Paper 1590 April, 1958 IR 2

Journal of the

IRRIGATION AND DRAINAGE DIVISION

Proceedings of the American Society of Civil Engineers

WATER YIELDS AS INFLUENCED BY WATERSHED MANAGEMENT[a]

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(Proc. Paper 1590)

ABSTRACT

Hydrologic studies on small brush-covered watersheds in the Coast Range and Sierra Nevada Mountains of California show that appreciable increases in runoff can result from replacement of brush by grass. Water yield increases of as much as 10 inches have been measured under favorable conditions without serious acceleration of soil erosion. These management practices also result in improved forage production on previously marginal land. Factors in precipitation disposal are discussed in relation to the influence of watershed vegetation on runoff.

INTRODUCTION

Watershed management is a term which has been used to describe many processes applied to watersheds. In its broadest sense watershed management may embrace the wide variety of management programs from the control of the area for the production of minerals, livestock, forage, timber, for recreation and certainly for water production. In the western United States as in all arid areas of the earth this latter consideration has been of principal concern. It is to the matter of the management of certain of our water-producing lands that this discussion will be devoted.

A brief look at the hydrologic cycle will reveal certain basic facts which must be considered in any study of the disposal of precipitation on a watershed. Precipitation falling on a typical watershed is disposed of in several ways: as direct runoff, indirect runoff, accretion to groundwater and soil moisture, or through loss to the atmosphere by evaporation. In each of these

Note: Discussion open until September 1, 1958. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 1590 is part of the copyrighted Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. IR 2, April, 1958.

a. Presented at a meeting of the Irrigation and Drainage Division, ASCE, San Francisco, Calif., April, 1957.

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categories there are numerous subdivisions. If the principal interest is in the management of watersheds for the production of water and increased water yields, then the management must take a form which will modify the proportion of the precipitation channeled into each category.

It is obvious, however, that if a management program is to be of greatest benefit, it must permit increases in water yield without deleterious effects. Perhaps the most practical method of modifying disposal of precipitation on the watershed is through the management of the vegetation. This does not, however, preclude certain programs which have been used in some areas to produce maximum water yields through complete paving of the soil surface.

Vegetative Manipulation

Manipulation of vegetation as a form of watershed management has long been of interest in the field of hydrology. Numerous experiments have been conducted to determine the responses of watersheds subjected to various treatments. In the opinion of the writer it seems quite clear at this time that the manipulation of vegetation will result in marked changes in precipitation disposal factors. Removal of the primary intercepting vegetative canopy permits a greater amount of precipitation to reach the soil surface. This item alone must result in a greater contribution of water from the area since for a given set of conditions of soils, geology, vegetation and climate the balance will have been disturbed. Furthermore, the removal of vegetation in many cases may result in a modification of the soil surface, the governing agent in infiltration. Within the limits of practicality it is impossible for man to affect a modification of the actual soil capacity for retaining moisture. Thus, increased runoff must be the anticipated result of manipulation of the vegetation on watersheds where precipitation is sufficient to satisfy soil moisture capacities. The actual method of vegetative manipulation is also important in determining the ultimate response.

A further effect of vegetative manipulation is that of reduced evapotranspirational losses after converting from dense, deep-rooted brushy species to a grassy type of cover. Many grasses are less deeply rooted and may persist less vigorously throughout the summer season. Thus on the deeper soils and on watersheds where the soil moisture deficit is satisfied annually there may be a carry over of moisture with a consequent savings of water.

As was noted earlier, management must produce a beneficial response in increased water yield without undesirable effects. It would be wonderful indeed to be able to simply modify the vegetation on a watershed and obtain increases in water yields. Unfortunately, this is not generally the case. The increased runoff occasioned by the additional precipitation arriving at the soil surface and contributing to a greater quantity of surface and subsurface runoff may create situations of increased movement of debris down channels. If infiltration rates have been modified, further increases in surface runoff may cause higher erosion rates.

Studies by the University of California

Recognizing these principles, the University have been engaged in studies for some time in an attempt to develop vegetative manipulation techniques that avoid the undesirable aspects and to take advantage of those desirable ones. Within the state of California there are several major zones of vegetation on the mountain watersheds. These are generally described as the woodland grass areas at the lowest elevation in the foothills: the chaparrel or brushlands lying in the intermediate elevations; and the forested lands at the upper reaches of the watersheds. It is within the second zone that a considerable amount of research has been centered.

Some 13,000,000 acres in this state are so situated with regard to climate and topography that they might well be considered as potential range lands to be used in the production of forage for livestock. Broad programs have been developed in attempts to control the undesirable chaparral growth on these areas and to substitute desirable forage species. Such procedures have been referred to as range management or improvement programs. These potential range lands which are being subjected to management are extremely critical due to their location, lying as they do between the areas of use in the irrigated valleys, and the upper watershed.

The Department of Irrigation of the University of California began hydrologic studies of the effects of brushland conversions in about 1933. The earlier phases of the operation involved the use of small plots situated in typical brushlands of California. These plots were established in pairs one of which was immediately subjected to a complete vegetative removal process. The other of the pair was held as a control or check plot. Some 40 pairs of these were established. Records of precipitation, runoff and erosion were collected continuously for approximately 10 years on each of the plots. The pairs were then reversed. The original treated plot was allowed to return to native vegetation and the brush-covered plot was converted to grass. In these early studies no attempt was made to revegetate the plots after removal of the brushy vegetation. Native grasses usually became established.

As the study progressed it became obvious that plots would not give a complete picture of the situation since they did not involve an entire unit in nature. Therefore, a series of small watersheds were established in the same general regions as the plots. These small watersheds consisted of pairs again. Because of the difficulty of locating two identical units in nature it was necessary to calibrate these watersheds to determine their relative hydrologic characteristics. Calibration was established at approximately 5 years on the presumption that within the 5 year period a reasonable experience of weather phenomena might be expected. As it developed, however, longer calibrations were used in the earlier studies. On both the plots and the small watersheds soil moisture samples were taken at frequent intervals throughout the season. At the end of the calibration phase of this study, one of the pair of watersheds was selected for treatment. These treatments generally consisted of the removal of the native brushy vegetation and the substitution of an improved grass-type cover.

Further experience again indicated that larger watershed units were necessary. There are several factors which enter into the selection of the most desirable size of watershed to study in such a program. One major concern is the cost of developing the equipment necessary to make the measurements. In this study erosion measurements were made by actual sedimentation of the debris coming down the channel of the stream. This debris is weighed out after each storm. The stream gaging stations used in conjunction with these sedimentation basins incorporated standard hydraulic measuring devices to avoid calibration difficulties and to permit as high a level of accuracy of measurement as was possible. In some cases volumetric measuring devices as well as weirs or flumes were used.

The largest complete watershed unit which has been developed thus far is approximately 200 acres in area. The sedimentation basin required for this watershed has a capacity of about 1/3 acre foot for debris storage. Larger watersheds have been included but these do not have debris measuring devices.

It might be noted here that the use of other sediment measuring devices such as aliquot samplers may be more economical and possibly more desirable since the labor required to service a sedimentation basin becomes appreciable. Devices of this type are being considered at the present time and may be incorporated in some of the existing structures to test the various types.

The vegetation management processes applied to these watersheds were designed to insure a complete treatment and to maximize the severity of the treatment. Certain preparatory steps were used. These involved the slashing of the vegetation early in the summer season, the slashed brush being allowed to dry on the ground for as long as possible before the application of fire to the area. Fire was used on all of the areas except one. Use of fire is indicated on this type of land cover as being the most economical means of removal of the vegetation. This preparation of the vegetation results in a much more severe treatment than would be possible otherwise. After the treatment had been applied a transitional period follows. A three-year minimum period is usually necessary to allow for a complete conversion from the brushy species to a new cover. The revegetation process is accomplished by reseeding the areas with grass species indicated to be suitable in these regions from agronomic studies.

Results of Experiments

At the present time seven major watershed installations involving either single watershed complexes or pairs are under study. These are located from in both the foothills of the Coast Ranges and Sierra Nevada Mountains. Five of these areas have been subjected to vegetation management treatments. On three of the areas the treatment has been in effect for a period of over three years. On the fourth the vegetation was removed in the fall of 1956 so only one season's record has now been gathered, and on the fifth the vegetation was removed over a period of about 1-1/2 seasons and involved a somewhat different type of vegetation management, the stripping of vegetation by means of mechanical equipment. As noted earlier, it is necessary to have several years of record after treatment to permit rational analysis. Therefore, only those which have been operated through several seasons will be considered here.

