MOOR HOUSE

24th ANNUAL REPORT, 1983.

THE NATURE CONSERVANCY COUNCIL

MOOR HOUSE

1983

24th ANNUAL PROGRESS REPORT

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C O N T E N T S

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APPENDICES

I GENERAL

a) Introduction (I.R. Bonner)

This 24th Report covers the period from 1 October 1982 to 30 September 1983, the first full year after closure of the Field Station.

Paul Burnham continues to warden Moor House and other National Nature Reserves in north Cumbria and can be contacted for information about the Reserve, proposals for research and survey etc. at Red Croft, Knock, Appleby, Cumbria (tel. Kirkby Thore (0930) 61520). Paul has contributed a fuller report about his work in 1983 at Moor House and it makes interesting reading.

Although strictly outside the report period, I would like to record how pleased we were that Phil Holms was promoted to warden and appointed to The Swale N.N.R., even though this means the loss of his services in North West England.

Judith Scott has continued to be involved in field work on the Reserve, in processing meteorological records, in preparing this Report and in dealing with countless other Moor House matters, in addition to other duties at the Regional Office.

Our continued thanks to Dr. Bill Heal at Merlewood for continuing advice and assistance and to all those engaged in work on the Reserve and who have contributed to this Report.

b) Warden's Report 1983 (P. Burnham)

This report covers the first working year since the official closure of the Field Station, with all Reserve administration run from the western side. Whilst a few teething problems occurred at first with so many people used to arriving at the Field Station "on spec" in the past, most problems of access seem to have been ironed out and are working smoothly now.

Access to the Reserve

There has been no noticeable increase in public pressure over the Reserve although motor cycle scrambling seems to be becoming more popular locally and could lead to problems in the future. Numbers of walkers staying at Dufton Youth Hostel indicate that between 800 - 1000 Pennine Way walkers crossed the summits of the Reserve this year.

Conditions were not suitable for skiing this winter until 11 December when the east drift became full and locals erected a ski tow there. Snow falls in February and again in late March/April also provided ideal conditions for skiers. Numbers of skiers were never high, however, although some groups, such as Howtown Activity Centre, regularly used the slopes.

Research workers have continued to use the Reserve and a brief account of their work occurs elsewhere within this Report.

Work continues in the extraction of barytes from the Silverband Mine, although the vein continues to get deeper and must make extraction less profitable. Regular checks are made on the working operations but no serious incident of overflow from the plant has occurred this year.

We continue to liaise closely with the National Air Traffic Services (N.A.T.S.) at the radio station on Great Dun Fell and they have made public recently their intention to replace the radio towers and erect a dome-type housing to incorporate the radar and radio equipment.

Field Station and Buildings

With the closure of the Field Station and the reduced number of staff, several buildings have run into disrepair or are no longer required. To avoid unnecessary maintenance costs and to make the area safer, the main garage block, dog kennels, met. room, laboratory and wind towers have been demolished. All remaining buildings will be used for storage, workshop etc. and the annex has been retained as a base shelter for visiting research workers. A telephone is installed in the warden's field office (the old generator block) and it is planned to install an emergency telephone in the adjoining old generator shed, which will become a shelter for the public if required. A workshop/store has been erected on the western side of the Reserve within the N.A.T.S. ground at Knock.

Management and Estate Work.

General maintenance work was carried out on all experimental exclosure fence-lines before the sheep returned in the spring. The complete replacement of Hard Hill exclosure fence-line marked the completion of a work programme started by the previous warden, Jim Parkin (1975) to replace all experimental exclosures. All the work has been carried out by wardens and Phil Holms, the estate worker at the time, with many a heavy load borne on shoulders to fence-lines over the fell. The completion of this work should ensure the continuity of these research sites until well into the 1990's, though even with a good fence-line sheep can still cause problems and during April this year we had to dig snow from the sides of exclosures to prevent sheep walking over the fences.

