THE APPLICATION OF RESEARCH ON EVAPORATION IN HYDROLOGY

by

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For the hydrologist the yield of water depends on precipitation and evapotranspiration. The latter depends in the first place on climate and weather, secondly on type of surface: water, bare soil, vegetation short or not short of water.

The hydrologist needs a simple method to estimate the quantity of water evaporating from a catchment area. In measuring precipitation (P) and run-off (R), only minor problems are involved. However, evapotranspiration for periods shorter than a year can not be estimated from the difference P — R, apart from special cases where the introduction of the «natural drainage period» (Penman and Schofield, 1941) enables the estimation of evapotranspiration for shorter period and for a vegetation. Non-weighable lysimeters (percolation gauges) do not give information on evapotranspiration in monthly periods, either.

Blaney and Criddle (1950), Thornthwaite (1948) and Penman (1948) developed convenient formulae to estimate from standard weather data, only, potential evapotranspiration (E_P), being evapotranspiration of a green surface never short of water. These formulae can be used to calculate even monthly evaporation for catchment areas. Van Wijk, De Vries and Van Duin (1953), and Van Wijk and De Vries (1954) showed that evapotranspiration (E_P) is in phase with radiation flux and not with temperature. For this reason Penman's calculation, where E_P mainly depends on radiation is to be preferred above the methods of Thornthwaite and of Blaney and Criddle, where E_P is based mainly on temperatuie.

In stead of calculating potential evapotranspiration, it is possible to determine it emperically by means of a tank with an infiltrated grass cover (Sanderson 1948). A standard evaporimeter may be used instead, provided the relation between the evaporation from the instrument (E_W) and E_P is known.

This approach of determining one basic factor (E_W or E_P) which is mainly of meteorological character, is a piactical one. However, a set of conversion coefficients is needed for all those parts of a catchment area where vegetation is wholly or partly lacking, where vegetation is short of water, or vegetation may not be considered a grasslawn, because of plantspecies, state of ripening, roughness length, permeability for wind, reflexion coefficient, etc. For vegetations where water is limiting Penman gives two estimates: *a*) the quantity of water obtainable without restriction (the «root constant») and *b*) the velocity of withdrawal of the remaining water (Penman 1949). He also gives a coefficient to overcome the aerodynamical stiucture of fruityards (Penman 1952). All those estimates have a provisional character and must be replaced in due course by experimentally determined ones.

Makkink and Van Heemst (1956) using weighable lysimeters, showed for a grass vegetation on undisturbed claysoil, how that actual (limited) evapotranspiration depends on soil moisture tension and potential evaporation. It is likely that it depends for a great part on density and growth of the plant roots whether a crop will suffer from water shortage or not. The controversy concerning availability of soil moisture may result from not taking in account root development (Veihmeyer and Hendrickson 1955).

Möller's (1951) method of obtaining an overall figure for the evapotranspiration of an extensive area must also be mentioned. He calculated the evapotranspiration from a water-balance sheet of the atmosphere. Variations in humidity are measured spectrographically and by pilot balloons. Precipitation is known, whereas advective transport of water in the air has to be zero or must be estimated in some way. Whether this method can be applied in hydrology is not known yet.

There are several other ways to determine evaporation of a surface. Most of them are not convenient for the hydrologist, because expensive instruments and too much work are needed.

In the first place there are the aerodynamic methods, based on turbulent vapour transport. Research at Lake Hefner (Oklahoma)(Harbeck and others, 1952) showed that the formulae of Sutton (1949) and of Sverdrup (1937) gave the best agreement with the waterbalance sheet data. Also Pasquill (1950) obtained a satisfactory agreement between observations and calculations after Prandtl's formula. In the Dutch Rottegatspolder the formula of Thornthwaite and Holzman, adapted according to the Businger's theory of stability (1954), is applied and the results are compared with those of the waterbalance sheet (Deij 1954).

Schmidt (1925) studied the vertical transport in the air and Swinbank (1951) measured the ever changing vertical component of the air velocity simultaneously with variations in water vapour density. This method seems to be promising for research work.

The heat balance sheet of the lower air layer provides another possibility to determine the evapotranspiration of a vegetation (Albrecht 1937, 1950); some data agree satisfactorily with data obtained with the «momentane» plantecological method, where loss of water is determined for short exposures of detached leaves or shoots (Berger-Landefeldt 1949). This method (Huber 1927, Stocker 1929, Pisek and Cartellieri 1932, Pfleiderer 1933) presents another experimental way to give all necessary coefficients for various vegetations, although critical application, especially concerning the conversion towards the unity of soil area, is necessary.

Also soil scientists, determining moisture content in the root layer, may contribute additional coefficients. Application of the electrical resistance method (Bouyoucos and Mick 1940) or the gravimetric method provided many crop constants on evapotranspiration (Blaney and Criddle 1950).

Finally, those who are working with weighable or with recording lysimeters may find some coefficients for kind of crop and for conditions of water shortage (Harrold and Dreibelbis 1951, Harrold 1955, Ramsauer 1956). These installations can be used, too, for checking basic formulae (Makkink 1955). Lysimeters planted with forest, though not weighable, are of great value for the study of interception (1) (Ovington (2), Wind 1955).

Most ways of determining or calculating evapotranspiration are not yet perfect, discrepancy between experiment and theory being often intolerably high. This is partly due to experimental errors, partly to the difficulty to develop formulae completely covering the complicated phenomena of turbulance and instability of the air (Harbeck and others 1952, Berger-Landefeldt 1953, Deij and others, 1956).

The investigations to be carried out in future must deal with improving of methods and formulae and with various aerodynamical exchange coefficients (Penman 1956).

As pointed out above we must collect from literature and experiment an arsenal of specific coefficients in addition to calculated or to the determined values of E_W or E_P.

Some attention has to be paid also to the choice of devices : evaporimeter and lysimeters (Harbeck and others, 1952, Baumbach 1952, Koriba 1943, Venema and De Vries 1954, Briggs and Shantz 1917, Boss 1952, Schubach 1952). If in future investigations on evaporation on an international base will occur, a discussion on instrumentation seems to be necessary.

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(1) See the separate paper on interception by R. Wind.
(2) Verbal communication.

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