(Reprinted in U. S. A. from *Transactions* of 1944
of the American Geophysical Union)

APPENDIX B--REPORT OF SUB-COMMITTEE ON SUBSURFACE-FLOW

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The full membership of the Sub-Committee on Subsurface-Flow has not yet been completed and will be announced later. The two accompanying statements have been prepared during the past year to serve as a general introduction to further discussion.

Subsurface-Flow

C. R. Hursh

The following review does not attempt to cover the literature on the development of current concepts of subsurface-flow. It will only serve as an elementary guide for anyone wishing to inquire further into the subject.

Interpretation of surface-runoff phenomena, and more particularly the movement of water after it has reached river-channels, has been the subject of much excellent research by HORTON, SHERMAN, and others. Interpretation of flood-hydrographs from areas of high soil-infiltration where there is little, if any, surface- or overland-flow, has received less attention. In southern California flood-phenomena have been described [see 1 of "References" at end of Appendix] that could not be explained without assigning a considerable amount of the flood-volume to subsurface return-flow of water. During the past year HORNER [2] has reemphasized the importance of stream-channel inflow that takes place during the storm-period from areas of high infiltration where overland-runoff is of little significance. HORNER points out that it is imperative that we understand this source of storm-water in order to properly interpret the role of land during flood-periods. COOK [3] has also stated that some of the most difficult hydrologic problems with which the Department of Agriculture Flood-Control-Survey organization has had to deal have arisen from "attempts to estimate the effect of treatment of land upon floods from areas in which the capacity of the soil-mantle to store infiltrated water is so small that a substantial proportion of the volume of damaging flood-flows is derived from subsurface-runoff".

The need for better methods for differentiating ground-water runoff and surface-runoff in the stream-flow hydrograph was specifically pointed out by the National Resources Committee [4] as one of the important deficiencies in hydrologic research. However, HOYT and others [5] had previously emphasized the difficulties in drawing a ground-water hydrograph under a complex storm-hydrograph. One of these difficulties lies in taking cognizance of the storm-water that reaches the stream-channel after a short period of temporary detention-storage within the soil-profile.

In 1934 LOWDERMILK [6] expressed the idea that a dynamic form of subsurface storm-flow is associated with certain soil-profiles, which is neither true overland storm-runoff nor true ground-water discharge. This type of flow he considered to be shallow seepage or discharge of wet-weather springs. Discussing this runoff-phenomenon in 1936 the writer [7] proposed the term subsurface storm-flow for the dynamic type of storm-water that enters the soil but moves away from the area through upper soil-horizons at a rate much in excess of normal ground-water seepage.

In his theory of maximum ground-water levels, HORTON [8] has introduced an essential assumption to the concept of subsurface storm-flow. His assumption is that topographic conditions such as gullies and natural drainage-lines may create temporary outlets for the ground-water aquifer at the upper limits of the rise of the water-table.

On sloping land and for natural soil-profiles with strongly differentiated horizons, the writer believes that another factor limiting the rise of the water-table is the tremendous increase in lateral transmission-rate as the water-table approaches the soil-surface. Studies employing numerous observation wells in the high rainfall-belt of the southern Appalachian Mountains tend to substantiate this theory [9]. In considering flow through natural upper soil-horizons, the formulas of soil-mechanics do not generally apply. Here porosity is not a factor of individual soil-particle size, but rather of structure determined by particle aggregates which form a three dimensional lattice-pattern. This structure is permeated throughout by biological channels which in themselves also function as natural hydraulic pathways [10]. A single dead-root channel, worm-hole, or insect-burrow may govern both the draining of water and the escape of air through a considerable block of soil. In the subsoil, less influenced by biological activity, water-movement is more directly related to soil-particle size and the formulas of soil-mechanics more nearly apply. These concepts have been developed recently in this country through the researches of BAVER [11], SLATER [12], and others.

The soil-profile must be viewed as an entity made up of definite horizons, a concept that is also of fairly recent origin. It was probably not till the appearance of MARBUT'S translation in 1927 of GLINKA [13] on soils and their development that the natural relations of soil-horizons became the basis of pedologic thought throughout the United States. The hydrologic significance of different soil-horizons as related to storage and movement of water still offers a valuable and relatively unexplored field for research. Herein lie some of the most critical of the practical problems of land-use hydrology, water-control on the land, and watershed-management.

