that a modification in the procedure of computing the Fourier coefficients has now been developed which gives greater accuracy in computing the individual monthly flows, but that the results were not available for inclusion in the paper. It would be very interesting to see if the forecast is significantly improved using the modified Fourier coefficients, and perhaps Mr. Milligan could include these findings in his author's closure so that the proceedings would carry a complete description of his method.

VARIATIONS IN STREAMFLOW FROM DIFFERENT HYDROLOGIC ZONES

By

M. T. Wilson[1]

Introduction

The Southwest drought, with its devastating effect upon agriculture, the livestock industry and other activities, emphasizes the desirability of employing every available method of studying the relationship between precipitation and the available water supply. Streamflow is a residue. It is the remainder of the base supply (precipitation) after natural losses and normal use of the original quantity have been subtracted. The principal factors affecting the residue (streamflow) are transpiration, evaporation, deep percolation, soil moisture, and interception. Much of the yearly normal use and natural losses approach a constant, particularly for areas in the same hydrologic zones. The phrase "same hydrologic zones" as used in this discussion are areas where the precipitation, altitude, geology, vegetative cover and other major factors that control the runoff characteristics are similar or nearly similar. The upper hydrologic zone for any given drainage basin could well be an alpine condition where the yearly precipitation exceeds 50 inches, the soil mantle is relatively shallow, and a dense vegetative cover prevails. In most of the arid or semi-arid west the lower hydrologic zone is a desert area or valley floor where the yearly precipitation is less than 10 inches, the soil mantle is deep, and the vegetation is very sparse.

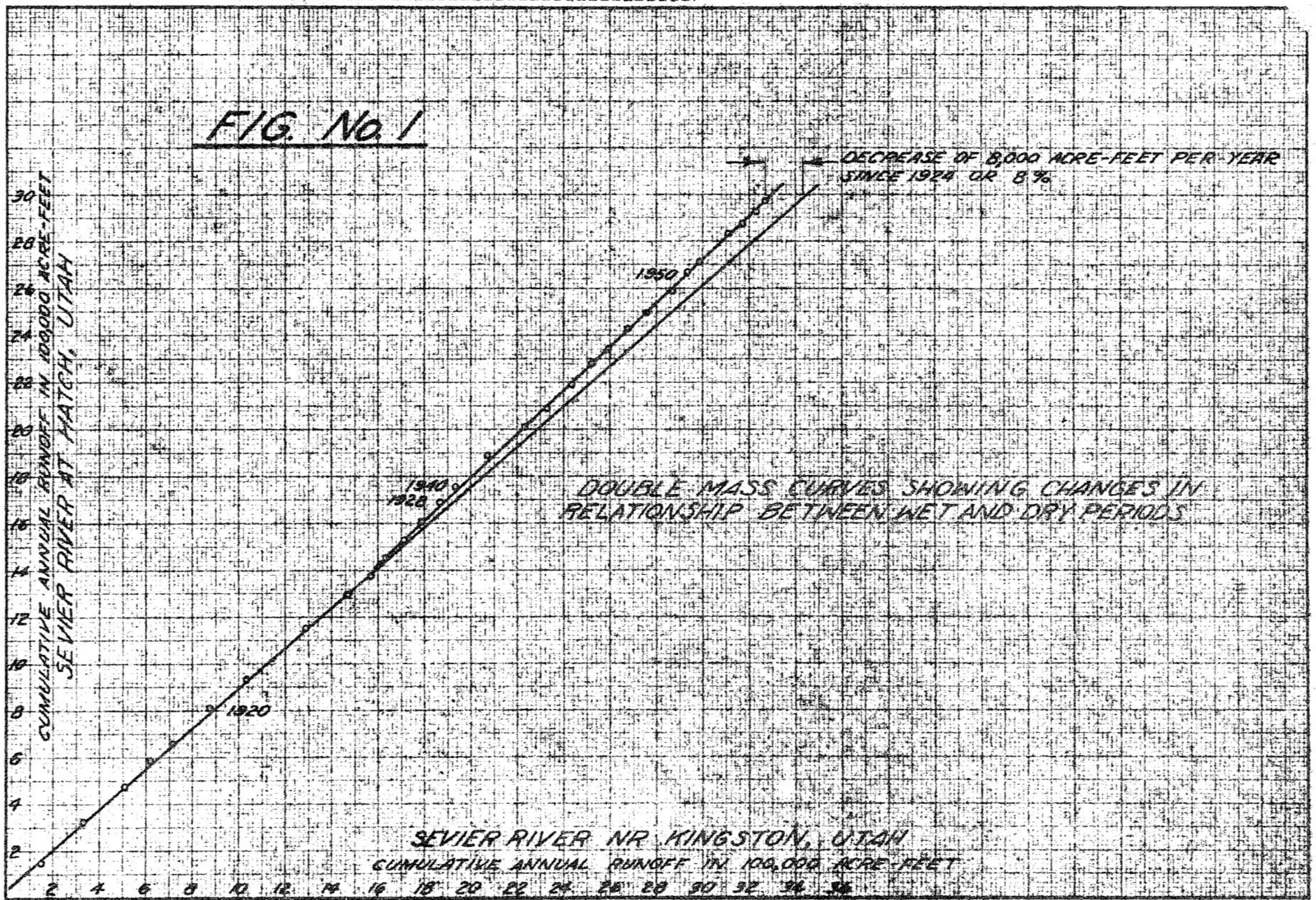
During several years of below-normal precipitation or several years of above-normal precipitation some negative factors in the equation, accounting for the total base supply, do not change significantly. In fact, during years of extremely high precipitation, the great accumulation of snow at the higher altitudes actually shortens the growing season and thus there is less transpiration by the vegetative cover. The reverse is likewise true: during years when the accumulation of snow is light, but still sufficient to supply the optimum transpiration requirements, the actual use is greater because of the longer satisfactory growing season. The remainder (streamflow), although not easy to define, will vary from year to year considerably more than the base supply (precipitation). Mathematically, the relationship between precipitation and streamflow is not a straight line but is curvilinear. Likewise, it is emphasized that the total precipitation in the basin is not accurately measured, because a precipitation station is only an 8-inch-diameter sample at that particular location and serves only as an index. It is often misleading to define relationships by the use of one precipitation record. A selection of precipitation records to obtain an index of wetness for a specified area will develop much more satisfactory results. Several valuable methods of presenting correlations in streamflow relationships and changes between precipitation and streamflow have been recognized for many years. One method of analyzing the relationships is to plot streamflow versus streamflow in a double mass diagram. The following discussion will be limited to consideration of only this method of studying the variable relationships. The double-mass method is a valuable tool to analyze changes over long periods of time, as the slopes of the mean lines define the relationships, but it should <u>not</u> be used to show changes in relationships from year to year or for short periods of time.

