THETFORD PROJECT

The Thetford project was initiated in 1967 to study the evaporation from forest in all its aspects. Several sections of the Institute are involved in this project, as well as a team from the Botany Department, Imperial College, University of London, which is investigating the biological factors affecting evaporation.

Thetford Chase, an extensive and flat area of forest (about 70 km^2) on the Norfolk-Suffolk border, was chosen for evaporation experiments because of its uniformity. The trees, mostly Corsican and Scots Pine, which were planted between 1928 and 1932, have now reached an average height of 15 m. In the $\frac{1}{4}$ km^2 experimental area there are now two 30 m high towers used for meteorological measurements, and one 15 m tower which is used for biological sampling. A network of access tubes for soil moisture estimation has been installed beneath the trees and a random network of litter sampling collectors set up. Also a 5·5 m deep pit has been dug for infiltration experiments with radioactive tracers.

This year the work has been divided between collecting and analysing preliminary data and planning and preparing equipment for the 1970 experimental season. Although instrumentation of the site was by no means complete, a considerable amount of useful information and experience was gained from the summer's experiments. The data acquisition system based on a Hewlett Packard 2116B computer did not arrive until early spring and could not be programmed in time for the 1969 season at Thetford. However, it was in constant use at Wallingford for the calibration of instruments and for the analysis of data.

Work during the summer was concentrated on the forest evaporation studies at Thetford. In July and August, when fortunately there were many fine days, measurements of temperature and humidity at five or six heights above the forest were obtained from instruments on one of the 30 m towers. Aspirated wet and dry bulb thermometers made from quartz crystal sensors were used at heights between 1·5 and 15 m above the trees. The wet and dry bulb temperature recordings were punched directly on paper tape which was sent back to Wallingford for immediate analysis by computer. The preliminary results of the experiment were thus obtained within a few days of data collection. Modifications to the thermometer positions were made on the basis of these results, and a fault in the humidity measurements, due to air entry into the porous ceramic tubes which enclosed the wet bulbs, was revealed. An improved design for the wet bulb thermometers is being developed for future use. Incoming solar radiation and windspeed at the top of the tower were also recorded during the experiment for use in the final analysis of the

