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UNCERTAINTIES IN IDENTIFYING PRECIPITATION TRENDS IN ARIZONA AND NEW MEXICO

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INTRODUCTION

Hydrologists, and others involved in arid lands water resources research, must try to explain past precipitation trends and variabilities and predict future occurrences based on available data. The accuracy and representativeness of data are crucial in the analysis, and often, researchers are interested in comparing a specific relatively short period of record to the long-term climatic record. For example, the USDA Walnut Gulch Experimental Watershed, established in 1955, includes a dense network of recording raingages. At times, the detailed records from such short-term study areas as Walnut Gulch must be compared to the less comprehensive long-term climatic data, which include many years of standard raingage records, periods of missing records, and station relocations. Ideally, hydrologists want to be as objective as possible in this analysis, but subjective decisions are difficult to avoid. In this paper, relative uncertainties in analysis, based on a few long-term as opposed to many short-term records, are examined.

PRECIPITATION

The summer season (May - Sep) in the Southwest is characterized by intense, short-duration thunderstorm rain of limited areal extent (Duckstein et al., 1972; Osborn and Laursen, 1973; Osborn, 1983). The winter season (Nov - Mar) is characterized by more widespread, lower intensity precipitation (Osborn et al., 1979). October and April precipitation can have either "summer" or "winter" characteristics, and because of this, were not used in this analysis. Precipitation during the two seasons has different impacts on the basin and range ecosystems in the Southwest. A greater change in precipitation during one season, as opposed to the other, could be significant in climatic evaluation. Therefore, seasonal as well as annual precipitation records were analyzed.

To compare the reliability of climatic analyses based on long-term, as opposed to short-term, precipitation records, we attempted to identify continuous precipitation records extending back before 1880. Much of the data for this study was obtained from a summary of Arizona climate (Green and Sellers, 1964). Additional data for earlier records were obtained from the U.S. Weather Bureau and National Weather Service climatic summaries (1930). There were some differences in overlapping records for some stations, indicating the ever present possibility of errors in transcribing climatic data from the original records. Stations were examined for continuity of record as objectively as possible, but the final decision on which records to analyze was somewhat subjective.

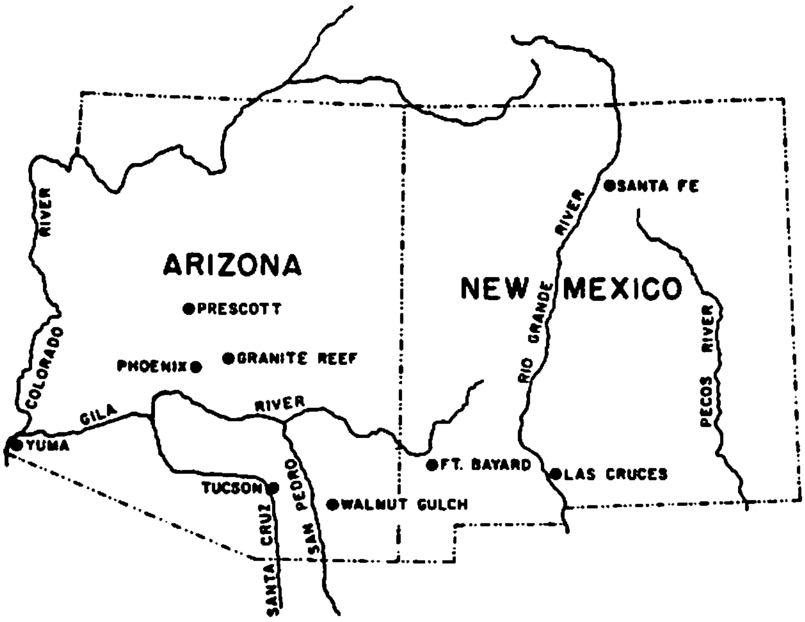


Figure 1. Location of long-term precipitation stations in Arizona and New Mexico, and the USDA Walnut Gulch experimental watershed.

