IRISH - DUTCH RAISED BOG STUDY

GEOHYDROLOGY AND ECOLOGY

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EXPERIMENTAL MANAGEMENT MEASURES IN THE SOUTH-EAST CORNER OF THE RAHEENMORE RAISED BOG RESERVE.

Sketch of Clara Bog by Catherine O' Brien, Clara, County Offaly.

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April, 1994

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1. INTRODUCTION

This document further specifies the technical measures which were described in a proceeding document, called "General proposals for technical measures for the conservation and restoration of the raised bogs Clara Bog and Raheenmore" (Streefkerk et al. 1993). Basic principles of the construction of dams of poorly and strongly humified peat on and alongside raised bogs are given and technical specifications for the construction of experimental peat dams in the SE-corner of Raheenmore are provided. Finally, an indication is given of the type of monitoring needed for the assessment of the proposed management measures.

A final and more detailed proposal for technical management measures for both bogs will be completed in september of 1994.

2. PLAN FOR EXPERIMENTAL DAMS IN THE SE-CORNER OF RAHEENMORE

2.1 General purpose of dams

The normal purpose of dams alongside and on a raised bog is the prevention of further peat subsidence. Subsidence of peat in the peripheral sections of a raised bog accelerates water discharge from the bog and leads to a gradually encroaching desiccation of the top peat layer (the so-called acrotelm) towards the more central parts of the bog. The conservation of the acrotelm with its specific hydrological and ecological functions, is essential for the bog's survival (Streefkerk and Casparie, 1989; Sijtsma and Veldhuizen, 1992; v.d. Cruysen et al., 1993).

Studies by van 't Hullenaar and ten Cate (1991) and v.d. Cruysen et al. (1993) have shown that at an inclination of the bog surface of more than 0.3 m/100 m, an acrotelm is largely absent on Clara Bog and Raheenmore. In bog sections with good conservation prospects, dams can be used to prevent further subsidence in order to maintain a surface inclination at the above magnitude or even to decrease the existing inclination if this has exceeded the critical level.

It has been ascertained that large parts of Raheenmore have been sufferd from peat subsidence and the central pool system seem to have been affected by the resulting increeased water discharge from the bog.
A plastic foilscreen alone is not sufficient to stop futher peat subsidence. Water discharge through the acrotelm can be stopped by such a screen but the inclination of the surface of the bog will not be reduced in this way. For that purpose dams will have to be built on the bog.

Care should be taken, however, that the peat-forming vegetation complexes are not negatively affected by this management measure. The so-called system-linked discharge (Streefkerk and Casparie, 1989), by which minerals are re-allocated, should be retained. Therefore, the lateral water movement over the bog surface and through the upper peat layer should not be fully obstructed.

After a dam has been built, water will collect on the bog surface at the inner side of the dam and at that location there will be no further peat subsidence. At the same time, the surface gradient (and the hydraulic gradient) is decreased. Next, two developments are possible. Colonization of the open water by Sphagnum cuspidatum may start after a certain period of time (usually 3-5 years), When the water has become completely in-filled with Sphagnum cuspidatum, other Sphagnum species may establish and after some 50 to a 100 years the original water body may have become fully terrestrialized; acrotelm functions will then have been restored at that location.
As a second possibility, the upper peat layer in the area towards the inner side of the dam may start to swell and eventually no open water is left at the bog surface. Usually no new acrotelm develops under these circumstances as the structural changes of the upper peat layer, which were caused by drainage, are irreversaible. But as the inclination of the bog surface has decreased as a result of peat-swelling, the surface-discharge will also be of a lower order than before, which ensures the conservation of more central bog sections with a still intact acrotelm. Retention of surface water in the central parts of the bog may even lead to new pool and hollow formation.

2.2 Experimental dams: aims and methods

Apart from the Corlea-project in which peat dams were built on a small bog remainder in order to conserve a Neolithic trackway in situ, there is little experience in Ireland with dam construction on peatlands. In the cases of Clara Bog and Raheenmore, the conditions are much wetter than in the Corlea-project. The water content of the peat at the surface of the two bogs was shown to be between 85 and 95% (Sijtsma and Veldhuizen, 1992; ten Dam and Spieksma, 1993; McGarry and Loughman, 1993). It may very well be possible that dam construction on relatively wet peat involves specific problems. There is a realistic chance that at a certain pressure, dams may partly sink into the weak bog peat, in that way losing their effectivity.

Soil mechanical studies may provide information on the carrying capacity of the bog surface in Clara and Raheenmore, but such studies need to be extensive and are, therefore, time-consuming and expensive. Moreover, they do not provide information on the technicalities of the actual dam building. A more direct (and possibly cheaper) way of assessing risks of dam failure and of determining preconditions for dam construction on the relatively weak peat of the two reserves, is by carrying out construction experiments in a comparable location. There is no indication that dam building in the reserves will be less successful when based upon empirical data obtained in this manner. As the experimental method was preferred as it will also provide information on a number of technical problems connected to the actual building of dams. An area in the SE-corner of Raheenmore was selected for the experiments.

It is clear that the weight of the dams on the high bog should be reduced as far as possible. For that reason experiments were designed for the use of light dams in combination with plastic-foil screens. Heavy dams will only be built alongside face-banks.

2.3 Vegetation, condition of acrotelm and hydrology of the experimental area.

The area in which the experiments will be conducted, comparises 4.0 ha of cut-away and about 4.5 ha of adjoining high bog in the SE-corner of Raheenmore. At its northern side, this area borders on a section of the bog which was drained some 150 years ago through a series of surface drains. The cut-away has been abandoned after peat extraction; the surface peat has completely dried out and the vegetation largely consists of Molinea caerulea-stands and Ulex europeus-scrub.
The high bog section in the experimental area contains the following plant communities:

- the face-bank has desiccated over a width of 10 to 40 m and shows a vegetation which is dominated by Calluna vulgaris, indicating extremely dry soil conditions. There is no acrotelm.
- Towards the centre of the bog the face-bank community is replaced by a vegetation-type dominated by Scirpus cespitosus (width of Scirpus-zone about 20 m). The Scirpus-dominated community is typical of raised bog margins which have suffered from drainage. The community also indicates a certain amount of peat mineralisation. Again there is no acrotelm in this zone.
- The largest part (>80%) of the high bog section in the experimental area is covered by a vegetation type in which Narthecium ossifragum and Calluna vulgaris codominate. This vegetation type is usually found as a sub-peripheral community in raised bogs. Locally the acrotelm is still reasonably intact but for the most part only rudiments of an acrotelm remain. This part of the bog presumably had a better developed acrotelm in the past (with the associated plant communities) but this has in all likelihood deteriorated as a result of drainage and peat subsidence.
- To the west, the experimental area borders on a zone with an intact acrotelm. The associated vegetation type (Sphagnum magellanicum-complex) is typical of sub-central sections of raised bogs and represents a transition between the central and the peripheral plant communities. The Sphagnum magellanicum-complex is occasionally also found in hollows in the experimental area.

2.4. Conclusions

An acrotelm is largely absent from the experimental area; only locally peat-forming plant communities are still present. Like in the rest of the bog, the catotelm is still quite wet with a water content between 85 and 90%. However, the top peat layer in the experimental area (up to a depth of several dm's) is drier than in the more central parts of both Raheenmore and Clara Bog. But as the dams will largely be constructed in the peripheral zones of the two bog sites, the selected area seems to be adequate for conducting the proposed experiments.

It is expected that dam construction will not lead to a regeneration of the acrotelm in the experimental area. Only where open water will be permanently retained on the bog surface (that is in areas where the top peat layer will not swell after the dams have been built and where even under

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periods of draught the water level will remain over the bog surface) terrestrialization processes may lead to new acrotelm formation. To the west, the experimental area borders on peat-forming vegetation complexes. These will be conserved if the proposed dams will indeed counteract further peat subsidence.

3. TYPES OF MANAGEMENT MEASURES AND POSSIBLE RESTRICTIONS TO DAM CONSTRUCTION.

3.1. Dams of poorly humified moss-peat on the high bog.

From the acrotelm map (v.'t Hullenaar and ten Kate, 1991) and the vegetation map (Kelly, 1993) it can be concluded that the effects of desiccation and subsidence reach into the Raheenmore bog reserve over a distance of 80 to 100 m. As stated above, an acrotelm was shown to be present where the inclination of the bog surface did not exceed 0.3 m/100 m. For the peripheral sections of the bog peat subsidence has been demonstrated (Sijtsma and Veldhuizen, 1992) and this has resulted in an increased inclination of the bog surface. In these sections an acrotelm is largely absent. It is not clear whether the process of desiccation and subsidence has come to a stand-still. A long-term study of the changes in surface-level should provide more information in this respect (see section 6.3).

