IRISH - DUTCH RAISED BOG STUDY

GEOHYDROLOGY AND ECOLOGY

- National Parks and Wildlife Service of the Office of Public Works, Dublin
- Geological Survey of Ireland, Dublin
- Department of Nature Conservation, Environmental Protection and Wildlife Management, The Hague
- National Forest Service, Driebergen

REGIONAL HYDROGEOLOGY OF CLARA BOG; AN IRISH RAISED BOG

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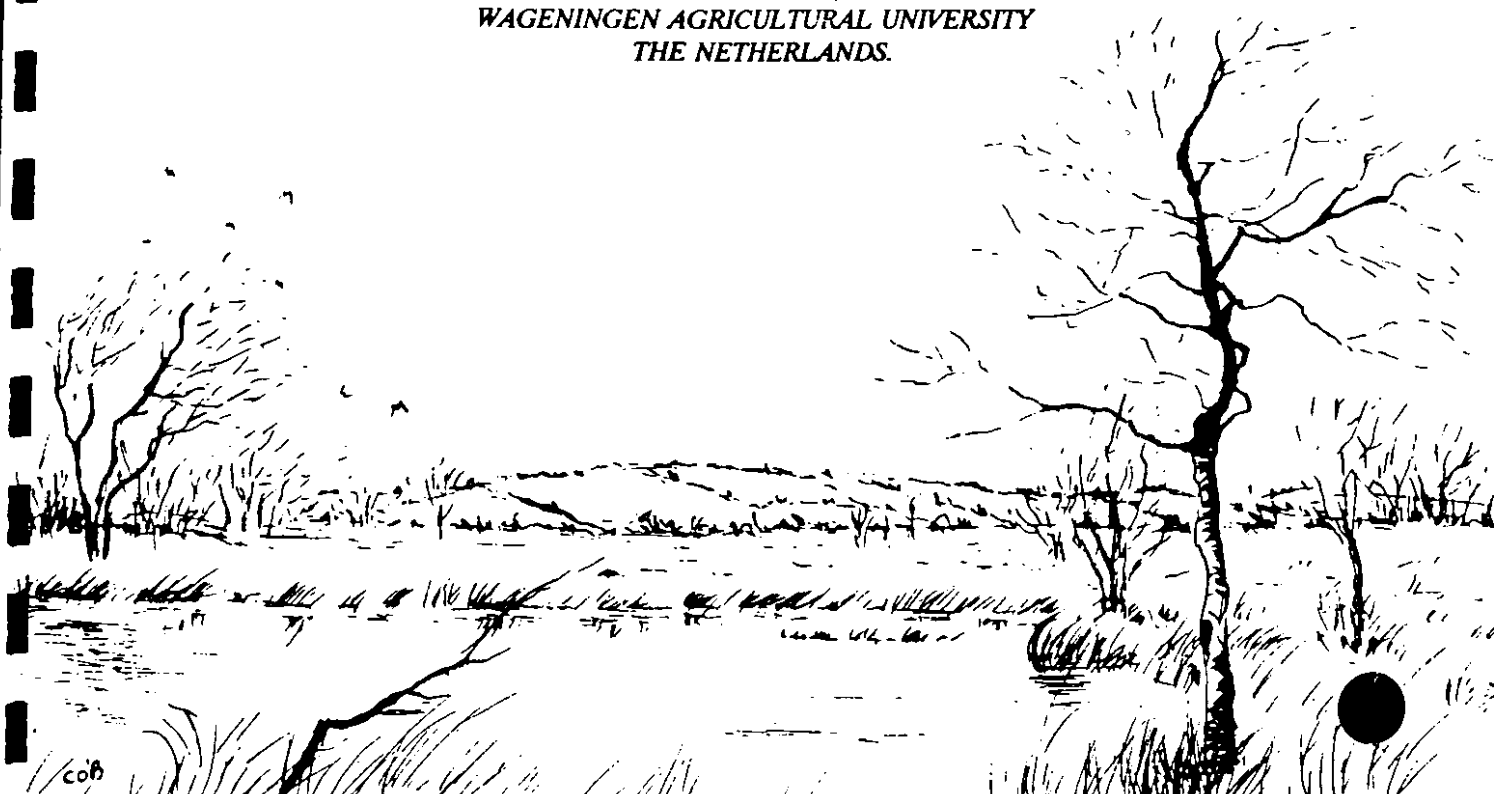

Sketch of Clara Bog by Catherine O' Brien. Clara, County Offaly.

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APRIL 1993

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I am very glad, to have had the opportunity to visit and work on a Irish raised bog. It was great to work in Ireland because of the charming people and the beautiful landscape. Furthermore it was interesting to get the bog known. Although, bogs and soaks have still many mysteries to me.

I had a great time in Clara and Ireland and this would have been impossible without the help of many individuals. Thanks to all the people, who made my stay pleasant and who gave me a hand with my research. I especially would like to thank my supervisors Henny van Lanen and Ben van de Weerd (Wageningen Agricultural University) for their patience with me and Jan Streefkerk (Dutch National Forestry Service), who gave me the opportunity to work on this project.

Wageningen, April 1993

Manon van den Boogaard

SUMMARY

Introduction

This report is the result of a MSc-thesis for the Wageningen Agricultural University. The thesis was undertaken within the framework of the Irish-Dutch Peatland Geohydrology and Ecology Study. The aim of the research program is to develop appropriate procedures concerning conservation and management of two Irish raised bogs, Clara Bog and Raheenmore Bog. Both bogs are relatively well-developed and intact and situated in the Irish Midlands. On Clara Bog three soaks occur, which make it a special raised bog. This thesis gives an overview of the regional hydrogeology of Clara Bog and surroundings. Special attention is paid to soak-systems.

Geology

The Clara Bog region is dominated by (Pleistocene) glacial deposits and Holocene bog development. Geomorphologically, the Clara Bog region is characterised by the hilly topography of eskers in the north-northeast and an undulating to hilly till-area in the west-southwest. A large part of the bog-area is underlain with till. The till in the Clara Bog region varies texturally from clayey loam to gravelly till. The peat formation started with the growth of fenpeat. Fenpeat accumulates under eutrophic circumstances. Sphagnum peat is a younger peat form which usually covers the fenpeat. It mainly consists out of Sphagnum species which are associated with an ombrotrophic situation.

Five hydrogeological cross-sections are compiled to increase insight in the geological framework of the whole Clara Bog region. Some simplification had to be made. The profiles show very clearly that Clara Bog is formed in a limestone depression and that several mounds at and near the bog occur. In most of cases the mounds consist of clayey till. The glacial deposits are covered with a blanket of lacustrine clay, which fills in the depressions. The fenpeat has almost everywhere a thickness of ca. 4 m, except at the cut-away areas.

Raised bogs

The current raised bog development started some 10.000 years ago, after the last glaciation. Sphagnum species are very important for raised bogs as they sustain the bog, draw up water, keep the surface wet and make the soil more acid.
Clara bog is famous for her soaks. Soaks are areas with a minerotrophic vegetation in an ombrotrophic bog-environment. The three soaks on Clara Bog are different from each other which can be seen in the vegetation. A raised bog is mostly confined by eutrophic fen vegetation, as it is the contact-zone of the acid, nutrient poor, peatwater and the basic, nutrient-rich (mineral) groundwater. This is called the lagg zone.

Hydrologically two layers (acrotelm and catotelm) can be distinguished in a raised bog. The acrotelm is a thin, partly saturated, surface layer of living vegetation. The catotelm is the layer where the peat is conserved in a waterlogged situation. The acrotelm protects the catotelm, which can be subsequently destroyed by oxidation, if it is exposed and allowed to dry out. The permeability of the peat increases significantly towards the surface. The permeability in the acrotelm is about 25-1000 m/day and of the catotelm about 10^{-3} m/day.
Drainage and cultivation of peat soils induces irreversible changes in the physical and chemical characteristics. It is obvious that due to the intensive drainage the Sphagnum carpet (acrotelm) is the first layer that will disappear, and consequently peat development will stop. With the destruction of the acrotelm the catotelm is exposed to the atmosphere and the bog is degraded to dry heatherland.

The excess rainfall on Irish raised bogs is about 350 mm/year. Most of the excess (230 mm/year) runs through the acrotelm towards the drains near the bog-margins. The surface runoff is relatively small. From the 80 mm/year which is estimated to flow through the catotelm, about half of the amount flows to the mineral subsoil and another half to the margins.

Hydrology

Two aquifers are distinguished in the Clara Bog Region. The first aquifer is the top-layer of the peat (in undisturbed, natural situation: the acrotelm). The second aquifer comprises the limestone, the esker and the (fluvio-glacial) gravelly-sandy layer direct upon the bedrock. This aquifer has a hydraulic conductivity varying from 10 to 100 m/day. The clayey till, the lacustrine clay and the catotelm act as confining layers.
The drains have strong effects on the first aquifer and in some cases also on the second aquifer. Some gravelly till mounds and the esker seem to be recharge areas for the second aquifer.
The mean difference in hydraulic heads between the first and second aquifer on the bog is some -3 m; this implies downwards seepage. Only near the Bogroad a positive difference is found, which means that upward flow prevails.
The phreatic watertable in the acrotelm changes some 0.1 - 0.3m, during the year. The hydraulic heads in the catotelm show the same (a bit flattened) pattern.

SUMMARY

The Clara Bog Region is, via a small drainage system, drained by the River Brosna and the Silver River. Most of the surface water flows to the Silver River. The discharge-pattern in the drains along the Bogroad and the Deep drain coincides with the precipitation-pattern. Most of the rainfall discharges quickly from the bog-area to the drains along the Bogroad.

Temperature

Temperature measurements were carried out to investigate if there is vertical water and associated nutrient transport in or nearby the soaks on Clara Bog. The temperature profile has been measured in boreholes and cobra-drillings near and at the bog and piezometers on the bog. The temperature was determined in the beginning of April and at the end of June 1992, by lowering a resistance thermometer in the tube. The data are put into isothermic transects and in graphs with temperature and temperature gradient against depth. The results did not give any evidence for upward flow near the soaks. Seasonal influences can recognized very well. There seems to be no correlation between the different types of peat and heat conductivity.

Hydrochemistry

Two kinds of hydrochemical data have been used; the electric conductivity (EC) and the hydrochemical composition of water.

In 1992 three hydrochemical sampling sessions took place i.e. in March, June and September. The ionic balance-error is used as a measure for the usefulness of the analysis. In this report twice the marge, according to the literature, is used. With this marge 7 % of the March samples and 49 % of the September samples are useful. For June the percentage is 95 %. This is the result of the estimation of the HCO_3^--concentration, as it was not analyzed in June. The high percentage was one of the reasons to use only the June samples for interpretation.

The Van Wirdum procedure, Stiff_diagrams, Stuyfzand classification and pH- and EC-values were used to interpret the June-samples. The mineral groundwater has pH-ranges of about 6-8 and an EC of 300 - 700 S/cm and can be characterized as a rather hard $CaHCO_3$ watertype. The till-samples show the greatest influences of the lithology and the gravel-samples the smallest.

The surface water is in general of the moderate hard $CaHCO_3$ watertype with a pH of about 7/8 and an EC of about 300-400 S/cm. The rivers show most lithological influence. The drain west of the Bogroad has a much lower EC (145 S/cm). It can also be seen in the drains along the Bogroad, the Deep drain and the Silver River that, when the waterlevel is rising the EC decreases. The River Brosna does not show this behaviour. Therefore it is likely that this river is less dependent on bogwater than the Silver River.

The precipitation, which has a very low content of ions, is of the soft $CaSO_4$ type and has a pH of 5.5 and EC of 35 S/cm. Two bogwater types can now be distinguished. In the shallow filters a soft NaCl/CaCl type occurs with a pH of 4-5.5 and an EC of about 80 S/cm (real bogwater). In the deeper bogfilters a soft/moderate hard $CaHCO_3$-type is present with an pH of 5/6 and an EC of 100-499 S/cm (more or less influenced by mineral groundwater) The Stiff-configuration of the deeper filters in the bog have the same configuration as the surface water and the mineral groundwater, but with much lower concentrations. In most cases the all but one deepest tubes have the most pronounced features of a minerotrophic watertype. On Clara east, site 119 is as a whole strongly influenced by minerotrophic water.

Synthesis

The regional hydrogeology of the Clara Bog Region is characterized by two aquifers, separated by series of confining layers. The current hydraulic heads show a downward seepage on the bog. This seepage will be very small because of the large hydraulic resistance of the confined layers. The downward seepage seems to contradict with the occurrence of $CaHCO_3$ watertype in the lower layers of the Sphagnum peat.

Two mechanisms are postulated to have contributed to the occurrence of a minimal watertype and associated development of a soak system:

1) *The escape of minerotrophic water from below a closing peat mat.*
2) *The removal of minerotrophic water from the pores of the lower fenpeat layers, because of compaction as a result of the overlying load of Sphagnum peat.*

Mechanism 1 stopped about 5000-300 years BC, whereas mechanism 2 will stop as the peat, which contains minerotrophic water, cannot be compacted anymore or because of a non-increasing load.

Recommendations

In general a good data management is recommended. This will improve the integration of the several disciplines. More attention for the regional hydrogeology is desirable. The quality of the chemistry data should be improved. Furthermore hydrochemical bog-samples outside the soak-areas are needed to know which difference prevail between the soaks and the remaining ordinary bog. More knowledge about the age of the water in the bog is necessary. Calculations to investigate the hypothesis around the soak-systems are also necessary.

1 INTRODUCTION

1.1. Irish-Dutch Peatland Study

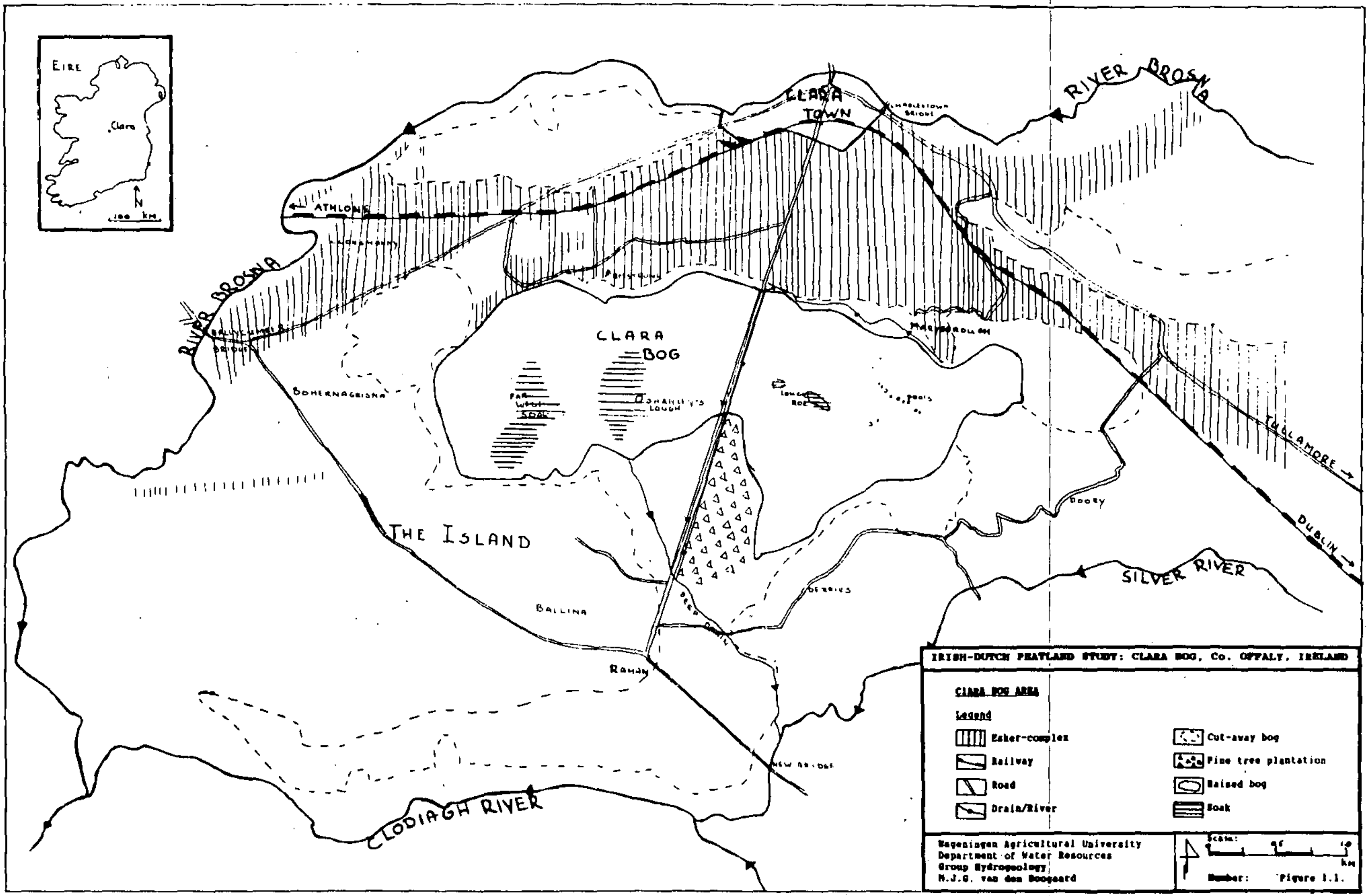
This MSc-thesis for the Wageningen Agricultural University, is undertaken within the framework of the Irish-Dutch Peatland Geohydrology and Ecology Study. It is a multidisiplinair project which was initiated in September 1989 and will last till the Summer of 1993. The Irish Nature Reserves Clara Bog and Raheenmore Bog, owned by Wildlife Service (part of the Office of Public Works), are the subjects of the Irish-Dutch Peatland Study. They both have a relative well-developed and intact raised bog-system.
A raised bog generally is a dome-shaped mass of peat centred in depressions of former lake basins. The vegetation on the bog only depends on precipitation for their nutrients. In this situation a paucity of species occurs. Bog mosses, sedges and ericaceous shrubs make up the low-growing open community. Nowadays intact raised bogs are rare in North-west Europe. But, there was a time when at large parts of this region, raised bogs were present (Scandinavia, North-west Germany, The Netherlands, Britain, Scotland and Ireland). Originally, 17 % of the Irish land surface was covered in peatland (1.1 m ha), of which 317.000 ha (5 % of Ireland) was composed of raised bogs. This is proportionally more than any other country in the world, except Finland and Canada. Peatland has long been regarded as wasteland suitable only for rough grazing or for cheap, but hard won fuel. A piece of peat, cut for fuel, is called turf. The primary use of bogs has been for fuel and very extensive areas have been cut away by hand. With the establishment of Bord na Mona (the Irish Peat Authority Development) in 1946, cutting became highly mechanised. Cross (1989) stated that at the present rate of decline, no really wet, more or less intact bog east of the Shannon will exist in three years, (except for three bogs which are partly protected) and those west of the Shannon will have gone by 1997. Due to turf-cutting, drainage and afforestation only 21.000 ha, 7 % of the former raised bog area, is suitable for conservation. In fact all domed mires on the island suffered from some drainage and excavation at their margins. In the Netherlands most of the raised bogs have been cut away and only some small relics are left.

Reasons for conserving peatland are:
Peatlands are essential parts of the biosphere. Because of there waterlogged, poor and exposed conditions they form a special habitat for animals and plants. Many plants only live on bogs e.g. certain Sphagna, while several birds live most exclusively on bogs during the breeding season...
Peatlands are genetic resources and reflect the climate and history of the last 10.000 years. Large structures, such as wooden trackway- and field-systems as well as smaller items, such as gold ornaments, amber beads, bog 'butter' (a soft cheese) and human bodies have been encountered.
In addition bogs are in a certain way places of great beauty and some larger areas have a wilderness aspect about them which many people value high (Cross, 1989).

The aim of the project is to develop appropriate programs concerning conservation and management of the two earlier-mentioned Irish raised bogs. The acquired knowledge can help to choose the best option for conservation and restoration of Irish raised bogs in general. Moreover, it might be implemented in regeneration programs for Dutch raised bogs. Organisations taking part in the project are:
- *Irish Wildlife Service of the Office of Public Works*
- *Geological Survey of Ireland;*
- *Dutch National Forestry Service;*
- *Dutch Department of Nature Conservation, Environmental Protection and Wildlife Management;*
- *Teagasc;*
- *Trinity College Dublin;*
- *University College Galway;*
- *Sligo Regional Technical College;*
- *Imperial College London;*
- *University of Amsterdam;*
- *Wageningen Agricultural University.*

1.2 Clara Bog

This report only deals with Clara Bog. Figure 1.1. shows the study-area which will be considered in this report. Clara Bog is a raised bog in County Offaly, part of the Irish Midlands. It is situated 2 km south of Clara town on either side of the road to Rahan (the Bogroad).
Clara Bog lies in between the River Brosna to the north and the Silver River and Clodiagh River in the south. In this report the Silver/Clodiagh Rivers are meant as Silver River is mentioned. The bog is separated from the River Brosna by the Esker-Riada. The area from Clara Bog to the Silver River is mainly cut-away bog. Clara


EIRE
Clara
N
100 KM
RIVER BROSNA
CLARA
TOWN
ATHLONE
CLARA
BOG
THE ISLAND
BOHERNAGRISHA
BALLINA
RAHAN
SILVER RIVER
CLODIAGH RIVER
TULLAMORE
DUBLIN
BOOLY
DEEP DRAIN
NEW BRIDGE
IRISH-DUTCH PEATLAND STUDY: CLARA BOG, Co. OFFALY, IRELAND
CLARA BOG AREA
Legend
Esker-complex
Railway
Road
Drain/River
Cut-away bog
Pine tree plantation
Raised bog
Soak
Wageningen Agricultural University
Department of Water Resources
Group Hydrogeology
M.J.G. van den Boogaard
Scale:
km
Number: Figure 1.1.

Bog is with 665 ha, one of the largest remaining Midland raised bogs. It is relatively intact but as all raised bogs in Ireland it is not free from human influences. As one of the last Irish raised bogs, Clara Bog is very special because of the soak-systems. Three soaks can be distinguished, Lough Roe, Shanley's Lough and the Far west soak (fig. 1.1.). They have there own characteristics, but each of them is richer in nutrients than the rest of the bog. As a result, an anomalous minerotrophic vegetation occurs in an ombrotrophic bog-environment. Plants characteristic of fens occur in soaks.
Clara Bog is divided in two parts by the Bogroad. This road is already marked on the Ordnance Survey map of 1840. Many roads like these are built in the 1700's (Bell, 1991). From the Bogroad several abandoned, limestone-based tracks lead on to the bog. They are probably constructed for turf-cutting and removal during the famine, in the 19th century.
Since 1983, the eastern side of the Bog has badly been damaged by a network of drains installed by Bord na Mona. The Wildlife Service of the Office of Public Works purchased Clara Bog from Bord na Mona, in 1986. Subsequently in 1987, the Irish Government declared 460 ha (69 %) of Clara Bog as National Nature Reserve. The attempt to block the drains on Clara Bog East seems to have worked well (Flynn, 1990).
The area south-east of the Bog is a cut-away area where coniferous tree species have been planted. At the edge of Clara Bog, especially on the south-west side, private owners actively cut turf for fuel. For turf-cutting the people of Clara have dug several drains. Not only on the south-west side but also at the other borders of Clara Bog, some drains occur. Along each side of the Bogroad a drain has been dug. The drains along the Bogroad finally come together in the, so called, Deep drain. This drain might be half-natural. South-east of Clara Bog, the Deep drain enters the Silver River.
There are several hydrological measuring points at and around Clara Bog, such as boreholes, domestic wells, piezometers, gauges and weirs. Those points are marked on map 1 which also gives an overview of the drainage-pattern. The most up to date Ordnance Survey map for the Clara Bog region has been used. This map dates from 1910 (Bell, 1991). In the appendices I and II an explanation is given about the measuring points.

For more information on the section 1.1. and 1.2. readers are referred to: Anonymous, 1990; Bell, 1991; Cross, 1989; Flynn, 1990; Sijtsma and Veldhuizen, 1992.

1.3. Construction of the report

Clara Bog is a special raised bog because of the three soaks.
There are several questions about soaks:

- *What are the water resources for the soak-systems?*
- *How is a soak-system working and is that the same as in the past?*
- *Did human influences at or near the bog affect the working of the soaks?*
- *What is the reason for ecological and hydrological differences between soaks-systems?*

As a soak-system differs from the rest of the bog, regional surroundings of the bog and the mineral subsoil might have there influence on soaks. Therefore it is important to investigate the relations between the geological layers, their hydrogeological characteristics and the regional and sub-regional waterflow-systems.
This thesis tries to give an overview of the regional hydrogeology of Clara Bog and surroundings. With this knowledge and the hydrological and ecological data gathered during the project some remarks will be made about the soak-systems.
As geology is the framework for the genesis of Clara Bog, the report starts, in chapter 2, with a general description of the geology of Ireland and in particular of Clara Bog and surroundings. Geological cross-sections are compiled to increase insight. The development of the raised bogs took places in recent geological times. In chapter 3 the development and associated characteristics of raised bogs are discussed.
Chapter 4 deals with the general hydrological features of Clara Bog, such as permeability of the different geological layers, drainage-patterns, groundwater contourlines and (downward) seepage. The measured temperature-profiles are explained in chapter 5. In chapter 6 the results of the several electric conductivity measurements and the hydrochemical data are discussed.
At last, the information of the chapters 2-6 is put together in chapter 7. This results in a overview of the regional hydrogeology of Clara Bog and a hypothesis about the development and the behaviour of soak-systems. Chapter 8 comprises the conclusions and recommendations.

2 GEOLOGY

2.1. General geology of Ireland

2.1.1. Pre-Quaternary

Ireland is composed of a central Carboniferous limestone plain which is surrounded along the coast by mountains of varying geological ages (like a saucer). The majority of the mountains originate from two important tectonic periods: the Caledonian orogeny and the Hercynian orogeny (fig. 2.1., 2.2. and 2.3.). This subparagraph will give a short chronological overview of the basic geological structures in Ireland from Silurian till Quaternary. All the older rocks have been very much deformed and metamorphosed.

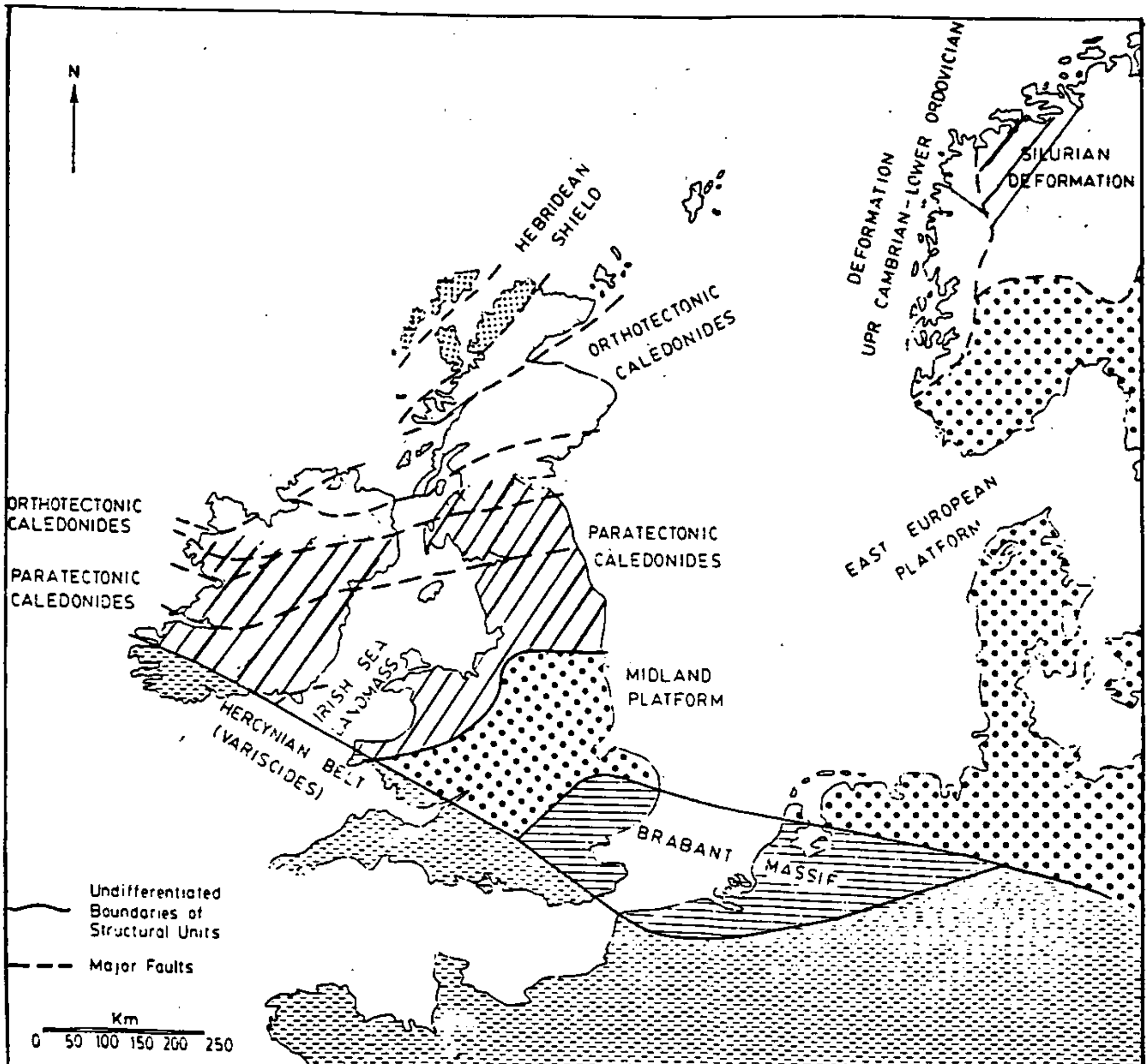


Figure 2.1. Ireland in relation to the major structural divisions of Europe (Synge, 1980)

*About 450 million years ago (<u>Silurian</u>) there was a plate collision of the American and Eurasian plate (**<u>Caledonian Orogeny</u>**). The main part of Ireland (except the south-west) is influenced by this orogeny, whose structures have a east-west direction.*

*In the following period (<u>Devonian</u>) the area, now known as Ireland, was above sealevel and exposed to atmospheric erosion. The rivers at that time seem to have flowed sluggishly, but by the end, they have transported great masses of sand and gravel, now cemented as sandstone (**Old Red Sandstone**). Fluctuations in river activity suggest marked seasonally changes and this type of climate tends to favour rapid erosion. Some terrestrial plants had evolved by this time but were probably not present in sufficient coverage to protect the land against erosion.*

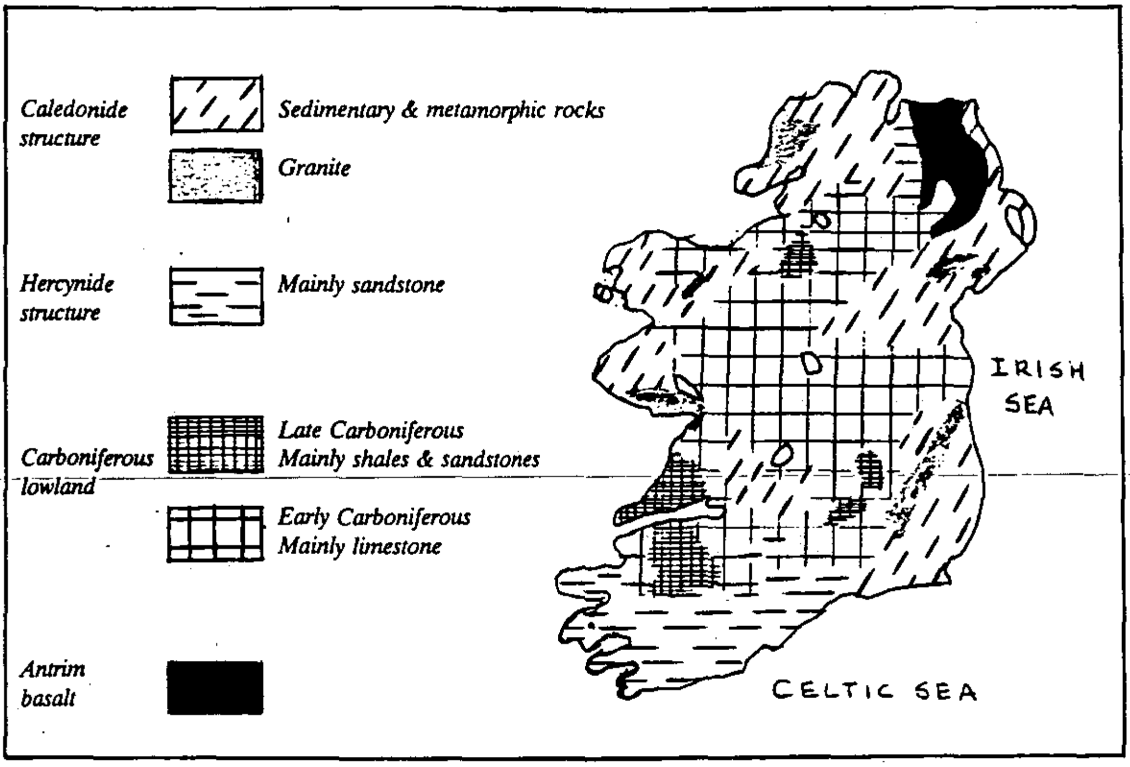


Figure 2.2. Outline of geological map of Ireland (Mitchell, 1990)

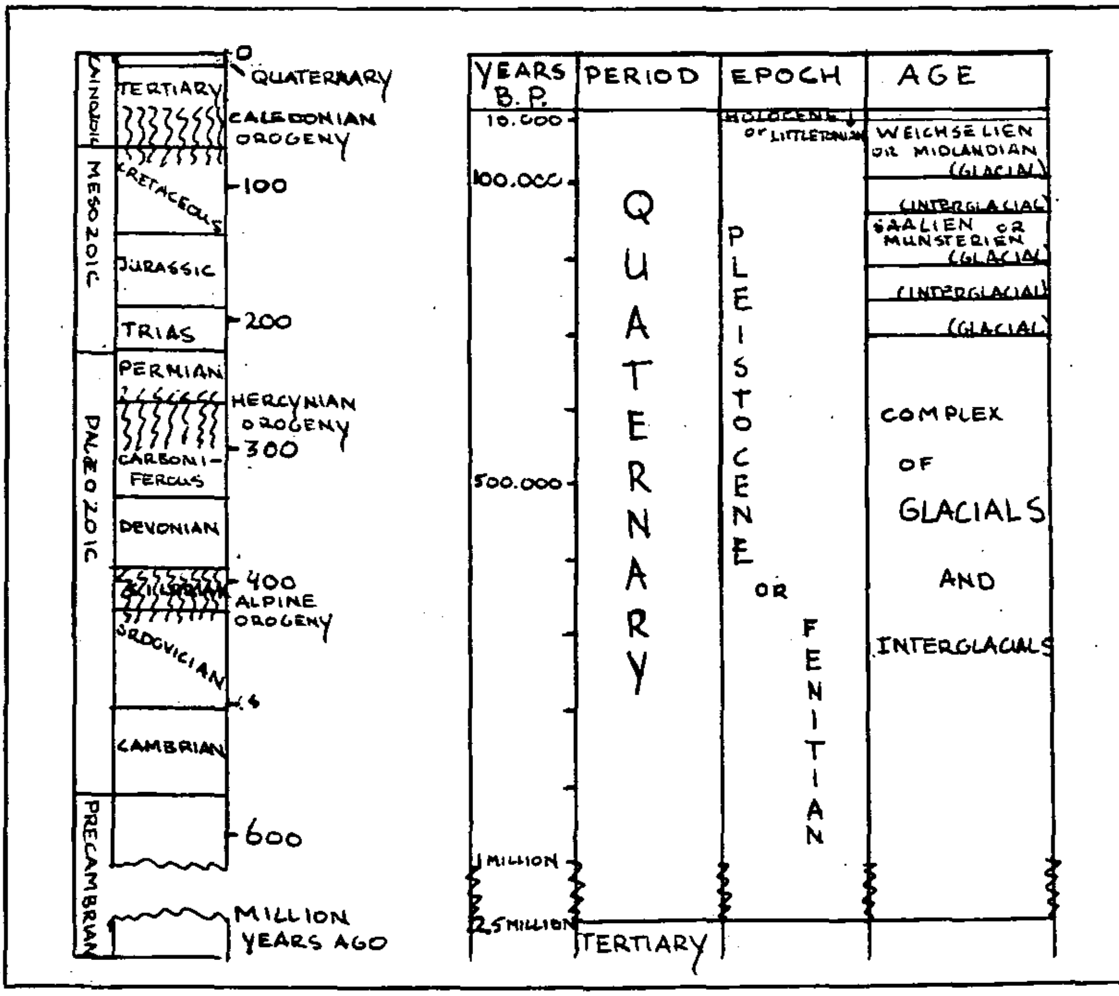


Figure 2.3. Chronostratigraphy

In the Carboniferous period North-west Europe was invaded by a great area of sea, whose water was warm and rich in the element calcium. Animals and plants used the calcium for supporting skeletons of calcium carbonate (calcite). When the animals and plants died, their skeletons largely disintegrated into calcareous debris which accumulated on the sea-floor or sometimes survived to become fossils. Great thickness of debris built up and the lower layers became consolidated into ***limestone.*** *First the sea was clear, but then sand and clay began to be carried in to it. These sediments consolidated into* ***sandstone and shale,*** *which lay on top of the limestone. Ultimately the water became so shallow that tropical forests could invade its margins and vegetable debris accumulated in backwaters and swamps. With passage of time this debris transformed into coal. This has stripped away virtually due to subsequent denudation, so that there is hardly any coal left in Ireland.*

The Carboniferous cycle was brought to an end by tectonic movements about 300 million yrs B.P. when there was relative movement of the European and African plates. This is known as the ***Hercynian orogeny.*** *As it approached Ireland, disturbance was beginning to lose force and its main effect was confined to the south of the country, where a great lateral thrust from the south caused extensive rock deformation. The Old Red Sandstone and the overlying Carboniferous deposits were folded and faulted into plates which run east-west. Further north the thrust progressively died away. The resulting structures were effected by the weaker force and the already existing older Caledonic structures, and tended to follow a north-east/south-west trend. Following on the Hercynian disturbance, in the Early and Middle Mesozoic, atmospheric denudation proceeded to whittle away the uplifted rocks. Erosion was very vigorous in the Irish area. Most of the erosion products that followed the Hercynia were carried off into basins where they formed the* ***New Red Sandstone.***

In the Cretaceous period (about 100 million yrs B.P.) continued erosion over much of Western Europe seems to have produced a land surface of very low relief with rivers incapable of carrying substantial amounts of sediments into the sea. At that time seawater flooded across Europe. On the bottom a calcareous sediment, free from sand and clay, was deposited. This was later consolidated and uplifted as a finegrained limestone, chalk. Siliceous debris, later coagulated as flint layers in the chalk, was deposited as well. This chalk, which must once have covered almost the whole of Ireland, has been completely stripped away by later erosion.

About 60 million years ago (Tertiary) Greenland was drifting away from Europe. Due to this, fissures developed in the North of the Irish Sea and quantities of molten material welt up from below. The molten substance flowed out over the surrounding countryside in Scotland and Antrim (Northern Ireland), burying it beneath great sheets of ***basalt*** *(a great example is the Giant's Causeway in Antrim). If the molten material solidifies in the fissure before it reaches the surface of the ground it becomes a dyke. Dykes tending north-west/south-east are known throughout the northern half of Ireland. These plutonic/volcanic features are associated with the* ***Alpine Orogeny.***

As soon as extensive areas of limestone had been exposed to atmospheric conditions, they began to be attacked by different physical and chemical processes of denudation which resulted in a karstic landscape. A landscape form which today can be seen in the Burren (area south of Galway).

Due to the post-Hercynian denudation only the roots of the Hercynian mountains did remain. Together with the other peripheral upland areas of Ireland they suffered Tertiary uplift relative to the central lowlands. That gave rise to rejuvenation of the landscape with the highest mountain in the south-western part of Ireland (Carrantuohill of 1042 m). The fact that the margins of Ireland did undergo a stronger uplift than the centre are reason for the present saucer form.

2.1.2. Quaternary

2.1.2.1. The glacial periods

The Quaternary period started about 2.5 million years ago and is divided in two epochs, the Pleistocene and the Holocene (Fenitian and Littletonian in Ireland, fig. 2.3.).

The Pleistocene is characterised by periods of extreme cold climates in which large icecaps were formed (glacials) and warmer periods (interglacials). In Ireland certainly two cold stages occurred: The Munsterian (200.000-130.000 yrs B.P.) and the Midlandian (30.000-13.000 yrs B.P.). The latter is named after the Irish Midland because its deposits are well displayed there. These ice-stages also occurred in the Netherlands where they are called Saalien and Weichselien.

In the Munsterian large ice-masses were formed and most of Ireland was covered by ice, where in the Midlandian the ice masses did not reach south Ireland (fig. 2.4.). In North- and Central Ireland the Munsterian glacial sediments were removed by the Midlandian ice. In South-Ireland permafrost (periglacial conditions) dominated during the Midlandian which resulted in a much smoother landscape than in the rest of Ireland.

In the following text the most important geological, ice-related phenomena from the glacial periods are described (fig. 2.5).

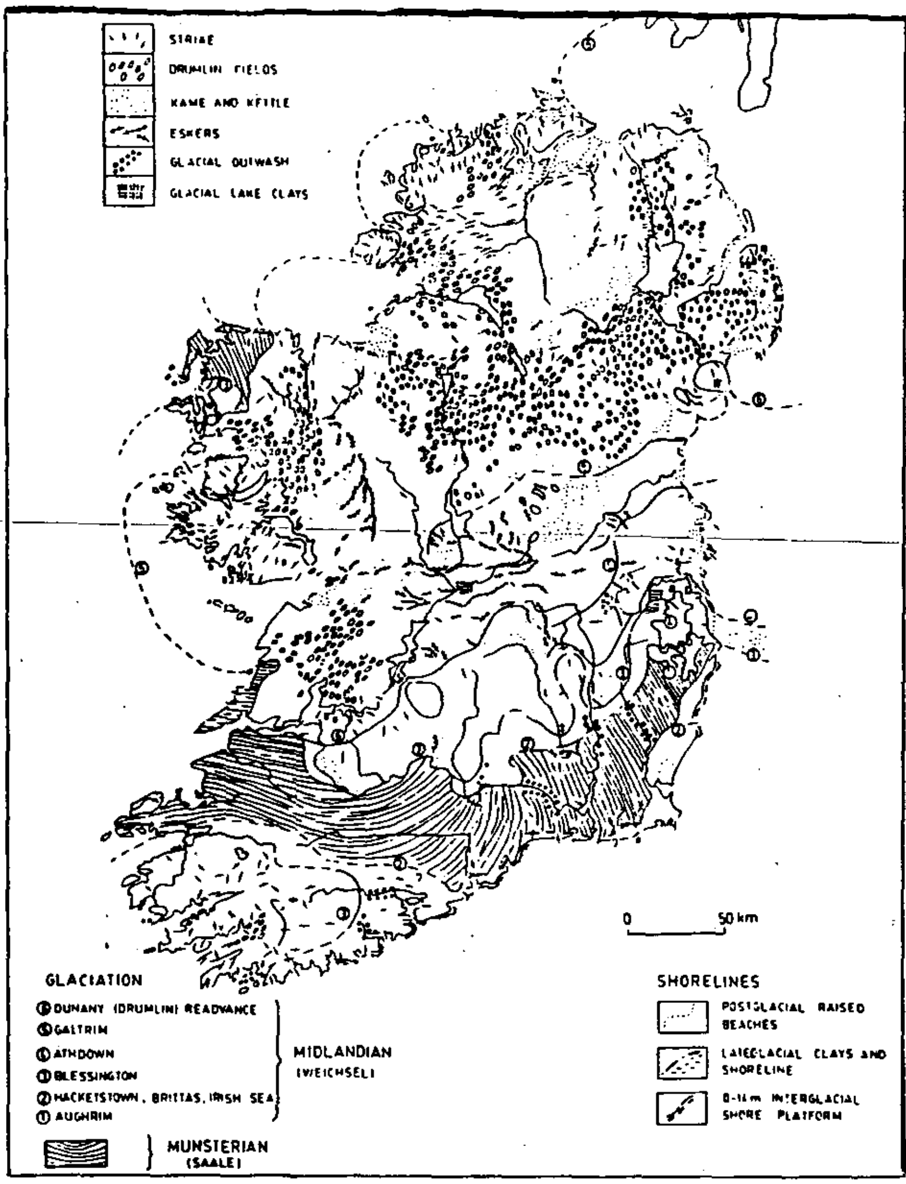


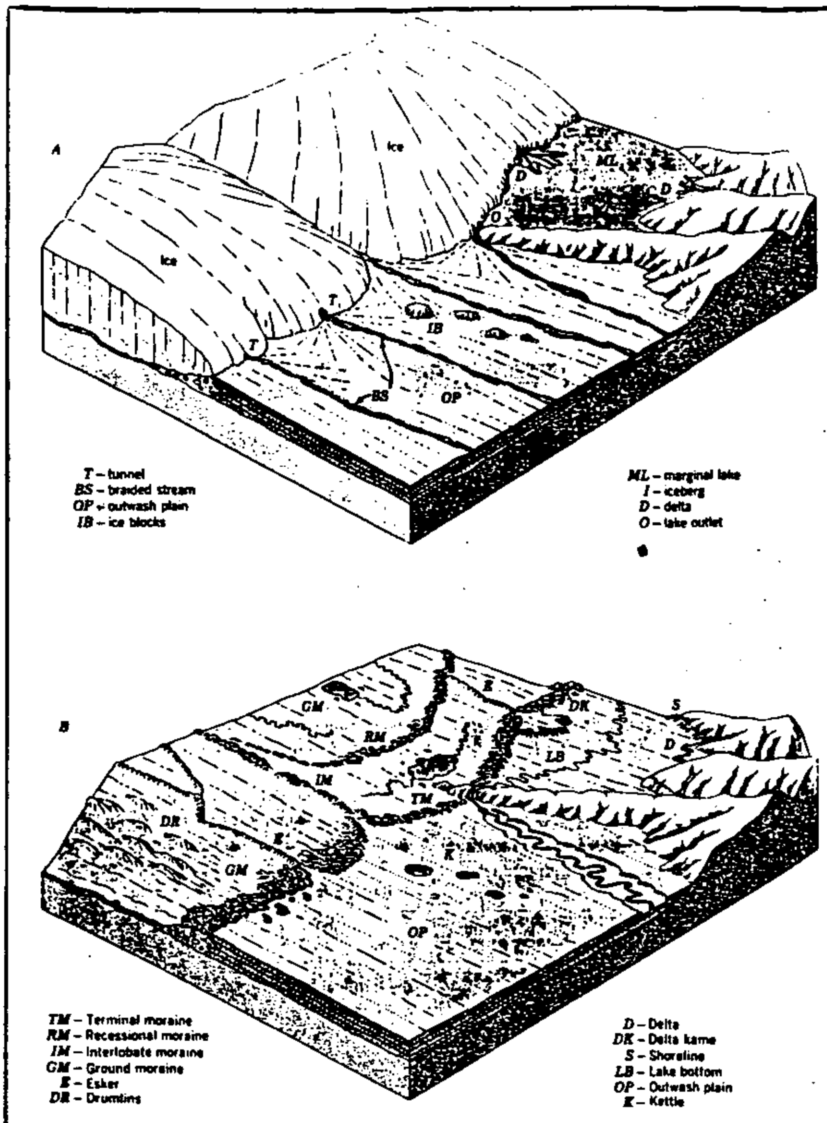
Figure 2.4. Quaternary deposits of Ireland (Synge, 1980)

The ice-sheet picks up the superficial weathered material that lies in its path, and thus comes in contact with the underlying bedrock. It is then armed with incorporated sand and pebbles and can abrade the rock, producing a surface which is in general rounded but shows on closer examination scratches or *__striae__*, *produced as stones were dragged across the rock. The ice carries not only the pebbles, sand and clay, that it picked up as it advanced, but also the new material detached from the underlying rock. This material can range in size from block of rocks to the finest rock-flour. When the ice thaws its load is deposited. There is little possibility of sorting and this indiscriminate mixture is known as* *__boulder clay or till__*. *Because of the poor sorting the permeability of these deposits is rather low. The ice sometimes mould the till into ovoid masses aligned with the direction of its flow, and when the ice has gone a field of* *__drumlins__* *is revealed. Depending on the climate, a ice-mass ablates away in situ and leaves a deranged topography.*

Meltwater on the ice surface sinks down through fissures in the ice to its base where major discharge tunnels gradually are established. When the ice ultimately disappeared, the tunnel fill will emerge as an poorly sorted drift, shaped into narrow sinuous ridges: *__eskers__* *(from the Gaelic word eiscir). Later on, in a boggy country, such ridges provide natural causeways. The fact that in eskers fine and coarse sediments alternate one overlying the other, reflects the constant changing of energy levels due to changes in the water-volume with fluctuating atmospheric temperatures. Esker ridges vary in height from 5-25 metres. The normal width of esker ranges from 15 to 250 metres and the length can vary from a few hundred metres to 500 kilometres.*

2.1.2.2. Period after the last glaciation

Some 13.000 years ago the last ice-sheet had gone, but permafrost-conditions still remained sometime. According to the esker pattern, the direction of the ice retreatment has been from west to east. The eskers which were imbedded in tunnels lost their side-walls an a considerable settling, collapsing and slumping along the esker ridges occurred. At the end of the Pleistocene depressions started to be filled in with ***lacustrine deposits***.



Marginal landforms of continental glaciers. (A) With the ice front stabilized and the ice in a wasting, stagnant condition, various depositional features are built by meltwater. (B) The ice has wasted completely away, exposing a variety of new landforms made under the ice. (Drawn by A. N. Strahler.)

Figure 2.5. Marginal landforms of continental glaciers

Because of the poorly developed drainage system at the end of the glaciation, nearly stagnant waters covered large, low-lying areas and deposited fine-grained sediments. A still-existing example of such a geological environment is Lough Ree in the River Shannon. Lake deposits are confined to topographical lows within the glacial landscape. The fine deposits in the basins sometimes contain coarse material, such as stones, which have been brought in by floating ice. An area developed where rivers deposited their sediments. Sometimes the boundary between river- and lacustrine deposits will be difficult to determine as a result of the gradual transition in the sedimentary environments involved (lake, standing water, broad low-energy river, small low-energy river).

The most important feature of the Holocene in Ireland, is peatland. As during the Holocene the climate slowly improved, vegetation returned and after some time peat started to develop in the wettest areas. The final result of the last process are the extensive organic deposits which are the main concern of this project. Chapter 3 deals with the development of peatland. In the following paragraph a brief overview will be given of the Quaternary geology in the area of Clara Bog.

For more information on the section 2.1. readers are referred to: Synge, 1980; Mitchell, 1990; Warren and Daly.

2.2. General geology of the Clara Bog region

2.2.1. Geomorphology

The present landscape of the Irish Midlands, part of the Central limestone plain, is largely a feature of the Quaternary period (fig. 2.6). According to this the Clara Bog region is dominated by glacial deposits and Holocene bog development.

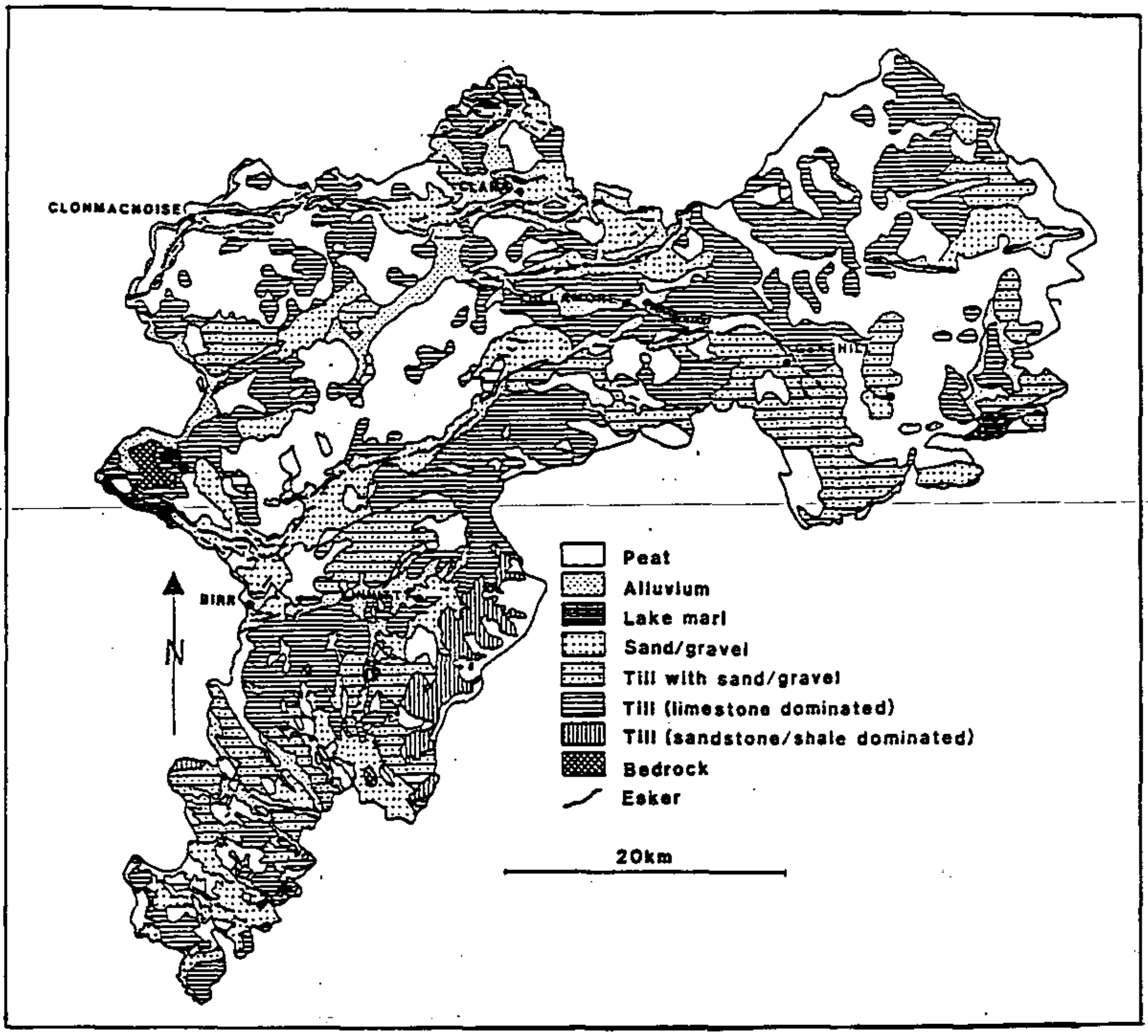
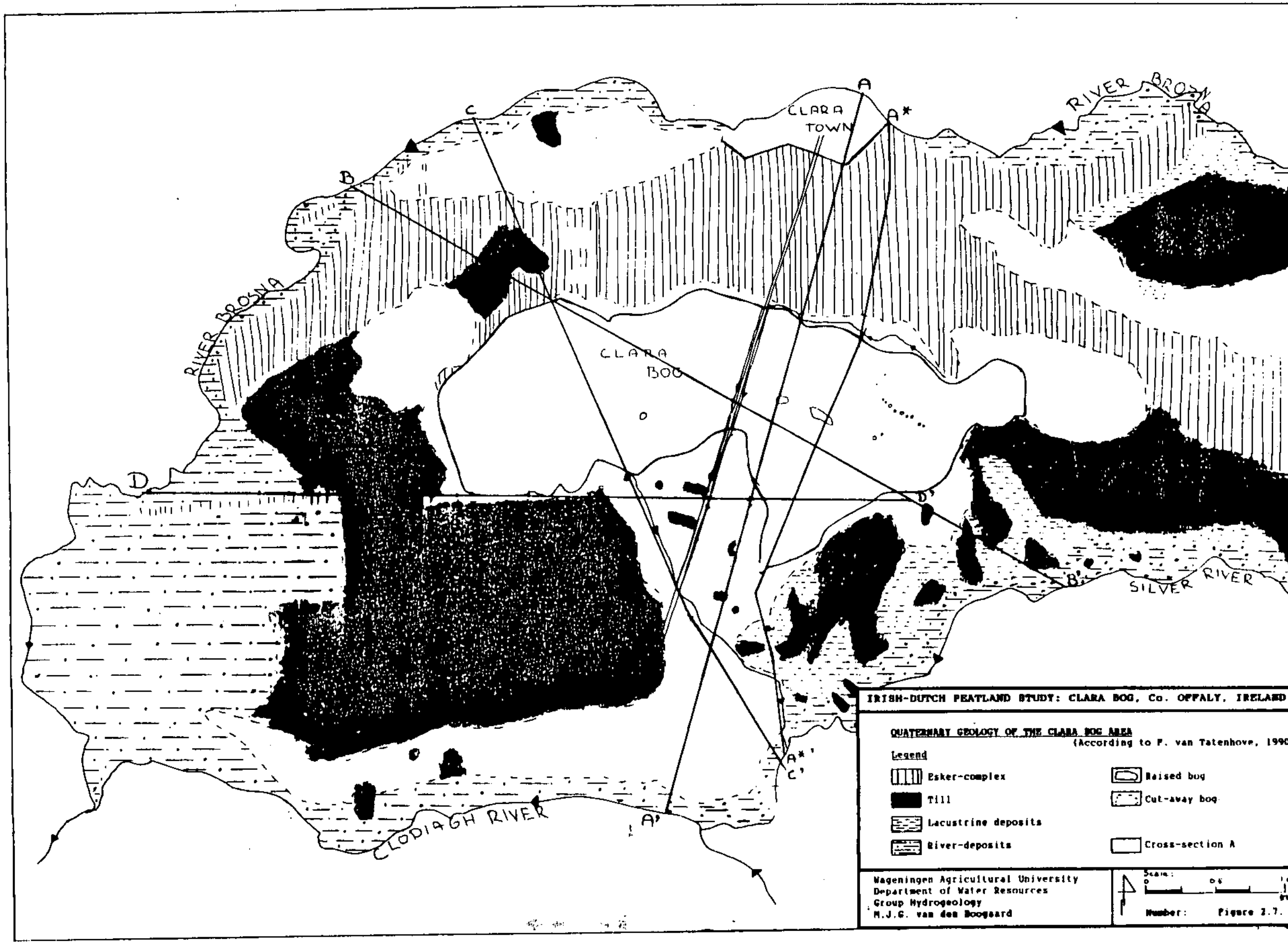


Figure 2.6. Quaternary geology of County Offaly (Daly)

Geomorphologically, the Clara Bog region is characterised by the hilly topography of eskers in the north-northeast and The Island, an area of undulating to hilly topography in the west-southwest. (See map 1 from Van Tatenhove, 1990.)
The height of the eskers is about 10 to 25 m above the surface of Clara Bog and therefore it is the highest elevated feature within the study area. The Clara esker is not a simple ridge but it is composed of a number of interconnecting ridges which sometimes run parallel and sometimes converge (Warren and Daly). In the southern part of the bog the most pronounced topographical feature is Ballina Hill, ca. 20 m above the bog surface (Van Tatenhove, 1990). The area direct south of Clara Bog west, where several facebanks occur, is marked by small scale undulations and many drains. Especially near the facebanks the ground is equalized for turf-cutting. South of the forest (south-east of Clara Bog) the undulations are less frequent and lower and larger in diameter (Van Tatenhove, 1990).

2.2.2. Geology

*The Clara Bog region is underlain by **Carboniferous limestone**. In the north-northwest and southwest of the study area the limestone has a reef lithology and in the other areas a pure fine-grained lithology. Outcrops of bedrock have not been found within the study area. The limestone consist almost entirely of $CaCO_3$, with only small quantities of clay apparent.*
Everywhere at the surface of the Clara Bog region Quaternary deposits are present (fig. 2.7. and Van Tatenhove, 1990). The (fluvio-)glacial deposits are the oldest. Van Tatenhove distinguished several kinds of till which vary texturally from clayey/loamy till to gravelly till. A till which is typical for the Clara Bog region has a sandy-loamy and stony texture, with a high content of big boulders. This unit probably underlies the southwestern part of Clara Bog. A gravelly till/gravel is found in several other places in the study area. These deposits are sometimes clearly related with geomorphology. Examples are the conical hills north-northeast of Ballina Hill and the broad medium-scale hummocks near the Silver River. As gravelly tills can also be expected in flat terrain, it may be that large areas of the map unit 'Cut-away Bog' are actually underlain by gravelly tills or gravel. South-southeast of Clara Bog an 'undefined' till is found in an undulating to rolling landscape with broad medium-scale hummocks. If these till deposits underlie Clara Bog, the same type of morphology can be



CLARA TOWN
RIVER BROSNA
RIVER BROSNA
CLARA BOG
SILVER RIVER
CLODIAGH RIVER
A
A*
B
C
D
D'
B'
A*'
C'
A'
IRISH-DUTCH PEATLAND STUDY: CLARA BOG, Co. OFFALY, IRELAND
QUATERNARY GEOLOGY OF THE CLARA BOG AREA
(According to F. van Tatenhove, 1990)
Legend
Esker-complex
Till
Lacustrine deposits
River-deposits
Raised bog
Cut-away bog
Cross-section A
Wageningen Agricultural University
Department of Water Resources
Group Hydrogeology
M.J.G. van den Boogaard
Scale:
0
0.5
1.0
Number: Figure 2.7.

expected here (Van Tatenhove,'90). At the north-eastern part of the bog the till is clayey and contains some coarser material (Flynn, 1990).
In the Clara Bog region 9 boreholes are drilled into the limestone (see map 1 and appendix I). At the boreholes 2,4,6,9 and 10 gravelly-sandy deposits underlain a clayey till. At the boreholes 7 and 8 only gravelly-sandy deposits occur and at borehole 5 clayey till lies directly on the limestone. Some of the domestic wells in the study-area are not deep enough to reach to the limestone. As they have to be in a permeable layer one can assume that they reach to a gravelly layer rather than to the clay till. Those gravelly-sandy deposits have the characteristics of fluvio-glacial deposits. On the other hand till can occur in all kind of textural varieties. In the case of fluvio-glacial deposits the explanation could be that the last ice-sheet did not remove all those deposits but covered it with till. In this report clayey till and gravelly-sandy deposits are distinguished, because the distinction is relevant from the hydrogeological point of view. The ***clayey till*** *is poorly sorted. It consists of coarse material in a clayey, silty matrix. The* ***gravelly-sandy deposits*** *are poorly sorted; coarse material in a sandy matrix. Although poorly sorted, they are better sorted as the clayey till.*
Extensive fluvioglacial esker-deposits are located north of Clara Bog. The ***Eskers*** *are characterised by lenticular units of predominantly cobble and boulders. The esker-deposits are dominated by medium sand, well sorted and sub-angular to subrounded in shape. This boulder rich esker tunnel deposit rests on bedrock (pers. comm. W. Warren, 1992). The* ***esker-associated sands and gravels*** *have a overall similarity to esker deposits although larger proportion of finer material is envisaged reflecting the less energetic conditions of the margin of subglacial meltout. The majority of the stones in the Clara esker are grey limestones from the Midlands. Sandstones are common as well and occasionally Galway granite is found confirming a west-east movement of the ice-mass during the Midlandian. Esker deposits are generally better sorted than till. They are gravelly to sandy in grain size and usually stratified.*
The gravelly-sandy deposits which underlie the bog are not related to the esker gravels. The latter are younger. It is thought that the older gravelly-sandy deposits may underlie part of the esker but can not be distinguished due to the lithological similarity with the younger fluvioglacial deposits (pers. comm. R. Flynn, 1992).

Clara Bog has been formed in a depression where the glacial deposits at first had been covered by a blanket of ***lacustrine deposits*** *which seals the peat of from underlying layers. The thickness of the lacustrine deposits varies from 0.1 to 5.5 m (Bloetjes, 1992), depending on the local topography of the (fluvio-)glacial deposits and the distance to the lake edge. It should be noted that the lake level was probably not constant. In most of the times the clay includes fine sand and pebbles. Bloetjes (1992) distinguishes a marl on top of the lacustrine clay in the middle of the bog. A marl consists of more than 30 % calcium. It is likely, but not quit sure, that the lacustrine clay also consists of >= 30 % calcium. For that reason the marl of Bloetjes (1992) is called a fossil rich layer, in this report. Near the shores of former lakes the sand and gravel content of clay increases. Also dropstones can be present embedded in the clay. It is expected that these dropstones are concentrated at the shallow lake shore. The clay is very sticky and has a low permeability although the peat-clay interface may be relatively permeable. Remarkable is the presence of a thin band of gritty clay outcropping in the drains along the northern boundary of the peat (Flynn, 1990).*
Van Tatenhove (1990) distinguished ***Holocene river-deposits.*** *According to M. Smyth and W. Warren the river-deposits are partly till or lacustrine clay and are mixed up in a lot of places because of human activities (pers. comm. J. Streefkerk). For this study these differences are not relevant.*
As during the Holocene the climate slowly improved, vegetation returned and some 9000 years ago, ***peat*** *started to develop in the wettest areas (Mitchell, 1990). Geologically one can distinguish two types of peat in the Clara Bog region: fenpeat, and Sphagnum peat.*
Fenpeat *is the oldest one and contains layers of reed, sedges and trees which accumulated under eutrophic circumstances. The thickness range from 1-3.5 m and shows a rather high spacial variability.* ***Sphagnum peat*** *is a younger peatform which usually covers the fenpeat. It mainly consists out Sphagnum which depends on a ombrotrophic situation. There are two kinds of Sphagnum peat, old and young:*
<u>Older, black, highly humified Sphagnum peat</u>, consisting out of Sphagna and roots, twigs from plants as Heather. This peat originates from a relative drier, warmer climate which occurred some 4500 years ago in Ireland. In this kind of climate the peat grows at a slower rate.
<u>Younger, white, poorly humified Sphagnum peat</u>, due to a wetter and colder climate.
The prefix old does not necessarily means that old is older in age than the young Sphagnum type. Especially on higher ground, the old Sphagnum peat is younger than the young Sphagnum peat on the lower parts.

For more information on the section 2.2. readers are referred to: Bloetjes, 1992; Lenting, 1992; Van Tatenhove, 1990.

2.3. Hydrogeological profiles

2.3.1. Introduction

Five hydrogeological cross-sections are compiled to increase insight in the geological framework of the whole Clara Bog region. Cross-sections give an impression about the geological conditions and help to explain some phenomena. Cross-sections, however will always be only abstractions of reality. The geological information (2.2.2.) is simplified for the cross-sections:

1) *The esker and the esker-associated deposits are drawn together as one esker-complex deposit.*
2) *No difference is made between the esker-complex deposits and the (fluvio-glacial) gravelly-sandy deposits. The permeability and the structure of those two deposits are rather similar in comparison with the clayey till. Hydrogeologically pumping tests have shown that the esker-complex deposits have a permeability which is an order of magnitude higher than the gravelly-sandy layer underneath the bog (pers. comm. R. Flynn, 1992). The permeability of the sandy loamy, stony till (clayey till in this report) is probably in the order of 10^{-5} to 10^{-1} m/day where the permeability of gravelly till could be in the range of 10 m/day. The permeability of eskers is 10 to 100 m/day (Van Tatenhove, 1990).*

The available data, on which the sections are based, were sometimes a handicap and determined the locations of the transects. Particularly the boreholes are very important and had to be included in the transects.
The cross-sections are named A, B, C, D and A (fig. 2.7.).*
Enough information was available of four important drains to compile cross-section for them as well: the Deep drain, the two drains along the Bogroad and the drain north-east of Clara Bog.
The sections were made at a horizontal scale 1:10.000 and a vertical scale 1:200. See the maps 2 and 3.

