MOUNTAIN PRECIPITATION AND HYDROLOGY FROM SNOW SURVEYS[1/] 534-71

By

Phillip E. Farnes[2/]

It has long been recognized that more precipitation occurs in the mountains of the West than in the inhabited valleys. Nearly all precipitation measurements however have been confined to the populous valleys. With the exception of a few storage gauges, very little precipitation data have been obtained in the more remote and mountainous areas. Contributing to this lack of data were inadequate funding and limited interest in these data.

In recent years, the mountains have become areas of research and there is an increasing desire for knowledge of their climatology. Through the years we have noted that average April 1 snow water equivalent (SWE) was generally near or above the average annual precipitation shown on isohyetal maps of the mountainous areas.

We attempted to obtain realistic estimates of mountain precipitation by plotting April 1 average snow water equivalent vs. average annual precipitation for sites where both snow course and precipitation gauge data were available. Plottings indicated that good estimates of annual precipitation could be obtained at nearly all sites by doubling the April 1 snow water equivalent. However, some points did not line up as well as expected.

During the past 10 years, canopy measurements were being made with the photocanopymeter, developed by Mr. A. R. Codd[1] at snow courses during the summer maintenance visits. Recent analysis of these canopy measurements indicated that forest overstory within a cone 30^{o} from the vertical affects the amount of snow that accumulates on the ground. The reduction in the snow pack was found to be related directly to the increase in percent canopy cover, as shown in Figure 1. This relationship proved valuable for adjusting all snow course records to a common base because many of the long-record Montana snow courses are in cover varying from open meadow to dense lodgepole.

Replotting the percent canopy from Figure 1 with the reciprocal of percent of an open sample would provide a factor that could be used to adjust snow water equivalent on courses with canopy. The snow course factor, as shown in Figure 2, is the multiplier that is used to estimate the amount of snow water equivalent that would be measured if all canopy were removed. This could also be explained as an estimate of the amount that would be measured if the snow course were located in an open meadow.

By adjusting all snow measurements to a similar base, that is, no effects from canopy, direct comparisons of snow accumulation could be made between snow courses at different elevations and locations. This would also permit uniform comparison with precipitation gauge measurements which are generally in non-canopy areas.

Average annual precipitation was determined for the few long-term high elevation precipitation stations operated by the National Weather Service. Long-term averages were estimated for precipitation gauges installed at SCS snow pillow sites.

April 1 snow water equivalent adjusted for canopy was compared to average annual precipitation for those sites with precipitation measurements on or near the snow course. Results are tabulated in Figure 3.

Correlation is very good between five or six month precipitation (snow courses) and annual precipitation in areas where mid-winter snowmelt is minor or non-existent. Some deviation is noted for areas having some mid-winter snowmelt, but this is not significant as regular precipitation data are usually available for this zone. Also, the degree of mid-winter snowmelt can be estimated from snow course records if necessary.

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2/ Hydrologist, Snow Survey Supervisor, Soil Conservation Service, Bozeman, Montana.

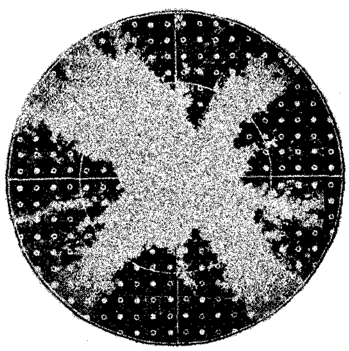

Figure 1. Print from canopy negative and dot grid used to determine canopy cover.

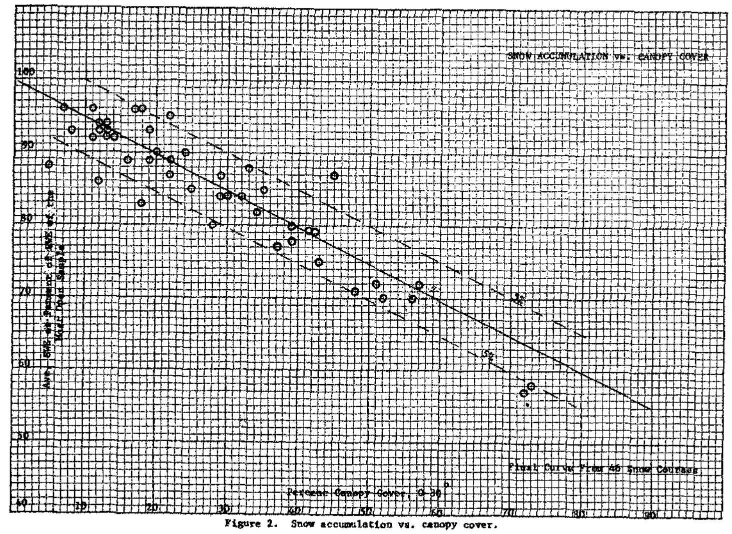

Figure 2. Snow accumulation vs. canopy cover.

