The hydrology of a hummock-hollow complex on Clara bog in Ireland in relation to chemistry and vegetation.

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Field work: October-November 1988
Report: Mai 3-1989.

Erratum

On page 1 (point four of the summary)
while potassium, nitrogen and show a relation with......
has to be while potassium, nitrogen and phosphorous
show a relation with........

On page 5 (chemistry)
....and nitrogen were measured colorimetrically with a Technicon II auto analyzer........
has to be: Phosphorous and nitrogen were measured colorimetrically with a Technicon II auto analyzer........

On page 10 (discussion weather conditions and watertable fluctuation)
Especially in autumn with low potential evapotranspiration figures it is not unthinkable to have a saturated intermediate zone.
Intermediate zone has to be capillary fringe.

On page 14 and 15 (the difference between the two days of sampling and the lawn): figure 7 has to be figure 9.
On page 15 (the lawn): Calcium is, like ..., a key mineral for the growth of Narthecium has to be Calcium is, like phosphorous, a key mineral for the growth of Narthecium.

THE HYDROLOGY OF A HUMMOCK-HOLLOW COMPLEX ON CLARA BOG IN IRELAND IN RELATION TO CHEMISTRY AND VEGETATION

SUMMARY

1). The watertable in winter is flat that is there is no difference in watertable fluctuation in hummocks and hollows because the watertable is in winter in the zone of high hydraulic conductivity. For two reasons:
-In winter is the watertable in the upper part of the profile and the hydraulic conductivity increases with wetness.

2). In summer the hydraulic conductivity will decrease and the evapotranspiration will exceed the precipitation so the watertable will probably be lower beneath the hummock than the hollow. The degree to which the watertable is lower beneath the hummock is dependent on the decrease in hydraulic conductivity and thus on the decrease in flowrate of the water from hummock to hollow. If the decrease in flowrate creates a stationary situation, the difference in watertable is measurable with dip wells and piezometers. This tilted watertable in summer has influence on the chemistry in hummock and hollow.

3).One can assume that the capillary fringe in the measured interval was saturated. This performs a keyrole in chemistry and surface flow and explains partly the fact that no watermovement was determined by piezometers in this formation.

4) Aluminium, manganese and iron have a distribution strategy in the hummock-hollow complex in relation to the position of the watertable and the species present, while potassium, nitrogen and show a relation with rainwater and the saturation of the capillary fringe. This means a seasonal change in elements distribution throughout the hummock-hollow and slope dependent on weather conditions (P,PE) and thus the saturation of the capillary fringe, the watertable fluctuation in hummocks and hollows (dependent on summer or winter) and the species present in hummock, hollow and especially the slope.

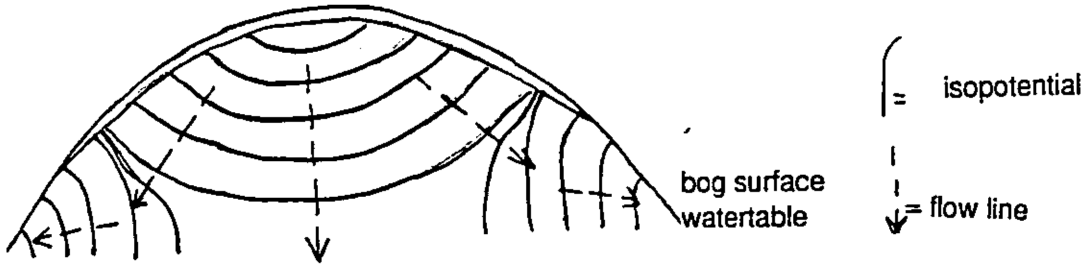
5) The *Narthecium* lawn is probably the lowest part of the site and surface flow will flow in this direction. This is confined by the fact that nutrient demanding species occur on places with increased waterflow.

6) The vegetation in the complex can be divided in nine vegetation types. For these nine vegetation types a definite position above the mean watertable was found.

INTRODUCTION

This study forms a small part of the research done by drs. PC van der Molen on the microtopographical structures of Clara bog in Ireland.
This study is a preliminary study of the hydrolgy, chemistry and vegetation of one of the microtopographical structures on Clara bog: the hummock hollow complex and deals as such with the (micro) differences between hummocks and hollows on the aspects mentioned above. The watertable fluctuations form the basis of this study because the hydrological features are indispensable in discovering why a bog shows an intricate pattern of pools, lawns, slopes etc
The problem with bog hydrology is that it is very different from the usual hydrological standards also most of the studies done on bog hydrology are done on the hydrological characteristics of a whole bog.
The aim of this study was to gain insight in the behaviour of the watertable and the

watermovement in a well developed hummock-hollow complex; this in relation to vegetational differences between hummocks and hollows and the chemistry of the water in this complex.
The assumption was that the behaviour of the watertable should differ in hummocks and hollows (Streefkerk and Casparie 1987, Ingram 1981). The experiments in relation to the watermovement are based on this assumption.
Flow takes place in the direction of steepest decline in potential and flow lines must be normal to the isopotentials (Ingram,1981). The assumption was that the watertable would be tilted and water flows parallel to the watertable. Flow lines are based on the ideas about drainage and seepage in a bog. This idea is demonstrated in figure 1 and is analogous to the figure Ingram made of isopotentials on a slope of a raised bog (Ingram,1981) If water flows from hummock to hollow or from hollow to hummock the water will also flow parallel to the watertable and thus the watermovement experiments were set up to investigate if the idea proposed by Ingram would also work for the hummock-hollow complex (on a microscale).



isopotentials and flow lines for a bog (and for a hummock- hypothesis) fig 1.

Peatlands having extensive lateral flow of water through peat may have highly variable water chemistry as water passes through peat, it is filtered and becomes less mineral rich (Bellamy 1959,Vitt et. al 1975,Moore and Bellamy 1974). For hummocks and hollows the general idea is that nutrients removed from the hummocks may accumulate in the hollows or possibly on the bog slope (Damman,1978).
The behaviour of nutrients in the*Sphagnum* plants and in the peat material itself is quite well known from literature, contrary to the behaviour of nutrients in the bog water.
In the process of leaching of the elements from hummock to hollow; it is important how the *Sphagnum* plant itself accumulates nutrients.
Three processes are known to dominate the accumulating process:
1). Direct influx of elements mainly to the chlorophyllose cells.
2). The adsorption of ions on the exchange sites on the cell walls.
3). A less specific accumulation of the elements, partly as particles, on the surface of the plant.
For most elements one of these three processes may predominate (Brown 1982, Clymo and Hayward 1982, Malmer 1988)

STUDY SITE

Clara bog is an ombrotrophic raised bog in the Midlands of Ireland and covers an area of 620 ha. It consists of two parts separated by a road.
The work was carried out on the western side of the bog because the eastern side has been drained seriously by Bord na Mona (Irish Turf Board). The western side is relatively undisturbed and has several well developed hummock-hollow complexes. The study was

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carried out on a site in the largest complex with beautiful hollows filled with *Sphagnum cuspidatum*. A map of the site with all the tubes for watertable measurement is added (see map 1). To minimize the disturbance, duckboarding was established on the site (see map 1). The field work of this study took place in October and November 1988.

METHODS

Hydrology

In order to establish the shape of the watertable in winter 92 PVC tubes (dip wells) were placed along the duckboarding. They were placed 20 cm apart and in this way formed two transects with a combined length of 25 m. One transect is the square formed by the duckboarding and the second is along the rest of the duckboarding (see map 1).
As the bog surface moves it is necessary to relate the measurements to a local datum surface. This surface was established by hammering a copper pipe down in the peat to a depth of about 8 metres, so we could be sure that it would not move significantly with the rise and fall of the bog surface due to "moorathmung". A plane two metres beneath the top of the copper pipe was chosen as a local datum surface, to which all measurements were related.
The waterlevel was determined by inserting a flexible hose into the tube. The tube was straightened with a bamboo rod and the waterlevel was reached (by blowing into the tube) till bubbles could be heard. In this way the height between the top of a tube and the waterlevel is measured (see figure 2). A method analogous to the method proposed by Ingram was used to calculate the height of the waterlevel with respect to the local datum surface.

a =height between top of the tube and the waterlevel.
b=height between the top of the tube and the bog surface.
c=height between top of the tube and the top of the copper pipe.
d=c-200cm.
e=d-a.(height of watertable above local datum surface).
f=a-b.
g=e+f.(height of bog surface above local datum surface).

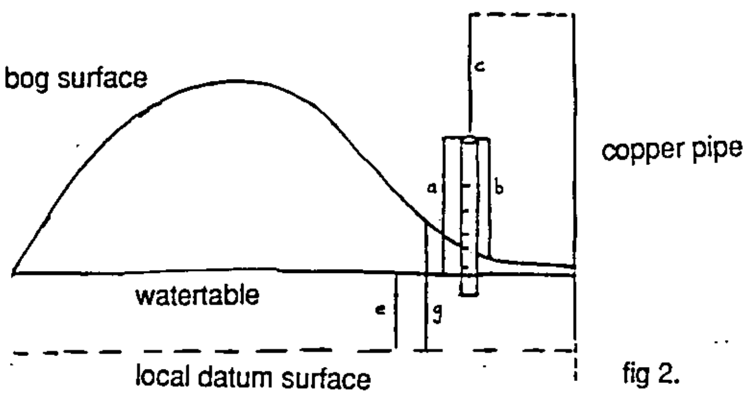

fig 2.

Parameter b was determined by using a folding rule and measure the difference in height between the bog surface and the top of the tube. A difficulty is the unevenness of the bog surface; parameter b thus has a large measuring error. To minimize this error, the electricity wires (next to the tubes) were used as an absolute point for measuring. See for the electricity wire the method for anaerobic zone measurement.
Parameter c was determined by a self made device that worked on the basis of the law of communicating vessels and consisted of a plastic watertank connected with a hose, equipped with a centimeter division.
The parameters d, e, f and g are calculated from these three parameters.
Parameter b is less reproducable than parameters a and c because of the unevenness of the bog surface. Parameter b is only used for the calculation of the height of the bog surface above local datum surface.

The consequence is that the height of the waterlevel above local datum surface is more accurate than the height of the bog surface above this level. The watertable measurements were carried out twice a week, during seven consequetive weeks. The results were processed by the hypsometry method proposed by Ivanov (Ivanov 1981, Bragg 1982).
The mean of the watertable for both hummocks and hollows was taken for every measuring day.
Hypsometry uses the construction of watertable frequency and residence curves. The basis for these curves is the division of both hummocks and hollows in horizontal thin layers of thickness ΔH and altitude H_i
The residence curve describes the occupation of the different layers by water as a percentage of time, while the frequency curve gives the variation of waterlevel in time and describes thus the frequency of inundation of a certain layer (Ivanov,1981).

PIEZOMETERS

The experiments in relation to the water movement were set up to measure the hydraulic pressure so to estimate the isopotentials. The piezometers were placed up to 30 cm beneath the watertable (one tube even up to 50 cm beneath the watertable).
As this is a small vertical range; we assume the isopotentials to be nearly vertical. In a representative hummock (see map 1) twenty-four piezometers were established at 6 locations (four per location). In front of every four piezometers a dip well was placed to estimate the position of the piezometer relative to the watertable.
(The waterpotential at a point below the watertable is due partly to the elevation of that point above that point above a local datum surface -z- and partly to the pressure -h-, or head of water above the point (Ingram,1981)).
The head of water is determined with the same flexible hose as for the watertable measurements and -z- is calculated in the same way as -e- for the watertable with respect to the local datum surface. The hydraulic pressure was measured at least four times a week.
At the end of October twelfve new piezometers were placed, in pairs, adjacent to the duckboarding;
next to three dip wells in the *Narthecium* lawn and next to three other dip wells in a *Sphagnum magellanicum* slope. These piezometers were also measured at least four times a week.

