107 34 30	7515	284.0	1928-64	1928-64	18.55 37.46	12.47 30.11	.67	1.01	8.1	113
1076420 (9.34950)	Piedra River near Piedra	37 14 0 107 20 30	6530	371.0	1912-64	1939-64	11.46 31.16	9.02 18.71	.79	.88	9.7	93
1077015 (9.34600)	Navajo River at Edith	37 0 10 106 54 25	7033	172.0	1913-64	1913-64	12.46 24.65	9.37 13.70	.75	.94	10.0	60
1077200 (9.34350)	Rito Blanco near Pagosa Springs	37 11 40 106 54 20	7330	23.3	1935-52	1935-52	10.74 35.33	9.43 19.81	.88	1.02	11.8	73
1077250 (9.34300)	Rio Blanco near Pagosa Springs	37 12 46 106 47 38	7950	58.0	1935-64	1935-64	19.65 59.20	15.39 46.42	.78	1.31	8.5	104
1077400 (9.34250)	San Juan River at Pagosa Springs	37 15 50 107 0 40	7052	298.0	1911-64	1935-64	16.83 51.86	13.66 38.54	.81	1.46	10.7	69
1272440 (9.17300)	Beaver Creek near Norwood	37 58 0 108 11 0	8008	35.2	1942-64	1963-64	6.55 35.73	5.46 17.89	.83	1.14	20.9	53
1272445 (9.17250)	San Miquel Creek near Placerville	38 2 5 108 7 15	7096	308.0	1909-64	1942-64	10.06 9.66	7.39 8.49	.73	.56	7.5	104
1278800 (9.16500)	Dolores River below Rico	37 38 25 108 3 5	8422	105.0	1952-64	1952-64	16.44 46.04	13.57 14.39	.83	1.57	11.6	22
1371530 (9.14700)	Dallas Creek near Ridgway	38 10 50 107 45 40	6980	96.2	1922-64	1956-64	5.47 4.74	2.94 2.41	.54	.24	7.9	161
1371555 (9.14620)	Uncompahgre River near Ridgway	38 11 5 107 44 40	6878	150.0	1959-64	1959-64	13.49 3.09	9.19 4.10	.68	1.16	12.6	12

TABLE 2(b) STATION CHARACTERISTICS - THE UPPER BASIN OF THE COLORADO RIVER

CSU ID (U.S.G.S. No.)	Name	Location Latitude Longitude	Elevation feet	Drainage Area mile^2	Recording Length	Continuous Recording Length	Mean (inch) & variance (inch^2)		Ratio of spring to annual runoff	Increase in runoff (inch)	Increase Percentage	Number of years for Evaluation
							Annual	Spring				
1762500 (9.0400)	East Fork Troublesome Creek near Troublesome	40 9 27 106 16 58	7750	76.0	1937-64	1954-64	4.95 4.46	4.04 4.32	.82	.31	7.7	173
1800900 (9.0355)	Strawberry Creek near Granby	40 5 10 105 49 30	8650	12.6	1936-45	1936-45	6.92 4.57	5.71 3.90	.83	.51	8.9	57
1801800 (9.0330)	Meadow Creek near Tabernash	40 2 55 105 46 30	9780	7.0	1936-56	1936-56	20.92 23.66	19.00 65.24	.91	1.39	7.3	181
1801816 (9.0320)	Ranch Creek near Fraser	39 57 0 105 45 54	8670	19.9	1934-64	1934-64	11.30 26.92	8.98 26.92	.80	.65	16.3	245
1802730 (9.0265)	St. Louis Creek near Fraser	39 54 30 105 52 45	8980	32.8	1934-64	1934-64	12.99 19.95	9.27 16.18	.71	.66	7.1	143
1804500 (9.0250)	Vasquez Creek near Winter Park	39 55 13 105 47 5	8769	27.8	1907-64	1934-64	7.10 24.21	5.05 12.00	.71	.75	14.9	81
1805400 (9.0240)	Frazer River near Winter Park	39 54 0 105 46 35	8900	27.6	1911-64	1911-64	14.84 64.70	10.99 23.74	.74	.26	2.4	1349
1810000 (9.0210)	Willow Creek below Willow Creek Res.	40 8 45 105 56 22	8024	134.0	1953-64	1953-64	4.08 10.84	2.72 6.39	.67	.55	20.2	81
1850000 (9.0180)	Stillwater Creek above Lake Granby	40 11 20 105 53 40	8310	18.8	1950-56	1950-56	7.45 9.35	6.42 3.24	.86	.85	13.3	17
1866000 (9.0165)	Arapaho Creek at Monarch Outlet	40 6 45 105 44 57	8310	47.1	1945-64	1945-64	23.79 24.78	19.94 22.98	.84	1.52	7.7	38
1880000 (9.0155)	Columbine Creek above Lake Granby	40 11 20 105 49 0	8282	7.3	1950-56	1950-56	12.56 22.39	10.36 88.21	.83	.95	9.2	375
1920000 (9.0135)	East Inlet near Grand Lake	40 14 20 105 48 0	8371	27.1	1948-56	1948-56	21.77 26.62	18.83 29.28	.87	1.57	8.3	46
1930000 (9.0115)	North Inlet at at Grand Lake	40 15 0 105 49 50	8380	46.6	1950-56	1950-56	19.99 30.44	16.89 17.31	.84	1.36	8.1	36
1960000 (9.0110)	Colorado River near Grand Lake	40 13 8 105 51 25	8380	103.0	1904-64	1934-64	15.17 25.34	12.28 12.11	.81	.92	7.5	55

TABLE 3 COVARIANCE MATRIX (Calculated for data within the period 1948 - 1964)

(a) The San Juan Mountains

CSU ID	1073080	1073420	1073448	1073460	1075830	1076420	1077015	1077200	1077250	1077400	1272440	1272445	1278800	1371530	1371555
1073080	40.30	31.28	24.93	37.18	31.87	25.39	22.28	23.,1	39.75	36.61	23.74	16.00	36.39	6.05	23.92
1073420	31.28	27.21	20.85	31.51	27.48	21.69	17.42	19.02	30.35	30.27	19.16	13.57	29.98	5.08	19.96
1073448	24.93	20.85	16.53	24.56	21.14	16.88	14.02	15.22	24.31	23.54	15.38	10.68	23.72	3.93	15.68
1073460	37.18	31.51	24.56	37.69	32.08	25.32	21.26	22.82	37.40	35.83	23.66	16.32	36.09	6.09	23.72
1075830	31.87	27.48	21.14	32.08	28.40	22.08	17.94	19.64	31.81	31.30	19.54	13.49	30.75	5.14	19.90
1076420	25.39	21.69	16.88	25.32	22.08	17.65	14.24	15.50	24.69	24.79	15.47	10.65	24.28	3.91	15.63
1077015	22.28	17.42	14.02	21.26	17.94	14.24	12.94	13.66	23.15	20.63	14.16	9.20	20.94	3.42	13.62
1077200	23.71	19.02	15.22	22.82	19.64	15.50	13.66	15.00	24.48	22.36	14.82	9.94	22.34	3.65	14.81
1077250	39.75	30.35	24.31	37.40	31.81	24.69	23.15	24.48	43.78	37.31	24.78	16.10	37.38	6.39	24.66
1077400	36.61	30.27	23.54	35.83	31.30	24.79	20.63	22.36	37.31	36.38	21.84	14.67	34.75	5.57	22.12
1272440	23.74	19.16	15.38	23.66	19.54	15.47	14.16	14.82	24.78	21.84	16.88	10.93	23.51	4.04	15.95
1272445	16.00	13.57	10.68	16.32	13.49	10.65	9.20	9.94	16.10	14.67	10.93	8.01	16.03	2.98	11.55
1278800	36.39	29.98	23.72	36.09	30.75	24.28	20.94	22.34	37.38	34.75	23.51	16.03	35.71	6.06	23.56
1371530	6.05	5.08	3.93	6.09	5.14	3.91	3.42	3.65	6.39	5.57	4.04	2.98	6.06	1.28	4.49
1371555	23.92	19.96	15.68	23.72	19.90	15.63	13.62	14.81	24.66	22.12	15.95	11.55	23.56	4.49	17.78

(b) The Upper Basin of the Colorado River

CSU ID	1762500	1800900	1801800	1801816	1802730	1804500	1805400	1810000	1850000	1866000	1880000	1920000	1930000	1960000
1762500	5.77	4.80	16.72	10.23	5.88	6.72	8.57	3.78	4.48	9.66	8.22	11.72	9.11	7.66
1800900	4.80	4.50	14.17	8.53	4.46	5.41	8.19	3.30	3.89	9.41	7.44	10.68	7.98	6.95
1801800	16.72	14.17	63.77	34.20	23.68	19.52	27.44	11.46	13.49	30.11	25.04	37.86	30.37	23.21
1801816	10.23	8.53	34.20	25.32	16.47	14.22	19.65	5.43	8.11	18.55	14.61	20.57	17.56	14.03
1802730	5.88	4.46	23.68	16.47	15.26	9.21	10.82	2.40	4.82	10.90	7.51	11.03	10.90	7.39
1804500	6.72	5.41	19.52	14.22	9.21	11.32	12.72	4.58	4.86	11.14	8.91	12.32	9.82	8.36
1805400	8.57	8.19	27.43	19.65	10.82	12.72	22.40	6.02	6.19	17.92	13.07	18.70	14.19	12.10
1810000	3.78	3.30	11.46	5.43	2.40	4.58	6.02	5.24	2.80	5.82	5.86	9.05	5.90	5.41
1850000	4.48	3.89	13.49	8.11	4.82	4.86	6.19	2.80	2.80	---	---	---	---	---
1866000	9.66	9.41	30.11	18.55	10.90	11.14	17.92	5.82	---	21.68	---	---	---	---
1880000	8.22	7.44	25.04	14.61	7.51	8.91	13.07	5.86	---	---	12.89	---	---	---
1920000	11.72	10.68	37.86	20.57	11.03	12.32	18.70	9.05	---	---	---	27.62	---	---
1930000	9.11	7.98	30.39	17.56	10.90	9.82	14.19	5.90	---	---	---	---	16.33	---
1960000	7.66	6.95	23.21	14.03	7.39	8.36	12.10	5.41	---	---	---	---	---	11.42

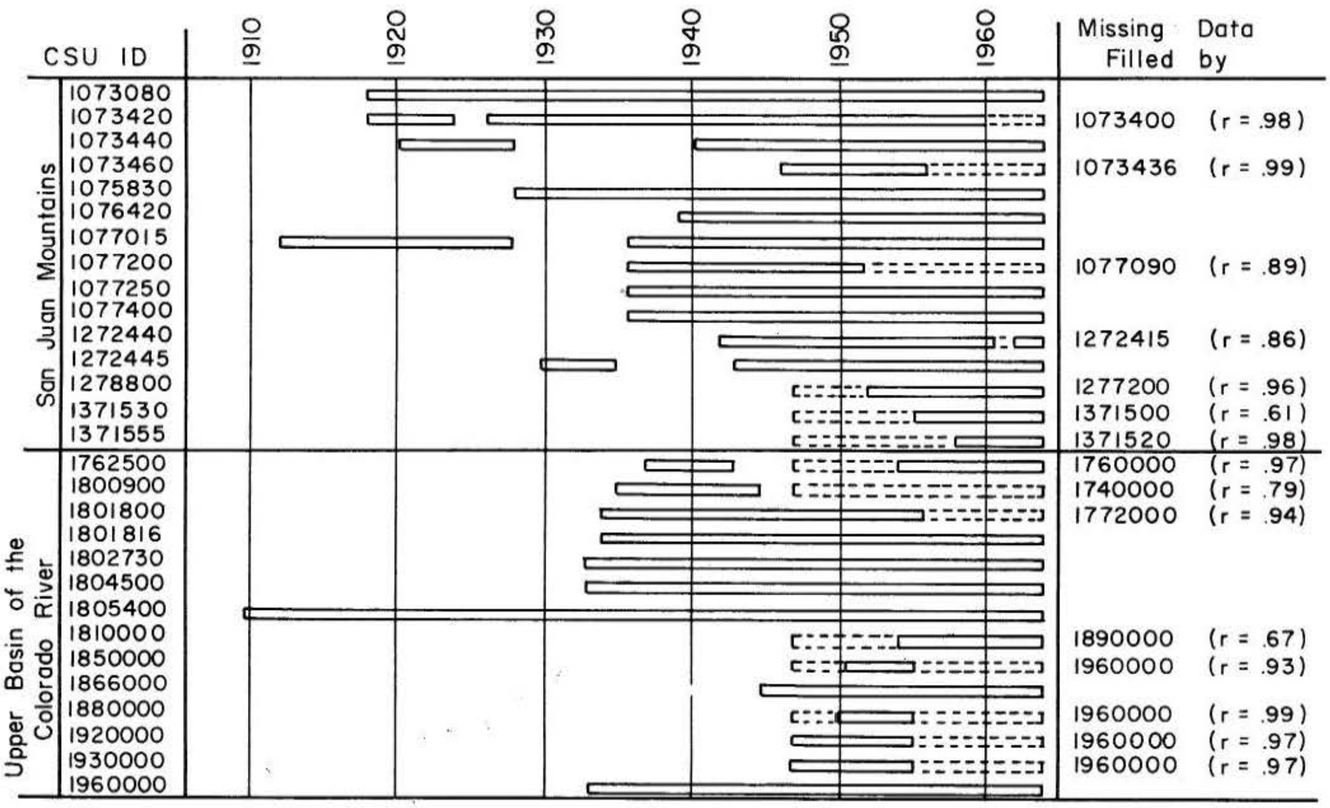

Fig. 11 Length of runoff records in the pilot area

TABLE 4(a) OPTIMAL COMBINATIONS OF GAGES FOR VARIOUS GROUP SIZES IN THE SAN JUAN MOUNTAINS

Number of Sub-basins in Combination	CSU ID	Name	Weight Factor α	Number of Years Needed for Evaluation
1	1371555	Uncompahgre River near Ridgway	1.00	12
2	1272440	Beaver Creek near Norwood	1.00	53
	1371555	Uncompahgre River near Ridgway	1.00	
3	1073080	La Plata River at Hesperus	-9.41	23
	1077015	Navajo River at Edith	4.68	
	1272440	Beaver Creek near Norwood	-2.78	
4	1073080	La Plata River at Hesperus	-9.90	16
	1077015	Navajo River at Edith	8.18	
	1077250	Rio Blanco near Pagosa Springs	-4.27	
	1272440	Beaver Creek near Norwood	-6.38	
5	1073080	La Plata River at Hesperus	-15.13	11
	1077015	Navajo River at Edith	10.80	
	1077250	Rio Blanco near Pagosa Springs	- 6.61	
	1272440	Beaver Creek near Norwood	-11.67	
	1371555	Uncompahgre River near Ridgway	2.09	
6	1076420	Piedra River near Piedra	-7.49	6.1
	1077015	Navajo River at Edith	24.55	
	1077250	Rio Blanco near Pagosa Springs	-32.45	
	1077400	San Juan River at Pagosa Springs	5.31	
	1272440	Beaver Creek near Norwood	-23.36	
	1371530	Dallas Creek near Ridgway	27.38	

TABLE 4(b) OPTIMAL COMBINATIONS OF GAGES FOR VARIOUS GROUP SIZES IN THE UPPER BASIN OF THE COLORADO RIVER

Number of Sub-basins in Combination	CSU ID	Name	Weight Factor α	Number of Years Needed for Evaluation
1	1850000	Stillwater Creek above Lake Grandby	1.0	17
2	1800900	Strawberry Creek near Grandby	1.0	32
	1850000	Stillwater Creek above Lake Granby	1.0	
3	1762500	East Fork Troublesome Creek near Troublesome	-2.38	8.2
	1804500	Vasquez Creek near Winter Park	.59	
	1930000	North Inlet at Grand Lake	2.39	
4	1762500	East Fork Troublesome Creek near Troublesome	-1.83	6.0
	1801800	Meadow Creek near Tabernash	-4.00	
	1804500	Vasquez Creek near Winter Park	.14	
	1930000	North Inlet at Grand Lake	3.10	
5	1762500	East Fork Troublesome Creek near Troublesome	-3.60	3.8
	1801800	Meadow Creek near Tabernash	-6.99	
	1804500	Vasquez Creek near Winter Park	2.67	
	1810000	Willow Creek near Winter Park	.34	
	1930000	North Inlet at Grand Lake	4.15	
6	1762500	East Fork Troublesome Creek near Troublesome	-3.37	2.9
	1801800	Meadow Creek near Tabernash	-5.45	
	1801816	Ranch Creek near Frazer	-2.31	
	1804500	Vasquez Creek near Winter Park	3.60	
	1810000	Willow Creek below Willow Creek Reservoir	.07	
	1930000	North Inlet at Grand Lake	4.51	

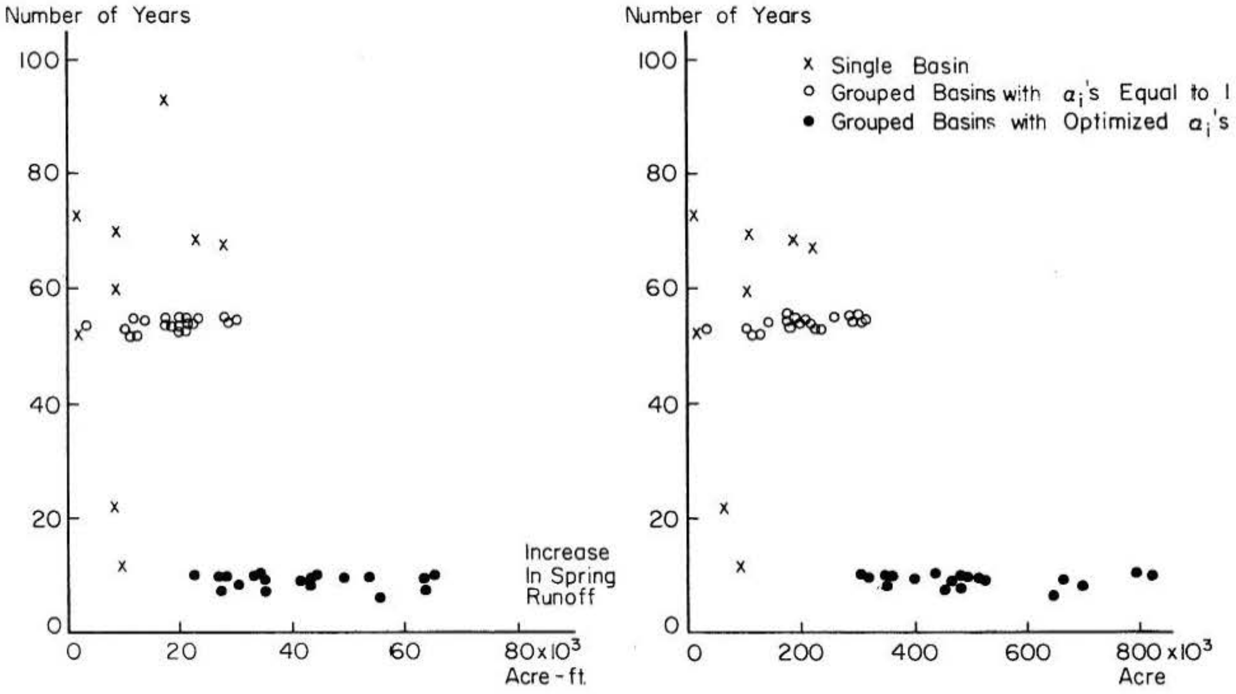

Fig. 12(a) Minimum number of years needed for evaluation for combinations of two through six sub-basins out of 15 in the San Juan Mountains

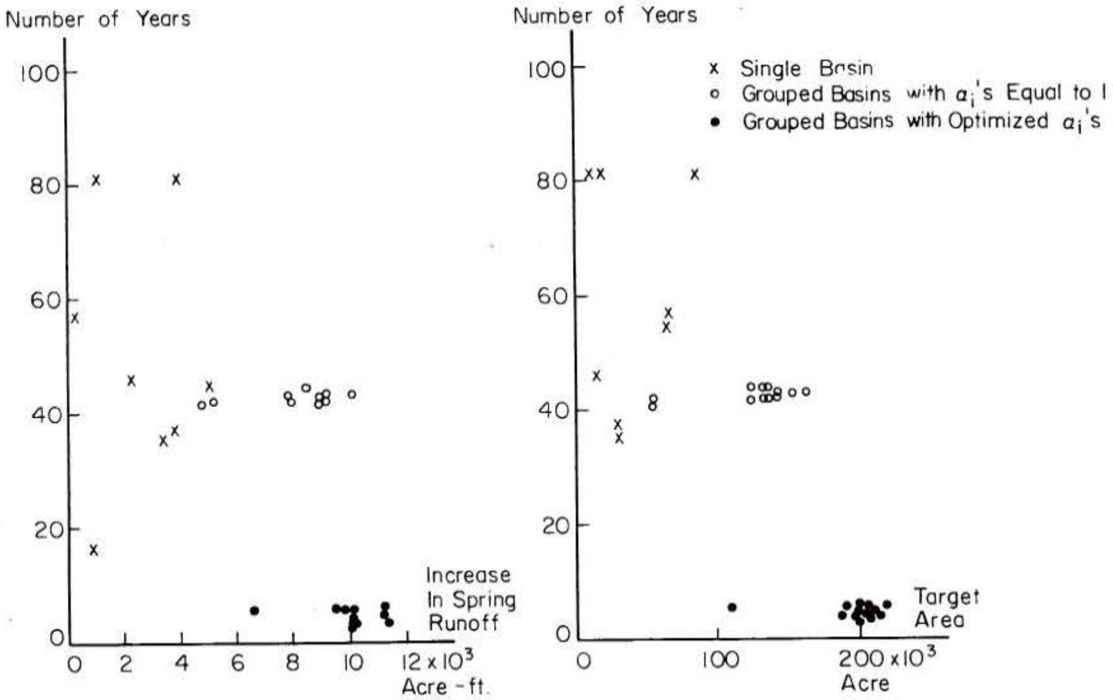

Fig. 12(b) Minimum number of years needed for evaluation for combinations of two through six sub-basins out of 14 in the Upper Basin of the Colorado River