Dams of poorly humified moss-peat are normally constructed to prevent further peat subsidence and to conserve the acrotelm functions. Such dams are built on top of poorly humified peat and they can be combined with screens of plastic foil which are inserted into the bog. The material used for dam construction should be moss-peat with a humification degree of 5 or less on the van Post scale.

Dutch experience in dam construction has shown that it is important to investigate the peat stratigraphy at the planned location before actually building a dam. Also in the Netherlands, dams of poorly humified peat were built on high bog (remainders). Usually the water content of the bog's top peat layer was much lower than in the case of Clara Bog and Raheenmore.

During bog restoration projects in the Netherlands the water content of the peat used for dam construction was never actually determined. Experience with the use of the generally rather dry peat material for dam building was gained experimentally. In the more humid Irish climate the requirements of the peat (to be used for dams) in terms of water content may be quite different from the Dutch situation. In the Corlea Bog-project Bord na Mona concluded that peat with a water content of 80% or less can be used for dam construction. At higher water contents, however, it proved to be unsuitable. This seem to be a useful guideline. It is to be advised to always determine the peat water content before dam construction so that possible relations between dam failure and water content can be estabIised.

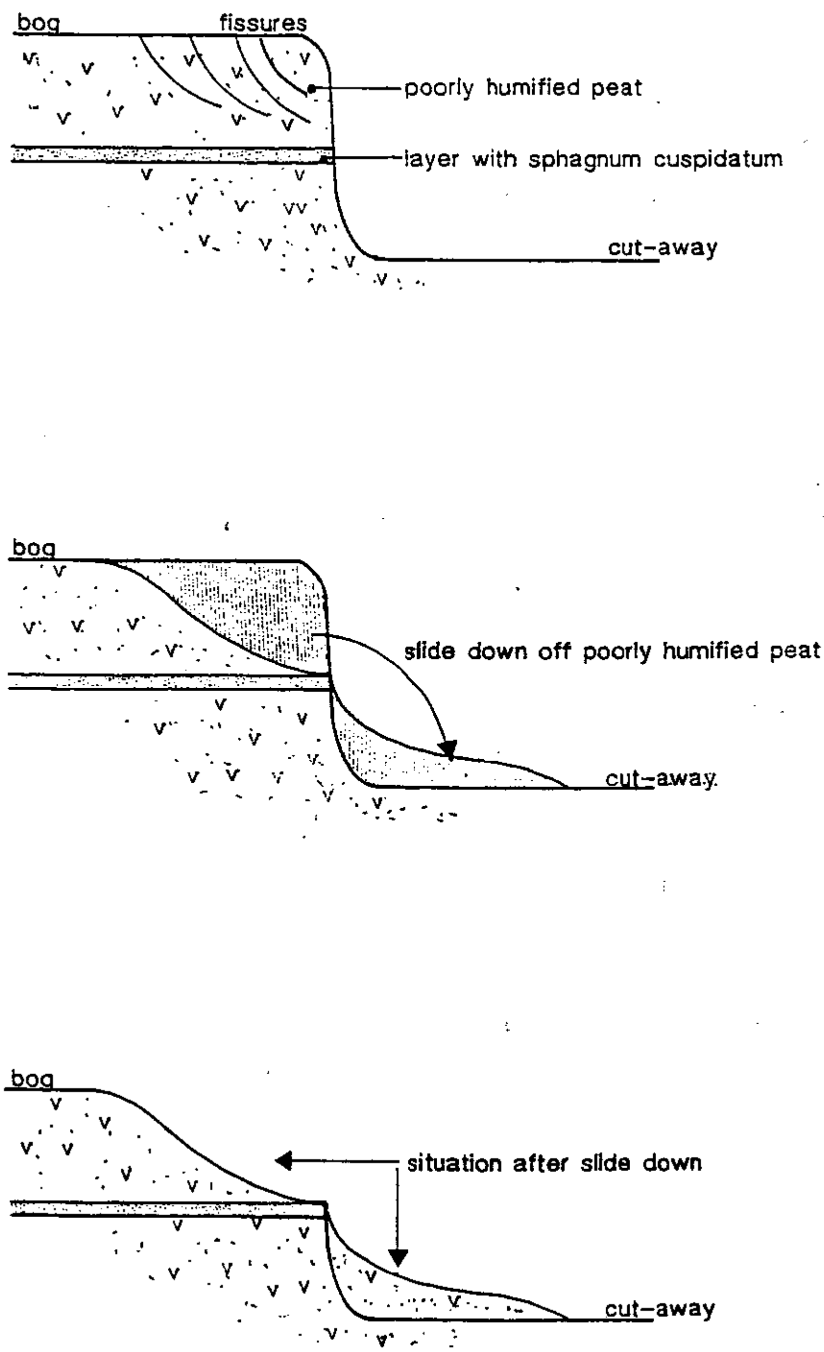
Nevertheless, dams have collapsed, particularly at the edges of the bog remainders. The presence in the bog of horizontal layers of weak and poorly decomposed peat, largely consisting of Sphagnum cuspidatum, was responsible for the collapse. Such layers, formed under very wet conditions, form potential sliding surfaces. When the soil mechanical balance is disturbed by peat extraction (decrease of lateral pressure) or by dam building (increase of vertical pressure) there is a chance of mass movement over such a sliding surface. The rewetting of the bog (including such Sphagnum cuspidatum layers) after the dam has been built and the increase of vertical pressure when surface water is retained at the inner side of the dam, further increase the risks of mass movement. Figure I. illustrates the process of mass movement.
At Clara Bog such poorly humified peat strata were also observed at freshly cut face-banks. Research by Bloetjes and van der Meer (1993) has indeed confirmed the presence of peat layers with a high water content in the bog. Furthermore, at the margins of Clara Bog and of Raheenmore, there are numerous locations where fissures have formed in the bog surface and in several areas the face-banks have partly collapsed (see maps by J. Moore, Ranger of the Wildlife Service, 1992). Further peat extraction or dam building near the bog margin may very well lead to mass movement. Before building dams on the high bog, the peat stratigraphy at the proposed location should, therefore, first be studied. If possible sliding surfaces are detected, plans should be modified. Despite such precautions however, a 100% garantee that mass movement will not occur at some stage, can not be given.

3.2 Dams of strongly humified peat against the face-bank

The purpose of such dams is the prevention mass movement and of further peat subsidence. The dam has to be built from strongly humified moss-peat and in the experiment two angles for the outer slope will be tested (2:1 and 4:1). The surface layer of the dam should consist of poorly decomposed moss-peat. This enhances the dam's stability and is , moreover, conducive to a quick colonization by vegetation.

In the Netherlands (Bargerveen, Engbertsdijksvenen, Fochteloerveen) experience has primarily been gained with dams of strongly humified peat (humification degree of 5 or more on the van Post scale). Also in Ireland (Corlea Bog) peat with a humification degree

Figure 1: Illustration of the proces of mass movement.



of 5 or more was successfully used for dam construction (pers. comm. O'Donnell, Bord na Mona). A humification degree of at least 5 on the van Post scale seems to be a basic requirement for this type of dam.

Bord na Mona (McGarry and Loughman, 1993) have investigated the peat stratigraphy of the experimental area at Raheenmore. The data show that no significant quantities of poorly humified nor of strongly humified moss-peat (humification degree > 5) remain in the cut-away. The peat that is left in the cut-aways has a humification degree of 5 or more and it largely concerns fen-peat with a high content of wood remains. In various locations this fen-peat has been mixed with poorly humified moss-peat in the process of peat extraction. No experience has been gained with the use of this type of material for dam construction. However, fen-peat is generally considered to be unsuitable for the following reasons:

- The C/N ratio of plant material has been used as a measure for its degradability (Janssen et al., 1989). If the C/N ratio is over 30, N becomes a limiting factor for microbiological activity and the organic matter is immobilized. Ombrotrophic bogs have a C/N ratio between 35 and 60, which explains why Sphagnum peat is only slowly broken down when exposed to the air. The C/N ratio of peat formed under minerotrophic conditions is considerably lower. For eutrophic fen-peat it is between 15 and 25; for mesotrophic fen-peat between 25 and 35. Fen-peat is, therefore, more readily decomposed through microbiological activity; when exposed to the air decomposition may be quite rapid.

- Because of the high content of wood remains, the degree of compaction of the fen-peat is relatively low. This further decreases its suitability for dam construction.

3.3 The creation of a flooded depression in the cut-away

By this experiment, the possibilities of lagg-restoration will be investigated. A permanently flooded basin will be created in a low-lying area of the cut-away by removing the top peat (down into the minerotrophic fen-peat layer. The depression formed in this way should be fed by both regional groundwater and by ombrotrophic bog water. Colonization by mesotrophic mire-communities is then expected.

