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ABSTRACT

The paper presents various equations of the water balance of natural catchments. It assumes that evapo-transpiration decreases with soil moisture decrease. Worked examples are shown of a water balance for the experimental catchment at Taita, Lower Hutt, of the Soil Bureau, Department of Scientific and Industrial Research. Investigations are recommended of a water balance equation whereby the soil moisture status of a soil is computed by complete hydrograph analysis.

INTRODUCTION

It has often been said that the main object of the science of hydrology is the determination of the hydrograph. However, an equally important task for the hydrologist is the calculation of the water balance of a catchment.

The water balance presents a model of the hydrologic cycle and, because it gives information of periods of moisture stresses, a water balance becomes a basic requirement in an evaluation of a water shortage or a water surplus of an area.

Unfortunately much less research has been carried out on the water balance than on the hydrograph; most of the knowledge available has come from the researches of Thornthwaite and his associates.

DISCUSSION

The water balance in its simplest form is as follows:

$$P - E = R_o$$

in which P is the precipitation, E the evapo-transpiration and R_o the runoff. A slight elaboration could be made in splitting up the runoff into direct runoff and groundwater runoff:

$$P - E = R_d + R_g$$

where R_d is the direct runoff and R_g the groundwater runoff. An example was presented by Packard[6](1959) for the Soil Bureau experimental catchment at Taita.

Such a water balance furnishes a check on the accuracy of flow or precipitation measurements and for certain purposes estimates may be made of precipitation or runoff. Worked examples are given in Hydrology Annual No. 7 (1959).

A somewhat improved form of the water balance is as follows:

$$P - E = R_d + \Delta S + R_{eg}$$

where ΔS is the change in soil moisture storage and R_{eg} the recharge to groundwater.

Water balances of this type are useful for (1) a continuous survey of irrigation requirements;(ii) the prediction of low flows and (iii) an index of the condition of a catchment. In the latter instance over-grazing of a grassed catchment may result in two changes of the environmental conditions which could influence the micro-climate. The grass removal may result in decreased transpiration and consequently more of the precipitation is available for soil moisture storage or runoff. At the same time additional compaction of the soil reduces infiltration and therefore surface runoff is increased with resultant erosion.

The actual calculation of a water balance requires not only precipitation and evapo- transpiration data but also information on the water-holding capacity of the soil. Evapo-transpiration values are best computed with Thornthwaite's formula (1955) on account of the general availability of temperature data.

Actual evapo-transpiration is not identical with potential evapo-transpiration since an assumption may be made that evapo-transpiration varies with the amount of soil moisture available. Thornthwaite (1955), considers that the ratio of actual to potential transpiration varies linearly with the amount of available water between field capacity and wilting point in the rooting zone of the vegetation considered. Veihmeyer (1955) holds the view that soil moisture has no influence on the transpiration rate but logically one would expect some transition since transpiration at wilting point would be very low or zero. Penman (1951) holds an intermediate view. The point is of obvious importance but it cannot be solved by a priori reasoning. Recent experiments, as carried out by Slayter (1956) and Smith (1959), seem to confirm Thornthwaite's findings (refer Fig.1.)

A water balance example has been worked out for the Soil Bureau's experimental catchment at Taita by Thornthwaite's method. On a monthly basis the results are as shown in Fig.2.

