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INSTITUTE of HYDROLOGY

REPORT No 16 MAY 1972

PEAT HYDROLOGY

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Summary Report of a joint meeting held on 20 February 1970 of the Peat Hydrology and Catchment Working Groups of the Natural Environment Research Council.

Present:

CHAIRMAN:	Dr. E.C. Childs, Dept. of Agriculture, Unit of Soil Physics, Cambridge
	Mr. J.K. Ballantyne, Ministry of Development, Northern Ireland
	Dr. D.J. Bellamy, Dept. of Botany, Durham
	Dr. W.O. Binns, Forestry Commission
	Dr. R. Common, Dept. of Geography, Belfast
	Mr. D.J. Dixon, Devon River Authority
	Dr. K.A. Edwards, Institute of Hydrology
	Dr. D.A. Goode, Nature Conservancy
	Dr. D. Grant, Meteorological Office
	Mr. F.H.W. Green, Nature Conservancy
	Mr. M.J. Green, Water Research Association
	Dr. M.J. Hall, Dept. of Civil Engineering, Imperial College
	Dr. D.M. Harding, Dept. of Geography, Swansea
	Dr. H.A.P. Ingram, Dept. of Biological Sciences, Dundee
	Mr. P.E.R. Lovelock, Inst. of Geological Sciences
	Dr. M.C. Pearson, Botany Department, Nottingham

Mr. D. Rycroft, Dept. of Civil Engineering, Dundee

Dr. K. Smith, Dept. of Geography, Durham

Dr. J.V. Sutcliffe, Institute of Hydrology

Dr. J.H. Tallis, Dept. of Botany, Manchester

Dr. I.E. Thomas, Dept. of Civil Engineering, Birmingham

Mr. B.D. Trafford, Field Drainage Experimental Unit, Cambridge

Mr. C.P. Young, Road Research Laboratory, Crowthorne

Dr. E.G. Youngs, Unit of Soil Physics, Cambridge.

INTRODUCTION

A meeting was organised by the Hydrology Committee of the Natural Environment Research Council in February 1970 to co-ordinate a national programme of research in peat hydrology and to encourage interest in a hydrological interpretation of water movement in peat.

Although many aspects of this subject are still unknown, there are indications of how some of the processes operate and it was felt that current programmes of research could benefit from an understanding of work accomplished in a number of different disciplines.

SESSION I

Dr. E.G. Youngs

BASIC LAWS OF SOIL WATER

Soils consist of an arrangement of solid particles which form an interconnecting network of channels containing the soil water and soil air. The physical properties of a given soil depend on the nature of the solid particles making up the soil and on the proportion of water present in it.

The most important property of the soil water is the pore-water pressure. Since it is impossible to measure what is actually taking place in the pores of a soil because of their small size, this property is inferred from the state of bulk water in equilibrium with the water in the pores. Below the water table where the soil is saturated and the pore-water pressure positive relative to atmospheric pressure, water will rise in an open-ended pipe (often referred to as a piezometer) until the head of water standing in it is in equilibrium with the pore-water pressure. This head is therefore a measure of this quantity. Above the water table no water will rise in such a pipe because the pore-water pressure is negative relative to atmospheric pressure. In this situation a tensiometer must be employed. In this instrument bulk water in a manometer is brought into equilibrium with the soil water via the pores of a membrane which are small enough not to allow bubbles of air to be drawn through at the equilibrium pore-water pressure. At the water table the pore-water pressure equals atmospheric pressure.

In a soil made up of inert particles the negative pore-water pressure is due to surface tension forces at the menisci in the pores, across which there is a difference of pressure. Because of the size distribution of the pores, different pores will drain at different negative pressures when the latter becomes too great for the menisci to be supported in the necks of the pores. In swelling soils the negative pore-water pressure is a result of the charged particles having a tendency to get as far away from each other as possible. In this case, the soil shrinks initially as the moisture content becomes less and the pore-water pressure becomes more negative, without air being drawn into the soil. Real soils show a mixture of these two extremes. The relationship between moisture content and pore-water pressure is often referred to as the <u>moisture characteristic curve</u> for a given soil; this relationship shows hysteresis and the draining curve is that most often referred to.

When there is no flow of water, the soil water is in equilibrium everywhere. Thus when there is a water table present, the height above it gives the negative pore-water pressure obtaining at a given point. That is, the moisture distribution plotted as a function of the height is the moisture characteristic for the soil.