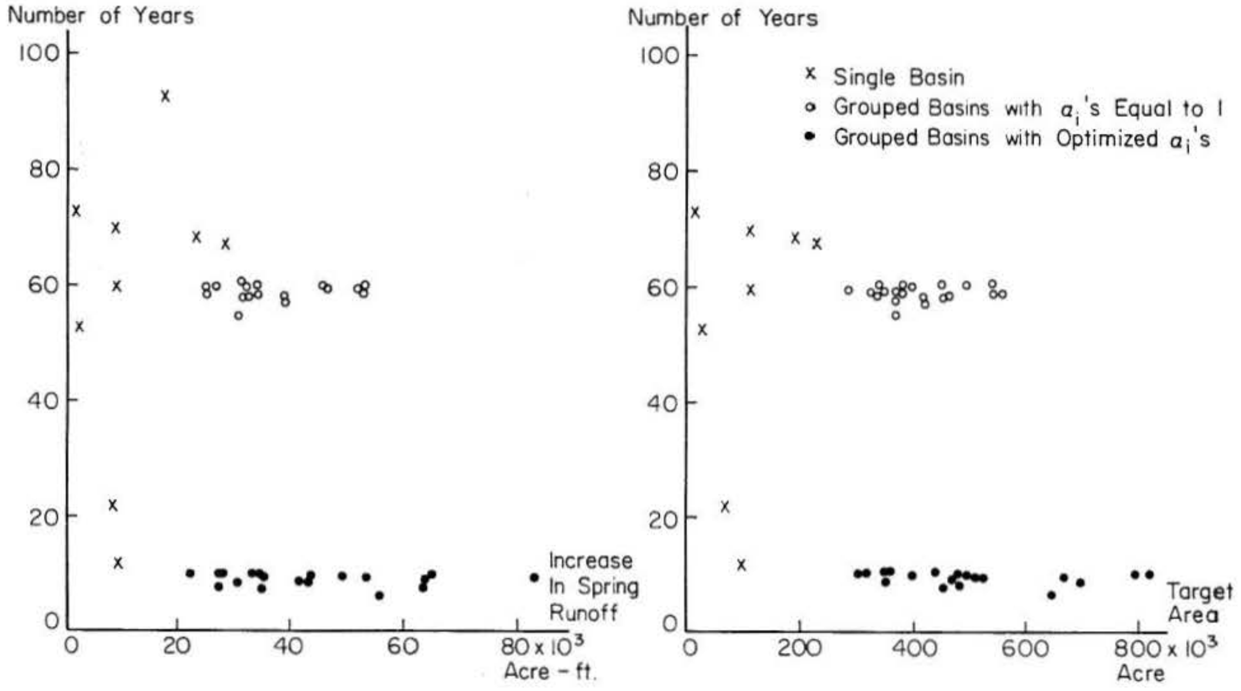

Fig. 12(c) Minimum number of years needed for evaluation for combinations of six sub-basins out of 15 in the San Juan Mountains

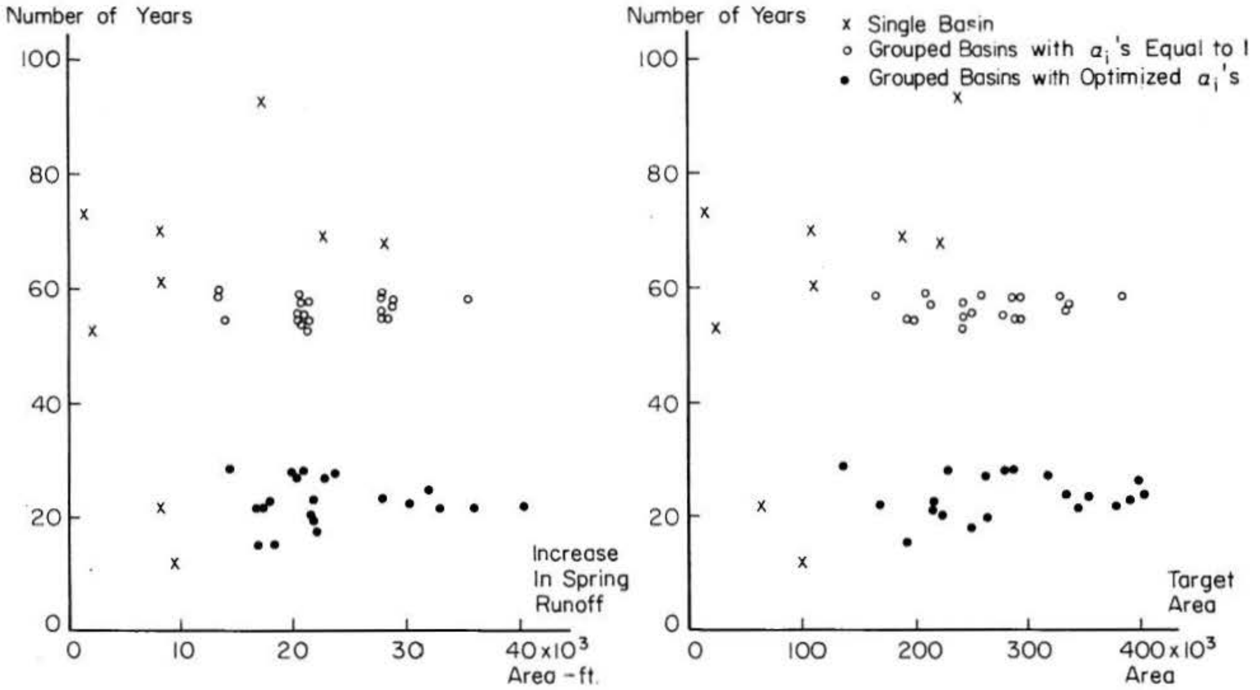

Fig. 12(d) Minimum number of years needed for evaluation for combinations of four sub-basins out of 15 in the San Juan Mountains

TABLE 5(a) 10 BEST COMBINATIONS OF SIX SUB-BASINS IN THE SAN JUAN MOUNTAINS

Rank	Number of Years for Evaluation	α_i	CSU ID	Station Name	Elevation (feet)	Length of Records (years)
1	6.1	- 7.49	1076420	Piedra River near Piedra	6530	26
		24.55	1077015	Navajo River at Edith	7033	45
		-32.45	1077250	Rio Blanco near Pagosa Springs	7950	29
		5.31	1077400	San Juan River at Pagosa Springs	7052	29
		-23.36	1272440	Beaver Creek near Norwood	8008	22
		27.38	1371530	Dallas Creek near Ridgway	6980	14
2	7.7	-14.54	1073080	La Plata River at Hesperus	8105	48
		14.38	1077015	Navajo River at Edith	7033	45
		- 9.90	1077250	Rio Blanco near Pagosa Springs	7950	29
		-14.46	1272440	Beaver Creek near Norwood	8008	22
		- 1.71	1272445	San Miguel Creek near Placerville	7096	28
		18.90	1371530	Dallas Creek near Ridgway	6980	14
3	7.7	-18.86	1073080	La Plata River at Hesperus	8105	48
		16.25	1077015	Navajo River at Edith	7033	45
		- 9.13	1077250	Rio Blanco near Pagosa Springs	7950	29
		-24.72	1272440	Beaver Creek near Norwood	8008	22
		- 1.31	1272445	San Miguel Creek near Placerville	7096	28
		4.33	1371555	Uncompahgre River near Ridgway	6878	6
4	7.9	- 7.37	1076420	Piedra River near Piedra	6530	26
		27.02	1077015	Navajo River at Edith	7033	45
		-31.10	1077250	Rio Blanco near Pagosa Springs	7950	29
		4.70	1077400	San Juan River at Pagosa Springs	7052	29
		-37.00	1272440	Beaver Creek near Norwood	8008	22
		6.06	1371555	Uncompahgre River near Ridgway	6878	6
5	8.4	-14.10	1073080	La Plata River at Hesperus	8105	48
		- 2.32	1073420	Florida River near Durango	7302	42
		14.00	1077015	Navajo River at Edith	7033	45
		- 8.93	1077250	Rio Blanco near Pagosa Springs	7950	29
		-18.16	1272440	Beaver Creek near Norwood	8008	22
		3.21	1371555	Uncompahgre River near Ridgway	6878	6
6	9.0	-20.93	1073080	La Plata River at Hesperus	8105	48
		- .88	1076420	Piedra River near Piedra	6530	26
		19.45	1077015	Navajo River at Edith	7033	45
		-12.54	1077250	Rio Blanco near Pagosa Springs	7950	29
		-21.47	1272440	Beaver Creek near Norwood	8008	22
		3.84	1371555	Uncompahgre River near Ridgway	6878	6
7	9.0	-22.05	1073080	La Plata River at Hesperus	8105	48
		- .59	1075830	Los Pinos River near Bayfield	7515	37
		18.85	1077015	Navajo River at Edith	7033	45
		-10.73	1077250	Rio Blanco near Pagosa Springs	7950	29
		-25.03	1272440	Beaver Creek near Norwood	8008	22
		3.80	1371555	Uncompahgre River near Ridgway	6878	6
8	9.1	- 8.36	1076420	Piedra River near Piedra	6530	26
		24.17	1077015	Navajo River at Edith	7033	45
		-30.86	1077250	Rio Blanco near Pagosa Springs	7950	29
		3.54	1077400	San Juan River at Pagosa Springs	7052	29
		-42.16	1272440	Beaver Creek near Norwood	8008	22
		15.30	1278800	Dolores River below Rico	8422	13
9	9.3	-29.89	1073080	La Plata River at Hesperus	8105	48
		- .70	1073460	Animas River above Tacoma	7520	11
		25.30	1077015	Navajo River at Edith	7033	45
		-14.72	1077250	Rio Blanco near Pagosa Springs	7950	29
		-30.20	1272440	Beaver Creek near Norwood	8008	22
		5.11	1371555	Uncompahgre River near Ridgway	6878	6
10	9.4	-16.80	1073080	La Plata River at Hesperus	8105	48
		1.95	1073448	Hermosa Creek near Hermosa	6706	36
		15.71	1077015	Navajo River at Edith	7033	45
		-10.69	1077250	Rio Blanco near Pagosa Springs	7950	29
		-14.95	1272440	Beaver Creek near Norwood	8008	22
		3.32	1371555	Uncompahgre River near Ridgway	6878	6

TABLE 5(b) 10 BEST COMBINATIONS OF FIVE SUB-BASINS IN THE SAN JUAN MOUNTAINS

Rank	Number of Years for Evaluation	α_i	CSU ID	Station Name	Elevation (feet)	Length of Records (years)
1	11	-15.13	1073080	La Plata River at Hesperus	8105	48
		10.80	1077015	Navajo River at Edith	7033	45
		- 6.61	1077250	Rio Blanco near Pagosa Springs	7950	29
		-11.67	1272440	Beaver Creek near Norwood	8008	22
		2.09	1371555	Uncompahgre River near Ridgway	6878	6
2	12	-10.93	1073080	La Plata River at Hesperus	8105	48
		8.36	1077015	Navajo River at Edith	7033	45
		- 5.41	1077250	Rio Blanco near Pagosa Springs	7950	29
		- 6.39	1272440	Beaver Creek near Norwood	8008	22
		5.36	1371530	Dallas Creek near Ridgway	6980	14
3	14	-15.75	1073080	La Plate River at Hesperus	8105	48
		10.42	1077015	Navajo River at Edith	7033	45
		- 6.26	1077250	Rio Blanco near Pagosa Springs	7950	29
		-11.30	1272440	Beaver Creek near Norwood	8008	22
		2.42	1278800	Dolores River below Rico	8422	13
4	14	- 4.05	1076420	Piedra River near Piedra	6530	26
		15.22	1077015	Navajo River at Edith	7033	45
		-18.47	1077250	Rio Blanco near Pagosa Springs	7950	29
		-26.12	1272440	Beaver Creek near Norwood	8008	22
		12.62	1278800	Dolores River below Rico	8422	13
5	15	-24.66	1073080	La Plata River at Hesperus	8105	48
		.65	1077400	San Juan River at Pagosa Springs	7052	29
		17.77	1077015	Navajo River at Edith	7033	45
		- 9.91	1077250	Rio Blanco near Pagosa Springs	7950	29
		-14.96	1272440	Beaver Creek near Norwood	8008	22
6	15	--10.73	1073080	La Plata River at Hesperus	8105	48
		8.07	1077015	Navajo River at Edith	7033	45
		5.34	1077200	Rito Blanco near Pagosa Springs	7330	17
		- 4.51	1077250	Rio Blanco near Pagosa Springs	7950	29
		- 7.20	1272440	Beaver Creek near Norwood	8008	22
7	15	- 5.21	1073420	Florida River near Durango	7302	42
		12.53	1077015	Navajo River at Edith	7033	45
		-11.73	1077250	Rio Blanco near Pagosa Springs	7950	29
		-18.43	1272440	Beaver Creek near Norwood	8008	22
		3.75	1371555	Uncompahgre River near Ridgway	6878	6
8	15	-15.90	1073080	La Plata River at Hesperus	8105	48
		.50	1073448	Hermosa Creek near Hermosa	6706	36
		11.84	1077015	Navajo River at Edith	7033	45
		- 6.03	1077250	Rio Blanco near Pagosa Springs	7950	29
		- 9.35	1272440	Beaver Creek near Norwood	8008	22
9	15	-18.36	1073080	La Plata River at Hesperus	8105	48
		- .33	1076420	Piedra River near Piedra	6530	26
		17.13	1077015	Navajo River at Edith	7033	45
		- 9.21	1077250	Rio Blanco near Pagosa Springs	7950	29
		-13.26	1272440	Beaver Creek near Norwood	8008	22
10	16	- 6.00	1076420	Piedra River near Piedra	6530	26
		25.83	1077015	Navajo River at Edith	7033	45
		-26.41	1077250	Rio Blanco near Pagosa Springs	7950	29
		4.11	1077400	San Juan River at Pagosa Springs	7052	29
		-23.92	1272440	Beaver Creek near Norwood	8008	22

TABLE 5(c) 10 BEST COMBINATIONS OF FOUR SUB-BASINS IN THE SAN JUAN MOUNTAINS

Rank	Number of Years for Evaluation	α_i	CSU ID	Station Name	Elevation (feet)	Length of Records (years)
1	16	- 9.90	1073080	La Plata River at Hesperus	8105	48
		8.18	1077015	Navajo River at Edith	7033	45
		- 4.27	1077250	Rio Blanco near Pagosa Springs	7950	29
		- 6.38	1272440	Beaver Creek near Norwood	8008	22
2	18	-16.03	1073080	La Plata River at Hesperus	8105	48
		6.57	1077015	Navajo River at Edith	7033	45
		- 6.34	1272440	Beaver Creek near Norwood	8008	22
		1.68	1371555	Uncompahgre River near Ridgway	6878	6
3	20	-18.25	1073080	La Plata River at Hesperus	8105	48
		1.93	1073448	Hermosa Creek near Hermosa	6706	36
		6.99	1077015	Navajo River at Edith	7033	45
		- 6.64	1272440	Beaver Creek near Norwood	8008	22
4	21	-16.41	1073080	La Plata River at Hesperus	8105	48
		6.22	1077015	Navajo River at Edith	7033	45
		- 6.60	1272440	Beaver Creek near Norwood	8008	22
		2.22	1278800	Dolores River below Rico	8422	13
5	22	-27.61	1073080	La Plata River at Hesperus	8105	48
		11.91	1077015	Navajo River at Edith	7033	45
		.66	1077400	San Juan River at Pagosa Springs	7052	29
		- 8.94	1272440	Beaver Creek near Norwood	8008	22
6	22	-10.69	1073080	La Plata River at Hesperus	8105	48
		4.87	1077015	Navajo River at Edith	7033	45
		- 2.92	1272440	Beaver Creek near Norwood	8008	22
		2.26	1371530	Dallas Creek near Ridgway	6980	14
7	22	-10.39	1073080	La Plata River at Hesperus	8105	48
		4.38	1077015	Navajo River at Edith	7033	45
		6.10	1077200	Rito Blanco near Pagosa Springs	7330	17
		- 3.55	1272440	Beaver Creek near Norwood	8008	22
8	22	-31.32	1073080	La Plata River at Hesperus	8105	48
		.68	1073460	Animas River above Tacoma	7520	11
		13.57	1077015	Navajo River at Edith	7033	45
		-11.23	1272440	Beaver Creek near Norwood	8008	22
9	23	-23.64	1073080	La Plata River at Hesperus	8105	48
		.34	1076420	Piedra River near Piedra	6530	26
		11.10	1077015	Navajo River at Edith	7033	45
		- 8.22	1272440	Beaver Creek near Norwood	8008	22
10	23	14.41	1073080	La Plata River at Hesperus	8105	48
		.67	1073420	Florida River near Durango	7302	42
		6.73	1077015	Navajo River at Edith	7033	45
		- 4.93	1272440	Beaver Creek near Norwood	8008	22

TABLE 5(d) 10 BEST COMBINATIONS OF THREE SUB-BASINS IN THE SAN JUAN MOUNTAINS

Rank	Number of Years for Evaluation	α_i	CSU ID	Station Name	Elevation (feet)	Length of Records (years)
1	23	- 9.41	1073080	La Plata River at Hesperus	8105	48
		4.68	1077015	Navajo River at Edith	7033	45
		- 2.78	1272440	Beaver Creek near Norwood	8008	22
2	34	-16.81	1073420	Florida River near Durango	7302	42
		5.17	1073460	Animas River above Tacoma	7520	11
		-10.74	1272440	Beaver Creek near Norwood	8008	22
3	34	- 9.42	1073080	La Plata River at Hesperus	8105	48
		7.41	1077015	Navajo River at Edith	7033	45
		- 2.60	1278800	Dolores River below Rico	8422	13
4	34	5.53	1077015	Navajo River at Edith	7033	45
		- 6.18	1077250	Rio Blanco near Pagosa Springs	7950	29
		- 3.67	1272440	Beaver Creek near Norwood	8008	22
5	35	- 2.72	1073080	La Plata River at Hesperus	8105	48
		11.38	1077200	Rito Blanco near Pagosa Spring	7330	17
		- 1.21	1272440	Beaver Creek near Norwood	8008	22
6	37	- 8.35	1073080	La Plata River at Hesperus	8105	48
		5.59	1077015	Navajo River at Edith	7033	45
		- .98	1371555	Uncompahgre River near Ridgway	6787	6
7	38	6.28	1073460	Animas River above Tacoma	7520	11
		- 6.39	1075830	Los Pinos River near Bayfield	7515	37
		-14.81	1272440	Beaver Creek near Norwood	8008	22
8	39	- 6.18	1073080	La Plata River at Hesperus	8105	48
		- 5.11	1272440	Beaver Creek near Norwood	8008	22
		4.34	1278800	Dolores River below Rico	8422	13
9	39	6.16	1073460	Animas River above Tacoma	7520	11
		-10.55	1076420	Piedra River near Piedra	6530	26
		3.47	1077400	San Juan River at Pagosa Spring	7052	29
10	41	-12.38	1073080	La Plata River at Hesperus	8105	48
		5.55	1073460	Animas River above Tacoma	7520	11
		- 4.54	1076420	Piedra River near Piedra	6530	26

TABLE 5(e) 10 BEST COMBINATIONS OF TWO SUB-BASINS IN THE SAN JUAN MOUNTAINS

Rank	Number of Years for Evaluation	α_i	CSU ID	Station Name	Elevation (feet)	Length of Records (years)
1	53	1.00	1272440	Beaver Creek near Norwood	8008	22
		1.00	1371555	Uncompahgre River near Ridgway	6878	6
2	54	1.00	1077200	Rito Blanco near Pagosa Springs	7330	17
		1.00	1272440	Beaver Creek near Norwood	8008	22
3	54	1.00	1077200	Rito Blanco near Pagosa Springs	7330	17
		1.00	1371555	Uncompahgre River near Ridgway	6878	6
4	54	1.00	1077015	Navajo River at Edith	7033	45
		1.00	1371555	Uncompahgre River near Ridgway	6878	6
5	55	1.00	1278800	Dolores River below Rico	8422	13
		1.00	1371555	Uncompahgre River near Ridgway	6878	6
6	57	1.00	1371530	Dallas Creek near Ridgway	6980	14
		1.00	1371555	Uncompahgre River near Ridgway	6878	6
7	58	1.00	1272440	Beaver Creek near Norwood	8008	22
		1.00	1278800	Dolores River below Rico	8422	13
8	58	1.00	1077015	Navajo River at Edith	7033	45
		1.00	1272440	Beaver Creek near Norwood	8008	22
9	59	1.00	1077200	Rito Blanco near Pagosa Springs	7330	17
		1.00	1278800	Dolores River below Rico	8422	13
10	59	1.00	1077015	Navajo River at Edith	7033	45
		1.00	1278800	Dolores River below Rico	8422	13