VEGETATION

The vegetation description consists of three parts:

The first part consists of 98 vegetation relevés along the transect of 25 m. Each relevé was a 20 cm. square and had the the dipwell at the centre of the relevé; as such the relevés are connected and cover the whole transect. Each relevé contained percentages cover of mosses, vascular plants and lichens. A classification was made of the resulting vegetation data using the computer program TWINSPAN (Hill,1979).
The result of this classification is presented in a vegetation table.
The second part consists of a condensed vegetation table composed of the same vegetation types (see vegetation table 2). This table shows the presence and the abundancies of the different species more clearly than vegetation table 1 does.
The third part consists of an overview of the mosses and lichens and vascular plants of all the hummocks adjacent to the duckboarding (see map no. 2).

The nomenclature follows Heukels and van der Meijden (1983) for vascular plants, Smith (1980) for bryophytes and Wirth (1987) for lichens.

THE ANAEROBIC ZONE

The depth of the top of the anaerobic zone beneath the bog surface was determined by means of earthing wire. Hydrogen sulfide in the anaerobic zone will change the colour of the earthing wire from yellow/green to black. The bog surface was taken as reference point. The black colour of the wire is often disturbed by roots; and thus it is very important to define where the beginning of the black colour is for the analyzer. The top of the anaerobic zone was determined next to every dip well once a week.

CHEMISTRY

In order to gather information on differences in nutrient behaviour in the hummock-hollow complex, water samples were taken in every hummock, slope and hollow. Eighteen of the 92 tubes were of larger diameter than the rest and these were used to take the water samples from. These 18 tubes were covered with a cap protecting them from rain.
The caps fitted loosely to prevent a buildup of pressure. The water samples were filtered and in the field the pH was measured with a glass electrode. A few drops of CCl_4 were added to fixate the samples and they were analyzed within five days in the laboratory in Amsterdam. and nitrogen were measured colorimetrically with a Technicon II auto analyzer, as a molybdate complex, nitrogen as a azo complex at 550 nm. Calcium, potassium, iron and manganese and aluminium were measured spectrophotometrically with a Perkin Elmer 1100 B atomary absorption spectrophotometer.

RESULTS

VEGETATION

These are the results of the 98 vegetation relevés (see vegetation table 1 and 2).

The vegetation of the site can be roughly divided in:

- Hummock vegetation	I
- Slope vegetation	II
- Edge vegetation	III
- Lawn and hollow vegetation	IV
- True hollow vegetation	V

These categories can be further subdivided.

I Hummock vegetation

The three dominant species of the hummock vegetation are *Sp. cappillifolium*, *Calluna vulgaris* and the moss *Hypnum*. The subdivision is based on the abundancies of one of these three species.

IA: Each relevé belonging to this vegetation type is totally dominated by *Sp. cappillifolium*.

IB: Each relevé belonging to this vegetation type has an abundancy of *Hypnum* of at least 15%.
IC: Each relevé belonging to this vegetation type has an abundancy of *Sp. papillosum* of at least 15%.

II Slope vegetation

The slope vegetation has no subdivision

IIA: The most dominant species for the slope vegetation is *Sp. magellanicum* with an abundancy of more than 50% in each relevé. *Sp. cappillifolium* is also present in each relevé but in much lower abundancies than *Sp. magellanicum.*

III Edge vegetation

The edge vegetation is characterized by the occurance of *Sp.cuspidatum* in each relevé. This type is further subdivided:

IIIA: This vegetation is dominated by *Sp. cappillifolium* and *Sp. imbricatum* and contains species like *Calluna vulgaris* and *Erica tetralix* and ofcourse *Sp.cuspidatum.* One could call this type: the *Sp.cappillifolium* edge or hummock edge.
IIIB: This vegetation contains the two dominant species *Sp. papillosum* and *Sp magellanicum* and has less amounts *Calluna* and *Erica*. This vegetation could be called *Sp.magellanicum* edge or slope edge.

IV Lawn and hollow vegetation

The lawn and hollow vegetation is characterised by large amounts of *Sp. cuspidatum* and the absence of all other *Sp.* species and the presence of some hummock species. We could consider this type as a transition to a true hollow
This vegetation can be divided in:

IVA: The appearance of *Narthecium ossifragum* in high abundancies (at least 40% in each relevé) is most noticable.
The high percentages of bare peat in 7 of the relevé is obvious. During the field work interval the lawn was flooded most of the time and so others than *Sp. cuspidatum* did not occur. For the large amount of bare peat found in the lawn this could be an explanation. The three dominant species in the lawn are *Narthecium ossifragum, Sp. cuspidatum* and *bare peat.*
IVB: Transition to hollow with both true hollow species and *Calluna* and *Erica.*

V True hollow vegetation

No subdivision can be made in this vegetation type.

V: Only true hollow species: *(Eriophorum, open water, Sp.cuspidatum* and some *Rynchospora* and).

THE MEAN HEIGHT ABOVE THE MEAN WATERTABLE.

If one considers the fact that the range of mean heights above the mean watertable can be considerable in every vegetation type; we can still see that every vegetation type finds it's place above the mean watertable (see figure 3 and table one)

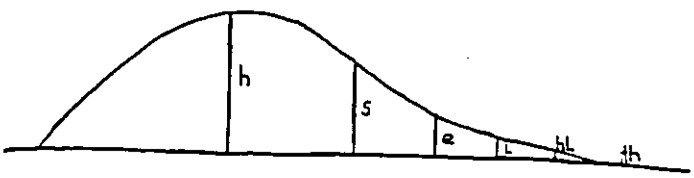

fig 3. height of the different vegetation types above the mean watertable

hwt= height above mean watertable.

	hwt	sdev	range
hummock (h)	8.43	0.18	3.11-13.26
slope (s)	5.52	0.1	1.19-8.99
edge (e)	1.5	0.02	0-4.36
lawn (l)	0.23	0.009	0-1.24
transition to hollow (hl)	0.14	0.0004	0-0.88
true hollow(th)	0	0	0-0.008

table one

For the classification of the mean height above the mean watertable six vegetation types were chosen. The hummock is composed of the vegetation types IA, IB and IC. The edge consists of vegetation types IIIA and IIIB. The reason for this is the small difference in mean height between those vegetation types (see vegetation table 1).

WATER TABLE FLUCTUATIONS IN HUMMOCKS AND HOLLOWS.

The watertable fluctuation in hummocks and hollows is summarized in figure 4 and 5.
As said before the method used is the method proposed by Ivanov (Ivanov 1975, Bragg 1982) for the comparison of the behaviour of the watertable in the different layers of the peat (see methods).
From the freguency curve it is obvious that there is no difference in
the watertable fluctuation in hummocks and hollows in the autumn (Oct/Nov.1988). The differences between the two curves are due to measuring errors.
The measuring error for watertable measurements has been determined by a tenfold repetiton of one measurement. This fault seems to be half a centimeter. The maximum difference in the curve is 0.3 cm.

The statistical t-test for indepent samples indicates with a significance of 0.358 that hummocks and hollows belong to the same statistical population during the autumn.
The fluctuation of the watertable is 4.2 cm over the measured period.

The mean watertable in this period was 132.2 cm.
(From 130 cm to 134.2 cm above local datum level).

RELATION WITH CLIMATOLOGICAL DATA

The climatological data used are from Birr 20 miles south east from Clara. This means that we had to be careful in using these data. For the weather on yearly basis data from Mullingar (20 miles north east from Clara) were also available. Comparing the weather data from Birr and Mullingar, the differences were quite small. The mean of the two towns gave an acceptable picture of the weather in Clara on yearly basis (see figure 6). The day to day data were only available from Birr so these data have to be treated with more care than the data on yearly basis (see figure 7).
Figure 7 shows the relation between the temperature, the precipitation, the amount of sunny hours and the difference in watertable of each day of observations as compared to the previous day of observation.
The rainfall seems to have the highest positive correlation coeffiënt with the watertable fluctuation r=0.75 (see figure 8).
For the sun the correlation coeffiënt is 0.450 and for the temperature -r- is 0.540.
This high correlation coeffiënt for rainfall is seen in figure 7 where the rainfall peaks coincide with the rise of the watertable.

RESULTS CHEMICAL ANALYSIS OF THE BOGWATER

The results are represented in figure 9. This figure gives both the behaviour of the nutrients in the spacial variation (over hummock, slope, hollow and lawn) and in the temporal variation.
It is clear that the results based on the variation in time are very incomplete; because in the Oct/Nov. period bog water samples were taken only twice.
From figure 9, it is obvious that in the shape of the lines presented two forms can be distinguished. The first form is that of the line in the diagram for the nutrients potassium, calcium and nitrogen; where the line increases from hummock, slope to hollow. The second form is that of the line in the diagram for the nutrients iron, mangenese and aluminium. This partition is also found by Malmer(1988) and Damman(1978). According to this literature phosphorous belongs to the first group while the form of the diagram for phosphorous corresponds more with the second group; this will be dealt with in the discussion. As concerns the nutrient amounts in the lawn, high amounts of potassium and phosphorous can be seen.

PIEZOMETERS

The results of the piezometers show no waterflux in the saturated zone which is not strange with a flat watertable. For the whole field interval the hydraulic pressure was the same in all piezometers as well for the horizontal space as with depth (see figure 10 (next page)for the 24 piezometers that were placed in the beginning of the field work interval).

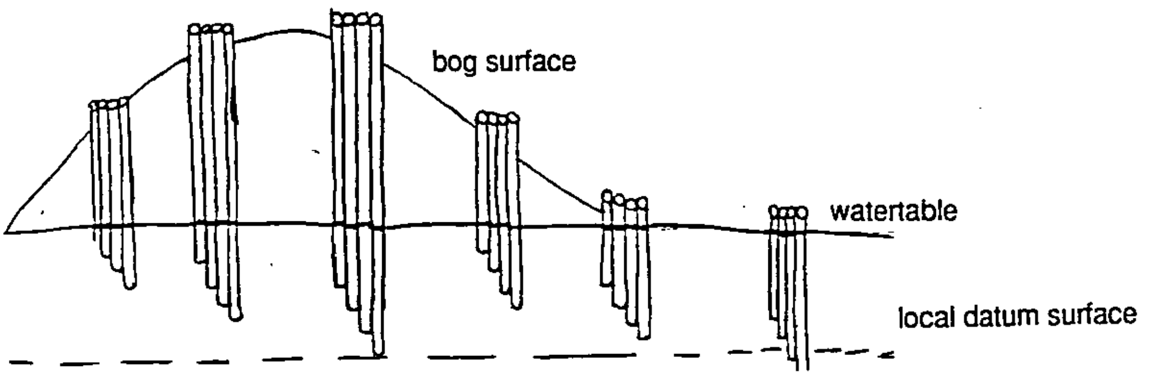

fig 10 The hydraulic pressure or head of water -h- above local datum level in the six piezometers nests.

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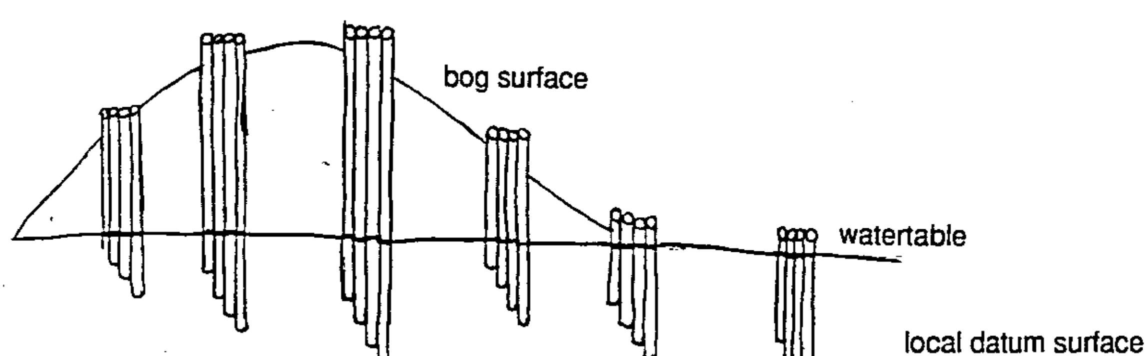

fig 10 The hydraulic pressure or head of water -h- above local datum level in the six piezometers nests.

ANAEROBIC ZONE

Figure 11, shows the top of the anaerobic zone for both transects (see methods). The variation in time in the top of this zone at one point was often very large; in one week the top of the zone could be up to 20 cm lower/higher than the week before. If one compares the different figures it is clear that a certain trend can be observed; beneath the hollows the top of the zone is 7 to 20 cm lower than beneath the hollows because a hummock has more vascular plants than a hollow. These vascular plants have roots that penetrate deep in the profile.