Although the pore-water pressure is negative above a water table, the soil often remains saturated above it for some height, since even the largest pores require some negative pressure to drain them. The height above the water table which is saturated is known as the <u>capillary fringe</u>.

The <u>hydraulic head</u> is the height of the water level in a piezometer tube above a given datum level when the piezometer water is in equilibrium with the soil water; it is equal to the sum of the pore-water pressure measured in terms of head of water and the height above the datum level of the point in question. Flow of water takes place whenever there is a difference of hydraulic head. Quantitatively the flow is described by <u>Darcy's Law</u> which states that the flow is proportional to the hydraulic head gradient. The constant of proportionality is known as the hydraulic conductivity which is a soil property.

Although a higher conductivity may be expected the coarser the texture of the soil, natural soils are characterized by structural cracks and fissures, so that there is not necessarily any correlation between conductivity and texture; for example, one measurement on a clay soil gave a hydraulic conductivity value of the order associated with coarse sands because of a network of worm holes.

Hydraulic head gradients also occur in the unsaturated zone above the water table, so that flow of water also occurs here. However, the resistance to flow is much greater in unsaturated soils because the flow takes place in fewer channels of much smaller size with the larger ones draining first. Darcy's law is again applicable, but in this case we have a hydraulic conductivity which varies with moisture content, becoming increasingly smaller as the moisture content decreases.

Points arising from the discussion

It is impossible to extend a table showing pore-water pressure against moisture content (and/or void ratio against moisture content) for peat soils because of the great variation in measured values; measurements from neighbouring sites in fen peat can vary by an order of magnitude.

Investigations in Germany and Poland had shown that the rate of flow was related to the variations in the nature of the wood content of peat. It is not considered possible in this country, however, to extrapolate results from one soil to another as there is great variation in hydraulic conductivity values in soils tentatively classed together by the Soil Survey of England and Wales. It is further complicated by the fact that some peats show more variability than others; for example, although it is very difficult to get consistent results from fen peat, better results can be obtained from studies of Romney Marsh peat.

On the whole alluvium, chalk and silt soils give consistent results with only small percentage errors, but because the structure changes from one site to another, it is not possible to extrapolate directly using grain size as a means of classifying the soil. The study of soils in the Dee catchment, carried out for the Water Resources Board by the Soil

Survey of England and Wales had difficulty in establishing the moisture characteristics of peat because the very long equilibriation period for peat samples in laboratory pressure plate equipment had to be curtailed. The methods of study used were more suitable for working on a small scale than for extrapolating over a wide area. Because hydraulic conductivity measurement depends so much on time, it is necessary to use the differential form of Darcy's law; this becomes evident when observations are continued for a long period (i.e. a period of the order of twelve hours). The great variation in values of the recordings should be noted. Many results reported in the literature emphasise the very large variations of conductivity in peat and further results presented at the meeting suggested that some of the values quoted may be of doubtful accuracy.

Values on Dun Moss of one peat at one site showed possible variations in K of a factor of 100; advice was sought on the kind of results needed bearing in mind that the purpose of the study was simply to get some order of magnitude of the amount of water flowing through a peat bog. It was felt that no very precise description of the experimental requirements was possible. Queries were raised about the replication and depth of tubes for determining hydraulic conductivity, with respect to both vertical and lateral variation in stratigraphy. It was agreed that this was an awkward problem for although piezometers were satisfactory for recording static water, a reasonable sample of wells was necessary to measure conductivity.

Although the large variations in K observed were doubtless ubiquitous, the drainage effects observed by the Forestry Commission were remarkably consistent for peat of the same appearance; the problem was to determine the mean value on which drainage for forestry could be based. If measurements were required over a large area, however, this could be done by a trial drainage system. Peat might be considered to be mechanically elastic rather than a material which responded simply by swelling and shrinkage. The work on the Dee catchment had shown that peat shrinkage was not effectively reversible; when water was returned to the peat, the peat did not expand to the same volume as before the water was extracted. This characteristic could also be demonstrated by putting dry peat into water, for the peat might remain hard even when covered by water.

A concept recently introduced to the English literature by the translation of V.V. Romanov's book was the possibility of much greater hydraulic conductivity values in an "active layer" in peat bogs. The "active layer" consisted of recently-formed peat and the plant roots extended in this layer, which showed higher values of hydraulic conductivity than at depths below. There was no data as yet from work at Dundee, but this was thought to be very important in actively-growing Sphagnum bogs. Bogs much influenced by grazing or drainage may not possess an active layer. Reference was also made to Professor Godwin's theory of bog growth which explains the growth of a bog until an equilibrium water surface was reached. However, it was felt that there could be no one theory to explain bog growth because regional differences were important. The cupola type described by Professor Godwin was not a common phenomena. On the Continent, no dome was found in some bogs, while others were domed only in the centre. A proposal that the classification of peat which had recently been developed in Central Europe might well be applied to peats in the United Kingdom was not accepted since this is of more botanical interest than of hydrological value.