TABLE 6(a) 10 BEST COMBINATIONS OF SIX SUB-BASINS IN THE UPPER BASIN OF THE COLORADO RIVER

Rank	Number of Years for Evaluation	α_i	CSU ID	Station Name	Elevation (feet)	Length of Records (years)
1	2.9	- 3.37	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 5.45	1801800	Meadow Creek near Tabernash	9780	21
		- 2.31	1801816	Ranch Creek near Fraser	8670	30
		3.60	1804500	Vasquez Creek near Winter Park	8769	31
		.07	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.51	1930000	North Inlet at Grand Lake	8380	14
2	3.5	- 4.04	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 6.79	1801800	Meadow Creek near Tabernash	9780	21
		- .49	1802730	St. Louis Creek near Fraser	8980	31
		2.96	1804500	Vasquez Creek near Winter Park	8769	31
		.18	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.89	1930000	North Inlet at Grand Lake	8380	14
3	3.6	- 3.41	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 3.72	1800900	Strawberry Creek near Granby	8650	10
		- 7.67	1801800	Meadow Creek near Tabernash	9780	21
		2.77	1804500	Vasquez Creek near Winter Park	8769	31
		.38	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.59	1930000	North Inlet at Grand Lake	8380	14
4	3.8	- 3.38	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 6.93	1801800	Meadow Creek near Tabernash	9780	21
		1.89	1804500	Vasquez Creek near Winter Park	8769	31
		- .19	1805400	Fraser River near Winter Park	8900	54
		.05	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.78	1930000	North Inlet at Grand Lake	8380	14
5	3.9	- 4.23	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 3.19	1801816	Ranch Creek near Fraser	8670	30
		- .70	1802730	St. Louis Creek near Fraser	8980	31
		4.58	1804500	Vasquez Creek near Winter Park	8769	31
		- .16	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.54	1930000	North Inlet at Grand Lake	8380	14
6	4.2	- 3.83	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		.13	1800900	Strawberry Creek near Granby	8650	10
		- 3.65	1801816	Ranch Creek near Fraser	8670	30
		4.37	1804500	Vasquez Creek near Winter Park	8769	31
		.01	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		3.88	1930000	North Inlet at Grand Lake	8380	14
7	4.4	- 3.61	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 3.63	1801816	Ranch Creek near Fraser	8670	30
		3.62	1804500	Vasquez Creek near Winter Park	8769	31
		.01	1805400	Fraser River near Winter Park	8900	54
		- .22	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.33	1930000	North Inlet at Grand Lake	8380	14
8	4.8	- 4.79	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 5.71	1800900	Strawberry Creek near Granby	8650	10
		- 1.98	1802730	St. Louis Creek near Fraser	8980	31
		4.40	1804500	Vasquez Creek near Winter Park	8769	31
		.02	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.86	1930000	North Inlet at Grand Lake	8380	14

TABLE 6(a) continued

Rank	Number of Years for Evaluation	α_1	CSU ID	Station Name	Elevation (feet)	Length of Records (years)
9	5.1	- 2.72	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 9.58	1801800	Meadow Creek near Tabernash	9780	21
		- 1.00	1801816	Ranch Creek near Fraser	8670	30
		1.29	1802730	St. Louis Creek near Fraser	8980	31
		.62	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.76	1930000	North Inlet at Grand Lake	8380	14
10	5.4	- 2.96	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 8.75	1801800	Meadow Creek near Tabernash	9780	21
		.64	1802730	St. Louis Creek near Fraser	8980	31
		.04	1805400	Fraser River near Winter Park	8900	54
		.29	1810000	Willow Creek below Willow Creek Res.	8024	11
		5.03	1930000	North Inlet at Grand Lake	8380	14

TABLE 6(b) 10 BEST COMBINATIONS OF FIVE SUB-BASINS IN THE UPPER BASIN OF THE COLORADO RIVER

Rank	Number of Years for Evaluation	α_1	CSU ID	Station Name	Elevation (feet)	Length of Records (years)
1	3.8	- 3.60	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 6.99	1801800	Meadow Creek near Tabernash	9780	21
		2.67	1804500	Vasquez Creek near Winter Park	8769	31
		.34	1810000	Willow Creek near Winter Park	8024	11
		4.15	1930000	North Inlet at Grand Lake	8380	14
2	4.2	- 3.71	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 3.54	1801816	Ranch Creek near Fraser	8670	30
		4.28	1804500	Vasquez Creek near Winter Park	8769	31
		.02	1810000	Willow Creek near Winter Park	8024	11
		3.74	1930000	North Inlet at Grand Lake	8380	14
3	5.0	- 4.98	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 1.63	1802730	St. Louis Creek near Fraser	8980	31
		4.00	1804500	Vasquez Creek near Winter Park	8769	31
		.03	1810000	Willow Creek near Winter Park	8024	11
		4.26	1930000	North Inlet at Grand Lake	8380	14
4	5.3	- 1.53	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 5.73	1800900	Strawberry Creek near Granby	8650	10
		- 5.02	1801800	Meadow Creek near Tabernash	9780	21
		.52	1804500	Vasquez Creek near Winter Park	8769	31
		3.71	1930000	North Inlet at Grand Lake	8380	14
5	5.4	- 2.85	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 9.25	1801800	Meadow Creek near Tabernash	9780	21
		.92	1802730	St. Louis Creek near Fraser	8980	31
		.67	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.41	1930000	North Inlet at Grand Lake	8380	14
6	5.5	- 2.85	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 9.25	1801800	Meadow Creek near Tabernash	9780	21
		.92	1802730	St. Louis Creek near Fraser	8980	31
		.67	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.42	1930000	North Inlet at Grand Lake	8380	14
7	6.1	- 2.63	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 6.66	1801800	Meadow Creek near Tabernash	9780	21
		- .16	1805400	Fraser River near Winter Park	8900	54
		.28	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.49	1930000	North Inlet at Grand Lake	8380	14

TABLE 6(b) continued

8	6.3	- 3.01	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 7.83	1801800	Meadow Creek near Tabernash	9780	21
		.61	1801816	Ranch Creek near Fraser	8670	30
		.69	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		4.29	1930000	North Inlet at Grand Lake	8380	14
9	6.7	- 1.93	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 4.11	1801800	Meadow Creek near Tabernash	9780	21
		- .26	1801816	Ranch Creek near Fraser	8670	30
		- .07	1804500	Vasquez Creek near Winter Park	8769	31
		3.48	1930000	North Inlet at Grand Lake	8380	14
10	6.7	- 4.95	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		3.75	1800900	Strawberry Creek near Granby	8650	10
		2.91	1804500	Vasques Creek near Winter Park	8769	31
		.39	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		3.01	1930000	North Inlet at Grand Lake	8380	14

TABLE 6(c) 10 BEST COMBINATIONS OF FOUR SUB-BASINS IN THE UPPER BASIN OF THE COLORADO RIVER

Rank	Number of Years for Evaluation	α_i	CSU ID	Station Name	Elevation (feet)	Length of Records (years)
1	6.0	- 1.83	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 4.00	1801800	Meadow Creek near Tabernash	9780	21
		.14	1804500	Vasquez Creek near Winter Park	8769	31
		3.10	1930000	North Inlet at Grand Lake	8380	14
2	6.9	- 2.66	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 6.95	1801800	Meadow Creek near Tabernash	9780	21
		.73	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		3.90	1930000	North Inlet at Grand Lake	8380	14
3	6.9	- 4.59	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		2.94	1804500	Vasquez Creek near Winter Park	8769	31
		.44	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		3.10	1930000	North Inlet at Grand Lake	8380	14
4	7.3	- 2.21	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		9.28	1800900	Strawberry Creek near Granby	8650	10
		- .15	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		7.71	1850000	Stillwater Creek above Lake Granby	8310	5
5	7.9	- 2.17	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 1.04	1801816	Ranch Creek near Fraser	8670	30
		.30	1804500	Vasquez Creek near Winter Park	8769	31
		2.82	1930000	North Inlet at Grand Lake	8380	14
6	8.2	- 2.50	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- .56	1800900	Strawberry Creek near Granby	8650	10
		.68	1804500	Vasquez Creek near Winter Park	8769	31
		2.57	1930000	North Inlet at Grand Lake	8380	14
7	8.4	- 3.26	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- .52	1805400	Fraser River near Winter Park	8900	54
		.30	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		3.58	1930000	North Inlet at Grand Lake	8380	14
8	8.5	-10.78	1800900	Strawberry Creek near Granby	8650	10
		- 7.23	1801800	Meadow Creek near Tabernash	9780	21
		.94	1804500	Vasquez Creek near Winter Park	8769	31
		3.48	1930000	North Inlet at Grand Lake	8380	14

TABLE 6(c) continued

9	8.7	- .78	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		-10.25	1800900	Strawberry Creek near Granby	8650	10
		- 4.15	1801800	Meadow Creek near Tabernash	9780	21
		3.59	1930000	North Inlet at Grand Lake	8380	14
10	9.1	- 1.11	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- .45	1804500	Vasquez Creek near Winter Park	8769	31
		- .29	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		11.95	1850000	Stillwater Creek above Lake Granby	8310	5

TABLE 6(d) 10 BEST COMBINATIONS OF THREE SUB-BASINS IN THE UPPER BASIN OF THE COLORADO RIVER

Rank	Number of Years for Evaluation	α_i	CSU ID	Station Name	Elevation (feet)	Length of (years)
1	8.2	- 2.38	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		.59	1804500	Vasquez Creek near Winter Park	8769	31
		2.39	1930000	North Inlet at Grand Lake	8380	14
2	9.5	- .94	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- .30	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		9.87	1850000	Stillwater Creek above Lake Granby	8310	5
3	9.8	- 8.57	1800900	Strawberry Creek near Granby	8650	10
		- 5.18	1801800	Meadow Creek near Tabernash	9780	21
		2.92	1930000	North Inlet at Grand Lake	8380	14
4	11	- 7.76	1800900	Strawberry Creek near Granby	8650	10
		- .07	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		9.44	1850000	Stillwater Creek above Lake Granby	8310	5
5	12	- 1.67	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		- 3.91	1800900	Strawberry Creek near Granby	8650	10
		2.49	1930000	North Inlet at Grand Lake	8380	14
6	12	- 3.61	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		.88	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		2.85	1930000	North Inlet at Grand Lake	8380	14
7	12	- 1.79	1801816	Ranch Creek near Fraser	8670	30
		- .18	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		8.68	1850000	Stillwater Creek above Lake Granby	8310	5
8	13	- 2.58	1801800	Meadow Creek near Tabernash	9780	21
		- .11	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		8.31	1850000	Stillwater Creek above Lake Granby	8310	5
9	14	- 7.23	1801800	Meadow Creek near Tabernash	9780	21
		.15	1804500	Vasquez Creek near Winter Park	8769	31
		2.54	1930000	North Inlet at Grand Lake	8380	14
10	14	- 4.21	1762500	East Fork Troublesome Creek near Troublesome	7750	17
		1.28	1804500	Vasquez Creek near Winter Park	8769	31
		2.23	1960000	Colorado River near Grand Lake	8380	45

TABLE 6(e) 10 BEST COMBINATIONS OF TWO SUB-BASINS IN THE UPPER BASIN OF THE COLORADO RIVER

Rank	Number of Years for Evaluation	α_i	CSU ID	Station Name	Elevation (feet)	Length of Records (years)
1	32	1.00	1800900	Strawberry Creek near Granby	8650	10
		1.00	1850000	Stillwater Creek above Lake Granby	8310	5
2	39	1.00	1800900	Strawberry Creek near Granby	8650	10
		1.00	1930000	North Inlet at Grand Lake	8380	14
3	41	1.00	1804500	Vasquez Creek near Winter Park	8769	31
		1.00	1930000	North Inlet at Grand Lake	8380	14
4	41	1.00	1800900	Strawberry Creek near Granby	8650	10
		1.00	1866000	Arapaho Creek at Monarch Outlet	8310	20
5	42	1.00	1804500	Vasquez Creek near Winter Park	8769	31
		1.00	1866000	Arapaho Creek at Monarch Outlet	8310	20
6	42	1.00	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		1.00	1866000	Arapaho Creek at Monarch Outlet	8310	20
7	44	1.00	1801800	Meadow Creek near Tabernash	9780	21
		1.00	1866000	Arapaho Creek at Monarch Outlet	8310	20
8	45	1.00	1810000	Willow Creek below Willow Creek Reservoir	8024	11
		1.00	1930000	North Inlet at Grand Lake	8380	14
9	45	1.00	1801800	Meadow Creek near Tabernash	9780	21
		1.00	1930000	North Inlet at Grand Lake	8380	14
10	46	1.00	1804500	Vasquez Creek near Winter Park	8769	31
		1.00	1850000	Stillwater Creek above Lake Granby	8310	5

TABLE 7(a) SENSITIVITY OF NUMBER OF YEARS FOR EVALUATION ACCORDING TO CHANGE OF COEFFICIENTS
(THE SAN JUAN MOUNTAINS)

Rank	Combination of Sub-basins and Coefficients							Number of Years for Evaluation
	CSU ID	1076420	1077015	1077250	1077400	1272440	1371530	
	Optimized	- 7.49	24.55	-32.45	5.31	-23.36	27.38	6.08
1	1% change	- 7.57	24.80	-32.70	5.33	-23.59	27.40	6.09
	5% change	- 7.86	25.78	-33.69	5.45	-24.50	27.45	6.23
	10% change	- 8.23	27.01	-34.93	5.59	-25.63	27.53	6.56
	CSU ID	1073080	1077015	1077250	1272440	1272445	1371530	
	Optimized	-14.54	14.38	- 9.90	-14.46	- 1.71	18.90	7.68
2	1% change	-14.68	14.53	-10.01	-14.62	- 1.73	18.94	7.68
	5% change	-15.26	15.10	-10.43	-15.27	- 1.81	19.09	7.86
	10% change	-15.99	15.82	-10.97	-16.09	- 1.90	19.29	8.42
	CSU ID	1073080	1077015	1077250	1272440	1272445	1371555	
	Optimized	-18.86	16.25	- 9.13	-24.72	- 1.32	4.34	7.69
3	1% change	-19.05	16.42	- 9.23	-24.85	- 1.33	4.32	7.70
	5% change	-19.80	17.07	- 9.66	-25.36	- 1.36	4.24	7.84
	10% change	-20.75	17.88	-10.20	-26.00	- 1.41	4.14	8.27
	CSU ID	1076420	1077015	1077250	1077400	1272440	1371555	
	Optimized	- 7.37	27.02	-31.10	4.70	-37.00	6.06	7.88
4	1% change	- 7.44	27.29	-31.36	4.72	-37.20	6.04	7.88
	5% change	- 7.73	28.37	-32.39	4.83	-37.97	5.94	8.00
	10% change	- 8.10	29.72	-33.68	4.97	-38.95	5.82	8.36
	CSU ID	1073080	1073420	1077015	1077250	1272440	1371555	
	Optimized	-14.10	- 2.33	14.00	- 8.93	-18.16	3.21	8.44
5	1% change	-14.24	- 2.35	14.03	- 8.89	-18.22	3.21	8.44
	5% change	-14.80	- 2.44	14.18	- 8.71	-18.46	3.24	8.49
	10% change	-15.50	- 2.56	14.37	- 8.50	-18.76	3.28	8.64
	CSU ID	1073080	1076420	1077015	1077250	1272440	1371555	
	Optimized	-20.93	- .88	19.45	-12.54	-21.47	3.84	9.01
6	1% change	-21.14	- .89	19.50	-12.49	-21.52	3.85	9.01
	5% change	-21.98	- .92	19.72	-12.25	-21.71	3.86	9.06
	10% change	-23.03	- .97	19.98	-11.95	-21.96	3.88	9.21
	CSU ID	1073080	1075830	1077015	1077250	1272440	1371555	
	Optimized	-22.05	- .59	18.85	-10.73	-25.03	3.80	9.05
7	1% change	-22.27	- .60	18.90	-10.66	-25.09	3.81	9.05
	5% change	-23.15	- .62	19.08	-10.38	-25.33	3.82	9.10
	10% change	-24.26	- .65	19.31	-10.03	-25.63	3.84	9.25

TABLE 7(a) continued

8	CSU ID	1076420	1077015	1077250	1077400	1272440	1278800	
	Optimized	- 8.36	24.17	-30.86	3.54	-42.16	15.30	9.13
	1% change	- 8.44	24.41	-31.08	3.59	-42.35	15.25	9.14
	5% change	- 8.78	25.38	-31.95	3.77	-43.11	15.06	9.25
	10% change	- 9.19	26.59	-33.04	4.00	-44.05	14.83	9.60
9	CSU ID	1073080	1073460	1077015	1077250	1272440	1371555	
	Optimized	-29.89	- .70	25.30	-14.72	-30.20	5.11	9.26
	1% change	-30.19	- .70	25.38	-14.63	-30.28	5.12	9.26
	5% change	-31.38	- .73	25.67	-14.30	-30.60	5.15	9.31
	10% change	-32.88	- .77	26.04	-13.89	-30.99	5.19	9.46
10	CSU ID	1073080	1073448	1077015	1077250	1272440	1371555	
	Optimized	-16.80	- 1.95	15.71	-10.69	-14.95	3.32	9.44
	1% change	-16.97	- 1.97	15.75	-10.65	-14.98	3.33	9.44
	5% change	-17.64	- 2.04	15.94	-10.49	-15.11	3.36	9.49
	10% change	-18.48	- 2.14	16.17	-10.28	-15.26	3.39	9.63

TABLE 7(b) SENSITIVITY OF NUMBER OF YEARS FOR EVALUATION ACCORDING TO CHANGE OF COEFFICIENTS (THE UPPER BASIN OF THE COLORADO RIVER)

Rank		Combination of Sub-basins and Coefficients						Number of Years for Evaluation
1	CSU ID	1762500	1801800	1801816	1804500	1810000	1930000	
	Optimized	- 3.37	- 5.45	- 2.31	3.60	.07	4.51	2.90
	1% change	- 3.41	- 5.51	- 2.24	3.58	.08	4.52	2.90
	5% change	- 3.54	- 5.72	- 1.98	3.51	.09	4.56	2.93
	10% change	- 3.71	- 6.00	- 1.65	3.43	.11	4.60	3.02
2	CSU ID	1762500	1801800	1802730	1804500	1810000	1930000	
	Optimized	- 4.04	- 6.79	- .49	2.96	.18	4.89	3.53
	1% change	- 4.08	- 6.86	- .47	2.97	.17	4.91	3.54
	5% change	- 4.24	- 7.13	- .41	3.01	.16	5.00	3.62
	10% change	- 4.45	- 7.47	- .34	3.07	.14	5.10	3.87
3	CSU ID	1762500	1800900	1801800	1804500	1810000	1930000	
	Optimized	- 3.41	- 3.72	- 7.67	2.77	.38	4.59	3.65
	1% change	- 3.45	- 3.76	- 7.59	2.78	.38	4.59	3.65
	5% change	- 3.59	- 3.90	- 7.24	2.84	.37	4.59	3.67
	10% change	- 3.76	- 4.09	- 6.81	2.91	.37	4.60	3.76
4	CSU ID	1762500	1801800	1804500	1805400	1810000	1930000	
	Optimized	- 3.38	- 6.93	1.89	- .19	.05	4.78	3.78
	1% change	- 3.41	- 7.00	1.91	- .17	.06	4.80	3.78
	5% change	- 3.54	- 7.28	1.98	- .08	.07	4.84	3.82
	10% change	- 3.71	- 7.62	2.07	.04	.08	4.90	3.96
5	CSU ID	1762500	1801816	1802730	1804500	1810000	1930000	
	Optimized	- 4.23	- 3.19	- .70	4.58	- .15	4.54	3.93
	1% change	- 4.27	- 3.22	- .69	4.61	- .16	4.56	3.93
	5% change	- 4.44	- 3.35	- .64	4.72	- .19	4.63	4.01
	10% change	- 4.66	- 3.51	- .57	4.86	- .23	4.72	4.26
6	CSU ID	1762500	1800900	1801816	1804500	1810000	1930000	
	Optimized	- 3.83	.13	- 3.64	4.37	.01	3.88	4.19
	1% change	- 3.87	.13	- 3.60	4.36	.01	3.88	4.19
	5% change	- 4.02	.14	- 3.39	4.33	.02	3.90	4.22
	10% change	- 4.22	.15	- 3.14	4.28	.03	3.91	4.30
7	CSU ID	1762500	1801816	1804500	1805400	1810000	1930000	
	Optimized	- 3.61	- 3.63	3.62	.01	- .22	4.33	4.35
	1% change	- 3.65	- 3.67	3.65	.04	- .22	4.34	4.36
	5% change	- 3.79	- 3.81	3.80	.14	- .22	4.36	4.40
	10% change	- 3.98	- 4.00	3.98	.26	- .22	4.39	4.54
8	CSU ID	1762500	1800900	1802730	1804500	1810000	1930000	
	Optimized	- 4.79	- 5.71	- 1.98	4.40	.02	4.87	4.85
	1% change	- 4.84	- 5.77	- 1.98	4.43	.02	4.89	4.85
	5% change	- 5.03	- 6.00	- 1.98	4.53	- .01	4.98	4.93
	10% change	- 5.27	- 6.28	- 1.98	4.65	- .04	5.09	5.17
9	CSU ID	1762500	1801800	1801816	1802730	1810000	1930000	
	Optimized	- 2.72	- 9.58	- 1.00	1.29	.62	4.76	5.15
	1% change	- 2.74	- 9.68	- .93	1.28	.62	4.77	5.15
	5% change	- 2.85	-10.06	- .66	1.24	.62	4.84	5.18
	10% change	- 2.99	-10.54	- .32	1.18	.61	4.92	5.29
10	CSU ID	1762500	1801800	1802730	1805400	1810000	1930000	
	Optimized	- 2.96	- 8.75	.64	.04	.29	5.03	5.39
	1% change	- 2.99	- 8.84	.66	.07	.29	5.04	5.39
	5% change	- 3.11	- 9.19	.72	.15	.32	5.07	5.43
	10% change	- 3.26	- 9.62	.80	.26	.35	5.12	5.57

TABLE 8 SENSITIVITY OF NUMBER OF YEARS FOR EVALUATION ACCORDING TO CHANGE OF COVARIANCE MATRIX
(THE UPPER BASIN OF THE COLORADO RIVER)

Years for which data were not used			Combination of Sub-basins and Coefficients						Number of Years for Evaluation
			1762500	1801800	1801816	1804500	1810000	1930000	
----	----	----	-3.37	-5.45	-2.31	3.60	.07	4.51	2.90
1948	1951	1954	-3.26	-5.69	-2.01	3.32	.14	4.46	2.64
1948	1951	1956	-3.74	-6.51	- .67	2.64	.30	4.53	2.76
1948	1951	1958	-3.65	-4.44	-1.90	3.81	.06	4.33	2.53
1948	1951	1960	-3.46	-5.41	-2.02	3.30	.15	4.49	3.21
1948	1951	1963	-3.49	-4.48	-2.27	3.39	.14	4.39	3.20
1948	1954	1956	-3.44	-6.89	- .93	2.83	.25	4.52	2.50
1948	1954	1958	-3.36	-4.87	-2.18	3.92	.02	4.35	2.20
1948	1954	1960	-3.20	-5.72	-2.24	3.45	.11	4.48	2.75
1948	1954	1963	-3.25	-4.54	-2.50	3.59	.09	4.35	2.68
1948	1956	1958	-3.70	-5.17	-1.49	3.53	.11	4.40	2.69
1948	1956	1960	-3.59	-6.27	-1.28	2.95	.22	4.55	3.21
1948	1956	1963	-3.60	-5.50	-1.57	3.05	.21	4.47	3.22
1948	1958	1960	-3.57	-4.59	-2.19	4.00	.01	4.38	2.71
1948	1958	1963	-3.66	-2.79	-2.60	4.19	.01	4.17	2.63
1948	1960	1963	-3.43	-4.41	-2.54	3.53	.10	4.41	3.33
1951	1954	1956	-3.59	-7.53	- .18	2.74	.28	4.52	2.37
1951	1954	1958	-3.47	-4.96	-1.79	3.89	.04	4.31	2.00
1951	1954	1960	-3.27	-6.11	-1.83	3.50	.10	4.48	2.69
1951	1954	1963	-3.30	-5.21	-2.08	3.64	.08	4.38	2.69
1951	1956	1958	-3.90	-5.61	- .67	3.32	.17	4.37	2.36
1951	1956	1960	-3.76	-7.03	- .41	2.82	.26	4.55	3.01
1951	1956	1963	-3.74	-6.78	- .57	2.83	.26	4.54	3.09
1951	1958	1960	-3.69	-4.70	-1.73	3.91	.04	4.34	2.42
1951	1958	1963	-3.75	-3.11	-2.14	4.15	.00	4.16	2.41
1951	1960	1963	-3.49	-5.28	-2.00	3.54	.10	4.46	3.27
1954	1956	1958	-3.56	-6.05	-1.05	3.53	.11	4.40	2.05
1954	1956	1960	-3.45	-7.33	- .77	3.05	.20	4.55	2.58
1954	1956	1963	-3.44	-6.69	-1.01	3.15	.18	4.48	2.60
1954	1958	1960	-3.39	-5.10	-2.06	4.06	-.01	4.35	2.15
1954	1958	1963	-3.48	-3.28	-2.45	4.35	-.05	4.14	2.03
1954	1960	1963	-3.24	-5.23	-2.30	3.77	.05	4.40	2.80
1956	1958	1960	-3.73	-5.45	-1.35	3.68	.08	4.41	2.62
1956	1958	1963	-3.74	-3.74	-1.95	4.01	.02	4.24	2.62
1958	1960	1963	-3.66	-3.25	-2.43	4.32	-.04	4.21	2.60

Chapter VI

CONCLUSION

Suitability of basins for weather modification over the whole Upper Colorado River Basin was discussed from a hydrologic standpoint.