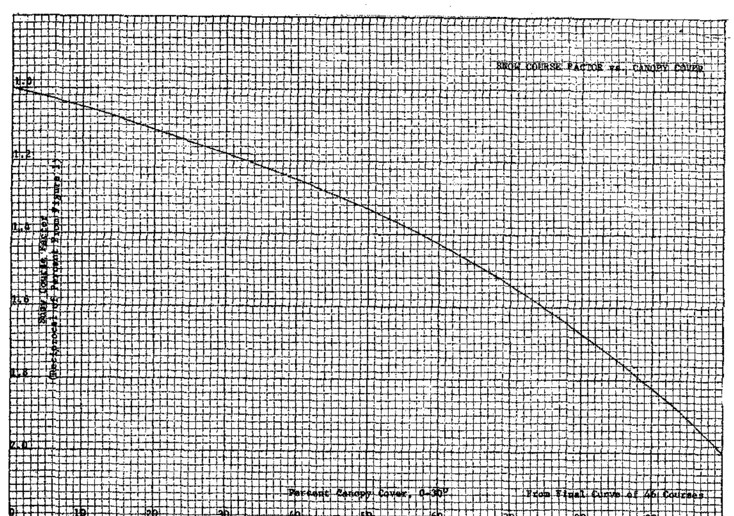

Figure 3. Snow cover factor vs. canopy cover.

Using the adjustment for canopy cover and the relationship between adjusted April 1 snow water equivalent, estimates of average annual precipitation were obtained for about 250 high elevation points in the western half of Montana. A good representation of the precipitation pattern was obtained when these data were combined with the regular precipitation data obtained by the National Weather Service.

By plotting precipitation vs. elevation for the various mountain range profiles, it is possible to determine realistic location of equal precipitation amounts. Connecting points of equal precipitation, using elevation and knowledge of mountain precipitation patterns gave an isohyetal map.[2] Isohyets were drawn on 10-inch increments for 20 inches and above.

Clear plastic overlays for use with Army Map Service quadrangles, scale 1:250,000, were made available to all interested persons. Some minor refinements may be necessary in areas having sparse data. It was also apparent that valley precipitation (below 20 inches) would be a valuable addition to the mountain precipitation map. Plans are being formulated to develop an annual precipitation map for Montana, based on the 1941-70 period, in cooperation with the National Weather Service and Montana Water Resources Board. Mountain precipitation maps, valley precipitation, and general soils survey maps, published by Soil Conservation Service will be used. Since soil development in valley areas is related to precipitation, soil boundaries can aid in locating isohyetal lines. Present plans are for isohyets on two-inch intervals below 20 inches.

The development of a realistic, large scale precipitation map has made possible the further analysis of mountain hydrology and many other precipitation related studies. We receive many requests for hydrology of mountain watersheds so we decided to investigate the relationship between runoff and precipitation. The objective being development of a simple, reasonably accurate, and realistic method which could be used by field staff as well as specialists, to evaluate hydrology of mountain watersheds.

To develop a relationship between precipitation and runoff, isohyets in gauged basins were planimetered to determine average annual precipitation. U. S. Geological Survey records were used to determine average annual runoff in inches. All data were based on the 1953-67 period as this is the current base period being used for hydrologic information in the western states.

Runoff was plotted vs. precipitation for about 25 snowfed streams for which data were readily available. Additional streams were plotted as data could be worked up and finally we were able to plot nearly 100 stream basins. Data were developed for high elevation; high producing streams with small drainage areas as well as for prairie streams. Consistent relationships between runoff and precipitation existed even though annual precipitation varied from 13 to over 100 inches, drainage areas varied from about 10 to 2,000 square miles, and mean elevation of drainage basins varied from about 3,000 to 9,000 feet. Results of runoff vs. precipitation data are shown in Figure 4.

It is noted that the rocky, alpine basins plotted along the high side of the curve and heavily timbered, deep soil mantle basins plotted along the lower portion of the curve.

Based on this information, reasonable estimates of runoff usually within 15 percent could be obtained.

By converting the runoff from Figure 4 to the percent of precipitation which occurs as runoff, the relationship between surface runoff and losses can be evaluated for any precipitation zone. This is shown in Figure 5. It is interesting to note that even in the heavier precipitation zones our data indicate significant losses.