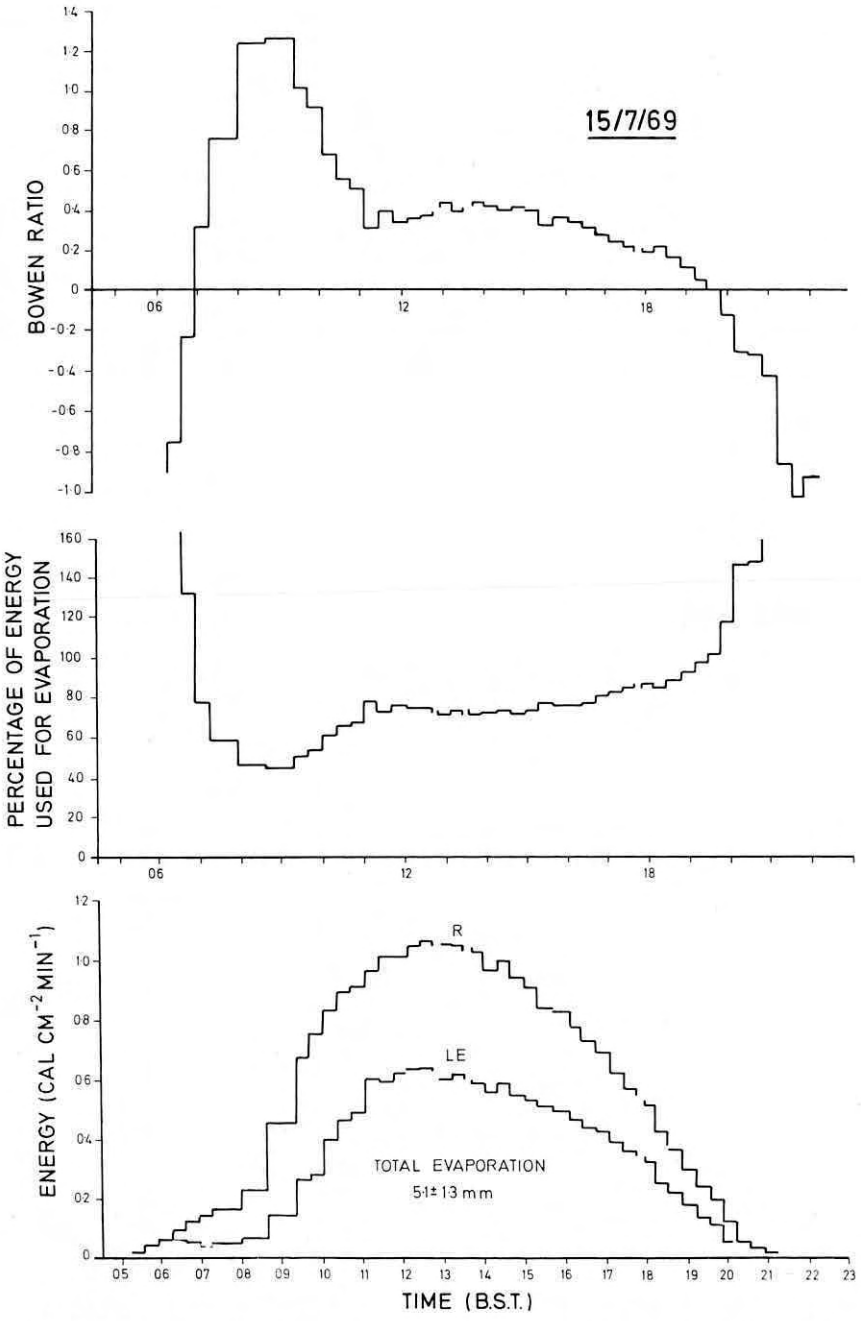


Figure 5 **Bowen ratio, percentage of energy used for evaporation, solar radiation (R) and latent heat flux (LE) for a sunny day**

data. By the middle of August 23 days of data had been collected, including several days when observations were recorded continuously from sunrise to sunset.

Two days were selected for detailed analysis and results from one of these days, 15th July, are shown in Fig. 5. This was a clear sunny day after the disappearance of early morning fog so that the trees were initially wet with dew. The most interesting feature of these results is the variation during the day of the percentage of available energy being used for evaporation. This is best illustrated by the variation in the Bowen ratio (the ratio of the fluxes of energy used for heating the air and for evaporation). The sharp peak in the Bowen ratio in the morning after most of the leaves had dried out is of particular significance. Consideration of the theory of evaporation from forest shows that the stomatal resistance of the leaves significantly reduces the evaporation rate when the trees are dry, unless there is a large vapour pressure deficit over the forest. A paper outlining the theory of evaporation from forests and presenting the results of the 1969 season was given at the Symposium on Aspects of Forest Climate at the University College of Wales, Aberystywth in March 1970 (Stewart and Oliver, in press).

In order to make measurements of the vertical temperature gradients above the forest, of which a typical value is 0·6°C between 2·5 and 15 m above the canopy, a very accurate intercalibration of the quartz thermometers was required. To obtain an environment with a stable temperature for such an intercalibration, a hole 4 cm in diameter was bored at Wallingford to below the 3 m deep water table. At this level and season the soil temperature increased steadily but by only 0·01°C per day. By immersing several thermometers close together in water at the bottom of the hole, intercalibrations were made to better than 0·005°C.

To improve the mounting of equipment on the instrument towers at Thetford, new booms for the anemometers, thermometers and radiation instruments were designed, manufactured and tested at the Institute. The design criteria included strength, corrosion resistance and ease of handling, and the resultant apparatus combined fabrication techniques using plastics and aluminium alloy materials. The data acquisition system was installed in a new caravan which will be used as a mobile computer laboratory (Fig. 6). Facilities on the site at Thetford too have been improved, and include housing for the 10 Kw portable generator as well as provision of fuel and water supplies.

For the 1970 experimental season many more instruments will be available, such as photoelectric anemometers in which the speed of rotation of the eight cup polystyrene rotors is measured by means of a

photo cell, light source and disc. The anemometer system, calibrated in a wind tunnel, incorporates circuits and interfaces developed at the Institute to feed the anemometer signals into the Hewlett Packard 2116B computer. A calibration unit, which will enable five anemometers to be calibrated against a standard in the field, is in the final stages of development; it will incorporate a magnetic tape data recording device using miniature tape and five interface units, each with its own counter and having a storage capacity of 2^{12} counts.

The data acquisition system is currently being programmed to control all the instruments and analyse the data as soon as measurements are taken; it will also carry out frequent tests for instrument failures. In this way an analysis of the meteorological and biological data can be automatically produced within an hour or so of measurements being made.