The relationship between precipitation and spring runoff with greater than 0.90 correlation coefficient was obtained for 365 sets by applying a multiple linear regression analysis, the independent variables being winter and spring precipitation. Using this relationship, the increase of spring runoff due to a 10 percent increase of winter precipitation was calculated and used as a criterion to discuss optimal water yield. The following watersheds are those where a relatively large amount of increase of runoff can be expected in order:

(a) San Juan Mountains,

(b) Upper reach of the Yampa River and its tributaries,

(c) Headwater of the Green River,

(d) Upper basin of the Colorado River,

(e) Upper basins of Uinta River, Lake Fork, and Rock Creek, and

(f) Headwaters of the Rafael River.

By applying the two-sample u-test, the number of years for evaluation of weather modification attainment for each basin was discussed. Though results show some variability between watersheds separated by a very short distance, the following basins lead to a smaller number of years needed for evaluation on the average:

(a) Upper reach of the Yampa River and its tributaries,

(b) Headwater of the Green River,

(c) Upper basin of the Colorado River,

(d) Upper basins of Uinta River, Lake Fork, and Rock Creek, and

(e) San Juan Mountains.

These results show that the upper reach of the Yampa River and its tributaries; the headwaters of the Green River; and the upper basins of Uinta River, Lake Fork, and Rock Creek are suitable, in addition to the two pilot-areas--the San Juan Mountains and the Upper Basin of the Colorado River.*

Furthermore, the number of years for evaluation was calculated for certain combinations of basins in the pilot area by using a new variable that is a linear combination of a given number of runoff variables from individual sub-basins. This was done in order to select the most desirable combination of basins for the planned experiment. It was found that particular gages play a particularly important role in keeping the number of years needed for evaluation to a minimum. They are in the

(a) San Juan Mountains

1077015	Navajo River at Edith
1077250	Rio Blanco near Pagosa Springs
1371555	Uncompahgre River near Ridgway

(b) the Upper Basin of the Colorado River

1762500	East Fork Troublesome Creek near Troublesome
1810000	Willow Creek below Willow Creek Reservoir
1930000	North Inlet at Grand Lake

However, the study shows that there exist a great deal of latitude in the actual choice of the stations with little loss of efficiency in evaluation. This fact is probably the most important result of this study.

It also was found the minimum number of years in the San Juan Mountains was six, and in the Upper Basin of the Colorado River Basin was three. It must be remembered that these results hold under the assumption of a uniform 10% increase in winter precipitation in both pilot areas. If the increase is greater the number of years decreases approximately at a quadratic rate.

At this point, no physical meaning is assigned to the α_i's in equation (3). It may be desirable to consider the meaning of the α_i's in a further study.

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*Since the initiation of this study the plans of the Bureau were modified. Currently (45) only one area is considered: the San Juan Mountains region.

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APPENDICES

A and B

APPENDIX A

List of Precipitation Stations

The numbers in the tables of the recorded data indicate the number of missing monthly data. However, the number "9" indicates that the number of missing monthly data is 9, 10, or 11 and the "*" indicates that there is no monthly data at all.

CSU NO	BUREAU NO	NAME	LATITUDE	LONGITUDE	ELEVATION	RECORDING BEGAN-ENDED	CONTINUOUS RECORDING	188 0123456789	189 0123456789	190 0123456789	191 0123456789	192 0123456789	193 0123456789	194 0123456789	195 0123456789	196 012345
10115000	37.0000	PAHREAH	37.15. 0	111.57. 0	4000.0	1895-1899	1896-1899	**********	*****10000	**********	**********	**********	**********	**********	**********	******
10180500	37.3847	HENRIEVILLE	37.34. 0	112. 0. 0	6000.0	1963-1965	1964-1965	**********	**********	**********	**********	**********	**********	**********	**********	***600
10190000	37.8847	TROPIC	37.37. 0	112. 6. 0	6296.0	1889-1965	1953-1965	*********7	000009*720	0000000000	0000002008	9700037954	*****30000	0000000000	3310000000	000000
10270000	2.4849	LEES FERRY	36.52. 0	111.35. 0	3141.0	1917-1965	1944-1965	**********	**********	**********	*******252	7000002000	0000000150	****000000	0000000000	000000
10400006	2.9114	WAHWEAP	36.59. 0	111.19. 0	3720.0	1961-1965	1962-1965	**********	**********	**********	**********	**********	**********	**********	**********	*70000
10400002	2.2049	COPPER MINE TRAD	36.38. 0	111.25. 0	5380.0	1941-1955	1952-1955	**********	**********	**********	**********	**********	**********	*300000000	020000****	******
10400003	2.4528	KAIBITO	36.36. 0	111. 5. 0	6000.0	1950-1960	1951-1960	**********	**********	**********	**********	**********	**********	**********	3000000000	0*****
10400004	37.6676	NAVAJO MOUNTAIN	37. 1. 0	110.44. 0	6020.0	1957-1965	1959-1965	**********	**********	**********	**********	**********	**********	**********	*******320	000000
10550000	37.3232	GLEN CANYON CITY	37. 5. 0	111.43. 0	4160.0	1962-1965	1963-1965	**********	**********	**********	**********	**********	**********	**********	**********	**4000
10700001	37.5810	MONUMENT VALLEY	37. 0. 0	110.12. 0	5230.0	1956-1959	1958-1959	**********	**********	**********	**********	**********	**********	**********	******7300	******
10702000	37.5582	MEXICAN HAT	37. 9. 0	109.52. 0	4230.0	1946-1965	1953-1965	**********	**********	**********	**********	**********	**********	******3000	1130006000	000000
10704001	2.2545	DINNEHOTSO	36.51. 0	109.51. 0	5100.0	1955-1959	1956-1959	**********	**********	**********	**********	**********	**********	**********	*****70007	******
10704002	2.5294	MANY FARMS	36.21. 0	109.37. 0	5310.0	1951-1965	1952-1965	**********	**********	**********	**********	**********	**********	**********	*500006000	000000
10704003	2.0800	BLACK MOUNTAIN M	36. 7. 0	109.52. 0	6350.0	1959-1965	1960-1965	**********	**********	**********	**********	**********	**********	**********	*********8	000000
10704004	2.2197	COTTON WOOD INDI	36. 4. 0	109.53. 0	6050.0	1956-1958	1957-1958	**********	**********	**********	**********	**********	**********	**********	******800*	******
10704005	2.1434	CHINLE	36. 9. 0	109.32. 0	5538.0	1909-1965	1943-1965	**********	**********	*********2	0000000000	000008905*	*****90330	8200000001	3000000000	000000
10704015	2.5129	LUKACHUKAI	36.26. 0	109.14. 0	6490.0	1915-1964	1962-1964	**********	**********	**********	*****31***	**********	**********	**********	*000000000	32000*
10706200	2.4474	KEYENTA	36.44. 0	110.16. 0	5665.0	1916-1965	1955-1965	**********	**********	**********	*******068	5000000000	0000000007	1*70252000	0000000000	000052
10714000	37.0788	BLUFF	37.17. 0	109.33. 0	4315.0	1911-1965	1928-1965	**********	**********	**********	*900026793	0078115200	0000000000	0000000000	0000000000	000000
10714001	37.0738	BLANDING	37.37. 0	109.28. 0	6035.0	1905-1965	1912-1965	**********	**********	*****20000	0*00000000	0000000000	0000000000	0000000000	0000000030	000000
10716000	37.0197	ANETH	37.13. 0	109.11. 0	4650.0	1900-1962	1962-1962	**********	**********	70000000**	9302******	**********	**********	**********	**********	*92***
10716001	5.0800	DOVE CREEK	37.46. 0	108.54. 0	5679.0	1916-1921	1917-1921	**********	**********	**********	******4000	00********	**********	**********	**********	******
10716002	5.0381	ATKINSON RANCH	37.36. 0	108.53. 0	7000.0	1948-1949	1949-1949	**********	**********	**********	**********	**********	**********	********74	**********	******
10716004	37.5795	MONTEZUMA CREEK	37.43. 0	109. 5. 0	6790.0	1946-1956	1947-1956	**********	**********	**********	**********	**********	**********	******6000	0000000***	******
10716005	37.1908	CEDAR POINT	37.43. 0	109. 5. 0	6740.0	1952-1965	1952-1965	**********	**********	**********	**********	**********	**********	**********	**00000000	000000
10716006	37.0000	LOCKERBY	37.47. 0	109. 4. 0	7300.0	1917-1924	1924-1924	**********	**********	**********	*******300	00001*****	**********	**********	**********	******
10716007	5.5970	NORTHDALE	37.49. 0	109. 1. 0	6693.0	1931-1965	1932-1965	**********	**********	**********	**********	**********	*300000000	0000000000	0000000000	000000
10716050	37.0000	VERDURE	37.47. 0	109.21. 0	6800.0	1906-1908	1908-1908	**********	**********	******356*	**********	**********	**********	**********	**********	******
10716350	37.5805	MONTICELLO	37.52. 0	109.21. 0	7066.0	1902-1965	1953-1965	**********	**********	**30092463	*300000000	17*****900	0000000000	0000000012	0520000000	000000
10718001	2.4698	TEEC NOS POC	36.56. 0	109. 0. 0	5190.0	1962-1965	1963-1965	**********	**********	**********	**********	**********	**********	**********	**********	**8000
10718301	5.6591	PLEASANT VIEW 2W	37.35. 0	108.48. 0	7000.0	1950-1951	1951-1951	**********	**********	**********	**********	**********	**********	**********	94********	******
10718302	5.9275	YELLOW JACKET IN	37.33. 0	108.44. 0	6856.0	1962-1965	1963-1965	**********	**********	**********	**********	**********	**********	**********	**********	**8000
10718600	5.1886	CORTEZ	37.21. 0	108.34. 0	6177.0	1931-1965	1932-1965	**********	**********	**********	**********	**********	*300000000	0000000000	0000000000	000000
10720000	5.5531	MESA VERDE NATIO	37.12. 0	108.29. 0	7070.0	1922-1965	1923-1965	**********	**********	**********	**********	**90000000	0009000000	0000000000	0000000000	000000
10720300	5.5327	MANCOS	37.21. 0	108.18. 0	7015.0	1898-1965	1940-1965	**********	********30	0000000000	0000000000	9*********	**********	*******900	0000000000	000000
10724000	25.0294	SHIPROCK 1 E	36.47. 0	108.39. 0	4974.0	1926-1965	1944-1965	**********	**********	**********	**********	******3000	0000000011	007*900000	0010000000	002700
10726151	25.6098	NEWCOMB	36.17. 0	108.42. 0	5565.0	1952-1965	1952-1965	**********	**********	**********	**********	**********	**********	**********	**00000000	000000
10726154	25.9657	WESTBROOK RANCH	35.56. 0	108.12. 0	6600.0	1948-1962	1952-1959	**********	**********	**********	**********	**********	**********	********91	001*******	******
10726155	25.6485	OTIS	36.19. 0	107.52. 0	6880.0	1957-1965	1958-1965	**********	**********	**********	**********	**********	**********	**********	*******700	000000
10726156	25.0000	NASEEZT	36.16. 0	107.45. 0	6800.0	1949-1951	1951-1951	**********	**********	**********	**********	**********	**********	**********	07********	******
10726157	25.5290	LYBROOK	36.14. 0	107.35. 0	7160.0	1951-1965	1956-1965	**********	**********	**********	**********	**********	**********	**********	*800060000	000000
10726158	25.1847	CHACO CANYON NAT	36. 4. 0	107.58. 0	6175.0	1932-1965	1950-1965	**********	**********	**********	**********	**********	**80000000	0112030002	0000000000	000000
10726159	25.6900	PITT RANCH	35.48. 0	108. 1. 0	6660.0	1952-1965	1952-1965	**********	**********	**********	**********	**********	**********	**********	**00000000	000000
10726161	25.2219	CROWNPOINT	35.41. 0	108. 9. 0	6978.0	1914-1965	1955-1965	**********	**********	**********	****300000	0000000000	0000000000	0000000002	0000300000	000000
10726600	25.5685	MEXICAN SPRINGS	35.48. 0	108.50. 0	6437.0	1934-1965	1950-1965	**********	**********	**********	**********	**********	****700000	0039125*6	0000000000	000000
10726750	25.8919	TOHATCHI	35.51. 0	108.46. 0	6800.0	1913-1965	1950-1965	**********	**********	**********	***3000*00	9393000000	0001000010	0002849012	0000000000	000000
10728000	25.3340	FRUITLAND	36.44. 0	108.24. 0	5165.0	1891-1965	1964-1965	**********	*3000000*0	0000000000	0000000000	000009****	********90	0120400001	0000000000	002300
10730000	25.3128	FARMINGTON FAA A	36.45. 0	108.45. 0	5495.0	1941-1965	1942-1965	**********	**********	**********	**********	**********	**********	*000000000	0000000000	000000
10730600	5.4414	KLINE 3W	37. 7. 0	108.11. 0	6619.0	1941-1949	1942-1949	**********	**********	**********	**********	**********	**********	*900000004	**********	******
10730601	5.0000	KLINE 9WNW	37.11. 0	108.16. 0	7000.0	1944-1946	1946-1946	**********	**********	**********	**********	**********	**********	****381***	**********	******
10730602	5.0000	ALKALI CREEK	37.12. 0	108.10. 0	7000.0	1945-1947	1947-1947	**********	**********	**********	**********	**********	**********	*****904**	**********	******
10730603	5.3016	FORT LEWIS	37.14. 0	108. 3. 0	7595.0	1880-1965	1955-1965	4300010000	01********	*********9	*900000000	0000000000	0000000000	0000000000	0000100000	000000
10734000	25.3136	FARMINGTON	36.45. 0	108.10. 0	5395.0	1914-1965	1933-1965	**********	**********	**********	****300000	0000000000	0690000000	0000000000	0000000000	000000
10734040	25.0492	AZTEC RUINS NAT	36.50. 0	108. 0. 0	5640.0	1895-1965	1911-1965	**********	*****30000	0000******	3000000000	0000000000	0000000000	0000000000	0000000000	000000
10734180	5.0000	FALFA	37.13. 0	107.45. 0	6954.0	1945-1945	1945-1945	**********	**********	**********	**********	**********	**********	*****1****	**********	******
10734360	5.2432	DURANGO	37.17. 0	107.53. 0	6554.0	1889-1965	1895-1965	*********3	2****00000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	000000
10734560	5.8156	TACOMA	37.31. 0	107.47. 0	7300.0	1906-1965	1952-1965	**********	**********	******9100	0000000000	0000000000	09********	**********	**00000000	000000
10734561	5.2424	ELECTRA LAKE	37.33. 0	107.44. 0	8398.0	1959-1965	1960-1965	**********	**********	**********	**********	**********	**********	**********	*********1	000000
10734640	5.0000	SAVAGE BASIN	37.55. 0	107.44. 0	11500.0	1915-1931	1925-1931	**********	**********	**********	*****41000	0300200000	00********	**********	**********	******
10734641	5.1384	CASCADE	37.40. 0	107.48. 0	8853.0	1906-1957	1908-1957	**********	**********	******9100	0020000000	0000000000	0000000000	0000000000	0000000***	******
10734800	5.7696	SILVERTON	37.48. 0	107.40. 0	9322.0	1906-1965	1950-1965	**********	**********	******9100	3000000000	0000000000	0000000000	0000000000	0000000012	000000
10734801	5.0000	SILVERTON NO. 1	37.48. 0	107.40. 0	9401.0	1905-1910	1910-1910	**********	**********	*****30107	3*********	**********	**********	**********	**********	******
10734720	5.0000	GLADSTONE	37.53. 0	107.39. 0	10400.0	1906-1917	1917-1917	**********	**********	******9100	10700001**	**********	**********	**********	**********	******
10738000	25.1003	BLOOMFIELD 3 SE	36.40. 0	107.58. 0	5794.0	1891-1965	1950-1965	**********	*300009***	****300000	0000000000	0000000000	0030000000	0002001893	0000000000	000000
10744000	25.3706	GRENVILLE	36.30. 0	107.17. 0	5990.0	1944-1962	1952-1962	**********	**********	**********	**********	**********	**********	****300002	1100000000	000***
10744002	25.6450	OTERO	36.16. 0	107.23. 0	6600.0	1953-1957	1954-1957	**********	**********	**********	**********	**********	**********	**********	***60000**	******
10746000	25.6081	NAVAJO DAM	36.49. 0	107.37. 0	5770.0	1963-1965	1964-1965	**********	**********	**********	**********	**********	**********	**********	**********	***800
10750000	25.3588	GOBERNADOR	36.42. 0	107.24. 0	6710.0	1955-1958	1956-1958	**********	**********	**********	**********	**********	**********	**********	*****9605*	******
10750001	25.3589	GOBERNADOR TW	36.41. 0	107.23. 0	7200.0	1925-1955	1955-1955	**********	**********	**********	**********	*****900**	**80000000	0000000100	010008****	******
10756000	25.0000	ROSA NEAR	36.53. 0	107.35. 0	6500.0	1930-1931	1931-1931	**********	**********	**********	**********	**********	30********	**********	**********	******
10758200	5.4250	IGNACIO 1 N	37. 8. 0	107.38. 0	6424.0	1909-1965	1951-1965	**********	**********	*********9	9***300000	0000000000	0000000000	0000000010	2000000000	000000
10758400	5.8582	VALLECITO DAM	37.24. 0	107.33. 0	7650.0	1943-1965	1943-1965	**********	**********	**********	**********	**********	**********	***0000000	0000000000	000000
10762000	5.0307	ARBOLES	37. 1. 0	107.25. 0	6175.0	1958-1963	1959-1963	**********	**********	**********	**********	**********	**********	**********	********30	0000**
10762001	5.0000	ARBOLES	37. 1. 0	107.23. 0	6013.0	1891-1896	1896-1896	**********	*7106*****	**********	**********	**********	**********	**********	**********	******
10764200	5.1570	CHIMNEY ROCK	37.12. 0	107.18. 0	6550.0	1961-1962	1962-1962	**********	**********	**********	**********	**********	**********	**********	**********	*99***