Five stations in Arizona and three in New Mexico (Fig. 1) had continuous records dating from before 1880. The Arizona stations were Yuma, Phoenix, Granite Reef, Prescott, and Tucson; the New Mexico stations were Ft. Bayard, Las Cruces, and Santa Fe. Although the records from the Arizona stations were all from more than one location, in each case the locations appeared to be within a reasonable distance and at similar elevations and aspects. The Ft. Bayard station appeared to be as close to a continuous one-location record as one could hope to find. The Prescott and Santa Fe stations are in more mountainous areas where location changes of relatively short distances could lead to significant differences in elevation and aspect. Apparent long-term records at such stations as Bowie, AZ and Roswell and Lordsburg, NM were not used. There were major location changes involved for Bowie and Lordsburg, and the early record for Roswell was actually estimated from the station at Ft. Stanton (50 miles away). Finally, with the exception of Tucson, AZ, there were gaps of up to 2 years in the records at all stations. Missing data were estimated based on a ratio method suggested by McDonald (1956).

METHOD OF ANALYSIS

The eight long-term precipitation records were analyzed on a seasonal and annual basis and divided into subsets. Subset 1 (1866-1914) represented the period before official runoff-measuring stations were established in the Southwest, and a period in which there were few precipitation records. Subset 2 (1915-1953) represented a period with a relatively large number of standard raingage records, which has been emphasized in many climatic evaluations (McDonald, 1956; Sellers, 1960). Subset 3 (1954-1981) represented the period of study on the USDA-ARS experimental watershed in Arizona, as well as the 25-yr period since many of the climatic evaluations were made.

Also, the long-term records were divided into two overlapping subsets. Subset A (1866-1953) represented the basis upon which many of the trend predictions for the 1970's and 1980's were made. Subset B (1915-1981) represents the period when there was a relatively large number of precipitation and runoff records. These five identifiable subsets of data are sufficient to illustrate the uncertainties which the researcher must face in climatic evaluation and prediction. The means and trends for each station record determined by linear regression are given in Tables 1 -3, and the linear regression slopes are shown in Fig. 2 - 9.

Table 1.--Mean and trend for annual and seasonal preciptation for 8 stations in Arizona and New Mexico (1866-1981)

Station	Winter precipitation		Summer precipitation		Annual precipitation	
	Mean	Trend*	Mean	Trend*	Mean	Trend*
	(in)	(in/yr)	(in)	(in/yr)	(in)	(in/yr)
Yuma	1.76	-.005	1.17	+.002	3.31	none
Prescott	8.19	+.007	8.38	+.012	18.48	+.022
Phoenix	3.71	-.002	2.86	none	7.40	none
Granite Reef	5.02	-.009	3.44	-.010	9.39	-.015
Tucson	4.27	none	6.09	-.015	11.32	-.009
Ft Bayard	4.04	-.008	9.65	+.003	15.18	-.005
Las Cruces	2.10	none	5.43	none	8.47	none
Santa Fe	3.52	-.002	8.54	-.003	13.97	-.005

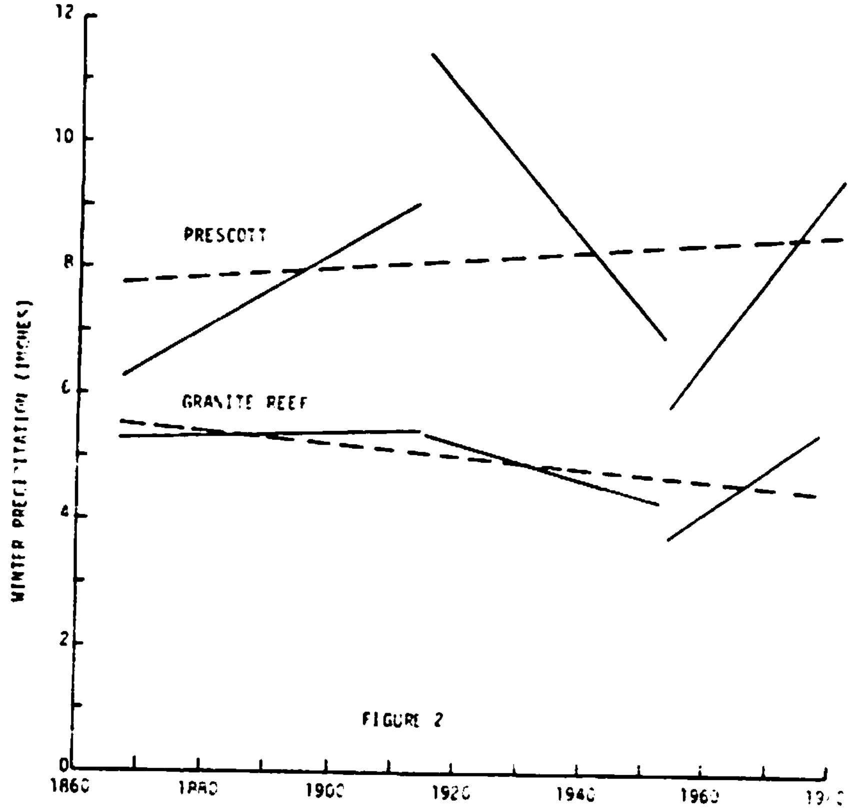
Table 2.--Mean and trend for 3 subsets of winter preciptation in Arizona and New Mexico (1866 - 1981)