DISCUSSION

VEGETATION

The idea was to correlate the watertable fluctuations with the vegetation. Correlations between a tilted watertable and the presence of a certain vegetation type were not found. It should be possible to find these correlations in summer (see discussion weather conditions). We did find another correlation between vegetation and mean watertable; the height of the vegetation types above the mean watertable.

DISCUSSION WEATHER CONDITIONS AND WATERTABLE FLUCTUATION

The rise in watertable did coincide with the rainfall peaks. In figure 7 the vertical scale is greatly extended so the impression could be that the correspondence between the rainfall and the watertable is greater
than it is in reality. The watertable fluctuation peaks are only two cm at the most and pure rainfall is not an accurate indicator of groundwater level changes; rainfall intensity and distribution is much more important (Todd,1959).
The mean watertable difference was only 0.2 cm over the measured interval, this is lower than would be expected, especially when we see that the rainfall amount for October was 89.3 mm and for November 40.3 mm (Birr and Mullingar).
The potential evaporation for October was 15 mm and for November 0 mm (also for Birr).
The mean watertable for october was131.3 cm and the mean watertable in november was 131.1 cm; the difference is only 0.2 cm.

According to these data it is strange that there is no difference in watertable between October and November. To determine any difference in watertable in November and October the difference had to be more than 0.5 cm (the measuring error).
Probably the saturation of the capillary fringe has an important role in this. The zone between the bog surface and the saturated zone is divided in the capillary fringe and the intermediate zone. The capillary fringe is associated with the saturated zone and thus is the zone where most of the pores are filled with water. The intermediate zone is the zone between the capillary fringe and the bog surface. The capillary fringe is associated with the saturated zone and thus is the zone where most of the pores are filled with water. The intermediate zone is associated with the root zone and as so it is a transfer zone, transfer by drainage and evapotranspiration (pers.communication Bruijnzeel,1989).
These definitions are used for soils rather than for a bog. The watertable in most of these soils is that low that the capillary fringe never reaches the root zone. In a bog the unsaturated zone is filled with roots; thus the zone above the watertable will be called the

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capillary fringe in spite of the roots. The water in this zone behaves like capillary water rather than transfer water.
When the acrotelm is above field capacity (pF=2) than it can not yield more water; so more precipitation does not result in a rise of the watertable.
Especially in autumn with low potential evapotranspiration figures it is not unthinkable to have a saturated intermediate zone.
This means that rainwater runs off over the top of unsaturated zone (capillary fringe) from the hummock to the hollow.
The saturation of this capillary fringe shoud not be seen as a firm waterfront. The form of the 'waterfront' will depend on the species present on the hummock (e.g. *Sp. fuscum* will hold water more firmly than e.g. *Calluna vulgaris* does).
Secondly the rainfall intensity will be of influence, a drizzle will not give as much runoff as pouring rain will do because of the fact that one raindrop will find its way in the less firm parts of the capillary fringe, while more rain will meet with a firm front because of its speed.
The regression coeffiënt for the amount of sunny hours with the watertable fluctuation is 0.450; this is low compared with the regression coeffiënt for the precipitation and the temperature.
The impression could be that evapotranspiration, being identified with the amount of sunny hours, would be less important for the watertable fluctuation than rainfall. Especially when the acrotelm is above field capacity (saturated capillary fringe), the evapotranspiration will be more important than the rainfall.

DISCUSSION ABOUT THE WATERTABLE FLUCTUATION

Though it is not directly in accordance with the hypothesis, it is easy to understand why the watertable is not tilted in winter. In the first place the watertable in winter is in the zone of high hydraulic conductivity . The hydraulic conductivity is high for two reasons: in winter we deal with the high watertable. The high watertable is found in the upper part of the profile where the hydraulic conductivity is higher than the lower part of the profile where the summer watertable is found.
This difference between high and low watertable determines the degree to which the hydraulic conductivity decreases in summer.
The second reason is that the hydraulic conductivity is dependent on the water content of the acrotelm.
In a drier period the hydraulic conductivity is decreasing because the hydraulic conductivity is inversely proportionate with the moisture content of the profile (acrotelm), while in winter the hydraulic conductivity , due to the very wet profile, is high.
Secondly as explained before, the capillary fringe is probably saturated during most of the winter (at least in Oct./Nov. 1988). Waterflow in the form of micro runoff takes place over the top of the capillary fringe (for the greatest part) so this micro run off combined with a flat watertable does not result in a flow of the watertable itself.
It can be found in literature that in summer a lower watertable beneath the hummock is found in comparison with the hollow (Ingram 1981, van der Molen pers.commun. 1989). Some evidence can be found that this will also happen in the hummock-hollow complex. As mentioned above the difference between the high and the low watertable is one of the components that determines the decrease in hydraulic conductivity. The amount of waterflow resulting from this decrease in hydraulic conductivity determines the extent of the difference in waterlevel between the hummock and the hollow. The decrease in waterflow rate has to create a stationary situation before a difference in waterlevel is detectable.

The evapotranspiration in summer will be significantly greater for the hummock than for the hollow. The difference in evapotranspiration is important with respect to the decrease in hydraulic conductivity because of the resulting difference in watercontent in hummock and hollow.
For the two reasons mentioned above, a difference in watertable level between hummocks and hollows can probably be detected in summer even without a continuous measuring process with a data logger.

A PRELIMINARY PREDICTION OF THE WATERTABLE BEHAVIOUR IN SUMMER FROM WEATHER DATA OF 1988

The water balance equation $Q=P-PE+/-\Delta S$; ΔS being the storage : the rise or fall of the watertable and Q being the output of the system in the form of run off, drainage etc. P= the pecipitation and PE the potential evapotranspiration. If one assumes (this is a simplification) the output to be minimal in a well developed hummock-hollow complex (this is more valid in a summer than in a winter situation) than P-PE is an important equation for the storage; the rise and fall of the watertable (pers.comm.Simmers 1989,Bragg 1982).
When the evapotranspiration starts to exceed P then the watertable will come in the zone of decreasing hydraulic conductivity and a difference in watertable between hummocks and hollows is to be expected.
In 1988 this period began possibly in April and ended in June or July. Figure 6 shows the weather of 1988 (from Birr); the last picture gives P minus the PE and shows the period mentioned of April to July. The measured interval occurs in a period with a relativily low PE (see figure 6). As said before in this period is the PE more important than the P because of the saturation of the capillary fringe. It will depend on the saturation of this zone if the P is more important than the PE. But though it is a simplification, the equation P-PE gives at least a indication of the difference in water table behaviour in hummocks and hollows.

CHEMICAL ANALYSIS OF THE BOGWATER

The results of the chemical analysis of the bogwater will be discussed using two approaches:
- by interpreting the results of each nutrient in figure 9 (spatial variation).
- by comparing the results of the two days when the bog water samples were taken (see also figure 9).

Spatial variation

The following hypothesis was created using Damman(1978) and Malmer(1988):
Nitrogen, phosphorous and potassium will leach from the hummock to the hollow by the following process (see figure 12):

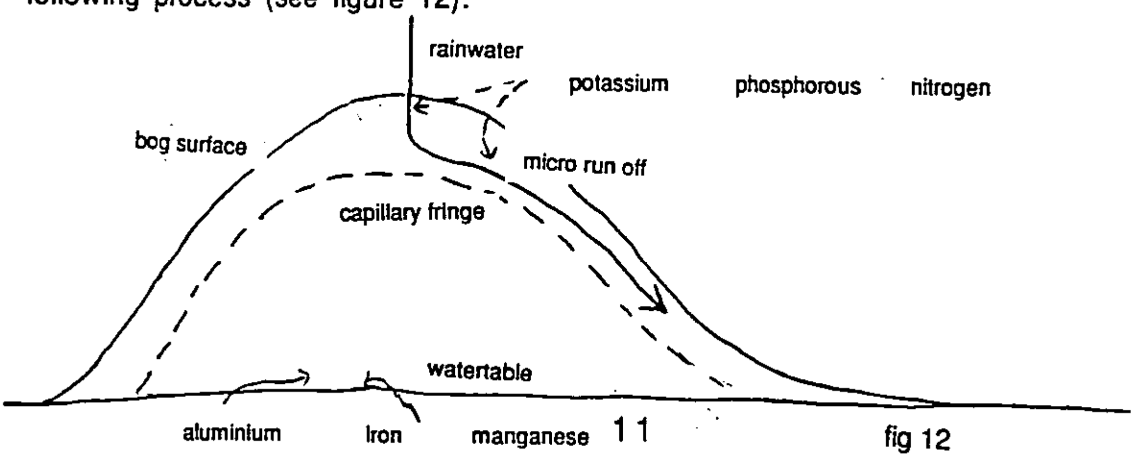

fig 12

while iron, aluminium and manganese will accumulate in the zone of watertable fluctuation. The distribution process for potassium, nitrogen and phosphorous is determined by the pH. The distribution process for iron, aluminium and manganese is determined by the redox potential of the peat (Malmer,1988).

1). Nitrogen, phosphorous and potassium.

As one can see from figure 12, it is clear that the position of the capillary fringe is very important in the process of leaching of these three elements. Although nitrogen, phosphorous and potassium are put together in this figure the strategy followed by the nutrients is not the same. The process of leaching is different for all three elements. Potassium and nitrogen clearly show an accumulation in the hollows (especially nitrogen). Phosphorous shows an accumulation in the slope so at first sight the diagram of phosphorous has more in common with the aluminium, manganese and iron diagrams. Phosphorous belongs strategically to the nitrogen and potassium group. The way in which these elements are accumulated in the *Sphagnum* plants is important for the difference in the distribution strategy.

The direct influx of solutes to the chlorophyllose cells in the growing parts is the dominating process for nitrogen, phosphorous and potassium. Thus for these three elements the concentration always distinctly decreased downwards in the moss plant (Malmer,1988).

The higher nitrogen concentration in the hollows indicates that some of itis leached from the hummock (Damman,1978).

Putting this together the rainwater will leach the nutrients from the capitulum to the capillary fringe and the run off over this capillary fringe will take the nutrients to the hollow or the slope.

For potassium this is supposed to be easier than for nitrogen and phosphorous, although the dominating accumulating process for potassium is accumulation in the chlorophyllose cells. Unspecific accumulation on the surface of the *Sphagnum* plant and replacement of potassium on the exchange sites are also supposed to occur (Malmer,1988).

Rainwater will take the available potassium and transport it to the slope and to the hollow. There are some indications that potassium does not accumulate in hollows or does not stay in the hollows. A correlation between high abundancies of *Sphagnum cuspidatum* and high concentrations of potassium was not found (pers.comm.van der Molen, 1989). *Sphagnum cuspidatum* occurs with low concentrations of potassium.

The surface flow in the hollows in the direction of the lawn could be an explanation for this. High abundancies of *Narthecium ossifragum* are related to high concentrations of potassium (Summerfield and Rieley,1963).

Surface flow can take the potassium from the hollows to the lawn. (see discussion lawn)

The *Sphagnum* species and the height and form of the capillary fringe will be important in the process of leaching. For nitrogen and phosphorous these other processes are not reported to play a role. The rainwater will have to free these elements from the chlorophyllose cells. Malmer says that for nitrogen and phosphorous virtually all the supply once accumulated is kept within the moss layer. It is lost from the mosses only during litter formation. The diagram of nitrogen shows a huge accumulation in the hollows. One theory could be (if one assumes that nitrogen and phosphorous are only freed during decomposition/litter formation) that the fluctuating capillary fringe creates the perfect alternating conditions for decomposition. The leached nitrogen and phosphorous from the chlorophyllose cells can thus be transported to slope or hollow. This suggests a seasonal change in leaching in relation to the height of the capillary fringe. As said before the concentration of nitrogen and phosphorous and potassium are highest in the top segments of a *Sphagnum* plant. So a high capillary fringe will be able to free more phosphorous and nitrogen and potassium than a low capillary fringe.