4. TECHNICAL PRINCIPLES OF THE EXPERIMENTAL MANAGEMENT MEASURES

4.1 Dams of poorly humified moss-peat

4.1.1 Principles of determining dam locations

- By the surface contour map, which shows the catchment boundary, and by the vegetation map (Kelly, 1993), the boundary of the area which should be affected by the management measures can be determined. This boundary line is indicated on a map in appendix 1. The location of the dams as well as the proposed water levels at their inner sides, should be such that the effects of the management measures do not reach beyond the catchment boundary.
- The inclination of the bog surface in the area adjoining the bog section which still contains peat-forming plant communities, should be brought to a magnitude of 0.3m/100m or less. The distance between the dams and the proposed water levels at their inner sides should be determined by this principle.
- The surface contours of the bog, which determine the flow direction of the surface-discharge, then prescribe the exact location of the dams. Dams should be planned in such a way that there is a logical drop in water levels.
- After the dam locations have been marked in the field, the peat stratigraphy at the respective locations should be surveyed and the bulk density of the bog peat should be determined:
  . the peat stratigraphical and bulk density data provide basic information on peat conditions in th bog which can later be related to the succes or failure of the respective dams.
  . If layers of Sphagnum cuspidatum peat are discovered in the upper 4 m or if the bog peat shows low bulk densities (little peat compaction), the location for the dam should be changed. Care should be taken that changes in the dam location do not effect the overall objective of the dam construction.

4.1.2 Principles of the application of plastic-foil screens

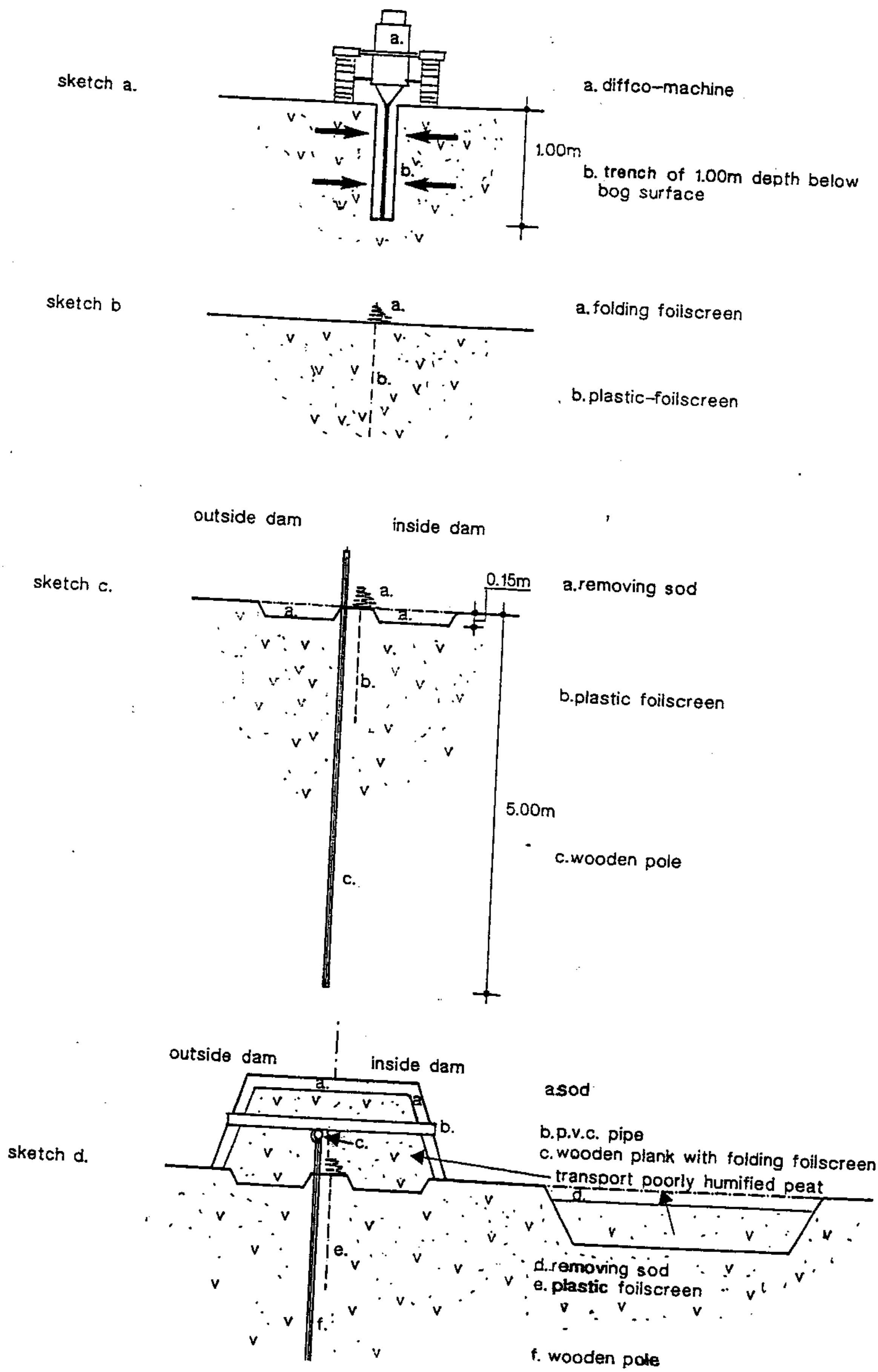
Figure 2. illustrates the use of plastic-foil screens.

a. The first procedure in the application of plastic-foil screens is indicated Fig. 1.a. A trench is dug by a Diffco-machine; a plastic screen is then inserted into the trench to a depth of 1 m under the bog surface.

b In the Bargerveen such screens were anchored in strongly humified moss-peat. In Raheenmore such peat is only found at depths greater than 2.5 m. For practical reasons the foil can not be inserted to such a depth. The foil should, therefore, be anchored by tightly closing the trench again after insertion (Fig. 2.b.)

c The height of the plastic screen is determined by:
  - The depth to which it is inserted (1 m).
  - The required water level at the inner side of the dam.
    Because of the steep hydraulic gradient at the bog margin, the depth of the water that will become stagnant in front of the dam will increase towards the bog margin (see section 4.2.2., Figs. 4. and 5.). The required screen heights will, therefore, also increase in this direction.
  - Possible raise of the bog surface level as a result of peat swelling.
    Swelling of the peat after it has been rewetted, may raise the bog surface level and also the dam level. As the foil needs to be extended when the surface level

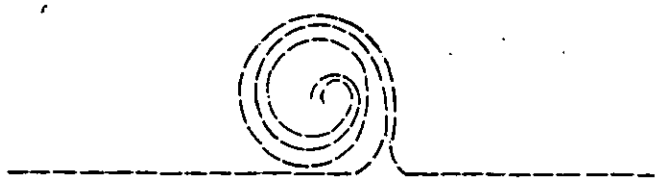
Figure 2: Application of plastic-foil screens



rises, a sufficient height of foil should be used (the surplus at the beginning of the operation is folded and is later incorporated into the base of the dam). The top of the screen is wrapped around a board and when the dam is eventually constructed, the foil will be incorporated in it (see section 4.1.3)

d. Different screens can be connected by adjoining and rolling up their two ends as indicated in Fig. 3.

Figure 3: Two plastic foilscreens rolled together



4.1.3 Technical principles of dam construction

If layers of Sphagnum cuspidatum peat are discovered in the upper 4 m or if the bog peat shows low bulk densities (little peat compaction), the location for the dam should be changed. Care should be taken that changes in the dam location do not affect the overall objective of the dam construction.

In the experimental stage, there are in principle two means of constructing dams of poorly humified moss-peat on the high bog, i.e. with or without a plastic-foil screen.

Dams with a plastic screen

a. After the screen has been inserted into the bog, dam construction can be initiated

b. First the top sod should be removed from the bog over the width of the dam base, so that the dam will directly connect with the (fresh) peat in the bog. This is essential for the dam's stability and for the prevention of leakages in the future. The top sod must be removed to a depth of about 0.15 m at both sides of the screen, but a small area adjacent to the screen should remain intact. The sod-stripping should be done with care as the sods will later be used to cover the dam (see below).

c. To stabilize the dam, wooden posts should be erected at the outside of the plastic screen (see Fig. 2.c.). The distance between the posts should be 5 m and they should be inserted into the bog down to a depth at which the pole sticks and will not go down any further. The length of the poles is determined by the insertion depth, the required height of the dam and the possible raise of the bog surface as a result of peat swelling. The pole should be sawn off at the predicted level of the water surface behind the dam. The top of the pole should be notched in order to hold the wooden plank with the folding foilscreen at the predicted level of the water surface behind the dam.

d. Next, the actual dam can be constructed. The height of the dam will be determined by the required water level at its inner side. Eventually, that is after the peat used for the construction will have subsided, the top of the dam should be 0.30 m over that water level. To account for peat subsidence, the dam should be erected to 0.20 m over the required dam height. After the envisaged height of the dam and required water level have been marked on a series of pickets, the dam can be erected. The peat needed will be dug from a zone directly adjacent to the inner side of the dam at 1 metre distance from the base of the dam (Fig. 2.d.). The top sod must be first removed down to a depth of 0.15 m and these sods can also be used for dam cover after completion of the dam.