Station	Winter Precipitation (Nov - Mar)					
	1866 - 1914		1915 - 1953		1954 - 1981	
	Mean	Trend*	Mean	Trend*	Mean	Trend*
	(in)	(in/yr)	(in)	(in/yr)	(in)	(in/yr)
Yuma	2.01	+.022	1.56	-.005	1.56	+.053
Prescott	7.67	+.059	9.21	-.115	7.66	+.134
Phoenix	3.81	+.017	3.71	-.026	3.56	+.081
Granite Reef	5.37	+.003	4.86	-.028	4.61	+.069
Tucson	4.38	+.033	4.04	-.034	4.42	+.074
Ft Bayard	4.35	+.032	4.09	-.031	3.41	+.019
Las Cruces	2.23	+.017	1.98	+.003	2.05	+.008
Santa Fe	3.65	+.018	3.43	-.007	3.44	-.013

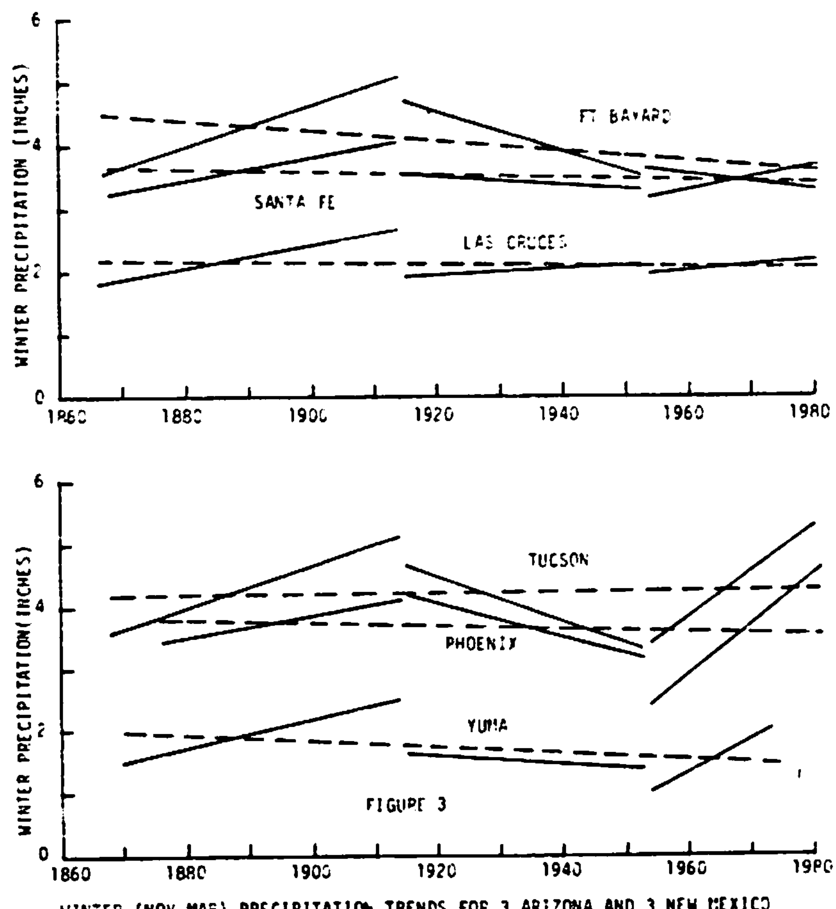
Table 3.--Mean and trend for 3 subsets of summer preciptation in Arizona and New Mexico (1866 - 1981)