SESSION II Dr. E.C. Childs

DRAINAGE APPLICATIONS

The basic laws described in Session I may be applied to the study of moisture profile development and of groundwater movements. These two topics will be taken in that order.

When the surface of initially dry land is suddenly flooded, a very high potential gradient is set up due to the very great increase of suction which occurs in the short distance between the wet surface and the dry lower soil. In addition there is of course a gravitational component. The initial infiltration rate is therefore high, since the saturated surface provides the maximum hydraulic conductivity here. The inrush of water produces with time a penetration of the water front, with a greater depth to dry soil and the high suctions that that implies, and therefore with a lower suction gradient and potential gradient. The rate of infiltration therefore decreases. Ultimately the development of the moisture profile must produce an appreciable depth of surface soil saturated to the maximum capacity so that here there is no suction gradient and the total potential gradient is the constant gravitational component. The infiltration rate at this stage has settled to a constant value equal to the saturated hydraulic conductivity. This is usually called the infiltration capacity.

When water is applied at a constant rate on initially dry soil, instead of at constant zero suction, again the profile developes from initial great surface steepness to a stage with a finite depth at constant moisture content. This moisture content provides a hydraulic conductivity equal to the rate of surface application. If the rate of surface application increases to equal the saturated hydraulic conductivity, the upper part of the profile becomes saturated and the situation is as in the first case described. Applications at a greater rate than this cannot be accepted and there is surface runoff.

The water which penetrates will sooner or later encounter an impermeable barrier upon which groundwater will collect. The upper surface of this, at which the pressure is zero, is the water table. Below, the pressure is positive and above the pressure is negative. The groundwater may be controlled by artificial channels (ditches, pipelines) located below the water table, so the groundwater may overflow into them.

Above the water table the suction increases with height and the moisture content decreases accordingly, thus producing the moisture profile. As described in Session I the soil remains saturated above the water table for a finite distance necessary to attain a certain finite suction, and this region of saturation above the water table is the capillary fringe. The suctions and therefore the moisture profile, including the capillary fringe, depend upon whether the profile is in static equilibrium, or whether infiltration is taking place at a greater or less rate, or whether the water table is rising or falling at a greater or less speed. But if the simplest case is assumed, of a moisture profile falling without change of shape as the water table on which it is based falls, then a fall of water table by a unit distance accompanies a water yield per unit area of land which is a constant amount known as the specific yield. The groundwater thus provides a reservoir; additionally short term changes of shapes of the water table provide a soil water reservoir.

Drainage systems conventionally consist of more or less uniform arrays or patterns of drain lines. If the distance between neighbouring parallel lines is small compared with their length, there is no variation of potential and no flow of groundwater in the direction of the length, and the flow net is two dimensional in the plane perpendicular to the length. If the length and separation are comparable, the potential distribution is three dimensional. In either case solutions of one kind or another are available to relate the ratio of precipitation to conductivity with the ratio of water table height to a parameter representing the dimensions of the drain system. Many natural drainage systems may be approximated to idealised artificial systems. The simplest treatment is of steady states, but transient states may also be treated.

The rise and fall of a water table is of primary importance in agriculture, but hydrologically the more important consequence is the effect on the delivery of water from the drains since this *determines* the character of stream flow from the area.

The rate of flow from drains is determined wholly by the water table configuration. It depends on rainfall only insofar as rainfall ultimately affects the water table. If the moisture profile can develop freely in the distance between the capillary fringe boundary and the land surface, then an increase of rainfall will raise the water table to a new level. The rate of rise amounts to a rate of storage, and the rate of efflux at the drain outfall rises gradually to the final state at which it again equals the rate of rainfall. The reservoir capacity of the groundwater acts as a moderator so that the drain-flow does not reflect instantaneously changes of rainfall rate. If the intensity of the drainage system is great (as for example by very narrow separation of drains) the water table is closely controlled and the reservoir effect is minimised. If the drains are widely separated the water table fluctuations may be great and the reservoir effect marked.