RIESBOL [14] has presented a summary of the aspects of subsurface-water in hydrologic research on agricultural watersheds. He concludes that inflow to a ground-water reservoir, already nearly filled, will return to the surface as effluent seepage to become a factor in the flood-hydrograph not only from small watersheds but from larger stream-drainages as well. HOYT [15] has expressed himself that after prolonged rain when natural storage has already become utilized, subsurface storm-flow may under some conditions reach the stream-channels nearly as promptly as overland storm-runoff.

BARNES [16] has been one of the first to make a practical application of the concept of subsurface-flow to runoff-phenomena. Using a graphical analysis he has presented a method for separating the components of storm-flow as surface-flow, storm-seepage, and ground-water.

It would be expected that rises in water-tables normally close to the soil-surface, would indicate that field-moisture deficiencies have been satisfied and that further rainfall will contribute directly to ground-water available for stream-flow. This idea was expressed by THOMPSON [17] as follows: "The question may be raised as to whether fluctuations of the water-table may also be used to show danger of flood conditions when heavy rains produce an unusual saturation of the ground." This is a suggested application of the general theory that maximum aquifer storage is directly related to maximum ground-water discharge. SNYDER [18] has made a practical application of this theory by introducing the use of the ground-water storage-curve. This curve is derived from the curve of ground-water depletion which has an accelerating rate as its upper limits are approached. It appears to the writer that the upper limits of the ground-water depletion-curve approaches or merges into the rapid rates of subsurface storm-flow. PARKER [19], and much earlier VERMULE [20] both discuss maximum ground-water discharge in terms of the maximum water-storage during spring months. Consequently, for a given amount of rain, floods are more likely to occur in the spring months than any other season because at this time storage-opportunity is at a minimum for temperate semi-humid climates. For humid climates, the soil-profile may conceivably function very much as a natural reservoir [21] for the temporary detention of storm-water as well as for the more permanent storage of ground-water that will ultimately become the base-flow of streams.

The importance of understanding subsurface-flow is to better interpret the hydrograph of stream-flow. Specifically, it will aid materially in interpreting the relation of the recession-curve of the storm-hydrograph to the curve of normal ground-water depletion. This will facilitate in relating watershed-management to stream-behavior. Recognition of conditions under which subsurface-flow does appear might aid in the selection of individual storms serving the unit-hydrograph most applicable for different conditions of storage present within the drainage-basin prior to any current storm.

There are several conceivable explanations that might account for subsurface-flow. One is the rapid spilling of the over-charged ground-water aquifer through extremely porous upper soil-horizons. Another is the relatively shallow penetration of storm-water into porous upper soil-horizons and its rapid lateral flow with the slope to natural outlets. In the first case, the water-table is close to the soil-surface and its position becomes an important factor. In the second case, the true water-table may have no part in the phenomenon.

WENZEL [22] has suggested that the increase in stream-discharge from subsurface-flow may result from the saturated cross-sectional area of the stream-bank. In areas of irregular topography there is a rapid accumulation of infiltrated storm-water in porous colluvial ravine fills and terraces that discharge directly into the stream-channel. The rapid increase of ground-water near the stream comes from subsurface-flow on slopes above the colluvial fills. The result is not only an increase in cross-sectional area through which water enters the stream, but principally in a sharp increase in the slope of the water-table at the stream-edge. Subsurface-flow under the above conditions should not be confused with subsequent return of temporary bank-storage that has taken place from the stream during periods of bank-full stage. Return from bank-storage takes place at a greater rate than normal ground-water depletion and on this basis it may be considered to be a form of subsurface-flow.

One of the handicaps in interpreting the nature of subsurface storm-flow has been the lack of records from suitable experimental basins. This handicap is being overcome through such cooperative studies as those conducted on the Ralston Creek and Rapid Creek basins at the University of Iowa. Other studies yielding suitable data for interpreting the nature of stream-flow are being conducted by the United States Forest Service of the Department of Agriculture on the Coweeta Experimental Forest in the high rainfall-belt of the southern Appalachian Mountains, in Colorado, and in southern California. The Soil Conservation Service has likewise obtained runoff-records from small drainage-areas on the Coshocton Experimental Area in Ohio, and elsewhere. All of these studies will aid materially in furnishing basic records from areas of known hydrologic characteristics. It is to be hoped that these and further intensive studies may contribute to better understanding the nature of subsurface-flow.

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