1/ District Engineer, Surface Water Branch, U. S. Geological Survey, Salt Lake City, Utah.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

File ....

FIG. No. I



Sheet No. ...... of ...... Sheets. Prepared by .... Date .... Checked by .... Date ....

Selection of Basin

Significant results should not be anticipated unless the drainage basin or basins to be analyzed contain two or more hydrologic zones. The best results will be obtained if the lower zone (that receiving the least precipitation) receives less precipitation than the potential evapotranspiration. In the western part of the United States where altitude is one of the major factors, if not the most important, in controlling the amount of precipitation, many basins meet the above requirement. Most moisture available to the West enters the land area from the Pacific Ocean. Moisture-laden masses of air moving in the prevailing easterly direction are forced to higher altitudes as they pass over the mountain ranges, causing precipitation to vary from less than 5 inches in the desert valleys to 50 or 60 inches on the mountain tops and then to diminish rapidly on the leeward side. This process is repeated again and again as other mountains are traversed. Changes in precipitation of several fold are not uncommon in distances of 50 miles or less; thus, even relatively small drainage basins usually lie in more than one hydrologic zone.

Another criterion necessary for obtaining significant results by the use of the double-mass method for analyzing variations in streamflow is a period of record that includes several consecutive years of above-average and below-average precipitation. This second requirement is not difficult to obtain, because precipitation varies considerably over relatively long periods of time, as has been recorded by the drought of the 1930's and the present (1957) Southwest drought. If streamflow relationships are to be analyzed for different hydrologic zones in the same basin, records at two or more gaging stations on the same stream are needed. However, changing relationships can be shown by the use of streamflow records for adjacent or nearby drainage basins if they include different hydrologic zones.