Station	Summer Precipitation (May - Sep)					
	1866 - 1914		1915 - 1953		1954 - 1981	
	Mean	Trend*	Mean	Trend*	Mean	Trend*
	(in)	(in/yr)	(in)	(in/yr)	(in)	(in/yr)
Yuma	1.93	+.002	1.41	-.008	1.03	+.035
Prescott	7.85	+.011	8.85	-.029	9.01	-.074
Phoenix	2.81	+.021	2.97	+.009	2.77	-.046
Granite Reef	3.76	-.019	3.16	-.011	3.25	-.079
Tucson	6.54	-.050	5.66	-.048	5.91	-.054
Ft Bayard	9.38	-.005	9.80	-.080	9.89	-.015
Las Cruces	5.53	-.006	5.11	-.020	5.68	+.090
Santa Fe	8.69	-.018	8.36	+.003	8.54	+.013

*Trend (±.002 in/yr or more)



WINTER (NOV-MAR) PRECIPITATION TRENDS FOR 2 ARIZONA STATIONS (1866-1981, 1866-1914, 1915-1953, 1954-1981)



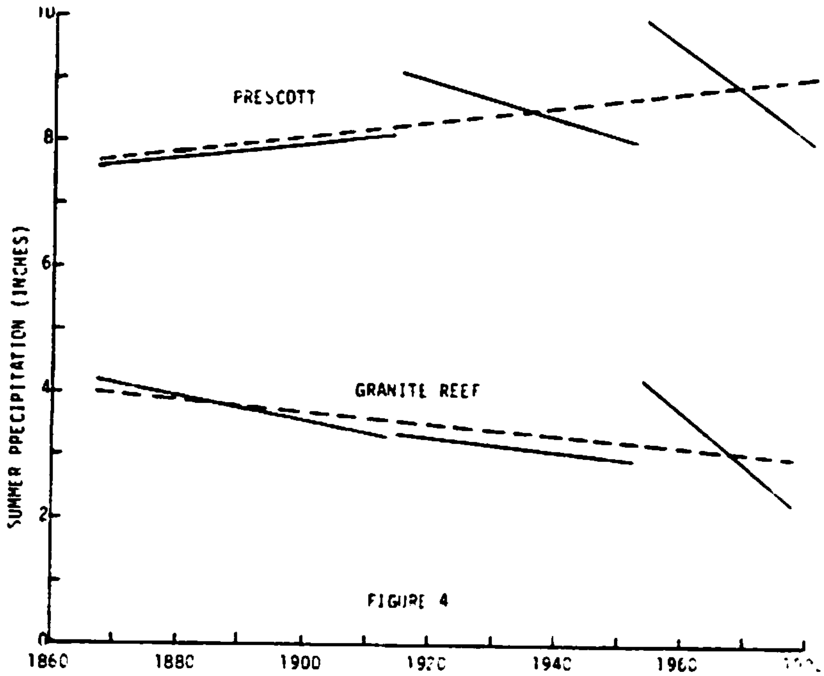
WINTER (NOV-MAR) PRECIPITATION TRENDS FOR 3 ARIZONA AND 3 NEW MEXICO STATIONS (1866-1981, 1866-1914, 1915-1953, 1954-1981).