The board around which the plastic foil was wrapped, has to be incorporated in the dam at the same level as the required water level in behind of the dam; discharge through the dam will then only occur when the water rises above that specific level. The top of the dam remains quite so that the chances of frost damage are reduced.

e. The width of the dam is dependent on the water depth in front of the dam. In the Bargerveen dams of different width were constructed and some empirical guidelines for the optimal relation between water depth and dam width could be drawn up (table 1).

Table 1:

Height of dam (m)	Water depth at inner side of dam (m)	Width of top of dam (m)
0.75	0.40	1.50
1.00	0.65	2.00

f. The sides of the dam should be completed at a slope of 1:1. To prevent erosion, the sides of the dam should be covered with the top sods which were removed from the bog. This is also conducive to a quick development of a vegetation cover. It is not necessary to cover the top of the dam with sods but the top 10 cms must consist of poorly humified peat in order to promote revegetation.

g. It is important to provide the dam with several discharge points, so that excess water can discharge rapidly.

Dams without a plastic screen

a. Complete removal of the bog's top sod (0.15 to 0.20 m) over the width of the dam base.

b. Dam construction up to a height of 0.50 m above the required water level at the inner side of the dam (accounting for a peat subsidence of about 0.20 m). For the width of the dam the same principles apply as in the above case. The dam should be completed in the same way as a dam with a plastic screen.

Warning: There is little experience in Ireland with construction of dams of weakly humified peat. Bord na Mona concluded in the Corlea Bog-project that a dam should never exceed a height of 1 m. At height over 1 m the dam weight is such that there is a risk of the dam sinking into the bog. This critical height may be used as a priorsional guideline. It is to be recommended, however, to first construct just a section of each dam at Raheenmore. If problems occur the dams can be completed (this could mean that a contract is given for a project in two phases).

4.2 Dams of strongly humified moss-peat

4.2.1. Principles for determining dam location

- The carrying capacity of the bog surface is deemed insuffient to support dams of strongly humified peat. Therefore, this type of dam will only be used alongside face-banks; its purpose is prevention of mass-movement and of further peat subsidence.
- As stated before, the cut-away in the experimental area does not contain sufficient amounts of strongly humified moss-peat. Therefore, the peat needed for the construction of this type of dam will have to be obtained from elsewhere.

4.2.2. Technical principles of dam construction

a. Strongly humified moss-peat should be transported to the proposed location.

b. The dam will be built against the face-bank. The first peat layer (1.0 to 1.5 m) should be removed from the face-bank in order to get a fresh wall of peat against which the dam peat can be placed.

c. The base of the dam should also be built on top of fresh peat in order to stabilize the dam and to prevent future leakages. Therefore, about 0.30 m of peat will have to be removed from the cut-away over the proposed width of the dam base.

d. The height of the dam is dependent on the required (eventual) bog surface inclination in the zone between the central intact bog section and the bog margin and on the proposed water levels at the dams. Fig. 4. and Fig. 5. illustrate how water levels and dam heights can be determined when one requires an eventual surface inclination of 0.30m/100m (see above).

e. The height of the dam at the face-bank should be 0.35 m over the required water level at its inner side. Because of the type of peat material used for its construction, peat subsidence will be negligible. The width of the dam is again dependent on the depth of water at its inner side. Experiments in the Bargerveen with this type of dam have provided certain guidelines (table 2).

Table 2:

Height of dam (m)	Water depth at inner side of dam (m)	Width of top of dam (m)
1.50	0.50 - 0.75	3.00
2.00	0.75 - 1.00	4.00
2.50	1.00 - 1.50	5.00

f. By way of experiment, the outer slope of the dam should be constructed in different angles (slope 2:1 and 4:1) for different sections. In fig. 6 the situation has been worked out for an angle (slope 2:1).

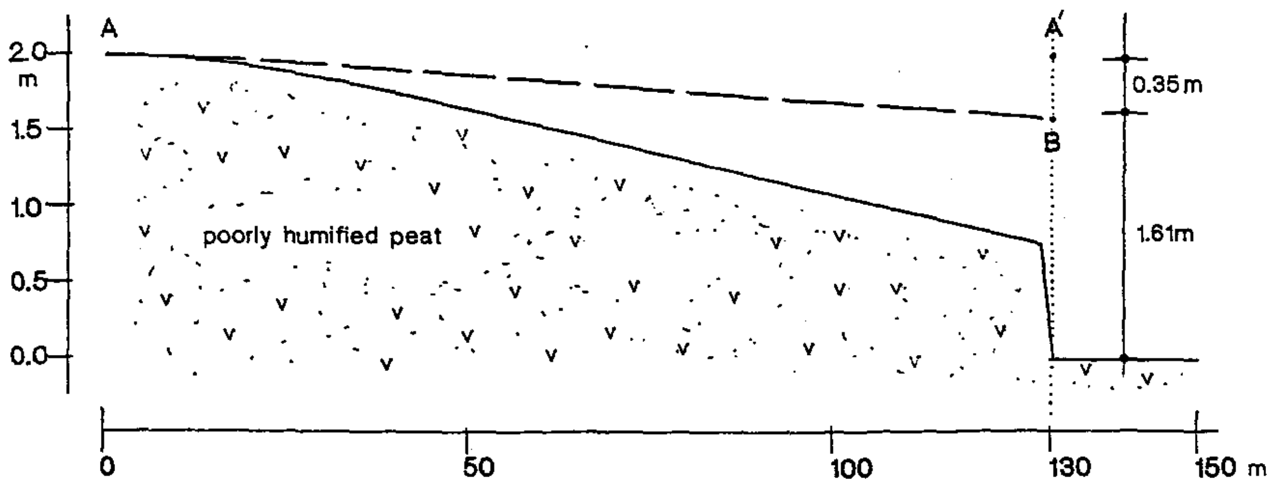
g. The dam should be covered by a layer of 0.10 to 0.20 m of poorly humified moss-peat to stimulate colonization by vegetation.

h. It is important to provide the dam with certain discharge points for excess water.

warning: When through peat swelling the bog surface will have reached the required inclination, dams lose their water retention function (this applies both for the dams on the high bog and the dam alongside the face-bank). Removal of the top part of a dam down to the bog surface level should then be considered to allow a normal surface-discharge again.

The determination of required water level and dam height for the strongly humified peat at the facebank has been worked out in fig. 4.

Figure 4: Determination of required water level and dam height for the dam of strongly humified peat at the face bank.



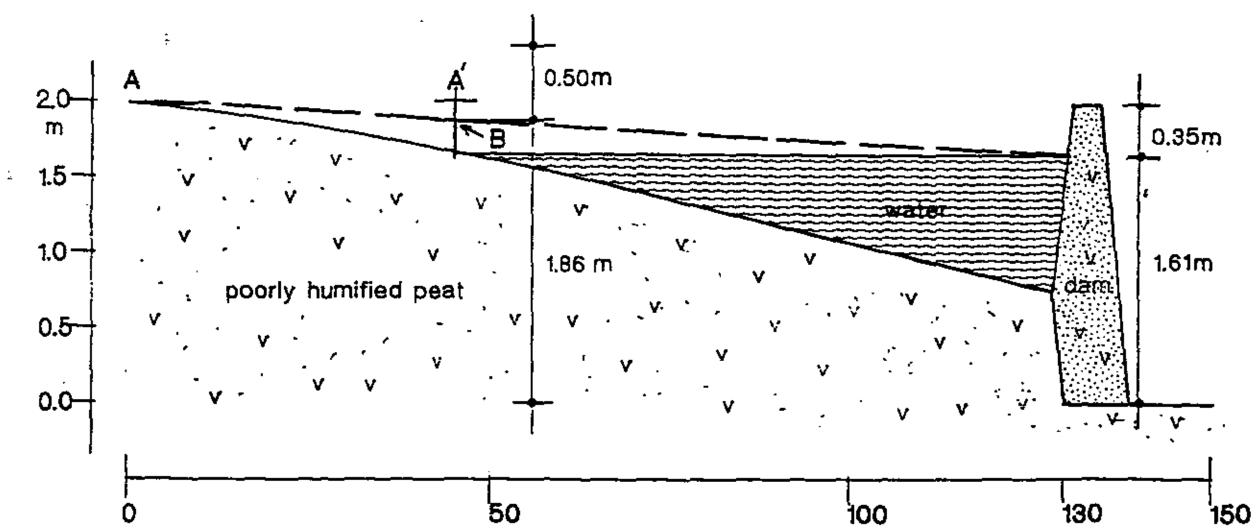
a. Given data:
   - the distance from the boundary (A) with peat-forming plant communities to the facebank (A') is 130 m.
   - the height of the bog surface at the boundary (A) is 2.0 m above the surface of the cut-away.
   - the slope for the reconstruction of the bog surface is 0.30m/100m (discontinuous line)

b. The height of the water level (B) inside the planned strongly humified dam at the facebank can been determined:
   - at first the maximum declination of the bog surface at the facebank has to be calculated: 0.30 x (130/100) = 0.39 m.
   - than the height of the water level (B) inside the dam can been calculated: 2.0 - 0.39 = 1.61 m above the surface of the cut-away.

c. Finally the dam height can been calculated. This is the summons of the height of the water level (1.61 m) inside the dam and the extra height required above the water level (0.35 m). The dam height at the facebank is than 1.96 m above the surface of the cut-away.