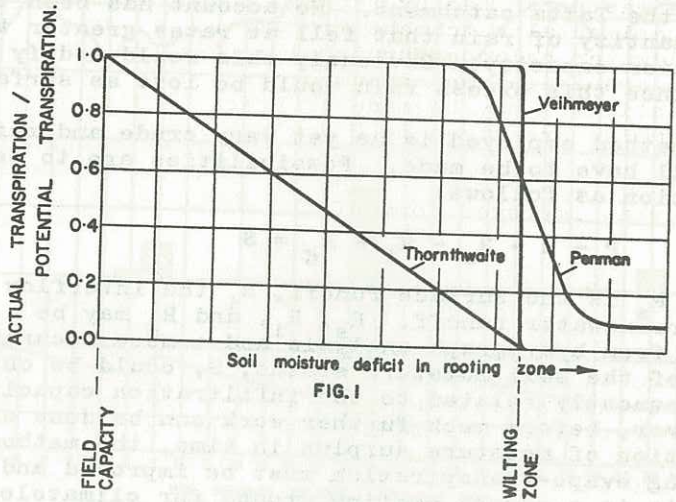


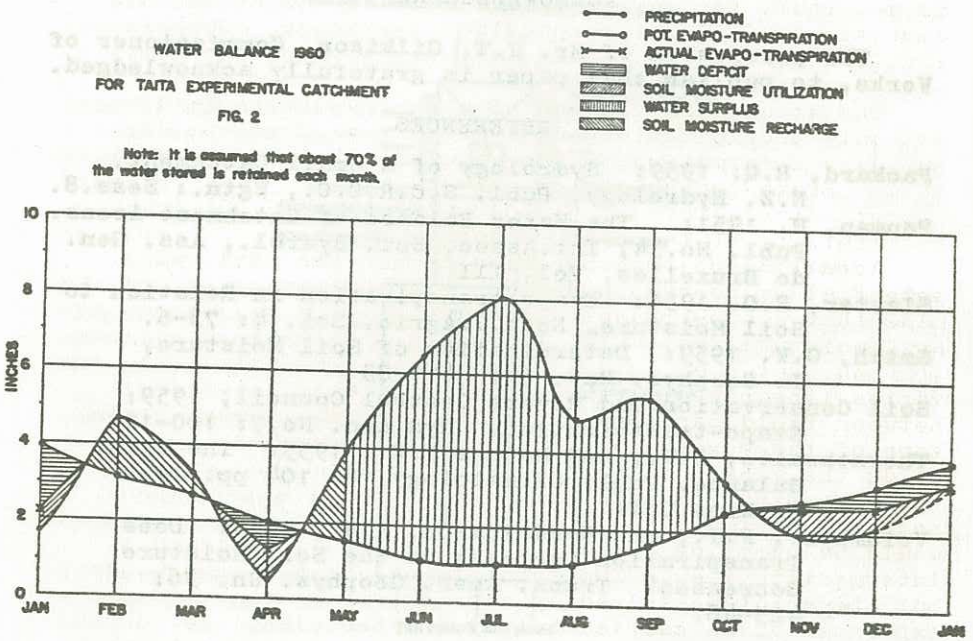
FIG. 1

WATER BALANCE 1960

FOR TAITA EXPERIMENTAL CATCHMENT

FIG. 2

Note: It is assumed that about 70% of the water stored is retained each month.



From such a water balance can be calculated the soil moisture fluctuation which, for greater significance, could be prepared on a daily basis. Fig. 3 shows the rainfall and the soil moisture balance during November 1960 for the Taita catchment. No account has been taken of the quantity of rain that fell at rates greater than infiltration capacity. Obviously this would modify the result since this excess rain would be lost as surface runoff.

The method employed is as yet very crude and refinements will have to be made. Possibilities are to set up the equation as follows:

$$P - E - R_s - R_i - R_g = S$$

in which R_s is the surface runoff, R_i the interflow and R_g the groundwater runoff. R_s, R_i, and R_g may be obtained from hydrograph analysis and a more accurate picture of the soil moisture status, S, could be obtained and subsequently related to the infiltration capacity.

However, before much further work can be done on the distribution of moisture surplus in time, the method of estimating evapo-transpiration must be improved and since this is a common meeting ground for climatologists, hydrologists and soil scientists, a combined effort seems most desirable.

ACKNOWLEDGMENT

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REFERENCES

Packard, R.Q. 1959: Hydrology of a Small Catchment. N.Z. Hydrology, Publ. S.C.R.C.C., Wgtn.: Sess.8.