For evaluating runoff from ungaged areas, we feel this procedure will be a useful tool for design or preliminary planning.

Some effort has been directed toward refining this procedure through use of additional variables and employing similar relationships for estimating peak flows. They are not presented in this paper but are included in the Preliminary Report on Mountain Hydrology[3].

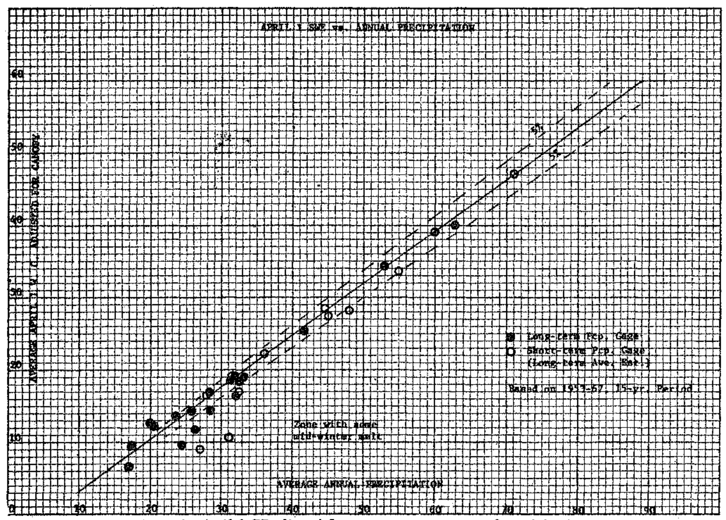

Figure 4. April 1 SWE adjusted for canopy vs. average annual precipitation.

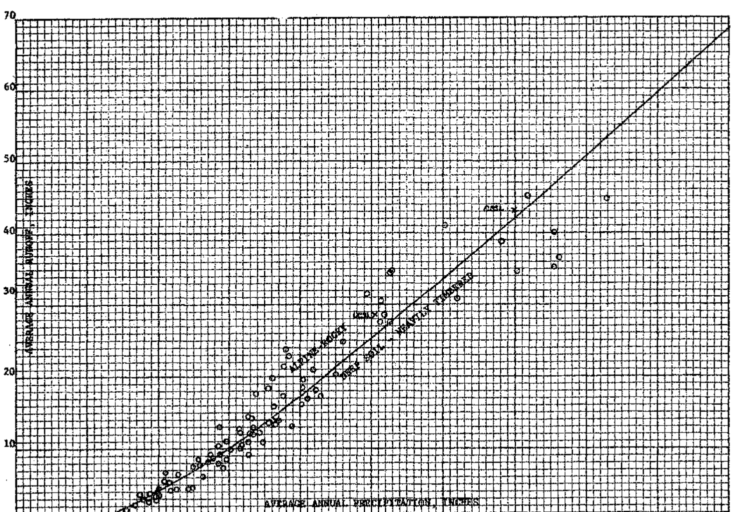

Figure 6. Average annual runoff vs. average annual precipitation.

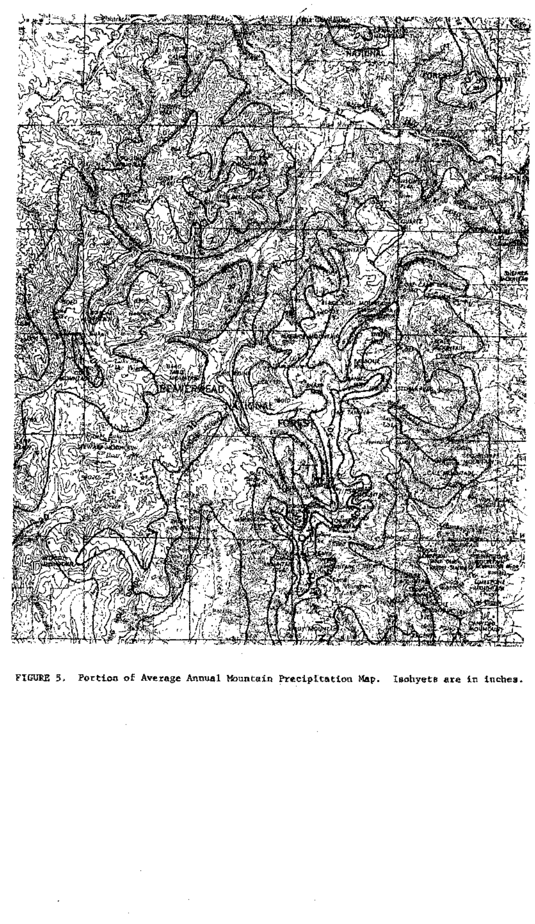

FIGURE 5. Portion of Average Annual Mountain Precipitation Map. Isohyets are in inches.