Cattle again grazed the meadow as in 1982, being turned in on 2 August after the main seeding had taken place. It was strip grazed by 7 Galloways to ensure a tight graze and this proved to be very successful, with the removal of the rank grass and dense litter layer. In the past staff have taken off a crop of hay by hand and sheep have grazed off the fog. It is hoped that using cattle in this way will maintain the diverse flora associated with the meadow without the past labour intensive tasks. Although in the past horses and house cows have grazed this area, no regular grazing by cattle has been known and the meadow will be monitored for possible changes in vegetation.

Natural History Notes.

The following account gives a general picture of events throughout the year and more detailed information is recorded in my Quarterly Reports.

The usual movement of winter birds, mostly thrushes, began to cross the Pennines in October and a small party of goldcrests was recorded in the tree enclosure at Moor House on 5 October. Peregrines were recorded on 2 dates at this time and a number of redwings were found killed by these falcons along Troutbeck. Woodcock recorded on the Reserve always seem to indicate a change in the weather at this time of the year and 2 flushed on 11 November were followed by the first snow of winter on 13 November. The

first snow buntings, a flock of 20, were seen on Great Dun Fell on 25 November and on several other dates afterwards. On the mammal side stoats were very active at this time, with 3 rabbits being killed in the Moor House meadow. Badgers too were busy and the sett at Crowdundle Beck showed signs of much activity.

January to March produced some moderate falls of snow which combined with gale force winds (99 mph recorded on Great Dun Fell in January and February) and some deep drifts were formed. These strong winds did, however, leave large areas of fell uncovered by snow on which the grouse and other species could feed. Although low temperatures occurred (-14.9° air frost on Great Dun Fell on 10 February) these periods were short-lived and the winter period for wildlife was a reasonably mild one.

During snow cover snow buntings were recorded feeding on Juncus squarrosus seed heads on several dates and also at this time I received a report of a golden eagle feeding on a badger carcass at Green Castle, east of Cross Fell. Ravens were of note by their absence, with only one being seen during the whole of the winter period.

During a mild spell in January, 2 buzzards displaying near the fell gate and a merlin (♂) hunting over Knock Ridge were both unusual and early records. Single lapwing and golden plovers had returned to the Reserve during the first week in March and golden plover were seen displaying at this time.

We did not have a spring period. April and May were cold and wet with snow showers frequently occurring up until 27 May, resulting in a disappointing start to the breeding season. Some species, such as lapwing, lost early eggs to chilling, whilst passerines at lower altitudes lost young because of the lack of food during the hatching period. A buzzard attempted to breed on the Reserve but its nest became waterlogged and it deserted. The majority of waders were late arriving on their breeding grounds, having been pushed off the high tops by storms. Few records for weasels occur for the Reserve but one was seen hunting in the snow covered meadow wall during this period on 12 April.

Temperatures remained low in the first weeks of June but began to rise towards the end of the month with long periods of sunshine. July was predominantly hot and sunny with only 3 days of rain recorded. This rain fell in thunderstorms and was very heavy. Over 3" fell in less than an hour in Appleby on 17 July. The good weather continued through August and into the second week of September, producing one of the best summers for many years.

The Waterways Bird Survey results showed that waders were late arriving to breed but only the common sandpiper showed any significant change in numbers when compared with other seasons. Over the 5 kms surveyed along the Tees, numbers dropped in 1982 to 11 pairs, compared with 15 pairs in 1979 and 16 pairs in both 1980 and 1981. This year numbers appear to have increased to 18 pairs (this is my provisional figure and the B.T.O. have still to verify it). A common sandpiper which had been colour ringed by Shirley Jones (research project) in 1977 returned to breed again near Troutbeck bridge.

A colony of black-headed gulls bred on the river Tees for the first time as they were unable to use an island in Cow Green reservoir, which remained submerged after the high rainfall earlier in the year. Ninety Five nests were counted and a high percentage of

young were hatched, but the colony was raided by foxes and most chicks were killed. Another new species attempting to breed on the river was ringed plover. A pair made a scrape and the female was seen sitting in it in May but then disappeared.

Despite the cold wet spring, grouse seem to have been fairly successful in rearing good, strong chicks, although perhaps broods were small (several seen, 3 to 5 birds in each, 11 July). Surrounding moors seem to have had a good season with reports of good numbers shot in late August.