Appendix A continued

CSU NO	BUREAU NO	NAME	LATITUDE	LONGITUDE	ELEVATION	RECORDING BEGAN-ENDED	CONTINUOUS RECORDINGS	1 8 8 0123456789	1 8 9 0123456789	1 9 0 0123456789	1 9 1 0123456789	1 9 2 0123456789	1 9 3 0123456789	1 9 4 0123456789	1 9 5 0123456789	1 9 6 012345
10784201	5.7928	STATE TURKEY EXP	37.13. 0	107.14. 0	6900.0	1944-1961	1961-1961	**********	**********	**********	**********	**********	**********	****910000	0010000000	03****
10770000	25.2408	DULCE	36.57. 0	107. 0. 0	6940.0	1906-1965	1946-1965	**********	**********	******3000	0000000000	0000000000	0000000000	0**4790000	0000000000	000000
10770300	5.0000	CHROMO	37. 4. 0	106.49. 0	7385.0	1890-1912	1912-1912	**********	79********	******3000	011*******	**********	**********	**********	**********	******
10774000	5.6258	PAGOSA SPRINGS	37.16. 0	107. 1. 0	7110.0	1882-1965	1953-1965	**0*******	06********	*******300	00000007**	**********	*********6	0000000001	1110000000	000000
10776000	5.0000	PAGOSA SPRINGS (	37.23. 0	106.57. 0	7736.0	1928-1937	1937-1937	**********	**********	**********	**********	*********1	000*7005**	**********	**********	******
10776001	5.6271	PALISADE LAKE 2	37.30. 0	107.10. 0	7721.0	1917-1965	1948-1965	**********	**********	**********	*******900	000000000*	**********	*******900	0000000000	000000
10778600	5.9183	WOLF CREEK PASS	37.29. 0	106.52. 0	9425.0	1936-1965	1958-1965	**********	**********	**********	**********	**********	******9599	0000000000	0910000400	000000
10810001	37.2592	ESCALANTE	37.46. 0	111.36. 0	5750.0	1901-1965	1959-1965	**********	**********	*9000*0000	00****8000	3700000000	0000000000	0006200000	0000000439	000000
10860250	37.0849	BOULDER	37.55. 0	112.29. 0	6590.0	1954-1965	1955-1965	**********	**********	**********	**********	**********	**********	**********	****900000	000000
11040000	37.3968	HITE	37.49. 0	110.26. 0	3670.0	1948-1954	1949-1954	**********	**********	**********	**********	**********	**********	********60	00000*****	******
11150000	37.6053	NATURAL BRIDGES	37.37. 0	109.59. 0	6500.0	1965-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	**********	*****1
11409000	37.3611	HANKSVILLE FAA A	38.25. 0	110.41. 0	4456.0	1910-1965	1945-1965	**********	**********	**********	3035300000	0000000000	0000000000	0075000000	0000000000	000000
11418000	37.0000	WILLOW SPRINGS C	38.43. 0	111.17. 0	5500.0	1941-1942	1942-1942	**********	**********	**********	**********	**********	**********	*76*******	**********	******
11418200	37.2484	EMERY	38.55. 0	111.15. 0	6280.0	1901-1965	1965-1965	**********	**********	*300000000	0000000000	0310000000	0000000000	0000000000	0000000000	000050
11418800	37.0000	YELLOW PINE	39. 0. 0	111.20. 0	8300.0	1916-1916	1916-1916	**********	**********	**********	******9***	**********	**********	**********	**********	******
11436000	37.0000	GILES	38.22. 0	110.51. 0	4640.0	1895-1906	1896-1906	**********	*****30000	0000000***	**********	**********	**********	**********	**********	******
11454000	37.3046	FUJITA	38.17. 0	111.15. 0	5410.0	1938-1965	1948-1965	**********	**********	**********	**********	**********	********00	5000000200	0000000000	000000
11454001	37.0000	TEASDALE	38.14. 0	111.21. 0	7100.0	1917-1919	1919-1919	**********	**********	**********	*******334	**********	**********	**********	**********	******
11483300	37.5148	LOA	38.24. 0	111.39. 0	7045.0	1892-1965	1936-1965	**********	**30000000	0000000000	099*******	**30000000	0010410000	0000000000	0000000000	000000
11483001	37.0000	ELKHORN FISH LAK	38.27. 0	111.28. 0	8000.0	1922-1928	1928-1928	**********	**********	**********	**********	**0*8677**	**********	**********	**********	******
11601300	37.2798	FERRON	39. 6. 0	111. 8. 0	5925.0	1952-1965	1952-1965	**********	**********	**********	**********	**********	**********	**********	**00000000	000000
11601420	37.1214	CASTLE DALE	39.13. 0	111. 1. 0	5675.0	1899-1965	1957-1965	**********	*********3	0000000000	0000000000	0000000000	0000000000	000**6***4	0110043000	000000
11605000	37.3418	GREEN RIVER AVIA	39. 0. 0	110. 9. 0	4055.0	1891-1965	1948-1965	**********	*94406*9**	0000004910	0000005000	0000000000	09********	*******300	0000000000	000000
11607000	37.9429	WOODSIDE	39.16. 0	110.21. 0	4640.0	1912-1958	1958-1958	**********	**********	**********	**30554***	**********	**********	*00394****	700000539*	******
11607001	37.8474	SUNNYSIDE	39.34. 0	110.22. 0	6660.0	1920-1965	1965-1965	**********	**********	**********	**********	3000211010	**********	**********	********40	0005**
11607003	37.0000	VICTOR LAKE	39.24. 0	110.42. 0	5250.0	1913-1922	1922-1922	**********	**********	**********	***3000000	001*******	**********	**********	**********	******
11607004	37.0000	DESERT LAKE	39.22. 0	110.44. 0	5600.0	1911-1911	1911-1911	**********	**********	**********	*9********	**********	**********	**********	**********	******
11607005	37.0000	WELLINGTON	39.32. 0	110.44. 0	5450.0	1900-1909	1909-1909	**********	**********	3000244978	**********	**********	**********	**********	**********	******
11607100	37.3896	HIAWATHA	39.29. 0	111. 1. 0	7230.0	1917-1965	1923-1965	**********	**********	**********	*******100	0930000000	0000000000	0000000000	0000000000	000000
11607150	37.7015	PRICE GAME FARM	39.37. 0	110.50. 0	5580.0	1911-1965	1944-1965	**********	**********	**********	*300602328	0000000000	0000000000	0005000000	0000000000	000000
11607151	37.7724	SCOFIELD DAM	39.47. 0	111. 7. 0	7630.0	1950-1965	1954-1965	**********	**********	**********	**********	**********	**********	**********	4524000000	000000
11607200	37.0000	CASTLE GATE	39.43. 0	110.52. 0	6000.0	1891-1896	1896-1896	**********	*9*1186***	**********	**********	**********	**********	**********	**********	******
11607400	37.7959	SOLDIER SUMMIT	39.55. 0	111. 5. 0	7460.0	1893-1960	1960-1960	**********	***7000010	10393000**	***0****94	5588122600	4000000000	0000000000	2791006*00	3*****
11607601	37.1472	CLEAR CREEK	39.39. 0	111. 9. 0	8300.0	1936-1965	1955-1965	**********	**********	**********	**********	**********	******1000	0000000000	0000500000	000000
11609300	37.6340	NUTTERS RANCH	39.48. 0	110.15. 0	5880.0	1963-1965	1964-1965	**********	**********	**********	**********	**********	**********	**********	**********	***900
11614001	37.0810	BONANZA PUMPING	40. 2. 0	109. 7. 0	5700.0	1960-1965	1961-1965	**********	**********	**********	**********	**********	**********	**********	**********	800000
11615000	37.0000	WATSON	39.51. 0	109.11. 0	6210.0	1911-1927	1912-1927	**********	**********	**********	*700000000	00000000**	**********	**********	**********	******
11615001	37.0000	DRAGON	39.47. 0	109. 6. 0	5890.0	1908-1909	1909-1909	**********	**********	********96	**********	**********	**********	**********	**********	******
11615002	5.0354	ARTESIA RE	40.14. 0	108.58. 0	5921.0	1948-1965	1965-1965	**********	**********	**********	**********	**********	**********	********91	0*********	***904
11615004	5.6832	RANGELY	40. 5. 0	108.47. 0	5216.0	1894-1965	1953-1965	**********	****906013	00007*9000	047*******	**********	**********	**********	**70000000	000000
11615005	5.0000	SKULL CREEK	40.15. 0	108.39. 0	5700.0	1941-1944	1944-1944	**********	**********	**********	**********	**********	**********	*3702*****	**********	******
11615150	5.5048	LITTLE HILLS	40. 0. 0	108.12. 0	6148.0	1946-1965	1947-1965	**********	**********	**********	**********	**********	**********	******9000	0000000000	000000
11615201	5.5409	MEEKER 1NNW	40. 8. 0	107.59. 0	6475.0	1930-1953	1953-1953	**********	**********	**********	**********	**********	4000000000	0000000004	5401******	******
11615202	5.5404	MEEKER	40. 2. 0	107.54. 0	6242.0	1891-1965	1942-1965	**********	*300000000	0000000000	0000000000	000000039*	**********	*200000000	0000000000	000000
11615203	5.0000	MEEKER NO. 3	40. 4. 0	107.55. 0	6182.0	1891-1926	1892-1926	**********	*300000000	0000000000	0000000000	0000000***	**********	**********	**********	******
11615550	5.5408	MARVINE	40. 0. 0	107.35. 0	7200.0	1947-1965	1955-1965	**********	**********	**********	**********	**********	**********	*******920	0000000000	000050
11617020	37.7395	ROOSEVELT	40.18. 0	109.59. 0	5094.0	1940-1965	1951-1965	**********	**********	**********	**********	**********	**********	2000000002	1000000000	000000
11617021	37.6123	NEOLA	40.25. 0	110. 3. 0	6000.0	1956-1965	1957-1965	**********	**********	**********	**********	**********	**********	**********	******7000	000000
11617040	37.0000	HIDDEN CAMP	40.29. 0	110. 8. 0	5400.0	1941-1942	1942-1942	**********	**********	**********	**********	**********	**********	**6*******	**********	******
11617041	37.0090	DRY GULCH RS	40.32. 0	110.13. 0	7800.0	1916-1929	1929-1929	**********	**********	**********	******8321	3544655165	**********	**********	**********	******
11617050	37.2996	FORT DUCHESNE	40.17. 0	109.51. 0	4990.0	1888-1965	1921-1965	********20	0000000000	0000000000	0000002405	2000000000	0000000000	0000000000	0000000000	000000
11617054	37.4927	LA POINT	40.24. 0	109.49. 0	5500.0	1944-1960	1948-1960	**********	**********	**********	**********	**********	**********	****320200	0000000000	0*****
11617061	37.0000	WHITE ROCKS	40.27. 0	109.56. 0	5970.0	1912-1914	1913-1914	**********	**********	**********	**300*****	**********	**********	**********	**********	******
11617062	37.0000	HAYDEN	40. 4. 0	109.59. 0	6000.0	1915-1917	1917-1917	**********	**********	**********	*****311**	**********	**********	**********	**********	******
11617140	37.2429	ELKHORN ASHLEY R	40.33. 0	109.57. 0	6850.0	1910-1955	1932-1955	**********	**********	**********	3000549703	7000000000	0300000000	0000000000	00000*****	******
11617250	37.5909	MYTON	40.12. 0	110. 4. 0	5084.0	1915-1965	1955-1965	**********	**********	**********	*****40000	0000000000	0000000000	0000000000	0000000000	000005
11617270	37.0074	ALTAMONT	40.19. 0	110.14. 0	6100.0	1952-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	**00000000	000003
11617271	37.0000	MOUNTAIN HOME	40.26. 0	110.24. 0	6750.0	1912-1918	1918-1918	**********	**********	**********	**7031099*	**********	**********	**********	**********	******
11617310	37.9479	YELLOWSTONE RS	40.33. 0	110.20. 0	7700.0	1931-1947	1942-1947	**********	**********	**********	**********	**********	*736678677	66000000**	**********	******
11617350	37.5815	MOON LAKE	40.34. 0	110.30. 0	8150.0	1935-1965	1965-1965	**********	**********	**********	**********	**********	*****80000	8000000000	2221004975	766993
11617480	37.2253	DUCHESNE	40.10. 0	110.24. 0	5515.0	1906-1965	1907-1965	**********	**********	******3000	0000000000	0000000000	0000000000	0000000000	0000000005	000000
11617530	37.3056	FRUITLAND	40.13. 0	110.51. 0	6620.0	1910-1965	1965-1965	**********	**********	**********	9000121141	3000000000	5*****4800	0000004113	200*******	***049
11617630	37.8370	STRAWBERRY HWY S	40.15. 0	111. 9. 0	7700.0	1962-1965	1963-1965	**********	**********	**********	**********	**********	**********	**********	**********	**7000
11617631	37.8376	STRAWBERRY RES.	40.10. 0	111.11. 0	7606.0	1956-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	******8776	667687
11617634	37.8371	STRAWBERRY JUNCT	40.14. 0	111.11. 0	7645.0	1954-1954	1954-1954	**********	**********	**********	**********	**********	**********	**********	****7*****	******
11617850	37.3424	HANNA	40.26. 0	110.44. 0	6780.0	1952-1965	1953-1965	**********	**********	**********	**********	**********	**********	**********	**90000000	000000
11618900	37.6508	OURAY	40. 8. 0	109.34. 0	4760.0	1943-1965	1956-1965	**********	**********	**********	**********	**********	**********	***3******	******1000	000000
11622001	37.9111	VERNAL AIRPORT	40.27. 0	109.31. 0	5280.0	1895-1965	1943-1965	**********	*****10000	0000*00170	0004960007	0000000000	0000000000	0003103704	0010000000	000000
11622150	37.0000	MASSEYS RANCH	40.37. 0	109.47. 0	7300.0	1938-1943	1940-1941	**********	**********	**********	**********	**********	*********4	0000******	**********	******
11623000	37.4342	JENSEN	40.22. 0	109.21. 0	4720.0	1916-1965	1953-1965	**********	**********	**********	******2379	1003930089	1410000000	0000000000	0000000000	001000
11624801	37.0000	TROUT CREEK RS	40.46. 0	109.36. 0	9200.0	1910-1930	1930-1930	**********	**********	**********	8378856788	8009787898	9*********	**********	**********	******
11627000	37.2172	DINOSAUR NATL MO	40.25. 0	109.20. 0	4880.0	1941-1957	1948-1957	**********	**********	**********	**********	**********	**********	*47**89700	00000000**	******
11627001	37.2173	DINOSAUR NATL MO	40.26. 0	109.19. 0	4770.0	1958-1965	1959-1965	**********	**********	**********	**********	**********	**********	**********	********60	000000
11632000	5.2800	FERNDALE RANCH	40.47. 0	107.59. 0	7000.0	1941-1960	1960-1960	**********	**********	**********	**********	**********	**********	*864445545	7685546667	9*****
11632030	5.3538	GREAT DIVIDE	40.47. 0	107.50. 0	6470.0	1948-1951	1951-1951	**********	**********	**********	**********	**********	**********	********30	01********	******

Appendix A continued

CSU NO	BUREAU NO	NAME	LATITUDE	LONGITUDE	ELEVATION	RECORDING BEGAN-ENDED	CONTINUOUS RECORDING	188 0123456789	189 0123456789	190 0123456789	191 0123456789	192 0123456789	193 0123456789	194 0123456789	195 0123456789	196 012345
11632000	42.2610	DIXON	41. 2. 0	107.32. 0	6360.0	1909-1965	1950-1965	**********	**********	*********9	**********	**50000000	0000000000	0000000001	0000000000	000000
11632201	42.0000	BATTLE MOUNTAIN	41. 2. 0	107.17. 0	7300.0	1910-1912	1912-1912	**********	**********	**********	607*******	**********	**********	**********	**********	******
11632300	42.0000	RAMBLER	41.10. 0	107. 1. 0	9293.0	1905-1911	1911-1911	**********	**********	*****76***	50********	**********	**********	**********	**********	******
11632430	5.8100	SUNBEAM 7SW	40.30. 0	108.16. 0	5681.0	1927-1951	1951-1951	**********	**********	**********	**********	*******600	0000000000	0000000100	1*********	******
11632432	5.5446	MAYBELL	40.31. 0	108. 5. 0	5970.0	1958-1965	1959-1965	**********	**********	**********	**********	**********	**********	**********	********90	000000
11632433	5.0000	LAY	40.32. 0	107.53. 0	6172.0	1890-1935	1901-1935	**********	30000000*9	1000000000	0000000000	0000000000	000000****	**********	**********	******
11632499	5.3738	HAMILTON	40.22. 0	107.37. 0	6210.0	1947-1965	1949-1965	**********	**********	**********	**********	**********	**********	*******900	0000008000	000000
11632520	5.0000	PAGODA	40.19. 0	107.20. 0	7040.0	1890-1912	1912-1912	**********	*400000000	0041010111	12********	**********	**********	**********	**********	******
11632521	5.9143	WILLOW CREEK 4SE	40.18. 0	107.16. 0	7250.0	1930-1948	1948-1948	**********	**********	**********	**********	**********	3105340000	000000029*	**********	******
11632522	5.0000	DUNKLEY	40.18. 0	107.11. 0	7400.0	1906-1908	1908-1908	**********	**********	******442*	**********	**********	**********	**********	**********	******
11632570	5.1928	CRAIG	40.31. 0	107.33. 0	6247.0	1936-1965	1954-1965	**********	**********	**********	**********	**********	******7000	0300000000	0001000000	000000
11632610	5.3867	HAYDEN	40.30. 0	107.15. 0	6337.0	1909-1965	1953-1965	**********	**********	*********3	9**3000***	3000530053	3000000000	0000000000	0010000000	000000
11632690	5.6797	PYRAMID	40.14. 0	107. 6. 0	8084.0	1911-1965	1948-1965	**********	**********	**********	*22*****96	000040008*	**********	*******900	0000000000	000000
11632800	5.0000	HAHNS PEAK	40.49. 0	106.56. 0	8153.0	1905-1908	1908-1908	**********	**********	*****7156*	**********	**********	**********	**********	**********	******
11632801	5.1792	COLUMBINE	40.51. 0	106.58. 0	8609.0	1909-1942	1918-1942	**********	**********	**********	0000005100	0000000000	0000000000	00********	**********	******
11632850	5.7936	STEAMBOAT SPRING	40.30. 0	106.50. 0	6770.0	1891-1965	1931-1965	**********	*900058009	********90	0000000000	0000000000	7000000000	0000000000	0000000000	000000
11632851	5.6811	RABBIT EARS PASS	40.22. 0	106.43. 0	9340.0	1948-1948	1948-1948	**********	**********	**********	**********	**********	**********	********9*	**********	******
11632940	5.9265	YAMPA	40. 9. 0	106.52. 0	7890.0	1909-1965	1944-1965	**********	**********	*********3	0000500004	*904******	**********	**7****900	0000000000	000000
11634000	5.0000	LADORE	40.39. 0	108.39. 0	5555.0	1910-1912	1912-1912	**********	**********	**********	*54*******	**********	**********	**********	**********	******
11636001	5.3439	GREYSTONE	40.37. 0	108.40. 0	6800.0	1937-1962	1962-1962	**********	**********	**********	**********	**********	*******500	000000002*	*********8	158***
11636002	5.3975	HIAWATHA	40.59. 0	108.37. 0	7100.0	1953-1957	1957-1957	**********	**********	**********	**********	**********	**********	**********	***90083**	******
11638000	37.0050	ALLENS RANCH	40.53. 0	109. 8. 0	5886.0	1962-1965	1963-1965	**********	**********	**********	**********	**********	**********	**********	**********	**9000
11640000	37.2864	FLAMING GORGE	40.56. 0	109.25. 0	6270.0	1958-1965	1959-1965	**********	**********	**********	**********	**********	**********	**********	********30	000000
11642009	37.0000	GREEN RIVER RS	40.53. 0	109.29. 0	6900.0	1916-1916	1916-1916	**********	**********	**********	******8***	**********	**********	**********	**********	******
11648000	37.0000	LINWOOD	41. 0. 0	109.39. 0	6000.0	1941-1942	1942-1942	**********	**********	**********	**********	**********	**********	*39*******	**********	******
11648001	37.5377	MANILA	41. 0. 0	109.43. 0	6420.0	1910-1965	1955-1965	**********	**********	**********	7000000000	0000000000	0210000000	0**7***2**	**91800000	000000
11648600	37.0000	HOLE IN THE ROCK	40.57. 0	110.10. 0	8600.0	1916-1930	1930-1930	**********	**********	**********	******9000	5000035876	**********	**********	**********	******
11654050	42.1736	CHURCH BUTTES GA	41.26. 0	110. 2. 0	7045.0	1955-1965	1957-1965	**********	**********	**********	**********	**********	**********	**********	*****20000	000000
11654200	42.0000	OPAL	41.46. 0	110.19. 0	6681.0	1916-1921	1921-1921	**********	**********	**********	******880*	3*********	**********	**********	**********	******
11654250	42.5105	KEMMERER	41.48. 0	110.32. 0	6954.0	1933-1965	1934-1965	**********	**********	**********	**********	**********	***8000000	0000000000	0000000000	000000
11654400	42.3430	FORT BRIDGER AIR	41.24. 0	110.25. 0	7016.0	1951-1965	1961-1965	**********	**********	**********	**********	**********	**********	**********	*90000****	500000
11654500	42.5836	LYMAN	41.20. 0	110.10. 0	6605.0	1922-1942	1933-1942	**********	**********	**********	**********	**40000501	6420000000	000*******	**********	******
11654800	42.0000	ROBERTSON	41. 9. 0	110.32. 0	7800.0	1943-1945	1945-1945	**********	**********	**********	**********	**********	**********	***303****	**********	******
11657000	42.7940	ROCK SPRINGS	41.35. 0	109.13. 0	6272.0	1952-1965	1952-1965	**********	**********	**********	**********	**********	**********	**********	**00000000	000000
11657001	42.7845	ROCK SPRINGS AIR	41.36. 0	109. 4. 0	6471.1	1954-1965	1955-1965	**********	**********	**********	**********	**********	**********	**********	****300000	000000
11657500	42.0000	SUPERIOR	41.46. 0	108.59. 0	7040.0	1914-1919	1919-1919	**********	**********	**********	*****20050	**********	**********	**********	**********	******
11657600	42.0000	BITTER CREEK 4NE	41.34. 0	108.34. 0	6702.0	1898-1945	1963-1965	**********	********95	20********	**********	**********	**********	**********	**********	**9000
11658000	42.4065	GREEN RIVER	41.32. 0	109.29. 0	6089.0	1897-1945	1952-1965	**********	*******97*	*****20000	2020000100	2000000000	0000000100	0000000002	2200000000	000000
11662100	42.3170	FARSON	42. 7. 0	109.26. 0	6591.0	1931-1965	1955-1965	**********	**********	**********	**********	**********	*600000000	000418*400	2004100000	000000
11662810	42.0000	DUTCH JOE	42.37. 0	109.15. 0	7886.0	1916-1926	1926-1926	**********	**********	**********	*******636	6312670***	**********	**********	**********	******
11663000	42.3396	FONTENELLE DAM	41.59. 0	110. 4. 0	6478.0	1963-1965	1964-1965	**********	**********	**********	**********	**********	**********	**********	**********	***900
11666000	42.0000	FONTENELLE	42. 5. 0	110.15. 0	6700.0	1904-1908	1908-1908	**********	**********	****80966*	**********	**********	**********	**********	**********	******
11671000	42.5252	LA BARGE 4WNW	42.17. 0	110.15. 0	6830.0	1894-1965	1964-1965	**********	****67**9*	**********	**********	**********	**********	**********	**********	***800
11673000	42.0695	BIG PINEY	42.32. 0	110. 7. 0	6821.0	1938-1965	1939-1965	**********	**********	**********	**********	**********	********30	0000000000	0000000000	000000
11678120	42.0698	BIG SANDY	42.40. 0	109.30. 0	7200.0	1965-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	**********	*****9
11678450	42.7260	PINEDALE 1E	42.52. 0	109.51. 0	7210.0	1906-1965	1963-1965	**********	**********	******3004	1100500000	1414722000	0029*****3	0000000000	0200003150	004000
11678660	42.0000	WILLOW CREEK CAB	43. 5. 0	109.54. 0	7500.0	1906-1915	1915-1915	**********	**********	******9*31	*55126****	**********	**********	**********	**********	******
11678690	42.0000	CORA	42.57. 0	109.58. 0	7300.0	1942-1943	1943-1943	**********	**********	**********	**********	**********	**********	**00******	**********	******
11682000	42.0000	JENKINS RANCH	42.50. 0	110. 0. 0	7070.0	1940-1942	1941-1942	**********	**********	**********	**********	**********	**********	300*******	**********	******
11684000	42.0000	DANIEL	42.55. 0	110. 4. 0	6760.0	1890-1915	1915-1915	**********	*********3	0000000000	020048****	**********	**********	**********	**********	******
11684600	42.6105	MERNA	42.57. 0	110.22. 0	7700.0	1963-1965	1964-1965	**********	**********	**********	**********	**********	**********	**********	**********	****00
11690000	42.5115	KENDALL	43.12. 0	109.59. 0	7645.0	1904-1965	1952-1965	**********	**********	****3000*4	*******312	5416699700	0000000000	0000000502	2100000000	000000
11700000	37.1160	CANYONLANDS-THE	38. 9. 0	109.45. 0	5040.0	1965-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	**********	*****9
11800000	37.1163	CANYONLANDS-THE	38.27. 0	109.50. 0	5900.0	1965-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	**********	*****9
11950000	37.4946	LA SAL	38.19. 0	109.15. 0	6075.0	1901-1965	1965-1965	**********	**********	*711514762	0502140412	2132335169	0000000143	500000005*	4930080000	05**43
12000001	37.0000	WARNER RS	38.31. 0	109.16. 0	9450.0	1916-1921	1921-1921	**********	**********	**********	******8999	99********	**********	**********	**********	******
12190000	37.5733	MOAB 4 NW	38.36. 0	109.36. 0	3965.0	1889-1965	1956-1965	*********9	0000000000	0000000000	0000000900	0000000000	0000000000	0000000000	0000240000	000000
12150000	37.0000	DALTON WELLS	38.43. 0	109.42. 0	4400.0	1941-1942	1942-1942	**********	**********	**********	**********	**********	**********	*38*******	**********	******
12150001	37.8705	THOMPSONS	38.58. 0	109.43. 0	5150.0	1911-1965	1952-1965	**********	**********	**********	*700731*76	0000000000	0000000000	0000000021	1100000000	000000
12300000	37.1240	CASTLETON	38.36. 0	109.19. 0	5920.0	1963-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	**********	****10
12700000	37.0000	FISHER VALLEY	38.40. 0	109. 5. 0	6000.0	1911-1911	1911-1911	**********	**********	**********	*9********	**********	**********	**********	**********	******
12708000	5.3248	GATEWAY 1SW	38.40. 0	108.59. 0	4562.0	1947-1965	1948-1965	**********	**********	**********	**********	**********	**********	*******900	0000000000	000000
12708002	5.0000	WATERFALL RANCH	38.47. 0	108.41. 0	7500.0	1935-1942	1942-1942	**********	**********	**********	**********	**********	*****70000	008*******	**********	******
12724000	5.8560	URAVAN	38.22. 0	108.44. 0	5013.0	1961-1965	1962-1965	**********	**********	**********	**********	**********	**********	**********	**********	*30000
12724150	5.0000	RED VALE	38.11. 0	108.24. 0	6350.0	1912-1922	1922-1922	**********	**********	**********	**80000500	003*******	**********	**********	**********	******
12724151	5.6012	NORWOOD	38. 8. 0	108.17. 0	7017.0	1931-1965	1951-1965	**********	**********	**********	**********	**********	*900800001	0130000000	1000008000	000000
12724152	5.0000	RED VALE (NEAR)	38. 3. 0	108.29. 0	6996.0	1939-1941	1941-1941	**********	**********	**********	**********	**********	*********9	10********	**********	******
12724450	5.6524	PLACERVILLE	38. 2. 0	108. 3. 0	7322.0	1947-1965	1956-1965	**********	**********	**********	**********	**********	**********	*******900	0010928000	000000
12724600	5.0000	ILIUM	37.55. 0	107.54. 0	8179.0	1915-1915	1915-1915	**********	**********	**********	*****7****	**********	**********	**********	**********	******
12724602	5.8454	TROUT LAKE	37.50. 0	107.53. 0	9700.0	1915-1956	1916-1956	**********	**********	**********	*****30000	0000000000	0000000000	0000000000	0000000***	******
12732000	5.0000	RED ROCK	38.19. 0	108.53. 0	5300.0	1910-1911	1911-1911	**********	**********	**********	97********	**********	**********	**********	**********	******
12732001	5.6315	PARADOX	38.22. 0	108.58. 0	5309.0	1942-1965	1942-1965	**********	**********	**********	**********	**********	**********	**40000001	4000008000	000000
12748300	5.0000	LAVENDER	37.52. 0	108.29. 0	7091.0	1891-1894	1894-1894	**********	*9103*****	**********	**********	**********	**********	**********	**********	******
12764000	5.2326	DOLORES	37.28. 0	108.30. 0	6936.0	1909-1945	1948-1965	**********	**********	*********1	58****9000	000000009*	**********	*******900	0000000000	000000
12788000	5.7817	RICO	37.41. 0	108. 2. 0	8842.0	1891-1965	1911-1965	**********	*300000009	**********	1000000000	0000000000	0000000000	0000000000	0000000000	000000