The determination of water levels and dam heights for the poorly humified peat can been done on the same way. In figure 5 the situation has been worked out.

Figure 5: Determination of water levels and dam heights for the dams of poorly humified peat on the high bog.



a. Given data:
   - the distance from the boundary (A) with peat-forming plant communities to the waterline (A') is 46 m.
   - the height of the bog surface at the boundary (A) is 2.0 m above the surface of the cut-away.
   - the slope for the reconstruction of the bog surface is 0.30m/100m (discontinuous line).

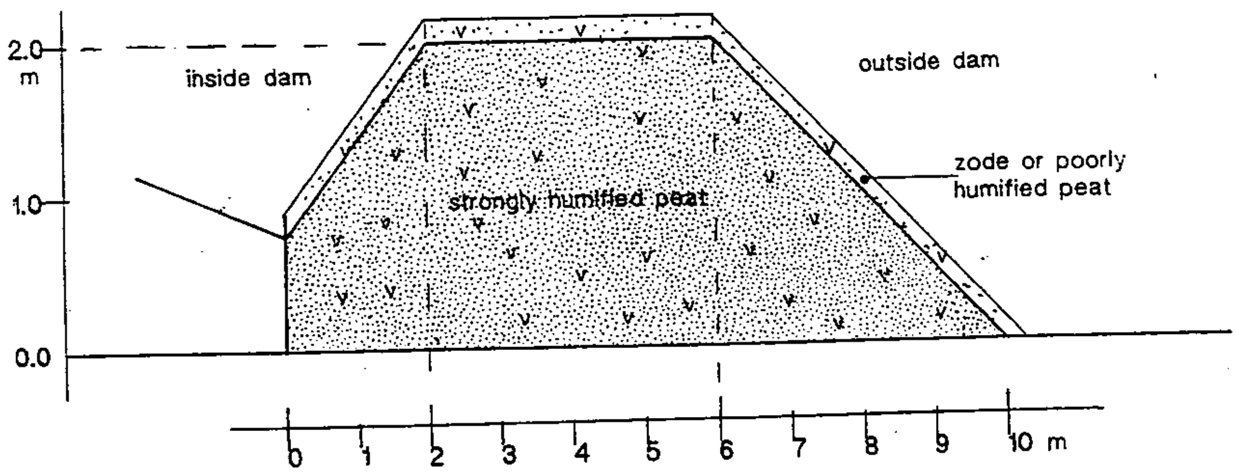
b. The height of the water level (B) inside the planned poorly humified dam can been determined:
   - at first the maximum declination of the bog surface at the facebank has to be

calculated: 0.30 x (46/100) = 0.14 m.

- than the height of the water level (B) inside the dam can been calculated: 2.0 - 0.14 = 1.86 m above the surface of the cut-away.

c. Finally the height of the dam can been calculated; this is the summons of the height of the water level (1.86 m) inside the dam and the extra height required above the water level (0.5 m). The height of the dam is than 2.36 m above the surface of the cut-away.

Figure 6: Construction of outer slope (2:1) of dam alongside the face-bank



4.3. Creation of a flooded depression in the cut-away.

4.3.1. Basic principles

- The basin's substrate should be mesotrophic fen-peat.
- The water level in the basin should be stable (fluctuations not exceeding 0.30-0.40 m). It is also crucial that the basin never dries out, because that would impede mire development.
- The basin should be fed by both regional groundwater and bog water.
- The basin should have a permanent discharge point; there should be no retention of rain water.

4.3.2. Technical problems and specifications

Surface levels and soil stratigraphy in the cut-away

The surface level of the proposed location for the flooded basin is between 101.6 and 102.4 m +O.D. (O.P.W. and Bord na Mona, 1993). From the cross-sections by McGarry & Loughman (1993) the depth of the mineral soil can roughly be determined. The peat wedges out against the mineral soil. At a distance of about 60 m. from the face-bank, the mineral subsoil is at c. 100.0 m +O.D. At the face-bank it is at 98.5 to 96.0 m +O.D.

The depth of the peat layer at a distance of about 60 m from the face-bank is 1.8 to 2.0 m; at the face-bank this is 3.0 to 5.0 m. Only one of the cross-sections allows a determination of depth and level of fen-peat. The fen-peat layer seems to have a magnitude of less than 2.0 m; the top of this layer is at a depth between 0.4 and 2.0 m in the proposed location.

Hydrology

The depth of the regional groundwater in the cut-away is only roughly known. The groundwater table contour lines as provided by Flynn (1993), indicate a level between 100 and 101 m +O.D., but in the cut-away the hydraulic head was never recorded.

In order to have a permanent supply of regional groundwater to the basin, it should be dug out to a level below the mean lowest hydraulic head (*)

(*)note:

The mean lowest hydraulic head is the average of the lowest piezometric heads recorded during a certain period of time. There are three methods to determine this parameter.

- Statistical research in the Netherlands has shown that a reliable indication of the mean lowest hydraulic head can be obtained by recording the piezometric head during at least 10 years; in that way the chances of anomalies as a result of abnormally dry or wet years are minimized. The results were shown to agree with the determination of the mean lowest hydraulic head by hydromorphological characteristics of the soil profile (oxidation/reduction parameters).
  The hydraulic head should be recorded every 15 days in order to obtain reliable results (this also applies to the following methods). The three lowest recordings in each year (30 figures after 10 years) are then used to calculate the mean.

- The second method, less reliable but, nevertheless, frequently used is based on data over three years, which are then connected to an available ten year data-set from another location with comparable climatic conditions and soil characteristics. In the case of a few consecutive relatively wet or relatively dry years, a three-year period of recording will provide an anomalous mean. By interpolation into a known data-set over a longer period of time from a comparable location, such anomalies can be detected and by certain statistical methods, adjustments can be made.

- If results need to be obtained in an even shorter period of time, or when no ten-year data-sets are available from other locations, the hydraulic head should be monitored during one year as well as the amount and frequency of precipitation at the location concerned. The precipitation data should then be interpolated into long-term data-sets of precipitation obtained in the same climatic region, so that it can be determined whether the mean lowest hydraulic head calculated for the one year of monitoring, represents a normal or an anomalous value. In this way a crude indication of the long-term mean can be obtained.

For the experimental area, the first method has to be ruled out because results are needed in a comparatively short time. The second method can not be used either, because no ten-year data-set from a comparable location is available. Therefore, the third method should be used to determine the mean lowest hydraulic head. A piezometer (with filter) should be installed at the proposed location of the basin. It should also be investigated whether the drain at the southside of the cut-away affects the groundwater level. The water level in the drain and the hydraulic head to the southern side of the drain should be monitored in order to assess the drain's impact. If the head of regional groundwater proves to be insufficient at the proposed location of the basin, it should be investigated whether the water level in the drain can be raised. Water levels and hydraulic heads should be monitored during one year before any further decisions are made.

5. BASIC DAM-PLAN FOR THE EXPERIMENTAL AREA

5.1. Location and type of dams

The high bog section in the experimental area inclines in two directions. Along the catchment boundary, the bog surface level drops by 2.0 m in east-west direction. In the north-south direction (from catchment boundary to face-bank) there is a drop of about 2.3 m over a distance of 80 m at western boundary of the experimental area and of about 2.0 m over a distance of 40 m at the eastern boundary. This complicates effective dam-plan for the area. Appendix 2 gives the proposed dam locations and the required water levels at the dams' inner sides. The boundary line of the area to be affected by the management measures (appendix 1) and the technical principles as discussed in 4.1 and 4.2 served as the basic guidelines for the design. One dam of strongly humified peat is planned alongside the face-bank, and five dams of poorly humified peat are proposed for the high bog, three of which will be combined with a plastic screen.

Note:

The determination of the exact dam location in the field as well as the actual dam building will involve detailed line-levelling.

5.2 Required water levels and dam heights

Required water levels at the inner sides of the proposed dams and the required dam heights are also given in appendix 2.