Short-eared owls do not seem to have bred this year, with only 2 records during May for the summer period. Kestrel and merlin were regularly recorded, as were peregrine, one seen stooping at a golden plover on 26 July. A male sparrowhawk was seen hunting meadow pipits low over the western escarpment of Great Dun Fell at 610 m in early August. Also during this month a red-legged partridge feeding on the roadside above Knock Ore Gill at 457 m was a new Reserve record.

The weather was ideal for butterflies during July and August. The small tortoiseshell increased dramatically and was abundant throughout the Reserve. Red admiral numbers also increased with up to 6 being counted on several dates. Also recorded were several peacocks, green-veined whites and small heaths.

More dragonflies too were seen, with around 12 sightings of Aeshna juncea on the eastern side of the Reserve.

A red deer hind recorded on the 3 August by research student C.H. Thomson within 274 m of the Field Station was a most unusual record and a new species for the Reserve.

Despite the late start to the breeding season for many species, especially waders, most had left the fells by 8 August when a 7 km walk along the river Tees and Troutbeck only produced 2 lapwings.

The first signs of autumn migration occurred on 30 September when small flocks of house martins and swallows were seen moving along the Pennines. The tree enclosures beside the Field Station contained greenfinch, chaffinch, goldfinch, linnet, reed bunting, meadow pipit, goldcrests (20+), song thrush, a juvenile merlin, 2 redwings and a fieldfare, all sheltering and feeding before moving on.

II. SCIENTIFIC

a) Monitoring vegetation change on Moor House National Nature Reserve

(*R.H. Marrs and +Judith Scott)

* I.T.E., Monks Wood Experimental Station, Abbots Ripton, Huntingdon, PE17 2LS.

\+ N.C.C., Blackwell, Bowness-on-Windermere.

During 1983, 3 studies have been carried out in the field:-

(i) Monitoring vegetation change at Johnny's Flush (D44)

The vegetation both inside and outside the exclosure at Johnny's Flush (Moss Burn flush) was monitored using the stratified point quadrat method developed by M. Rawes. The monitoring programme was increased to include sampling of the vegetation and soil. To do this 10 sub-quadrats (30 x 30 cm) were randomly positioned in both the grazed and ungrazed areas and the vegetation clipped and a soil sample taken. Nutrient analysis of both plants and soils will be carried out.

(ii) Studies on the Hard Hill burning experiment (D35 - 38)

Vegetation and soil samples were taken for nutrient analysis from the discard surrounding the sampling areas in each of the 28 treatments, i.e. 4 blocks x 7 treatments - initial burn only (N), short rotation burning (S), long rotation burning (L) - all ± grazing, and in each block there is an untreated control where no burning has been applied.

It is expected, weather conditions allowing (?) to burn the short rotation plots this winter (1984).

(iii) Little Dun Fell Flush

The vegetation at the Little Dun Fell flush was mapped.

Transfer of selected Moor House data to computer storage

In addition to this field work, progress has been made with the transfer of field data to computer storage. To date all of the data for 2 experiments (D35 - 38) and (D44) has been transferred, and the data for a further 2 experiments (J1 and N1) have been encoded and await final checking before transferring to the computer. It is hoped that the bulk of the data transfer will be completed this winter.

Acknowledgements

The senior author would like to thank N.C.C. North West Region for allowing Judith Scott to assist with the annual monitoring programme, and for financial support from the Chief Scientist's Team to pay for the data transfer.

b) Moorland Management - House Hill heavily grazed plot
(M. Rawes and Judith Scott)

A problem encountered with frequent monitoring of plots is the possible, and in some cases, known damage that investigators can inflict on the vegetation they are sampling by their activities. This is particularly liable to occur where the method involves returning to the same sites each year, and the use of permanently located point quadrats is a feature in this experiment's accuracy. The lower plants are especially likely to be affected. Therefore in 1983, when recording resources were low, the study was restricted to assessing the cover of vascular species only.