Appendix A continued

CSU NO	BUREAU NO	NAME	LATITUDE	LONGITUDE	ELEVATION	RECORDING BEGAN-ENDED	CONTINUOUS RECORDING	188 0123456789	189 0123456789	190 0123456789	191 0123456789	192 0123456789	193 0123456789	194 0123456789	195 0123456789	196 012345
12900000	37.1440	CISCO	38.58. 0	109.19. 0	4330.0	1952-1965	1961-1965	**********	**********	**********	**********	**********	**********	**********	**90000001	200000
13000000	5.5441	LITTLE DOLORES 5	39. 3. 0	108.51. 0	6375.0	1961-1965	1963-1965	**********	**********	**********	**********	**********	**********	**********	**********	**0000
13000002	5.5040	LITTLE DOLORES	38.56. 0	108.51. 0	6700.0	1942-1955	1955-1955	**********	**********	**********	**********	**********	**********	**00000001	0****1****	******
13000003	5.0000	GLADE PARK	39. 0. 0	108.43. 0	6500.0	1911-1918	1912-1919	**********	**********	**********	*30000000*	**********	**********	**********	**********	******
13100000	37.3706	HARLEY DOME	39.10. 0	109. 0. 0	5247.0	1959-1963	1963-1963	**********	**********	**********	**********	**********	**********	**********	*********9	0003**
13500000	5.1772	COLORADO NATIONA	39. 6. 0	108.44. 0	5790.0	1940-1965	1951-1965	**********	**********	**********	**********	**********	**********	5000100000	1000000000	000000
13500001	5.3146	FRUITA 2 W	39.11. 0	108.44. 0	4510.0	1890-1965	1908-1965	**********	2100******	***1000400	0000000000	0000000000	0000000000	0000000005	0000000000	000000
13700000	5.0000	T.S.RANCH	39. 0. 0	108.19. 0	5250.0	1888-1901	1897-1901	*********5	3203101000	00********	**********	**********	**********	**********	**********	******
13709000	5.0000	ALTMAN	38.44. 0	108.10. 0	10640.0	1898-1898	1898-1898	**********	********6*	**********	**********	**********	**********	**********	**********	******
13715050	5.6081	OLATHE	38.37. 0	107.59. 0	5360.0	1941-1965	1955-1955	**********	**********	**********	**********	**********	**********	*400000000	000102****	******
13715051	5.5717	MONTROSE NO 1	38.29. 0	107.53. 0	5830.0	1939-1965	1944-1965	**********	**********	**********	**********	**********	*********6	2002000007	0000000000	000000
13715052	5.5722	MONTROSE NO 2	38.29. 0	107.53. 0	5810.0	1885-1965	1900-1965	*****30000	00009*0099	0000000000	0000000001	0000000000	0000000000	0000000005	0000000000	000000
13715100	5.0000	FORT CRAWFORD	38.23. 0	107.49. 0	6695.0	1889-1890	1890-1890	*********7	3*********	**********	**********	**********	**********	**********	**********	******
13715150	5.0000	LUJANE	38.29. 0	107.44. 0	6620.0	1906-1910	1907-1910	**********	**********	******9000	0*********	**********	**********	**********	**********	******
13715600	5.6203	OURAY	38. 1. 0	107.41. 0	7720.0	1943-1965	1951-1965	**********	**********	**********	**********	**********	**********	***9000000	3000000000	000000
13715750	5.0000	IRONTON	37.56. 0	107.41. 0	9800.0	1909-1920	1920-1920	**********	**********	*********9	2000000000	3*********	**********	**********	**********	******
13716000	5.2192	DELTA 1 E	38.45. 0	108. 3. 0	5125.0	1888-1965	1889-1965	********30	0000000000	0000000000	0000000000	0000000000	0000000000	0000000007	0000000000	000000
13718100	5.1440	CEDAREDGE	38.54. 0	107.56. 0	6175.0	1891-1965	1947-1965	**********	*300000000	0000******	9100000053	0085000000	0000000000	0000001000	0000000000	000000
13730211	5.6306	PAONIA	38.52. 0	107.35. 0	5685.0	1957-1965	1959-1965	**********	**********	**********	**********	**********	**********	**********	*******800	000000
13730212	5.6307	PAONIA 1S	38.51. 0	107.34. 0	6125.0	1892-1957	1957-1957	**********	**6222100*	*****40000	0000000000	0000000000	0000000000	0001300000	00010005**	******
13730350	5.9045	WILCOX RANCH	38.55. 0	107.32. 0	5950.0	1948-1951	1949-1951	**********	**********	**********	**********	**********	**********	********30	0*********	******
13730700	5.0000	COLUMBINE RANCH	39. 2. 0	107.31. 0	6075.0	1909-1934	1911-1934	**********	**********	**********	1000000000	0000000000	00000*****	**********	**********	******
13730701	5.8063	WEST MUDDY RANGE	39. 6. 0	107.31. 0	8680.0	1950-1957	1957-1957	**********	**********	**********	**********	**********	**********	**********	88877877**	******
13730800	5.6651	POWDER HORN	39. 7. 0	107.38. 0	8600.0	1964-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	**********	****90
13733300	5.0000	CRAWFORD	38.42. 0	107.36. 0	6800.0	1909-1922	1910-1922	**********	**********	*********8	0000000000	000*******	**********	**********	**********	******
13736005	5.0000	RIVER PORTAL	38.31. 0	107.39. 0	5532.0	1906-1916	1911-1916	**********	**********	******9000	1000000***	**********	**********	**********	**********	******
13742250	5.1609	CIMARRON	38.24. 0	107.31. 0	7096.0	1951-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	**00000000	000041
13745000	5.7456	SAPINERO 9W	38.28. 0	107.28. 0	9300.0	1920-1946	1946-1946	**********	**********	**********	**********	3000000000	0000000000	0004478***	**********	******
13748000	5.0000	SAPINERO (NEAR)	38.27. 0	107.25. 0	8125.0	1899-1919	1906-1919	**********	*********9	000**70000	0000000000	**********	**********	**********	**********	******
13754000	5.6966	RED STONE	39.11. 0	107.14. 0	7200.0	1963-1964	1964-1964	**********	**********	**********	**********	**********	**********	**********	**********	***91*
13754001	5.4734	LAKE CITY	38. 3. 0	107.19. 0	8890.0	1905-1965	1944-1965	**********	**********	*****70000	00000299**	**********	**********	*******900	0000000000	000000
13760250	5.0000	CATHEDRAL	38. 4. 0	107. 3. 0	8925.0	1917-1934	1934-1934	**********	**********	**********	********20	0300021100	00001*****	**********	**********	******
13763000	5.7455	SAPINERO 8E	38.28. 0	107.10. 0	7800.0	1960-1965	1961-1965	**********	**********	**********	**********	**********	**********	**********	**********	*00000
13772000	5.1713	COCHETOPA CR	38.26. 0	106.46. 0	8000.0	1909-1965	1949-1965	**********	**********	*********9	00000009**	**********	**********	********10	0000000000	000000
13772400	5.6513	PITKIN	38.36. 0	106.32. 0	9200.0	1909-1965	1946-1965	**********	**********	*********8	0000000000	0000000000	0000000000	0000030000	0000000000	000000
13772700	5.7461	SARGENTS 6W	38.24. 0	106.28. 0	9125.0	1899-1958	1954-1954	**********	*********9	1*********	**********	**********	**********	*******900	000000002*	******
13772701	5.7460	SARGENTS	38.24. 0	106.26. 0	8445.0	1958-1965	1959-1965	**********	**********	**********	**********	**********	**********	**********	********90	000000
13775000	5.3662	GUNNISON	38.33. 0	106.56. 0	7694.0	1888-1965	1963-1965	********90	***9000040	1300000000	0000000000	0000000000	0002300000	0000000000	0000000000	021000
13781450	5.1959	CRESTED BUTTE	38.52. 0	106.58. 0	8855.0	1910-1965	1953-1965	**********	**********	**********	1000000004	0000000000	0000000000	0000000000	0010000000	000000
13790000	5.8154	TAYLOR PARK	38.49. 0	106.37. 0	9206.0	1941-1965	1942-1965	**********	**********	**********	**********	**********	**********	*100000000	0000000000	000000
13800001	5.3489	GRAND JUNCTION 6	39. 3. 0	108.27. 0	4710.0	1962-1965	1964-1965	**********	**********	**********	**********	**********	**********	**********	**********	**4700
13800003	5.3488	GRAND JUNCTION W	39. 7. 0	108.32. 0	4849.0	1885-1965	1952-1965	*****9*75*	**30000000	0000000000	0000000000	0000000000	09********	**********	**00000000	000000
14000000	5.6266	PALISADE 1 S	39. 6. 0	108.21. 0	4740.0	1911-1965	1951-1965	**********	**********	**********	*710000000	8700000000	0023000000	0000000000	1000000000	000000
14240000	5.0425	BOWMAN OBSERVATIO	39. 4. 0	107.54. 0	9820.0	1963-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	**********	***910
14230000	5.1741	COLLBRAN	39.14. 0	107.58. 0	6137.0	1892-1965	1952-1965	**********	**30000000	0000000000	0000000000	2300000000	0000000000	0000000002	0100000000	000003
14300002	5.0000	DE BEQUE	39.19. 0	108.12. 0	4935.0	1914-1954	1954-1954	**********	**********	**********	666*******	**********	**********	**********	**707*****	******
14525000	5.0214	ALTENBERN	39.30. 0	108.23. 0	5690.0	1947-1965	1948-1965	**********	**********	**********	**********	**********	**********	*******900	0000000000	000000
14700000	5.0000	GRAND VALLEY	39.28. 0	108. 2. 0	5100.0	1889-1913	1890-1913	*********9	0000000000	0000000000	0000******	**********	**********	**********	**********	******
14780000	5.6673	OIL SHALE MINE	39.33. 0	107.56. 0	8200.0	1947-1951	1948-1951	**********	**********	**********	**********	**********	**********	*******400	00********	******
14900000	5.7031	RIFLE 2 ENE	39.33. 0	107.44. 0	5314.0	1911-1965	1913-1965	**********	**********	**********	*800000000	00000**0*0	3010000000	0000000005	0000000000	000000
15150000	5.0000	RIFLE FALLS	39.41. 0	107.42. 0	5418.0	1889-1891	1891-1891	*********7	80********	**********	**********	**********	**********	**********	**********	******
15200000	5.0000	SILT	39.33. 0	107.39. 0	5441.0	1900-1907	1907-1907	**********	**********	30010001**	**********	**********	**********	**********	**********	******
15545000	5.0000	LONESOME	39.18. 0	107.32. 0	7660.0	1917-1918	1918-1918	**********	**********	**********	*******60*	**********	**********	**********	**********	******
15921000	5.0000	MARBLE	39. 4. 0	107.10. 0	7951.0	1908-1917	1917-1917	**********	**********	*********3	00000000**	**********	**********	**********	**********	******
15924000	5.0000	EMMA	39.22. 0	107. 3. 0	-.1	1889-1891	1891-1891	**********	0*********	**********	**********	**********	**********	**********	**********	******
15942000	5.0514	BASALT	39.22. 0	107. 2. 0	6624.0	1965-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	**********	*****7
15942120	5.5407	MEREDITH	39.22. 0	106.45. 0	7797.0	1963-1965	1964-1965	**********	**********	**********	**********	**********	**********	**********	**********	***900
15942150	5.5513	MEREDITH 4NE	39.22. 0	106.41. 0	8560.0	1949-1953	1953-1953	**********	**********	**********	**********	**********	**********	**********	2183******	******
15942600	5.0000	NAST	39.19. 0	106.37. 0	8800.0	1909-1934	1934-1934	**********	**********	*********3	000000000*	*000000000	04001*****	**********	**********	******
15963000	5.0370	ASPEN	39.11. 0	106.50. 0	7913.0	1888-1965	1951-1965	********75	93*******9	6*********	****300003	**********	*****00000	0000000000	1000000000	000000
15970000	5.0000	ASHCROFT	39. 4. 0	106.48. 0	9443.0	1901-1922	1914-1922	**********	**********	*300000000	0005100000	000*******	**********	**********	**********	******
15984000	5.4270	INDEPENDENCE PAS	39. 5. 0	106.39. 0	10550.0	1947-1959	1951-1959	**********	**********	**********	**********	**********	**********	*******900	100000000*	******
16100000	5.3359	GLENWOOD SPRINGS	39.34. 0	107.20. 0	5823.0	1888-1965	1954-1965	********75	8**9*****9	*810000004	0000140000	0000050000	0000000000	0000000000	6001000000	000000
16300000	5.7618	SHOSHONE	39.34. 0	107.14. 0	5923.0	1910-1965	1911-1965	**********	**********	**********	3000000000	0000000000	0000000000	0000000000	0000000000	000000
16614001	5.2454	EAGLE FAA AIRPOR	39.39. 0	106.55. 0	6497.0	1904-1965	1944-1965	**********	**********	****900000	0*********	**********	**********	**71000000	0000000000	000000
16628000	5.0000	EAGLE	39.39. 0	106.50. 0	6598.0	1904-1947	1944-1947	**********	**********	****900011	0*********	**********	**********	**710000**	**********	******
16628001	5.0000	PINEY	39.42. 0	106.32. 0	9000.0	1917-1919	1919-1919	**********	**********	**********	*******8*3	**********	**********	**********	**********	******
16628002	5.0000	AVON	39.37. 0	106.29. 0	7445.0	1938-1942	1942-1942	**********	**********	**********	**********	**********	********30	034*******	**********	******
16670000	5.6917	REDCLIFF	39.31. 0	106.22. 0	8608.0	1890-1951	1951-1951	**********	530101110*	**********	1010110***	**********	**********	*********2	11********	******
17100000	5.0810	BOND	39.53. 0	106.42. 0	6780.0	1958-1965	1966-1965	**********	**********	**********	**********	**********	**********	**********	*********2	000000
17300000	5.0000	BLUE VALLEY RANC	39.59. 0	106.23. 0	7400.0	1907-1915	1914-1915	**********	**********	********00	1**8017***	**********	**********	**********	**********	******
17403000	5.3592	GREEN MOUNTAIN D	39.53. 0	106.20. 0	7740.0	1939-1965	1952-1965	**********	**********	**********	**********	**********	*********8	0000000000	0100000000	000000
17445000	5.2281	DILLON 1 S	39.36. 0	106. 3. 0	8900.0	1891-1965	1914-1965	**********	*30*******	*********8	0*33000000	0000000000	0000000000	0000000000	0000000000	000000
17448600	5.1660	CLIMAX 2 NW	39.23. 0	106.12. 0	11300.0	1952-1965	1953-1965	**********	**********	**********	**********	**********	**********	**********	**1000*000	000000
17480000	5.0909	BRECKENRIDGE	39.29. 0	106. 2. 0	9579.0	1889-1965	1948-1965	*********3	0000000000	0000000000	0005******	**********	**********	*******900	0000000000	000000

Appendix A continued

CSU NO	BUREAU NO	NAME	LATITUDE	LONGITUDE	ELEVATION	RECORDING. BEGAN-ENDED	CONTINUOUS RECORDING	188 0123456789	189 0123456789	190 0123456789	191 0123456789	192 0123456789	193 0123456789	194 0123456789	195 0123456789	196 012345
17520000	5.4664	KREMMLING	40. 4. 0	106.24. 0	7359.0	1908-1965	1965-1965	**********	**********	********30	1*********	**********	**********	*****60005	1106******	****70
17540000	5.3423	GORE PASS RANCH	40. 9. 0	106.28. 0	7682.0	1957-1963	1958-1963	**********	**********	**********	**********	**********	**********	**********	*******800	0000**
17710000	5.0000	PARSHALL	40. 1. 0	106.15. 0	7705.0	1909-1912	1912-1912	**********	**********	*********3	139*******	**********	**********	**********	**********	******
17720002	5.6342	PARSHALL 10SSE	39.55. 0	106. 7. 0	8270.0	1951-1965	1957-1965	**********	**********	**********	**********	**********	**********	**********	*800107000	000000
17740000	5.0000	LEAL	39.49. 0	106. 3. 0	8680.0	1910-1910	1910-1910	**********	**********	**********	5*********	**********	**********	**********	**********	******
17740001	5.3345	GLEN MAR	39.47. 0	106. 1. 0	8687.0	1947-1951	1951-1951	**********	**********	**********	**********	**********	**********	*******901	17********	******
17900000	5.4129	HOT SULPHUR SPRI	40. 3. 0	106. 4. 0	7680.0	1896-1965	1955-1965	**********	******13**	**********	**********	**********	**********	**100*****	***7100000	000000
18030000	5.3113	FRASER	39.57. 0	105.50. 0	8560.0	1889-1965	1930-1965	*********5	5*********	**********	2000000900	0000000006	0000000000	0000000000	0000000000	000000
18034000	5.9175	WINTER PARK	39.54. 0	105.46. 0	9058.0	1943-1965	1950-1965	**********	**********	**********	**********	**********	**********	***1000001	0000060000	000000
18081000	5.0674	BERTHOUD PASS	39.49. 0	105.47. 0	11314.0	1950-1965	1944-1965	**********	**********	**********	**********	**********	**********	**********	8*********	***900
18450000	5.3500	GRAND LAKE 6 SSW	40.11. 0	105.52. 0	8288.0	1952-1965	1952-1965	**********	**********	**********	**********	**********	**********	**********	**00000000	000000
18450001	5.3508	GRAND VALLEY	40.11. 0	105.52. 0	8288.0	1965-1965	1965-1965	**********	**********	**********	**********	**********	**********	**********	**********	*****7
18450000	5.3496	GRAND LAKE 1 NW	40.16. 0	105.50. 0	8576.0	1907-1965	1947-1965	**********	**********	*******951	0000000000	0*********	**********	0001318000	0000000000	000000

APPENDIX B

Table of mean spring runoff, of mean winter precipitation, of correlation coefficient between winter, spring precipitation and spring runoff, of expected increase in spring runoff, and of the number of years needed for evaluation, based on the two-sample u-test.