In calculating dam heights the principles desribed under 4.1.1. have been used. This process involved the following steps:

5.2.1. Calculation of waterlevels behind the strongly humified peat dams.

- The OPW produced a detailed map of surface levels (map 2 in the appendix). From these levels a contour map with intervals of 0.10 m was produced.
- On this contour map the boundary between peatforming vegetation types and communities of desiccated peat was indicated (derived from the vegetation map by Kelly, 1993). The boundary line more or less coincides with the 105.80 m+O.D. contourline and the boundary line of the peat-forming communities shows an inclination of 0.30 m over 100 m, the 105.80 m+O.D. contour line was kept as the reference level.
- From this reference level down to the bog margin the inclination of the bog surface should be no less than 0.30 m over 100 m.
- In principle the waterlevel at the inner side of the strongly humified peat dam can now be calculated. However, the bog surface not only inclines towards the south but also towards the east. Water will flow from the bog surface in both directions and a single dam of strongly humified peat at the bog margin will therefore not be sufficient. Additional dams of poorly humified peat with plastic foil screens will have to be constructed on top of the bog. The waterlevels at the inner sides of these dams will than determine what water level is required at the inner side of the strongly humified dam.

5.2.2. Calculation of the waterlevels at the inner sides of the dams on the bog surface.

- If the bog will swell as a result of the proposed measures, swelling will be possible up to the level of the water behind a dam. If one wants to restore the bog surface inclination to a drop of 0.30 m over 100 m, the subsequent differences in waterlevels between the different compartments should be an approximation of such an inclination. The more dams are constructed the smaller the drops in level between the compartments will be. As in an intact bog the phreatic level is usually not deeper than 0.10 m below the surface, a drop in water level between compartments should be no more than 0.10 m. In this case a drop of

0.06 m was chosen.

- With the give surface inclination dams will have to be constructed every 20 m in order to acquire a drop in water level between the different compartments of 0.06 m. Where the bog surface does not incline (in the north of area) no dams are needed.
- The other dams of poorly humified peat merge with the strongly humified dam at the bog margin forming the other compartments. Following the above principles, the water level in these other compartments (and therefore also the water level at the strongly humified peat dam) can be determined.

5.2.3. The technical specifications of the poorly humified dams in Appendix 2.

- For dams A,B and C the width at the top must be 1.5 m. For dams D and E the width at the top must be 1.0 m.
- Dams A,B,C and D must have a plastic foil screen while dam E must have no plastic foil screen; see for Technical Principles of Dam Construction paragraph 4.1.3.
- Dams D and E must not be covered with sods. Dams A, B and C should be covered with sods.
- The ends of all of the dams must be graded into the bog surface in order to prevent erosion around the ends of the dams.

5.2.4. The technical specifications of the strongly humified dams in Appendix 2.

Follow the instructions in Technical Principles of Dam Construction paragraph 4.2.2.

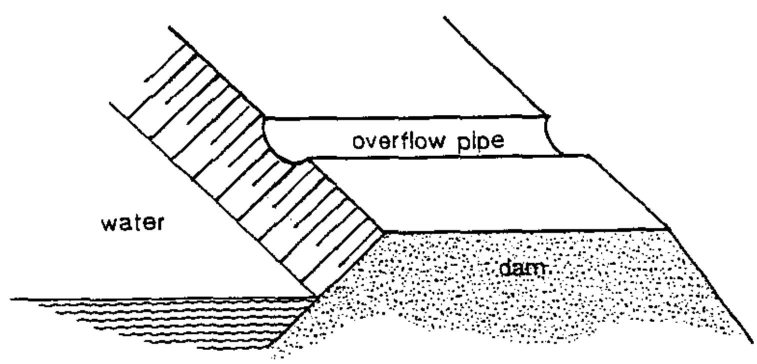
5.2.5. Technical specifications for the pipes through the dams

A basin of open water of about 2,000 sq. metres requires 1 pipe of diameter 20 cm. The total number of pipes required is 21.

5.2.6. Technical specifications for overflow pipes for the top of the dams.

Should blockages arise in the through pipes the water level may rise to the top of the dams and cause erosion. To prevent this it is necessary to install 21 overflow pipes on top of the dam, see Fig. 7. The sods should be removed from the places where these pipes are installed.

Figure 7: Design of overflow pipe for the top of the dam.



6. MONITORING

A monitoring programme is required to assess the effects of the proposed experimental management measures. Assessments (and possible adjustments to the managements measures) should be made at various stages in the experiment:

a. Peat stratigraphical and soil physical research before and during dam construction.
b. Assessment of dam effectivity (winter 1994/winter 1995)
c. Monitoring and assessment of short-term changes (three year period)
d. Monitoring and assessment of long-term changes (fifteen year period)

6.1. Peat stratigraphical and soil physical research before and during dam construction.

6.1.1. Peat stratigraphical research

Along the planned dam trajectory the peat stratigraphy and the peat bulk density should be determined at intervals of 25 m (see als 4.1.1.). Cores should be taken down to the mineral; bulk densities in the cores should be determined at intervals of 0.25 m in the first 2 m and intervals of 0.5 m below.

6.1.2 Water content and bulk density of dams

Water content and bulk density of both black peat dams and of dams of poorly humified peat will be assessed to see if these change significantly. For the poorly humified dams these measurements will be taken with a special auger (Russian) at the face-bank, then 10 metres in, then 10 metres further in, then every 25 metres until the end of where the experimental dam is to be constructed. For the strongly humified dams measurements will need to be taken at intervals of 25 metres. For the above parameters analysis will be carried out every 25 cm down the profile. Such measurements will take place 1 month, 6 months and one year after construction and will then be reviewed. Sampling for water content and bulk density will be undertaken independently of the contracter carrying out the work.

6.1.3 Dam-related Activities

- Quantity Surveying - to establish the basis for future costings OPW will monitor the peat volumes used, the distances peat is moved and the machine time required.
- Quality Control - to ensure that construction specifications are adhered to and to gather precise information against which future performance can be measured and to provide a basis for design improvement. Regular samples of peat will be taken to from the stockpile just prior to use. Water content will be analysed immediately and half the sample kept in plastic bags wrapped in tin foil in a cold store for later analysis for humification in the event of problems arising. (Sample number around 500).

6.2. Dam effectivity (winter 1994/winter 1995)

During the first year after the construction of the dams, it should become clear whether their water retention function is sufficient and whether the required water levels can be realised.

- Water-level gauges should be installed at the inner sides of the dams (see appendix 2) and water levels should be recorded near the 14 and 28 of every month.The gauges should be levelled each month to check for possible changes in reference level. For this purpose a benchmark needs to be installed (the easiest is to use one of the benchmarks described under 6.3.).
- 2 automatic groundwater recorders should be installed inside the dams A and B to monitor the fluctuation of the water table in the site of the dams. It is essential to note the frequency of run-off through the pipes and storage changes in the open water. Donal Daly (GSI) must

be consulted about the installation of the groundwater recorders and John Curtin (OPW) must supervise their installation in the field.
- Provisions should be made for an automatic recording of the precipitation.
- Levelling of all dams will be undertaken every month for the first 6 months and then reviewed.

After a year, water level data and precipitation data will allow an assessment of dam effectivity.

6.3 Monitoring and assessment of short-term changes

The proposed management measures may lead to the swelling of the bog's upper peat layers. Whether peat swelling will occur, will be clear within three years. To detect possible peat swelling and to determine the effects on the bog's surface inclination, a series of benchmarks needs to be installed in a transect (see appendix 2) from the face-bank to the boundary line of the Sphagnum magellanicum complex (bog section with intact acrotelm). At a fixed point in time each month the surface levels in relation to benchmarks need to be recorded near the 14 and 28 of every month during three years. A first assessment can then be made of the effects of the management measures. Technical specifications of the monitoring equipment is desribed under 6.5..

In order to analyse changes in hydrological conditions as a result of management measures, piezometric heads should be monitored. In this way insights can be obtained in changes in water movement through the bog which may occur as a result of:
- the construction of the dam of strongly humified peat which raises the phreatic level at the bog margin.
- the installation of plastic foil screens which block the water movement in the upper peat layer.
- the construction of poorly humified dams without the inner foil screen.
- possible swelling of the upper peat layers and the effects on water movement in the peat layer.

A proposal for a monitoring network is given in section 6.5.2.. Piezometric heads should be determined arround the 14th and the 28th of each month during 3 years. The locations of the piezometers are indicated in appendix 2. Technical specifications for the piezometers are given in section 6.5.3. Donal Daly (GSI) will advise how and where to install the piezometers. The actual installation of the piezometers must be supervised by John Curtin (OPW).

6.4. Monitoring and assessment of long-term changes

From the political, financial and management technical point of view it is important that the effectivity of management measures for the realisation of the conservation objectives as formulated by the Wildlife Service, is properly assessed. This can only be done by long-term monitoring of changes in surface inclination, hydrology and vegetation.