RESULTS

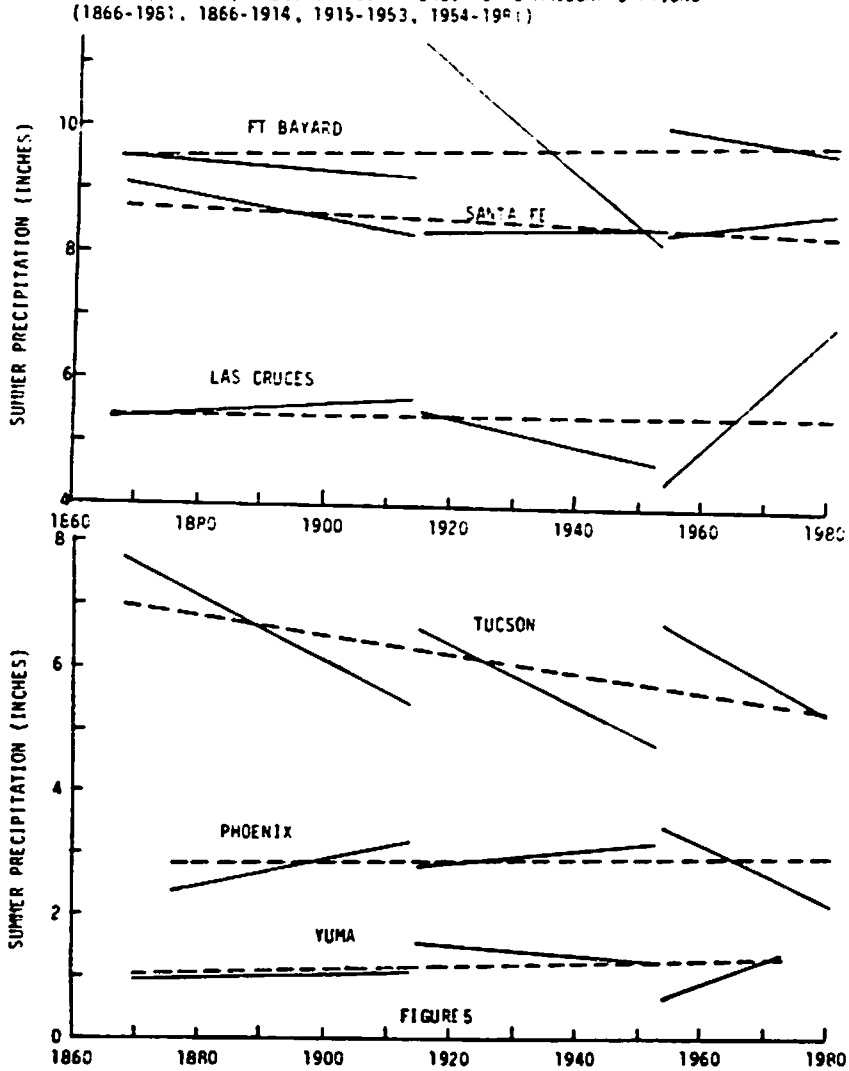
Long-term records at Tucson and Granite Reef indicate a decreasing trend in both annual and summer precipitation in southern Arizona (Table 1); however, the trend was not statistically significant. Phoenix and Yuma records indicated no change in either summer or annual precipitation. There were suggestions of both negative and positive trends in winter precipitation at different stations in Arizona and New Mexico (Table 1), but no clear overall trend for the region.

Whereas, in the full length record, the greatest concern was for reliability of the data, the greatest concern with the subsets was whether they were representative of the longer record, and how these short-term records might lead to incorrect evaluations of changing range and basin ecosystems and unreliable predictions of future changes.

For winter precipitation, there was a strong positive trend from 1866 through 1914 (subset 1), a strong negative trend from 1915 through 1953 (subset 2), and a strong positive trend from 1954 through 1981 (Table 2, Fig. 2 and 3). However, the full-length record indicated no overall positive or negative trend in winter precipitation. The trends were statistically significant for all subsets for Prescott. However the station was moved several times, so these differences might not be due to climate. However, the record is unusual enough to warrant a separate study concentrating



SUMMER (MAY-SEP) PRECIPITATION TRENDS FOR 2 ARIZONA STATIONS (1866-1981, 1866-1914, 1915-1953, 1954-1981)



