Landform Characteristics Affecting Watershed Yields on the Mississippi-Missouri Interfluve

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The purpose of this paper is to present the results of an analysis to determine the extent to which certain landform elements affect the spatial variation of runoff on part of the Mississippi-Missouri interfluve. The area studied lies between the Mississippi and Missouri Rivers, mainly in the state of Iowa but it overlaps into Minnesota. There are 16 drainage basins included in this study and the boundaries of the drainage basins in each case were determined by the sites of gaging stations which had a continuous record from 1939 to 1956. The 18-year record was selected as it was the longest that could be obtained for all major streams in the area. The size of the drainage basins ranges from the greater Des Moines River, with a drainage area of 14,467 square miles above the gage at Keosauqua, to the Chariton River with an area of 727 square miles above the gage at Centerville. This area all lies within the portion of the Upper Mississippi Valley which is covered by glacial drift, the drift being of several different ages. The differences in the morphology of the basins are due primarily to the erosional destruction and weathering changes that are factors based upon the interval since glaciation. Fig. 1.

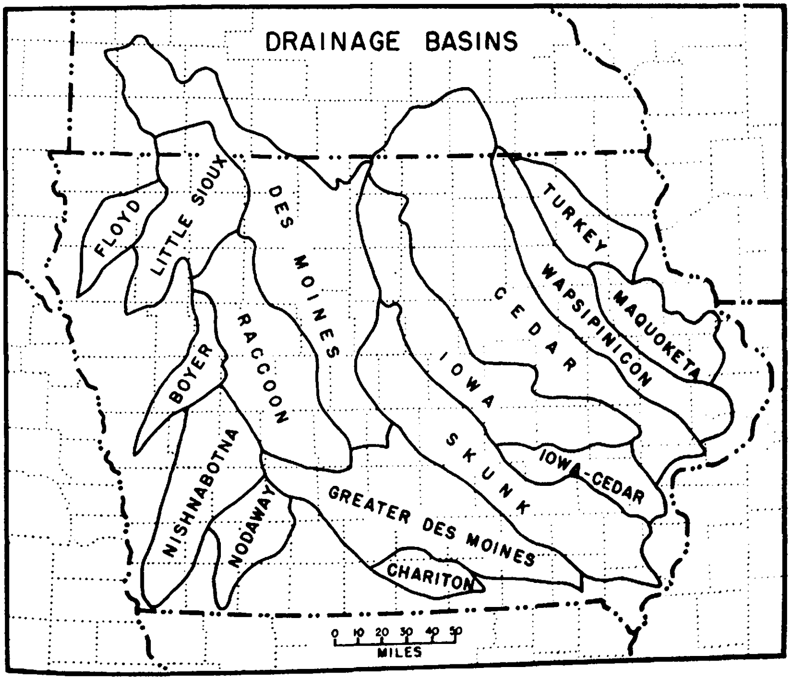

Figure 1. Location of sample drainage basins.

Perhaps the most commonly used expression for indicating runoff is average discharge, or average volume of water flowing past a gaging station during a given period of time. For comparing the yields of watersheds of varying sizes this means is not very useful as there is an almost direct relationship between discharge per unit time and the size of the watershed. By using discharge per square mile the effects of variation in size of watersheds are greatly reduced, and this is the manner in which runoff is compared here.

A comparison of the annual runoff from the 16 basins considered in this paper shows a fairly distinct decline from east to west. The largest amount of runoff, on an annual basis, is discharged into the Maquoketa river where it averages some 8.67 inches per year. The lowest average is found in the Floyd River basin where annual runoff only averages some 3.09 inches. The difference over a distance of some 250 miles amounts to over 5.5 inches, and more significantly the amount of runoff on the Maquoketa River is more than twice that of the Floyd River.

There is a considerable difference in the proportion of the total runoff which occurs during different seasons. The spring months of April, May and June produce the greatest share of the yearly runoff. Between a third and a half of the annual runoff takes place within these three months. If the six months from January to June are considered, 65-75% of the total runoff is accounted for. The sequence of spring, winter, summer, and fall indicate the decreasing order of seasonal runoff. Although the overall patterns of seasonal runoff show the same east to west decrease as the annual, the magnitude of the gradient varies from season to season. The gradient is greatest in the winter months and least in the summer.

Although the primary purpose here is to test the influence of morphologic characteristics on runoff it is not the intent to deny the importance of climatic variables. Since precipitation is the ultimate source of runoff this was correlated with watershed yields first. That a close relationship should exist between precipitation and runoff was expected and a statistical test indicated that the differences in precipitation over the area could account for about 75% of the variation in watershed yields on an annual basis. The seasonal watershed yields could not be explained to as great an extent by precipitation as the annual yields. Variations in temperature from basin to basin were also tested against basin yield but results indicated that temperature differences were not significant.

In all, eight landform characteristics were calculated and their association with runoff determined. They were shape of the watershed, stream order, erosional stage, average slope, median elevation, average length of overland flow, average length of first order streams, and stream density. Two of the parameters, stream order and erosional stage, had to be discarded from the study. Stream orders were discarded because of their close association with size of the watershed. The erosional stage of the watershed was discarded because the hypsometric integral devised by Strahler (1952) wasn't sensitive enough, when applied to watersheds of this size, to be of any utility.

Two indices relating to shape have been developed by Gravelius (1914). They are the compactness coefficient and the form factor. The compactness coefficient is $K_c = 0.28 \frac{P_1}{A}$ where P_1 is the length of the perimeter and A is the area. This coefficient is essentially the relationship of the shape of the drainage basin to a circle. If the basin were a perfect circle then K_c would be equal to 1. The form factor is the ratio of width to length of the watershed. The form factor $(F_F) = \frac{\frac{\text{area}}{\text{axial length}}}{\text{axial length}}$. Hypothetically the more elongated a watershed is the slower the runoff from the basin will be. The coefficients of correlation between shape and runoff were not significant.

The average slope of the watersheds was determined using the method devised by Horton (1914). He suggested that the slope of the watershed would be instrumental in controlling the time of overland flow. His equation for average slope is $S = \frac{DL}{A}$ where S is the average slope, D the contour interval, L the total length of contour lines and A the area. Here again there was no significant relationship with runoff.

Three measures of the drainage network were calculated as the network of stream channels is likely to reflect factors such as permeability and slope. The measures used were stream density, length of overland flow, and average length of first order streams. Stream density (D_s) is the amount of surface drained by each stream. $D_s = \frac{A}{N_s}$, where A is the area of the watershed and N_s the total number of streams. Average length of first order streams is the average length of the smallest unbranched tributary streams and the average length of overland flow (1) $= \frac{A}{4}$ L, where A is the area of the watershed and L the total length of stream channel in the watershed. These three measures of the drainage density when correlated with the pattern of runoff showed no significant association.

Median elevation was the only variable which proved to be closely related to variation in yields. The reasons for this are apparently two. The first is that the watersheds with the lowest median elevations have cut their channels deeply enough to have cut into the sedimentary strata beneath the drift which contributes groundwater to these streams during dry periods. The second is due to coincidence of elevation and precipitation. Elevation and precipitation are inversely associated so that as elevation increases precipitation decreases.

Most of the watershed characteristics examined here failed to have any significant effect on runoff for the time periods analyzed. The variation in precipitation from basin to basin seems to be such a strong factor in explaining runoff that the effects of differences in watershed characteristics are negligible. The parameters tested in this study are only a selected group from many which have been presented in the literature, but they should be fairly representative.

REFERENCES

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