This would mean that higher amounts of phosphorous, nitrogen and potassium will be leached

in winter rather than in summer. Malmer found in all his sampling areas and all his *Sphagnum* samples at least fifty times as much nitrogen in the *Spagnum* plants as compared to phosphorous ; this could be an explanation for the high values of nitrogen in the hollows (higher amounts leach from hummock to hollow).
The problem that phosphorous is found in higher amounts in the slope than in the hollow is not solved. A possible association of phosphorous with *Sphagnum magellanicum* is not reported and Malmer did not find more phosphorous in *Sp.magellanicum* than in other*Sphagna*. Only if in nitrogen the process of unspecific accumulation would also be important and phosphorous should solely depend on accumulation in the chlorophyllose cells this could explain the difference in both elements. But how this should work and what the impact of this difference in method of accumulation form is on the transport of nutrients by rainwater is not known.

The diagram of calcium. The form of the diagram is the same as the diagram for potassium. As opposed to potassium, nitrogen and phosphorous , calcium has a uniform concentration in the whole moss plant and it is that element, where the exchange reactions are most important (Malmer,1988).
Despite this difference in behaviour the shape of the diagram suggests the same process of leaching of calcium by rainwater.
For seeping rainwater it is easier to free elements by exchange reactions than elements that are accumulated in chlorophyllose cells.
If one assumes that calcium is leached by rainwater than this leaching will also be seasonal and dependent on the height of the capillary fringe.

SECOND GROUP OF NUTRIENTS

The second group of nutrients that can be distinguished is the group that manganese, aluminium and iron belongs to. The positions of these elements differ from the first group of elements (potassium, nitrogen and phosphorous) because the amounts of these elements are determined by the location of the *Sphagnum* surface with respect to the watertable rather than by the biological demand for the element (Damman,1978).
For all three elements the distribution is controlled by the redox potential of the peat. The distribution of the elements of the first group is controlled by the acidity (pH)
This strong relation with the watertable reported by Damman is found in the accumulation of iron and aluminium around the zone of watertable fluctuation in the cores analyzed by Damman. According to Damman manganese accumulates above the high watertable. This distribution in the *Sphagnum* profile performs a keyrole for the difference in behaviour compared to other elements. In the case of aluminium, iron and manganese which are most concentrated in the oldest parts, an unspecific accumulation on the surface of the moss plant may be most important. For all three elements the distribution is controlled by the redox potential of the peat. In aerobic conditions iron, manganese and aluminium are immobile (Malmer, 1988).

Iron: in the anaerobic peat iron becomes mobile as a ferrous ion and accumulates in the zone of watertable fluctuation (Damman,1978) and can be found as such in the bog water. This means that iron can only be removed from the zone of watertable fluctuation, which also applies to manganese and aluminium. In the winterperiod the watertable is a straight plane (more or less) so replacement of iron by waterflow from one vegetation type to the other is not to be expected, at least not for the winterperiod.
manganese: under anaerobic conditions manganese is reduced from the tetravalent to the

divalent state and thus from very insoluble manganese oxide to a mobile cation (Damman,1978). Damman also found, in cores, lower concentrations in the hollow than in the hummock. He imputes this to the accumulation of manganese above the high watertable. It is removed not only from the permanent anaerobic peat (like iron and aluminium) but also from the zone of watertable fluctuation. This is different for iron and aluminium; iron shows no difference in concentration in hummock and hollow while aluminium has a higher concentration in the hummock than in the hollow.

Aluminium: it seems to be surprising to see that the behaviour of aluminium in the peat is somewhat similar to that of iron, because aluminium unlike iron remains immobile under poorly drained conditions (Holmes et al. 1938, Mc. Keague 1965, Damman 1978) in mineral soils. Damman states that the reason might be that in the anaerobic peat the aluminium reacts with hydrogen sulfide to from soluble aluminium sulfide (Damman,1978).

The concentration of an element on the*Sphagnum* plant (or in the *Sphagnum* profile and the anaerobic peat) determines how much can be found in the bogwater. The concentrations found in the hummocks and hollows and slopes are dependent on the*Sphagnum* species present.

That leads to the question what determines the high concentration of iron, aluminium and manganese in the slope. This is most obvious in the histograms of these three elements. A correlation was established between high abundancies of*Sphagnum magellanicum* and high concentrations of iron (personal communication, van der Molen).

Malmer also found higher concentrations of iron in*Sphagnum magellanicum* than in*Sphagnum balticum*; which was used as a hummock species. One could assume that the high concentrations of iron found in the slope are due to *Sphagnum magellanicum* itself and not to a realocation of the element by waterflow in one way or the other.

For aluminium this could also be an explanation on account of the cores analyzed by Malmer. He found higher concentrations of aluminium in *Sphagnum magellanicum* than in *Sphagnum balticum*.

For manganese a nutrient abundancy relation like for iron and aluminium was not found (personal communication, van der Molen 1989) and Malmer did not find a difference in manganese concentration in *Sphagnum magellanicum* and *Sphagnum balticum*. The only difference for manganese is the accumulation of manganese above the high watertable as opposed to iron and aluminium but what this means for the difference in accumulation in the water in the slope is not known.

THE DIFFERENCE BETWEEN THE TWO DAYS OF SAMPLING

The partition of the elements in the two groups mentioned can also be seen in figure 7 with respect to the difference between the first and the second sampling.

For phosphorous, nitrogen, calcium and potassium the concentrations found in the first samples are more or less the same or a bit more than in the second sampling. This gives an acceptable standard deviation of 0 to 25% of the total amount of each nutrient in ppm (see figure 7).

For iron, aluminium and manganese the difference between the first and the second sample is very large; reflected in a un unacceptable standard deviation of 50 to 80% of the total amount of each nutrient in ppm (see figure 7).

The reason for this difference between the two groups is difficult to give. It inforces the conviction that we deal with two groups of elements with totally different strategies.

The rain figures for the two sampling days:
The eleventh of October: the rain accumulated from the first of September to the sampling day is 98.6 mm.
The fourteenth of December: the rain accumulated from the first of November to the sampling day is 56.4 mm.
More rain fell in the first period than in the second period.

Potassium, nitrogen and phosphorous are elements in short supply in the precipitation and are activily conserved by the living *Sphagnum* while the amounts of iron, aluminium and manganese are determined by the location of the watertable rather than the biological demand for the element (Damman,1978).
The amounts of nitrogen, phosphorous and potassium are regulated actively: the concentration of these elements found in the bog water is not directly dependent on the supply in the precipitation.
For aluminium, manganese and iron the relation between the concentration in the bogwater and in the precipitation could be more direct. The saturation of the capillary fringe could be important for this assumption.
If one assumes that the capillary fringe was not saturated yet by the eleventh of October, then a part of the rainwater will have reached the watertable. Some nutrients will then have reached the watertable below the hummock but the rainwater will also have diluted the nutrients in the bogwater of the hummock. In case of a saturated capillary fringe no rainwater will directly reach the bogwater and the runoff from the hummock will collect in the hollows and will take part in the surface flow. This can mean no dilution of the nutrients in the bogwater in December opposed to the situation in October.
As stated above this counts especially for the water samples taken in the hummocks. The surface flow will take the superfluous water away from the hollows as stated above.

THE LAWN.

Obvious from figure 7 are the large amounts of potassium and phosphorous in the water of the lawn. These amounts are associated with winter and thus with dead *Narthecium* leaves. The rainwater leaches potassium and phosphorous from the dead leaf material in winter (Summerfield and Rieley,1963). In summer a lesser amount of potassium and phosphorous will be found in the bog water because most of it will be taken away from the water by root uptake. As mentioned in the discussion about the leaching of potassium, it is possible that potassium from the hollows reaches the lawn in the surface lawn. Calcium is, like , a key mineral for the growth of *Narthecium.*
The rest of the elements presented are indirectly important for *Narthecium* plants:
aluminium is an element which stimulates the uptake and is not favourable for *Narthecium* in large amounts.
manganese: a decrease in Ph and a high watertable increase the availabilaty of manganese which is also unfavourable.
Narthecium needs iron as a trace element but the roots are only able to take up the iron in the presence of other elements (Summerfield and Rieley,1963).

SURFACE FLOW IN THE SITE

Table 2 represents (see below) the amount of nutrients in the three tubes of the *Narthecium* lawn. It is conspious that all the elements show large amounts in tube one (see table 2 next page). This fact coincides with the field observation that the surface flow in this site is in

the direction of tube one. This observation was made when accidentally three different objects fell into the water of a hollow on the opposite side of tube one on different days (see map no.1): a pen, a pen cap and a little plastic cover. All three objects were very light and were suspended in the water, so they could not have been moved by the wind. A few days after each object fell into the water, it was found in the neighbourhood of tube one.
Combining this with the saturation of the capillary fringe and thus with surface flow from the hollows to presumably the lower side of the site; one can assume the surface flow in this site to be in the direction of tube one and thus the *Narthecium* lawn could be the lowest spot in this site. Damman affirms this by his statement that increased waterflow, rather than higher nutrient concentration appears to account for the occurance of more nutrient demanding species (Damman,1986).

Narthecium lawn

tubes no.	*1*	*45*	*51*				
phosphorous	0.35	0.03	0.03	iron	0.16	0.19	0.22
second time	0.12	0.04	0.09	second time	0.25	0.37	0.26
nitrogen	0.12	0.02	0.01	manganese	20	9	9
second time	0.04	0.01	0.06	second time	663	162	266
calcium	3	0.4	1.5	aluminium	0.01	0.01	0.02
second time	1.82	1.58	2.21	second time	0.4	0.2	0.55
potassium	2.1	0.5	0.5				
second time	1.13	0.58	1.04				

table 2 the amount of nutrients in the lawn

HYPOTHESIS FOR THE NUTRIENT BEHAVIOUR IN SUMMER.

The whole theory about nutrient behaviour has been hung on the watertable situation in winter. As there is a hypothesis for the summer situation (see also Ingram,1981), one can say that the situation will be completely different. On the first place because the capillary fringe will not be saturated which has consequences for the amount of nutrients that leach from hummock to hollow. This counts for nitrogen, phosphorous, potassium and calcium. For aluminium, iron and manganese, it is important that the watertable in summer is probably not flat but tilted. Following the hypothesis: the watertable will be lower beneath the hummock than beneath the hollow; one can expect a flow from hollow to hummock (in a stationary situation) meaning a realocation of iron, aluminium and manganese from hollow to hummock or slope.

CORRELATION WITH THE VEGETATION.

The correlation of the chemical data with the vegetation: it is notable from the dissussion that the position of the watertable is more important for the chemistry of hummocks and hollows than the floristical composition (Damman,1978). The floristical composition is ofcourse important but the distribution of elements by the watertable and the rain- and the bogwater determines the availability of nutrients i.e the occurance of *Narthecium ossifragum* on the site.

PIEZOMETERS

The piezometers were placed to detect a waterflow from hummock to hollow or eventually from hollow to hummock. This was based on the hypothesis of a tilted watertable (in that case a flow should be measurable). Firstly a flat watertable was observed so no stationary tilted watertable existed that could give rise to a waterflux. Secondly we now assume the capillary fringe to be satuarated. As said, we assume a measurable micro runoff from hummock to hollows to exist but only detectable in the unsaturated zone by tensiometers. It should have been possible to detect a surface flow from the hollows to the *Narthecium* lawn but the piezometers were not placed with the option to measure this surface flow. In summer the situation is different. According to the hypothesis the watertable will be tilted then and as this is a stationary situation there must be a detectable waterflux from hollow to hummock. A last remark, one has to take into account that the piezometers used are not suitable to measure flow from situation which is not stationary; that is flow with high speed because the piezometer reacts so fast that one has not time to measure this flow.

ANAEROBIC ZONE

The method used is inaccurate because the black colour on the wire is not unambiguous and one has to reckon with the movement of the bog surface. But if the wires are always analysed in the same way, this is a simple method to give an indication of the top of the anaerobic zone beneath the bog surface. The trend observed (see figure 7) was to be expected; but especially in transect no.1 (the square transect) the top of the anaerobic zone is lowest beneath a hollow (see the figure). If one sees the vegetation relevé belonging to tube no.41 (see vegetation table 1) the only species present is *Sp.cuspidatum* and this bog moss is not able to bring oxygen so deep down into the profile. The only explanation could be the *Eriophorum angustifolium* in relevé no.42 that is the only vascular plant in the neighbourhood with long roots. So possibly the vascular plants in the hollows disturb the picture sketched by transect no.2. The explanation for the large variation in time is very difficult to give. It can not be due to inaccuracy alone because the wires were always analyzed by the same person, an error of 20 cm is a bit too much. The fluctuation of the watertable has influence on the position of the anaerobic zone but the watertable only fluctuates 4.2 cm (over the measured interval).
It is not known why this large variation in time takes place, therefore a lot of information is needed about root ength and penetration in the rooting zone.