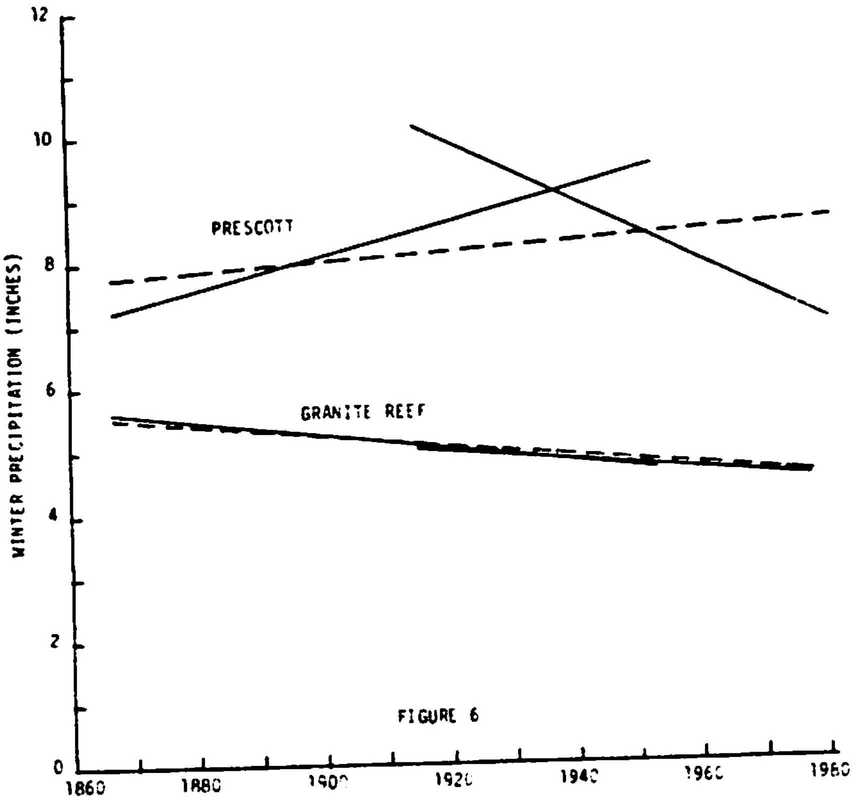
SUMMER (MAY-SEP) PRECIPITATION TRENDS FOR 3 ARIZONA AND 3 NEW MEXICO STATIONS (1866-1981, 1866-1914, 1914-1953, 1954-1981)

on available data from nearby stations for subsets 2 and 3.

There were negative trends in all three subsets of summer data for most stations (Table 3, Fig. 4 and 5). However, for Tucson and Granite Reef, the means for subset 3 are actually higher than for subset 2, so the overall negative trend is much weaker than suggested by the subsets. Extrapolations for expected precipitation, based on subset 2, could be particularly misleading. In fact, several stations exhibited strong positive or negative trends during one or more of the shorter periods, whereas the overall trends were insignificant. The trends for subset 2, for Ft. Bayard, and subset 3, for Las Cruces, were statistically significant.

Data from the Arizona stations suggested that, if anything, the Walnut Gulch record encompasses a period of increasing winter precipitation and decreasing summer rainfall (Table 2, 3). The decreasing trend, for summer rainfall in subset 3, is offset by a higher mean in subset 3 than in subset 2. The winter trend in subset 3 might be meaningful, which could explain the continued encroachment of brush species, which are more dependent on winter precipitation, into the warm-season grasslands.

The overlapping subsets (subset A, 1866-1953; subset B, 1915-1981) illustrate the climatic as well as data uncertainties, which make both evaluation and prediction of precipitation trends



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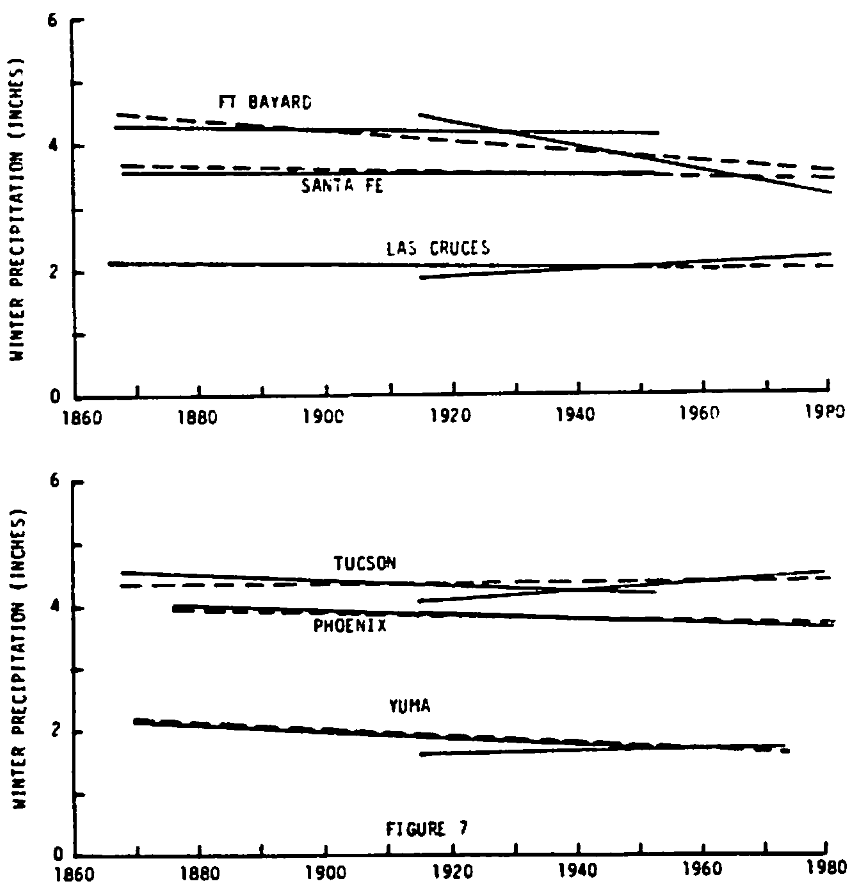