If the water table is very high so that either it or the capillary fringe boundary is practically at the surface, there can be no reservoir effect and the outflow from the area must closely reflect the incidence of rainfall.

One may see therefore that the effect of drainage on the outflow characteristics of a catchment depends on circumstances. If the initial state is one of very high water table and predominantly surface runoff, then a lowering of the water table by a drainage system of just sufficient intensity to produce a subsurface capillary fringe, may result in introduction of the moderating influence of a fluctuating water table. But if the intensity of drainage installed is such as to inhibit fluctuation of the water table, the moderating effect may be minimal and the catchment outflow characteristics not much affected.

Finally one further effect needs to be mentioned. In the case of blanket peat for example, where the groundwater is in a fairly steeply sloping hillside situation, water may drain to the downhill boundary where it may escape as groundwater from a surface of seepage or a drain. If however, that same peat is traversed by artificial drainage channels penetrating to the impermeable base, then the water in each band must drain out at the channel at its immediate boundary, so that in effect each drain is a boundary holding up the drainage of water. In such a situation the drains may in effect decrease the reservoir capacity and reduce the moderating effect due to such reservoir capacity. It must be said that the unimpeded drainage from the highest to the lowest boundary of the blanket peat deposit must be a fairly slow process, so that the paradoxically impeding effect of transverse drains is only likely to be noticeable in a fairly extended rainless period, which from the nature of the case may well not be characteristic of an area which supports blanket peat.

To summarise, the effects of drainage on the outflow characteristics of a catchment depend on a variety of circumstances such as have been outlined and can only be understood if the relevant factors have been recognised and observed.

Points arising from the discussion

It was felt that the low conductivity of the underlying clay or mud has a very great influence on the initial formation of peat and as the plants grow and turn to peat they, as the results show, have a low conductivity and tend to perpetuate the low infiltration conditions conducive to bog formation. At the same time, the peculiar properties of peat allow for a very low specific yield and a small amount of rain, say 13 mm, could raise the water level in some cases by as much as 100 mm. Rainfall is intercepted by the Sphagnum cover which, in the sense of an active layer, has a very high conductivity giving effectively instantaneous filtration and a high specific yield. As only limited storage is available, when this is filled the water level will be situated in the porous conductive upper layers producing a runoff situation approximating to rainfall on a flat impermeable area. It is quite clear that any theory of bog formation must allow for an equilibrium condition otherwise bogs would never reach stability.

The depth of the layer showing high hydraulic conductivity is about 6", *the capillary fringe being thin in the active layer but* thicker below. Flash runoff that takes place following storm rainfall pushes the water table up to this level, a situation which occurrs at certain seasons in the year. The development of the high conductivity layer was thought to be more common where the plant cover was of vascular plants, for example, Galloway in South-west Scotland, where the water table was frequently found in the "active layer". It was pointed out that many hydrogeologists considered that the state of saturation within the capillary fringe was slightly less than complete and that it reduced very rapidly towards the top. Because of this, the fringe was normally included in the soil water zone by groundwater hydrologists, and in the groundwater zone by soil scientists. It seems that the state of saturation and pore water pressure which exists in the capillary fringe cannot be defined accurately, but a capillary fringe occurred in the zone between the water table and the level at which the soil first becomes markedly unsaturated, if indeed such a level is identifiable. Thus the suction in the fringe increases upward from zero at the water table. The capillary fringe is commonly included in the region of groundwater flow because its effective saturation gives it the same conductivity as the region below the water table. When the groundwater table rises, air is trapped in the zone above, leaving the zones below saturated but still under suction. It was felt that the definition of the capillary fringe was not affected by considerations of whether the water table was rising, falling or stationary, but that the measured thickness of the fringe was affected. Boreholes drilled into the water table in low hydraulic conductivity material showed seepage. This seepage is controlled by the low hydraulic conductivity of the material in the vicinity of the well and seepage will be very slow - the attainment of equilibrium taking a very long time; the water level there approaches the equilibrium level as an exponential function of the inverse of the lapsed time. Therefore, where no hydraulic conductivity peats are being investigated, the water level observed in an auger hole may not truly represent the upper surface of the groundwater zone. This can lead to a misunderstanding of the true saturation conditions existing at a site.

As temperature is correlated with water flow, in that it determines whether or not water is in liquid form, variations of temperature in time, and also in space, should not be neglected. It might be an important factor, therefore, in studies of viscosity but probably not in studies of conductivity except where the temperature variations were larger than might be expected in peat. This was confirmed by observations that the variations in temperature measured in the saturated zone of peat were very small but in the unsaturated zone can be large enough to have an effect.