Sevier River Basin

The Sevier River in the south-central part of Utah has experienced almost drastic changes in water supply during the period of available streamflow records. The area is on the dividing line between the precipitation pattern of the northwestern United States, where the winter and early spring months provide most of the precipitation, and the southwest or Colorado Plateau area, where the heaviest precipitation occurs in the summer months. This intermediate area seems to have been more drastically affected by changes in precipitation or storm patterns over long periods of time than the adjoining areas. The altitude of the drainage area above the Hatch gaging station, which records natural streamflow, ranges from 6,900 to 10,500 feet and includes more than one hydrologic zone. Precipitation ranges from about 11 inches at Hatch to 35 inches at the Cedar Breaks snow course. Some of the drainage area is in a hydrologic zone where precipitation exceeds the potential evapotranspiration; the residue (streamflow) at the Hatch gaging station, therefore, is much nearer being directly proportional to precipitation changes than streamflow at the Kingston gaging station farther downstream, where a larger part of the drainage area is in the zone of least precipitation. Although the record at Hatch is not continuous--it includes the two periods 1915-1928 and 1940-1956--the double mass chart (see fig. 1) clearly shows the change in relationship from the early wet period of years to the later dry period of years starting about 1924. The chart shows that in relation to flow at the upper station there has been 11 second-feet less flow at the lower station during recent dry years than during the earlier years.

Adjacent or nearby Drainage Basins

The upper Beaver River drainage basin is about 50 miles north of the upper Sevier River drainage basin. A much larger part of the Beaver River basin lies at higher altitudes than that of the Sevier River near Kingston, and precipitation exceeds the potential evapotranspiration over a large part of the basin above the gaging station near Beaver. Change in streamflow characteristics between these two basins for dry and wet periods is unusually large, as shown by fig. 2. Streamflow of the Beaver River during recent dry periods was 38% greater than that of Sevier River near Kingston in relation to the earlier wet water-years. Much of the drainage area of the Sevier River above Kingston produces little or no streamflow during periods of low precipitation when the evapotranspiration and other uses consume most, if not all, of the available moisture. During the current southwest drought period, 5 of the 7 lowest years of record in 42 years have occurred during the past 7 for the Beaver River basin.

Streamflow Correlations

When satisfactory correlations of streamflow can be obtained between adjacent or nearby drainage basins, one gaging station may be designated as a primary station to be operated for an indefinite period of time, while the others may be classified as secondary and need be maintained