WINTER (NOV-MAR) PRECIPITATION TRENDS FOR 3 ARIZONA AND 3 NEW MEXICO STATIONS (1866-1981, 1866-1953, 1915-1981)

hazardous. As stated earlier, several analyses were made in the late 1950's and early 1960's on precipitation trends in the Southwest. Subsets 1, 2, and A represent this period. Subsets 2, 3, and B represent the period beginning about 1915 in which precipitation could be correlated with runoff peaks and volumes for major stream systems in the Southwest. Flood frequencies are based on the period of subset B.

Analyses of the few complete records for subset A (Fig. 6-9) seemed to reinforce the conclusion based on many records from subset 2, which led several investigators to predict continued drying trends throughout the Southwest in the 1960's and 1970's (Sellers, 1960, and others). Subset B generally indicated increases in winter precipitation and slightly negative summer trends at most stations.

CONCLUSIONS

Hydrologists and others often hypothesize on the reasons for apparent changes in the basin and range ecosystems in the Southwest, and whether there will be more changes in the future. These hypotheses are often based on apparent trends in precipitation as indicated by available data. However, analyses of trends in Arizona and New Mexico are subject to considerable uncertainty. In this study, eight long-term precipitation stations, with more-or-less continuous records, were analyzed as full-length records, then divided into subsets representing identifiable historical periods. The uncertainties in relying on a few long-term records include accuracy, stationarity, and spatial representativeness. The principal uncertainty in relying on the short-term records is one of representativeness in time, and how reliance on relatively short-term records can mislead the researcher. Hydrologists, and others who are asked to explain and predict changes in the range and basin ecosystems of Arizona and New Mexico should be aware of the uncertainties in their analyses, and provide to the user confidence limits for their hypotheses or predictions.