6.4.1. Inclination of the bog

The inclination of the bog surface determines crucial hydrological and ecological processes in raised bog systems. Changes in surface inclination should, therefore, be carefully monitored. These data allow timely adjustments to the management plan: If peat subsidence continues despite the proposed management measures, additional measures will be required. If the surface inclination will decrease through peat swelling, management measures should be adjusted as soon as the required surface inclination will have been obtained.

Surface levels should be recorded in the area just outside the central bog sections with an intact acrotelm; this should be done inside and (for reasons of reference) also outside the experimental area. Surface levels should be recorded at a fixed point in time each month during 15 years. Every 5 years data should be assessed so that necessary adjustments can be made to the management measures. Locations at which changes in the bog surface level should be monitored are given in appendix 2.

6.4.2. Phreatic levels and vegetation

Vegetation and phreatic water levels will be monitored to establish the rate and direction of change and to link the changes in vegetation to changes in phreatic water levels. Permanent sample plots will be located using a gridded vegetation map taking into account proposed water level changes and vegetation boundaries. Nested series of releves will be recorded to give information on vegetation communities as well as the vegetation complex. The following monitoring should be carried out:

- Phreatic tubes will be installed on the margins of the permanent plots. Phreatic water levels will be measured every 14 days. Based on this data duration lines will be drawn.
- Vegetation descriptions will be made pre construction and then at least every 5 years. Where water levels change dramatically, surveys at 1, 2, 4, 7 and 10 years after construction are suggested (after that, a survey at five year intervals will be sufficient).
- Automatic groundwater recorders should be installed to measure the changes in storage coefficient.

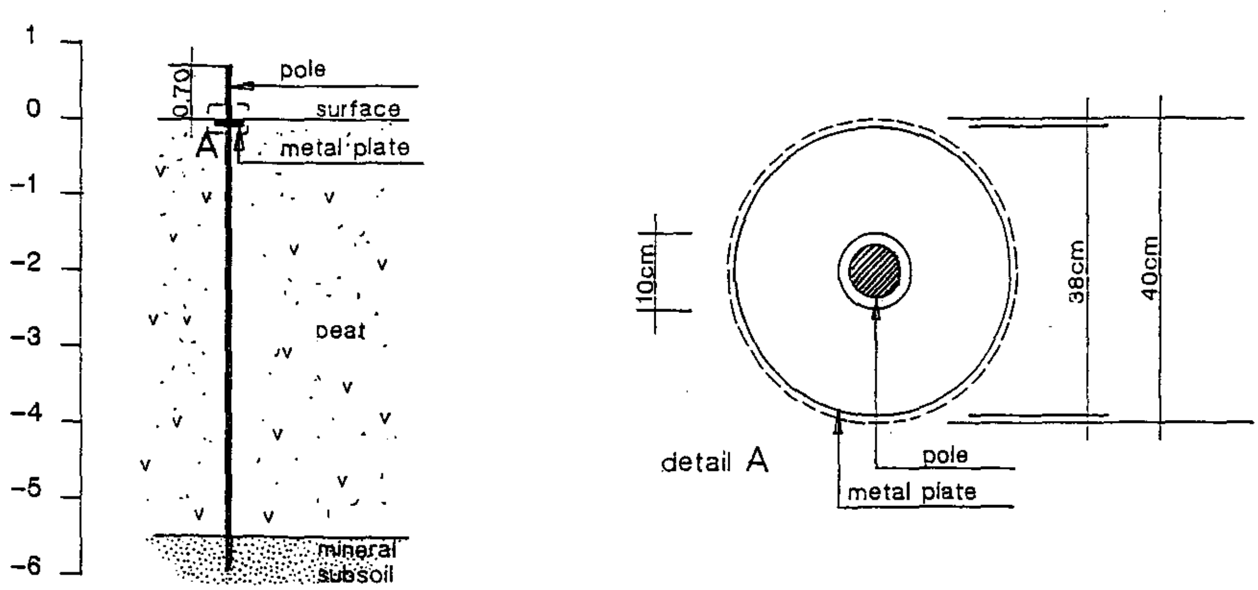
Locations at which the phreatic water level and the vegetation should be monitored are indicated in appendix 2. Donal Daly (GSI) must advise on the installation and John Curtin (OPW) must supervise the actual installation of these recorders.

6.5. <u>Technical specifications for a monitoring network.</u>

6.5.1. Technical specifications for the equipment to momitor changes in the bog surface level

Figure 8 shows the monitoring equipment. It will consist of a solid iron pole driven through the peat into the mineral subsoil. The top of the pole should be 0.70 m above the bog surface or above the expected water level after dam construction.
In a circular area around the pole (diameter 0.40 m) the top sod is removes from the bog. A 0.40 m diameter metal plate is then installed to rest on the base peat surface (the central hole in the plate should be wide enough for the plate to move easily over the pole). The plate is than covered again with sods, except for the central part with a diameter of 0.10 m. The tops of all the poles/benchmarks will be levelled in and the poles marked in such as way as to facilitate measurements. The distance between the top of the pole and the metal plate is then measured every 14 days (on the 14th and the 28th).

Figure 8: Technical specifications of equipment for monitoring changes in bog surface level



6.5.2. Outline of the dephts for filters of piezometers in relation to the measurements.

The monitoring network should be installed following the guidelines in the figure 9.

Figure 9: Outline of the depths for filters of piezometers in relation to the measurements from the dams of strongly humified peat and the dams of poorly humified peat with the plastic foil screens.