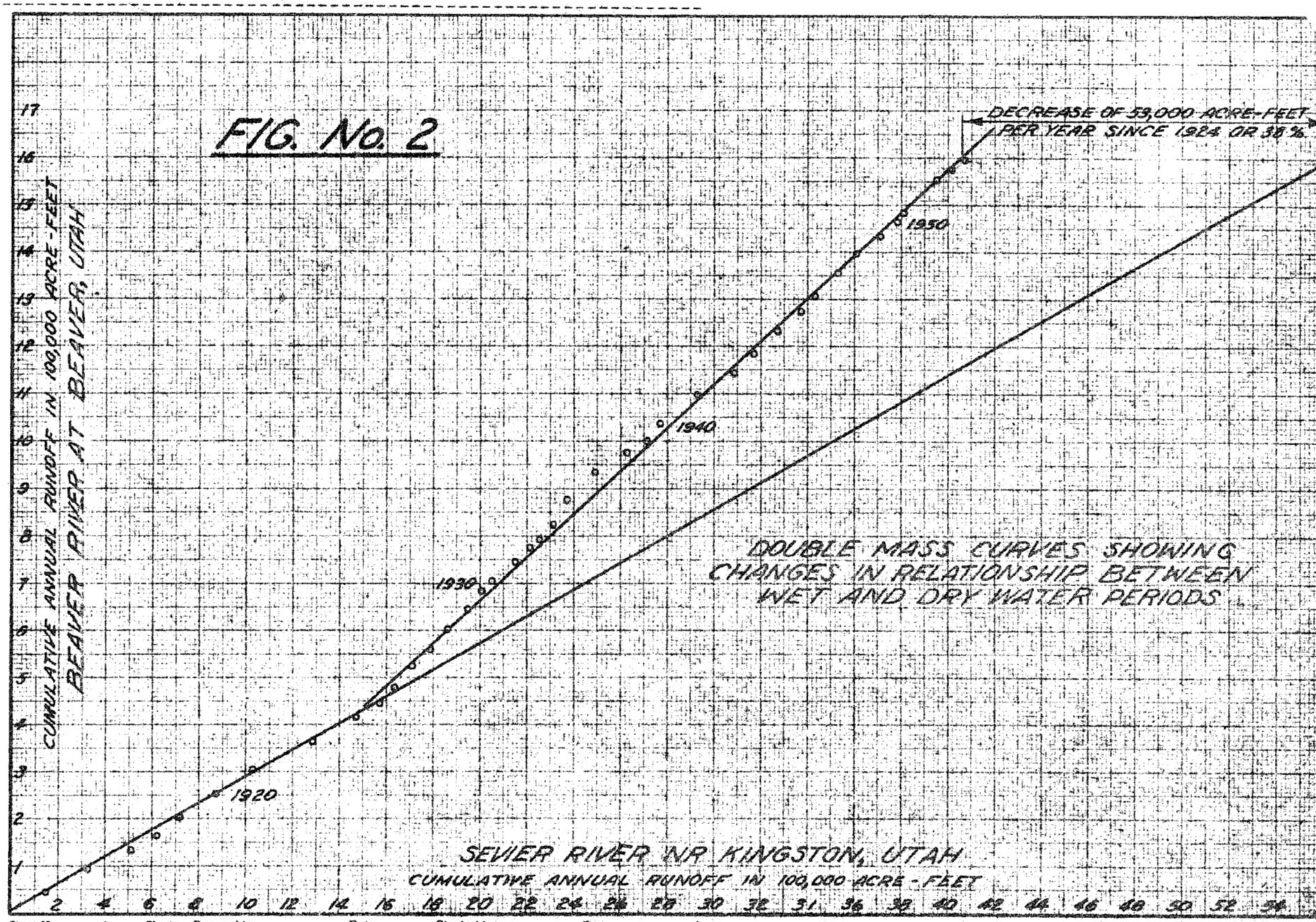


FIG. No. 2

Sheet No. .... of .... Sheets. Prepared by .... Date .... Checked by .... Date ....

only for 5- or 6-year periods. A sound approach can then be applied for computing a record at the secondary stations as long as the primary station is continued in operation. From changing relationships in streamflow as shown in this discussion it is obvious that considerable caution should be exercised in extending correlations from one basin to another if they include different hydrologic zones. A satisfactory correlation for a wet period of years will not necessarily apply for a series of dry years.

Considerable research and experimental work are now being accomplished to record and evaluate the water yield derived from a given drainage basin as such yield may be affected by changes in land management practices and by changes in the vegetative cover. Comparisons are often made between the water yield from a drainage basin under rigidly controlled conditions and that derived from an adjacent drainage basin under natural or uncontrolled conditions. Such comparisons could be very misleading unless the respective drainage basins contain similar hydrologic zones and unless the proportional parts of each drainage basin are likewise of similar hydrologic zones.

DISCUSSION

By

F. B. Blanchard[1/]

Mr. Wilson's paper is a reminder that hydrologists should be cautious in choosing a mathematical framework for analysis of data. He shows, in effect, that the so-called "double mass analysis" technique, heretofore successfully used to compare precipitation data at nearby locations, is ill-adapted for general use with runoff data, particularly if the latter cover a considerable range of conditions. The writer agrees that because of the residual nature of streamflow, some other technique must be used to fill in gaps in runoff data.

The criterion for suitability of the double mass analysis technique is that the magnitudes of corresponding members of the two sets of data should be proportional to one another, or should approach proportionality over substantial periods of time. Mere linearity between two sets of data does not suffice to justify use of this technique.

The relationship between sets of runoff data from the same general region may occasionally be one of proportionality, but relationships of linear, curvilinear, or even more complex nature are more general and more likely to yield satisfactory results. Consequently, problems of filling in gaps in runoff data demand techniques which suit the particular circumstances.

SNOW SURVEYS FROM THE SNOW SURVEYORS' SIDE

By

Pete Wyckoff[1/]

The theme of this paper could be: "For reliable snow measurements, it is best to hire a contented snow surveyor." And I am sure that reliable measurements of the snow pack are what you gentlemen want from your field men.

1/ F. B. Blanchard, Manager, Water Resources and Planning Division, East Bay Municipal Utilities District, Oakland, California.

1/ Pete Wyckoff, Research Forester, Central Sierra Snow Laboratory, California Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture.