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RAINFALL AND SNOWMELT RUNOFF FROM INTERMEDIATE ELEVATION WATERSHEDS

by

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FORWARD

The Water Resources Research Institute has provided the administrative coordination for this study and organized the interdisciplinary team that conducted the investigation. It is the Institute policy to make available the results of significant water related research conducted in Idaho's universities and colleges. The Institute neither endorses nor rejects the findings of the authors. It does recommend careful consideration of the acumulated facts by those who are assuredly going to continue to investigate this important field.

ABSTRACT

Many low and intermediate elevation watersheds in the Pacific Northwest receive both rain and snow precipitation during the winter months. This results in winter runoff events that are damaging to agricultural land and can also decrease the snow water storage limiting water availability in late spring and early summer.

The winter and spring runoff from forested lands was studied at a snow research site where melt from the rain and snow events could be measured. Predictable lags occurred between time of melt and time of peak in stream hydrographs. The Kentucky Watershed Model was also used to evaluate the effects of precipitation type and amount on runoff patterns. Runoff in the early winter was not satisifactorily modeled.

An agricultural watershed was used to study runoff and erosion resulting from rain on snow and rain on frozen ground. Soil loss was found to depend mainly on amounts of precipitation since runoff began, volume of runoff, change in snow cover and soil moisture conditions. Rain on frozen ground produced less erosion than comparable amounts of rain on bare unfrozen soil.

A study of the water balance showed that precipitation was distributed approximately 27 percent to runoff, 57 percent to evapotranspiration and 16 percent to deep percolation. It also showed the Penman method of computing evapotranspiration was satisfactory when compared to soil moisture changes.

KEYWORDS

Water balance, snowmelt, runoff, erosion, evapotranspiration, mathematical modeling, agricultural watersheds, forested watersheds.

ACKNOWLEDGMENT

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INTRODUCTION

The Pacific Northwest receives most of its precipitation from gentle winter rains and snowfall. The fact that both forms of precipitation are mixed presents a significant problem in the understanding of the hydrologic properties of storm systems. The original objectives of this project were to:

1. Delineate the differences in seasonal runoff patterns among intermediate elevation watersheds.

2. Study the relationship of solar radiation, snowmelt, soil heat flux, soil moisture and snow water equivalent during periods of snow accumulation and active melt on a small upper elevation watershed.

3. Study sediment production, snowmelt, rainfall, and hydrograph characteristics of small watersheds which receive both snow and rain during winter months. Observe, if possible, frozen soil runoff events.

4. Study an agricultural watershed to determine the pattern resulting from interaction of rainfall, snow and frozen ground runoff events and the sediment production resulting from these events.

The first objective was deleted from this study when it became apparent that funds would not be sufficient to accomplish all the objectives.

SYNOPSIS OF ACCOMPLISHMENTS

The second objective was carried out at the Moscow Mountain Snow Research Facility, a fully instrumented site ideal for snow studies, located 15 miles NE of the University. The 1971-72 winter was one of very high snow-water equivalent and provided excellent data. By way of contrast, 1972-73 was an extremely low snowfall year. Because of the low snow cover, several tests that were to be made in 1972-73 in comparison with the previous year could not be made. This was due mostly to freezing of the instrumentation which resulted from a lack of insulating snow cover. Consequently, the study will continue one more year under sponsorship of the Agricultural Experiment Station in order to obtain needed comparisons. A complete report will be prepared when this study is completed.

One published paper has resulted from the study thus far. Instrumentation and techniques described in the paper were later adopted for a large scale investigation in Alberta, showing a significant transfer of knowledge.

But, perhaps the most significant contribution of this project to the general knowledge of hydrologic processes occurred in pursuit of objectives three and four. The results of the water-balance provided an overall view of water utilization in the Palouse Hills. This information has been used by the City of Moscow and other agencies in assessing groundwater recharge to the Moscow Basin. In addition, floods of January, 1972, inundated

large portions of northern Idaho. The Soil Conservation Service and Corps of Engineers were supplied with snow data, runoff hydrographs, precipitation data as well as other hydrologic data resulting from this storm.

Several events such as the 1972 flood and some frozen ground events provided the information for completion of the third and fourth objectives. Much of the hydrologic information has been analyzed by Davis and Druffel but this was primarily on storms that produced erosion or on drought periods that gave good estimation of evapotranspiration. The overall record has yet to be analyzed as a whole to determine the hydrologic performance of the various watersheds involved. This will be done in the future using the watershed model of Lee or some other model.

In an effort to study rain and snow interaction on these watersheds, the Kentucky version of the Stanford Watershed Model was used on the Palouse River near Potlatch, Idaho. This study showed that the model could be used under Idaho conditions. Changes in the precipitation regime could also be studied. This model will be used in the future to study the runoff on the agricultural watershed. During this study emphasis will be placed on observing the differences between frozen ground events and more normal events. In addition to testing runoff events, this model can be used to simulate soil moisture conditions. This makes it an ideal tool for testing the evapotranspiration results of Davis and Molnau.

More detailed information on all phases of this project is available from the various publications resulting from the work completed during this investigation. Abstracts of these publications are attached.

ABSTRACTS OF PUBLICATIONS

1. Darryl Jerome Davis. A water balance on a small agricultural watershed, Latah County, Idaho. Master of Science thesis in Agricultural Engineering, 1971.

During the 1969-70 water year instrumentation was installed to begin a water balance study on the Thompson watershed near Moscow, Idaho. A water balance was made for this initial year using rough estimates for some of the water balance factors. During the 1970-71 water year a better water balance was made that included actual measurements for all factors except deep percolation which was the unknown factor in the water balance equation.

The overall water balance for 1970-71 indicated that of the total precipitation 27% went to runoff, 57% to evapotranspiration and 16% to deep percolation. These percentages compare favorably with those obtained from previous studies in nearby forested watersheds.

Several methods were used to determine evapotranspiration. Measurement of changes in soil moisture storage was considered the most accurate method used. Correlation analysis showed both the Jensen-Haise and Penman methods will give good values for evapotranspiration when the crop coefficients used take into consideration crop stress. Pan evaporation in its present form was found to be a poor method for determining evapotranspiration at the Thompson watershed.

Analysis of the results of the water balance for the 1970-71 water year was made to determine what further study was needed on

the water balance. It was found that the factors of precipitation and deep percolation will require additional study.

2. LeRoy Druffel. Characteristics and prediction of soil erosion on a watershed in the Palouse. Master of Science thesis in Agricultural Engineering. 1973

The objective of this project was to study the process of soil loss by water on this one watershed and determine the effect of various hydrologic parameters.

The 1971-72 water year provided good data and 3.71 tons/acre soil loss was measured on a storm basis. The annual figure is estimated to be 4 tons/acre which would include unmeasured events and low flow periods with minimal losses. The 1972-73 water year was a poor year from the standpoint of erosion data as it was quite dry. However, three of the events which occurred were of the frozen ground type which provided valuable hydrologic data.

The soil loss events that were not on frozen ground were analyzed on a storm basis and a predictive equation for use on this watershed was developed by multiple regression techniques using several hydrologic parameters. Soil loss was found to depend mainly on amounts and timing of precipitation, volume of runoff, snow melt, and the conditions of the soil.

The data collected yielded good results but left unanswered the question of the effect of cropping patterns, tillage practice, slope, slope length, and slope aspect on soil erosion. These parameters are all very important to amount of soil loss but did

not vary in this case because the work was done on one watershed with one cropping practice.

3. Robin S.C. Lee. An evaluation and application of a digital hydrologic simulation model to an Idaho watershed. Master of Science thesis in Agricultural Engineering. 1973.

Watershed simulation models have many engineering applications in the areas of both research and project planning and management. In this study the Kentucky Watershed Model, a Fortran version of the Stanford Watershed Model, was adapted for use in Idaho.

Due to the limited storage capacity of the IBM 360/40 computer at the University of Idaho, minor changes and modification of the program were made. The model application and evaluation was made to the 317 square mile Palouse River near Potlatch watershed in northern Idaho. During the application, an adjustment had to be applied to recorded hourly precipitation because no data were available in the mountain area. The synthesized monthly flows are tabulated and the daily streamflow hydrographs were plotted against the recorded values. The annual water yield synthesized appeared to be within measurement accuracy, although a few discrepancies were found in some months and peak discharges. The model was calibrated based on the data for water year 1969-70. A verifying run was also conducted using 1967-68 water year data. The correlation coefficients between synthesized and recorded streamflow were arrived at 0.85 and 0.91 for water year 1969-70 and 1967-68 respectively. It was concluded that the application of the model to Idaho watershed conditions seemed feasible.

Several recommendations for further improvement of the model and its applications are given.

4. Myron Molnau. Comparison of runoff from a catchment snow pillow and a small forested watershed. Proceedings Western Snow Conference 39:39-43. 1971.

A 12-by-12 foot square pressure pillow was modified by the addition of drains to collect the snowmelt from the pillow. This meltwater was collected in tanks and monitored by stage recorders. The daily runoff amounts from the catchment pillow was compared with the mean daily runoff from a 1580-acre watershed and one of approximately 80 acres. The runoff from the pillow provided a good measure of the timing of runoff from the two watersheds. A time lag of one day was found for the small watershed and 2 to 3 days for the latter watershed.

5. Darryl J. Davis and Myron Molnau. The water cycle on a watershed in the Palouse Region of Idaho. Transactions of the American Society of Agricultural Engineers (in press) 1973.

The distribution of water in the hydrologic cycle within the Palouse region of Idaho is becoming a concern of the people in the region. A few investigations have been made to determine the distribution of water, but most of these have resulted in only very rough estimates.

During the 1969-70 water year approximate water balance showed 25 inches of total precipitation was distributed 20% to runoff, 64% to evapotranspiration, and 16% to deep percolation. Some of the data used in this water balance were estimated or transposed rather than directly measured at the watershed. During the 1970-71 water year improved instrumentation and procedures provided a better

water balance. It was found that 27.5 inches of total precipitation was distributed 23% to surface runoff, 56% to evapotranspiration, 18 1/2% to deep percolation, and 2 1/2% to an increase in soil moisture. All of these values are based on data collected at the watershed and are, therefore, considered a good representation of the distribution of water at the watershed.

6. Myron Molnau and Darryl J. Davis. Evapotranspiration on a Palouse Watershed. Paper 73-218. Presented at annual meeting of the American Society of Agricultural Engineers. Lexington, Kentucky. June 1973.

Evapotranspiration of a spring barley crop was estimated by measuring soil moisture changes. An evaporation pan, the Penman method, and the Jensen-Haise method were used to estimate evapotranspiration. On an overall evaluation, the evaporation pan was found to be unacceptable for use in determining evapotranspiration while the other two methods performed about equally well with the Penman method to be preferred.

7. C.W. Johnson and Myron Molnau. A gravity sediment sampler for drop-box weirs. Presented at annual meeting of PNW Region, American Society of Agricultural Engineers. Bozeman, Montana, 1970.

Two versions of a gravity suspended sediment sampler have been tested in the laboratory at the University of Idaho and field installations have been completed on a watershed near Moscow, Idaho, and on a sub-basin of the Reynolds Creek Watershed in southwestern Idaho. These gravity samplers incorporate proven features of the drop-box weirs, single-stage samplers and the Chickasha pumping sampler into an improved design for certain free overfall site

conditions. Although no runoff events have occurred since completion of the sampler installations, the instruments promise to be a simple and inexpensive solution to the problem of sampling suspended sediment at these appropriate sites.

CONCLUSIONS

The research conducted under this project resulted in the following conclusions:

1. There is a predictable lag in the movement of water from a snow pack to the watershed outlet. This lag seems to depend on watershed area.

2. The Penman equation is to be preferred for use in potential evapotranspiration computations in the Palouse.

3. The Kentucky Watershed Model can be used to evaluate the effect of precipitation type and amount on runoff pattern. It appears that the present model has some difficulty when only portions of the watershed contribute to runoff.

4. Frozen ground runoff events caused less erosion than non-frozen ground events of comparable runoff.

5. Erosion on a specific watershed depends mainly on the amount of precipitation since runoff began, the volume of runoff, the change in snow cover during the storm, and antecedent moisture conditions.

6. The precipitation falling on the Palouse area of Idaho is distributed approximately 27 percent to runoff, 57 percent to evapotranspiration and 16 percent to deep percolation.

7. The sediment sampler has worked quite well in both gravity and pump filling conditions.

PUBLICATIONS RESULTING FROM PROJECT

Master of Science Theses

Davis, Darryl Jerome, 1971. A water balance on a small agricultural watershed, Latah County, Idaho. Department of Agricultural Engineering, University of Idaho, Moscow.

Druffel, LeRoy, 1973. Characteristics and prediction of soil erosion on a watershed in the Palouse. Department of Agricultural Engineering, University of Idaho, Moscow.

Lee, Robin S.C., 1973. An evaluation and application of a digital hydrologic simulation model to an Idaho watershed, Department of Agricultural Engineering, University of Idaho, Moscow.

Papers Presented at Meetings

Johnson, C.W., and Myron Molnau, 1970. A gravity sediment sampler for drop-box weirs. Presented at annual meeting of PNW Region, American Society of Agricultural Engineers. Bozeman, Montana.

Molnau, Myron and Darryl J. Davis, 1973. Evapotranspiration on a Palouse watershed. Presented at annual meeting of the American Society of Agricultural Engineers, Lexington, Kentucky, Paper 73-218.

Published Papers

Molnau, Myron. 1971. Comparison of runoff from a catchment snow pillow and a small forested watershed. Proceedings Western Snow Conference 39:39-43.

Davis, Darryl J., and Myron Molnau. 1973. The water cycle on a watershed in the Palouse Region of Idaho. Transactions of the American Society of Agricultural Engineers. (In press).