RECOMMENDATIONS

It will be clear that it is very important to establish the position of the capillary fringe (both for elemental distribution and floristical composition). The position of the capillary fringe can be established by tensiometer measurements. If the tensiometer shows a suction of 100 mbar (pF=2) at a certain point above the waterttable, the capillary fringe is saturated at that point. The boundary between the saturated and unsaturated capillary fringe can thus be established by tensiometers. A simulation of a capillary fringe should be made in the laboratory to determine the influence of the different species on the activity of the capillary fringe.

In winter other waterflow measurements are useful than in summer.
The position of the piezometers on hummock, slope and hollow is useful in summer (these piezometers were placed in Oct.1988).
In winter it is more important to measure the surface flow in the direction of tube one on the site (to understand the behaviour of the elements in hollows). Hot water and salt can be used to determine the flow direction of the water in the hollows.
In the hollows that are expected to contribute to the surface flow the flow direction could also be determined by piezometers.
In order to calculate Q (the output of the site for the water balance equation) other techniques are needed.

The position of the top of the anaerobic zone should be measured with other techniques than electricity wire only (i.e.with electrodes).
Electricity wire can only give a rough indication of the top of this zone. Together with better techniques pore distribution and rooting profiles should be determined.

To determine the accumulation and reallocation of elements in the *Sphagnum* and the *Spaghum* profile, it is important to understand their distribution in the bogwater.

ACKNOWLEDGEMENTS

I thank Peter van der Molen (who gave me the chance to do this project) for all his help in Ireland to get the project started and for listening to my ideas and giving constructive criticism on them.
I thank Marjel Neefjes for her being on the bog at the same time and making life more pleasant during pouring rain.
Thanks to Mary and Nancy Nestor for their help on the bog and supplying tea and a nice fire when we were totally wet.
Thanks to John Flyn, Jim Moore and Pat Warner of the Wild Life Service for their help and nice company. To Rob Bregman for carrying out chemical analysis and to Asker for correcting my english and last but not least to Raymond, Lex and Henk for solving computer problems.

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23

no.	species	
1	1 Drosera rotundifolia	[illegible]
2	2 Aulacomnium	[illegible]
3	3 Sp. tenellum	[illegible]
4	4 Cladonia portentosa	[illegible]
5	5 Cladonia ...	[illegible]
6	6 Hypnum	[illegible]
7	7 Sp. cappillifolium	[illegible]
8	8 Sp. imbricatum	[illegible]
9	9 Sp. papillosum	[illegible]
10	10 Sp. magellanicum	[illegible]
11	11 Calluna vulgaris	[illegible]
12	12 Erica tetralix	[illegible]
13	13 Andromeda polifolia	[illegible]
14	14 Oxycoccus palustris	[illegible]
15	15 Bare peat	[illegible]
16	16 Eriophorum vaginatum	[illegible]
17	17 Eriophorum angustifolium	[illegible]
18	18 Narthecium ossifragum	[illegible]
19	19 Open water	[illegible]
20	20 Sp. cuspidatum	[illegible]
21	21 Rhynchospora alba	[illegible]
22	22 Drosera anglica	[illegible]

Ia
Sp. cappillifolium hummock

Ib
Hypnum hummock

Ic

II
slope

IIIa

IIIb

IVa
lawn

IVb
transition to hollow

no.	species	
1	1 Drosera rotundifolia	[illegible]
2	2 Aulacomnium	[illegible]
3	3 Sp. tenellum	[illegible]
4	4 Cladonia portentosa	[illegible]
5	5 Cladonia ...	[illegible]
6	6 Hypnum	[illegible]
7	7 Sp. cappillifolium	[illegible]
8	8 Sp. imbricatum	[illegible]
9	9 Sp. papillosum	[illegible]
10	10 Sp. magellanicum	[illegible]
11	11 Calluna vulgaris	[illegible]
12	12 Erica tetralix	[illegible]
13	13 Andromeda polifolia	[illegible]
14	14 Oxycoccus palustris	[illegible]
15	15 Bare peat	[illegible]
16	16 Eriophorum vaginatum	[illegible]
17	17 Eriophorum angustifolium	[illegible]
18	18 Narthecium ossifragum	[illegible]
19	19 Open water	[illegible]
20	20 Sp. cuspidatum	[illegible]
21	21 Rhynchospora alba	[illegible]
22	22 Drosera anglica	[illegible]

V
true hollow

Ic = Sp. papillosum hummock

IIIa = Sp. cappillifolium edge

IIIb = Sp.magellanicum edge

vegetation table 1

vegetation table 2 (condensed vegetation table)

no.	veg. type	Ia			Ib			Ic			IIa		
1	number of relevé's.	11			7			4			11		
2	Drosera rotundifolia	I	0.09	1									
3	Aulacomnium	II	0.54	1-2				III	0.5	1	II	1.0	1-5
4	Sp.tenellum	III	1.45	1-10				III	0.5	1	III	1.09	1-3
5	Cladonia porticularis	I	2.5	3-25	III	15.7	15-50	II	9.5	38			
6	Cladonia epiphytisch	I	0.09	1	I	0.14	1						
7	Hypnum	V	4.3	1-10	V	31.4	15-60	III	2.25	4-5	II	1.2	2-5
8	Sp.cappillifolium	V	86.6	57-98	V	39.8	5-79	V	49.5	15-68	V	17.9	2-38
9	Sp.imbricatum	I	0.72	1-7	I	0.14	1	II	0.75	3	I	0.36	1-3
10	Sp.papillosum	I	0.27	1-2	I	0.43	3	V	23.75	15-35	II	2.5	3-20
11	Sp.magellanicum	III	1.64	1-5				IV	2.5	1-7	V	72.9	51-96
12	Calluna vulgaris	V	21.8	2-55	V	19.3	10-30	V	26.0	9-50	V	11.5	3-40
13	Erica tetralix	V	2.9	1-10	IV	1.14	1-2	IV	1.5	1-4	V	5.2	1-10
14	Andromeda polifolia	III	0.45	1	I	0.14	1	II	0.25	1	II	0.27	1
15	Oxycoccus palustris	IV	0.64	1	IV	0.71	1	III	0.5	1	I	0.18	1
16	Bare peat	II	1.27	4-5	IV	8.0	1-40				I	0.27	3
17	Eriophorum vaginatum	II	0.36	1-2	II	0.29	1	IV	0.75	1	II	0.72	1-3
18	Eriophorum angustifolium	III	1.36	1-8	IV	1.71	1-5	III	0.5	1	II	0.82	1-5
19	Narthecium ossifragum	II	1.63	1-10							II	2.64	5-10
20	Open water												
21	Sp.cuspidatum												
22	Rynchospora alba												
23	Drosera anglica												

no.	veg. type	IIIa			IIIb			IVa			IVb			V		
1	number of relevé's.	10			10			11			10			22		
2	Drosera rotundifolia															
3	Aulacomnium															
4	Sp.tenellum	I	0.5	5												
5	Cladonia porticularis	I	0.3	3												
6	Cladonia epiphytisch	II	0.3	1	I	0.1	1									
7	Hypnum	IV	11.6	1-58	II	11.0	45-65									
8	Sp.cappillifolium	V	24.8	4-80	III	1.9	2-10									
9	Sp.imbricatum	II	4.5	20-25	I	0.2	2									
10	Sp.papillosum	III	3.3	3-20	III	12.8	5-73									
11	Sp.magellanicum	II	2.0	5-15	IV	25.4	5-96									
12	Calluna vulgaris	IV	11.5	3-35	III	4.4	2-19	V	8.45	1-60	V	3.8	1-10			
13	Erica tetralix	V	4.9	1-21	IV	3.3	1-10	IV	1.2	1-5	II	1.2	1-7			
14	Andromeda polifolia	III	0.5	1-2	II	0.3	1-1	I	0.18	1-1	I	0.1	1			
15	Oxycoccus palustris	II	0.2	1-1	II	0.3	1-1	IV	1.54	1-6						
16	Bare peat	II	2.5	10-15	I	2.0	20	IV	45.8	5-97						
17	Eriophorum vaginatum	II	0.6	1-3	II	0.4	1-2	V	7.09	1-40	III	0.7	1-3	III	0.64	1-4
18	Eriophorum angustifolium	IV	1.1	1-4	IV	1.1	1-3	V	3.2	1-10	III	1.2	1-5	III	1.14	1-5
19	Narthecium ossifragum	II	0.3	1-2	II	1.0	3-7	V	67.2	40-85	III	1.2	1-7	II	0.36	1-2
20	Open water	V	6.4	3-25	IV	3.9	2-15	II	2.4	1-20	V	8.0	2-30	IV	4.14	1-20
21	Sp.cuspidatum	V	31.9	6-75	V	37.4	4-95	V	31.5	2-75	V	92.2	70-100	V	100	80-100
22	Rynchospora alba				III	1.4	1-5				III	1.2	1-3	III	1.77	1-10
23	Drosera anglica													I	0.045	1

The information in this table consists of three parts:
the first part shows the presence (times present in total number of relevés)
I = 0-20%
II = 21-40%
III =41-60%
IV =61-80%
V =81-100%
The second part is the average abundancy of the total number of relevés.
the third part represents the lowest and highest occuring abundancies.