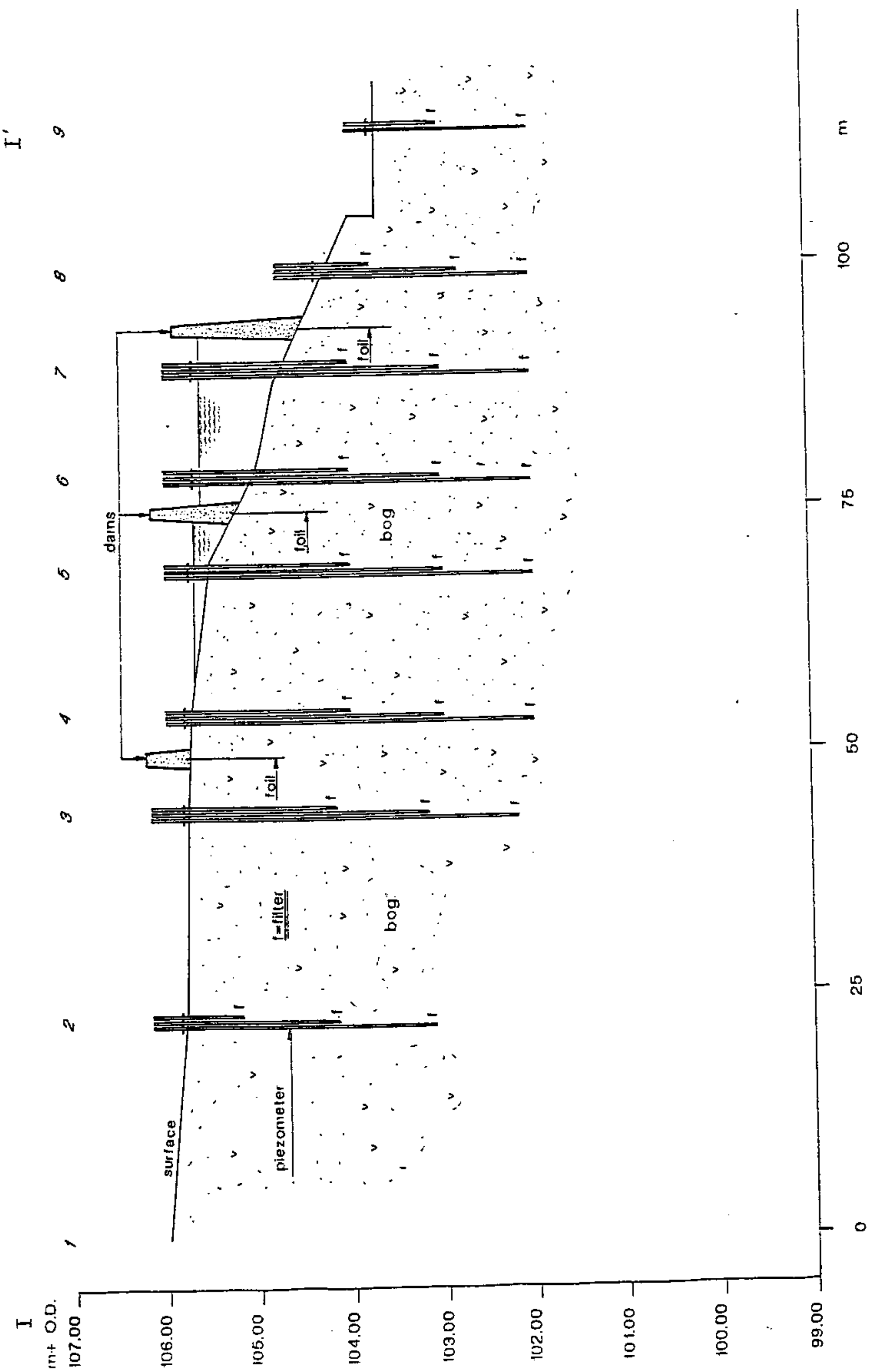
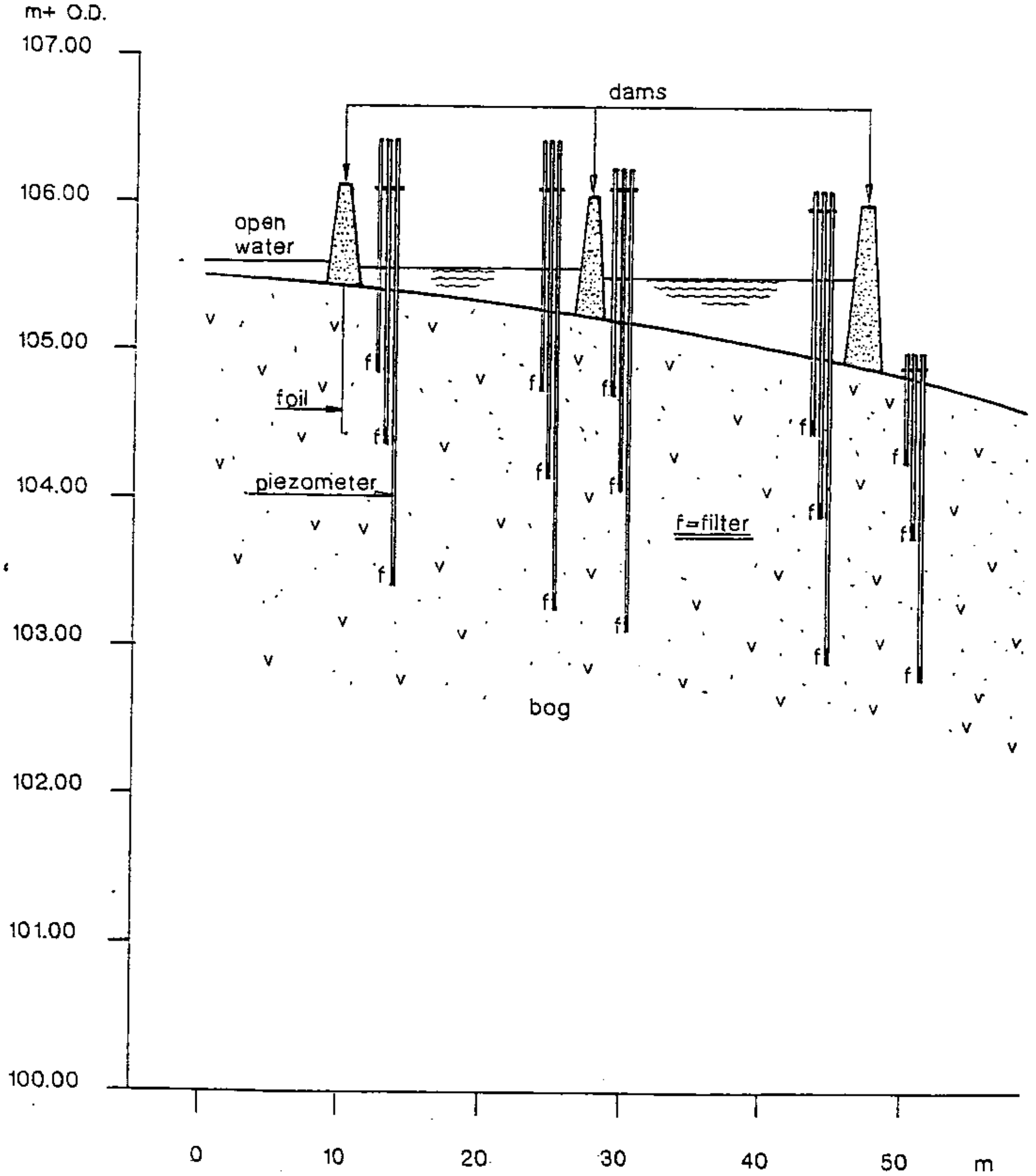


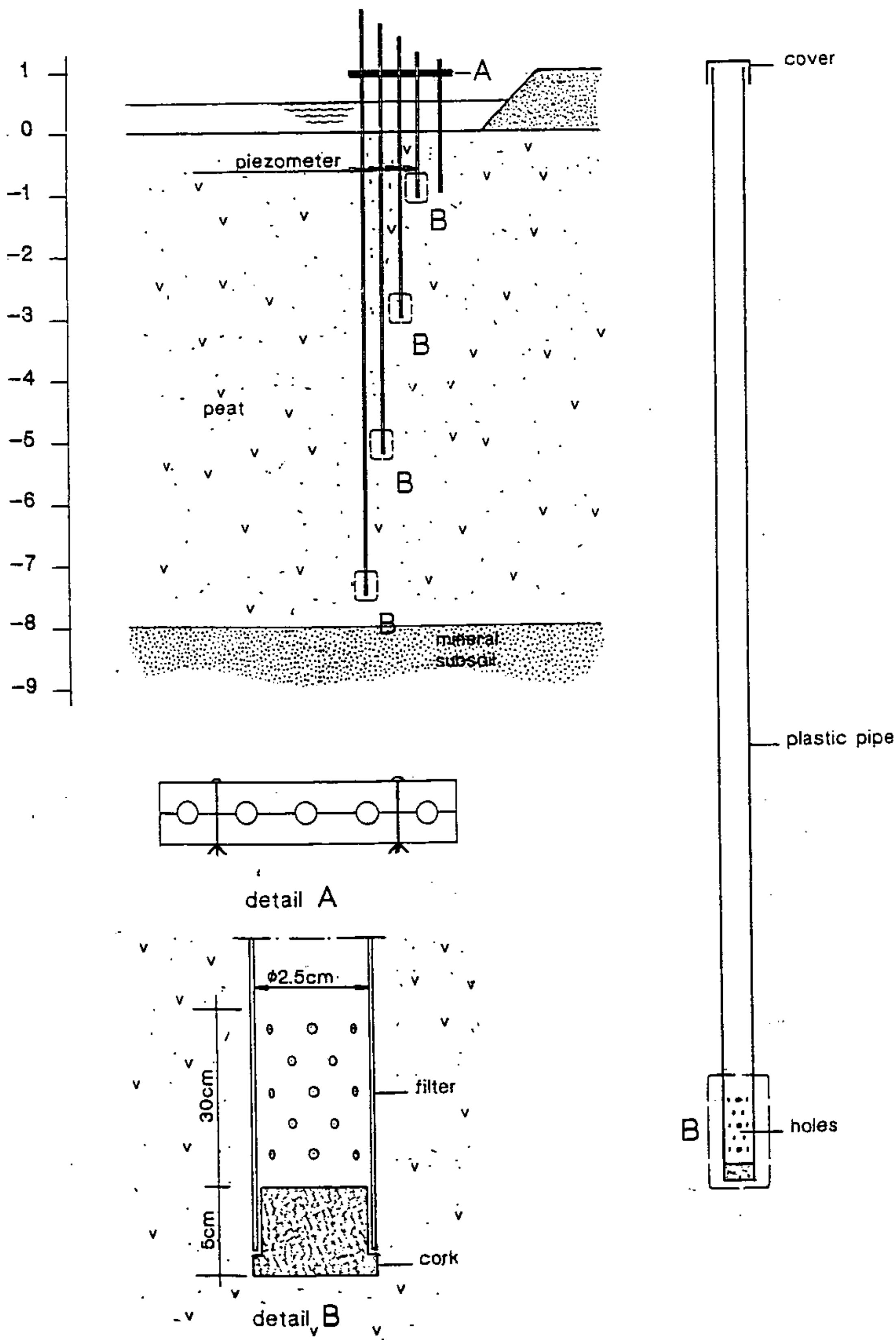
Figure 10: Outline of the depths for filters of piezometers in relation to the measurements from the poorly humified peat without the plastic foil screens.



6.5.3. Technical specifications for piezometers

In figure 11 the technical specifications for piezometers are given. A nylon screen must be wrapped around the filter and this must be taped so that it remains fixed in place when the tube is inserted. The diameter of the cork must not exceed the outside diameter of the tube otherwise the hydrological conditions around the tube will be disturbed.

Figure 11: Technical specifications for piezometers.



6.6. Analysis of results.

All the above data gathered will have to be assessed at least monthly in the first year to establish if unfavourable trends are developing. This will be carried out by the OPW Engineering Services with Staatsbosbeheer as contract consultants. Once a proper assessment system is in place, the situation can be reviewed regularly, say after 1, 2, 4, 7 and 10 years in association with the vegetation assessments.

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