The use of mass-curves of runoff have been chosen to present the relationships between pairs of very small watersheds, one of which has been treated. Figs. 1 through 4 show the relationship between cumulative runoff in inches for the several seasons of operation. The cumulative precipitation curve has also been shown on the graphs to indicate the variation in seasonal precipitation. In all of these cases the time of the treatment is indicated on the graph.

The longest period of record is represented by the Ono watersheds. From this record we may observe that for the treated watersheds, A and D, the curves lie below the adjacent B and C curves prior to the accomplishment of the treatment. However, after treatment a reversal takes place and the D watershed particularly will be observed to show a marked increase in total seasonal runoff. Watershed A also indicates an increase in runoff by coming into position two in descending order at the end of the record. It will be noted from the graph that runoff increased in all cases on the mass curves but that for the two treated watersheds the increases are significantly higher during the post-treatment period, even for those years of extremely low rainfall. This indicates that the vegetation management process has caused an increase in water yield or runoff even during the lowest of rainfall years.

The Tulare record, Fig. 2, shows relatively comparable runoff data up to the 1952-53 season. Thereafter the yield from the A watershed begins to increase more rapidly. The actual treatment on Tulare watershed A was accomplished during the 1955-56 season and yet you will note a slight increase in the earlier record. Perhaps this may be explained by the fact that wide firebreaks were cut around these watersheds. Additionally the A watershed lies at a slightly higher elevation and receives a greater amount of precipitation in some seasons than does B.

Fig. 3 for the Ahwahnee Stations in Madera County represents another condition wherein the runoff during the season immediately following the vegetative conversion was sharply increased on A as opposed to zero runoff on B. Precipitation during the 1953-54 season was normal for this area. During 1954-55, however, precipitation was somewhat below normal which resulted in zero runoff from both watersheds. In the succeeding 1955-56 season which was notable in California as a high rainfall year the runoff from both A and B was appreciable but with the greater quantity coming off of the B watershed. However, because of the previous runoff the total record is higher for the A watershed. This greater runoff from the brush covered watershed B leads to the conclusion that during storms of excessive duration and precipitation rate, 14.3 inches in 4 days, where saturation of the watershed mantle is attained, vegetation management effects are completely obscured by the excesses of runoff which occur. This effect has been observed at other locations.

It might be of interest to note that in this above-mentioned storm, watershed B produced erosion at the rate of 1400 pounds per acre while that from the grass covered A watershed reached only 985 pounds per acre.

Fig. 4 is that of Diamond Range located in Tehama County. At Diamond Range the record begins with the 1942-43 season and progresses on upward with the B watershed curve well below that of the A record up to the time of treatment. This treatment was accomplished in the 1953-54 season and it will be noted that the B record immediately responded with a slight increase in runoff. This increase was not noted in the 1954-55 season which was slightly below normal precipitation. However, in the 1955-56 season again a large increase in runoff is indicated on the graph.

From an interpretation of these graphs definite runoff responses from vegetation management on these typical brush covered watersheds are indicated. The whys of this response in increased water yield have been discussed earlier and are undoubtedly related to the removal of the intercepting canopy. Certainly the soil, the vegetative cover, geographical location of the study area, and the character of the storms producing the runoff all have a profound influence upon the hydrologic responses of these watersheds. During those seasons immediately following treatments when normal or greater than normal precipitation was experienced increases in runoff were noted from the treated watersheds. On all of the watersheds the areas are very small. These data represent principally surface runoff. This is important since none of the subsurface contributions from the watersheds could be measured.

It appears evident from these considerations that vegetation management may have an effect upon the runoff characters of watersheds so treated. The data available at the present time are only for small watersheds ranging in size from less than one to approximately twenty acres. Current studies include watersheds up to 4,000 acres in area which will, it is believed, give a more realistic picture of the situation. As was suggested earlier the scope of vegetation manipulation for watershed management is rapidly developing. Further studies along these lines are now under way and will be continued in an effort to isolate in greater detail the effects of various management practices on the hydrologic characteristics of watersheds.