2.3.2. Data and methods

The available data are:

- *Borehole and cobradrilling information, G.S.I. (1992);*
- *Levels at pegs on Clara west, O.P.W. (1990) (Appendix II.C.);*
- *Levels at pegs on Clara east, O.P.W. (1991) (Appendix II.C.);*
- *Levels from P. McGowan, July 1992 (Appendix II.D.);*
- *Cross-sections of the River Brosna, Silver and Clodiagh River, O.P.W. (1947);*
- *Quaternary geology map and augerings, Van Tatenhove (1990);*
- *Augerings at removed bog area south of Clara Bog, Lenting (1991);*
- *Augerings on whole Clara Bog, Bloetjes (1992);*
- *Augerings near mound and soak at Clara Bog west, Sijtsma & Veldhuizen (1992);*
- *Geophysical maps of Clara Bog, Smyth (1992).*

The methods that have been used are:

a. *First the information from the borehole logs and the augering-sites from Bloetjes, Lenting and Sijtsma & Veldhuizen are marked. If the transect runs between 2 augerings-sites the profile on the section has been determined by linear interpolation. For the data on the bog the interpolation has been done using the maps from Bloetjes (1992). These maps are interpretations of the augering data and sometimes the augering-description differs from the maps. The data from Lenting are interpolated using the profile descriptions (1991).*
b. *The surface-levels are put into the transects. At the used scale it does not matter that the levels are of different years.*
c. *With the cross-section of the rivers (O.P.W., 1947), the river-profiles and if possible some geological profiles near the rivers are put into the transects.*
d. *The Quaternary geology according to the map from Van Tatenhove (1990) is noted at the top of the cross-sections.*
e. *At last the geophysical maps from Smyth (1992) are used. With these maps and the information from the earlier-mentioned reports, contour-lines are compiled. The way of compiling the contour-lines is discussed later in this subparagraph.*

The profiles are in most cases from river to river. As for the areas around Clara Bog few data are available, only rough estimations can be made there.
The following remarks have to be made at the cross-sections:

* *As bedrock is geophysically easy to distinguish (Smyth, 1992) the geophysically determined bedrock-line is taken as the bedrock-surface.*

* *For the layers other than bedrock, geophysics are used as check. The till which has been distinguished by the geophysics consists either of clayey till or the gravelly-sandy layer.*

* *In almost all the cross-sections the geophysically determined surface of the mineral layers (subpeat-surface) is too high according to the augerings. Therefore this surface is mainly defined using the augering and borehole information. The maps from Lenting and the augerings from Van Tatenhove are used as makeshifts.*
* *The geophysically determined till-surface lies in most cases (except transect E) too high - probably in relation with the too high subpeat-surface.*
* *The lacustrine clay under the bog will never be thicker than 7 m (Smyth, 1992) and lies not much higher than ca. 52 MOD (Bloetjes, 1992).*
* *Sphagnum peat often overgrows fenpeat right up to the bog margin. Because of the influence of nutrient-rich groundwater from the surroundings there will often be a zone of fenpeat. At the borders of Clara a lot of turf-cutting is going on which removes the upper Sphagnum peat layer. This means that the present situation can be like in figure 2.8. and not as in the cross-sections.*
* *The fenpeat on the top of the mound at Clara west (cross-section C) might not be laterally connected to the surrounding fenpeat (pers. comm. R. Flynn, 1992).*
* *Figure 2.9. gives an overview of the situation near the esker without the simplification that are made (see also cross-section A and A*).*

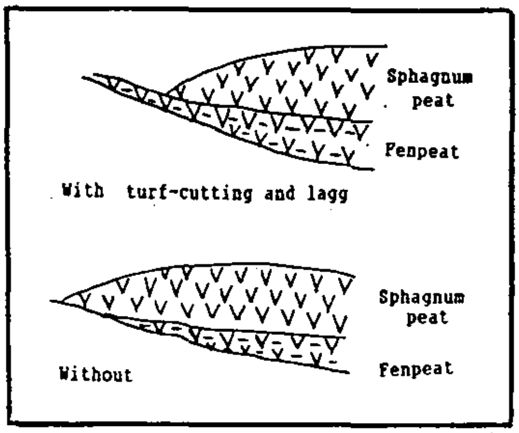


Figure 2.8. Bog margins (To R. Flynn, 1992)

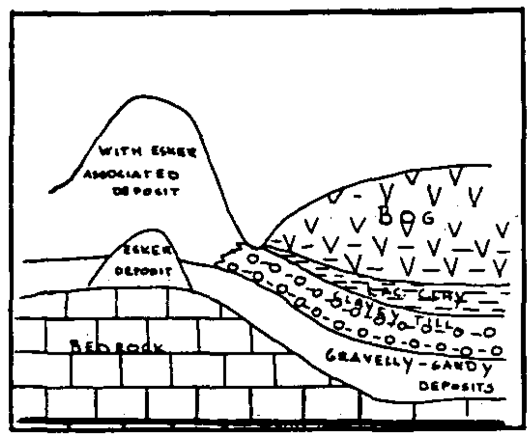


Figure 2.9. Bog margin near esker without simplifications (To R. Flynn, 1992).

2.3.3 Results

* *The hydrogeological profiles (maps 2 and 3) show very well that Clara Bog is formed in a **limestone-depression**. The (fluvio-)glacial deposits follow most of the time the surface of the limestone. The limestone and the (fluvio-)glacial deposits are deepest situated in the middle of the Bog, near the Bogroad.*
* *There are several **mounds of (fluvio-)glacial deposits** at and near the Bog. These mounds consist in most cases of clayey till. The mounds can be found:*
  - *near the edge of Clara Bog east (transect A and A*); At transect A it is a high mound of gravelly-sandy deposits. At transect A* the mound consists of gravelly material which underlies clayey till.*
  - *at the southern part of Clara Bog west (transect C);*
    No Young Sphagnum peat is found on the mound at Clara Bog west. Maybe this part was not wet enough after the dry period or the peat has been removed or oxidised (Bloetjes, 1992).
  - *south of Clara Bog west to the Bogroad (transect C,D);*
    The bottoms of the Deep drain and the drains near the Bogroad reach this mound.
* *At the removed bog area, near the Silver River there is probably no clayey till but only a rather thin layer (2-5 m) of gravelly-sandy material (transect A).*
* *The **lacustrine deposits** really act as a blanket which fills the depressions in the underlying deposits. Only in the middle of Clara Bog, around the Bogroad (deepest part of the former lake) a layer with molluscs and carbonate-precipitates is present (transect B). Near the edge of the bog the clay-layer is very thin (all transects).*
* *It is very clear that both Clara Bog west and east form a dome. Originally there was only **one dome** (Bell, 1991). The effect of the road can very well be seen in transect B. Because of the Bogroad the bog has shrinked 5-6 m. More information about this subject is available in the*

reports from Bell (1991) and Samuels (1992).

* *The **fenpeat** has almost everywhere the same thickness, i.e. ca. 4 m. Remarkably the fenpeat-layer is thicker under Lough Roe (transect A*)*
* *The **cut-away areas** have a very irregular topography and in most cases only a small fenpeat-layer is left.*
* *The **drains west and east of the Bogroad** start in Sphagnum peat and in the middle of the bog they flow in fenpeat (map 3.A). The east-drain reaches the fenpeat ca. 200 m before the west-drain. Between CLBH10 and CLCD2 those drains passes a clayey till mound. Near the Bogroad-bridge, where they enter the Deep drain, the drains flow through lacustrine clay.*
* *The **Deep drain** starts on Clara Bog west (bottom consists of fenpeat, map 3.B). Near the edge of the bog till, some 0.5 km west from the Bogroad, it reaches a clayey till mound. In between the border of this mound and the Bogroad, the Deep drain runs through fenpeat. From the Bogroad on, it lies in lacustrine clay till it enters the Silver River.*
* *The **drain north-east of Clara Bog** runs through fenpeat from the Bogroad to CLBH2 and in the lacustrine clay from CLBH2 to transect A* (map 3.C). More east from transect A* it passes again fenpeat and maybe also lacustrine clay. The beginning of the drain lies probably in the clayey till.*

The geophysically maps of Smyth (1992) give also a good impression of the depressions and hills in the geological subsoil of the peat. For more information about the different peat-layers the readers are referred to Bloetjes (1992).

3 RAISED BOGS

3.1. Peatland

Peat consist of partly rotted plants plus small quantities of animal remains, pollen and dust. It has accumulated over thousands of years in areas where the rate of plant production exceeds the rate of plant decomposition. In the waterlogged conditions of peatland, micro-organisms which cause decay, are unable to survive so that the dead material gradually accumulates. The history of the peat-forming system can be seen, as the preserving goes with distortion. Climatic changes are of main importance for changes in the vegetation, but also many internal and other external factors determine the evolution of the mire. Physically over 90 % of the bog volume consists of water. Therefore bogs are very sensitive to amount and quality of water.

The main types of peatland are fens and bogs. Fens occur in eutrophic circumstances and bogs are characteristic for nutrient-poor (ombrotrophic) conditions. There are several types of bogs. The two principal types are raised and blanket bogs. Blanket bogs occur in areas of very high precipitation (lowland of West-Ireland and highlands). Raised bogs develop in areas of impeded drainage (centre of Ireland). The word 'bog' is derived from the gaelic word 'bogeach' meaning soft.

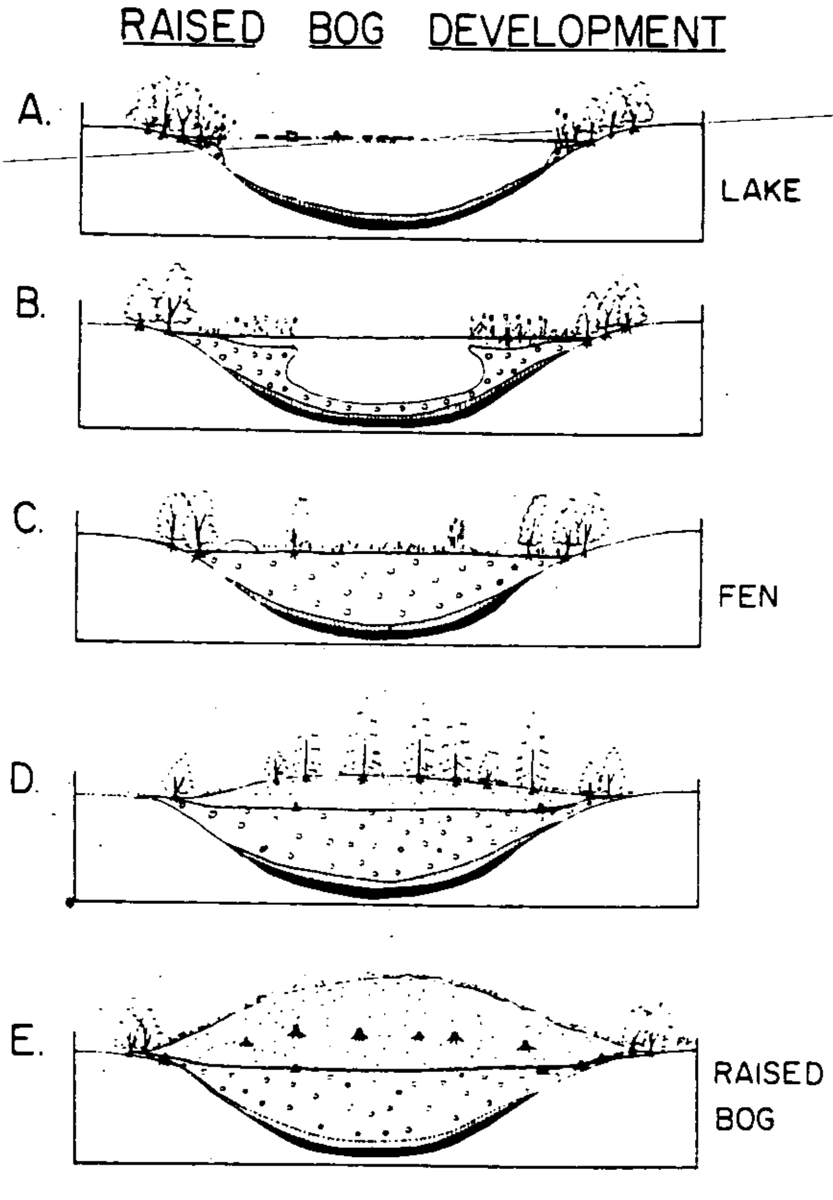
3.2 Development of raised bogs

3.2.1. General development

The current raised bog development started some 10.000 years ago when the last glaciation ended and glaciers retreated northwards. In a large part of Central Ireland shallow lakes were left behind due to the deranged topography, caused by melting ice. In the lakes the free drainage was impeded and so the water was trapped. Raised bog starts in open water (lake filling) or by swamping wherever the soil is moist enough throughout the year (figure 3.1.). First a deposition of fine inorganic sediments occurs in the lakes (silt, clay and sometimes also shell-rich marl). At the bottom a debris of floating plant material accumulates while the shores are overgrown with a fen-bed (with for example reed). As the fen-plants die, their remains fell into the water. Because of the anaerobic conditions this material only decomposes partly and is deposited as peat on the bottom of the lake. The accumulation of plant material makes the lake shallower and in this environment sedges and, later on, alder and birch starts to grow. At first the lake is fed with mineral-rich groundwater. Once the lake is overgrown the influence of eutrophic water gradually declines. As the roots can not reach the mineral groundwater, a mesotrophic environment develops. Plants of mineral-poor habitats invade. Very important for the development of raised bogs are Sphagnum species. These Bog mosses sustain the bog, draw up water and keep the surface wet. They are waterlogged in all but the driest period, so that the bog is able to continue it's upward growth. They also make the soil more acid by its ionic-exchange activity (H^+ ions are exchanged by other ions like Na^+, K^+, Mg^+, etc.). In time the plant is solely dependent on nutrient-poor, meteoric-atmospheric water (ombrotrophic stage). Other plants typical of raised bogs, such as Heather, Sundews and Deer sedge then invade the bog.
Bogs are not very hospitable places for animals, mainly because of the fluctuating waterlevels and the intermittent nature of food supplies. The most abundant animals on bogs are tiny mites and springtails which are living in the surface layers of the dead plant material. There are numerous species of spiders and moths on the raised bog. Large caterpillars and brightly coloured dragonflies and damselflies are also very common. Numerous and for us unwelcome inhabitants of bogs are the small, biting midges. The most frequently seen from the larger animals are frogs, hares and certain birds e.g. Snipe, Curlew, Kestrel, Skylark, Red Grouse.

3.2.2. Hummock and hollows

The living surface of a raised bog is made up of a series of hummocks and hollows, formed by the differential growth of Sphagna. Hummocks are higher parts of a bog-surface where hollows are lower parts. On the wetter parts some of the hollows form small pools of shallow water which may consist entirely of open water or may be wholly or partly colonized by aquatic plants. Some Bog mosses grow on hummock and others in the damp hollows, pools and drains. Hummocks are the driest places on the bog. They are suitable habitats for Cross-leaved heather, Bog rosemary, Deer sedge and Bog cotton. The hummocks are often colonised by rich mats of Lichens, mainly species of Cladonia. In the hollows White-beaked sedge, Bog asphodel and cotton grasses grow. According to Kelly (pers. comm. 1992) the theory that hollows are gradually replaced by hummocks and vice versa, is refuted. In pools Bogbean occurs. Nowadays, it is generally considered that pools are a product of stability in the watertable and peat surface and that the vegetation pattern reflects this stability, which is largely controlled by climate (pers. comment Cross). Bog rosemary and Cranberry are often creeping through the Sphagnum carpets. Carnivorous plants as Sundew-species and Butterwort are common on the bog. They gain additional nutrients by trapping and digesting invertebrate animals in its leaves. If the bog has been unburnt *for many years a variety of Lichens may occur, often producing large grey-white patches, which contrast strikingly with the Sphagna*



The developmental stages from a lake to a raised bog. A represents a lake with an open body of water and marginal reedbeds. The lake has thin layers of marl and lake peat (for an explanation of the symbols, see previous figure). B represents a lake which is being infilled with fen reed peat. C is the fen stage. D is the raised bog woodland phase and E is a profile through a present raised showing a Pine stump layer buried in acid peat.

Figure 3.1. Raised bog development (From Bell, 1992: Hobbs, 1986)

3.2.3. Soaks and lagg-zones

Much of the rainwater is held close to the surface of the bog through the sponge-like action of Sphagnum moss. Excess of rainwater runs off the bog's surface either directly or via an internal drainage system known as soak (Bell, 1991). Soaks act as spillover in times of high water, avoiding the bog to burst (Bloetjes, 1992). On Clara Bog the trend is towards enclosure of soaks by vegetation. The three soaks on Clara Bog are different from each other. According to Kelly (pers. comm. 1992) Lough Roe is the most nutrient-rich soak and Shanley's Lough the poorest. ***Shanley's Lough*** *has a lake which is rather shallow (1.35 m). From 3.8 m on, at the place of the lake, heather twigs are found, indicating drier stages. Wood and reed remains are only found down from a depth of 6.4 m. The lacustrine clay was found to underlie the peat (Bloetjes, 1992). At Shanley's Lough and the* ***Far west soak*** *a well-developed birch woodland occurs.* ***Lough Roe*** *had originally a 0.8 ha area of open water. In the second half of the 1980's the open water became covered by a floating mat of fen vegetation. This is how the lough appears today. With the closure of Lough Roe there are no longer anymore large bodies of open water on Clara Bog East. According to sediment analysis (Connolly, 1992) all cores show similarity in fen peat composition (fig. 3.2.). Core 3 (centre of Lough Roe) and core X (control) show very different sediment types once the bog succeeded the fen. In core 3 a very dark brown mud was laid down, between 1 and 6 m below the surface, with virtually no identifiable plant parts. This sediment was more characteristic of organic lake mud and would appear to have been laid down under water. In core X a more typical raised bog sediment sequence is represented. The peat was highly humified in the lower part of the bog sequence and less humified above this. The other cores fell between those two types. So, this suggest that, since the onset of the ombrotrophic conditions, Lough Roe was a open water system (figure 3.2.). In the fen-stage the soaksystem might been present in it's initial phase. The lough continued to increase in area (length was 25 m at the beginning and reached to 200 m in the recent past). The recent reduction in size appears to be a phenomenon that has never occurred before at the site. If the Ordnance Survance Maps of 1838 and 1910 are accurate and sedimentary analysis suggest it is, the enclosure of the open water occurred over the last century. Humification evidence, as well as sediment description, suggest a much drier bog surface about one century ago. This dry stage is also observed in the Birchwood on Clara Bog west. The underlying cause of this drying out is probably human impact on the bog. Macrofossil analysis proved to be inappropriate as very little identifiable material was collected. Therefore an evaluation of the occurrence and time course of upwelling nutrient rich groundwater is not possible (Connolly, 1992).*

Soaks were common on the larger Irish bogs and there seems to be a correlation between soaks and adjacent ridges of high ground, usually eskers. Preliminary studies of these soaks indicate that the pH and conductivity of the water is either the same as, or slightly but significant higher than that of the mire expanse. These figures suggest that the vegetation differences are a reflection of an increased nutrient budget (pers. comm. Cross). On some raised bogs underground streams occur. There may be little surface indication of their existence although not uncommonly their course can be traced by the presence of Molinia caerulea. Such streams are a result of 'pipe flow' along the peat-mineral soil interface. Eventually the overlying peat collapses forming swallow holes which gradually amalgamate to form a surface channel (pers. comm. Cross).

Accumulation of peat at the margins of the bog is much slower than in the centre. The margins of the bog are consequently drier and better drained so that decomposition is going faster. This is the contact-zone of the acid, nutrient-poor, peatwater and the basic, nutrient-rich (mineral) groundwater. The nutrient-rich seepage-water encourages rapid decomposition of the dead vegetation. As result a raised bog can be confined by eutrophic fen vegetation. This zone is called the lagg zone, and has a convex surface raising above its surroundings.

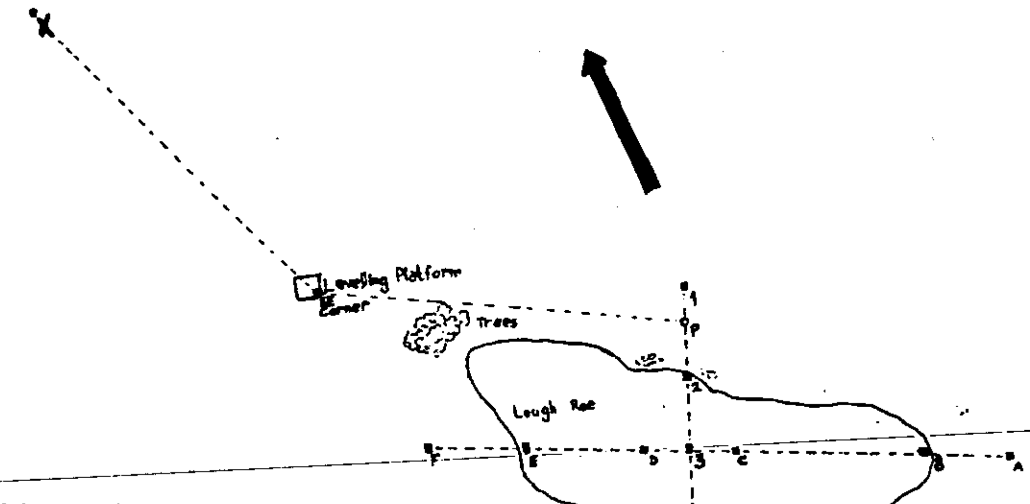
In the past, the exact time is still unknown, raised bogs dried out, enabling trees to invade the surface. Trees do not like a very wet environment and they prefer a limited fluctuation of the waterlevels. Subsequently trees died as the bog began to grow again. Their remains are preserved in the peat. The most common tree remains are pine but birch, oak and yew are also found. Today most bogs are treeless.

For more information on the section 3.2. readers are referred to: Anonymous, 1990; Bell, 1991; Bloetjes, 1992; Cross, 1989; Flynn, 1990.

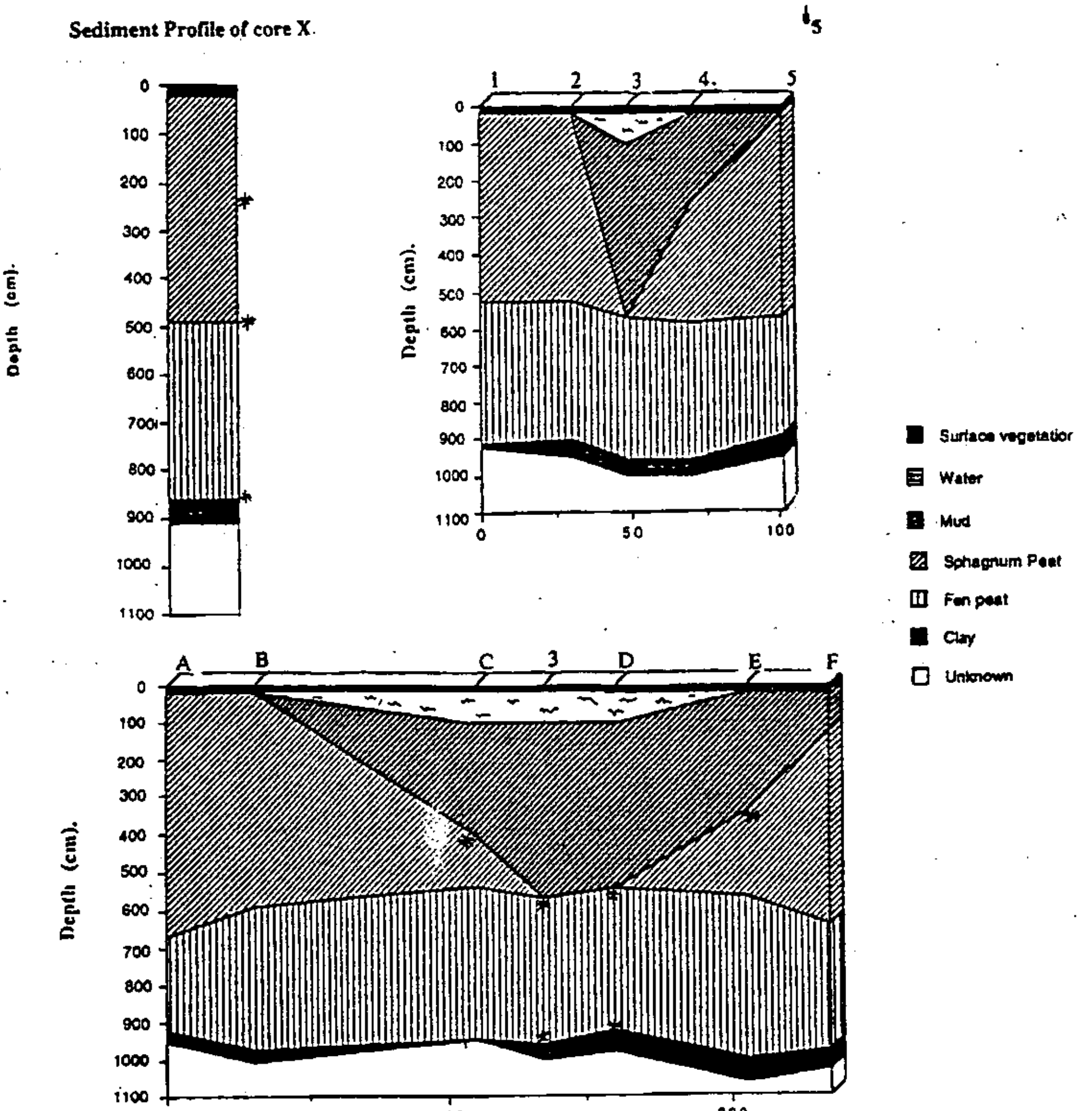
3.3. Hydrological properties of raised bogs

3.3.1. Introduction

In this paragraph a general overview will be given of the most important hydrological features of a raised bog. First the characteristics of the top-layer and the core-layer of the bog are discussed (3.3.2.). In 3.3.3. some remarks are made about the permeability. In 3.3.4. the influence of drainage and turf-cutting is discussed. The hydrologic cycle of a raised bog is discussed in 3.3.5.



Position of the core sites
(X on the bog, presumed to be distant from the influence of Lough Roe)



Diagrammatic sediment profiles of the Lough Roe basin
(The asterisks are suggested points for radiocarbon dating and are located at sediment boundaries. The highest asterisk on core X is the boundary between highly and poorly humified peat.)

Figure 3.2. Palaeoecology of Lough Roe (Connolly, 1992)

This paragraph is based on the reports of the students from Ir. S. van der Schaaf (Wageningen Agricultural University) and Dr. P. Johnson (Imperial College London). More background information can be found in their reports.

3.3.2. Acrotelm and catotelm

Hydrologically two layers can be distinguished in a raised bog:

***The acrotelm:** a thin surface layer of living vegetation, partly saturated (seldom more than a few tens of centimetres thick);*

***The catotelm;** the layer where the peat is conserved in a waterlogged situation.*

The acrotelm

The acrotelm is characterised by (Lensen, 1991):

- *The presence of a living plant cover, which constitutes the top-layer of the acrotelm.*
- *An intensive exchange of moisture with the atmosphere and the surrounding area.*
- *Frequent fluctuations in the level of the water table and a changing content of moisture. The acrotelm retains the watertable close to the surface.*
- *High hydraulic conductivity and wateryield and a rapid decline of these with depth.*
- *A large quantity of aerobic bacteria and micro-organisms facilitating the rapid decomposition and transformation into peat of each year's dying vegetation.*
- *The capacity to swell and shrink, depending on the weather conditions.*
- *The presence of hummocks and hollows with a big difference in transmissivity at short distance (because the different vegetation types of the hummocks and hollows). At long distance the difference is also big: on the edge of the bog there is a poorly developed acrotelm with a low transmissivity and in the middle there is a well developed acrotelm with a high transmissivity. The other aspect that makes the transmissivity very complex, is the fluctuation of it during the year in relation to the watertable and because of swelling and shrinkage (van 't Hullenaar & ten Kate, 1991).*

The catotelm

The catotelm is typified by (Lensen 1991):

- *A constant or little changing water content.*
- *A very slow exchange of water with the adjacent and subjacent mineral strata.*
- *Very low hydraulic conductivity compared to the acrotelm.*
- *No access of atmospheric oxygen to the pores of the soil.*
- *No aerobic micro-organisms and a reduced quantity of anaerobic micro-organisms compared to the acrotelm.*

The depth of the water table in the acrotelm varies not only over time but also with space. It is deepest on the margins, which are consequently drier and better drained and shallowest on the mire expanse, which therefore is wetter. The acrotelm serves the very important function of protecting the catotelm, which if exposed and allowed to dry out, can be subsequently destroyed by oxidation. This protective role is partly a function of the remarkable properties of Sphagna which are the dominant plants on an intact bog surface. The acrotelm also inhibits sheet flow by the nature of its structure. The permeability of the peat increases towards the surface so that, during heavy showers, water-flow through the peat significantly increases, as the watertable rises.
The height of the watertable is dependent on rainfall rather than on capillary action. The rate of water loss from the peat is so slow, that in an undrained bog, additional rain always recharges the water table before it falls more than a few cm (pers. comm. Cross).

3.3.3. Permeability

One of the most striking characteristics of peat is its ability to hold water. Three states of water can be recognised (Bell, 1991):

1. *Free water in large cavities of the peat;*
2. *Capillary water in narrow cavities;*
3. *Water bound physically, chemically, colloidally and osmotically.*

Physically, over 90 % of the bog volume consist of water, but the effective porosity can be less than 10 % (Flynn, 1990). As Sphagnum peats are deposits which are built up in layers, they show changes in hydrological behaviour at different levels in the bog or in different parts of the bog (Bell, 1991).
The permeability depends on (Bell, 1991):

- *Botanical composition; Sphagnum peat is least permeable and sedge peat most.*
- *Degree of humification; the least humified peat of a given botanical composition is most permeable.*
- *Bulk density; this aspect is negatively correlated with permeability.*

- *Fibre content; fibre content and permeability are positively correlated.*
- *Porosity; the higher the effective porosity, the higher the permeability.*
- *Surface loading; this decreases the permeability by decreasing the porosity.*

*So, **permeabilities** in peat are highly variable. It seems that there is a correlation between the humification degree and the transmissivity/hydraulic conductivity. An acrotelm with a humification degree between 2 and 4 has a high permeability (25 to 1000 m/d), while an acrotelm with a humification degree of 6 or 7 can be considered to be impermeable (0.1 to 7 m/d) (van 't Hullenaar and ten Kate, 1991). See also Sijtsma and Veldhuizen (1992) for further reading.*
The geometric mean (without extreme values) for the catotelm on Raheenmore Bog calculated by Veldkamp and Westein (1992) is $1{,}5*10^{-3}$ m/day. This has been measured with a piezometer test, which gives the horizontal permeability. The assumption for the catotelm is that the horizontal permeability is the maximum of the vertical permeability. The horizontal permeability of the catotelm for Raheenmore Bog varies from 10^{-4} to 10^{-3} m/day (pers. comm. Veldkamp, 1992).

*The **transmissivity** of the acrotelm varies in horizontal direction and is related to the waterlevel. The transmissivity values in the acrotelm varies from <1 m^2/day on the margins of the bog to >1000 m^2/day in the middle of the bog (Sijtsma & Veldhuizen, 1992).*

3.3.4. Drainage and cultivation

Drainage and cultivation of peat soils induces irreversible changes in the physical and chemical characteristics. The principal effect of cutting and associated drainage is lowering the watertable. It removes excess of water, stops peat accumulation, causes peat subsidence and changes physical properties, such as permeability of the peat.
*Peat subsidence is a result of different processes which gradually change the peat into a peat soil. Causes of subsidence are shrinkage (due to drying), consolidation, contraction by capillary forces (result are cracks), biochemical oxidation, humification, wind-erosion, burning and compaction by machines or roads. According to the observations in different countries and climates, the average rate of collapse of a peat deposit after drying over a period of 40-50 years varies from 1-2 to 8 cm/year (Lensen, 1991). **Shrinkage** is a physical process of compaction as a result of water loss by the vegetation (transpiration). The roots of the vegetation absorb moisture from the soil up to or above wilting point (pF=4.2), while deep drainage drops the water pressure down to field capacity, i.e. pF 2.0-2.2 (Lensen, 1991).*
*While the organic structures stay visible during **oxidation** (biochemical process), during **humification** these structures are decomposed by macro-organisms. Gradually, the organic structure disappears and becomes a particular type of humus. Under very dry conditions peat becomes turf. During this humification, organic matter disappears and hence the surface falls (Lensen, 1991).*
*Of the three states of water found in peat, only the free water and capillary water can be expelled by **consolidation**. Permeability controls the rate of consolidation of peat under load and therefore its strength. A striking characteristic of peat is the remarkable decline in permeability with reduction in void ratio or water content. The permeability falls by some three orders of magnitude against a change in void ratio of half an order. Based on laboratory tests, Hobbs reported that the pressure causing compression does not appear to be important. The significant factor is the initial void ratio, reflecting the natural state of the peat, and the void ratio attained under loading (Bell, 1991).*

It is obvious that due to the intensive drainage the Sphagnum carpet is the first layer that will disappear, and consequently peat development stops. Moreover, before the acrotelm disappears totally, its hydraulic features will change as a result of compaction and humification. Hence the acrotelm lost its regulating function, so that during wet periods overland flow is stimulated, while during drier periods the desiccated peat is subjected to wind erosion. Both also accelerate the destruction and disappearance of the bog (Lensen, 1991). With the destruction of the acrotelm the catotelm is exposed to the atmosphere and the bog ecosystem is degraded to dry heatherland.
Another response of the bog to drying out as a result of cutting is the development of large, vertical cracks parallel to the cut margin. If the cut face is straight, the bog may slump outward in an 'attempt' to re-adjust to its original shape by forming a new margin. The net effect is that the bog shrinks from the edge inwards (pers. comm. Cross).

*The **Bogroad** and the drains running parallel to that road have, had a major effect on the hydrology of the bog. The bog was originally one raised dome. The road and its drains have caused a subsidence of more than 6 metres and have in effect caused two domes (bell, 1991). The subsidence has increased the density and decreased the permeability of the peat near the road. Water flows towards the Bogroad from Clara east and west and it acts as the major drain on the bog.*
The effect of peat-cutting (especially in the south of the area) has increased the subsidence due to the Bogroad.

The difference in altitude of the Bogroad between 1910 and 1990 would indicate that subsidence still occurs (Bell, 1991).

*The areas of **hand cut-away bog** revegetate relatively quickly, but the original plant and animal communities and the unique and irreplaceable pollen record are all lost. It has been suggested that cut-away is analogous to the lagg of an intact bog. Cut-away areas therefore acts as a valuable buffer zone around the intact bog and its retention is important, not only to retain habitat and species diversity, but also to improve the chances of controlling the mire hydrology. If the cut-away is left undisturbed for a sufficient long period (hundreds of years) and provided the conditions are sufficiently wet, raised bog communities will almost certainly regenerate (pers. comm. Cross).*

3.3.5. Hydrologic cycle

Lensen (1991) described in his report a general hydrologic cycle of a raised bog (figure 3.3.). Sijtsma, Veldhuizen, Veldkamp and Westein (1991/1992) performed measurements on Raheenmore Bog and Clara Bog to precise the waterbalance. In this report the hydrologic cycle of Lensen has been just.

The hydrologic cycle (figure 3.3.) shows that the excess rainfall is about 350 mm/year (850-500 mm/year). Most of the excess rainfall (230 mm/year, 66%) runs through the acrotelm towards the drains near the margins of the bog. The surface runoff is some 11% of excess rainfall (40 mm/year). This means that 80 mm/year flows through the catotelm. According to figure 3.3. one half (40 mm/year) flows to the mineral subsoil and another half to the margins.
Romanov (1968) has quoted seepage velocities in the acrotelm as high as 10^3 m/day (365 mm/year, Bell, 1991). Veldkamp and Westein (1992) calculated a downward seepage in the middle of Raheenmore Bog of maximally 10^{-4} m/day (47-67 mm/year), with a hydraulic head difference of some 3 m (pers. comm. R.Flynn). Near the margins the downward seepage is getting less. They used groundwater-head differences and estimated the vertical hydraulic resistances for their assessment of downward seepage.

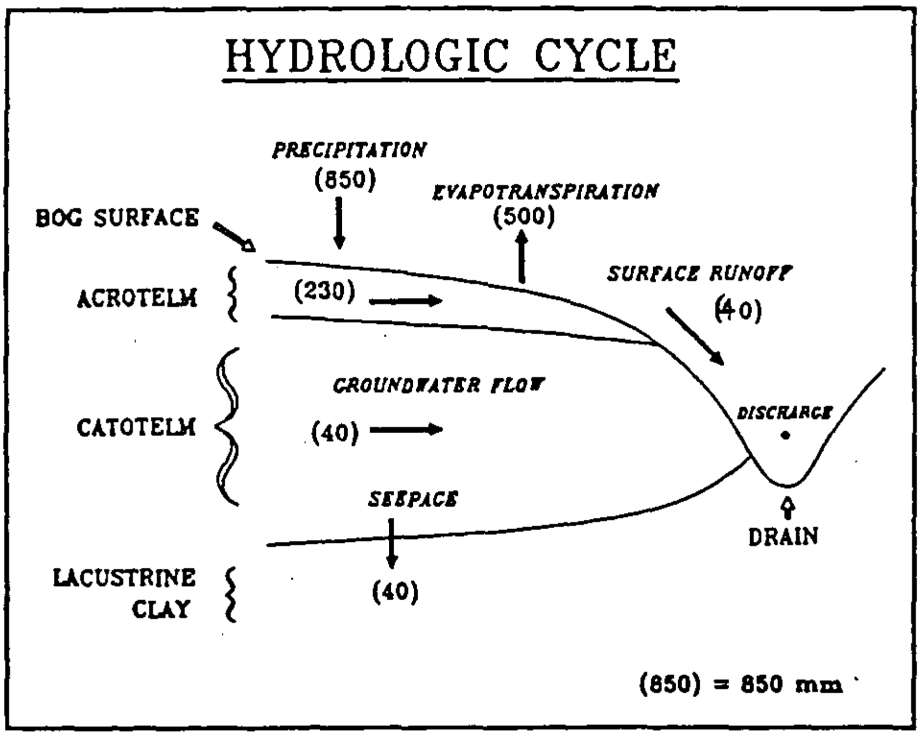


Figure 3.3. The hydrologic cycle of a raised bog (Lensen, 1991)

4 HYDROLOGY

4.1. Introduction

Map 1 shows the drainage-pattern and the hydrological measuring sites at and near Clara Bog. Information about the measuring sites can be found in appendix I. The waterlevel-data of the several boreholes, cobra-drillings, wells, drains and Rivers can be found in appendix III.A. Although the data of the bog piezometers are used, they are not present in this appendix because they take too much space and are not that important.
In this report only some hydro(geo-)logical features of Clara Bog and its surroundings will be discussed. Other students of the Wageningen Agricultural University and students of Imperial College London look more in detail at the hydrology of Clara Bog itself (see paragraph 3.3.). In this chapter the following subjects are discussed: permeabilities; horizontal groundwater movement in the aquifers and vertical groundwater movement; surface water. Hydrological data for these purposes, have been collected by students from Sligo Regional Technical College, Imperial College London, Wageningen Agricultural University and by the author.

4.2 Permeabilities

The Carboniferous limestones are aquifers with a very variable yield: 100-10^5 m^3/day. It is likely that in large parts of the Clara Bog region the glaciers have removed the upper, fissured layers of the limestone. Therefore, the remaining limestone will have a relatively low permeability.
The permeability of tills is in the range of 10^{-1} to 10^{-7} m/day and seems to be relatively unaffected by weathering. The permeability of gravelly till/gravel could be in the range of 10 m/day. The permeability of eskers is in the range of 100 to 10 m/day (Van Tatenhove, 1990).
The clayey, lacustrine deposits have a low permeability and therefore they act as a confining layer. Due to the textural variability of these deposits, the overall permeability will be about 10^{-5} m/day.
The permeability of the peat layers is already discussed in paragraph 3.3. Most important is that the permeability of the acrotelm is larger than that of the catotelm. The major part of the rainwater will be transported through the acrotelm to the lagg-zones and only a small part will flow into the catotelm.

4.3. Horizontal groundwater movement in the aquifers

4.3.1. Two aquifers

Although very thin, the toplayer of the peat (in undisturbed, natural conditions, the acrotelm) is the first aquifer in the Clara Bog region. The second, much larger, aquifer in the Clara Bog region that has been distinguished is the aquifer comprising the limestone, the esker and the (fluvio-glacial) gravelly-sandy layer direct upon the bedrock. Although the permeabilities of those three layers are different they are put together. Reason for this is the fact that they all have a much greater permeability than the overlying clayey till and the catotelm and because no confining layers are in between.

4.3.2. Groundwater contourlines of the first aquifer

With the waterlevels of 9 July 1992, from almost all the bog-piezometers, a phreatic surface map has been drawn (map 4.A). At places where no piezometers are, the watertable is estimated by using interpolation procedures. The watertable of the bog is everywhere some 0-30 cm below the bog-surface. The several drains clearly show their effect. Especially the drain north-east of Clara, the drains along the road and the drains near the new facebank have a pronounced effect on the contourlines. At the facebanks the watertables drop very abrupt to a lower level. Most of the bog-water flows in the direction of the Silver River.

Appendix III.B1 shows the phreatic surface in November 1991. In that period less hydraulic heads were measured. At Clara Bog west the difference with the map of July 1992 seems to be small. For Clara Bog east the differences seem to be bigger but this is because of the level problems that occurred (appendix I).

4.3.3. Groundwater contourlines of the second aquifer

The piezometric surface of the second aquifer (map 4.B) is based on the waterlevels from the boreholes and the wells from 4 September 1992. One has to know that two days before the measuring-date most of the boreholes have been sampled.
Under the Island, where a limestone-/till-mound occurs, the piezometric surface is very high. Presumably, this is a recharge area for the aquifer. A small part of the groundwater flows towards the River Brosna. The main part flows to the Silver River. The water divide in the aquifer lies under the bog in a NE-SW direction which is similar to the direction of the geological structures in Ireland.

The esker (350 mm/year) and the centre of the bog-body (< 40 mm/year) seem to be a recharge-area. Under the south-west end of the bog and at the east-side the groundwater flow might be rather slow as head differences are small. Well_18 (on the esker, in limestone) is only measured by the end of 1991. Those data show that the waterlevels are some ten metres below those of the nearby well_19. The reason, for this difference is not known yet. There might be abstraction from well_18.
The Deep drain has a pronounced effect on the piezometric surface of the second aquifer. The drains at the south-west side of the bog also seem to affect the groundwater flow in the second aquifer.

Appendix III.B2 shows the piezometric surface from the dates of 14 November 1991, 30 April 1992 and 9 July 1992 as compared with 4 September 1992. The differences are small and occur near CLBH4, CLBH5, the wells 5-9, 15, 19, 21 and 23.

4.4. Vertical groundwater movement

4.4.1. The two aquifers

Map 4.C gives an idea of the differences in the hydraulic heads of the first and second aquifer. The maps 4.A (phreatic surface, July 1992) and 4.B (potentiometric surface of second aquifer, September 1992) have been used to compile map 4.C. The different dates do not give problems as the differences in the second aquifer are small (see paragraph 4.3.3.). The mean difference in hydraulic head on the bog is some -3m; this implies downwards seepage. Only near the Bogroad a positive difference is found, which means that upward flow prevails. The high negative values at the south-east side of the bog occur at the place of a till mound.
The hydraulic heads are also put into the hydrogeological cross-sections (maps 2 and 3). The convexity of the hydraulic head of the second aquifer, under the esker in the cross-sections A and A is most of the year greater as the cross-sections show. Because there is hardly convexity, it looks if there is a lateral flow through the esker. The absence of convexity in the esker watertable is a function of the esker permeability which preveals a significant recharge mound from developing (pers. comm. R. Flynn).*
As can be seen in cross-section B the seepage near the Bogroad will be small because of the presence of the lacustrine clay layer. Cross-section D, however, shows that the water is going to the drains along the road. This is probable the result of the till mound. According to cross-section C there is a seepage-zone just south of Clara West, where no lacustrine clay is present. Near this site Carex flava is observed which indicate calcium-rich water (pers. comm. J. Streefkerk). The Deep drain will discharge this seepage water (map 3.B). Along the whole cross-section the hydraulic head is higher as the bottom of the Deep drain. The waterlevel is not known yet. If the hydraulic head of the second aquifer is larger as the head of the first aquifer (and the waterlevel in the Deep drain), a significant seepage will not occur, because of the hydraulic resistance of the lacustrine clay.

4.4.2. The bog surroundings

Appendix III.C1 contains the hydrographs of the waterlevels in the boreholes, wells and cobra-drillings over the period from 3 September 1990 to 11 November 1992. One hydrograph shows the hydraulic heads of different filters at one site.
Some remarks are made:

- *The hydraulic heads in the second aquifer differ not more than 0.2 m.*
- *The hydraulic heads are lowest in wintertime.*
- *No direct relation with the precipitation can be found.*
- *From September 1990 till September 1991 there is downwards seepage at CLBH2. After September 1991 seepage occurs. The (downwards) seepage is thought to reflect the waterlevel in the adjacent drain. A high head will cause downward flow and a low head upward flow, reflecting the hydraulic connection between the drain and the second aquifer (pers. comm. R. Flynn)*
- *The head in the clayey till at CLBH4 fluctuates a lot. probably because of a low storage coefficient.*
  Most of the time there is downward seepage.

4.4.3. In the peat

Appendix III.C2 contains hydrographs of piezometersets on the bog. A piezometerset is a cluster of several piezometers at one site with different filter depths. A selection of piezometersets have been made. The following piezometersets, which also are sampled for hydrochemically purposes, are taken into account.
On Clara Bog west: 46, 54, 57, 90, 92, 96, 901, 902, 903.
On Clara Bog east: 113, 114, 119, 120. (No hydrochemical samples of 114)
Because of problems with the surface levels of the bog (appendix I), the hydraulic heads of the tubes at Clara Bog east shift from 1991 to 1992. Leveldata are in general not very accurate on the bog (Huisman, 1991). The surface levels can vary 5- 10 cm as they are measured with a ruler and the surface around a tube is not flat.

Moreover, the bog is there treaded a lot, so the surface level is lowered. Therefore, the hydrographs are just used for analyzing the relative differences.
According to the hydrographs everywhere in the peat downward seepage occurs. This supports with the information discussed in paragraph 4.4.1. As expected there is no direct relation between the hydraulic heads and the precipitation. In wintertime, the watertable (acrotelm) is higher than in summertime (0.1-0.3 m difference). The hydraulic heads in the catotelm show in general the same (a bit flattened) pattern as the phreatic watertable in the acrotelm. The hydrograph of 114 shows seepage in January 1991. However, this is only based on one measurement.

4.5. Surface water

4.5.1. Drainage pattern

The Clara Bog region is, via a small drainage system, drained by the River Brosna and the Silver River (map 1 and figure 4.1.). Most of the surface water from this area flows to the Silver River. Only on the west-side of Clara Bog surface water flows to the River Brosna. South-west of the Clara Bog region the Silver River enters the River Brosna. The drains north of Clara Bog transport water from the esker and bogwater. Most of the other drains carry a mixture of bogwater and water from the till deposits. In the Deep drain a lot of the surface water of the Clara Bog region is collected and flows to the Silver River.

4.5.2. Stages in the drains and rivers

In appendix III.C3 the waterlevels of the drains and rivers during the period March - July 1992 can be seen in relation with the precipitation. The sites of the gauges and weirs are marked on map 1.

Drains along the bogroad

Every weir has its own stake from which the waterlevel was measured. The reference height (MOD) of those stakes was unknown. Therefore, the three graphs of the weirs 921, 922, 923 can not be related with each other in absolute way.
All the weirs show the same discharge-pattern. This pattern coincides with the precipitation-pattern. There is almost no delay between the rainfall and the discharge of the drains. The discharge of most of the rainfall is very quick from the bog-area to the drains along the bogroad. During the period 19 March till 11 June 1992 the maximal difference in waterlevel was about 0.2 m for the weirs 922 and 921 and 0.1 m for weir 923. According to the data of weir 923, the precipitation seems to have less effect on the north-side of the east-side drain. The drain north-east of Clara Bog enters the drain east of the road just before weir 923. This means that the north-east drain flattens the peaks of the rainfall. At weir 922, downstreams of weir 923, the bog has had its influence on the discharge.
One has to have in mind that those drains are manmade. In the natural situation quick runoff from the bog, by drains is impossible.

Deep drain

The stages of the Deep drain show the same pattern as the precipitation and the drains along the road. The figure is compared to the weirs 921 and 922 a bit flattened.

Silver River and River Brosna

The stages of the Silver River show the same pattern, in a more extreme way, as the Deep drain (differences during period March-June 1992: 0.3m). The discharge pattern of the River Brosna is different. It seems not to react immediately on the precipitation as the Silver River does. This can be seen very well in June 1992. At that time there is a peak discharge at the Silver River while the Brosna River reaches a dip. No clear flood wave can be recognised. It could be said that the River Brosna has a much greater groundwater baseflow whereas the Silver River is more dominated by surface runoff.

4.5.3. Discharges

At the end of May 1992 the discharge in the Deep drain and a drain at the east-side of the bog have been measured with the dilution or tracer method (appendix III.D1). June was a dry period and therefore the discharge is relatively low.
Near the gauge of the Deep drain a discharge of 25 l/s was measured. A drain east of Clara Bog discharges then 5 l/s (fig. 4.1.). Mr. P. MacGowan (Office of Public Works, Ireland) did also some measurements during 1992 (appendix III.D2). He measured the discharge in the Deep drain (February and June 1992) and in the Silver River (at New Bridge, February 1992). The discharges in the Deep drain varied from 40 l/s in February 1992 to 20 l/s in June 1992 (appendix III.D2). The discharge of the Silver River in February 1992 was almost 100 l/s.

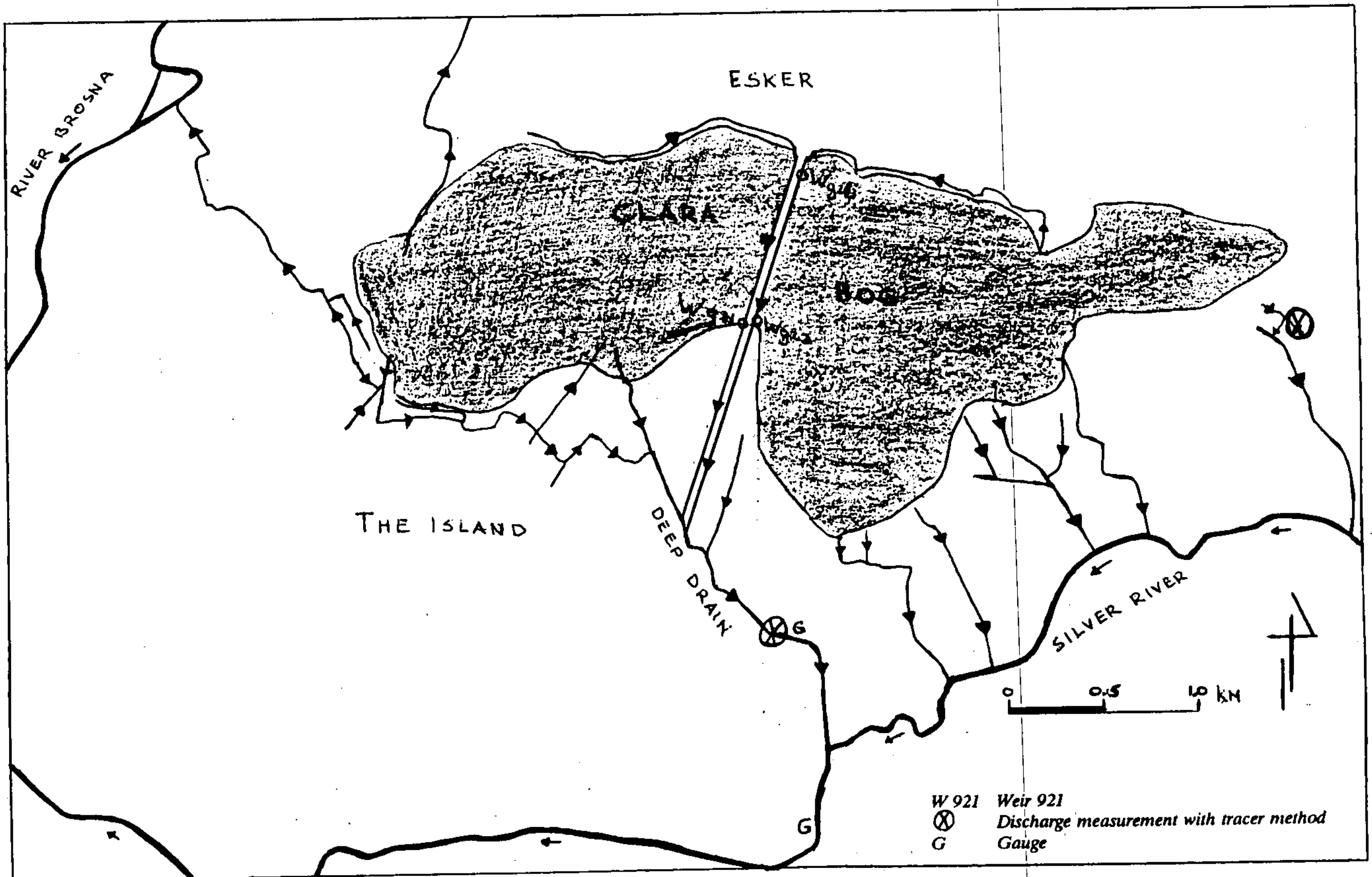


Figure 4.1. Drainage pattern of Clara Bog region (reduction of map 1)

The measurements give the discharge at a specific moment. They give an impression about the proportion of the several streams. The drains which do not join in the Deep drain, have approximately the same size as the measured drain east of Clara Bog. This means that the Deep drain drains less than half of the surface water of the Clara Bog region.

4.6. Discussion

The regional hydrogeological system of the Clara Bog region is difficult to describe because data are incomplete. The discharge of the bog in the drains on the far west and east side of the bog is not measured. More discharge measurements at and around Clara bog during the year are needed.
In the summer of 1992 some new recorders were placed at the drains along the road. The q-h relation of these recorders is known. The stakes are not used anymore.
Some data are only available for a small period of time. This makes it hard to use them as a base for drawing firm conclusions. Furthermore the leveldata on the bog are inaccurate, which makes its impact on the reliability of the hydrological data inaccurate. Differences less than 10 cm cannot be used for the interpretation. More information about the permeabilities of the geological layers in the Clara Bog region is needed. Now, pumping tests are planned to measure the permeability. Decisive answer is than given on the nature and permeability of the several geological layers, which in this report are distinguished as the second aquifer.
The last hundred years, mankind intervened in this region by turf-cutting, drainage and other activities. It would be relevant to survey history to see what the effect was on the hydrological system in the Clara Bog region (e.g. flooding of the R. Brosna).

5 TEMPERATURE

5.1. Theory

5.1.1. Geothermic principle

In the middle of the earth heat is produced. As the earth-surface is relatively cold, heat transport takes place towards the surface. Because of this heat-flux, the temperature of the earth will increase with depth. The heat transport in the deeper subsoil takes mainly place by conduction according to Fourier's law:

$$q_h = -\lambda \, T\delta s \qquad [1]$$

q_h	*Heat-flux density by conduction*	$(Jm^{-2}s^{-1})$
λ	*Heat conductivity*	$(Jm^{-1}s^{-1}\,{}^oC^{-1})$
T	*Temperature*	$({}^oC)$
δs	$\delta/\delta x + \delta/\delta y + \delta/\delta z$	

If depth increases (depth (z) is negative) the temperature will increase as well, so q_h is positive and has an upwards direction (figure 5.1.; Gaag & Sauer, 1989). This is called the geothermic gradient.

5.1.2. Deviations of the geothermic gradient

Figure 5.1. only holds for a homogeneous, isotropic, saturated soil in a steady state condition. In reality, deviations of the geothermic gradient occur due to the following phenomena:

1) *Seasonal fluctuations*
2) *Groundwater flow*
3) *Lithology*
4) *Unsaturated zone*

Ad 1) Seasonal fluctuations

The geothermic principle applies to a situation with a constant surface temperature. In reality, the surface temperature depends on daily, seasonal and annual fluctuations because of the heat input from the sun. The fluctuations also depend on climate and vegetation. In a forest the fluctuations are smaller than on bare soil. The fluctuations will be damped with depth (fig. 5.2.; Gaag & Sauer, 1989).

In nature, the daily and annual temperatures fluctuations are more or less cyclic variations of the surface temperature. Both can be approximated by a sinus function. The damping depth is the depth at which the amplitude of the temperature fluctuation has decreased to 0.37 A_0. A_0 is the amplitude of he sinusoidal temperature variation at the soil surface. The damping depth (d) depends on the thermal properties of the soil (λ, C_h) and on the angular frequency of the temperature variation (ω) according to

$$d = \sqrt{2\lambda/\omega C_h} \qquad (m)$$

ω	$2\pi/t_c$	(s^{-1})
λ	*Heat conductivity*	$(Jm^{-1}s^{-1}K^{-1})$
C_h	*Volumetric heat capacity*	$(MJm^{-3}K^{-1})$
t_c	*Time to complete 1 cycle of the wave*	(s)

For organic matter with a C_h of 2.5 $MJm^{-3}K^{-1}$ and a of 0.25 $Jm^{-1}s^{-1}K^{-1}$, the daily damping depth is 0.05 m and the annual damping depth is 1.0 m. Organic matter has a relatively very low heat conductivity (table 5.1.), and therefore the damping depth is rather low. Gaag and Sauer (1989) report that the daily fluctuations can be neglected from some 0.5 metres below the surface and the annual fluctuations from some 15 metres. These figures are typical for a mineral soil, however, for a peaty soil these will be far less.

Table 5.1. Heat conductivity of soil components at 10^oC (Koorevaar et al., 1983).

Material	*Heat conductivity, λ $Jm^{-1}s^{-1}K^{-1}$*
Air, saturated with water vapour	*0.025*
Organic matter	*0.25*
Water	*0.57*
Ice ($0\,{}^oC$)	*2.18*
Clay minerals	*2.9*
Quartz	*8.8*

Ad 2) Groundwater flow

In the upper layers of the earth, heat transport through groundwater flow (convection) occurs. This convection equation can be written as:

$$q_c = \rho_w c_w T v \qquad [2]$$

q_c	*Heat-flux density by convection*	$(Jm^{-2}s^{-1})$
ρ_w	*Specific mass of water*	(gm^{-3})
c_w	*Specific heat capacity of water*	$(Jg^{-1}{}^{o}C^{-1})$
v	*Volume fluxdensity*	(ms^{-1})
v	$-k*\delta h/\delta z$ *Darcy's law* [3]	
	k *permeability*	(ms^{-1})
	h *hydraulic head*	(m)

The total heat-flux in a saturated soil has to follow the continuity equation (no heat is created or lost). In a homogeneous, isotropic, saturated soil with no transport by diffusion the continuity equation is:

$$\delta q/\delta z = \rho_s c_s \delta T/\delta t + Q \qquad [4]$$

	$q = q_h + q_c$ = *total heat-flux*	$(Jm^{-2}s^{-1})$
ρ_s	*Specific mass of saturated soil*	(gm^{-3})
c_s	*Specific heat of saturated soil*	$(Jg^{-1}{}^{o}C^{-1})$
t	*Time*	(s)
Q	*Heat production*	$(Jm^{-3}s^{-1})$

Substituting [1] and [2] in [4] gives the equation:

$$Q + \lambda \delta^2 T/\delta z^2 - \rho_w c_w \delta v T/\delta z = -\rho_s c_s \delta T/\delta t \qquad [5]$$

This equation can only be used in an isotropic, homogeneous and saturated soil.

Because of groundwater flow, deviations in the geothermic gradient occur. This flow is the result of differences in hydraulic heads and can be lateral or vertical. According to the equations 1, 2 and 3, a negative, downward groundwater flow has as result a negative downward heat-flux by convection. This heat-flux is than opposite of the geothermic heat-flux by conduction. When there is downward seepage the influences of the seasons will be recognized deeper in the soil. In the next examples absolute values are used (increasing of the temperature gradient means getting a higher negative value).

*A **vertical, downward flow** of relatively cold water replaces warm water by cold. The heat-flux by convection is opposite of the geothermic (conductive) heat-flux and decreases with depth. The temperature gradient will increase with depth and as a result of this, the geothermic heat-flux (conduction) will also increase with depth. The geothermic heat-flux increases in a positive way as the direction is opposite to the temperature gradient (figure 5.3.A).*

*A **vertical, upward flow** (relatively warm water) replaces cold water by warm. The heat-flux by convection has the same direction as the geothermic heat-flux (conduction) and increases with depth. The temperature gradient will decrease with depth as does the conductivity heat-flux (figure 5.3.B.).*

*A **horizontal flow** of relatively warm or cold water changes the geothermic conductivity heat-flux as well. In case of cold water at the bottom of the stream the temperature gradient increases and as a result of this, the geothermic heat-flux increases. The horizontal stream of water will be warmed up. Going upwards the temperature gradient decreases and can become positive if the temperature above the stream is higher (fig. 5.4.; Gaag & Sauer, 1989)*

Ad 3) Lithology

The geothermic principle applies to a homogeneous, isotropic medium. The earth is built of several lithological units with different physical characteristics. The heat conductivity (λ) depends on those characteristics and increases from peat, clay to sand (table 5.1.). Exact values of different saturated soils are hardly known.

Depending on the occurrence of different lithological layers, there will be vertical and lateral variation in the temperature gradient of the subsoil (figure 5.5.). The lithology affects not only the geothermic heat-flux but also the heat-flux by convection. The volume flux density (v) (see equation 2) depends on the permeability. The permeability is a function of the lithology. Heat transport by convection only exists if there is a difference in hydraulic heads. The effect of the groundwater flow is more pronounced than the direct influence of the lithology (Gaag & Sauer, 1989).

Ad 4) Unsaturated zone

The geothermic principle only holds for a saturated soil. Most of the time, however, there is a unsaturated zone, varying in thickness, between the saturated zone and the soil-surface. The pores of this unsaturated soil are filled with water or air. As air has a very low heat conductivity (table 5.1.), the geothermic heat-flux is hindered. Due to the very low heat conductivity the temperature gradient in the unsaturated soil is large (figure 5.6.).

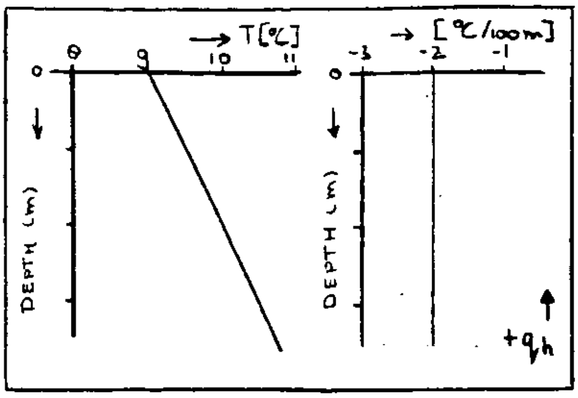


Figure 5.1. *Temperature in a homogenous, isotropic saturated soil with no groundwater flow*

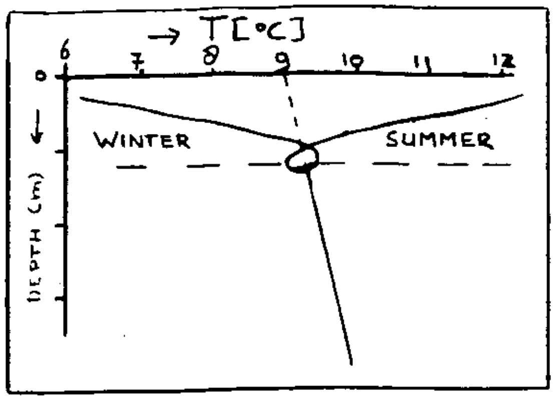


Figure 5.2 *Influence of Summer and Winter on the temperature profile*

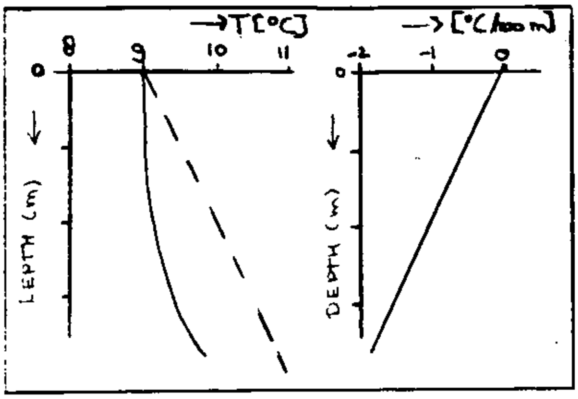


Figure 5.3.A *Effect of downward seepage on the temperature profile*

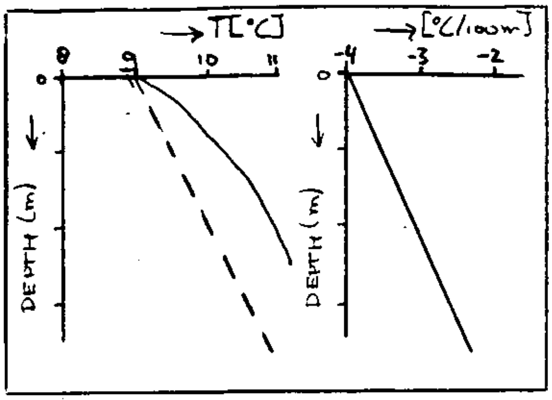


Figure 5.3.B *Effect of seepage on the temperature profile*

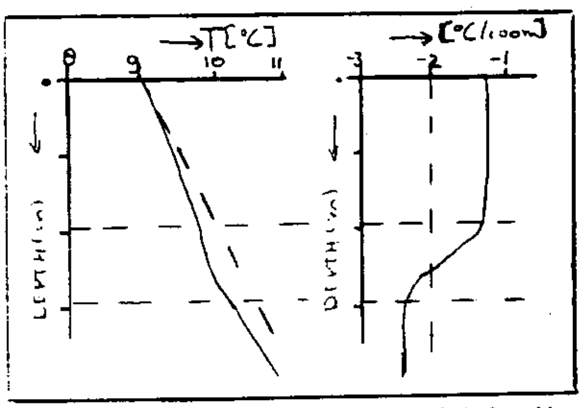


Figure 5.4.A *Horizontal stream with relatively cold water and the temperature profile*

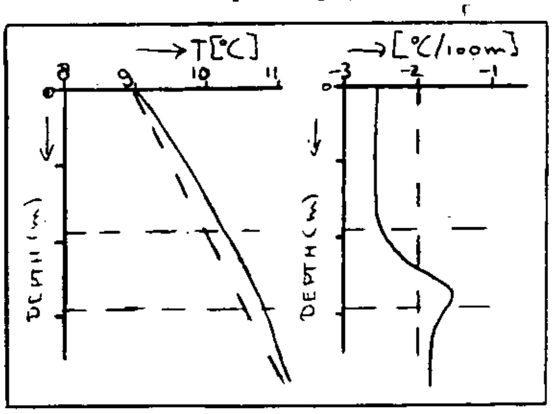


Figure 5.4.B *Horizontal stream with rel. warm water and the temperature profile*

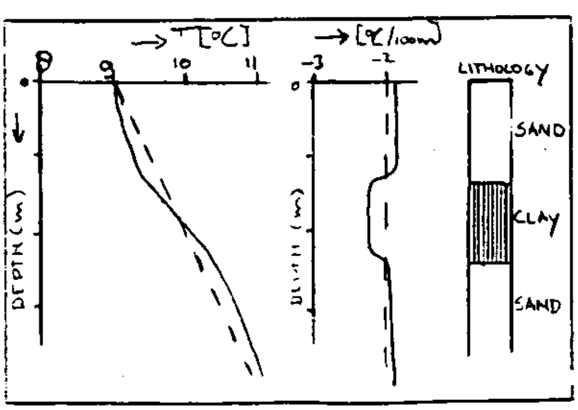


Figure 5.5. *Influence of the lithology on the temperature profile*

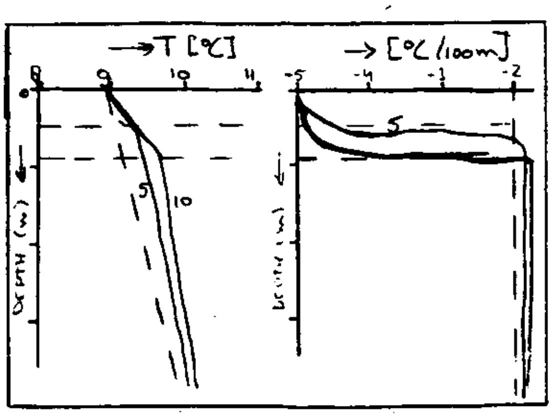


Figure 5.6 *The temperature profile in a soil, unsaturated soil 5 and 10 m*

When there is downward seepage in the unsaturated zone, heat transport opposite to the geothermic heat-flux prevails (Gaag & Sauer, 1989). The water vapour in the soil will be mainly transported by diffusion which is also influenced by temperature. Water vapour diffusion takes places from higher to lower vapour pressures and thus from higher to lower temperatures (Koorevaar et al., 1983). The acrotelm is the (partly) unsaturated zone of the peat. It can be excepted that the acrotelm will absorb most of the daily temperature fluctuations and a large part of the annual fluctuations.

5.2 Methods

5.2.1. Aim

Temperature measurements were carried out to investigate if there is vertical water and associated nutrient transport in or nearby the soaks on Clara Bog. The hypothesis was that because of temperatures differences water flow would occur and with this transport of nutrients as well. Water flow due to temperature differences has to be upwards to explain the soak-systems. Supposing that deep groundwater in the subsoil is at 10 degrees Celsius, upwards flow would occur in wintertime when the surface water temperature is much lower (pers. comm. J. Streefkerk). Temperature measurement of groundwater can also give insight in the regional groundwater flows (recognition of seepage and downward seepage areas).

5.2.2. Fieldwork

The temperature profile has been measured in boreholes and cobra-drillings near and at the bog and in piezometers on the bog. The measured piezometers on the bog are most cases situated at or near a soak-area (figure 5.7.). It is supposed that, at every depth, the water in the tubes, has the same temperature as the water in the soil which surrounds the tubes.

The temperature was determined by lowering a resistance thermometer in the tube. The temperature was measured at intervals of 0.5 metre. Two measurement sessions have been carried out. The first one at the beginning of April 1992 with an IWACO-apparatus, and the second one at the end of June 1992 with a BECKMAN-apparatus. Both apparatus use the same measurement principle: the resistance of the water is measured and is converted to a temperature.

IWACO: The IWACO apparatus is a platinum resistivity thermometer. It exists of a copper probe with a - thermic isolated- platinum resistor. A small electric stream is sent through this resistor. The electric potential difference over this resistor is a measure for the temperature at the place of the resistor. A calibration curve is available which specifies the relation of the potential difference and the temperature. The temperature is calculated with the formula: $T = 525.9290 * R_w^{-0.07368} - 273$ in which R_w is the resistance of the water in the tube. This resistance is calculated by subtracting the cable resistance from the total resistance (water and cable). Both resistances are measured. The cable of this apparatus is some 100 metres long.

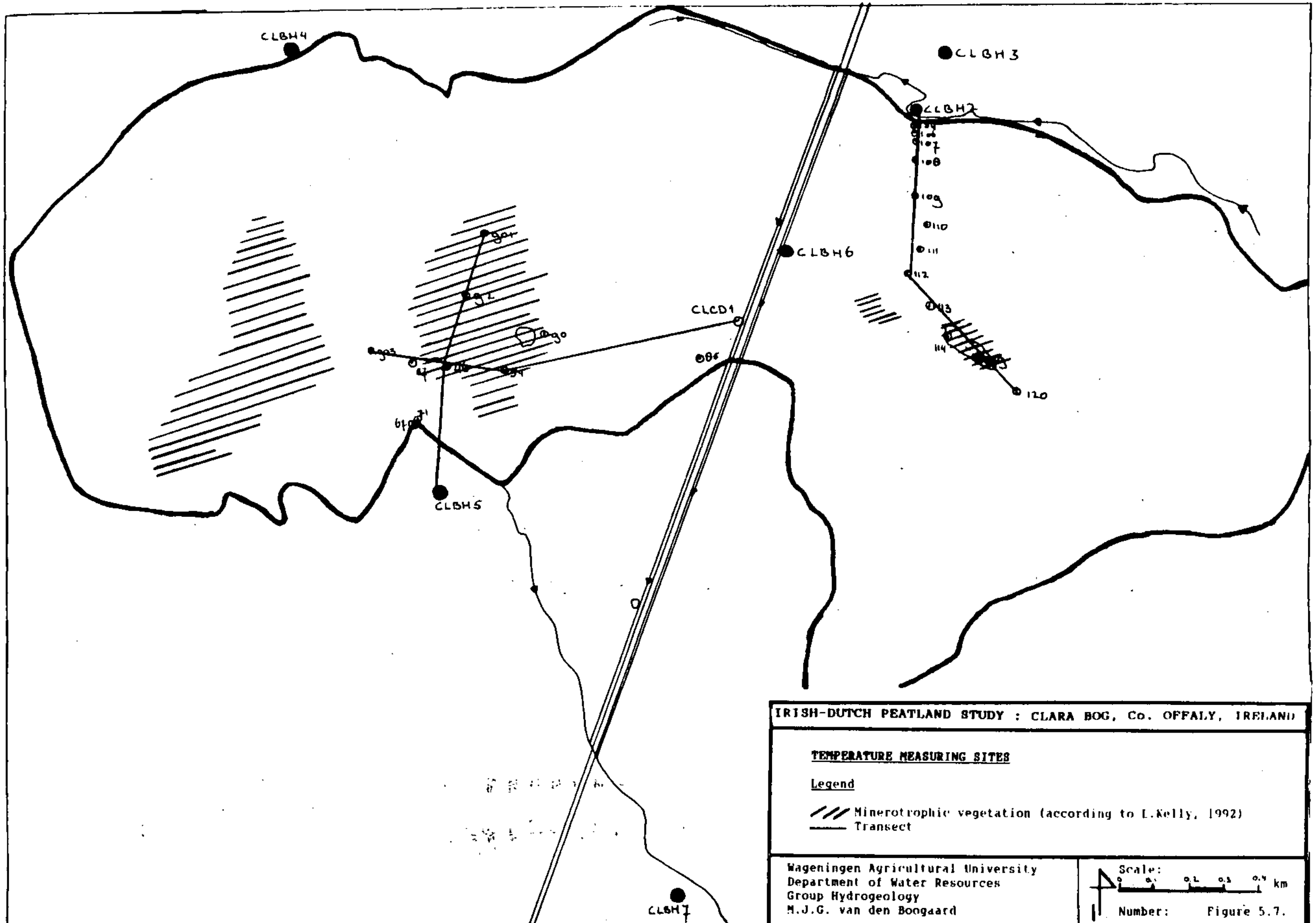
BECKMAN: This apparatus uses the same principle. It is just a cable with a small resistor at the end. Here one resistance value is measured which can be converted to a water temperature using a table. The table gives only figures for round data. Appendix IV.A gives this table. Furthermore the values calculated with the formula used for the IWACO-apparatus are presented to investigate possible differences. Assuming that a relative error of 0.01 °C is acceptable, the formula of the IWACO-apparatus can be used for the BECKMAN-apparatus when the temperature ranges from 2 to 30 degrees Celsius. In the important temperature traject from 12 to 21 degrees Celsius, the relative error is even close to zero. For that reason the formula has been used for both the IWACO and the BECKMAN-apparatus. The cable of this apparatus is only some 6 m long where some of the measuring sites are much deeper. In April 1992 the bottom of the tubes and boreholes could be reached where in June 1992 with the BECKMAN-apparatus only to 6 m below groundlevel could be measured.

Table IV.1 (appendix IV.B). gives an overview of the sites which have been measured in April and June 1992. Figure 5.7. gives the locations of the sites.

5.2.3. Reliability of the measurements

The reliability of the measurements is determined by the physical features round the tubes, accuracy of the apparatus and the observer and the effect of the descending probe on the temperature profile. In 5.2.2. is noted that we assume that the water in the tube has the same temperature as the water in the surrounding soil. However, if the tube is made of material with a high heat conductivity capacity (for example metal), it would influence the temperature profile. The measured temperature gradient is than lower than in the tube. Most of the tubes are made of plastic, which has a low heat conductivity capacity..

If the tube is too wide, convection in the tube itself occurs and the temperature gradient will be smaller than in the surrounding soil. In tubes with a diameter of 5 cm and temperatures lower than 15 °C, convection only occurs if the temperature gradient is greater than 0.1 °C/m. Most of the tubes which have been used had a diameter smaller than 5 cm. Of course, if there is an open space between the tubes and the soil, the measured temperature profile is not the same as the profile in the soil (Gaag & Sauer, 1989).



IRISH-DUTCH PEATLAND STUDY : CLARA BOG, Co. OFFALY, IRELAND

TEMPERATURE MEASURING SITES

Legend

/// Minerotrophic vegetation (according to L.Kelly, 1992)
—— Transect

Wageningen Agricultural University
Department of Water Resources
Group Hydrogeology
M.J.G. van den Boogaard

Scale: 0 0.1 0.2 0.3 0.4 km

Number: Figure 5.7.

It takes some time (15 sec.) till the probe has the same temperature as it's environment. An error is made when people read the resistivity too early. The resistivity of the cable can change. With the IWACO-apparatus this resistivity can be measured but this has not been done at every measuring-depth. With the BECKMAN-apparatus this resistivity can not be measured. For the IWACO-apparatus the verification-error is estimated to be 0.1 ^oC, and the reading-error at 0.01 ^oC. The error made with the depth-measurements is some 5 cm.

Because of the descending of the probe, the temperature profile is disturbed. This disturbance is minimized by descending very slowly and gradually.

Under normal conditions (plastic tubes, no convection in the tubes, good contact between tubes and soil and careful measuring) the error only depends on the apparatus. The IWACO-apparatus has an error of 0.1^oC for temperatures and 0.02 ^oC for temperature differences (Gaag & Sauer, 1989).

5.3. Results

5.3.1. Data

Appendix IV.B gives the measuring data. The following graphs are made, to interpret the data:

- *Isothermic transects (see appendix IV.C and figure 5.7).*
- *Temperature and temperature gradient against the depth (April and June 1992 in one figure)*
  Temperature gradient at depth x is calculated:

$$\frac{T_{(x+a)} - T_{(x-a)}}{d_{(x+a)} - d_{(x-a)}} \qquad (^oCm^{-1})$$

T	Temperature	(^oC)
d	Depth	(m)
a	Depth-interval at which temperature is measured	

Those graphs are put together with the hydrochemical data (Chapter 6). This makes it easier to correlate those data. Graphs without hydrochemical data are given in appendix IV.D. and graphs with hydrochemical data in appendix V.

5.3.2. Interpretation

5.3.2.1. Isothermic transects

Some remarks about these transects (appendix IV.C) are made. In general no relation with the temperature profiles and temperature gradients seems to exist.

CLARA WEST 1 (901-CLBH5; April and June 1992)

* *Due to the downward bending of the isotherms near CLBH5 groundwater flow is supposed to go in that direction. The colder water flows towards CLBH5 and the temperature decreases.*
* *The higher elevation of the mineral subsoil near site 92 seems to have no influence on the temperature.*
* *From April to June the 10 ^oC isotherm has moved downwards in the profile. This means that between April and June there was a downwards flow of cold water from the surface.*

CLARA WEST 2 (903-CLCD1; April and June 1992)

* *Remarkable is the dip in the 10 ^oC isotherm at site 90 (April 1992) while the other isotherms do not show anything special.*

CLARA EAST (April 1992)

* *Tube 111 and 114 have lower temperatures than the surrounding tubes. Maybe this is the result of a higher downward seepage.*
* *Tube 114 is situated in Lough Roe and represent very wet conditions. If the high water content is the reason for the slower warming up, tube 119 (also in Lough Roe and wet) should show the same behaviour.*
* *Near the edge of the bog, a downward flow towards the margins is suggested by the lower temperatures. This can be explained by the occurrence of the lagg-zone and the drainage due to peat-cutting.*

CLARA EAST (June 1992)

* *The isothermic pattern near the surface runs parallel to the surface. .*
* *In the lower 9.5 ^oC isothermic a dip occurs in the tubes 111 and 114. The tubes 112 and 119 have this isothermic at a relatively higher depth.*

5.3.2.2. Temperature profile and temperature gradient

In general, there is no very clear difference between the measured temperature in the tubes. As discussed in chapter 4 almost everywhere at the bog downward seepage occurs. This will have its influence on the temperature graphs. The seasonal influences can be recognized very well in the graphs of the temperature and the temperature gradient against the depth (appendix IV.D and V). These graphs also show that in April 1992, in most of the tubes constant values are reached at about 4 m-G.L.. The temperature at this depth than about 10 degree Celsius and the temperature gradient about 0 $^{o}C/m$. As this is almost everywhere there seems to be no correlation with the different types of peat and the heat conductivity. In June the measurements could only be done to 6 m-G.L. Because of this limited depth hardly any interpretation is possible. The measured temperature profiles and figure 5.2. show that the seasonal influence in peat reaches to about 7 m-G.L..

CLBH3 is a borehole with a diameter of 15 cm. As expected convection has taken place in this tube which is reflected in the constant temperature. So this measurement is of no use. CLBH4 shows a rather different profile and gradient as the other boreholes (except CLBH7). It looks like there is more downward seepage at this borehole. The shape of the profile is concave while the other have a convex shape. At a greater depth water with a temperature of 10 degrees Celsius is present. At the site of CLBH7 the same shape can be found but the measurement is not as deep. No relation between the lithology and the temperature profile or temperature gradient can be identified.

5.4. Discussion

The geothermic principle applies mainly to the deeper subsoil. Gaag and Sauer (1992) only use measurements deeper than 15 m-G.L. Although the seasonal influences in peat will not reach that deep, people have to be very careful with the interpretations. The measurements, especially those in June are not done to a sufficient depth. At least, an instrument is needed, which can reach the bottom of the several tubes. The theory is very complex. If one could concentrate on this subject might be useful. The measurements should be carried out in special periods of time when changes in temperature are expected, due to seasonal variation.

The temperature-probe of the Dutch National Forest Service, which just can be pushed in the ground (max. 2 m) and which measures electric conductivity and temperature could be very useful for more information on the seasonal fluctuation. Then, this fluctuation can be eliminated from the measurements.
The temperature data show some remarkable features but as it is only a small part of this hydrogeological study no relevant conclusions can be drawn now. Maybe later in this project, when more knowledge on hydrology and hydrochemistry is available, a thorough interpretation of the data can be worthwhile.

6 HYDROCHEMISTRY

6.1. Introduction

The hydrochemical data of this report consist of two kinds of measurements. The first and easiest to obtain, are the electric conductivity data (EC) which gives an idea about the ionic mobility of water. The second type of data comprise the hydrochemical composition of water which are obtained from laboratory analysis.
In this chapter both methods are explained and the results and problems, especially with the chemical data are discussed. From the literature (see chapter 3) it is very clear that the bogwater is very nutrient-poor and due to this it has a low EC (60-100μS/cm). The soak-area should have, according to the minerotrophic vegetation, some supply from mesotrophic water (more nutrients in amounts and type) which results in a relatively higher EC. The mineral groundwater is nutrient-rich and has a high EC (500-600μS/cm). This groundwater will be rich in calcium due to groundwater flow through the limestone subsoil and glacial deposits which are derived of this limestone.

6.2 Methods

6.2.1. Electric Conductivity

The electric conductivity (EC) has been measured during the period April-July 1992. Field measurements are carried out with a WTW-LF 91 (HE 1/T) from the Wageningen Agricultural University. The EC of the samples for laboratory analysis, were measured at Chapel Hill (Clara) with a WTW LF 91 (LS 1/T-1.5) and in the laboratory (O.P.W. or State lab). The drains along the Bogroad and the Deep drain are measured regularly. On and around the bog the EC is occasionally measured. On the bog the water in the piezometers is pumped out to measure the EC in a sample.

6.2.2. Hydrochemical analysis

6.2.2.1 Fieldwork

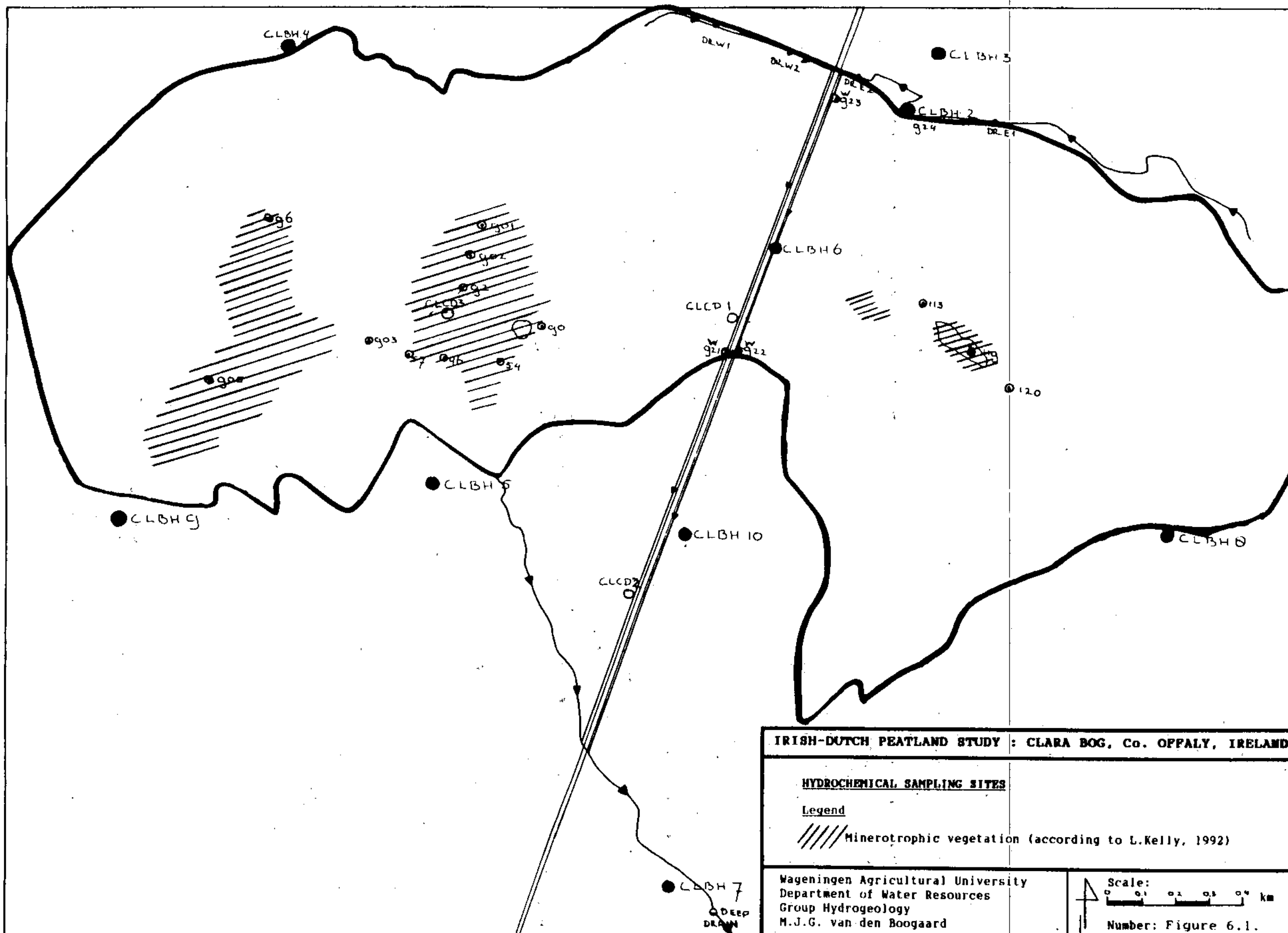
Electric conductivity can just be measured in the field, but for laboratory analysis water samples are needed. In 1992 (till October) three hydrochemical sampling sessions took place i.e. in March, June and September. The water in the tubes, which also are being used to measure hydraulic heads, is sampled. The pH and EC are measured as soon as possible measured at Chapel Hill (Clara). Figure 6.1. and table 6.1. give an overview of the sites that have been sampled.

In March 1992 the shallow filters (< 3m) were pumped out with a handpump and the deeper with an electric pump. The sampling was carried out by Richard Henderson, Larissa Kelly and the author. The samples were analyzed at the O.P.W.-laboratory in Dublin and showed very high contents of HCO_3 and NH_4
There could be 3 reasons for this:

- *Because of time limitations the piezometers were not pumped out before the samples were taken.*
- *The use of an electric pump is likely to introduce a large amount of oxygen into the water.*
- *Problems with analysis in the laboratory.*

Normally, there is a high NH_4-content in recently dug boreholes (pers. comm. D. Daly). The figures from March however, are extremely high.
To solve the problems with the water analysis the sampling was carried out otherwise in June and September 1992:

- *a bailer is used to get out the minimum amount of water needed for the analysis, thus minimising the introduction of O_2 and CO_2;*
  For most of the shallow filters the handpump is still used. The bailer is placed on a gardenhose (14.5 m). The hose was not very good because of several bends. Sometimes the amount of water in the tubes was too small to get it out with the bailer. Then the water was sucked out. It was not exactly known when sufficient water was coming out of the hose. Therefore the first amount of water at every site was not used.
- *the samples were taken at some 50 cm above the bottom of the tube;*
- *smaller bottles (250 ml) which can be filled to the top with water were used;*
- *a coolbox, in which the bottles were placed, directly after sampling, was used; Samples should be stored at approximately 4^0C;*
- *the tubes were pumped out till 3 days before the sampling took place and covered with a cap;*
- *as soon as possible the samples were transported to the State Laboratory. There was asked for a fast analysis.*



IRISH-DUTCH PEATLAND STUDY : CLARA BOG, Co. OFFALY, IRELAND

HYDROCHEMICAL SAMPLING SITES

Legend

//// Minerotrophic vegetation (according to L.Kelly, 1992)

Wageningen Agricultural University
Department of Water Resources
Group Hydrogeology
M.J.G. van den Boogaard

Scale: 0 0.1 0.2 0.3 0.4 km

Number: Figure 6.1.

Table 6.1. Ionic Balance Error (IB_ERR) of hydrochemical samples 1992

SITES	MARCH		JUNE[1]		SEPTEMBER	
CLARA BOG, |IB_ERR|	<= 5	5-10	<= 5	5-10	<= 5	5-10
West						
46 A,B,D,F	*/ B, F	*	*/A,B,D,F	*	*/A,B	*/ D
54 A,B,D,F	*	*/F	*/A,B,D,F	*		
57 A,C,D,E	*	*	*/A,C,D	*	*/A	*/ D
90 A,B,D,F	*	*/A	*/A,B,D,F	*	*/A,B,D,F	*
92 A,B,D,F	*	*/A	*/A,B, F	*		
96 A,B,D,F	*	*/A	*/A,B,D,F	*	*/ D,F	*
901 A,B,D,E	*/ B	*	*/A,B,D,E	*		
902 A,B,D,E	*	*/A	*/A,B,D,E	*	*/ B, E	*/A
903 B,C	*	*/ B	*/ C	*		
905 A,B,D,E			*/ B,D,F	*	*/ F	*
Lake water,S.L.	*	*/*	*/*	*		
East						
113 6,5,4,3,2,1	*	*/3	*/6,4,3,1	*	*/6,4,3,1	*
119 3,3*,2,1	*	*	*/3,3*,2,1	*	*/ 2,1	*
120 A,B,D,E	*	*	*/A,B,D,F	*	*/ B,D	*/A
Surface L.R.	*	*/*				
	44/3[2]	44/9	49/47	49/-	36/20	36/4
MINERAL GROUNDWATER, |IB_ERR|			<=2	2-4	<=2	2-4
CLBH2 1,2,3			*/1,2	*/3	*/1	*/2
CLBH3					*/PT1,2[3]	*
CLBH4 1,2,3					*/1,2	*
CLBH5 B,A			*/B,A	*	*	*
CLBH6 1,2,3			*/1,2,3	*	*/1,2	*
CLBH7 1,2					*/1,2	*
CLBH8 1,2					*/1	*/2
CLBH9 1,2					*	*
CLBH10 1,2					*	*/2
CLCD1			*/*	*	*/*	*
CLCD2 N,S					*/S	*
CLCD3			*/*	*	*/*	*
	-	-	10/9	10/1	26/13	26/3
SURFACE WATER, |IB_ERR|			<=2	2-4	<=2	2-4
921			*/*	*	*	*
922			*/*	*	*/*	*
923			*/*	*		
924			*/*	*		
Drain_w1					*	*
Drain_w2					*	*
Drain_e1					*	*
Drain_e2					*	*/*
Deep_drain			*/*	*	*	*
Brosna			*/*	*		
Silver			*/*	*	*	*
	-	-	7/7	7/-	8/1	8/1
TOTAL 180	44/3	44/9	66/63	66/1	70/34	70/8

Percentage of samples with IB_ERR in the marge (bog samples <= 5, mineral groundwater/surface water samples <=2) and twice the marge

TOTAL		MARCH		JUNE		SEPTEMBER	
Marge	2*marge	marge	2*marge	marge	2*marge	marge	2*marge
56 %	66 %	7 %	27 %	95 %	97%	49 %	60 %

---

[1] In June samples the concentration HCO_3 is estimated

[2] 44/3 : Of total (44), 3 samples with an |IB_ERR|<= 5

[3] PT1,2 Sampling on 13/08/92

In June 1992 the sampling was done by Larissa Kelly and the author and in September 1992 by Larissa Kelly and Ray Flynn. The precipitation data are the mean over the period June 1991 till June 1992 and gathered by L. Kelly.

6.2.2.2. Computer program, Chemproc.

The data of the chemical analysis were stored and processed in Chemproc., a Dutch computer-program. With the input of the analysis Chemproc. calculates some features (figure 6.2.). The first three columns represent the analyzed data and the last two columns, the calculated features, by Chemproc.. If there is no measured temperature, the program assumes a temperature of 10^{o}C.

Name	46F1	SO4	0.60	Pt		********** Calculations **********			
City		NO3		ECfld				Sum +	0.38
Map	1	Fe	0.19	SecDp		** LOG IAP/KT **		Sum -	-1.07
Date	1992.0325	Mn	0.01	UVext		Calcite	-3.18	error %	-48.15
Unit	3	Al		Color		Dolomit	-6.67	TIC mg/l	14.76
Code	46A	SiO2		Turb		Siderit	-2.22	Ion.rat	0.05
Depth	phreatic	o.PO4	0.01	SuspM		Rhodoch	-3.51	Na*	-0.77
Altitude57.9		KMnO4f		CO3	No	Gypsum	-4.91	K*	-0.13
Filter1 1.0		KMnO4u		Tot N		OH-Apat	-17.73	Mg*	-0.34
X-Coord.		NO2		Chlf		Chalced	-12.08	SO4*	-1.09
Y-Coord.		CO2		Phaeo	DATA	Quartz	-11.53	Ca*	1.16
Type	G	TotdH		DOC		Gibbsit	-9.18	Na+K+Mgm	0.30
EC	80.60	HCO3dH		O2		Kaolini	-41.19	Na+K+Mgc	0.36
pH	6.58	Tot P	0.01	O2%		pe		K-20	61.02
Temp.	10.00	TOC		COD		Viviani	-8.07	EC-20	71.33
Na	5.90	Pb		BOD1i		P CO2	-2.01	error %	-7.79
K	0.11	As		BODda				ANC	7.23E-1
Mg	0.47	Ni		Fe T				Buf.CO2	6.93E-7
Ca	1.42	Zn		F				Buf.tot	1.17E-3
NH4		Cd		a)				Stuyfzand class:	
Cl	12.00	Kjel-N		b)				HCO3H	F0-NaHCO3
HCO3	44.14	Q		c)				Tot H	F*-NaHCO3
remarks								Exch	-0.06

Figure 6.2. Chemproc. datasheet, site 46 filter 1

The following features are used in this report:

Ionic balance error %

The ionic balance-error[4] (IB_err) is a measure for the usefulness of the analysis. The IB_err[5] calculated according to Nota and Van de Weerd (1989) is twice as large as the IB_err according to Chemproc. Still the standards from Nota and Van de Weerd are used. This because bog is hard to sample. For bogwater with few ions the IB_err has to be less than 5 % and for mineral groundwater and surface water less than 2 %. (Nota & Van de Weerd, 1989).

Ionic ratio

*The ionic ratio (Ion_rat.) is used in the Van Wirdum graph. Ion_rat. = 0.5 * Ca /(0.5 * Ca + Cl) with Ca and Cl in mmol/l.*

EC_20

The electric conductivity at 20^{o}C (EC_20), is calculated with the measured EC, at 25^{o}C.[6]

Stuyfzand classification

The Stuyfzand classification is a system to classify watertypes. The system distinguishes maintypes, types, subtypes and classes. The first classification is based on the chloride content (Fresh-Brackish-Hyperhaline water). All the samples in the Clara Bog area are of the fresh water type. Therefore the classification starts with a F.

---

[4] $$\text{IB\_err (\%)} = 100 * \frac{(\text{Sum\_cat} - \text{Sum\_an})}{(\text{Sum\_cat} + \text{Sum\_an})}$$

(Sum_cat, Sum_an both positive and in meq/l)

[5] $$\text{IB\_err (\%)} = 100 * \frac{(\text{Sum\_cat} - \text{Sum\_an})}{0.5 * (\text{Sum\_cat} + \text{Sum\_an})}$$

(Sum_cat, Sum_an both positive and in meq/l)

Sum_cat + Sum_an < 2 meq/l   IB_err <= 5 %
Sum_cat + Sum_an > 2 meq/l   IB_err <= 2 %

(Nota & Van de Weerd, 1989)

[6] EC_20 = EC_25 * 0.885 with EC in S/cm

The second classification is based on the total hardness of the sample[7]. The subtypes are marked by the dominant anion and cation of the dominant anion- and cation-family. Every subtype is divided in three classes (sum of Na, K and Mg corrected for the sea-salt contribution). These classes are not considered in this report (Biesheuvel, 1990). For a detailed description of the Stuyfzand classification method readers are referred to Stuyfzand (1986).

In June, the HCO_3^--concentration was not analyzed, although it is an essential ion in most water samples. Furthermore, the ionic balance-error, a measure for the usefulness of the analysis, was not calculated by the laboratory. The HCO_3^--content for the June-samples have been estimated by using the ionic balance. An IB_err of <=2 or 5% was still accepted. The measured HCO_3^--concentrations from March and September are used as guidelines[8]. Differences in the HCO_3^--content between samples from June, March and September 1992 are very large for the following filters: 46F3,F4; 57F2,F3; 90F3,F4; 96F3,F4; 902F3,F4; 905F2,F3,F4; 113F1,F4; 119F2; 120F3,F4; CLBH2.F3; CLBH5.F1,F3. From these samples, only the sites 901F2, 902F3,F4 and 113F1,F4 are really doubtful as the samples of the other sites show in March and September 1992 ionic balance errors larger than 5%.

6.3. Results

6.3.1. Electric conductivity from field measurements

The electric conductivity of the drains on or near Clara Bog are presented in figure 6.3.A and 6.3.B. Most of these data were collected in relatively dry periods. The following remarks can be made:

- *The **drains south-east of Clara Bog** have relatively high EC-values (300-700μS/cm) which is an indication for groundwater from the limestone or the till.*
- *The **drain on the north-west side of Clara Bog** collects bogwater. Just before the Bogroad a stream with esker-water enters the drain (fig. 6.3.B).*
- *The **drain on the north-east side of the bog** collects both groundwater from the esker, till deposits and from the bog. In the mainstream the EC is about 400-500μS/cm where in the streams coming from the esker the EC reaches values of 700μS/cm. The influence of the esker and till-deposits is dominating.*
- *The **drain along the west-side of the Bogroad** has an lower EC (190-260μS/cm) than the **drain on the east-side** (400-600 μS/cm). In the southern direction the EC-values are decreasing due to the influence of bogwater. Near the cut-away area on the east-side, bogwater flows into the east-drain along the road and this results in a lowering of the EC. However, this bogwater has relatively high EC-values compared to typical bogwater. This can be a result of the mineralisation which occurs in the peat due to turf-cutting.*
- ***Near the facebank area on Clara Bog** west peatwater is coming from the bog (70-80μS/cm). At the facebank, with a lot of drains, the EC-values are increasing strongly (300-500μS/cm). This is a result of the mineralisation of peat near the facebank and because part of the drains is incised in till deposits.*
- *The **Deep drain** has along the Bogroad relatively high EC-values (450μS/cm). The influence of bogwater in is small (in the period of measuring).*

---

[7]

Total Hardness mmol/l			Code	
0	-	0.5	*	Very soft
0.5	-	1	0	Soft
1	-	2	1	Moderate hard
2	-	4	2	Hard
4	-	8	3	Very Hard
8	-	16	4	Extreme hard
16	-	>256	5-9	Extreme hard

[8] In March and September 1992 HCO_3^- is expressed as alkalinity : $[HCO_3^-] + [CO_3^{2-}] + [OH^-]$
For most groundwaters pH <= 9 i.e. looking at the carbonate phase diagram,
CO_3^{2-}/HCO_3^- is very small. So CO_3^{2-} can be ignored.
In this range the concentration OH^- is also very low. So OH^- can be ignored.

For most groundwaters (unless pH is very high or very low): Alkalinity = $[HCO_3^-]$
This is measured in mg/l $CaCO_3$ and has to be convert to bicarbonate (HCO_3^-).

$$1 \text{ mg/l } CaCO_3 = 0.6 \text{ mg/l } CO_3^{2-}$$
$$0.6 \text{ mg/l } CO_3^{2-} = 0.02 \text{ meq/l } CO_3^{2-}$$
$$0.02 \text{ meq/l } CO_3^{2-} = 1.22 \text{ mg/l } HCO_3^-$$

$$1 \text{ mg/l } CaCO_3 = 1.22 \text{ mg/l } HCO_3$$

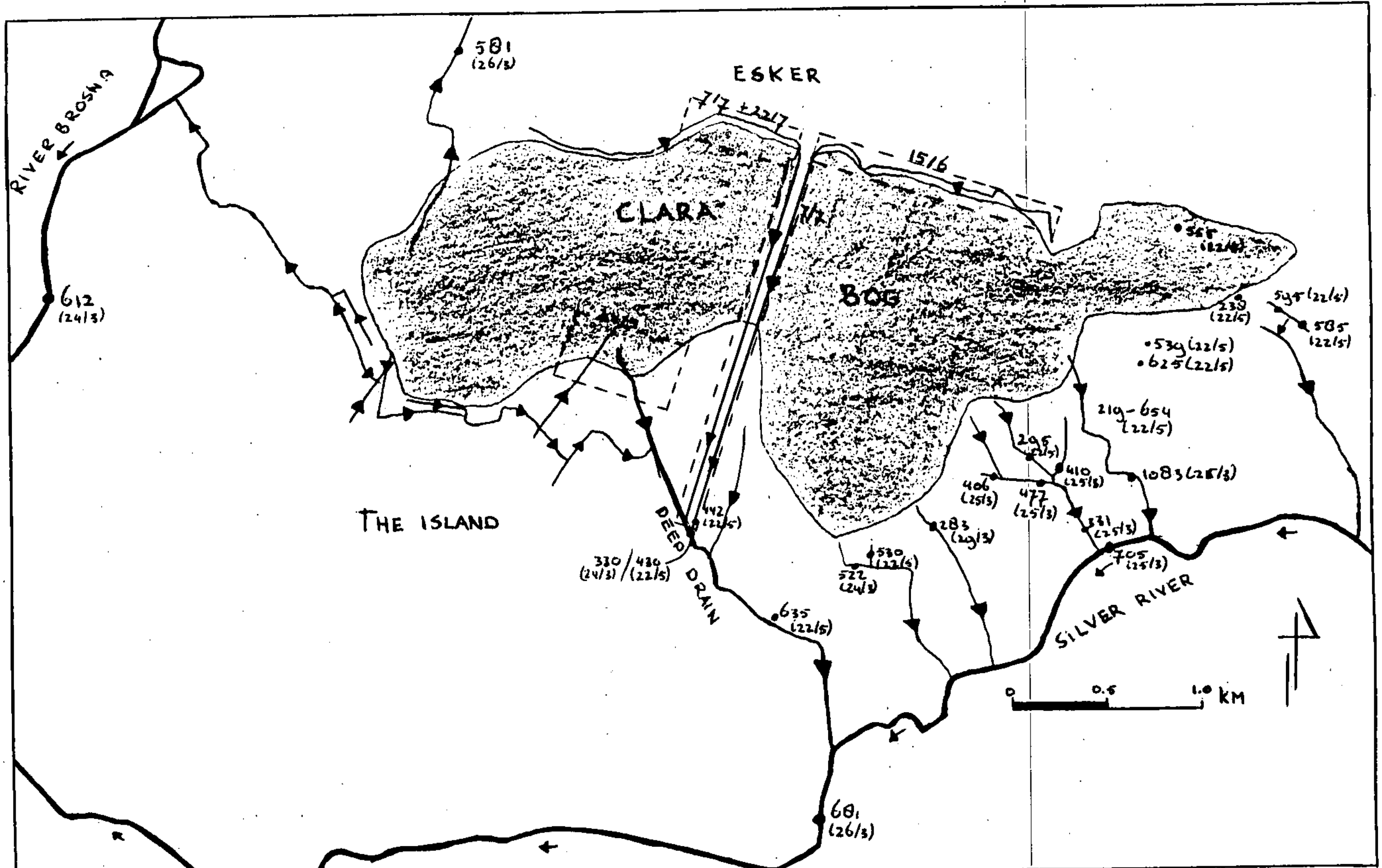


Figure 6.3.A Electric conductivity (µS/cm), March-July 1992, Overview

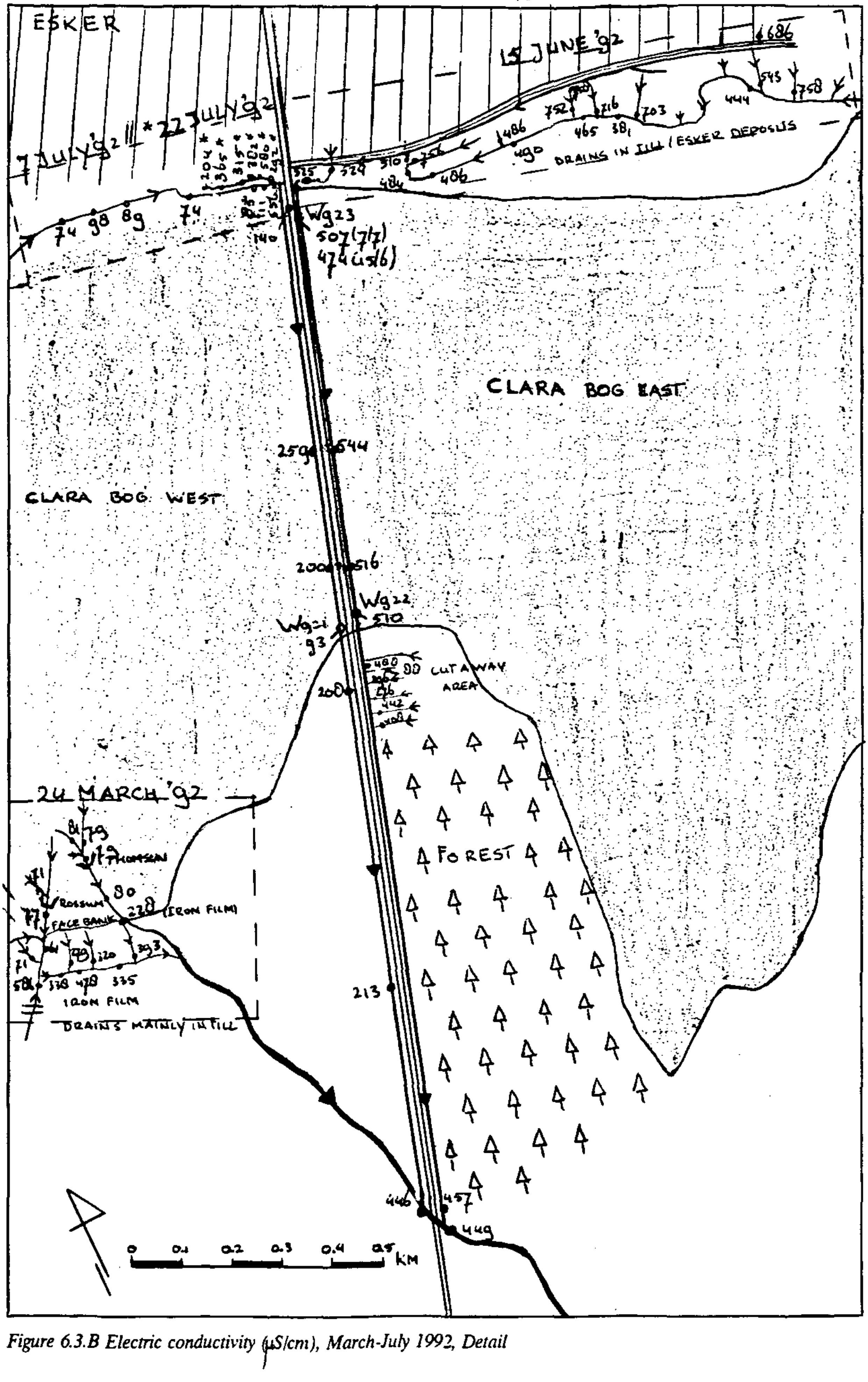


Figure 6.3.B Electric conductivity (μS/cm), March-July 1992, Detail

The EC of the drains along the Bogroad, the Deep drain, the Silver River and the River Brosna, which are measured regularly, are presented in appendix III.A1. The relation between the EC and the discharges, indicated by the waterlevels, can be derived from figure 6.4.A-F. If the waterlevel rises in the drain along the east-side of the Bogroad, the EC-value decreases (fig. 6.4.A/B). The cause of this is the greater influence of bogwater, which reacts quickly on precipitation (see chapter 4). The same can be seen, but less pronounced, at the west-drain, the Deep drain and the Silver River. The River Brosna behaves differently, therefore it is likely that this river is less dependent on bogwater than the Silver River. Near weir 923 a place occurred with higher EC-values (550-600µS/cm) than the drain itself (300-500µS/cm). This maybe caused by water coming from the Bogroad fundament which consists of esker- and till-deposits.

The EC, measured at the several piezometer sites on and near the bog are given in appendix V. On one site the EC has been measured at several depths (filters). The graphs of the EC against depth can be found in appendix VI, together with the hydrochemical analysis. These will be discussed in the next section.

6.3.2. Chemical composition

6.3.2.1. Introduction

From a bog-piezometerset filter 1 is the shallowest filter (mostly phreatic) and 4 or 6 the deepest. For the boreholes and the cobra-drillings filter 1 is the deepest.
The ionic balance-error (IB_ERR) of the sampling sites is given in the table 6.1. Table 6.1. shows that the (absolute) ionic balance-error for 93 % of the March-samples and 51 % of the September-samples is too high according to the standards discussed in 6.2.2.. From the March samples 27 % has an |IB_error| <= 5 for the bog area. From the September-samples 60 % has an |IB_error| <= 5 % for the bog area and an |IB_error| <= 2 % for the mineral groundwater and surface water. As the hydrochemical data of June 1992 have the most samples (95 %) with a ionic balance error whithin the marge, these data have been used. It should be noted, however that this high percentage of samples with a low error is mainly caused by the procedure used to calculate the HCO_3^--concentration (see 6.3.2.2.). Other reasons to choose the June-samples:

- *The June-samples are not better or worse as those of March or September;*
- *In March only a few samples are available;*
- *The September data arrived in the Netherlands when the author already had started with the interpretation of the data from March and June.*
- *At first sight no principal differences between the three data-sets seem to occur.*

The electric conductivity and pH-measurements of the other sampling dates are taken into account as well.

L. Kelly sampled the rainfall in Clara Bog several times during the period June 1991- June 1992. The mean value of those data has been used in this report. The HCO_3^-concentration of the precipitation-samples was not analyzed, so it has been estimated (using the same procedure as discussed in 6.3.2.2.).

6.3.2.2. Van Wirdum graph

First a Van Wirdum graph is made of the June data. In a Van Wirdum graph the ionic ratio is set out against the electric conductivity. A triangle can be distinguished with water strongly influenced by lithology at the top. The left angle (low Ionic ratio and low EC) is marked by atmospheric water and in the right angle saline water (seawater) is found (fig. 6.5.).
In the Van Wirdum graph (fig. 6.5.) the till-samples are in the top of the figure (LITHO) and the limestone in the middle of the figure (except of CLBH6, at the top of the graph). The gravel-samples are in between those two types of samples. The sample of CLBH6.2 (gravelly layer) is a strange one as it is very much to the Thalo (Seawater) side of the figure. This is due to the high Na+k and SO4 concentration. The lower and upper filters from this borehole (CLBH6.3 and CLBH6.1.) do not show this saline influence.
The samples of the Silver River and River Brosna are found in the LITHO-top. The samples of the Deep drain and the drain north-east of Clara Bog and the drain on the east-side of the Bogroad are just under the river-samples. The influence of the lithology is there still large. The sample of the drain on the west-side of the Bogroad has relatively large atmospheric influences (bogwater), which is supported by the low EC-values from the field measurement (fig. 6.4.).
In the Van Wirdum graph three bog watertypes can be distinguished:

1) *The deeper bog filters (F3 and F4) which are situated near the litho-part of the figure (F3 often closer to this than F4).*
2) *The real bogwater-type under the line ATMO-THALO.*
3) *The filters in between the types 1 and 2.*

On Clara Bog west the tubes 57F3; 90F3; 96F3; 901F3,F4; 902F3 and 905F3,F4 belong to the first type, and 46F3,F4; 54F2,F3,F4; 57F2; 901F1; 902F4; 903F2 and 905F2 to the third type.
From the Van Wirdum graph people can read that in all samples from site 119 and 113F4 the litho-influence is rather great (type 1). The samples of 113F6 and 120F4 are from the intermediary type. The rest of the samples taken at Clare Bog east are of the real bogwater type (type 2).

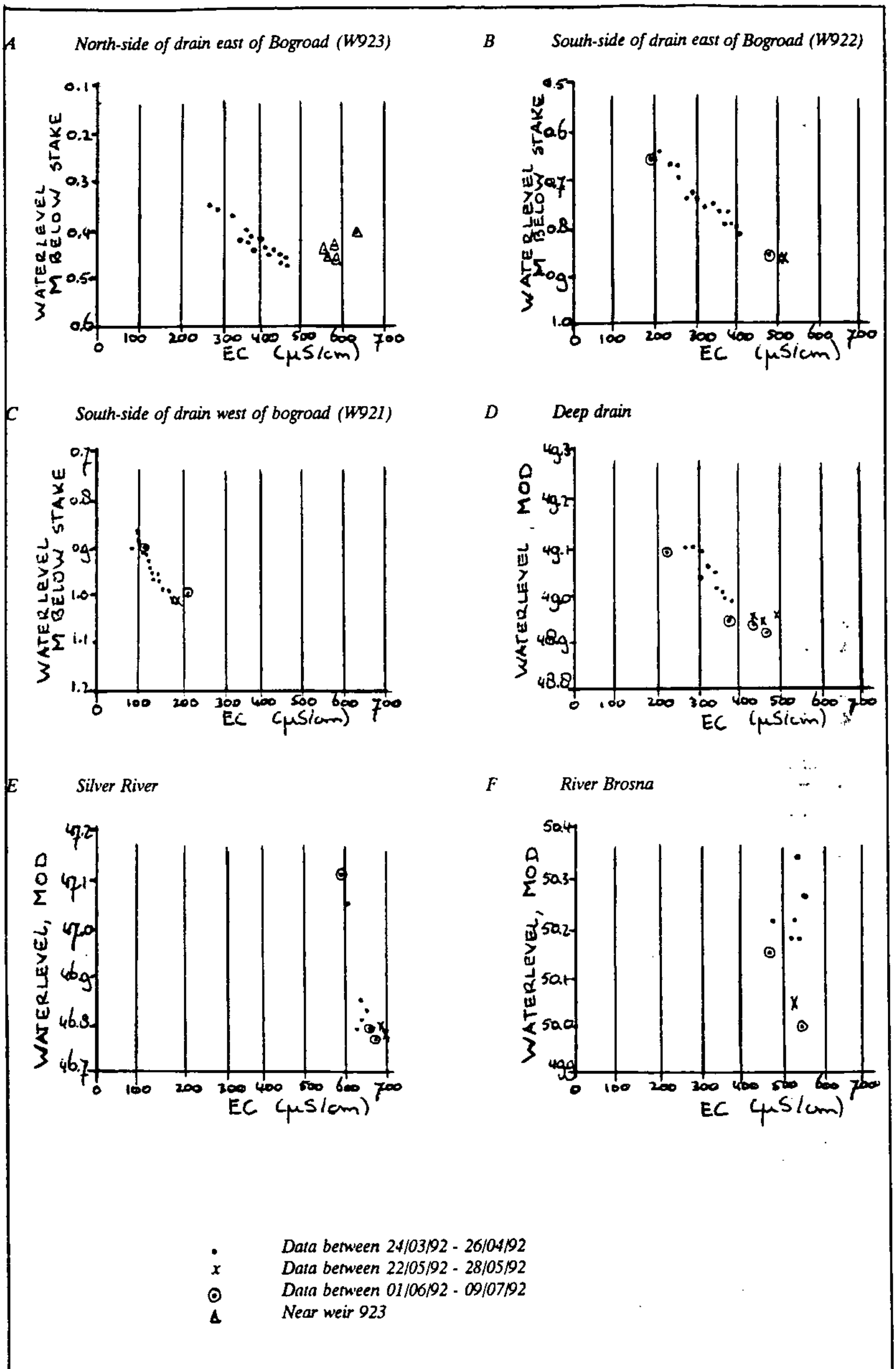


Figure 6.4. Electric conductivity in relation with stageheight, March-July 1992

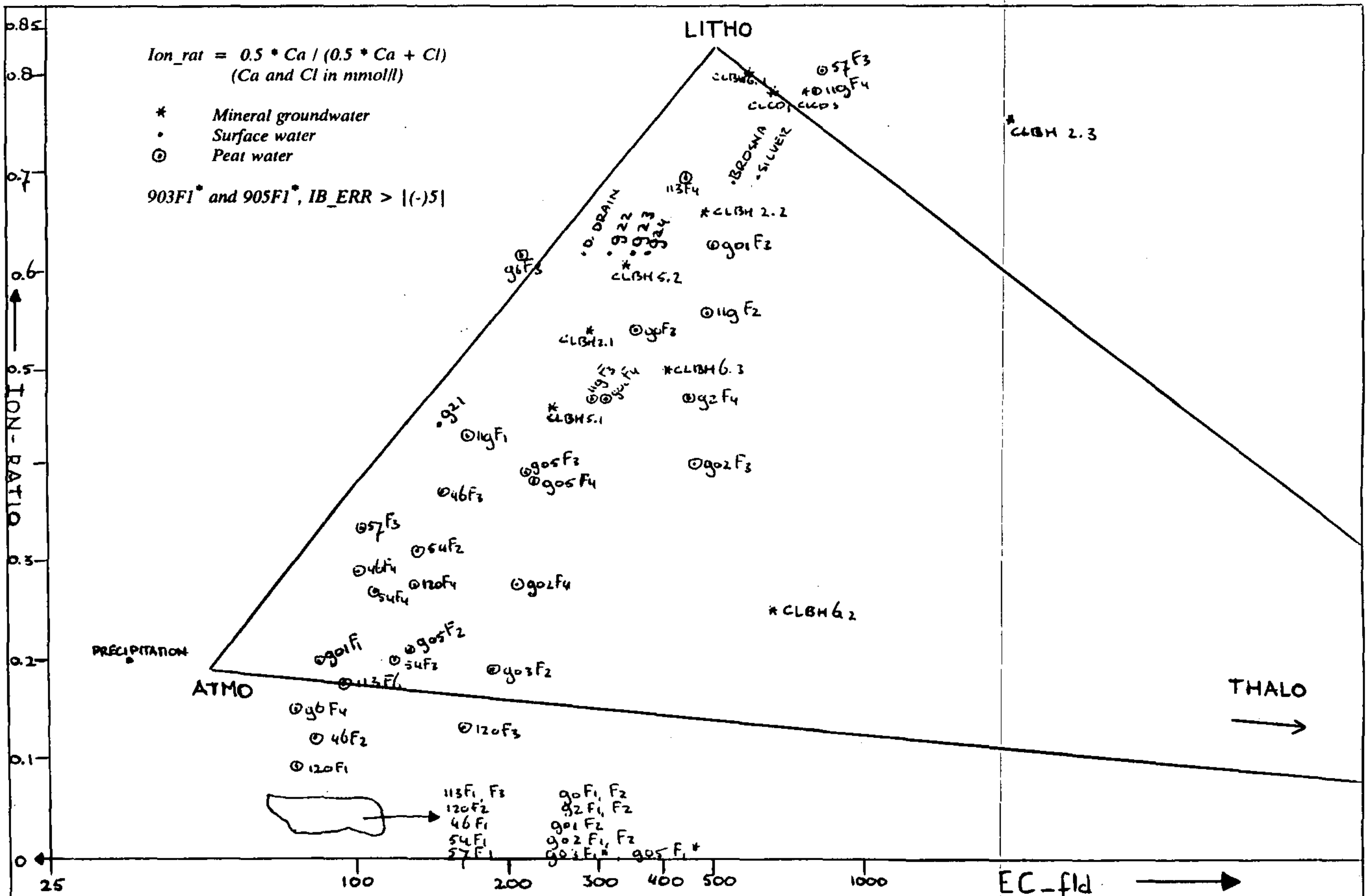


Figure 6.5. Van Wirdum graph, 4 June 1992

6.3.2.3. Hydrochemical profiles

The method of Van Wirdum was chosen to review all the June-samples together. Besides the Van Wirdum procedure, Stiff_diagrams, Stuyfzand classification and pH- and EC-values are used for each sample.
The Stiff-diagram is based on the concentration (meq/l) of 5 cations ($Na^+ + K^+$, Ca^{2+}, Mg^{2+}, Fe^{2+}) and 4 anions (Cl^-, HCO_3^-, SO_4^{2-}, NO_3^-). In the diagram the concentrations of the cations are put at the left side and the concentration of the anions at the right side (figure 6.6.). The concentrations of the anions have to be almost the same as those of the cations (IB_ERR<=2 or 5%).

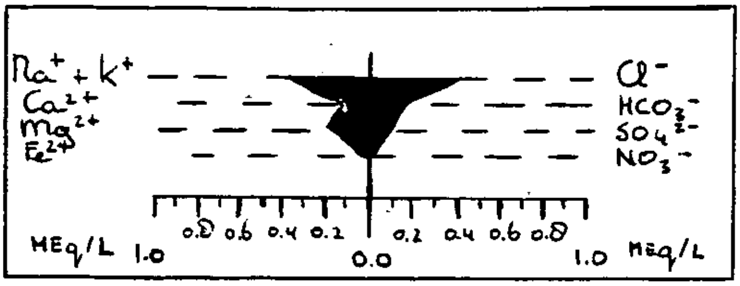


Figure 6.6. Example of a Stiff-diagram

The hydrochemical data of June are shown in appendix VI together with the temperature-data. Also the lithology of the several sites is described, using the report of Bloetjes (1992). The arrow on the right of the lithology-description marks the hydraulic head in the second aquifer. Figure 6.7. is an example of such a hydrochemical profile.
The hydrochemical data will be discussed in a short way. The Stiff-configuration present a mean of all relevant data (figure 6.8.). Table 6.2. gives an general overview of the data in appendix VI. The data of the Noorbeek-area (Chalk area in the Netherlands, without bogs) are used as a reference.

Table 6.2. General overview of the hydrochemical data, 4/6/92

MINERAL GROUNDWATER			
LIMESTONE	*$F^{0/3}$_CaHCO3*	*pH: 6/7*	*EC: 250- 600μS/cm*
TILL	*$F^{1/2}$_CaHCO3*	*pH: 6-12*	*EC: 350-1200μS/cm*
GRAVEL	*$F^{1/2}$_CaHCO3*	*pH: 7/8*	*EC: 400- 650μS/cm*
SURFACE WATER			
922-924, DEEP DRAIN, SILVER, BROSNA			
	F^1_CaHCO3	*pH: 7/8*	*EC: 300-400μS/cm*
921	*F^0_CaHCO3*	*pH: 7.4*	*EC: 145 μS/cm*
BOGWATER			
<u>CLARA WEST</u>			
F1,F2:	*F^*_NaCl/CaCl*	*pH: 4-5.5*	*EC: 70- 90μS/cm*
F3,F4:	*$F^{*/1}$_CaHCO3*	*pH: 5/6*	*EC: 100-400μS/cm*
<u>CLARA EAST</u>			
113, same as Clara west			
119, almost till surface minerotrophic influences			
120, less minerotrophic influences than anywhere else			
NOORBEEK SOUTH-LIMBURG			
	F^2_CaHCO3	*pH: 7/8*	*EC: 500-750 μS/cm*

*The **mineral groundwater** follows the statements made in section 6.1. The till of CLBH2 has extremely high EC-values (2000-3000 μS/cm) and has rather high Na+K-concentrations. EC-values >= as 1000 S/cm are hardly possible in this type of area. It is not clear what the reason could be for those values. The relatively low values in the limestone and high values in the till/gravelly layer are somewhat strange. People would expect that the limestone where the water might stay very long has the highest values. Only if the limestone is karstified, small travel times occur. Maybe the values in the till are that high, due to the low permeability of the till (long 'residence time') and due to the large contact area (high dissolution).*

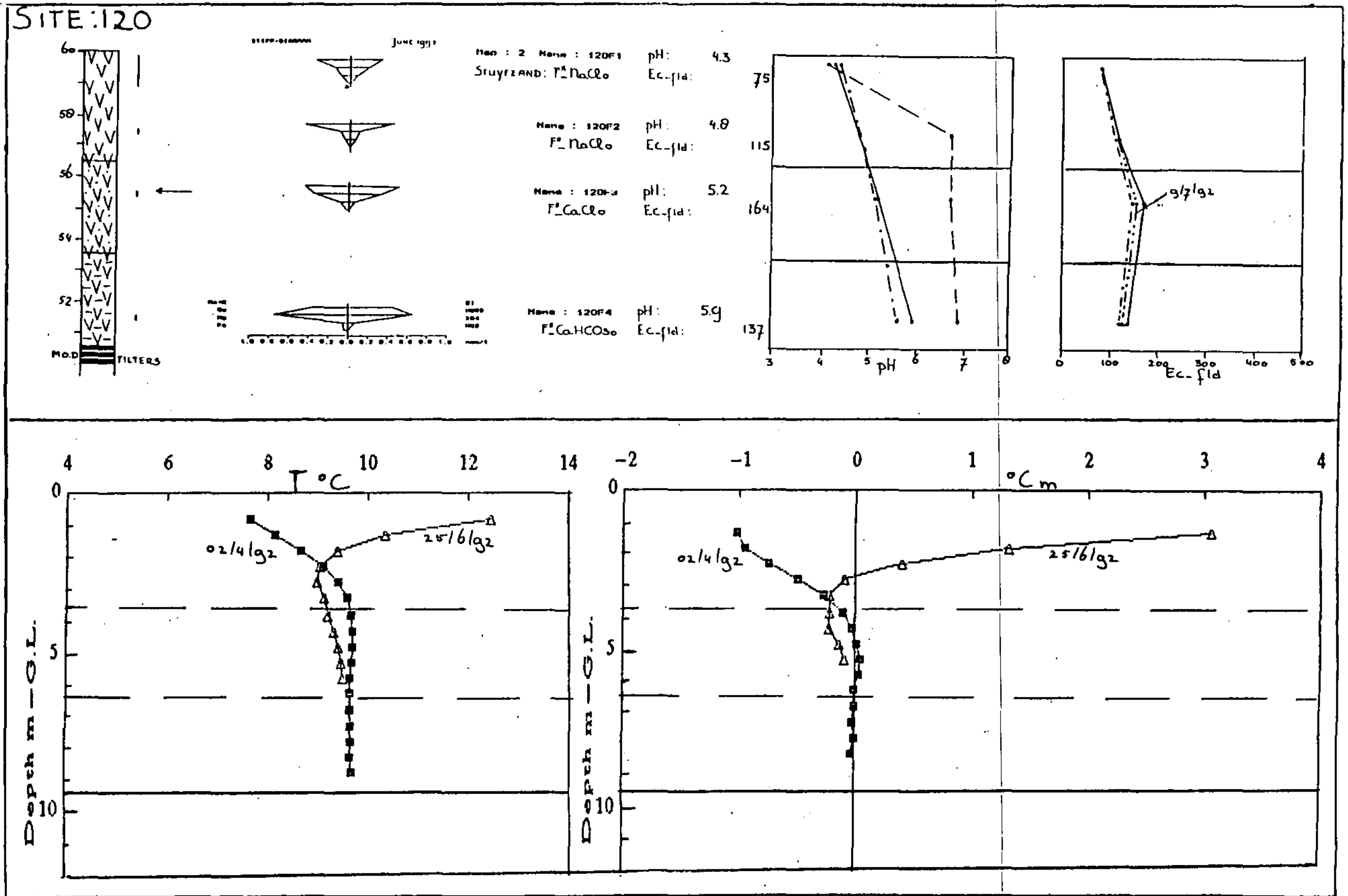


Figure 6.7. Example of hydrochemical profile, site 120

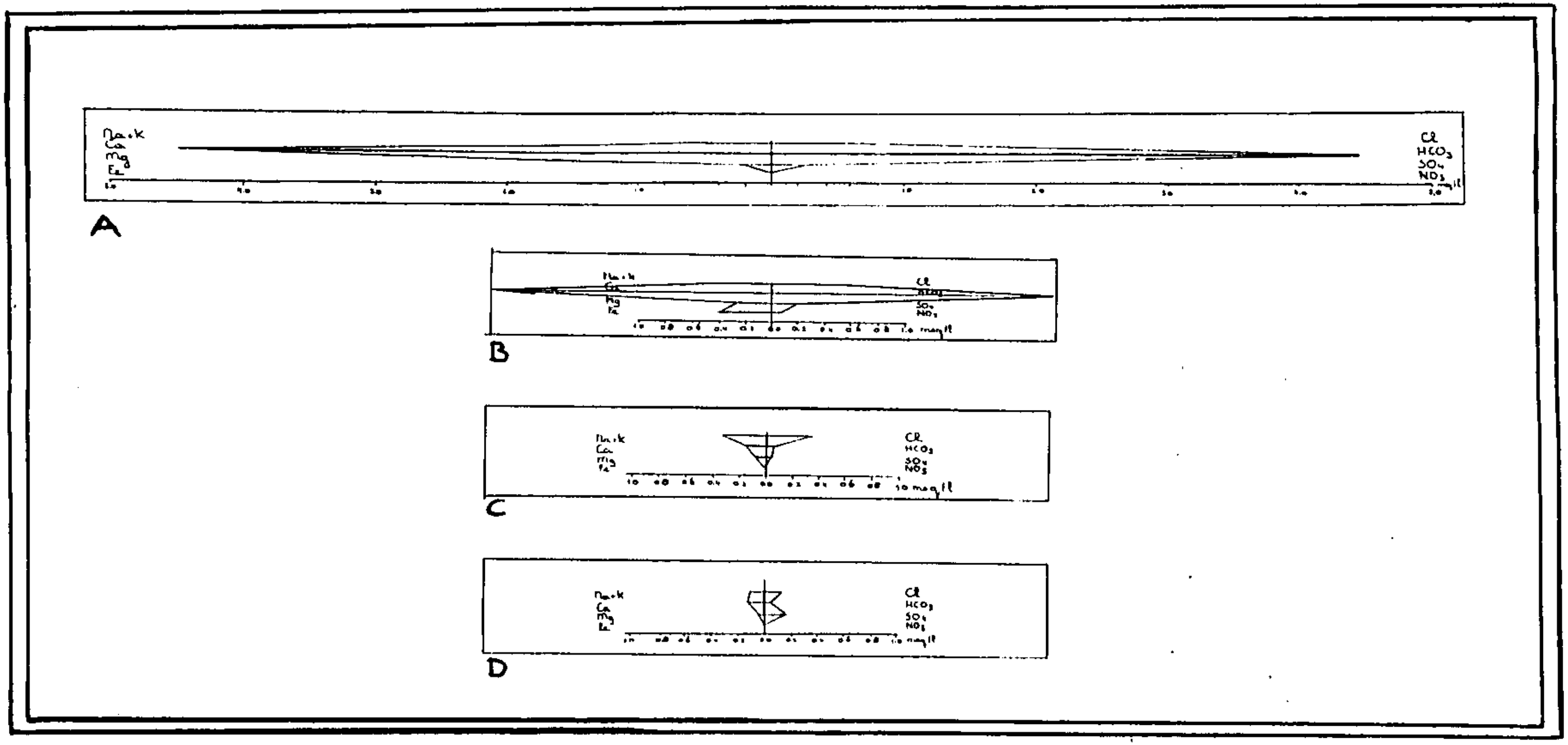


Figure 6.8. Stiff-figurations

6.8.A	*Mineral groundwater, Surface water*
6.8.B	*Bogwater in filters 3 and 4 on Clara Bog West*
6.8.C	*Bogwater in filters 1 and 2 on Clara Bog West*
6.8.D	*Precipitation (Mean June 1991 - June 1992)*

*The **surface water** samples show that the influence of the mineral soil and/or the deeper layers on the bog is great. Weir 921 (drain on the west side of the Bogroad) is still classified as a F0_CaHCO3 type of water, but the ion-concentration is much lower than from the previous surface water samples. Instead of the expected lower pH and higher EC-values at weir 922 (drain east of the road), a rather high pH and lower EC occurs. At this weir the peatwater has more influence on the drain than in all the rest of the sampled drains. Reason for the hydrochemical differences in the drains east and west of the Bogroad is the fact that the drain east of the road transport a lot of water coming from the drain at the north-east side of the bog. The water from the north-east drain has a rather mineral resource. Near the drains there could be seepage of the groundwater from the mineral subsoil (see paragraph 4.4.).*

*The precipitation has a very low content of ions, with a rather high conductivity value. The water on **Clara Bog** is different from the **precipitation** (figure 6.8). The precipitation contains more SO4 and less of the other ions. The sulphate becomes in reducing conditions (bog) sulphide. The Cl-concentration is rather low for a location with atlantic conditions. Calcium is at the sites 46, 901, 113 and 119 the dominant cation at the bog-surface. Calcium is a mineral ion which does not belong to the bog. Maybe the calcium-rich deposits, which occur everywhere around the bogs in the Irish Midlands, can give an explanation to that. The famine-roads at the bog can also give rise to a (small) dispersion of calcium. But no relation seems to exist between the famine road and the above mentioned sites.*

*The **Stiff-configuration** of the two shallowest filters (F1 and F2) on Clara Bog west is different from the deeper filter there (F3 and F4) (fig. 6.8.). The last ones usually have the same figuration as the samples of the surface water and the mineral groundwater but the concentrations are much lower. In most cases, the all but one deepest tubes have the most pronounced features of a minerotrophic water-type. On Clara Bog west these features can best be seen at the site 57, 90, 92, 96, 901 and 902.*
On Clara Bog east the site 119 is strongly influenced by minerotrophic water. Site 120, which lies outside a soak area, is maybe an example of an 'ordinary' bog-sample, with hardly any soak-remarks (figure 6.7). Only at great depth in the peat, the groundwater is classified as a $CaHCO_3$-type. The concentrations of Ca and HCO_3, however, are relatively low.
Table 6.3. shows some remarks at the several sites compared to the general notes (table 6.2.).

Table 6.3. Remarks on the hydrochemical data compared to the general overview (table 6.2.)

Site 54:	*F2 already CaHCO3-type*
	F4 relatively much Fe
Site 57:	*F2 already CaHCO3-type*
	F3 Extremely high EC and pH
Site 90:	*F4 relatively much NO3*
Site 92:	*F4 relatively much Fe*
Site 96:	*F3 relatively much Fe*
Site 901:	*F1 CaHCO3 -type with low EC*
	F2 NaCl-type with high EC, low pH
	F3 relatively much Fe
Site 902:	*F3 relatively much Fe*
Site 903:	*strange configuration, high Cl-content*
Site 113:	*F2, Fe-type*
	F4 (5.5 m-G.L.) is more clearly a CaHCO3-type as F6 (9m-G.L.)
	F4 has relatively a high NO3-concentration
Site 119:	*F1(1.5 m-G.L.) relatively much Fe*
	F3 less minerotrophic as the layers above and below
Site 120:	*Less minerotrophic influence*

Larissa Kelly sampled the surface water of two soaks: Lough Roe and Shanley's Lough. The samples of Shanley's Lough are in general almost the same as those of the 'common' bog area. The pH and EC values are a bit higher. The Lough Roe samples however show several differences with the bog area (table 6.4.).

Table 6.4. Hydrochemical differences between the 'ordinary bog' and Lough Roe (pers. comm. L. Kelly).

	Bog	Lough Roe	
pH	3/4	4	
EC	75	100	µS/cm
Na	10	4/5	mg/l
Ca	0.4/1.4	10/18	mg/l
Mg	0.7	1.2/2.0	mg/l
HCO3	>3	50	mg/l
Sulfate not very different			

The higher Ca and HCO_3 concentrations are very obvious. According to the hydrochemical and botanic data, collected by L. Kelly, the centre of the minerotrophic area of Lough Roe lies on the east-side of the soak. Marco Scheffers did twice electric conductivity measurements at Lough Roe (June and July 1992) and he found the highest values on the east-side. The vegetation at Lough Roe indicates more minerotrophic influences as at Shanley's Lough. The Bog myrtle (between Shanley's Lough and the facebank) is an indication for horizontal water movement in the underground. Molinia is also present there. Molinia indicates besides a water movement also relatively nutrient-rich conditions.

6.3.2.4. Electric conductivity and Stuyfzand classification

In appendix VII the electric conductivity is related to the Stuyfzand-classifications in several transects (figure 6.1.). The transects are the same as those from the temperature. Data are available from March, June, September 1992 and in some cases from July 1992. The data from June will be discussed, and if great differences with the other data occur they will discussed as well.

Transect 1 Shanley's Lough Site 901 - CLBH5

Sites 901 and 902 show EC-values and Stuyfzand-types which indicate minerotrophic influences in the upper layers of the old Sphagnum peat. At the sites of 46 and 92 minerotrophic influences are less pronounced and occur at the bottom of the old Sphagnum peat. At all the dates (except March '92) the EC at the base of the lacustrine clay near site 46 is relatively low (100µS/m).

Transect 2 Shanley's Lough Site 903 - 90

The most minerotrophic influences seems to occur at 54 MOD near the sites 57 and 90, just below (site 57) or above (site 90) the old Sphagnum peat. At the other dates the EC-values are much lower and the depth of the minerotrophic influences is less pronounced.

Transect 3 Lough Roe Site 113-120

Site 119 is marked by a clear minerotrophic influence which reaches to 1.5 m-G.L. The minerotrophic influence on site 120 seems minimal. On site 113 only at 54 MOD (Old Sphagnum peat) a strong minerotrophic influence seems to be present. At the others dates, however, this effect can not be seen and the EC's are even lower than at site 120. At the Young Sphagnum peat of site 113 and 120 a Na-type of groundwater occurs.

The July-profile (sites 106-120) shows very high EC-values near the edge of the bog. This is maybe the effect of some esker- and till- water in the bog.

6.4. Discussion

The hydrochemical data, discussed in this chapter, give only an indication of parts of the hydrochemistry of Clara Bog, i.e. at and near to the soak systems. It is a pity that there are almost no data of the 'common' bog surface. Furthermore the fact that the data of March and September were of little use is a great lose of valuable information, time, money and energy. Even the data of June are not very accurate as the HCO_3 had to be estimated. There are sometimes great differences between pH and EC values in the time. It is not clear if this is due to inaccuracy of the measurements or seasonal influences. The June samples reflect the hydrochemistry of a relatively dry period. If the data of this report are put together with the hydrochemical data and botanic/vegetation data of L. Kelly, relations might become clear.

7 SYNTHESIS

7.1. **Regional hydrogeology** -- *A very preliminary analysis*

In this paragraph a short overview is given of the regional hydrogeology of Clara Bog. Hydrological and chemical features are shown in the figure 7.1. The Stiff-diagrams on the bog and of the precipitation are 5 times enlarged. The Stiff-diagrams on the bog are those from site 120. It is not sure if this is a good example of a bog-type without soak-influences.
The two aquifers in this region are separated by several confining geological layers. The current hydraulic heads show a downward seepage on the bog. This seepage will be small because of the hydraulic resistance of the confined layer. In the past, the drainage from water from the bog-surface was difficult as the bog reached till the Silver River. As soon as the peat-cutting started and drainage was improved by man, the discharge of the bog has increased. One knows for sure that the regional groundwater levels dropped in the eighteenth century due to agricultural activities (pers. comm. S. van der Schaaf and R. Flynn). From the nineteenth century on, peat-cutting and drainage also have had a great impact on those waterlevels.

The mineral groundwater is flowing underneath the bog towards the Silver River and in a smaller amount towards the River Brosna. These rivers are largely draining the mineral surroundings of the bogs in this part of the Midlands. The drains of the Clara Bog region have also a base flow of minerotrophic water. A quick runoff from the bog occurs in times of rainfall. This has immediately influence on the composition of the surface water, i.e. a dilution of the base flow with bogwater.

7.2. **Hypotheses around the soak-systems**

With the hydrochemical data (chapter 6) and the overview of the regional hydrogeology (paragraph 7.1.), some hypotheses around the soak-systems are postulated. They are still speculative and they have to be worked out. According to the hydrochemical data, discussed in chapter 6 it seems that there is still fossil minerotrophic water present in the bog. In chapter 3 the general development of a raised bog is explained but this is not sufficient to explain those data and the existence of soaks. The Sphagnum-species, which are the reason that the bog has grown above the mineral groundwater influence, depend on nutrient-poor rainwater. However, nowadays minerotrophic water is found at depths where peat, consisting of Sphagnum-species occurs. Paleoecological research in Lough Roe (see paragraph 3.2.3.) shows that it always existed as a soak, or at least as a wet area, different from the rest of the bog. From the time that the Sphagnum peat started to grown, the soak-area increased till about 100 years ago (paragraph 3.2.3).

Figure 7.2. shows a raised bog development with soak-systems. After the glacial times a lake formed in the till-depressions. Here lacustrine clay was deposited. There is no evidence for extremely dry periods directly after that time. So the lake situation will remain. The lake was fed by rainwater but mainly by mineral groundwater from the surrounding soils (mainly esker deposits). Therefore fenpeat (developed in a nutrient-rich environment) is found at top of the lacustrine layer (Bloetjes, 1992). The lake basin, in which Clara Bog is formed has a kind of threshold in the south (see hydrogeological cross-sections A and A). This threshold separates Clara Bog from the (former) bog towards the Silver River. Because of this threshold the deepest part of the lake could have been some 3 m deep. In such a deep lake it is impossible for plant-roots to reach the soil. Floating peat mats may have grown in such a deep lake (pers. comm. S. van der Schaaf). These mats filled up the lake from the top to the bottom. When they reach a certain thickness growth of trees would have been possible on these mats. Near the edge, where the lake is not that deep, trees can grow almost immediately. For simplicity, all kinds of peat that have developed directly on the top of the lacustrine clay are called fenpeat. Bloetjes (1992) noted that this layer is a horizon with a rather complex nature: it consist of series of alternative supersessions of trees by reed and vice versa.*
Even if people do not know precisely what the situation was, it is likely that near the edges of the basin the peat mats first reached the lacustrine clay. So the groundwater from the esker was blocked to flow freely in the lake, and the lake-water was trapped in the middle of the basin. The rest of the basin was also gradually filled with fenpeat which shows that the lake still mainly consisted of mineral groundwater. But when the lake was going to be filled by fenpeat, the excess water had to seek a outlet. The idea is that there where weak points where the water, from below the peat mats, could flow to the surface and finds its way to a runoff channel (like 'chimneys'). Presumable a preferential flow was present. In the middle of Raheenmore Bog a much lower volume density than anywhere else on the bog is found (pers. comm. S. van der Schaaf). It is likely that on Clara Bog also such conditions occur. The hydraulic conductivity will be higher at these sites and it is easy for the trapped water to find its way out.
The development of these 'chimneys' (initial stage of soak system) occurred at the begin of the Sphagnum peat

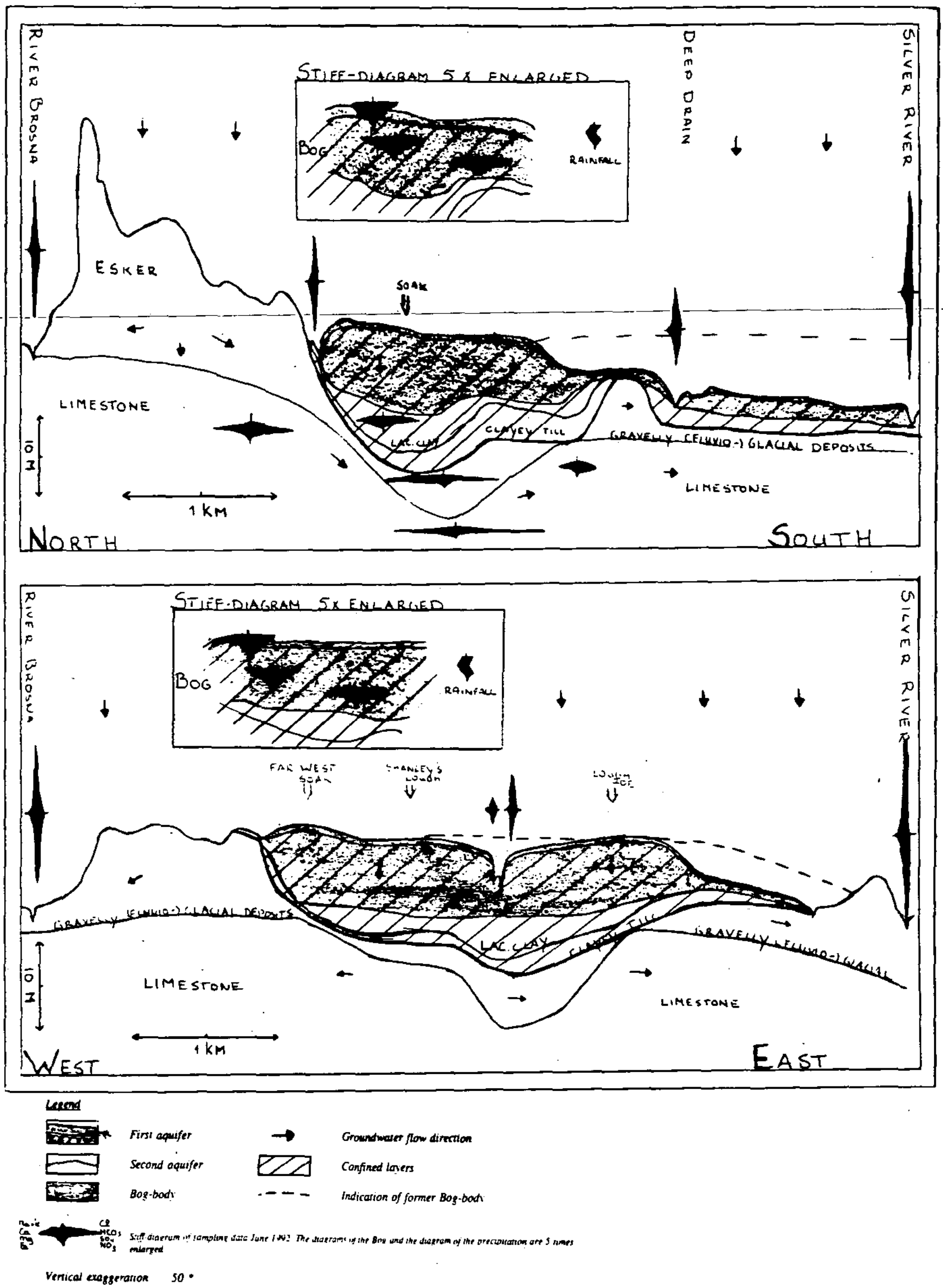


Figure 7.1. Hydrogeological overview

development. Peat growth started in North-western Europe about 7000 years BC. The ombrotrophic peat (Sphagnum peat) started some 5000 years BC to grow and, optimal growth occurred from 3000 years BC on (Streefkerk & Casparie, 1991). But, today still minerotrophic influences are present in the bog-body. L. Kelly found minerotrophic vegetation at Lough Roe, the Far west soak and Shanley's Lough (map 1). Lough Roe has the most minerotrophic features and Shanley's Lough least. Hydrochemically the minerotrophic influences are found in the deeper peat-layers, but at some small sites also near the surface (especially site 119, Lough Roe). Therefore it seems that the influence is still there or certainly till the last years (see paragraph 3.2.3.). The drains on Clara East, dug by Bord na Mona have been blocked again. This was effective in terms of a decrease of drainage, but Lough Roe now consists of stagnant water which is filling in.
As the peat is growing, compaction will occur due to the own increasing peat-weight. As a result of the compaction the (effective) porosity decreases and the water in those pores has to go somewhere. Compaction is likely to be highest in the lower peat layers, i.e. the fenpeat is containing minerotrophic water. Considering the facts, that the lacustrine clay is less permeable than the peat, the minerotrophic water will seek its upwards way in the peat. Then, the 'weak' sites will might act again as chimneys for this water. With time the compaction reaches a maximal value and the porosity a minimal. From then on, the influence of upwards flowing minerotrophic water will decrease.

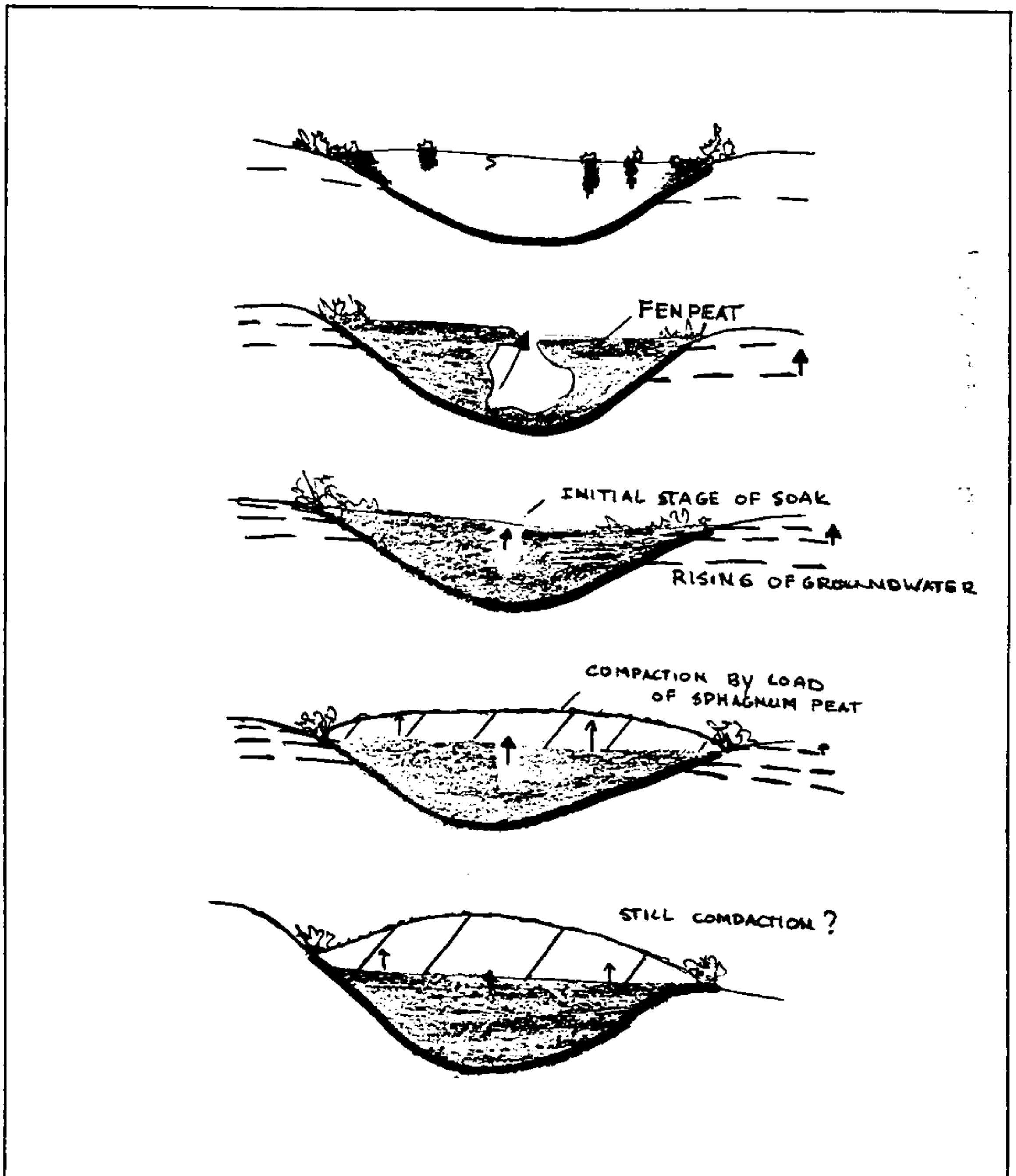


Figure 7.2. Hypothesis about a soak-system

So, there might have been two mechanisms which have contributed to the development of a soak system:

1) *The escape of minerotrophic lake water from below a closing peat mat. This process took place by the end of the fenpeat growth stage.*
2) *The removal of minerotrophic water from the pores of the lower fenpeat layers, because of compaction as a result of the overlying load of Sphagnum peat. The resulting upward flow of minerotrophic water occurred, or is still occurring, in the Sphagnum peat growth stage.*

Mechanism 1 stopped about 5000-3000 years BC, whereas mechanism 2 will stop as the peat, which contains minerotrophic water, cannot be compacted anymore or because of a non-increasing load, i.e. stop of peat growth.

The mineral soils make almost everywhere contact with the fenpeat which underlie the Sphagnum peat. Although the conductivity of the (fen-)peat is rather low, there might be some ***horizontal flow from the mineral groundwater*** *to the fenpeat. This mineral water in the fenpeat had in the beginning maybe a greater hydraulic head than the peatwater in the top layers and can flow vertically into the Sphagnum peat. This will predominantly happen at the sites where the peat has a weak structure (soaks). It is not very likely that this water had its influences on the rest of the bog.*

Although the tubes on Clara West does not show the hydrochemical picture of 119, at most sites $CaHCO_3$ water can be found in the subsoil. These tubes are similar to site 113 on Clara Bog east. So, the same system might occur at Shanley's Lough and the far west soak. A remarkable fact on ***Shanley's Lough*** *is it's relative low surface-level. So, here the* ***surface runoff*** *of most of Clara Bog west is collected. Maybe this surface runoff does not enrich the bog, as people think, but to the contrary, it dilutes the minerotrophic water coming from the subsoil.*

A reason for the greatest influence of mineral groundwater in the all but one deepest tube in the peat, could be the ***climatological history****. Another reason maybe that the compaction of the fenpeat already reached it's maximum some 2000 years BP. Afterwards the lower Sphagnum peat layers are compacted and water from this peat is also seeking its way out. This water will be far less minerotrophic.*

By ***C14-measurements*** *the age of peat and or water can be estimated. Maybe in peat soils this is hard as peat consist mainly out carbon. Tritium radioisotope dating is also possible to confirm or disprove the presence of fossil water (pers. comm. R. Flynn). To know if the minerotrophic water in the bog is old water one need samples of this water, but also of ordinary bogwater (at the same depths) and of the mineral groundwater.*

Nowadays there is downward seepage, but this will be very small. ***Calculations*** *are necessary to give an idea of the time all the water in the bog-body will have been replaced and how much minerotrophic water had been stored in the fenpeat.*

8 CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusions

The most important conclusions of the several subjects are mentioned below.

Geology
There is a kind of till-threshold with no lacustrine clay, between the Clara Bog region and the bog near the Silver River. In the past these two bog were connected. Nowadays, because of turf-cutting this connection is lost and drainage from the Clara Bog region is enlarged.
Hydrology
The water from the Clara Bog region and the water in the second aquifer is mainly flowing towards the Silver River. The drains along the Bogroad have an important drainage-effect on the bog.
The drains south-west of Clara Bog seem to drain the second aquifer.
The Island (till mound) is a small recharge area for the second aquifer. Also the esker and even the bog (very small, 40 mm/year) are recharge areas for the second aquifer.
Everywhere at Clara Bog downward seepage occurs, except near the Bogroad. Although the head-differences are big, the downward seepage is small because of the low permeabilities of the catotelm, the lacustrine clay and the clayey till underneath the acrotelm.
Hydrochemistry
The base flow of the drains along the east-side of the Bogroad, the Deep drain, the Silver River and the River Brosna consist mainly of mineral groundwater.
In the soak-areas of Clara Bog bogwater can be found in the upper 2-3 m. Below 2-3 m the influence of mineral groundwater is obvious. In the middle of Lough Roe (site 119) the mineral influences are very clear from 1.5 m-G.L. on.
Synthese
According to the hydrological information everywhere at the bog (except near the Bogroad) downward seepage occurs. Therefore, the mineral groundwater in the lower peatlayers in the soak-areas have to be fossil water. The hypothesis is that after a particular bog development, entrapped water had to escape in an upward direction from the fenpeat. These sites stayed weaker points in the peat-body, so they could act later as outlets of mesotrophic water out of the fenpeat. Later, by compaction of the fenpeat by the overlying load of Sphagnum peat, the outlets were used again to get loose of the compaction-water. The downward seepage was then or is still being, counteracted by this mechanism. More information and calculation are needed to prove these hypotheses.

8.2 Recommendations

In general a good data management is recommended. This will improve the integration of the several disciplines, which is necessary to solve questions about the soaks and the laggs. Also the regional hydrogeological aspect of Clara Bog is important for the understanding of features on Clara Bog. This aspect has to been taken more into account.
Some recommendations can be made about the several subjects of this report:

Geology
- *From the geologically point of view, more information should be gathered to know if the gravelly material is a till or a fluvioglacial deposit.*
- *In geological terms it is interesting to know if the lacustrine clay is a marl.*

Hydrology
- *Pumping tests are necessary to have more precise information on the permeabilities of the different geological layers.*
- *In 1992, the regional hydrogeological monitoring network has been enlarged (new boreholes and cobra-drillings). Measurements should be done regularly on all these sites during several years.*
- *If a water balance is needed for whole Clara Bog (east and west) quantative data on the drainage is necessary. Thus, not only the discharge of the Deep drain has to be measured, but also in the others larger drains at the east and north-west side of the bog.*
- *There were a lot of problems with the level data. Good level data, however, are indispensable for a study like the bog-project.*

Temperature

- *An apparatus to measure water temperature at great depths (about 30 m) is necessary to acquire more information about (regional) temperature profiles.*
- *A specific temperature-study seems to be of no use for answering the questions of the functioning of the soak-system. However, several measurements during the year (at time of great temperature changes) could bring relevant additional information.*

Hydrochemistry

- *Hydrochemical bogwater-samples outside the soak-areas are needed to known which differences prevail between the soaks and the 'ordinary' bog.*
- *To prevent ionic_balance errors > 5 % or 2%, the samples have to been analysised direct after sampling. Improvement of the analyzing and sampling methods is also recommended.*
- *L. Kelly has sampled the phreatic bogwater during the year. Correlation of these data with the hydrochemical data from this report could bring in some more information.*

Synthese

- *The hypothesis about the soak-systems has a very preliminary nature. To support this hypothesis, calculations have to be made about the amount of fossil water, the amount of downward seepage and the time it takes before all the fossil water will be replaced.*
- *C14-measurements should be carried out to know the age of the water at several sites (common bog, soaks, laggs and mineral soil) and depths in the bog.*
  Connolly (1992) gives already some advices on possibly relevant locations near Lough Roe.
- *Climatic variation during the last 10.000 years could be a reason for the higher ionic concentrations at 4-5 m depth than at 7-10 m-G.L. So more information about that should be gathered.*

Most of the above mentioned recommendations will not be of prime importance for the aims of the Irish-Dutch project.

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APPENDIX I

BASIC INFORMATION CONCERNING BOREHOLES, COBRA-DRILLINGS, WELLS AND GAUGES

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B	*PRINT OUT OF LOTUS FILES;*	*6*
C	*LITHOLOGY OF BOREHOLES AND COBRA-DRILLINGS.*	*15*

APPENDIX I.A SHORT DESCRIPTION

Boreholes at Clara Bog

There are 9 boreholes in the Clara Bog area. They are numbered CLBH 2-10. CLBH stands for CLara BoreHole. The boreholes 2 and 3 were drilled in 1990, the boreholes 4,5,6, and 7 in 1991 and 8, 9 and 10 in the Summer of 1992. In appendix I.C. the lithologies and the place of the filters are shown. Number one is the deepest and 2 or 3 the shallowest piezometer. An exception is CLBH5, where the piezometers are called A and B and CLBH5.B is the deepest piezometer. (see figure I.1.)

CLBH2 is located on the northern margin of the bog, 200 m east of the bog road.
CLBH3 is situated on the esker ridge 180 m north of CLBH2 and at a surface elevation of almost 6 m above that of CLBH2.
CLBH4 is located at the base of the esker on the north west margin of Clara Bog.
CLBH5 is placed in an area of cutaway peat to the south of Clara Bog west.
CLBH6 is situated in the centre of the bog, near the bog road and the carpark. CLBH7 is located on farmland approximately 700 m south of Clara Bog, and 300 m east of the road.
CLBH8 is placed on the south-eastern margin of the bog, some 12.5 m north of the road and some 175 m east of the track.
CLBH9 is situated at a track and old facebank, south-west of Clara Bog.
CLBH10 is located at the forest road, south-east of Clara Bog and 48 m east of the bog road.
CLBH2-7 have been levelled in 1991 and CLBH8-10 in the Summer of 1992. The levels of the borehole-casings of CLBH2 and 3 from 1991 differs 0.466 m with the levelling data of Summer 1992. As it is quit sure that the data of the last Summer are alright those are used.

Measuring of the waterlevels
CLBH2 monthly, 19/09/90 up to and including 22/12/91
CLBH3 monthly, 02/08/90 up to and including 14/11/91
CLBH4,6 and 7 monthly, 21/10/91 up to and inclusive 22/12/91
CLBH2-7 every fortnight since 17/04/92
CLBH5 every fortnight since 5/9/91
CLBH8, 9 and 10 measured monthly since the Summer of 1992.

Cobra-drillings

There are three cobra-drillings on the bog. The first two have been drilled at 13-03-1992 and the thirth one on 16-4-1992. They are marked as CLCD1,2 and 3 (CLara Cobra-Drilling) and are measured every fortnight since 17 April 1992.There were only estimations available for the tubelength, midfilter_depth and geological profile at the sites CLCD1 and 2. After 18/05/1992 CLCD1 has a casing and waterlevels are from than on measured with a ruler from the casing-bracket.

Domestic Wells

There are several domestic wells in the Clara Bog area. There is not much known about there age, depth and geological profile. According to R. Henderson none of the wells is abstracted anymore (although I saw a farmer pumping at well_05). Most of the wells are in esker-deposits, with eskers-associated material or gravelly till. Well_00 reaches the limestone.

Measuring of the waterlevels

Monthly, 21/10/91 up to and including 22/01/92:	*Wells 1 2 3 5 6 7 8 9 12 14 15 16 18 19 20 21 22.*
Monthly, since 15 May 1992:	*Wells 0 2 3 5 7 9 12 15 16 19 20 21 22 23.*

Piezometers at Clara Bog

Several piezometers have been placed on Clara Bog. The ones that are used in this report are mapped. The piezometers on Clara West have been placed by students of the Wageningen Agricultural University and the piezometers on Clara East are placed by Richard Henderson (Regional Technical College Sligo) and Iain Blackwell. Judy Bell installed some piezometers near the Bog Road. Piezometers are simply devices for measuring the hydraulic head at a point in the ground. The piezometer are PVC-tubes with a outer diameter of 1 inch (=2.54 cm). They have holes of 5mm diameter over 1 m for phreatic tubes and over a length of 10-15 cm for the rest of the tubes. The holes are covered with a fine mesh geotextile stocking to prevent blockage and a rubber cap is been placed at the bottom. (See figure I.2.) The midfilter-depth has been used as the depth *of a piezometer. Most of the piezometers are monitored every fortnight. The head in each tube can be calculated relative to Ordnance Datum (metres OD) by subtracting the distance to water from the top of the tube from the levelled value of the top of the tube.*

Piezometers on Clara West

The piezometers-sites on west are numbered from 46 to 99 and from 901 to 905. In most cases there is a set of piezometers at one site. The letter after the number is a mark for the depth of the filter. Looking to the North the most left one is a phreatic tube (letter A) and the one on the right is the deepest tube.

The filterlength of the phreatic tube (.A) is 1.0 m and for the other tubes 0.15 m. As the level of the tube changes in time the midfilter-depth will also change.

These tubes are measured every fortnight from the summer of 1990.

Piezometers on Clara East

The numbering of these tubes is such that when on the bog, facing north, the tube-number decreases from left to right. Thus, in general, the deepest tube has the lowest number (1), and is positioned on the right, while the phreatic tube has the highest number, and is positioned on the left. There are exceptions to this. R Henderson levelled the deepest piezometers (.1) per site in 1991. I. Blackwell and H. Samuels did the same in 1992. All the tubes at one site had the same level in 1991, where in 1992 the tubes at one site had a different level. The levels of CLBH2 and CLBH3 according to R. Henderson (1991) differs 0.466 m with the levels measured by I. Blackwell and H.Samuels (1992). For the boreholes the levels of 1992 are used. Probably those boreholes have been used as benchmarks for the levelling of the bog-piezometers. Then the levels of the piezometers of 1991 will change but this has not been done!

Both R. Henderson and I. Blackwell have data for the tubelengths. For some tubes the lengths differs. In general the tubelengths according to R. Henderson are used. The data of I. Blackwell are used in the following cases (per set of tubes):

- *The tubelength given by I. Blackwell is > 0.1 m deeper than the tubelength according to R. Henderson;*
- *The tubelengths differ more than 0.7 m.*

The filterlength of the piezometers is 0.20 m.

In most cases the midfilter-depth (m - G.L.) in 1991 and 1992 is the same.

Most of those tubes are measures every fortnight from the summer 1990 up to and including 22-12-1991. In the summer of 1992 some of the tubes are again measured every two weeks (see appedix I.B.).

Piezometers near the road

These tubes are called NW1-5, NE1-4, SW1-5 and SE1-4. At every spot 4 tubes are present of which one phreatic. For those tubes the information of J. Bell and H.Samuels has been used. They measured the tubes in the summer of 1991 and 1992.