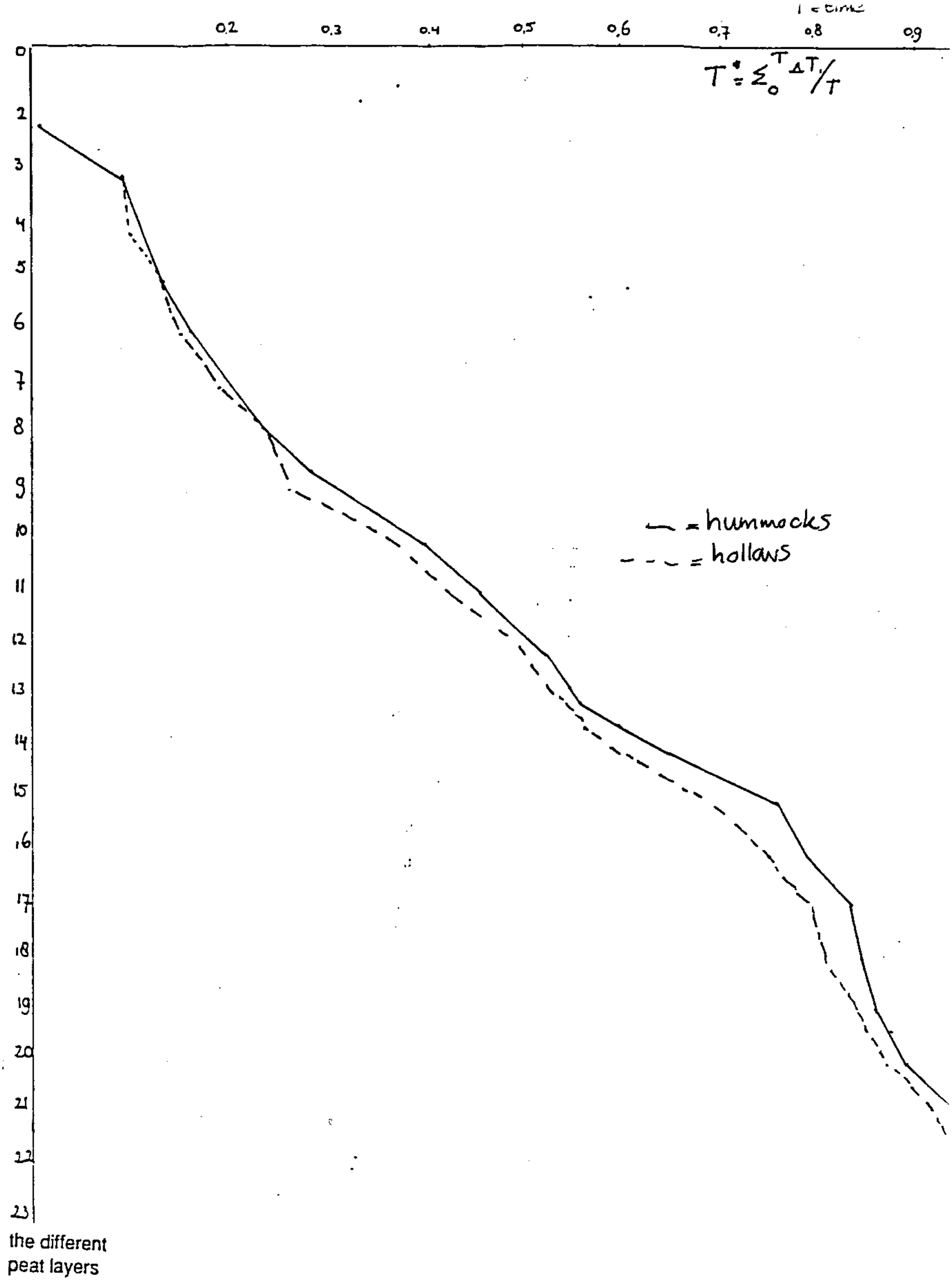
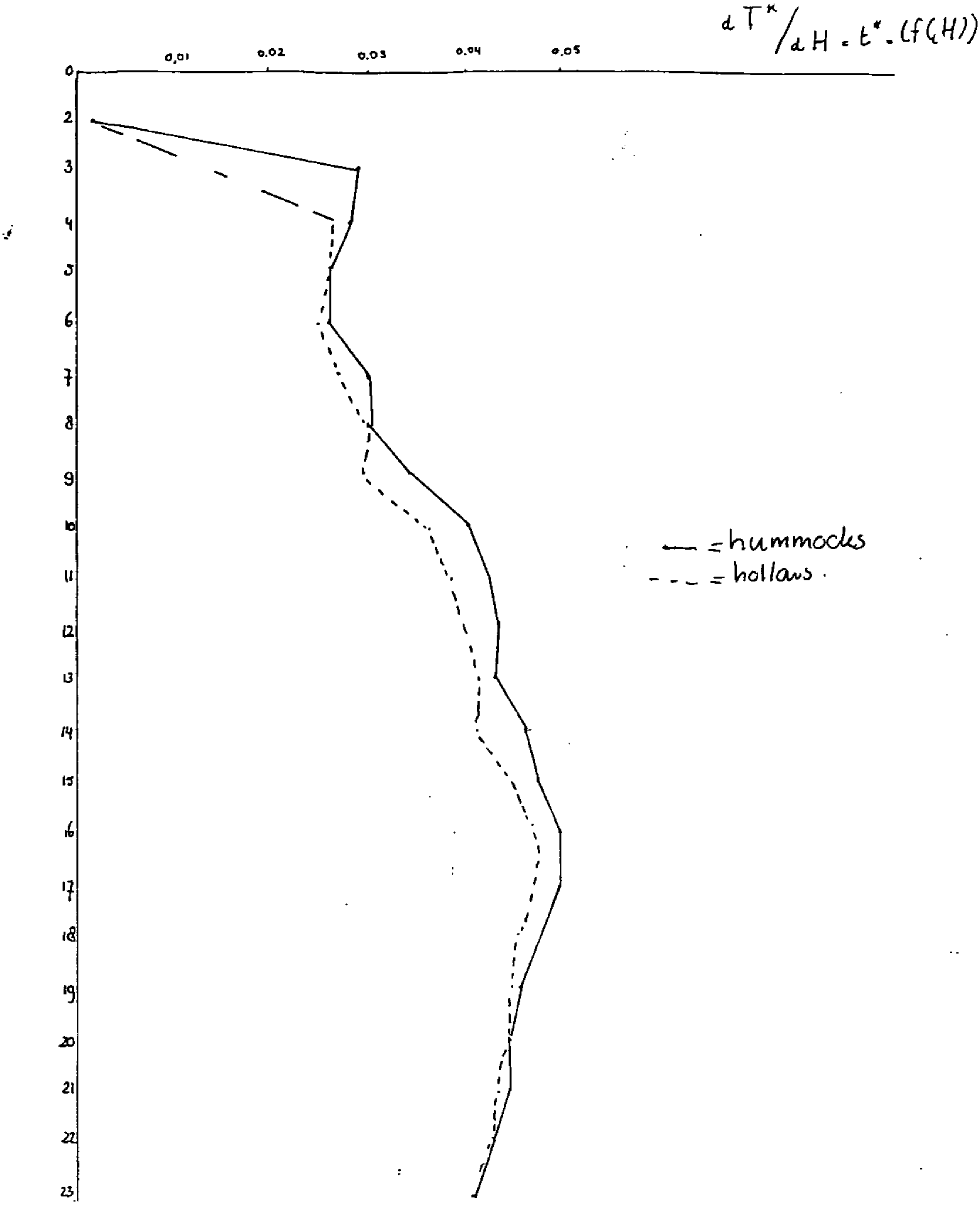


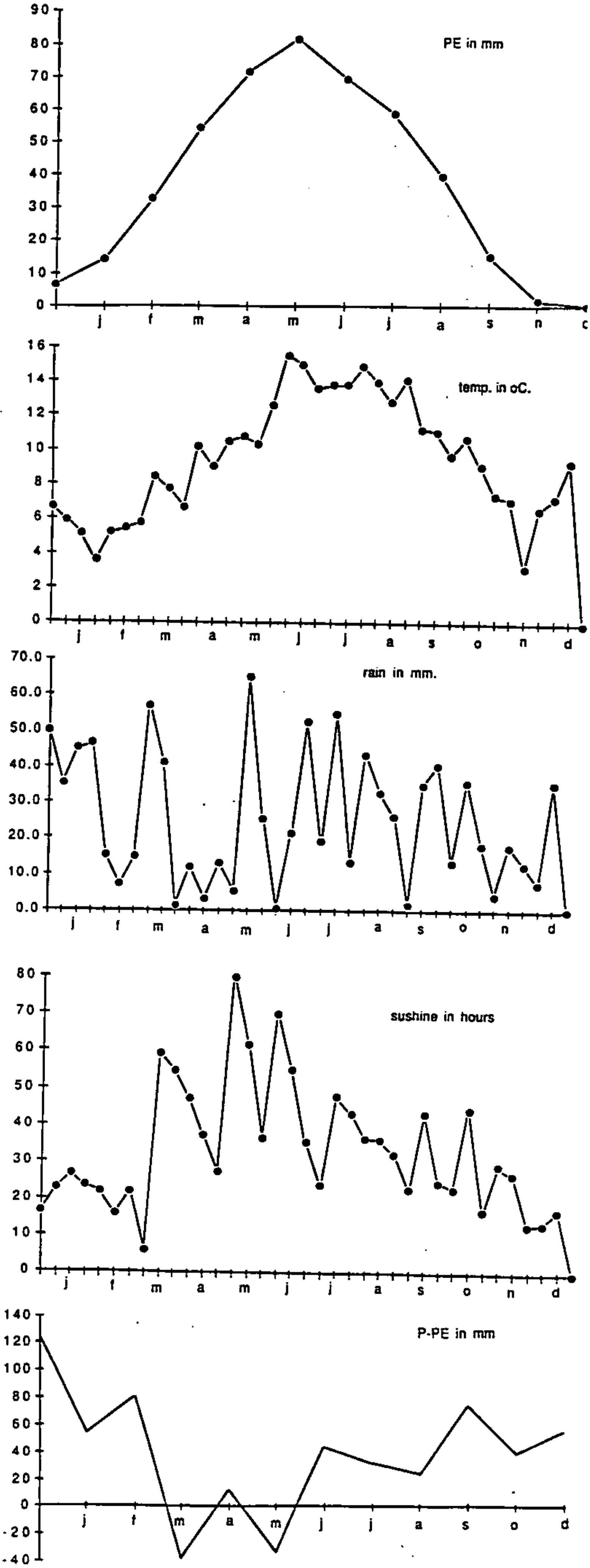
fig 4 watertable residence curve (the occupation of the different peat layers by water as a percentage of time)



the different
peat layers

fig 5 watertable frequency curve (the frequency of inundation of a certain layer)

H=the height of each layer above local datum surface T=time



on all the [illegible] axis months of the year

fig 6 the weather of 1988 and a

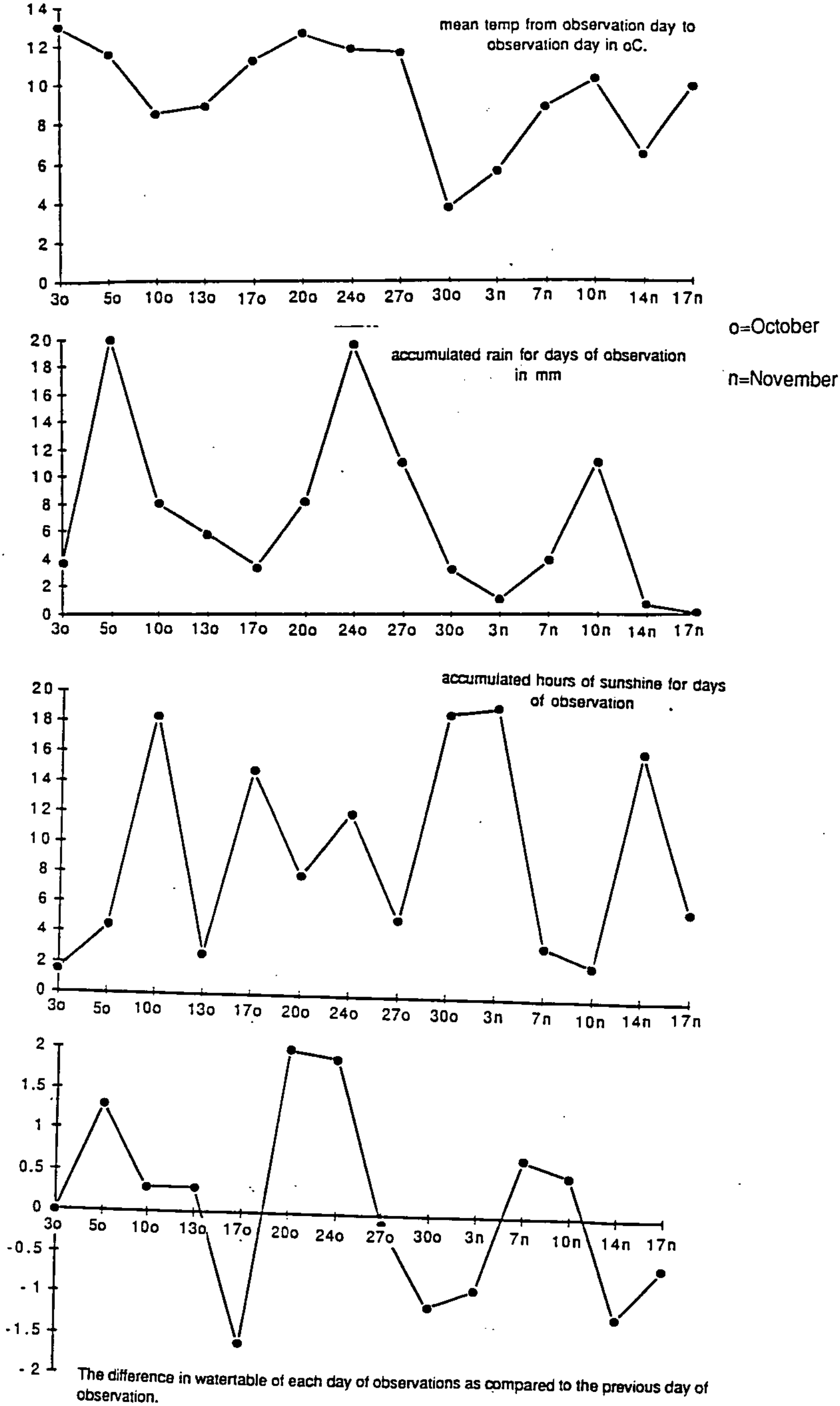
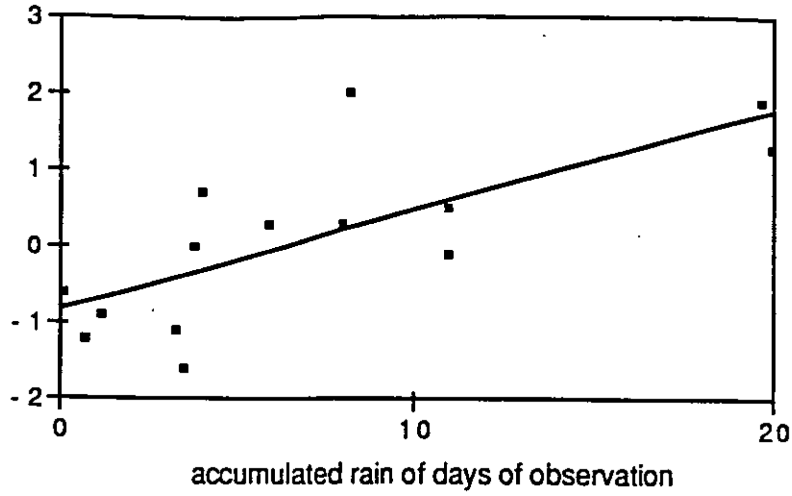