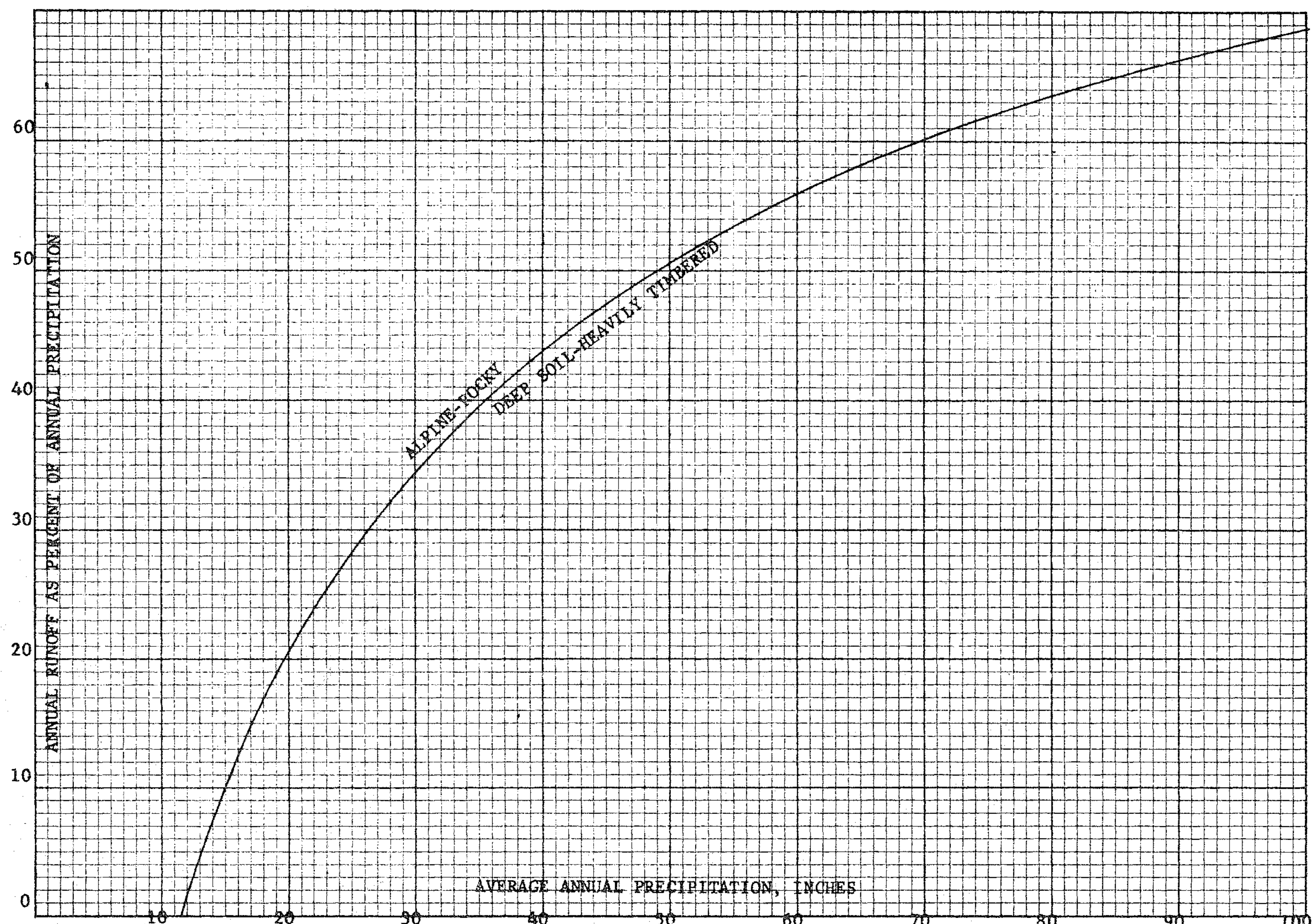

Figure 7. Percentage of annual precipitation which occurs as runoff.

REFERENCES

1. Codd, A. R. The Photocanopyometer, Proceedings, Western Snow Conference, Reno, Nevada, 1959.

2. Mountain Precipitation Map for Montana. Prepared by Soil Conservation Service in cooperation with Montana Water Resources Board. Ordering information available from State Conservationist, Box 970, Bozeman, Montana.

3. Preliminary Report, Hydrology of Mountain Watersheds. Prepared by Soil Conservation Service, Snow Survey Unit, January 1971.