On the biological side, the recording apparatus to be used with the data acquisition system was developed for field use in the coming season. It is planned that rainfall, throughfall, stemflow, and leaf and air temperature measurements will allow an analysis of the role of individual

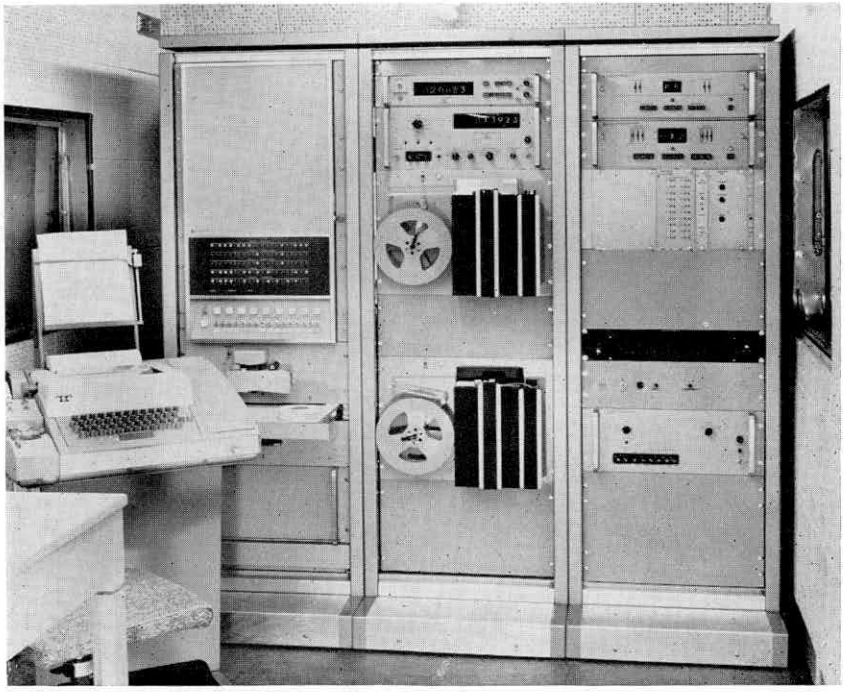


Figure 6 **Data acquisition system in the mobile computer laboratory**

resistances, both plant and environmental, to be made in the evaporation process. Equipment for measuring stomatal resistance and for studying water within the leaves has been prepared and will be used to provide information on the responses of individual leaves, with a view to a better understanding of the response of the canopy as a whole. The basic requirement of such an analysis is a knowledge of the quantity and distribution of foliage in the canopy; last summer such information was obtained by felling 12 sample trees and removing, drying and weighing the foliage. Further sampling procedures provided information on the height distribution of foliage, weight, area and age. It is planned to supplement this information during the coming season by a non-destructive method of sampling the horizontal distribution of the foliage.

The programme of work on roots for this project is concerned with examining the distribution, seasonal pattern of development and the physiological characteristics of roots as they affect water uptake and water potential in the plant. Root growth and activity in relation to environmental factors in the soil are also to be examined as part of this programme. Work has been confined so far to the construction of equipment; for example a powered soil coring system which will be used to obtain soil and root samples has recently been completed.

In addition to these projects, subsurface investigations into the temporal and spatial distribution of soil moisture in relation to the trees are being pursued. This work complements the study on uptake of water by roots; it should give considerable information on the abstraction characteristics of the trees and comprises part of the investigations into soil moisture distribution being undertaken with neutron moisture measurements in grid networks of closely spaced access tubes. Data processing has been delayed pending completion of a new computer programme, but on first appraisal it has become clear that last year's pilot project (consisting of a 24 access tube network on a three-foot grid) was too small to reveal any pattern of moisture distribution relatable to the trees. Consequently this network is now being replaced by a larger one in a nearby part of the forest. As before, measures are being taken to avoid any disturbance of the bracken or the litter layer. The soil moisture data from the woodland grid networks are processed by computer.

SUBSURFACE HYDROLOGY

The movement of water from the surface through the subsurface environment of soil and rock and the eventual discharge back to the surface is a fundamental part of the hydrological cycle. The complexity of these physical processes, which on the one hand exert control over runoff and flooding and on the other sustain dry weather flows, are such that the needs for basic research remain. The subsurface section is concerned with the study of movement and storage of water in these zones. At present much of the work has been devoted to general aspects of the catchment research, such as at Plynlimon, Grendon Underwood and the Cam, while at the same time field and instrument techniques have been developed to enable detailed subsurface studies to be undertaken. The physical and chemical examination of the flow and storage processes depend upon carefully designed experimentation and the use of reliable, sophisticated instruments and techniques.