In appearance the vegetation in May 1983 showed little change from the previous year; Eriophorum vaginatum remained clearly dominant. However, Calluna was making a steady recovery and was now found in 10% of the quadrats. But the biggest change was with Eriophorum angustifolium, which nearly doubled its cover and was recorded in 26 of the 30 10-pin frames. It was the most abundant species after E. vaginatum, which increased its cover to 92%. The increase in E. angustifolium is interesting. Hobbs (Oikos in press) has shown a similar increase after burning. But the absence of Calluna canopy permitting good light interception appears to me to be the main factor in the species success. The sharp drop in Rubus chamaemorus in 1983 is associated with the exceptionally late spring. Very few leaves had emerged. Empetrum nigrum remained largely absent, and species such as Juncus squarrosus, Deschampsia flexuosa, Festuca ovina and Agrostis tenuis that had entered the enclosure during the grazing regime, were mainly eliminated.

c) Moor-Draining: A Review of Impacts on Land Use
(A.J.A. Stewart and Art N. Lance. 1983. Journal of Environmental Management 17, 81 - 99).

Extract.

Open ditches are traditional for draining the 1½ million ha of native hill pasture in Britain with wet peat soils. Moor-draining is grant-aided at 70% of cost, but its effectiveness has never been fully investigated. Evidence on vegetation impacts and the production of sheep and other animals is reviewed here, along with soil erosion and other unintended consequences of draining.

The structure of hill peat determines its hydrology and therefore the response to draining. Water moves freely through the thin (< 10 cm) fibrous surface layer only; the deeper humified layers are permanently waterlogged at > 400% of dry weight, and conduct water at only a few metres per year. Drains can relieve saturation only within 1 - 2 m of the channel-edge.

There is no documented evidence of economic benefits from moor-draining. Better performance and production of hill sheep appear to be mere surmise. Heather (Calluna vulgaris), an important winter food for sheep, grows taller and denser after draining, but only immediately beside the drain-edge. The extracted peat spoil and the drain channel together occupy an area half as wide as the zone of improved heather. Alleged increases in red grouse (Lagopus l. scoticus) for sport shooting have been indistinguishable from natural population fluctuations, and similarly for other vertebrates.

In addition to soil erosion, the drawbacks of moor-draining are: scarring of the landscape, downstream flooding after rainstorms, rush (Juncus spp.) invasion and possibly the spread of sheep liver-fluke (both of which draining is supposed to ameliorate), and sedimentation in streams important for fish and water supplies. These effects have had little more study than the agricultural objectives, but the evidence indicates that drawbacks exceed benefits.

d) Climatological Recordings

Judith Scott reports on the weather, October 1982 - September 1983 as follows:-

February proved to be the coldest month of the winter, with some heavy snowfalls and drifting; the winter's lowest minimum air temperature of -14.9°C was recorded during this month. Over the winter period, days of snow-lie (when the ground was completely or more than half covered) reached a total of 72 days, compared with the 30 year average of 68 days; February having at least twice the number of days of snow-lie than any other month this winter.

No "spring" occurred this year, the weather remaining cold and wet, with some sleet and snow. Heavy snow fell in late April during the evening of the 20 and on 27 May, during a bitterly cold day, there was sleet with snow at times.

The summer of 1983 must be one of the warmest for a number of years. Temperatures fose during mid-June, giving plenty of warm, sunny weather over the summer months. The highest maximum temperature of the summer was 26.7°C, recorded during mid-July. This was slightly greater than the highest maximum temperature reached during the hot summer of 1976 at Moor House (25.6°C). Total rainfall over the months of June, July and August was 200.7 mm, much lower than the total of the averages for these 3 months (395.6 mm).

The summary table for 1982 is given in the Appendix.

III RESEARCH BY THE INSTITUTE OF TERRESTRIAL ECOLOGY

a) Climate and Tree Growth
(A. Millar, Merlewood Research Station)

Studies are continuing.

IV RESEARCH BY THE FRESHWATER BIOLOGICAL ASSOCIATION

a) Fish populations
(D.T. Crisp)

Examination and tagging of trout from Cow Green reservoir, whilst spawning in streams within the Moor House National Nature Reserve, was continued during the autumn of 1983.

Studies on the fish populations downstream of the reservoir have now been written up and published:-

Crisp, D.T., Mann, R.H.K. & Cubby, P.R. 1983. Effects of regulation of the river Tees upon fish populations below Cow Green reservoir. Journal of Applied Ecology 20, 371 - 386.

