The chief source of deficit between rainfall on the area and resultant flow is evaporation loss. Another source of deficit is the loss of percolation water, which is inevitable, though it might be small in amount; but, on the other hand, this loss might be more than compensated for by gains of percolation water from sources outside the topographical drainage area.

(1) *Surface Run-off.*—That part of the rainfall which falls on the water surfaces as a "direct contribution" to the stream is measurable by the product of rainfall and water area. It causes the first upward turn of the curve at a peak; normally small in amount, it becomes a greater proportion of peaks towards the end of a period of drought, and might at such times be the only benefit from rainfall.

Some of the factors affecting surface run-off have been already mentioned. Absorption and percolation are factors which are probably not of equal effect over the whole of the drainage area, and also vary according to weather conditions. Surface run-off will occur when and where the rate of rainfall exceeds the rate of absorption until the surface soil is saturated; then it depends upon the difference between rates of rainfall and percolation.

The proportion of rainfall yielded as surface run-off is high when the ground remains frozen, and is generally very small in summer, sometimes very large, however, after the ground has been "baked," but whether this is actually due to the "baked" condition of the soil or to greater intensity of rainfall, such as obtains in thunder showers, has not been satisfactorily determined. The author has observed in ground over clay subsoil that extensive and frequent cracks develop during droughts, and it is questionable whether such cracks, at times two inches in width and more than a foot in depth, would not counter-balance the effect of baking the ground.

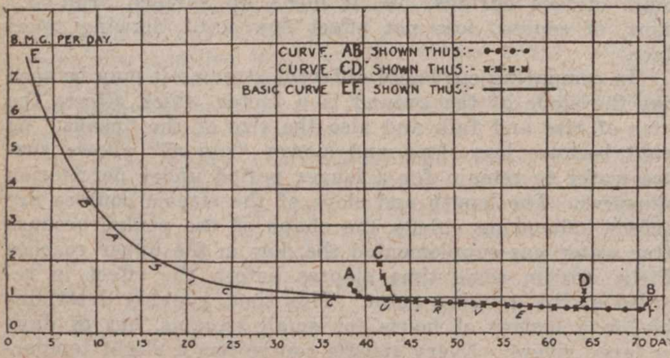

FIG. 4—BASIC CURVE OF PERCOLATION DISCHARGE

Whilst the ground is under the effect of recent rains, a subsequent rainfall produces a greater result in the amount of run-off. A few hours after rainfall has ceased it would be very difficult to detect, on the gathering ground, any indication of surface run-off (except where flooding has occurred), though it is quite noticeable during heavy rains from the newly formed streamlets appearing in ill-formed and miniature valleys in the drainage area.

In estimating the time at which it becomes *nil* or negligible, the fact of thin films of water being almost unnoticeable should be taken into account, and the author's estimate of the time which might elapse before the surface water has reached a stream course is given as seldom more than 48 hours, but variable according to the amount of rainfall, percolation rate, and surface slope. On this assumption dividing lines have been inserted in the flow curve in Fig. 2, to show an estimate of the increase of flow due to surface run-off; this is shown by the cross-hatched portions. By treating all the peaks in the same manner, an estimate of the yearly total of surface run-off can be made. The amount of flow, as shown by the low-lying parts of the curve, and up to the dividing line or lines is likewise an estimate of the percolation discharge. Where rainfalls succeed one another, the guide to the insertion of the dividing lines should be the estimate of percolation discharge, which has but a slowly increasing rate, and the dividing lines must obviously commence at a part of the curve which indicates percolation discharge alone. In the case of large rivers, allowance for the time taken in flowing down the river will be necessary, but percolation discharge will be the best guide for estimating purposes. It is not, of course, possible to determine accurately what proportion is due to the two intermediate sources of supply, but it will be noted from Fig. 2 that were the time of 48 hours altered to 36 or 60, it would not affect the estimate very materially.

The area from which surface run-off occurs is obviously defined by the natural water partings, but it must be noted that this area is not necessarily identical with the percolation drainage area.

Conditions Affecting Percolation Discharge

(2) *Percolation Discharge.*—Of percolation discharge there is visible and irrefutable evidence in the existence of springs discharging percolation water at the surface of the ground. There are also subaqueous springs discharging into the beds of streams, rivers and the ocean less apparent and likely to escape notice. There are doubtless similar discharges of percolation water which, from finding easy passage through alluvial deposits to open water, are perhaps outside the possibility of detection. Considering that almost all rocks are fissured, and that the beds and banks of streams are, as a general rule, extensive alluvial deposits, it is most probable that a surface discharge occurs as an exception rather than a rule. There is no better evidence of the temporary storage of considerable volumes of percolation water than stream flow when the surface soil is parched, for at such a time the whole of the flow is obviously from such sources. So far as stream flow is concerned there is no need to make any distinction between visible spring flow and other percolation discharge, as the laws which apply to one apply with equal force to the other, and to percolation discharge as a whole.

The geological conditions of the drainage area affect percolation storage and discharge, yet in the author's opinion physical conditions have often greater influence. For example, the same bed of grit may be in one locality very much fissured, and in another considerably less so, and such differences mean like differences in storage capacity. Limestone, granite, other compact rocks, and also alluvial deposits, likewise differ in storage capacity in fissures and interstices. The rate of discharge also depends probably more on physical than geological conditions, and the greater width of an outlet for percolation water might be merely accidental. The volumes of water which can be absorbed by compact rocks after they have been heated to dryness is very considerable; yet this should not be taken into account, as all the deep subsoil rocks are, and remain, moist whilst *in situ*, and the amount they can retain, despite the force of gravity, is most probably constant. For these reasons the author strongly inclines to the belief that it is the fissures, and not the compact rock, which yields the percolation discharge. There will doubtless be cases where the water percolates through compact rock; but where fissures occur, they provide much quicker drainage for the bulk of percolation water.

Percolation and Hydraulic Laws

It is not proposed to consider the subject from a geological point of view, but to consider how far percolation discharge is subject to known hydraulic laws, and in order to do that it is necessary to consider the physical conditions which affect storage and discharge. Percolation water, having passed through surface soil into permeable strata, trickles downwards through interstices and fissures until its downward progress is stopped by impermeable strata, or until it reaches an existing water surface. Its course afterwards, in either case, is most probably like that of water in open channels, to which fissures and large interstices in the strata are a rough parallel. Each fissure or miniature channel has its rate of discharge and a hydraulic gradient inseparably related to the discharge rate. The hydraulic gradient is, of course, the water surface. The surface of percolation water in a network of fissures and interstices, assumed continuous through intervening rock, has been termed the surface of saturation, but is more generally called sub-soil water level. It is really a network of hydraulic gradients, and for any particular position there is a related flow, or rate of discharge. Its slope depends partly on the size and