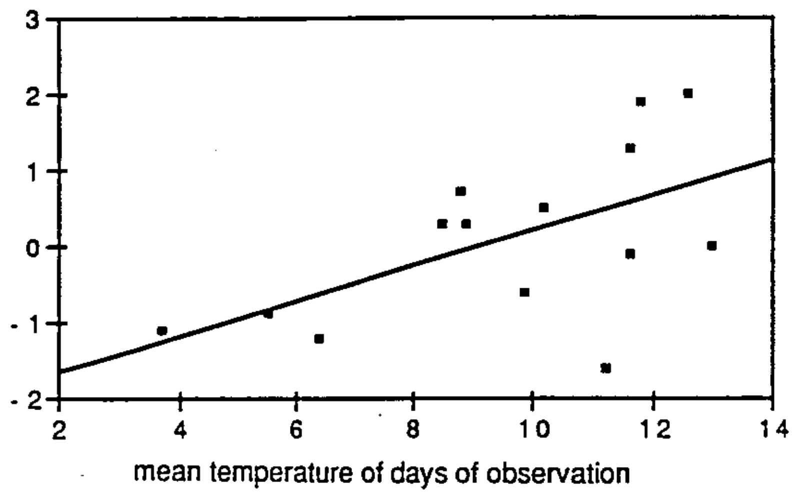
fig 7 weather during the measured interval.

The difference in watertable of each day of observations as compared to the previous day of observation. (on the vertical axis)

r=0.77



r=0.57



r=0.442

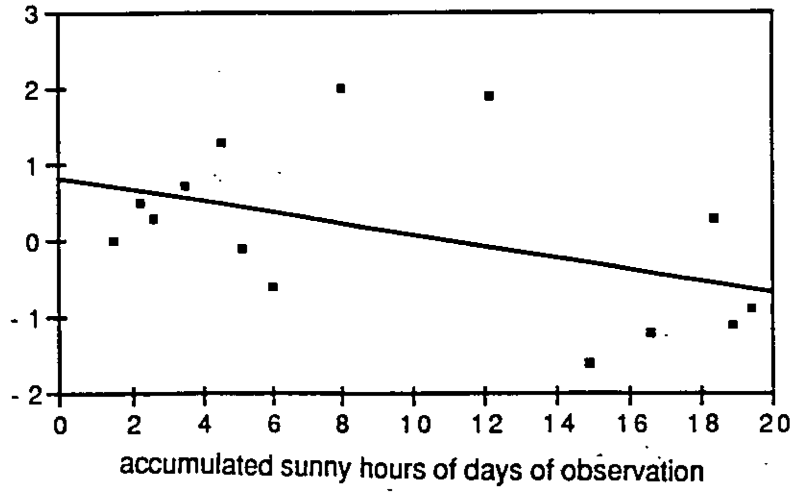


fig 8 regression coeffiënt for watertable difference with rain, temp and sunny hours

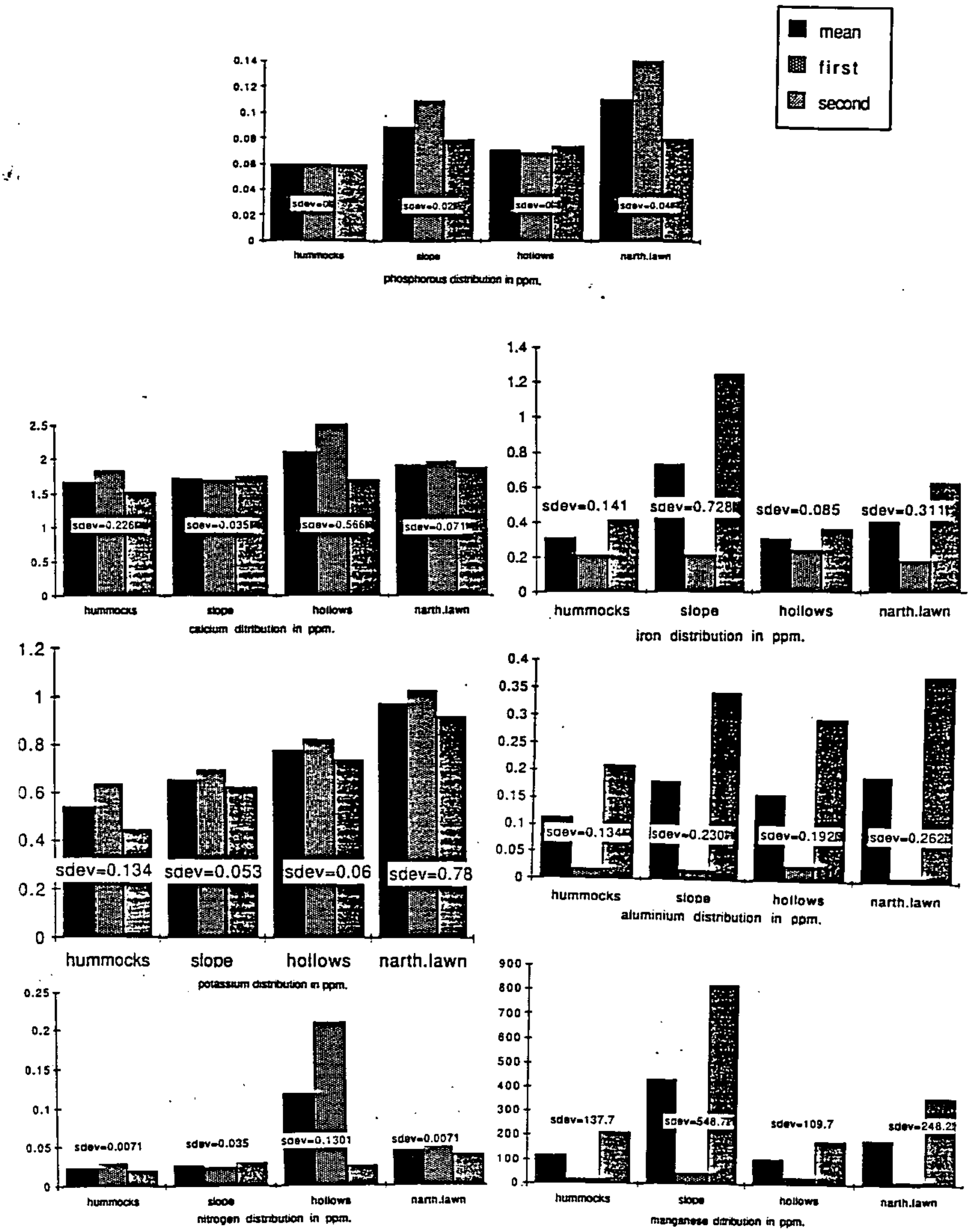
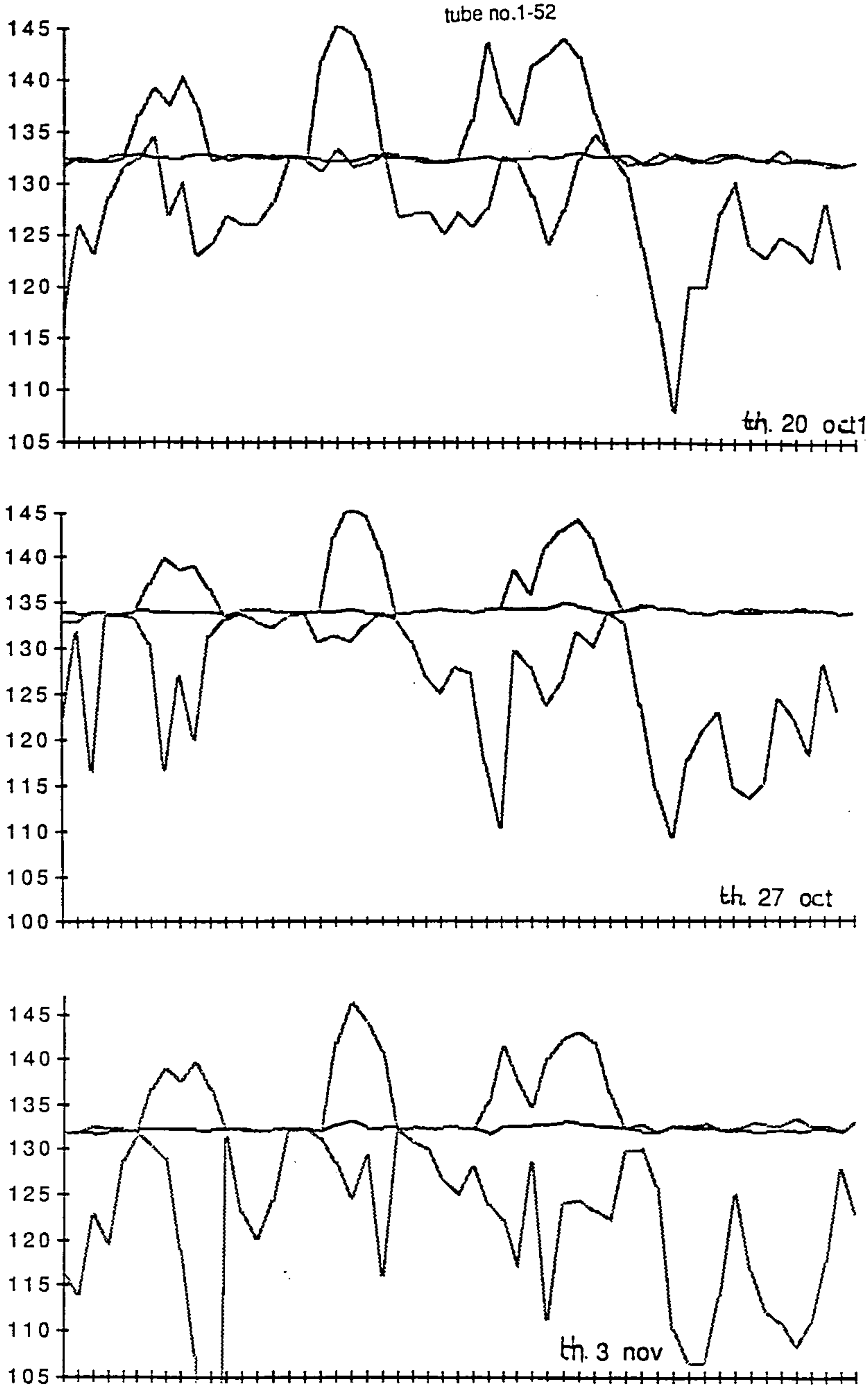


fig 9 nutrients distribution in ppm both in spacial and temporal variation.
first= first date of sampling
second= second date of sampling



Under hummock no. 1 one electricity wire was missing.

fig 11: The height of the bog surface
the watertable
and the top of the anaerobic zone
above local datum surface. (in cm)