SESSION III

Dr. J.V. Sutcliffe

HYDROLOGICAL STUDIES OF PEAT SITES

Hydrological balances are difficult to obtain on peat sites because of the uncertainties of catchment boundaries. The special hydrological properties of peat as a catchment cover are its permeability and its moisture-tension relationship. Evidence is limited by the problem of measuring in situ, but examples show a very variable but generally low permeability (Boelter, 1965) and a high saturated moisture content and water availability (Baden and Eggelsmann, 1964).

Although other studies in peat areas may require some knowledge of the hydrology, the main value of a hydrological study of peat catchments is in runoff prediction, where the differences in behaviour between peat and mineral soil may be important. The main practical problem is the possible effect of changes in land use on the runoff. If the effect is to be measurable the change must be drastic; an example which has attracted some attention is drainage. Several studies have been made of this problem which approach to a greater or lesser extent the classical method of experiment, using paired catchments, where a change is made on one of two similar catchments after a period of calibration.

At Moor House, on the Pennines, runoff has been measured for four catchments with drained, eroded and natural peat cover (Conway and Millar, 1960). The catchments provide interesting comparisons in flow, the peaks being somewhat earlier and higher on the drained and eroded catchments than on the natural catchments; on the other hand flow ceased on several occasions from the former but not from the latter. However, it is difficult to draw firm conclusions from simple comparison of peak flows, because size of catchment is confounded with treatment as the larger catchments are undrained. For instance, runoff is delayed on the larger undrained catchments, but recent empirical relationships between lag, area and slope,show lag to be proportional to the same power of slope (Nash, 1960). Thus one would expect the lag from a doubled area to increase by about a quarter. This example is quoted to urge caution in attributing the whole of the difference in behaviour to land use differences and to suggest further analysis.

An interesting study of the hydrological budget of a raised bog area of north-western Germany has been published (Baden and Eggelsmann, 1964). In a comparatively low and dry area at Koenigsmoor a comparison was made between a heather-covered raised bog area and an adjacent area of 'German raised bog culture', drained since 1912 by tile drains and used as grassland. It was found that the runoff from the uncultivated area was much more variable than the runoff from the grassland; for instance peak flows in the former were frequently two to four times greater than in the latter. This is attributed to the predominance of surface runoff in the uncultivated area, which is saturated for almost all the year, while runoff from the grassland is delayed because of the storage above the water table in the drained area. This is illustrated by the average depths of water level over eight years, which are 13 cm below soil level in the uncultivated area and 70 cm below soil level in the grassland.

When comparing the results of these two investigations, the difference between the surface drainage at Moor House and the tile drainage at Koenigsmoor should be remembered as well as the contrast between the high rainfall at the former site and the low rainfall at the latter.

Other investigations relating to the hydrology of peat drainage were being carried out by the Hill Farming Research Organization and the Macaulay Institute on a raised peat bog in Lanarkshire, where a seventeen acre site was drained after calibration (Hill Farming Research Organization, 1964),and by the Agricultural Institute on blanket peat in

Ireland, where drained and undrained one acre plots are being observed (Anon, 1965).

In a recent study of four forested bog catchments in northern Minnesota, runoff was measured over five years (Bay 1969). The experimental basins ranged in size from 24 to 130 acres and included both organic and mineral soils. Annual runoff was not evenly distributed; spring runoff, from the beginning of flow in late March to the 1st of June, accounted for 66% of total annual water yield. Summer and fall runoff was normally very low and ceased on most of the bogs during each summer. Annual peak rates of discharge were low and recessions were long, indicating the bogs were effective as storage areas for short-term runoff. However, they were not effective as long-term storage areas or regulators of streamflow. Current work on experimental basins and flood frequency relationships may provide further evidence in a few years.

Points arising from the discussion

Queries were raised concerning the measurement of overall slope in the equation described by Dr. Sutcliffe, particularly, how the mean values were influenced by local changes such as ridge and furrow structures and surface roughness effect. It was felt however, that these local effects were not great enough to invalidate the equations. There were also queries relating to the peculiar shape of the hydrograph drawn up by Bay showing fast peak and slow recession curves. Because the research had been carried out on small confined basin bogs in a territory not otherwise covered by peat, it was difficult to extrapolate these results to Britain where blanket bog was so common. It was difficult also to separate out the effects of topography from those of peat. Work carried out for seven years on Blacklaw Moss was described; although unfortunately this experiment has been closed down as itwas not felt to be appropriate for support by the Agricultural

Research Council, the Macaulay Institute are analysing data for future publication.