Column 1 of Table B lists the CSU code number for identification of runoff station (7 digits) or precipitation station (8 digits).

Column 2 of Table B lists the mean spring runoff or the mean winter precipitation, in inches.

Column 3 lists the variance of the spring runoff, in inches square .

Column 4 lists the coefficient of correlation between spring runoff and precipitation from one or several precipitation gages.

Column 5 indicates the number of years of record on which the correlation is based.

Column 6 gives the value of coefficient b_j of equation (11) for each precipitation station.

Column 7 gives the expected value of increase in spring runoff (inches) corresponding to a 10% increase in winter precipitation at each precipitation station.

Column 8 gives the expected relative increase in spring runoff assuming a uniform 10% increase in winter precipitation.

Column 9 gives the number of years for evaluation at the 95% level of significance and 50% power assuming a uniform 10% increase in winter precipitation.

TABLE

Column 1	2	3	4	5	6	7	8	9
CSU ID	Mean in.	Variance in.^{2}	Cor Cof	Case	Coeff	Increase Runoff	Increase Ratio	Years Eval.
1071830	.50	.08	.96	13		.040	.080	192
10718302	8.87				.045			
1071860	1.29	.23	.98	14		.087	.067	117
10718600	8.02				.108			
1073020	.68	.55	.93	10		.155	.228	87
10730600	7.95				.444			
10730603	10.42				-.190			
1073040	1.02	.63	.95	10		.184	.180	71
10730600	7.95				.479			
10730603	10.42				-.189			
1073060	1.49	1.44	.94	10		.316	.212	55
10730600	7.95				.867			
10730603	10.42				-.358			
1073200	3.38	2.98	.98	52		.383	.113	77
10734000	4.42				-.324			
10734040	5.10				-.038			
10734360	11.06				.220			
10734641	18.60				.048			
10734680	12.90				.046			
10738000	4.27				-.084			
10758200	8.52				.075			
10770000	9.37				.136			
1073400	6.74	9.71	.98	52		.694	.103	77
10734000	4.42				0			
10734040	5.10				-.343			
10734360	11.06				.443			
10734641	18.60				.120			
10734680	12.90				.121			
1073408	8.12	12.78	.98	31		.830	.102	71
10734360	11.06				.280			
10734641	18.60				.221			
10734680	12.90				.085			
1073436	38.89	7.74	.98	52		1.117	.029	23
10734360	11.06				.480			
10734641	18.60				.286			
10734680	12.90				.042			
1073448	8.91	22.00	.97	9		.726	.082	160
10734560	11.65				1.287			
10734561	15.04				-.514			
1073460	15.98	34.29	.99	11		1.415	.089	65
10734641	18.60				.761			
10734680	12.90				0.0			

Table continued

1 CSU ID	2 Mean	3 Variance	4 Cor Cof	5 Case	6 Coeff	7 Increase Runoff	8 Increase Ratio	9 Years Eval.
1074400	3.87	4.24	.97	25		.399	.103	102
10750001	6.51				.377			
10758200	8.52				-.261			
10758400	15.47				-.085			
10764201	11.03				0.0			
10770000	9.37				.311			
10774000	11.90				-.120			
10776001	13.78				.081			
10778600	30.53				.081			
1075200	3.16	3.33	.99	15		.372	.118	92
10758200	8.52				-.464			
10758400	15.47				-.874			
10764201	11.03				0.			
10770000	9.37				1.551			
10774000	11.90				-.223			
10776001	13.78				.698			
10778600	30.53				-.010			
1075820	7.40	19.69	.89	19		.441	.060	389
10758200	8.52				0			
10758400	15.47				.285			
1076200	6.12	8.21	.97	22		.587	.096	91
10764201	11.03				.076			
10770000	9.37				.365			
10774000	11.90				-.314			
10776001	13.78				.388			
1076800	5 64	9.80	.98	25		.749	.133	67
10770000	9.37				.460			
10774000	11.90				-.314			
10776001	13.78				.502			
10778600	30.53				0.			
1077200	9.43	29.10	.97	13		1.019	.108	107
10774000	11.90				.856			
1077600	16.05	72.85	.97	17		1.479	.092	128
10776001	13.78				1.073			
1077800	19.70	74.85	.97	25		1.652	.084	105
10778600	30.53				.541			
1146300	.51	.03	.97	21		.045	.089	55
11463000	3.44				.132			
1160121	1.31	1.87	.84	17		.162	.123	274
11601300	4.22				-.127			
11601420	4.29				.502			
1160720	2.41	1.74	.98	29		.187	.078	191
11607400	9.38				-.012			
11607601	15.72				.126			
1160725	2.71	2.83	.96	30		.351	.130	88
11607400	9.38				-.125			
11607601	15.72				.298			
1160740	4.22	9.30	.83	25		.225	.053	704
11607400	9.38				.240			
1160755	4.49	5.66	.95	25		.489	.109	90
11607601	15.72				.311			
1161500	1.40	.29	.98	25		.190	.136	30
11615004	5.47				.083			
11615150	7.35				.097			
11615202	8.94				.067			
11615550	12.25				.011			
1161520	4.93	2.58	.98	16		.380	.077	68
11615202	8.94				.240			
11615550	12.25				.135			
1161525	6.99	4.00	.98	17		.592	.085	43
11615550	12.25				.483			
1161706	.47	.09	.90	13		.032	.067	347
11617060	4.78				.066			
1161725	2.19	1.33	.99	10		.259	.118	76
11617250	3.24				0.			
11617270	4.20				-.897			
11617350	9.95				.210			
11617460	4.58				.932			
11617850	6.02				0.			

Table continued

1	2	3	4	5	6	7	8	9
CSU ID	Mean	Variance	Cor Cof	Case	Coeff	Increase Runoff	Increase Ratio	Years Eval.
1161726	2.66	3.42	.97	25		.163	.061	492
11617270	4.20				.280			
11617350	9.95				.046			
1161746	2.31	1.65	.95	15		.207	.090	148
11617530	6.67				.406			
11617631	7.11				-.090			
1161752	1.52	1.08	.93	15		.205	.135	98
11617530	6.67				.308			
1161774	5.10	4.07	.99	12		.370	.072	114
11617580	6.02				.614			
1161783	5.30	4.25	.99	12		.400	.076	101
11617850	6.02				.665			
1161785	7.95	7.49	.99	11		.709	.089	57
11617850	6.02				1.170			
1162200	1.13	.84	.96	12		.066	.059	737
11622001	4.76				.139			
1163200	1.75	.52	.98	20		.147	.084	92
11632080	6.91				.213			
1163203	1.82	.86	.96	15		.190	.104	91
11632080	6.91				.275			
1163243	5.25	2.99	.99	25		.114	.022	880
11632490	10.11				-.197			
11632570	7.31				-.192			
11632610	9.20				.322			
11632690	12.12				.165			
11632850	15.17				-.028			
11632940	9.19				0.			
1163256	7.70	3.09	.99	25		.555	.072	38
11632570	7.31				.257			
11632610	9.20				.047			
11632690	12.12				-.087			
11632850	15.17				.283			
11632940	9.19				0.			
1163257	1.99	.87	.97	21		.156	.079	136
11632570	7.31				.214			
1163268	3.83	4.62	.94	9		.288	.075	213
11632690	12.12				.238			
1163274	16.58	17.40	.97	18		1.331	.080	37
11632801	14.71				.900			
1163280	19.34	29.98	.96	32		1.399	.072	58
11632801	14.71				.951			
1163285	8.64	6.40	.98	18		.562	.065	77
11632940	9.19				.612			
1163291	2.78	1.48	.97	25		.145	.052	269
11632940	9.19				.158			
1164700	1.19	.17	.98	15		.066	.056	149
11648001	5.13				.019			
11654500	5.50				.050			
11658000	4.00				.036			
11662180	3.78				.048			
11678450	5.29				-.070			
11690000	9.79				.034			
1165000	1.30	.28	.98	34		.099	.076	109
11654250	4.96				.167			
11658000	4.00				.062			
11662180	3.78				-.082			
11673000	3.85				-.167			
11678450	5.29				.038			
11690000	9.79				.068			
1165400	.88	.28	.96	17		.081	.092	165
11654050	4.08				.046			
11654250	4.96				-.075			
11654400	4.31				.230			
1165410	1.01	.28	.94	15		.052	.051	404
11654250	4.96				.104			
1165445	1.74	.97	.92	5		.113	.065	293
11654500	5.50				.205			
1166200	.15	.01	.93	10		.007	.048	744
11662180	3.78				.019			

Table continued

1	2	3	4	5	6	7	8	9
CSU ID	Mean	Variance	Cor Cof	Case	Coeff	Increase Runoff	Increase Ratio	Years Eval.
1167800	5.51	3.45	.80	15		.397	.072	83
11678450	5.29				.751			
1167827	6.93	5.27	.95	50		.398	.057	127
11678450	5.29				.753			
1167845	11.91	17.94	.93	40		.668	.056	154
11678450	5.29				1.260			
1167857	2.54	.69	.97	6		.196	.077	69
11678690	5.57				.351			
1168800	10.63	5.67	.98	33		.663	.062	49
11690000	9.79				.677			
1270000	1.58	1.03	.96	25		.217	.138	83
12708000	6.54				.067			
12724151	8.45				-.047			
12724450	7.30				-.012			
12724602	16.59				.109			
12732001	6.09				-.109			
12764000	11.25				.367			
12788000	15.33				-.203			
1272400	2.10	2.85	.96	24		.525	.157	39
12724151	8.45				.481			
12724450	7.30				-.096			
12724601	16.59				.114			
1272430	3.77	4.80	.95	13		.471	.125	83
12724450	7.30				.347			
12724602	16.59				.131			
1272445	7.39	7.76	.91	22		.539	.073	102
12724450	7.30				.739			
1272455	7.66	12.54	.96	18		.816	.107	72
12724602	16.59				.492			
1274000	3.07	.95	.97	13		.344	.112	30
12764000	11.25				.186			
12788000	15.33				.088			
1275600	5.43	10.64	.94	26		.606	.112	111
12764000	11.25				.490			
12788000	15.33				.036			
1277200	8.78	14.37	.96	43		.805	.092	85
12788000	15.33				.520			
1278000	8.80	15.99	.97	25		.958	.109	66
12788000	15.33				.625			
1371200	4.24	3.84	.98	16		.561	.132	46
13730212	9.62				.159			
13772400	8.71				.286			
13775000	5.18				-.234			
13781450	14.25				-.188			
13790000	9.10				.602			
1371505	3.51	1.85	.98	25		.346	.099	59
13715051	5.26				1.209			
13715052	5.15				-.989			
13715600	11.69				.188			
1371510	3.93	.39	.99	8		.412	.105	8
13715150	6.44				.630			
1371515	5.79	1.48	.99	8		.743	.128	10
13715150	6.44				1.150			
1371520	5.96	4.60	.97	22		.228	.038	341
13715600	5.15				.442			
1371565	24.61	8.79	.98	11		2.327	.095	6
13715750	13.49				1.720			
1371810	7.58	11.42	.96	48		.610	.081	117
13718100	6.70				.911			
1373000	7.35	14.92	.97	15		.457	.062	274
13730211	8.71				-.382			
13730212	9.69				.821			
1373035	10.04	5.69	.99	9		.963	.096	23
13730700	14.70				.655			
1373055	9.60	12.60	.95	15		.513	.053	184
13730701	12.12				.423			
1373070	8.23	25.00	.93	8		.698	.085	197
13730701	12.12				.567			

Table continued

1	2	3	4	5	6	7	8	9
CSU ID	Mean	Variance	Cor Cof	Case	Coeff	Increase Runoff	Increase Ratio	Years Eval.
1374500	3.72	4.09	.97	25		.502	.135	62
13754001	8.05				.329			
13772000	4.97				.484			
13742400	8.71				.118			
13772700	6.12				-.634			
13775000	5.18				-.590			
13781450	14.25				.071			
13790000	9.10				.534			
1375100	3.66	1.40	.98	25		.173	.047	179
13754001	8.05				-.161			
13772000	4.97				.326			
13772400	8.71				-.030			
13772700	6.12				-.040			
13775000	5.18				-.239			
13781450	14.25				.014			
13790000	9.10				.327			
1375400	7.47	6.62	.97	17		.621	.083	65
13754001	8.05				.772			
1376300	3.29	2.19	.97	27		.347	.106	69
13772000	4.97				.436			
13772400	8.71				-.101			
13775000	5.18				-.203			
13781450	14.25				.065			
13790000	9.10				.254			
1377200	1.47	.73	.93	27		.125	.085	180
13772000	4.97				.188			
13772400	8.71				.036			
1377230	4.58	5.35	.94	27		.358	.078	160
13772400	8.71				.411			
1377500	7.78	7.85	.98	20		.658	.085	69
13775000	5.18				-.225			
13781450	14.25				.229			
13790000	9.10				.493			
1378100	12.60	15.53	.97	30		.798	.063	93
13781450	14.25				.56			
1378145	23.66	9.67	.96	11		1.540	.065	15
13781450	14.25				1.084			
1378400	5.95	5.91	.97			.510	.086	87
13790000	9.10				.560			
1420000	3.10	3.15	.94	25		.386	.124	81
14250000	9.69				.398			
1590000	9.54	9.31	.97	18		.696	.073	73
15963000	11.30				.616			
1592110	16.99	24.24	.99	8		.675	.040	204
15921800	17.12				.394			
1592140	17.13	18.43	.98	14		1.169	.068	51
15921800	17.12				.683			
1592160	18.71	39.28	.98	9		.909	.049	182
15921800	17.12				.531			
1592170	20.02	27.48	.99	5		1.765	.088	33
15921800	17.12				1.031			
1592180	35.09	47.91	.99	7		1.063	.030	162
15921800	17.12				.621			
1594212	16.78	16.83	.98	10		1.602	.095	25
15942180	12.20				1.313			
1594218	9.47	12.99	.99	6		.785	.080	86
15942180	12.20				.621			
1596300	18.94	22.29	.99	5		1.425	.075	42
15963000	11.30				1.260			
1598400	15.36	16.22	.98	12		1.003	.065	61
15984000	17.41				.576			
1600000	6.37	3.60	.99	25		.339	.053	120
16100000	9.47				-.158			
16300000	10.80				-.541			
16614001	6.14				.442			
17403000	8.56				-.112			
17448600	14.32				.038			
17460000	12.34				-.444			
17720002	9.71				.023			

Table continued

1	2	3	4	5	6	7	8	9
CSU ID	Mean	Variance	Cor Cof	Case	Coeff	Increase Runoff	Increase Ratio	Years Eval.
17900000	7.08				1.029			
18036000	10.69				-.349			
18054000	15.82				-.135			
18500000	6.80				.745			
19500000	9.76				.738			
1650000	5.59	3.08	.96	24		.326	.058	111
17403000	8.56				0.			
17448600	14.32				.075			
17460000	12.34				-.304			
17720002	9.71				0.			
17900000	7.08				.178			
18036000	10.69				-.101			
18054000	15.82				-.043			
18500000	6.80				.427			
19500000	9.76				.362			
1700000	5.98	7.32	.96	25		.467	.078	129
17403000	8.56				-.061			
17460000	12.34				-.217			
18036000	10.69				.311			
18054000	15.82				.128			
19500000	9.76				.258			
1740000	8.15	4.67	.98	17		.824	.101	26
17403000	8.56				.120			
17448600	14.32				.278			
17460000	12.34				.262			
1742100	8.29	6.21	.98	21		.784	.095	38
17448600	14.32				.338			
17460000	12.34				.243			
1743900	8.64	9.13	.98	15		1.034	.120	32
17448600	14.32				.268			
17460000	12.34				.527			
1744800	11.85	11.24	.98	8		.965	.081	46
17448600	14.32				.674			
1744815	9.80	9.68	.99	7		1.403	.143	18
17448600	14.32				.980			
1745400	8.90	5.95	.98	14		.856	.096	31
17460000	12.34				.694			
1745700	6.82	5.02	.98	7		1.514	.222	8
17460000	12.34				1.220			
1770000	5.57	6.33	.95	16		.326	.059	228
17720002	9.71				.336			
1790000	9.03	7.63	.98	25		.655	.073	68
18036000	10.69				.332			
18054000	15.82				-.201			
18500000	6.80				.585			
19500000	9.76				.226			
1800000	7.26	5.21	.98	18		.738	.102	36
18036000	10.69				.374			
18054000	15.82				.214			
1801800	19.00	19.60	.98	21		1.381	.073	39
18036000	10.69				1.292			
1801816	3.98	22.89	.90	30		.649	.163	208
18036000	10.69				.607			
1820000	11.58	9.96	.97	20		.932	.080	44
19500000	9.76				.955			
1830000	13.88	16.54	.99	14		.978	.078	53
18500000	6.80				.161			
19500000	9.76				1.002			
1890000	14.48	11.46	.993	12		.956	.066	48
19500000	9.76				.980			
1920000	18.83	21.18	.99	8		1.567	.083	33
19500000	9.76				1.606			
1930000	16.89	23.05	.99	8		1.363	.081	47
19500000	9.76				1.390			
1960000	12.28	18.66	.97	31		.923	.075	84
19500000	9.76				.946			
1073080	13.50	38.37	.97	14		1.146	.085	112
10734560	11.65				.984			
1073420	12.21	34.79	.98	5		1.004	.082	132
10734560	11.65				.862			

Table continued

1	2	3	4	5	6	7	8	9
CSU ID	Mean	Variance	Cor Cof	Case	Coeff	Increase Runoff	Increase Ratio	Years Eval.
1073448	8.91	22.00	.96	19		.984	.110	87
10734560	11.65				.565			
10734641	18.60				.175			
1073460	15.91	36.36	.99	11		1.495	.094	62
10734641	18.60				.804			
1075830	12.47	26.43	.97	22		1.010	.081	99
10758400	15.47				.653			
1076420	9.02	25.30	.97	22		.878	.097	126
10758400	15.47				.290			
10774000	11.90				-.081			
10778600	30.56				.172			
1077015	9.37	17.80	.97	25		.939	.100	77
10774000	11.90				.571			
10778600	30.53				.085			
1077200	8.64	24.35	.97	13		1.019	.118	90
10774000	11.90				.856			
1077250	15.39	47.06	.97	25		1.305	.085	106
10774000	11.90				1.097			
1077400	13.66	40.00	.98	25		1.460	.107	72
10774000	11.90				-.142			
10776001	13.78				.699			
10778600	30.53				.218			
1272440	5.46	27.64	.91	15		1.142	.209	81
12724602	15.69				.728			
1272445	7.39	7.76	.98	9		.555	.075	96
12724450	7.30				.189			
12724602	15.69				.266			
1278800	13.57	39.08	.96	13		1.571	.116	60
12788000	15.33				1.025			
1371530	2.94	2.41	.93	9		.234	.079	169
12724450	7.30				-.117			
13715600	11.69				.273			
1371555	9.19	2.93	.99	6		1.158	.126	8
13715600	11.69				.991			
1762500	4.04	3.84	.96	11		.310	.077	153
18036000	10.69				.125			
18054000	18.52				.095			
1800900	5.71	4.13	.94	10		.509	.089	61
18036000	10.69				.476			
1801800	19.00	19.60	.98	21		1.381	.073	39
18036000	10.69				1.292			
1801816	8.98	22.89	.90	30		.649	.072	208
18036000	10.69				.607			
1802730	9.27	12.31	.94	31		.662	.071	108
18036000	10.69				.619			
1804500	5.05	18.41	.81	31		.753	.149	124
18054000	15.82				.476			
1805400	10.99	44.69	.86	22		.261	.024	2019
18054000	15.82				.165			
1810000	2.72	9.10	.78	11		.549	.202	115
18500000	6.80				.808			
1850000	6.42	8.22	.99	5		.854	.133	43
19500000	9.76				.875			
1866000	19.94	20.23	.99	18		1.528	.077	33
19500000	9.76				1.566			
1880000	10.36	16.47	.99	5		.949	.092	70
18500000	6.80				1.395			
1920000	18.83	21.18	.99	8		1.566	.083	33
19500000	9.76				1.605			
1930000	16.89	23.05	.99	8		1.363	.081	47
19500000	9.76				1.397			
1960000	12.28	18.66	.97	18		.923	.075	84
19500000	9.76				.946			