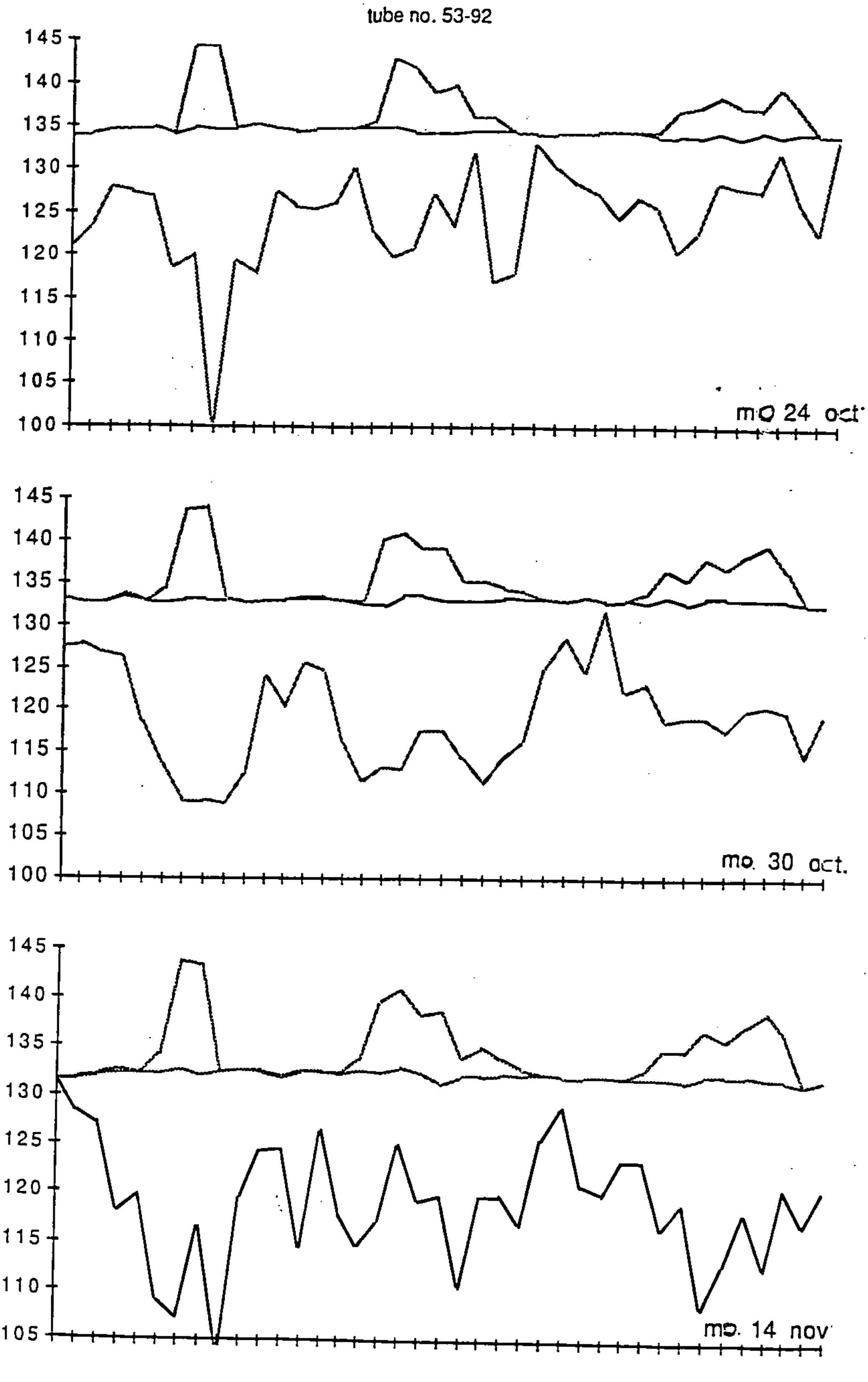
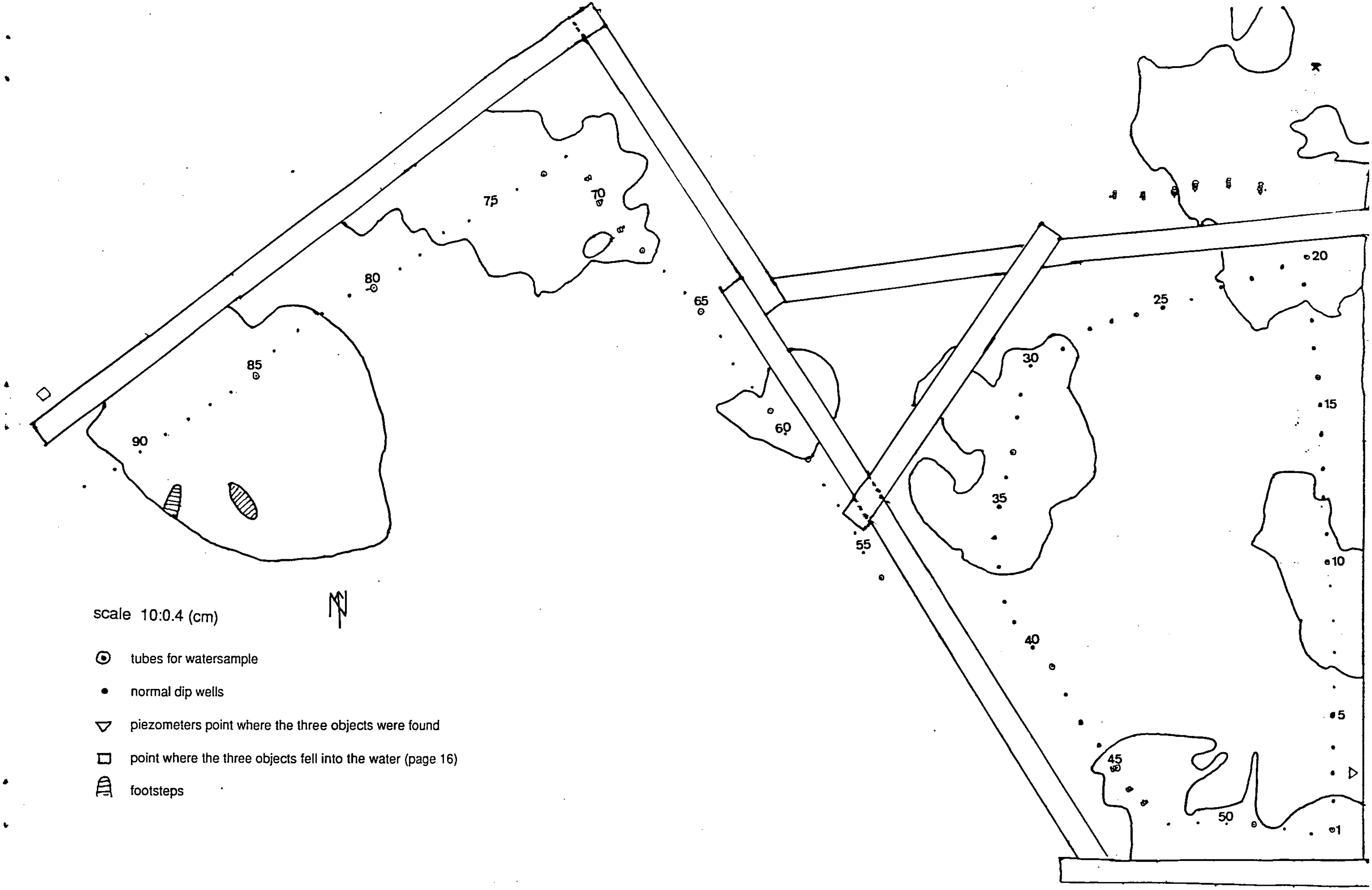
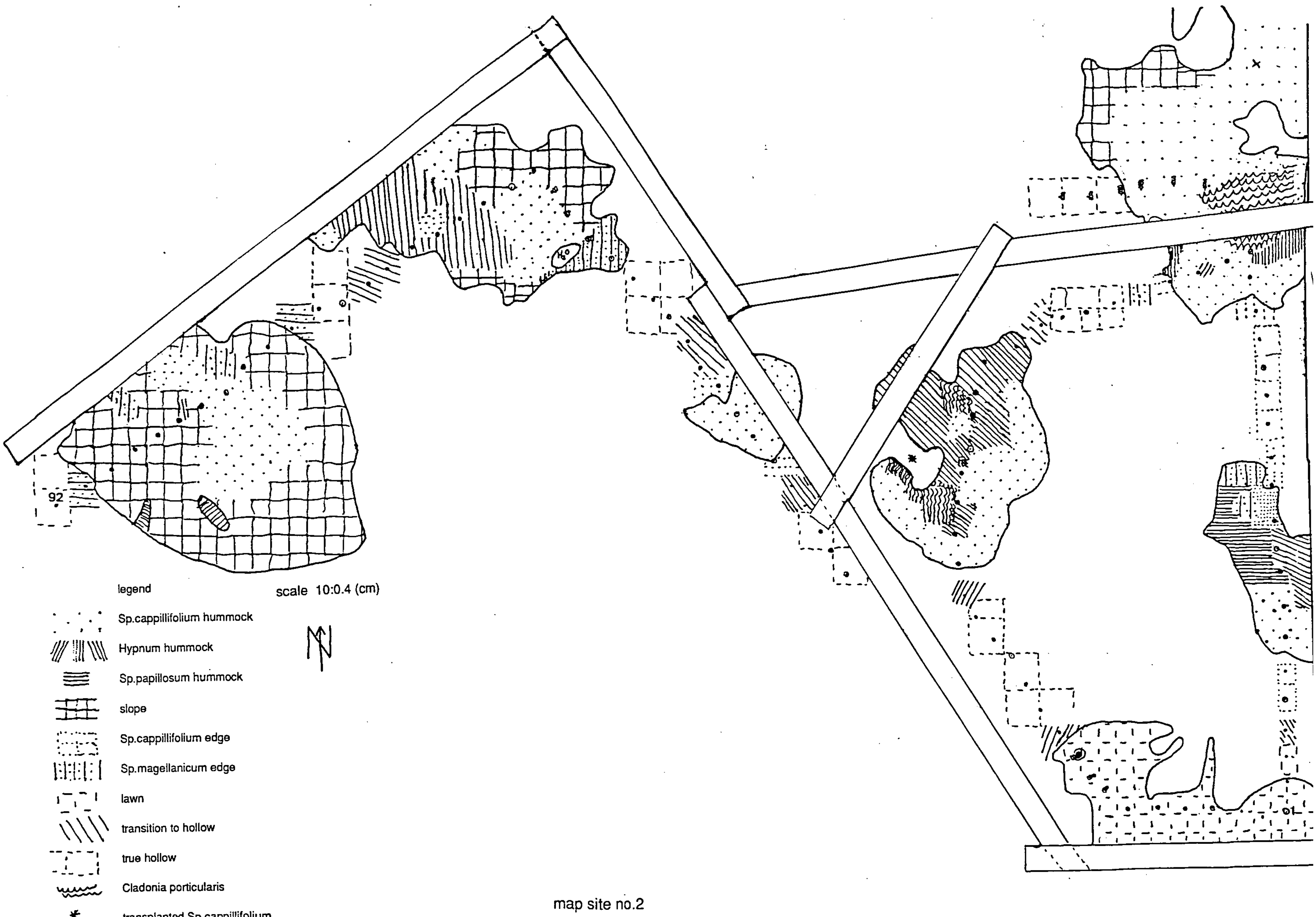


fig 11 The height of the bog surface
the watertable
and the top of the anaerobic zone
above local datum surface. (in cm)



70
75
80
85
90
65
60
55
30
35
40
45
50
25
20
15
10
5
1
scale 10:0.4 (cm)
N
tubes for watersample
normal dip wells
piezometers point where the three objects were found
point where the three objects fell into the water (page 16)
footsteps

map site no. 1


92
legend
scale 10:0.4 (cm)
N
Sp.cappillifolium hummock
Hypnum hummock
Sp.papillosum hummock
slope
Sp.cappillifolium edge
Sp.magellanicum edge
lawn
transition to hollow
true hollow
Cladonia porticularis
transplanted Sp.cappillifolium

map site no.2