Soil Moisture Distribution and Storage Studies

The comprehensive field and laboratory testing of the Wallingford Moisture Probe, started in 1967, has been successfully concluded. The probe and ancillary equipment is now commercially available, although work continues in conjunction with the instrument section in refinements and on new accessories, such as the ratescaler. This neutron probe has been specially designed to combine the long-term stability and reliability necessary for subsurface hydrological investigation, with lightness and portability; this is important as the equipment has to be carried long distances on foot in rugged terrain such as Plynlimon. The Institute now uses these probes exclusively in its work in Britain for studying soil moisture storage changes, distribution and abstraction patterns.

It is accepted practice to calibrate neutron probes in terms of moisture volume fraction against count rate ratio, R/R_s where R is the soil count rate and R_s is the count rate in a standard. This is done to guard against possible changes in count rate due to ageing or replacement of components, and to make all the probes interchangeable, employing the same calibration curves. Prior to 1970 the probes' individual shields were used as standards for this purpose, on the assumption that these were for all practical purposes identical. However, when the increased number of probes came into use during 1969-70 this assumption was invalidated; minor variations in the shields are inevitable and consequent variations in R_s give rise to biased moisture measurements. Current practice has therefore been changed and a water tank in the laboratory is now used for the standard counts for all equipment; this is calibrated in terms of

R/R_w, where R_w is the count rate in the standard water tank. Providing that the detector/source systems are very similar, and that 'dead' time corrections are made (if relevant), then different probes may be interchanged in the field without the introduction of bias.

Calibration work continued in order to check, extend and refine the existing curves for all the experimental areas, including the East African catchments (Fig. 4).

Studies of soil moisture distribution under woodland were started on the Ray catchment (mixed natural wood) and in Thetford Chase (Scots and Corsican Pine plantation). The main object of this work is to investigate abstraction patterns of trees and to estimate the consequent areal and depth variability of soil moisture, in order to rationalise the design of neutron moisture gauge access tube networks in woodland. Another study of soil moisture distribution is currently being undertaken in the Plynlimon catchments which offer a marked contrast to the dry, flat, sandy soil and low rainfall conditions of Thetford.

Unsaturated Flow Studies

Field trials of a system designed to examine infiltration processes have taken place using surface injections of Cr^{51} EDTA and I^{131} as tracers. Scintillation detectors placed at several depths below the surface, together with a neutron soil moisture probe and several quartz thermometer probes, were then used to monitor water movement. Downward movement to a depth of 1·4 m was observed by the scintillation detectors, while additional movement at greater depths was indicated by the temperature and soil moisture probes.

The study has shown that a more sophisticated experimental system is required if unsaturated flow processes are to be examined and in particular continuous recording equipment capable of long term operation is essential.

Saturated Flow Studies

Groundwater investigations based upon geological studies lose much of their significance when applied to areas lacking major aquifers. Alternative methods of prospecting and study have therefore been considered for application in the Institute's catchments. Results obtained from Reading University work in Plynlimon have shown that there is a rapid subsurface flow response to rainfall in certain soil horizons. The hydrographs of these flows are of fairly typical form and in winter their duration correlates well with stream hydrographs; however this is not apparent under summer conditions. Undoubtedly a considerable contribution to the hydrograph peaks is made by direct

surface runoff (Fig. 7). Additional mapping work to show the distribution of drainage channels, superficial deposits and the solid geology has been carried out by the Institute as the first stage in the expansion of this work from a single section of a hill slope to selected sub-catchments.

A network of 30 boreholes has been constructed at Wallingford in the

Figure 7 **Close-up photograph of surface runoff in the Wye catchment following a winter rainstorm; the water is seen running over an eighteen inch slip face**

alluvial tract of the River Thames. This network is being used both as a test bed for equipment and techniques and as an area of intensive examination of the relationships between groundwater, bank storage and river stage. Water level data have been collected over a period of nine months and sufficient qualitative information is now available to enable the second, quantitative stage, of the programme to proceed.