V RESEARCH BY UNIVERSITIES

a) Atmospheric Physics Research at Great Dun Fell (a brief summary)
(Staff of the Atmospheric Physics Research Group, U.M.I.S.T., Manchester.

Previous studies by the A.P.R.G. at Great Dun Fell have been concerned largely with ground-based measurements of the evolution of cloud droplet distributions at an elevated site, and these studies have indicated the importance and, indeed, necessity of understanding the dynamical nature of the environment in which the cloud is evolving (Baker et. al., 1982). Theoretical modelling of the airflow around a hill such as Great Dun Fell has been carried out at U.M.I.S.T. (Carruthers & Choularton, 1982), together with the development of a diffusive model of the turbulent mixing of dry and cloudy air (Baker & Latham, 1982).

To test some of the ideas propounded in these 2 studies, our efforts during the past 12 months have been largely devoted to incorporating the equipment necessary to quantify the dynamic structure of the atmosphere into our cloud-microphysical measurement system. This has centred around the installation and testing of a 3-axis sonic anaemometer, together with the introduction of industry-standard magnetic tape drives (with concomitant hardware and software modifications) to the microprocessor-controlled data acquisition system. Preliminary analysis of the data from the sonic anaemometer and cloud droplet spectrometer logged at 40 Hz is beginning to reveal the fine structure and complexity of the nature of cloud evolution in a turbulent environment.

Concurrent with the studies of cloud evolution has been an investigation of the nature and extent of the orographic enhancement of rainfall. Using 2 novel raindrop disdrometers developed at U.M.I.S.T. specifically to operate in the high wind speeds commonly occurring at Great Dun Fell, with one located at the summit of Great Dun Fell and one at Wharleycroft, Dufton, several case studies were carried out during October and November 1982. These measurements were complemented by measurements of meteorological variables at both sites, together with acoustic soundings above Great Dun Fell and radar soundings from Wharleycroft. Analysis of the data is

shedding fresh light on the nature of orographic enhancement and the seeder - feeder mechanism (Stevens, 1983).

In addition to the studies outlined above, several other avenues of research continued to be pursued. These included the attenuation of both visible and infra-red radiation by clouds using a Barnes transmissometer, and the testing of a new device to measure both total water content and relative humidity in cloud. The preliminary results from this device (acronymically known as HICUP - Humidity In Cloud Under-saturation Probe!) suggest it may be a powerful tool in making what have long been important but extremely difficult measurements.

As a pleasant diversion from our scientific endeavours, we were visited in November, 1982 by a team from Granada Television who recorded a short item on our work at Great Dun Fell for the "Look Northwest" programme.

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Carruthers, D.J. & Choularton, T.W. 1982. Quart. J. R. Met. Soc., 108, 603 - 624.

Stevens, C.J. 1983. Ph.D. Thesis, University of Manchester.

For further information on the study, please contact Dr. M.J. Gay, U.M.I.S.T.

b) Long term studies of Strophingia cricae and other Homoptera
(J.B. Whittaker, Department of Biological Sciences, University of Lancaster)

This study has now been completed. Analysis of 15 years' data for Strophingia shows that interaction between overlapping cohorts occurring together on Calluna causes regular oscillations in population density with approximately 7 - 8 year periodicity.

c) Gas production during peat formation
(Jane Claricoates, Department of Botany, Westfield College, London)

The project described in the previous Annual Report (1982) has continued for a further year. Field trips were made to Moor House on 5 occasions between April and September, 1983, to collect surface and deep peat gas samples. Profiles of S^{2-} activity, pH and redox were measured at the same time.

The results obtained in general agree with those from the 1982 field season, but a detailed statistical analysis is still to be carried out.

A similar set of peat gas and profile data has again been collected from Coom Rigg Moss National Nature Reserve this year, and measurements of the efflux of gases from the peat installed in the garden at Westfield have been continued.

In addition to the routine peat gas collections, samples of peat have been collected for the determination of bulk density and species composition. This analysis is now in progress.