Penman, H. 1951: The Water Balance of Catchment Areas. Publ. No.34, Int.Assoc. Sci. Hydrol., Ass. Gen. de Bruxelles, Vol. III

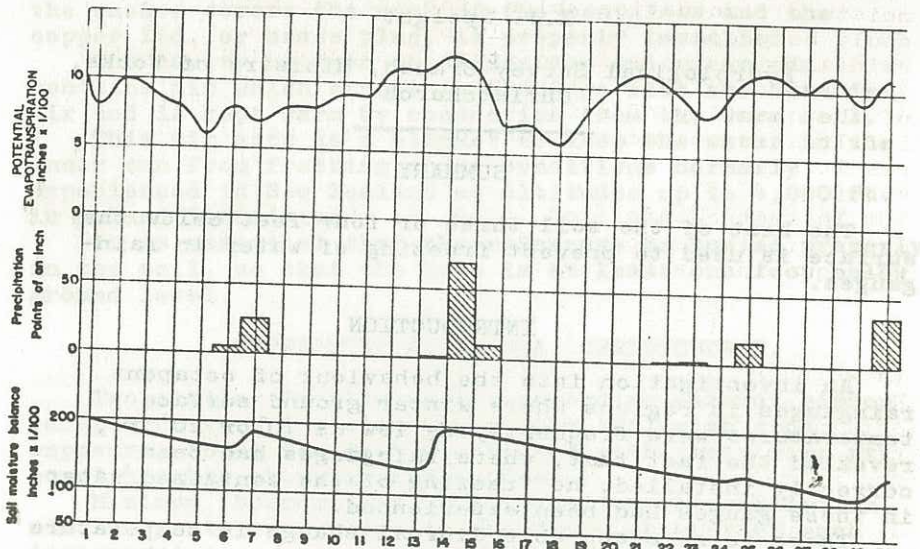
Slayter, R.O. 1956: Evapo-transpiration in Relation to Soil Moisture. Neth.J.Agric. Sci. 4: 73-6.

Smith, G.W. 1959: Determination of Soil Moisture, J. Geophys. Res. 64: 477-83

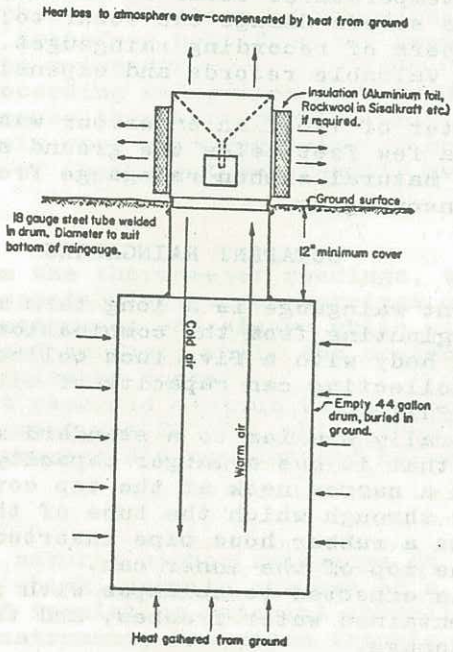
Soil Conservation and Rivers Control Council, 1959: Evapo-transpiration. Hyd.Ann. No.7: 100-12

Thornthwaite, C.W., and Mather J.R., 1955: The Water Balance. Publ. Climatology, 8: 104 pp. John Hopkins Univ.

Veihmeyer, F.J., and Hendrickson, A.H., 1955: Does Transpiration Decrease as the Soil Moisture Decreases? Trans. Amer. Geophys. Un. 36: 425-48.



SOIL MOISTURE BALANCE NOVEMBER 1960
FOR TATA EXPERIMENTAL CATCHMENT
FIG. 3



FROST PROTECTION FOR RAINGAUGES
PROVISIONAL SKETCH
NOT TO SCALE