Additional investigations into the relationships between surface water and shallow groundwater were conducted as a series of instrument evaluation trials throughout the summer and autumn. During the testing of dissolved oxygen and temperature sensors as potential groundwater flow indicators, Hampshire River Authority and Thames Conservancy provided field facilities in areas of suspected recharge from river to aquifer. Dissolved oxygen as a tracer proved to be disappointing but useful data regarding the interrelationships between air, river, ground and groundwater temperatures were obtained using quartz thermometer equipment.

Tritium Studies

Investigations have been continued during the year into the distribution and significance of bomb-produced tritium in hydrological studies. Water samples have been obtained for analysis by the Atomic Energy Authority's Wantage Research Laboratory from a series of varying situations. A sudden summer flood at Plynlimon is being examined and tritium levels are being compared against levels at normal low flows in the area. Springs along the foot of the Berkshire Downs have also been sampled to provide additional tritium data for water of known groundwater origin.

A paper written in collaboration with the Wantage Research Laboratory and the Water Resources Board, concerning water movement in the unsaturated zone using tritium as a tracer, was presented at the IAEA March Symposium in Vienna (Smith, Wearn, Richards and Rowe, 1970). This examines the significance of tritium profile work as an aid to unsaturated flow studies and the results are sufficiently encouraging to promote a more intensive research programme during 1970.

INSTRUMENTATION AND COMPUTING

As in preceding years an important part of the Institute's instrument development programme has been concerned with data logging systems for automatic weather stations, while at the same time specialised equipment for studies of groundwater, soil physics and micrometeorology has been developed. The evaluation of equipment has been helped by the installation of a sophisticated climate chamber in which wide ranges of temperature and humidity can be produced. The computing facilities at the Institute have been augmented by a line-printer (printing at 400 lines per minute) which allows rapid listing of the output from programmes as well as coping with a substantial increase in the work in micrometeorology.

Data Logging and Automatic Weather Stations

The d-mac data logging system proved, in the experience of the Institute, to be insufficiently reliable for installation in large numbers and for operation by non-engineering personnel in remote areas and severe environments. Much of its unreliability is mechanical, and d-mac Ltd are now developing a completely new tape transport mechanism to replace the existing one. The d-mac system has therefore not been used at the Institute in this year's weather station work.

The year has seen the continued development of the Microdata logging system (Fig. 8). A fairly high standard of field reliability has now been achieved in all five pre-production loggers, although its long term reliability is as yet unknown. Computer programmes have been written for the PDP8 computer to make preliminary calculations on data from the Microdata automatic weather stations, and work is proceeding on software to read data directly from the Microdata magnetic tape reader into the PDP8.

Epsylon Ltd have shown much interest and activity this year in adapting their EDL 12 data logging system to hydrological applications and the Institute has cooperated with them in the development of a system based on the Institute's weather station. One such system has been in operation at Wallingford since mid-1969. During this period, logger and tape reader development has continued and computer software has been written. The processing of tapes is carried out on the Institute's PDP8 computer coupled to the Epsylon reader.

Wallingford Probe

The first production batch of ten Wallingford Probes was manufactured and sold by D. A. Pitman Ltd, at the beginning of the year. The Institute purchased three of the first batch (one being sent to Kenya) and two of