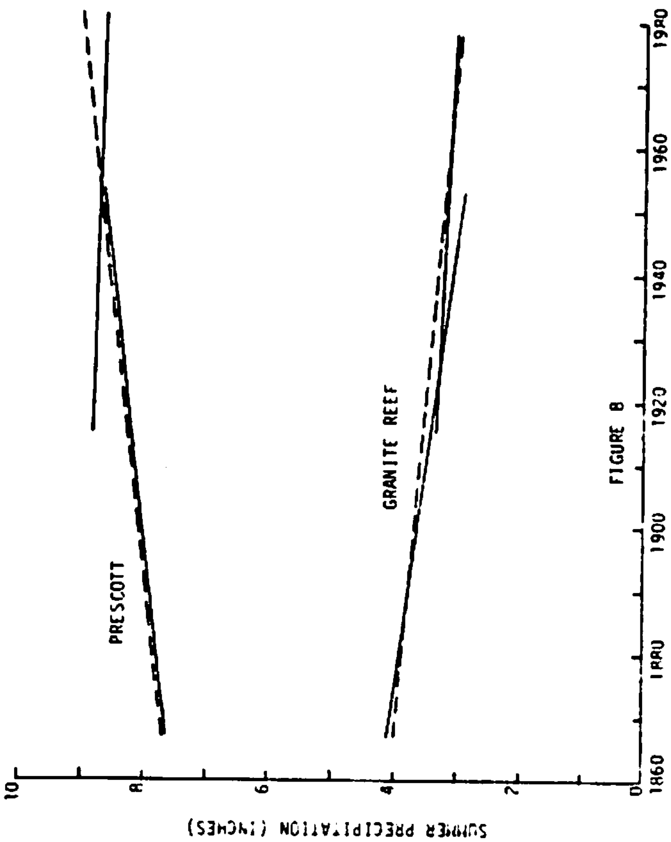

FIGURE 8

SUMMER (MAY-SEP) PRECIPITATION TRENDS FOR 2 ARIZONA STATIONS (1866-1981, 1866-1951, 1915-1981)

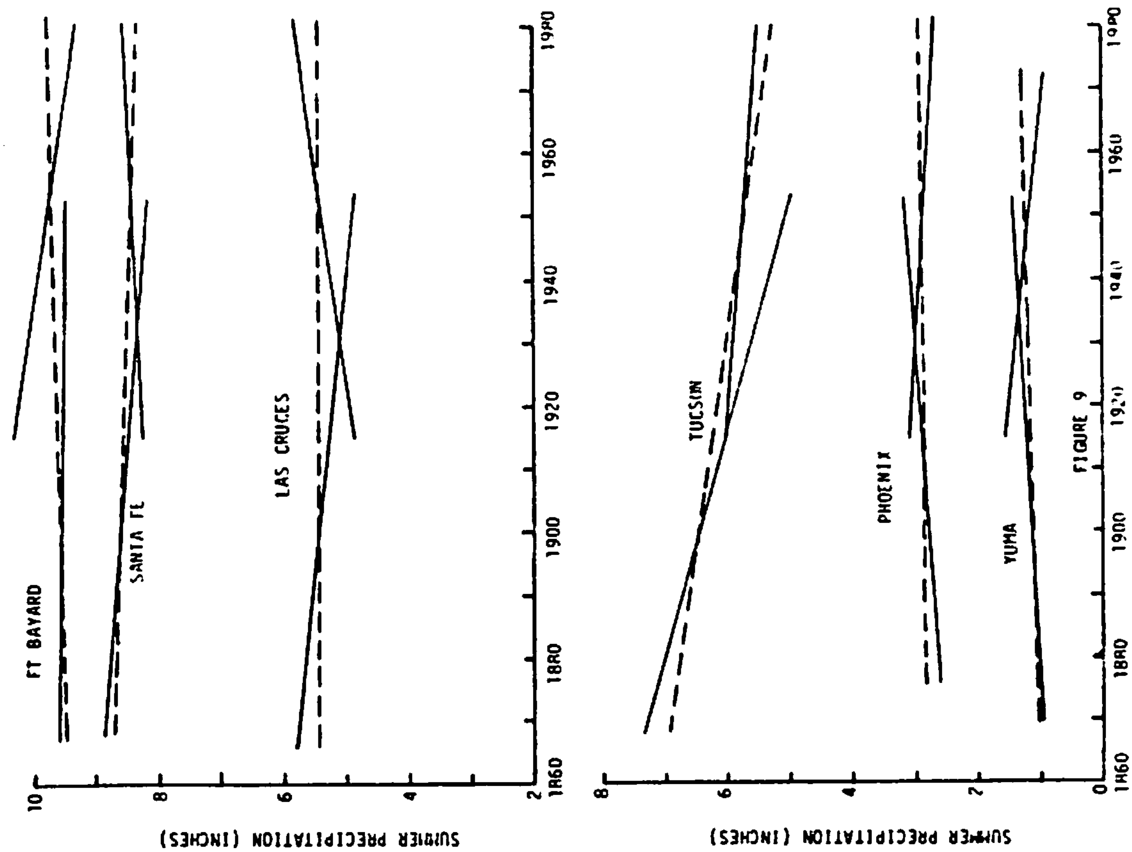

FIGURE 9

SUMMER (MAY-SEP) PRECIPITATION TRENDS FOR 3 ARIZONA AND 3 NEW MEXICO STATIONS (1866-1981, 1866-1951, 1915-1981)

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