Figure 4. Accumulated Seasonal Runoff in Inches for Diamond Range Watersheds

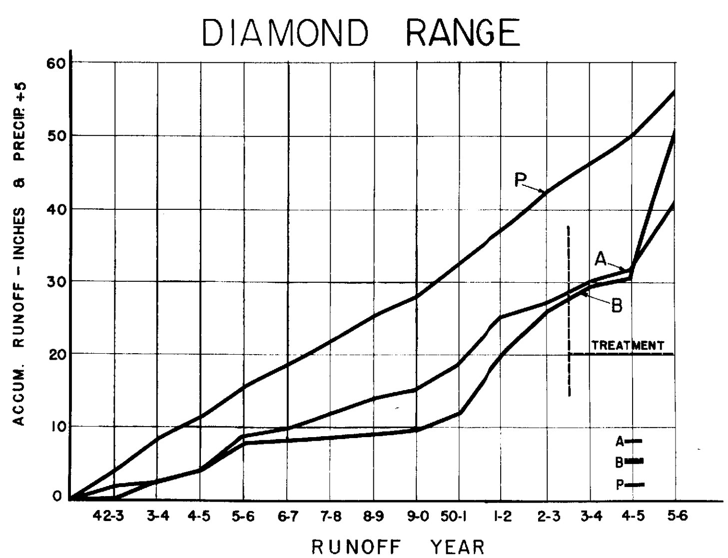

Figure 1. Accumulated Seasonal Runoff in Inches for Ono Watersheds

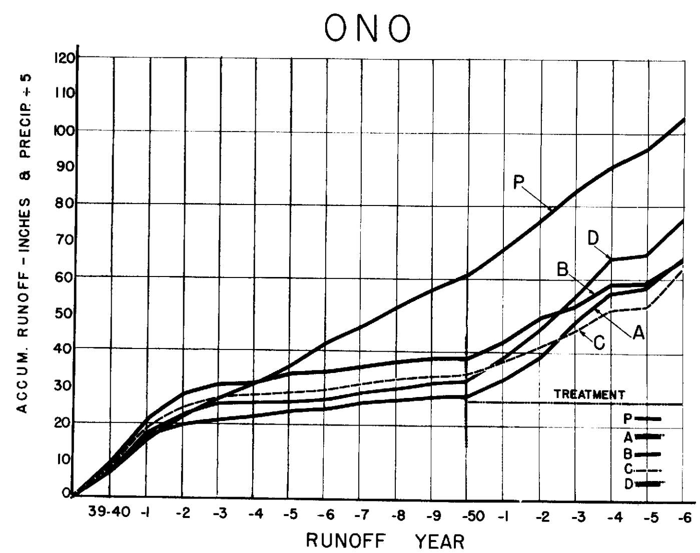

Figure 2. Accumulated Seasonal Runoff in Inches for Tulare Watersheds

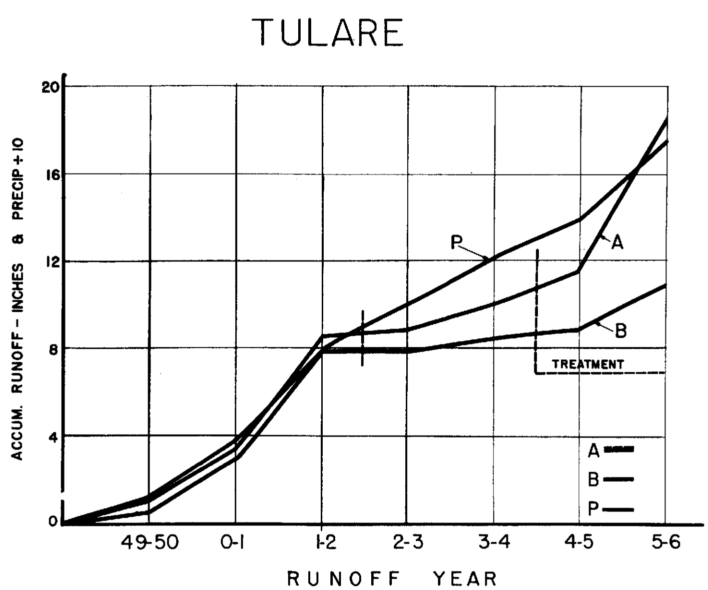

Figure 3. Accumulated Seasonal Runoff in Inches for Ahwahnee Watersheds