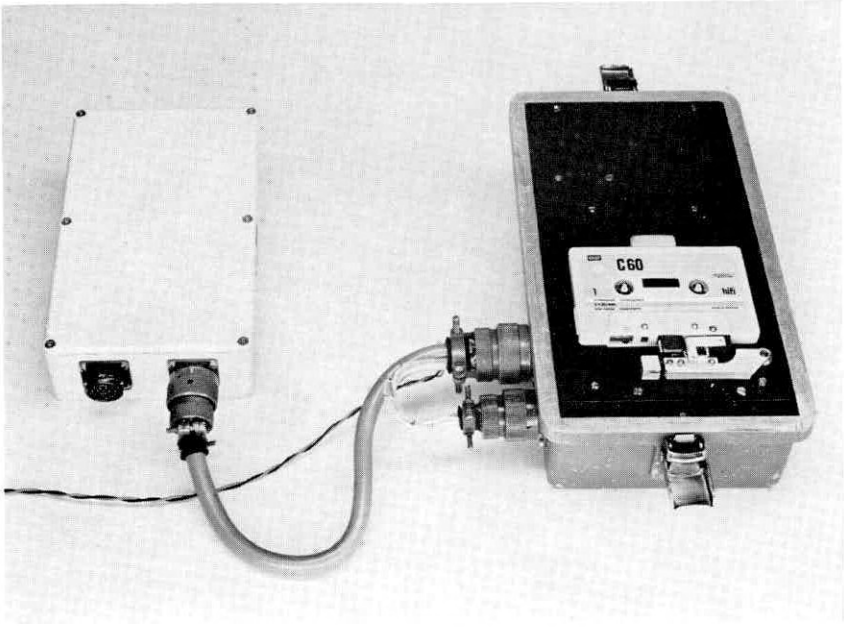


Figure 8 **Microdata logger with sensor interface unit**

the second production batch early in 1970. Considerable effort has been devoted to testing these probes and ratemeters to ensure that their performance reached the very high standards of the prototype (Bell, 1969). These tests revealed a number of minor faults and a few major ones, but close liaison with the manufacturer made it possible to incorporate many improvements in the second production batch. It is vital that instruments to be used in long-term field studies should be reliable, electronically stable and uninfluenced by a wide range of temperature variation.

The first two batches of Wallingford Probes have been sold with ratemeters. Ratemeters are inherently less stable and have a lower reading precision than scalers, and the Institute is developing a ratescaler as an accessory to the Wallingford Probe. The performance of the first laboratory prototype ratescaler indicated that a more accurate and stable time base was required; a second prototype was built using an improved time base and the control logic was extended so as to require only a minimum of front panel controls. The use of low-power consumption logic elements greatly reduces the power requirements, enabling a larger number of field measurements to be made with the same battery capacity. The ratescaler counts the pulses from the probe

Figure 9 **Wallingford Neutron Soil Moisture Probe with the prototype ratemeter mounted in the hinged lid**

for a preset 16 or 64 second period and then displays the count rate digitally in counts per second. Evaluation of the prototype ratescaler is in progress and during 1970 a production instrument, combined with probe and carrier, should be commercially available.

A prototype version of the ratemeter mounted in the lid of the probe housing is shown in Fig. 9 and the ratescaler is to be mounted similarly. The advantages of this arrangement are:

(i) the whole system constitutes one portable package weighing about 12 Kg., with batteries,

(ii) the meter does not need to be placed on the ground and is therefore less likely to be damaged by dirt and moisture,

(iii) the operator can use it standing up.

Groundwater Velocity Probe

Isotope techniques in saturated flow studies have been concerned mainly with the design and testing of a prototype point dilution system for the measurement of low groundwater velocities. This consists of an underwater probe and a surface ratemeter, both of which have been designed and constructed at the Institute. The probe comprises a scintillation counter and an isotope chamber operated by a mechanical release. It is suitable for use to depths of 10 m in a standard 3 in Johnson Well Screen which can be emplaced using the Institute's drilling equipment. The ratemeter is portable and battery operated, it has been designed to accept up to 10^4 counts per second, and it incorporates a facility for driving a chart recorder. Several trial runs in a small laboratory model have been made using Na^{24} and a larger outdoor tank has been constructed for calibration purposes.

Neutron Moisture Gauge Computer Programme

Although the data from neutron work has been processed by computer since 1965, it has become evident that the increase in types and combinations of different scalers, ratemeters and probes could give rise to considerable errors in the estimates of catchment storage changes. Because equipment faults occur from time to time, it is impossible to ensure that a given access tube is always read using the same combination of probe and meter, and minor differences in the geometries of the probes, source strengths, E.H.T. settings, and ratemeter 'dead' times give rise to biases which cannot be ignored. It has therefore become necessary to write a much more sophisticated programme to cope with these and other factors. Briefly the objectives of the new programme are to:

(i) minimise the effects of instrumental differences by expressing count rate as a ratio to the count rate in a common standard,

(ii) eliminate copying errors by using new field data cards from which data can be punched without transcription,

(iii) impose stringent rules to ensure that only 'quality controlled' data will be written onto magnetic tape for processing,

(iv) write processed data onto magnetic tape,

(v) print out results in one of three different forms, depending upon whether a scaler, a ratemeter or a ratescaler was used,

(vi) draw graphs of moisture profiles and of seasonal variations in moisture at selected depths for each site.

A computer programme in Hartran has been developed in collaboration with staff at the Atlas Computer Laboratory, Harwell, to fit the best possible surface to the soil moisture values for the grid network beneath the forest at Thetford and at Plynlimon, and to produce a plot of moisture isopleths. This programme is adapted from an IBM programme developed by U.S. Geological Survey.