Table continued

1 CSU ID	2 Mean	3 Variance	4 Cor. Coef	5 Case	6 Coeff	7 Increase Runoff	8 Increase Ratio	9 Years Eval.
1072030	7.10	15.86	.91	14		.81	.114	92
10724000	3.94				2.05			
1072045	7.09	20.67	.97	14		.69	.098	164
10724000	3.94				1.76			
1072060	11.36	31.71	.99	14		1.07	.094	105
10724000	3.94				2.72			
1073412	2.94	2.96	.95	15		.290	.099	134
10734360	11.06				.26			
1076400	8.98	7.97	.97	15		.840	.094	43
10770000	9.37				.89			
1082075	6.70	3.67	.94	14		.510	.076	54
10810001	6.15				.82			
1086000	.69	.13	.95	10		.062	.089	132
10810001	6.15				.10			
1148100	1.73	.16	.95	9		.121	.070	41
11463000	3.44				.35			
1160133	4.90	4.13	.95	17		.368	.075	117
11601420	4.29				.85			
1160142	2.36	4.44	.89	11		.242	.102	292
11601420	4.29				.56			
1160145	5.42	5.12	.95	32		.379	.070	137
11601420	4.29				.88			
1160181	1.88	.914	.914	12		.072	.072	428
11601420	4.29				.16			
1160184	5.11	4.77	.94	55		.367	.072	136
11601420	4.29				.85			
1160190	22.97	22.40	.97	10		1.716	.075	29
11601420	4.29				4.00			
1160765	8.37	13.50	.95	26		.691	.083	108
11607150	5.19				1.33			
1160770	12.98	33.18	.96	24		1.090	.085	105
11607150	5.19				2.10			
1161250	.41	.07	.91	14		.056	.137	84
11615004	5.47				.10			
1161530	2.41	1.44	.95	15		.227	.094	107
11615550	12.25				.18			
1161540	5.15	5.87	.95	15		.409	.079	134
11615550	12.25				.33			
1161545	14.34	16.07	.98	13		1.137	.079	47
11615550	12.25				.92			
1161550	16.59	12.01	.98	10		1.029	.062	43
11615550	12.25				.84			
1161555	10.20	10.31	.98	13		.773	.076	66
11615550	12.25				.63			
1161560	10.74	9.50	.98	13		.829	.077	53
11615550	12.25				.67			
1161570	11.51	14.92	.98	13		.804	.070	88
11615550	12.25				.65			
1161709	9.77	18.74	.95	51		.667	.068	162
11617140	7.23				.92			
1161710	6.86	7.12	.96	9		.582	.085	80
11617140	7.23				.80			
1161718	8.15	7.11	.98	35		.612	.075	72
11617140	7.23				.84			

Table continued

1 CSU ID	2 Mean	3 Variance	4 Cor Cof	5 Case	6 Coeff	7 Increase Runoff	8 Increase Ratio	9 Years Eval.
1161720	2.78	2.96	.96	10		.243	.087	193
11617250	3.24				.74			
1161721	9.24	10.56	.98	10		.608	.066	109
11617250	3.24				1.87			
1161723	12.65	19.36	.97	10		.786	.062	120
11617250	3.24				2.42			
1161730	8.45	7.13	.98	20		.753	.089	48
11617350	9.95				.75			
1161734	11.07	11.03	.98	22		.916	.083	50
11617350	9.95				.92			
1161736	5.34	4.10	.97	13		.365	.068	118
11617350	9.95				.36			
1161737	13.49	18.09	.99	13		.995	.074	70
11617350	9.95				1.0			
1161753	2.82	2.34	.94	30		.246	.087	148
11617460	4.58				.53			
1161754	2.51	3.72	.915	18		.259	.103	212
11617460	4.58				.56			
1161755	5.52	10.98	.94	18		.567	.103	130
11617460	4.58				1.23			
1161756	.80	.43	.93	10		.065	.082	385
11617460	4.58				.14			
1161761	1.35	.42	.93	10		.101	.075	158
11617460	4.58				.22			
1161778	11.37	9.97	.98	27		.779	.069	63
11617460	4.58				1.70			
1161780	8.53	13.18	.96	11		.927	.109	58
11617460	4.58				2.02			
1161787	6.24	7.21	.97	19		.529	.085	98
11617460	4.58				1.15			
1161788	7.82	10.31	.97	19		.704	.090	79
11617460	4.58				1.53			
1161791	15.48	22.67	.97	17		1.034	.067	81
11617460	4.58				2.25			
1161793	17.13	21.22	.96	25		.950	.055	90
11617460	4.58				2.07			
1162205	5.07	4.23	.97	25		.416	.082	93
11622001	4.76				.87			
1162215	3.79	5.32	.92	10		.390	.103	134
11622001	4.76				.82			
1162225	7.92	15.39	.96	17		.785	.099	95
11622001	4.76				1.65			
1162235	5.40	6.93	.952	18		.539	.100	91
11622001	4.76				1.13			
1162240	7.69	10.24	.97	25		.633	.082	98
11622001	4.76				1.32			
1162285	9.30	13.09	.97	51		.680	.073	108
11622001	4.76				1.42			
1162275	11.28	18.31	.98	12		.655	.058	163
11622001	4.76				1.37			
1162280	10.73	19.62	.98	12		.590	.055	216
11622001	4.76				1.24			
1162620	6.30	24.73	.92	10		.539	.086	327
11623000	4.23				1.27			
1163212	3.78	2.79	.95	11		.306	.081	114
11632080	6.91				.44			
1163213	21.28	39.38	.97	11		1.419	.067	75
11632080	6.91				2.05			
1163214	6.18	5.14	.97	26		.435	.070	104
11632080	6.91				.63			
1163215	4.15	2.74	.94	10		.352	.085	84
11632080	6.91				.51			
1163216	3.35	2.75	.96	23		.326	.097	99
11632080	6.91				.47			

Table continued

1	2	3	4	5	6	7	8	9
CSU ID	Mean	Variance	Cor Coef	Case	Coeff	Increase Runoff	Increase Ratio	Years for Eval.
1163220	1.85	.68	.93	12		.200	.108	65
11632080	6.91				.28			
1163224	5.12	3.83	.96	33		.403	.079	90
11632080	6.91				.58			
1163225	11.29	11.01	.98	11		.233	.021	779
11632080	6.91				.33			
1163228	11.54	6.27	.98	12		.741	.064	43
11632610	9.20				.80			
1163230	24.53	45.29	.98	10		2.037	.083	41
11632610	9.20				2.21			
1163232	9.06	8.33	.98	22		.693	.076	66
11632610	9.20				.75			
1163234	7.39	6.53	.97	10		.763	.103	43
11632610	9.20				.82			
1163236	17.85	20.08	.98	10		1.492	.084	34
11632610	9.20				1.62			
1163237	32.67	58.32	.99	10		2.685	.082	31
11632610	9.20				2.91			
1163238	13.94	21.18	.98	10		.982	.070	84
11632610	9.20				1.06			
1163247	3.88	4.39	.94	12		.249	.064	271
11632610	9.20				.27			
1163249	7.09	4.68	.98	18		.464	.065	83
11632610	9.20				.50			
1163252	7.92	11.51	.97	11		.519	.066	164
11632610	9.20				.56			
1163253	10.67	14.78	.98	10		.703	.066	114
11632610	9.20				.76			
1163261	5.66	4.08	.97	10		.398	.070	98
11632610	9.20				.43			
1163263	8.39	9.97	.97	10		.719	.086	74
11632850	15.17				.47			
1163264	9.08	11.30	.97	11		.819	.090	64
11632850	15.17				.54			
1163265	9.23	9.40	.97	11		.812	.088	54
11632850	15.17				.53			
1163276	37.50	29.84	.99	10		3.475	.093	9
1162850	15.17				2.29			
1163282	32.81	65.43	.99	10		2.894	.088	30
11632850	15.17				1.90			
1163284	13.10	15.57	.98	10		1.335	.102	33
11632850	15.17				.88			
1163294	6.00	6.33	.98	10		.593	.099	69
11632850	15.17				.39			
1163296	8.53	.48	.99	10		.560	.066	5
11632850	15.17				.36			
1163298	14.59	9.02	.99	12	.84	1.279	.088	21
11632850	15.17							
1164400	5.69	7.27	.96	9		.188	.033	787
11648001	5.13				.36			
1164810	1.13	.46	.90	36		.052	.046	645
11648001	5.13				.10			
1164880	7.69	5.43	.96	22		.517	.067	78
11648001	5.13				1.00			
1165425	5.02	3.70	.92	15		.381	.076	98
11658000	4.00				.952			
1165430	5.68	6.10	.95	19		.405	.071	143
11654250	4.96				.81			
1165435	7.85	7.10	.94	12		.546	.070	91
11654250					1.10			
1165455	2.88	1.77	.92	16		.199	.069	171
11654250	4.96				.40			
1165465	6.38	2.91	.96	25		.370	.058	81
11654250	4.96				.74			

Table continued

1 CSU ID	2 Mean	3 Variance	4 Cor Cof	5 Case	6 Coeff	7 Increase Runoff	8 Increase Ratio	9 Years for Eval.
1165470	9.18	6.09	.96	25		.558	.061	75
11654250	4.96				1.12			
1165480	3.30	4.98	.89	18		.185	.056	561
11654250	4.96				.37			
1165485	10.78	5.11	.96	25		.685	.064	41
11654250	4.96				1.38			
1166236	10.45	8.17	.96	25		.573	.055	95
11662180	3.78				1.51			
1166254	2.85	1.07	.97	11		.257	.090	62
11662180	3.78				.67			
1166272	9.67	7.32	.95	25		.544	.056	94
11662180	3.78				1.44			
1166630	3.89	2.53	.93	13		.432	.111	52
11673000	3.85				1.12			
1167030	4.11	3.29	.94	9		.402	.098	78
11673000	3.85				1.04			
1167460	8.22	12.50	.96	15		.927	.113	55
11673000	3.85				2.40			
1167600	9.96	12.22	.933	33		.563	.057	147
11678450	5.29				1.06			
1167806	5.39	3.82	.97	10		.510	.095	56
11678450	5.29				.965			
1167809	11.93	14.20	.95	26		.590	.049	156
11678450	5.29				1.11			
1167815	14.90	16.93	.96	26		.753	.051	114
11678450	5.29				1.42			
1167818	18.41	45.45	.98	10		1.597	.087	68
11678450	5.29				3.01			
1167821	16.55	13.52	.96	25		.789	.048	83
11678450	5.29				1.49			
1167836	12.53	11.40	.95	26		.530	.042	156
11678450	5.29				1.00			
1167842	13.73	10.61	.96	26		.589	.043	117
11678450	5.29				1.11			
1167854	24.17	26.66	.98	10		1.789	.074	32
11678450	5.29				3.38			
1167875	15.72	4.06	.95	26		.650	.041	36
11678450	5.29				1.22			
1168060	3.64	5.59	.92	16		.418	.115	122
11690000	9.79				.42			
1168430	5.93	9.01	.96	23		.617	.104	90
11690000	9.79				.63			
1168460	17.90	31.07	.99	10		2.191	.122	24
11690000	9.79				2.23			
1168600	2.62	3.40	.90	16		.310	.118	135
11690000	9.79				.31			
1200000	.39	.05	.96	10		.037	.094	142
12100000	5.32				.06			
1203000	1.29	.55	.93	15		.122	.094	142
12100000	5.32				.22			
1206000	2.80	3.48	.93	10		.290	.104	158
12100000	5.32				.54			
1270800	2.38	2.18	.97	9		.220	.092	173
12100000	5.32				.41			
1272405	3.37	8.32	.91	10		.821	.244	47
12724602	16.59				.49			
1272425	1.78	1.26	.90	11		.196	.110	126
12724602	16.59				.11			
1272435	6.28	21.98	.94	10		1.083	.173	71
12724602	16.59				.65			
1272450	2.94	2.77	.91	10		.382	.130	73
12724602	16.59				.23			

Table continued

1	2	3	4	5	6	7	8	9
CSU ID	Mean	Variance	Cor Cof	Case	Coeff	Increase Runoff	Increase Ratio	Years Eval.
1273230	3.38	5.25	.93	10		.229	.068	384
12732001	6.09				.37			
1274830	.99	.41	.91	10		.066	.067	357
12732001	6.09				.10			
1276400	4.80	4.75	.93	10		.228	.048	349
12732001	6.09				.37			
1370300	6.49	8.42	.94	48		.444	.068	164
13715052	5.15				.86			
1371500	1.51	.56	.95	25		.128	.085	131
13715052	5.15				.24			
1371520	5.96	4.60	.96	52		.435	.073	93
13715052	5.15				.84			
1371545	11.94	16.67	.97	17		.956	.080	70
13715052	5.15				1.85			
1371550	7.81	6.02	.97	10		.617	.079	60
13715052	5.15				1.19			
1371560	22.06	8.79	.98	16		1.510	.068	14
13715052	5.15				2.93			
1371565	25.60	9.42	.98	10		1.814	.071	10
13715052	5.15				3.52			
1371570	21.86	12.93	.98	14		1.418	.065	24
13715052	5.15				2.75			
1371575	17.02	23.19	.98	10		1.360	.080	48
13715052	5.15				2.64			
1371815	15.20	29.11	.97	25		.926	.061	130
13715052	5.15				1.79			
1371835	7.01	11.41	.97	10		.540	.077	150
13718100	6.70				.80			
1371845	6.69	9.90	.97	10		.553	.083	124
13718100	6.70				.82			
1371855	12.15	22.83	.98	10		.888	.073	111
13718100	6.70				1.32			
1371870	7.03	11.23	.97	10		.509	.072	166
13718100	6.70				.76			
1371890	6.58	12.93	.96	10		.527	.080	179
13718100	6.70				.78			
1373020	15.36	28.04	.97	20		1.424	.093	53
13730212	9.62				1.48			
1373025	6.60	3.61	.98	11		.656	.099	32
13730212	9.62				.682			
1373080	7.16	16.08	.94	10		.367	.051	457
13730212	9.62				.38			
1373085	7.56	6.72	.97	19		.646	.085	61
13730212	9.62				.67			
1373360	11.35	20.96	.97	29		.941	.083	90
13730212	9.62				.97			
1374275	14.62	35.42	.99	10		.569	.039	420
13730212	9.62				.59			
1374800	11.13	20.70	.97	19		.746	.067	143
13730212	9.62				.77			
1375400	7.47	6.62	.96	27		.588	.079	73
13772400	8.71				.67			
1375750	11.61	30.69	.96	10		.822	.071	174
13772400	8.71				.94			
1376000	2.68	2.32	.90	18		.247	.092	145
13772400	8.71				.28			
1376050	4.93	6.15	.94	10		.313	.063	241
13772400	8.71				.35			
1377210	1.41	.63	.92	10		.179	.127	75
13772400	8.71				.20			
1377250	1.42	.64	.92	10		.131	.092	144
13772400	8.71				.15			
1377270	2.46	1.65	.94	10		.192	.078	171
13772400	8.71				.22			

Table continued

1	2	3	4	5	6	7	8	9
CSU ID	Mean	Variance	Cor Cof	Case	Coeff	Increase Runoff	Increase Ratio	Years for Eval.
1377280	3.99	3.13	.93	27		.225	.056	237
13775000	5.18				.43			
1377825	7.66	6.75	.98	10		.717	.044	50
13775000	5.18				1.38			
1377850	10.38	28.99	.92	10		.440	.042	574
13775000	5.18				.85			
1378130	12.36	14.51	.97	11		.828	.067	81
13781450	14.25				.58			
1378160	24.89	6.41	.96	10		1.743	.070	8
13781450	14.25				1.22			
1379000	6.88	5.08	.97	26		.540	.078	66
13781450	14.25				.37			
1420800	12.32	10.11	.98	23		1.178	.096	27
14250000	8.79				1.34			
1423260	7.26	4.74	.98	10		.757	.104	31
14250000	8.79				.86			
1424050	7.47	2.86	.98	13		.806	.108	16
14250000	8.79				.91			
1424820	16.58	14.51	.98	12		1.554	.094	23
14250000	8.79				1.76			
1425600	8.57	21.39	.96	9		.793	.093	130
14250000	8.79				.90			
1425625	4.11	4.58	.94	43		.431	.105	94
14250000	8.79				.49			
1425675	5.54	13.05	.91	10		.527	.095	180
14250000	8.79				.59			
1426400	13.09	27.35	.96	39		1.137	.087	81
14250000	8.79				1.29			
1428800	6.20	13.47	.93	10		.637	.103	127
14250000	8.79				.72			
1480000	7.36	16.22	.94	10		.645	.088	149
14900000	6.36				1.01			
1500000	5.68	5.92	.96	12		.683	.120	48
15963000	11.30				.60			
1510000	1.24	.13	.98	12		.113	.108	28
15963000	11.30				.11			
1515050	6.01	2.10	.97	10		.619	.103	21
15963000	11.30				.54			
1554500	5.34	7.13	.95	9		.655	.123	63
15963000	11.30				.58			
1556000	10.77	10.29	.95	9		1.259	.117	24
15963000	11.30				1.14			
1560000	3.80	5.50	.89	10		.297	.078	239
15963000	11.30				.26			
1570000	6.12	6.36	.94	10		.537	.088	84
15963000	11.30				.47			
1580000	11.70	19.26	.96	10		1.072	.092	64
15963000	11.30				.94			
1590700	6.15	8.57	.96	10		.793	.129	52
15963000	11.30				.70			
1594206	10.25	11.38	.97	10		.899	.088	54
15963000	11.30				.79			
1594218	9.85	12.10	.98	10		1.113	.113	37
15963000	11.30				.98			
1594224	19.34	31.31	.98	10		1.832	.095	35
15963000	11.30				1.62			
1594236	15.19	21.10	.97	17		.972	.064	85
15963000	11.30				.86			
1594260	15.84	20.25	.98	17		1.133	.072	60
15963000	11.30				1.06			
1660000	6.05	4.11	.97	18		.612	.101	42
166114001	6.14				.99			

Table continued

1	2	3	4	5	6	7	8	9
CSU ID	Mean	Variance	Cor Cof	Case	Coeff	Increase Runoff	Increase Ratio	Years for Eval.
1662150	5.18	3.83	.96	14		.532	.103	51
16614001	6.14				.86			
1662800	11.29	5.26	.98	14		.510	.045	77
16614001	6.14				.83			
1664900	14.82	12.99	.98	12		1.232	.083	32
16614001	6.14				2.00			
1664960	16.59	25.13	.97	9		1.370	.083	51
16614001	6.14				2.23			
1664980	22.61	28.80	.98	9		1.854	.082	32
16614001	6.14				3.02			
1666300	16.10	15.12	.98	20		1.442	.090	27
16614001	6.14				2.34			
1666350	2.32	.27	.98	10		.183	.079	30
16614001	6.14				.29			
1667000	11.91	12.57	.97	12		.925	.078	56
16614001	6.14				1.50			
1667700	8.79	10.01	.96	20		.713	.081	75
16614001	6.14				1.16			
1720000	10.14	11.70	.97	20		1.049	.103	40
17403000	8.56				1.22			
1742400	9.32	10.26	.96	12		.782	.084	64
17403000	8.56				.91			
1742700	17.09	9.82	.99	9		.966	.056	40
17403000	8.56				1.12			
1743000	15.62	11.87	.98	14		1.344	.086	25
17403000	8.56				1.57			
1743300	12.24	6.21	.97	9		.831	.068	34
17403000	8.56				.97			
1743600	11.76	4.83	.98	9		.876	.074	24
17403000	8.56				1.02			
1745160	10.07	8.48	.98	13		1.356	.135	17
17403000	8.56				1.58			
1752000	4.96	4.00	.95	10		.475	.096	68
17403000	8.56				.55			
1754000	11.02	12.19	.98	10		1.158	.105	34
17403000	8.56				1.35			
1758000	7.22	6.05	.96	10		.781	.108	38
17403000	8.56				.91			
1760000	2.86	1.50	.94	19		.275	.096	76
17403000	8.56				.32			
1767500	5.94	6.89	.96	11		.815	.137	39
17403000	8.56				.95			
1775000	13.60	5.41	.98	10		1.033	.076	19
17403000	8.56				1.20			
1776000	11.80	11.25	.97	31		.985	.083	44
18036000	10.69				.92			
1777000	14.91	37.97	.94	9		1.497	.100	65
18036000	10.69				1.40			
1780000	4.97	6.77	.91	10		.797	.160	40
17403000	8.56				.93			
1801808	8.24	7.45	.97	26		.557	.068	92
18036000	10.69				.52			
1817500	7.16	4.78	.98	19		.729	.102	34
18036000	10.69				.68			
1863000	19.16	12.37	.99	10		1.487	.078	21
18036000	10.69				1.39			

Key Words: Suitability, Upper Colorado River Basin, Precipitation Management, Evaluation, Optimal combinations

Abstract: The purpose of this study was the determination of suitable watersheds or combinations of watersheds for precipitation management programs in the Upper Colorado River Basin in general and for two special zones: the San Juan Mountains and the Upper Basin of the Colorado River. The study shows that the introduction of optimal weight factors in the linear combination of runoff from several basins will reduce significantly the number of years necessary for evaluation of the operations. Assuming a uniform 10% increase in winter precipitation throughout the Upper Colorado River Basin, the calculations show that three years of operations would be needed in the Upper Basin of the Colorado versus six years in the San Juan mountains

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