One of the characteristics of peat which is often not appreciated is its high erodibility. In parts of the Towy forest in Mid Wales erosion rates from different catchments with particular types of land use are to be measured, with emphasis on peat catchments. The rates of erosion of the peat catchments are particularly high and have lead to experiments on erosion control. The erosion of main drains could be very serious and other smaller drains were so eroded that it will be difficult for these to develop as part of the natural established forest surface cover.

The results from the Brenig catchment were then described. This catchment covers an area of 20.2 km^2 at an elevation of 330 m to 520 m, mean slope 2.5^o and aspect southerly. The average annual rainfall was 1300 mm and the average runoff was 890 mm. Forty years of records were available for this peat covered catchment but during the period 1960 - 1965 the Forestry Commission had ploughed and drained 40% of the area. Over 90% of the soil has a peat cover 20 - 50 cms deep. Unfortunately records from before 1963 had been destroyed but from the five years 1963 - 1968 the average increase of stream flow was 82 mm or 10% more than that predicted from the calibration period 1949 - 1963. The flow duration curves constructed from daily flows showed an increase in flows of $2.5m^3$/sec above those for the 1963 - 1968 period. The soil moisture measurements of the whole soil profile, which included the clays and shales underlying the peat, showed a drier condition in the drained than in the undrained portion of the catchment. The form of the drains was the all important factor in these results.

The Devon River Authority showed that peat catchments on Dartmoor maintain higher flows than non-peat catchments and they also had higher peak flows because of low infiltration.

It seems clear that the work of Bay and Boelter indicates that more knowledge is needed of the physical properties of peat. Accuracy may not be important for some purposes but it is essential for groundwater flow determinations; a variation of ten in a value of K makes nonsense of the quoted flow seepage values.

Papers on peat studies often did not make it clear whether the conditions described were ones of water deficiency or water surplus and this led to ambiguous results. Some papers did not even state whether or not the peat was drained; in addition there was frequently no indication of the size of the drains being described.

It was agreed that it was important to describe everything known about a peat bog although it might not be thought to be relevant to the immediate objectives of the study; the most important physical features to be described should be the moisture characteristics, hydraulic conductivity and capillary fringe. If these and the physical boundaries were known then the flow could be estimated. (It appeared that only the Peat Experimental Group of the Soil Survey located in Derby, which had been working in the Dee catchment,was doing work on the capillary fringe in natural peat).

The purpose of peat studies was questioned because when peat was drained it disappeared. In the Pennines large stretches of peat had already gone; this is a problem area because subsidies are given for drains in the peat and yet this led to rapid erosion. In the short term, a drained upland or lowland peat may be a better "sponge" than an intact mire surface. All long term planning of peat covered catchments must take into account whether it is better to have bare bed rock or an undrained mire. It may be that many drained mires have already past through their "short" useful agricultural life to become wet rush-infested scrub pasture maintained only by expensive pumped drainage. In Holland, for example, peat was preserved by grassland and no more drainage was done than was absolutely necessary. In the land fringing the Baltic there was drainage in the farm areas but others had to be abandoned to scrub. There was a need for long term economic studies of lowland peat to formulate some useful criteria for management of these lands. Care is needed in extrapolating the results from continental conditions however because the climate is very different from that in Britain. Comments were then made on water budgets in basin and valley sites, on measurements of gradients of hydraulic head, and on measurements of flow using modified Poppendick thermal electric anemometers. Some interest was shown in the effect of flow on vegetation; for low flows very sensitive instrumentation was needed. There was a need to calibrate these instruments on many different peat and non-peat areas. It was felt that measurements of hydraulic conductivity and moisture characteristics were sufficient for interpretation in the near future because from these specific yield could be calculated. Although it was suggested that some index of the extent of fissuring would be needed it was thought that this would not be measurable.

It was important to have a close relationship between ecologists and hydrologists in the study of peat, because of the link between vegetation and water table fluctuations. Such combined studies would be of great value in predicting the effect of land use changes in these sensitive areas.

Reference had been made to the wide variation in the measured values of hydraulic conductivity and the question raised as to the accuracy required. This problem had arisen at Birmingham in electrical analogue investigations of groundwater flow in aquifers of variable conductivity. As a result a two-year investigation, supported by NERC, was in progress on the effect of introducing changes in conductivity over areas of an aquifer.

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