Quality Control and Data Processing

The Atlas computer has also been used for other purposes. A special purpose editing programme has been written for the correction and updating of records held on magnetic tape, and a general revision of both the 'quality control' programmes (to test for the internal consistency of a large data file) and processing programmes for rainfall, streamflow and evaporation data is underway. This follows their successful application to the data from Grendon Underwood, Coal Burn and the East African catchments (Mandeville, Plinston and Hill, 1969). General programmes are being prepared to enable data from any reasonable instrument network to be processed to give estimates of flow, rainfall and evaporation.

REFERENCES TO 1969 PAPERS OF THE STAFF

(including those awaiting publication and others to which reference has been made in the text)

Bell, J. P. 1969. A new design principle for neutron soil moisture gauges: the 'Wallingford' Neutron Probe. *Soil Sci., 108,* 160-164.

The 'Wallingford' Neutron Probe is a new, lightweight, rugged and electronically stable soil moisture probe developed jointly by the Institute of Hydrology and Atomic Weapons Research Establishment. The principal design feature of this instrument, which is now commercially available, is the inherent versatility and reliability which has been achieved by miniaturising the circuitry and housing it inside the probe.

Bell, J. P. and McCulloch, J. S. G. (In press). The use of neutron moisture gauges in catchment hydrology. *Proc. RILEM Symp., Brno, Czechoslovakia, Oct. 1969.*

The paper discusses the problems of access tube network design for catchment hydrology. Topics discussed include random versus systematic networks, and the compromise between available time for measurement, precision of individual measurements and the optimum areal site density.

Eeles, C. W. O. 1969. Installation of access tubes and calibration of neutron moisture meters. *Inst Hydrol., Wallingford, Rep. 7.*

The neutron back-scattering method has very great advantages in the determination of soil moisture content. The results obtained, however, can be easily rendered invalid by faulty calibration methods and incorrect installation of access tubes. This report describes the routine methods developed at the Institute in an attempt to overcome these problems.

Hosegood, P. H. and Bridle, M. K. 1969. A feasibility study and development programme for continuous dilution gauging. *Inst. Hydrol., Wallingford, Rep. 6.*

Dilution gauging is becoming a standard technique for measuring stream flow. The application and feasibility of continuous dilution gauging is examined in relation to the Institute's own work and in general as an alternative to flow measurement structures.

Key, M. T. H. 1965. A weekly recording anemometer. *Met. Mag., Lond., 94,* 113-114.

A 24-volt battery operated electro-mechanical system for scanning and displaying the run of wind from a conventional cup contact anemometer, is described.

McCulloch, J. S. G. 1969. The estimation of factors controlling streamflow in areas with limited data. *Cento Seminar on evalution of water resources from scarce data. Central Treaty Organisation, Tehran, Iran,* 171-180.

The paper considers estimation potential evaporation and transpiration from minimal data of rainfall, air temperature and humidity, and indicates the effect of altitude on these hydrological variables. The value of catchment area research to relate actual transpiration to potential evaporation, together with the role of soil moisture measurements, are stressed.

Mandeville, A. N., O'Connell, P. E., Sutcliffe, J. V. and Nash, J. E. 1970. River flow forecasting through conceptual models: Part III – the Ray catchment at Grendon Underwood. *J. Hydrol., 10.*

Methods of modelling the runoff process on the Ray catchment are described. These depend on soil moisture accounting and simple descriptions of the generation of

runoff and of routing. It is found possible with simple models, to account for about 90 per cent of the initial variance of runoff volumes and about 75 per cent of the initial variance of the discharge rate.

Mandeville, A. N., Plinston, D. T. and Hill, A. 1969. Processing errors in the analysis of catchment data. *Inst. Hydrol., Wallingford, Rep. 5.*

A revised system of processing catchment data recently introduced at the Institute of Hydrology is described. The features of particular interest are the form of the raw and final data, and the use of a quality control programme. The results of applying the system to a record of previously hand-checked data are tabulated. Possible sources of processing errors are examined and the success of the new system in minimizing them is discussed.

Nash, J. E. and Sutcliffe, J. V. 1970. River flow forecasting through conceptual models: Part I – a discussion of principles. *J. Hydrol., 10.*

The principles governing the application of the conceptual model technique to river flow forecasting are discussed. The necessity for a systematic approach to the development and testing of the model is explained and some preliminary ideas suggested.