A detailed plane table survey of the area on Burnt Hill used for the project has been made.

The field work at Moor House and Coom Rigg is now finished; the Westfield garden peat measurements will be made until December 1983. Analysis of all the results is continuing.

d) Mechanisms of plant interaction on blanket bog
(K. Taylor and C.H. Thomson, Department of Botany, University College London)

Investigations have been continuing on the types and mechanisms of plant interaction between Rubus chamaemorus and Calluna vulgaris on blanket bog at Moor House.

The experiments have focused on phosphorus utilization using ^{32}P as a tracer and carbon assimilation using $^{14}CO_2$ exposure to estimate field rates of photosynthesis. The $^{14}CO_2$ apparatus used was the "Pogometer 2" Labelling Porometer kindly lent by the John Innes Institute, which also simultaneously measured transpiration.

^{32}P was injected at 3 depths, and at intervals throughout the growing season within an intact community to establish any spatial and/or temporal differences in P-utilization between Rubus and Calluna.

$^{14}CO_2$ assimilation was measured on a number of morphologically distinct leaf-forms produced under the following treatments: intact canopy, clipped plot, clipped plus shade screen. Measurements were taken throughout the season under natural daylight and beneath shade screens in an attempt to produce crude light-response curves.

The field $^{14}CO_2$ assimilation data will be compared with laboratory measurements of photosynthesis (T.C. Marks, 1974) and related to the growth response found in previous field experiments.

Experimental results and analysis, when completed, will be presented in a final report.

References

Marks, T.C. 1974. The effects of moorland management on the growth of Rubus chamaemorus L. Ph.D. Thesis, University of London.

e) The effect of altitude, climate and soil nutrient status on the growth of Agrosto-Festucetum grass swards at Moor House National Nature Reserve
(J.C. Hatton, Department of Botany, University College London)

The research carried out during the 1983 growing season (May - October) represents the final sampling programme of a 3 year project designed to identify and to determine the extent of the separate effects of altitude (climate) and mineral supply on Agrosto-Festucetum sward productivity on the Reserve.

Four altitudinal sites have been investigated:-

Sites	Altitude (m)	Nat. Grid Ref.	Underlying bed-rock
1. Low Cairn	502	NY 792 296	Melmerby Scar Limestone
2. Rough Sike	562	NY 756 327	Tyne-bottom Limestone
3. Johnny's Flush	639	NY 745 317	Scar Limestone
4. Knock Fell	747	NY 716 311	Great Limestone

All sites are Agrosto-Festucetum grass swards on brown calcareous soils and show a typical hummock-hollow relief reflecting the underlying clints and grikes. Within each site the hummocks and hollows have been considered as 2 distinct subsites and all sampling has been carried out on a stratified random basis within each of the subsites.

Soil measurements have concentrated on the dynamics of the 2 major nutrients, nitrogen and phosphorus. Parameters measured include inorganic nitrogen content, nitrogen mineralization rates, phosphatase enzyme activity and plant "available" inorganic pools of phosphorus. Above-ground plant growth has been measured and nutrient analyses are presently being carried out on botanical components of the sward. A comprehensive set of microclimatological data for each of the 4 altitudinal sites has been obtained throughout the 1983 growing season using memory recorders linked to thermistor probes.

It is intended to collate this data to produce an integrated model of the nutrient dynamics within the soil/vegetation ecosystems for each of the 4 altitudinal sites.

f) Attributes of drainage basin topography
(Sarah A. Bell, Department of Geography, University of Durham)

This research has been carried out over 3 years, and will be submitted for the degree of Ph.D. in late 1983 to early 1984. The work has involved comparison of 2 methods of sampling land surface form - by contour orthogonals (slope profiles) and from a square grid pattern of altitudes (an altitude matrix). The latter represents complete sampling coverage of an area of interest, whereas the sampling basis of profiles is less secure, although they are much used in geomorphology. In this work the quality of land surface coverage by profiles is evaluated by comparing summary statistics of the land form

attributes altitude, gradient and profile convexity derived from them, with similar statistics derived from the point-based matrix sample by a FORTRAN program, G (devised by Dr. I.S. Evans of the above Department).