O'Connell, P. E., Nash, J. E. and Farrell, J. P. 1970. River flow forecasting through conceptual models: Part II – the Brosna catchment at Ferbane. *J. Hydrol., 10.*

An attempt to model the runoff process on the Brosna catchment is described. Different models are compared and it is found possible to account for about 80 per cent of the initial variance of the discharge by very simple models.

Rodda, J. C. 1970. The precipitation component of the water balance – its problems and prospects. *Wld met. Orgn Bull., 19,* 102-105.

The World Meteorological Organisation is undertaking several projects that are important to the assessment of precipitation. This paper describes these projects such as the international comparison of raingauges based on the use of pit gauges and snow surveying by artificial satellite.

Rodda, J. C. 1970. A trend surface trial for the planation surfaces of North Cardiganshire. *Trans. Inst. Brit. Geogr., 50.*

An objective study is made by using the technique of trend surface analysis of the landscape of the Aberystwyth hinterland. The results show that of the earlier studies, Brown's division of the area into three was the most rational.

Rodda, J. C., Langbein, W. B., Kovzel, A. G., Dawdy, D. R. and Szesztay, K. 1969. Hydrological network design – needs, problems and approaches. *WMO/IHD Project Rep. 12, Wld met. Orgn, Geneva.* 57pp.

This report considers methods of network design, such as those based on regionalization, mapping and systems analysis. The networks developed in certain countries are examined and the prospects for future networks are discussed in the light of advances in instrumentation.

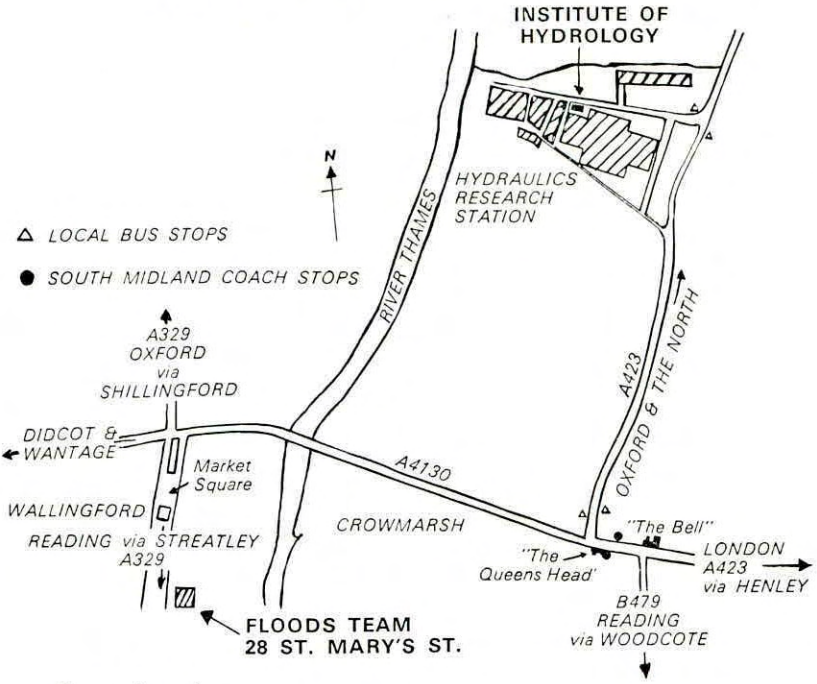
Smith, D. B., Wearn, P. L., Richards, H. J. and Rowe, P. C. (In press).

Water movement in the unsaturated zone of high and low permeability strata using natural tritium. *Symp. on Use of Isotopes in Hydrol., IAEA, Vienna, 1970.*

Stewart, J. B. and Oliver, S.A. (In press). Evaporation from forests. *Aspects of Forest Climate, Aberystwyth. Symp. agric. Meteorol., 13, 1970.*

The theory, the micrometeorological measurements and some initial experimental results into evaporation from the forest at Thetford are described.

ROUTES TO HOWBERY PARK



From London

1. *By road*

Leave by Cromwell Road, M4 and A423 through Henley towards Oxford to Crowmarsh Gifford. Entrance to Howbery Park on A423.

2. *By coach*

South Midland Henley-Oxford coaches leave approximately every two hours. Journey time two hours.

3. *By rail*

From Paddington to Cholsey and Moulsford station. Thence by Oxford-bound bus direct to Howbery Park. Journey time 75 minutes by rail and 30 minutes by bus.

Printed by George Over Ltd., Rugby and London.