An altitude matrix at 10 m grid mesh was made of the 1.3 km^2 catchment of Nether Hearth sike, a tributary of Moss Burn at Moor House. The matrix was made by digitizing the contours on a 1:2,500 scale map of the catchment made from aerial photography, and interpolating a grid of altitudes using the General Purpose Contouring Program, a package available on the IBM computer at Newcastle-upon-Tyne.

A program in FORTRAN, SLOPROFIL 2, has been constructed by this researcher to draw slope profiles through an altitude matrix by approximating the latter as a series of locally-valid quadratic surfaces weighted to ensure first-order continuity across their mutual boundaries. It was possible using this program to generate large numbers of profiles in the Nether Hearth catchment. Detailed field validation of program results had to be carried out in another catchment - that of the Gara river near Slapton in south Devon - because it was very difficult to locate one's position accurately on a map in the Nether Hearth's rather featureless topography, whose poor dissection also meant that commonly-used profile sampling strategies in geomorphology were inappropriate here. This eroding peat catchment provided a challenge for testing of the applicability of the method evolved in this research to <u>any</u> study area, however. The method is to plan on computer a field survey that will give unbiassed coverage of a land surface, this objective being achieved by optimizing the fit between attributes of land form generated by SLOPROFIL 2 (from profiles) and those from G (sampling by a grid pattern of points) by altering profile lengths and numbers.

It was concluded that a sample of at least 32 profiles extended from a grid pattern of points of origin and averaging a length of 171 m would provide adequate surface coverage in the Nether Hearth. The emphasis in the thesis is more on development of a new method combining profile and matrix approaches to measurement, than it is on any results specific to the catchments studied however. Evidence is presented of the applicability of the approach to a variety of areas at different scales, for which matrices were made or were available.

The work has many applications in geomorphology, especially for process-based hydrological modelling, because the flow paths of water in or over the land surface are approximately contour orthogonals, and the ability of SLOPROFIL 2 to generate limitless numbers of these will enable modellers to sample their attributes (e.g. profile lengths, inclinations, length and degree of any concavity at slope base). This approach could replace the derivation of averaged topographic attribute values over subjectively-chosen sub-catchments, as is a common strategy in hydrological modelling at present.

Appendix 1

Publication List

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Appendix 2

Meteorological Summary for Moor House 1982
c 558 m OD (Instrument Site) Lat 54° 41' N Long 2° 23' W Nat Grid Ref NY/758328

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean max temp °C (See * below)	2.2	3.4	5.0	9.4	11.4	13.5	16.4	14.3	13.2	8.6	5.6	2.7	8.8
Mean min temp °C (See * below)	-4.0	-1.3	-1.3	0.1	2.1	6.8	8.1	8.1	6.7	3.9	1.6	-2.2	2.4
½(max + min) °C (See * below)	-0.9	1.1	1.9	4.8	6.8	10.2	12.3	11.2	10.0	6.3	3.6	0.3	5.6
Highest max temp °C	6.9	7.7	11.4	16.8	20.4	24.4	23.1	23.4	21.7	11.9	11.3*	8.7	24.4
Lowest min temp °C	-20.5	-7.8	-5.6	-4.4	-4.7	-1.4	3.1	1.4	0.7	-2.5	-4.3*	-9.7	-20.5
Lowest grass min temp °C	-14.6*1	-10.1	-10.6	-9.1	-8.9	-5.0	-2.4	-2.1	-3.0	-2.9	-7.8*	-7.9*2	-14.6*1
Rainfall (mm)	231.2	131.0	221.5	47.7	103.9	104.2	42.8	198.6	149.0	162.6	326.7	329.6	2048.8
Days snow lying (See * below)	17	1	9	0	0	0	0	0	0	0	3	10	40
Air frost (days) (See * below)	19	18	25	13	11	1	0	0	0	3	13	26	129
Ground frost (days) (See * below)	22	21	31	21	20	5	4	2	8	14	19	30	197

* = Estimates reached by using Moor House and Widdybank data (Widdybank met. station, Teesdale, Co. Durham).

*1 snow covered, estimate = -23.0+

*2 snow covered, estimate = -10.0+