Weirs and Gauges

There are several weirs (V-Notches) at or near Clara Bog:

- *921, west of Bog road, Clara Bog south*
- *922, east of Bog road, Clara Bog south*
- *923, east of Bog road, Clara Bog north*
- *Tomson and Rossum with recorders, Clara Bog south west.*

The gauges near Clara Bog are:

- *River Brosna at Charlestown Bridge (1024 according to R.Henderson);*
  The absolute level of this gauge is doubtful!
- *Silver River at New Bridge, (1025 according to R. Henderson);*
- *Deep drain, (1026 according to R.Henderson).*

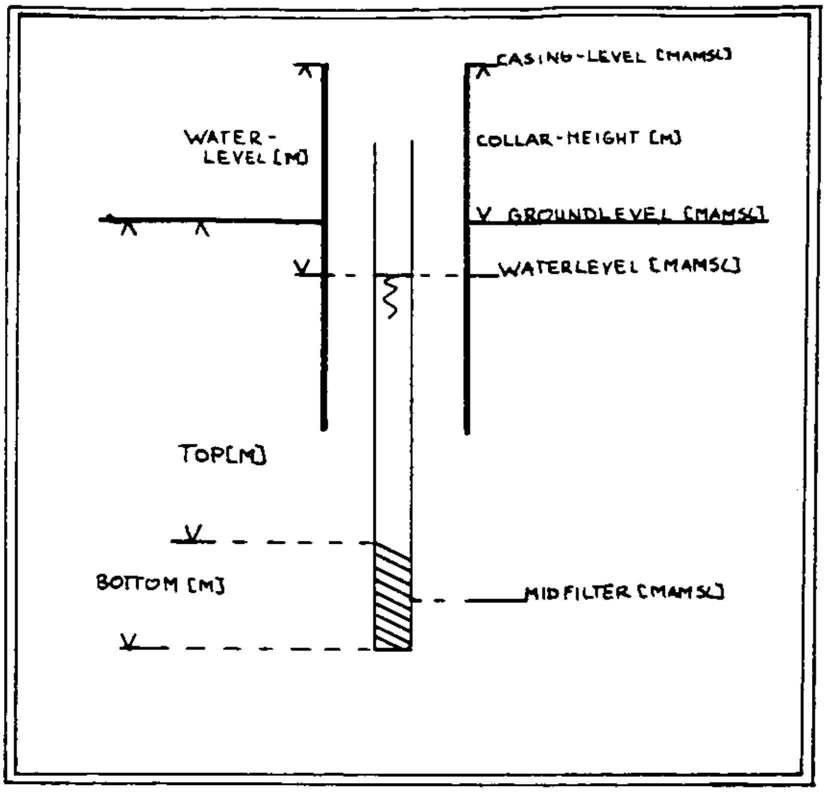


Figure I.1. Draft of boreholes

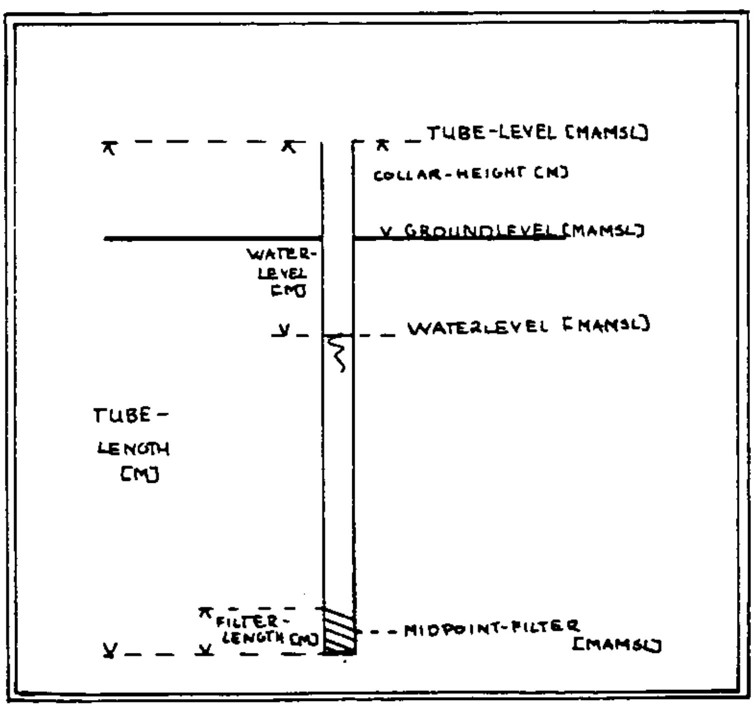


Figure I.2. Draft of Bog piezometers

APPENDIX I.B PRINT OUT LOTUS FILES

BASIC INFORMATION CLARA BOREHOLES, COBRADRILLINGS and WELLS

BOREHOLES
PIEZOM_NR CLBH2.1 - CLara BoreHole 2, Piezom. nr. 1
MATERIAL: PVC
OPENINGS: Perforated or slotted by drilling with exception CLBH3: Screen
Levels CLBH4-7 from summer 1991
CLBH2 and 3 levelled on 29-06-92 by Vincent and Manon:
Change of 0.466 m also calculated for filterlevels.
Levels CLBH8,9 and 10 from summer 1992

EXAMPLE :

X_COORD	national x-coordinate	PIEZO_NR	
Y_COORD	national y-coordinate	FILTER	filterlength, m
DATE_INST	installation date	TOP	top of filter, m - G.L.
GRNDLVL	groundlevel, mod	BOTTOM	bottom of filter, m - G.L.
COLLAR_HI	collar_heigth, m	MID_FLTR	midpoint of filter, mod
CAS_LVL	casing_level, mod	PIEZ0_ID	inner diameter, m
CAS_ID	casing inner diameter, m	LAYER	

BOREHOLE	2				
X_COORD	225360	PIEZO_NR	CLBH2.1	CLBH2.2	CLBH2.3
Y_COORD	230760	FILTER	4.0	1.0	0.2
DATE_INST	1990	TOP	9.0	4.8	2.0
GRNDLVL	57.73	BOTTOM	13.0	5.8	2.2
COLLAR_HI	0.63	MID_FLTR	46.73	52.48	55.63
CAS_LVL	58.36	PIEZ0_ID	0.055	0.055	0.022
CAS_ID	0.20	LAYER	Limestone	Till	Till

BOREHOLE	3		
X_COORD	225410	PIEZO_NR	CLBH3.1
Y_COORD	230930	FILTER	2.0
DATE_INST	1990	TOP	11.2
GRNDLVL	63.83	BOTTOM	13.2
COLLAR_HI	0.47	MID_FLTR	51.62
CAS_LVL	64.30	PIEZ0_ID	0.146
CAS_ID	0.15	LAYER	
COMMENT	Well screen		

BOREHOLE	4				
X_COORD	223535	PIEZO_NR	CLBH4.1	CLBH4.2	CLBH4.3
Y_COORD	230940	FILTER	2.9	1.0	0.2
DATE_INST	1991	TOP	9.6	4.2	2.5
GRNDLVL	58.82	BOTTOM	12.5	5.2	2.7
COLLAR_HI	0.70	MID_FLTR	47.77	54.12	56.22
CAS_LVL	59.52	PIEZ0_ID	0.055	0.055	0.022
CAS_ID	0.20	LAYER	Limestone	Till	Till

BOREHOLE	5			
X_COORD	223975	PIEZO_NR	CLBH5.A	CLBH5.B
Y_COORD	229606	FILTER	0.4	2.0
DATE_INST	1991	TOP	4.5	4.9
GRNDLVL	55.74	BOTTOM	4.9	6.9
COLLAR_HI	0.47	MID_FLTR	51.04	49.84
CAS_LVL	56.21	PIEZ0_ID	0.055	0.055
CAS_ID	0.09	LAYER	Limestone	Till

BOREHOLE	6				
X_COORD	224950	PIEZO_NR	CLBH6.1	CLBH6.2	CLBH6.3
Y_COORD	230320	FILTER	3.0	1.1	0.8
DATE_INST	1991	TOP	19.0	13.6	11.8
GRNDLVL	55.95	BOTTOM	22.0	14.8	12.6
COLLAR_HI	0.83	MID_FLTR	35.45	41.78	43.80
CAS_LVL	56.78	PIEZO_ID	0.055	0.022	0.055
CAS_ID	0.25	LAYER	Limestone	Till	Till

BOREHOLE	7			
X_COORD	224670	PIEZO_NR	CLBH7.1	CLBH7.2
Y_COORD	228370	FILTER	1.2	0.4
DATE_INST	1991	TOP	5.5	3.7
GRNDLVL	50.33	BOTTOM	6.7	4.1
COLLAR_HI	0.46	MID_FLTR	44.27	46.43
CAS_LVL	50.79	PIEZO_ID	0.055	0.055
CAS_ID	0.20	LAYER	Limestone	Till

BOREHOLE	8			
X_COORD	226110	PIEZO_NR	CLBH8.1	CLBH8.2
Y_COORD	229460	FILTER	3.0	1.0
DATE_INST	June 1992	TOP	8.6	6.0
GRNDLVL	55.52	BOTTOM	11.6	7.0
COLLAR_HI	0.20	MID_FLTR	45.42	49.02
CAS_LVL	55.72	PIEZO_ID	0.055	0.055
CAS_ID	0.20	LAYER	Limestone	Till

BOREHOLE	9			
X_COORD	223470	PIEZO_NR	CLBH9.1	CLBH9.2
Y_COORD	229480	FILTER	3.0	1.0
DATE_INST	July 1992	TOP	8.9	4.0
GRNDLVL	57.66	BOTTOM	11.9	5.0
COLLAR_HI	0.24	MID_FLTR	47.31	53.16
CAS_LVL	57.90	PIEZO_ID	0.055	0.055
CAS_ID	0.20	LAYER	Limestone	Till

BOREHOLE	10			
X_COORD	224700	PIEZO_NR	CLBH10.1	CLBH10.2
Y_COORD	229430	FILTER	1.0	1.0
DATE_INSTAug.	1992	TOP	9.0	5.8
GRNDLVL	51.68	BOTTOM	10.0	6.8
COLLAR_HI	0.35	MID_FLTR	42.18	45.38
CAS_LVL	52.03	PIEZO_ID	0.055	0.055
CAS_ID	0.20	LAYER	Limestone	Till

COBRADRILLINGS
PIEZOM_NR: *CLCD2_N/S - COBRA 2, N northern and S southern tube*
MATERIAL: *PVC*
ALL CLCD IN TILL.
Notes of CLCD1 and 2 are uncomplete, estimation filterlength 0.2 m. tubelength measured afterwards.
Filterlength CLCD3 0.19 m, with 0.12 m in the till and cap of 0.03 m.
Date for levelling: CLCD1 29-06-92 CLCD2 23-06-92 CLCD3 22-06-92
CLCD1: 18-05-92, Casing installed, tube_ is now casing_!
Tube_lvl CLCD1 before 18-05-92, collar_hi + groundlvl 29-06-92.
Tube_lvl CLCD1 after 18-05-92, heigth of casing-bracket.

	CLCD1		CLCD2_N	CLCD2_S	CLCD3
X_COORD	224850		224560	224560	224019
Y_COORD	230100		229240	229240	230132
DATE_INST	13-03-92	18-05-92	13-03-92	13-03-92	16-04-92
TUBE_LVL mod	55.62	54.23	51.81	51.72	58.89
GRND_LVL mod	54.1	54.12			
TUBE_LNGT m	12.2	10.9	5.2	4.0	9.7
TUBE_ID m	0.04	0.03	0.03	0.04	0.02
MID_FLTR mod	43.43	43.43	46.71	47.82	49.26
COMMENT		Casing!		Lac.clay	

WELLS
NUMBER: *WELL 01 - Domestic well nr. 1*
ALTITUDE: *Point from where waterlevel is measured*
Levels from september 1991 except well_00.
Well_00 levelled on 22-06-92 by Vincent and Manon: Level from lip of floor. Floorlevel is 66.979.

NUMBER	ALTITUDE	DEPTH m	DEPTH mod	
WELL_00	67.00	34.05	32.96	Boland, Clay-layer, 0.9 m.
WELL_01	60.12	3.80	56.32	
WELL_02	58.53	2.95	55.58	
WELL_03	57.71	3.73	53.98	
WELL_04	53.98			
WELL_05	60.42	4.40	56.02	
WELL_06	60.26	3.65	56.61	
WELL_07	60.51	5.10	55.41	
WELL_08	60.89	4.25	56.64	
WELL_09	60.04	3.50	56.54	
WELL_12	56.09	4.73	51.36	
WELL_13	62.75			
WELL_14		3.80		
WELL_15	54.07	16.10	37.97	
WELL_16	51.15	3.77	47.38	
WELL_17	61.26			Dry well
WELL_18	64.86	18.30	46.56	Flemings
WELL_19	70.27	12.90	57.37	Keen
WELL_20	54.03	4.25	49.78	
WELL_21	60.04	13.95	46.09	
WELL_22	55.41	6.00	49.41	
WELL_23	57.85	3.75	54.10	Mitchels well

BASIC INFORMATION PIEZOMETERS CLARA EAST

MATERIAL:	*PVC*
OUTER DIAMETER:	*0.025 m*
INNER DIAMETER:	*0.022 m*
FILTERLENGTH:	*0.20 m*
OPENINGS:	*6 mm, Perforated or slotted by drilling*

Levels June 1990 - December 1991 from Richard Henderson, Summer 1991
Levels April 1992 - July 1992 from Iain Blackwell, June 1992
Tubelength according to Richard's data: 101-103(in 1990 and 1991), 104-109,112,114,122-127.
Tubelength according to Iain's data: 101-103(in 1992),110,111,113,119,120,121,128,129,130,131 and 141-153.

	Richard Henderson,'91			Iain Blackwell,'92
	TUBE_LVL	COLLAR_HI	GRNDLVL	GRNDLVL
TUBE NO.	mod	m + G.L.	mod	mod
101	58.19	0.10	58.09	57.39
102	58.38	0.12	58.26	57.57
103	58.34	0.15	58.19	57.27
104	58.50	0.30	58.20	58.68
105	59.23	0.51	58.72	58.68
106	59.87	0.44	59.43	59.46
107	60.41	0.45	59.96	59.54
108	60.57	0.43	60.14	59.69
109	60.71	0.48	60.23	59.73
110	60.71	0.44	60.27	59.81
111	60.58	0.41	60.17	59.76
112	60.41	0.32	60.09	59.80
113	60.65	0.47	60.18	59.79
114	60.64	0.52	60.12	59.69
119	60.18	0.59	59.59	59.74
120	60.18	0.59	59.59	60.01
121	60.52	0.21	60.31	60.14
122	60.99	0.12	60.87	60.78
123	58.22	0.20	58.02	60.89
124	57.97	0.42	57.55	58.83
125	61.8	0.46	61.34	60.97
126	61.55	0.38	61.17	60.93
127	61.13	0.40	60.73	60.43
128	60.96	0.21	60.75	60.61
129	61.12	0.23	60.89	60.72
130	59.23	0.20	59.03	59.86
131	59.21	0.23	58.98	59.78
141				57.64
142				57.51
143				57.78
151				60.33
152				60.97
153				60.52
154				60.16

PIEZONR.	Tube-length m	Mid-filter '90/'91 mod	Tube-level 1992 mod	Mid-filter June '92 mod	Mid_fltr m - G.L.	Comment	Date_inst
101.1	3.3	55.0			3.1		
.2	2.3	56.0			2.1		
101.1	2.2		57.59	55.5	1.9		92.05
.2	1.7		57.53	55.9	1.5		92.05
.3	1.2		57.53	56.4	1.0		92.05
.4	1.5		57.75		phreatic		92.05
102.1	3.3	55.2			3.1		
.2	2.3	56.2			2.1		
102.1	2.8		57.77	55.1	2.5		92.05
.2	2.2		57.77	55.7	1.9		92.05
.3	1.5		57.77	56.4	1.2		92.05
.4	1.5		57.97		phreatic		92.05
103.1	3.4	55.1			3.1		
.2	2.4	56.1			2.1		
103.1	2.8		57.46	54.8	2.5		92.05
.2	2.2		57.46	55.4	1.9		92.05
.3	1.5		57.46	56.1	1.2		92.05
.4	1.5		57.73		phreatic		92.05
104.1	4.5	54.1	59.09	54.7	4.1		
.2	3.5	55.1	59.09	55.7	3.1		
.3	2.5	56.1	59.09	56.7	2.1		
.4	1.5	57.1	59.10		phreatic		
105.1	5.7	53.6	59.18	53.6	5.1		
.2	3.7	55.6	59.18	55.6	3.1		
.3	2.7	56.6	59.18	56.6	2.1		
.4	1.7	57.6	59.19		phreatic		
106.1	5.6	54.3	59.87	54.3	5.1		
.2	3.6	56.3	59.88	56.3	3.1		
.3	2.6	57.3	59.88	57.3	2.1		
.4	1.6	58.3	59.89		phreatic		
107.1	5.7	54.9	59.95	54.4	5.1		
.2	3.7	56.9	59.95	56.4	3.1		
.3	2.7	57.9	59.95	57.4	2.1		
.4	1.7	58.9	59.97		phreatic		
108.1	7.6	53.0	60.13	52.6	7.1		
.2	5.6	55.0	60.13	54.6	5.1		
.3	3.6	57.0	60.14	56.6	3.1		
.4	2.6	58.0	60.16	57.6	2.1		
.5	1.6	59.0	60.15		phreatic		
109.1	7.7	53.1	60.18	52.6	7.1		
.2	5.7	55.1	60.19	54.6	5.1		
.3	3.7	57.1	60.20	56.6	3.1		
.4	2.7	58.1	60.20	57.6	2.1		
.5	1.7	59.1	60.23		phreatic		
110.1	9.5	51.3	60.24	50.8	9.0		
.2	5.5	55.3	60.25	54.9	4.9 *		
.3	8.0	52.8	60.24	52.3	7.5 *		
.4	3.5	57.3	60.28	56.9	3.0		
.5	2.6	58.2	60.28	57.8	2.0		
.6	1.6	59.3	60.30		phreatic		
111.1	8.6	52.1	60.11	51.6	8.1		
.2	7.5	53.2	60.11	52.7	7.0		
.3	5.9	54.8	60.12	54.3	5.4		
.4	3.4	57.2	60.13	56.8	3.0		
.5	2.4	58.2	60.14	57.8	2.0		
.6	1.6	59.1	60.18		phreatic		

PIEZONR.	Tube-length	Mid-filter '90/'91	Tube-level 1992	Mid-filter June '92	Mid_fltr	Comment	Date_inst
	m	mod	mod	mod	m - G.L.		
112.1	9.5	51.0	60.09	50.7	9.1		
.2	7.5	53.0	60.10	52.7	7.1		
.3	5.5	55.0	60.11	54.7	5.1		
.4	3.5	57.0	60.11	56.7	3.1		
.5	2.5	58.0	60.11	57.7	2.1		
.6	1.5	59.0	60.12		phreatic		
113.1	9.5	51.2	60.19	50.8	9.0		
.2	7.6	53.2	60.20	52.7	7.1		
.3	6.0	54.8	60.19	54.3	5.5		
.4	3.5	57.3	60.25	56.9	2.9		
.5	2.5	58.3	60.25	57.9	1.9		
.6	1.5	59.3	60.23		phreatic		
114.1	9.7	51.0	60.09	50.5	9.2		
.2	7.7	53.0	60.09	52.5	7.2		
.3	5.7	55.0	60.09	54.5	5.2		
.4	1.7	59.0	60.09		phreatic		
119.1	9.5	50.7	60.19	50.7	9.0		
.2	7.5	52.8	60.19	52.8	6.8	@1	
.3*	2.0		60.15	58.2	1.5		92.06.01
.3	5.5	54.8	60.19	54.8	4.8 *	@2	
120.A	1.3	59.0	60.21		phreatic		
.B	2.8		60.21	57.5	59.6 *	@3	92.03.23
.D	4.8		60.21	55.6	59.6 *	@4	92.03.23
.E	9.0		60.21	51.3	59.6 *	@5	92.03.23
121.1	1.3	59.3	60.42		phreatic		
.2	3.4	57.3	60.39	57.1	3.0 *		
.3	5.4	55.2	60.37	55.0	5.1 *		
.4	7.4	53.3	60.37	53.1	7.1 *		
.5	8.6	52.1	60.33	51.9	8.3 *		
122.1	1.3	59.8	60.93		phreatic		
.2	3.3	57.8	60.91	57.7	3.1 *		
.3	5.3	55.8	60.89	55.7	5.1 *		
.4	7.3	53.8	60.88	53.7	7.1 *		
123.1	7.4	50.9	60.89	53.6	7.3		
.2	5.4	52.9	60.89	55.6	5.3		
.3	3.4	54.9	60.91	57.6	3.3		
.4	1.4	56.9	60.94		phreatic		
124.1	2.6	55.5	59.25	56.7	2.1		
.2	1.6	56.5	59.25		phreatic		
125.1	5.7	56.2	61.43	55.9	5.1		
.2	3.7	58.2	61.43	57.9	3.1		
.3	2.7	59.2	61.43	58.9	2.1		
.4	1.7	60.2	61.44		phreatic		
126.1	7.6	54.1	61.25	53.8	7.2		
.2	3.6	58.1	61.29	57.8	3.1 *		
.3	5.6	56.1	61.24	55.7	5.2 *		
.4	2.6	59.1	61.28	58.8	2.1		
.5	1.6	60.1	61.34		phreatic		
127.1	7.6	53.6	60.83	53.3	7.1		
.2	5.6	55.6	60.78	55.3	5.1		
.3	3.6	57.6	60.74	57.2	3.2		
.4	2.6	58.6	60.77	58.3	2.2		
.5	1.6	59.6	60.78		phreatic		
128.1	6.7	54.3	60.81	54.2	6.4		
.2	4.3	56.8	60.81	56.6	4.0		
.3	3.0	58.1	60.80	57.9	2.7		
.4	1.3	59.8	60.80		phreatic		

PIEZONR.	Tube-length m	Mid-filter '90/'91 mod	Tube-level 1992 mod	Mid-filter June '92 mod	Mid_fltr m - G.L.	Comment	Date_inst
129.1	1.2	60.0	60.97		phreatic		
.2	3.0	58.2	60.97	58.1	2.7		
.3	3.7	57.5	60.97	57.3	3.4 *		
.4	3.0	58.2	60.96	58.1	2.7 *		
130.1	1.2	58.1	60.07		phreatic		
.2	3.7	55.7	60.07	56.5	3.4 *		
131.1	1.2	58.1	60.03		phreatic		
.2	2.9	56.4	60.10	57.3	2.6 *		
.3	1.4	57.9	60.10	58.8	1.1 *		
141.1	2.3		57.79	55.6	2.0	92.05	
~~.2~~	~~1.8~~		~~57.79~~	~~56.1~~	~~1.5~~	~~92.05~~	
.3	1.2		57.79	56.7	1.0	92.05	
.4	1.5		58.11		phreatic	92.05	
142.1	2.8		57.67	55.0	2.5	92.05	
.2	2.2		57.67	55.6	1.9	92.05	
.3	1.5		57.67	56.3	1.2	92.05	
.4	1.5		57.97		phreatic	92.05	
143.1	4.3		57.98	53.8	4.0	92.05	
.2	3.2		57.99	54.9	2.9 *	92.05	
.3	2.2		57.99	55.9	1.9	92.05	
.4	1.5		58.23		phreatic	92.05	
151.1	9.0		60.60	51.7	8.6	92.05	
.2	7.0		60.60	53.7	6.6	92.05	
.3	5.0		60.60	55.7	4.6	92.05	
.4	3.0		60.60	57.7	2.6	92.05	
.5	1.5		60.78		phreatic	92.05	
152.1	9.0		60.97	52.1	8.9	92.05	
.2	7.0		60.97	54.1	6.9	92.05	
.3	5.0		60.97	56.1	4.9	92.05	
.4	3.0		60.97	58.1	2.9	92.05	
.5	1.5		61.11		phreatic	92.05	
153.1	9.0		60.84	51.9	8.6	92.05	
.2	7.0		60.84	53.9	6.6	92.05	
.3	5.0		60.84	55.9	4.6	92.05	
.4	3.0		60.84	57.9	2.6	92.05	
.5	1.5		60.92		phreatic	92.05	
154.1	9.0		60.45	51.6	8.6	92.05	
.2	7.0		60.45	53.6	6.6	92.05	
.3	5.0		60.45	55.6	4.6	92.05	
.4	3.0		60.45	57.6	2.6	92.05	
.5	1.5		60.59		phreatic	92.05	

** and @ See notes.*

NOTES:

- <u>*Exceptions to the rules:*</u>

110 Piezometers 3 and 2 are mixed up.
119 No phreatic tube.
120 Piezometer depth increases from right to left facing west. (The tubes are in a line running north to south).
121 Piezometer depth increases from right to left.
122 Piezometer depth increases from right to left.
126 Piezometers 3 and 2 are mixed up.
129 Piezometer depth increases from right to left.
Piezometers 4 and 3 are mixed up.
Piezometer 4 or 2 is redundant as depths are roughly the same. 2nd deepest tube was levelled, not the deepest one.
130 Piezometer depth increases from right to left.
131 Piezometer depth increases from right to left.
Piezometers 3 and 2 are mixed up.
143 2nd deepest tube was levelled, not the deepest one.

Mid_fltr (m - G.L.) : when data in 1990/1991 differs less than 0.1 m with the data in 1992 than the deepest one is taken.
If the difference is more than 0.1 m see @.

@1- Mid_filter 1992, 7.0 m - G.L.
@2- Mid_filter 1992, 5.0 m - G.L.
@3- Mid_filter 1992, 2.5 m - G.L.
@4- Mid_filter 1992, 4.5 m - G.L.
@5- Mid_filter 1992, 8.7 m - G.L.

BASIC INFORMATION PIEZOMETERS CLARA WEST (CHEMICAL SAMPLES, 1992)

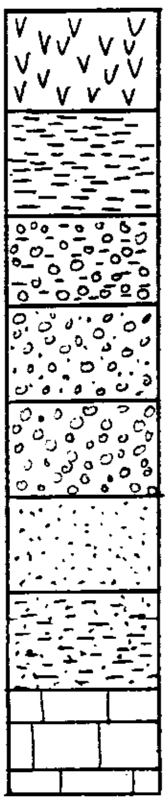
MATERIAL:	*PVC*
OUTER DIAMETER:	*0.025 m*
INNER DIAMETER:	*0.022 m*
FILTERLENGTH:	*A-tube: 1.0 m Rest of tubes: 0.15 m*
OPENINGS:	*6 mm, Perforated or slotted by drilling*

57:	*Surface_level according to B. Sytsma and A. Veldhuizen, 1992_*
92:	*Tube_level 92A,92B and 92D + 1m !!*
904 and 905:	*Tube_level is estimated!! This has effect on Midfilter-depth in mod and m-G.L..*

PIEZO_NR	Tube m	Tub_lvl mod	Surface mod	mid_fltr m-Tub_lvl	Mid_fltr mod	mid_fltr m-G.L
46A	1.3	58.3	57.9	0.7	57.6	0.3
46B	2.5	58.3	57.9	2.4	55.9	2.0
46D	4.5	58.3	57.9	4.4	53.9	4.0
46F	7.4	58.3	57.9	7.3	51.0	6.9
54A	1.3	58.0	57.9	0.7	57.3	0.6
54B	2.5		57.9	2.4	55.6	2.3
54D	4.5		57.9	4.4	53.6	4.3
54F	8.8	58.0	57.9	8.7	49.4	8.5
57A	1.3	58.7	58.5	0.7	57.9	0.6
57B	1.8		58.5	1.6	57.0	1.5
57C	3.2	58.7	58.5	3.1	55.6	2.9
57D	4.7	58.7	58.5	4.6	54.1	4.4
57E	6.0	58.7	58.5	5.9	52.8	5.7
90A	3.0	58.6	58.3	0.8	57.8	0.5
90B	2.5	58.6	58.3	2.4	56.2	2.1
90D	4.8	58.6	58.3	4.7	53.9	4.4
90F	12.2	58.6	58.3	12.1	46.5	11.8
92A	3.0	58.9	58.8	0.8	58.2	0.6
92B	2.5	58.9	58.8	2.4	56.5	2.3
92D	4.8	59.0	58.8	4.7	54.4	4.4
92F	5.4	59.0	58.8	5.3	53.7	5.1
96A	3.0	61.0	60.5	0.8	60.2	0.3
96B	2.8	61.0	60.5	2.6	58.4	2.1
96D	4.8	61.0	60.5	4.7	56.4	4.1
96F	11.8	61.0	60.5	11.7	49.4	11.1
901A	3.0	59.5	59.3	0.8	58.7	0.6
901B	2.8	59.4	59.3	2.6	56.8	2.5
901D	4.8	59.4	59.3	4.6	54.8	4.5
901E	9.7	59.5	59.3	9.6	49.9	9.4
902A	3.0	59.2	59.0	0.8	58.5	0.5
902B	2.8	59.3	59.0	2.6	56.6	2.4
902D	4.8	59.2	59.0	4.6	54.6	4.4
902E	9.0	59.3	59.0	8.9	50.4	8.6
903B	2.8	61.9	60.5	2.6	59.3	1.2
903C	3.3	61.9	60.5	3.2	58.7	1.8
904A	3.0	61	60.6	0.8	60.3	0.3
904B	2.8	61	60.6	2.6	58.4	2.2
904D	4.8	61	60.6	2.6	58.4	2.2
904E	8.3	61	60.6	8.1	52.9	7.7
905A	1.3	61	60.7	0.7	60.3	0.4
905B	2.8	61	60.7	2.6	58.4	2.3
905D	4.8	61	60.7	4.6	56.4	4.3
905E	9.0	61	60.7	8.9	52.1	8.6

APPENDIX I.C LITHOLOGY OF BOREHOLES AND COBRA-DRILLINGS

LEGEND GEOLOGY



Peat

Lacustrine clay

Gravelly clay (Clayey till)

Gravelly sand (Esker deposits or Gravelly-sandy layer)

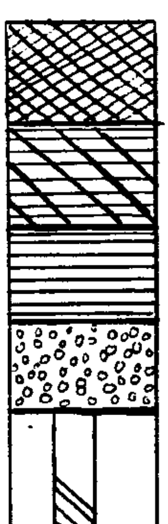
Gravel (Esker deposits or Gravelly-sandy layer)

Sand (Esker deposits or Gravelly-sandy layer)

Silty sand

Limestone

LEGEND BOREHOLES



Concrete

Bentonite and concrete

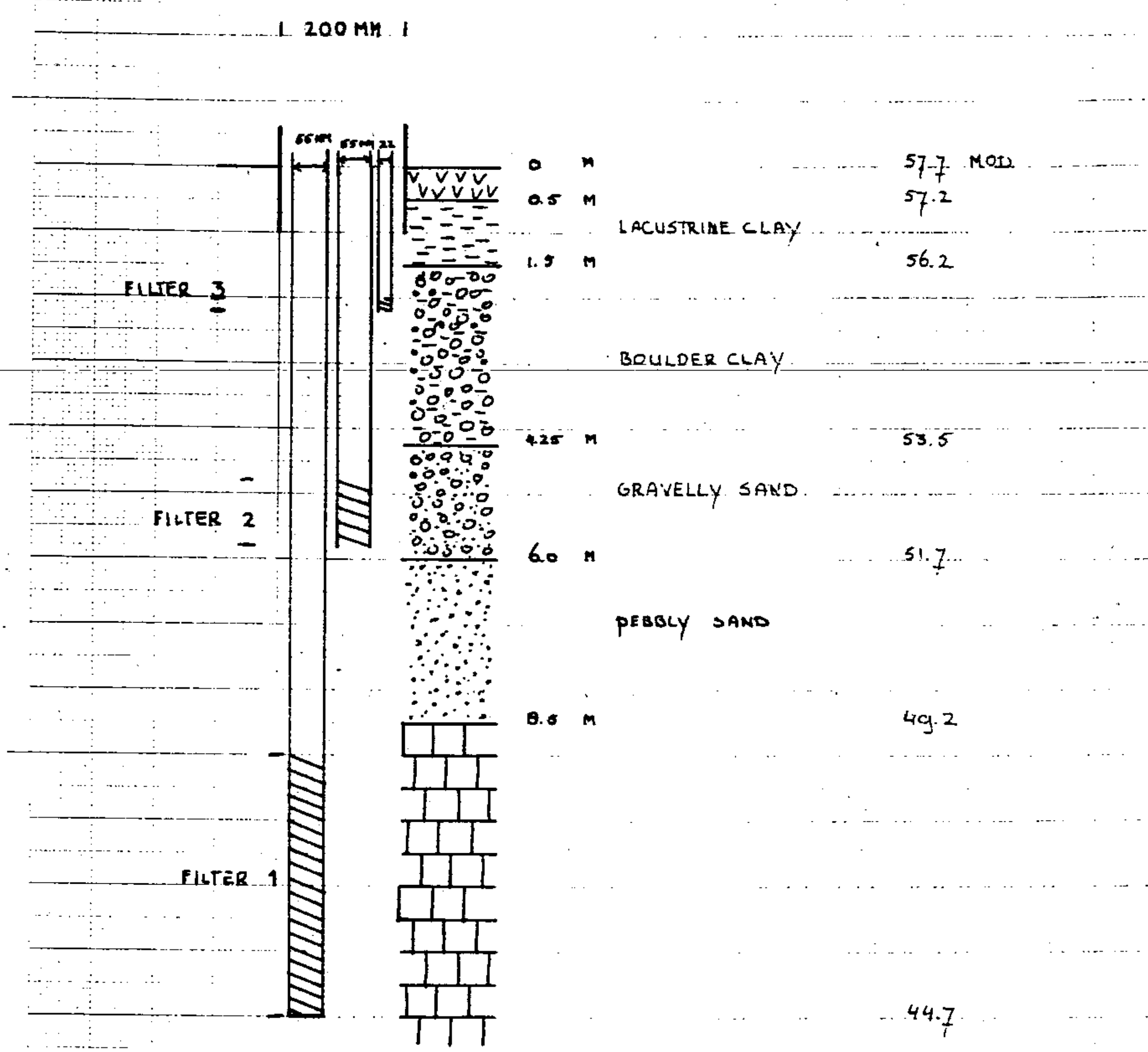
Bentonite

Gravelpack

Piezometerfilter

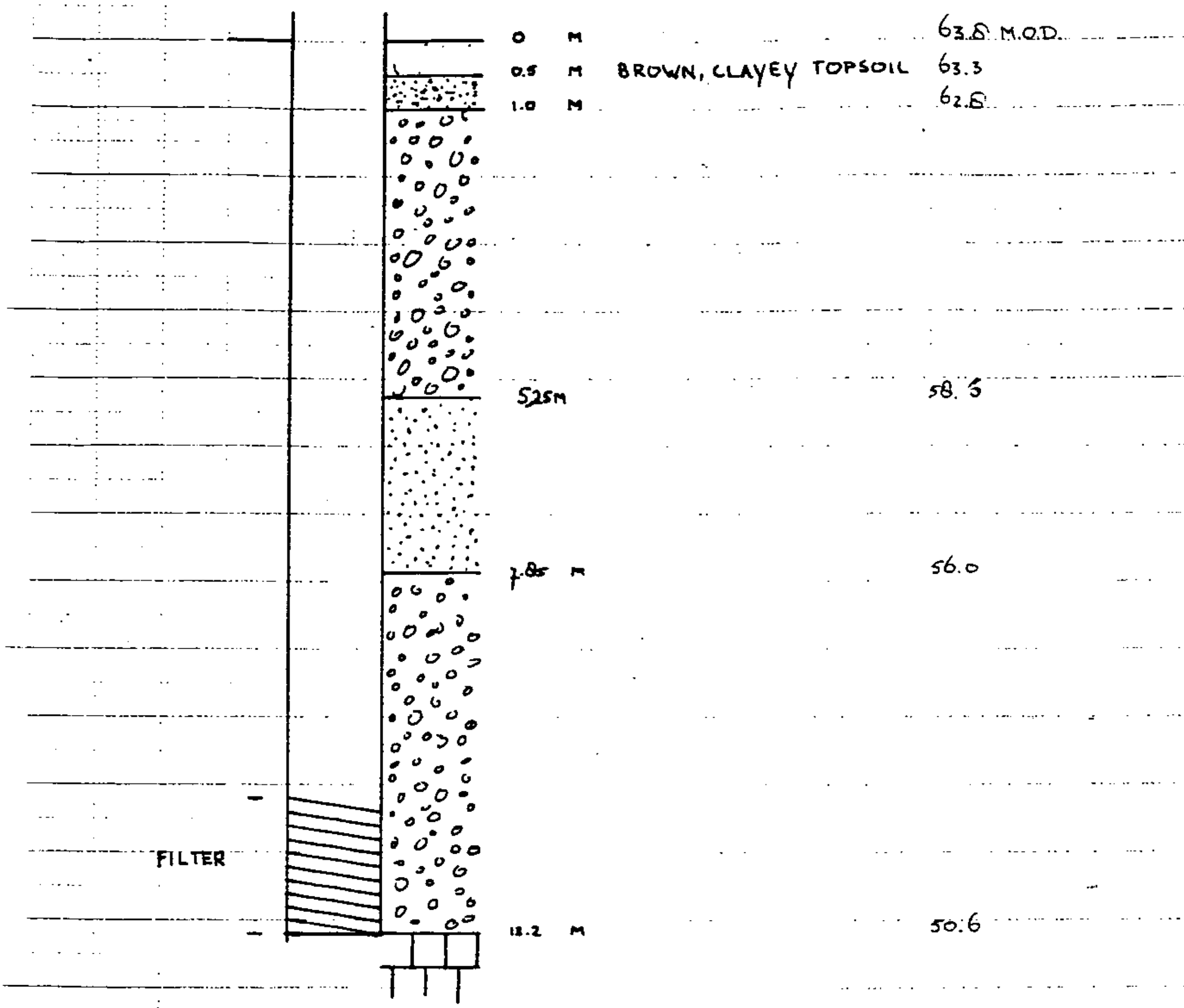
Vertical scale: *1:100*

CLBH 2

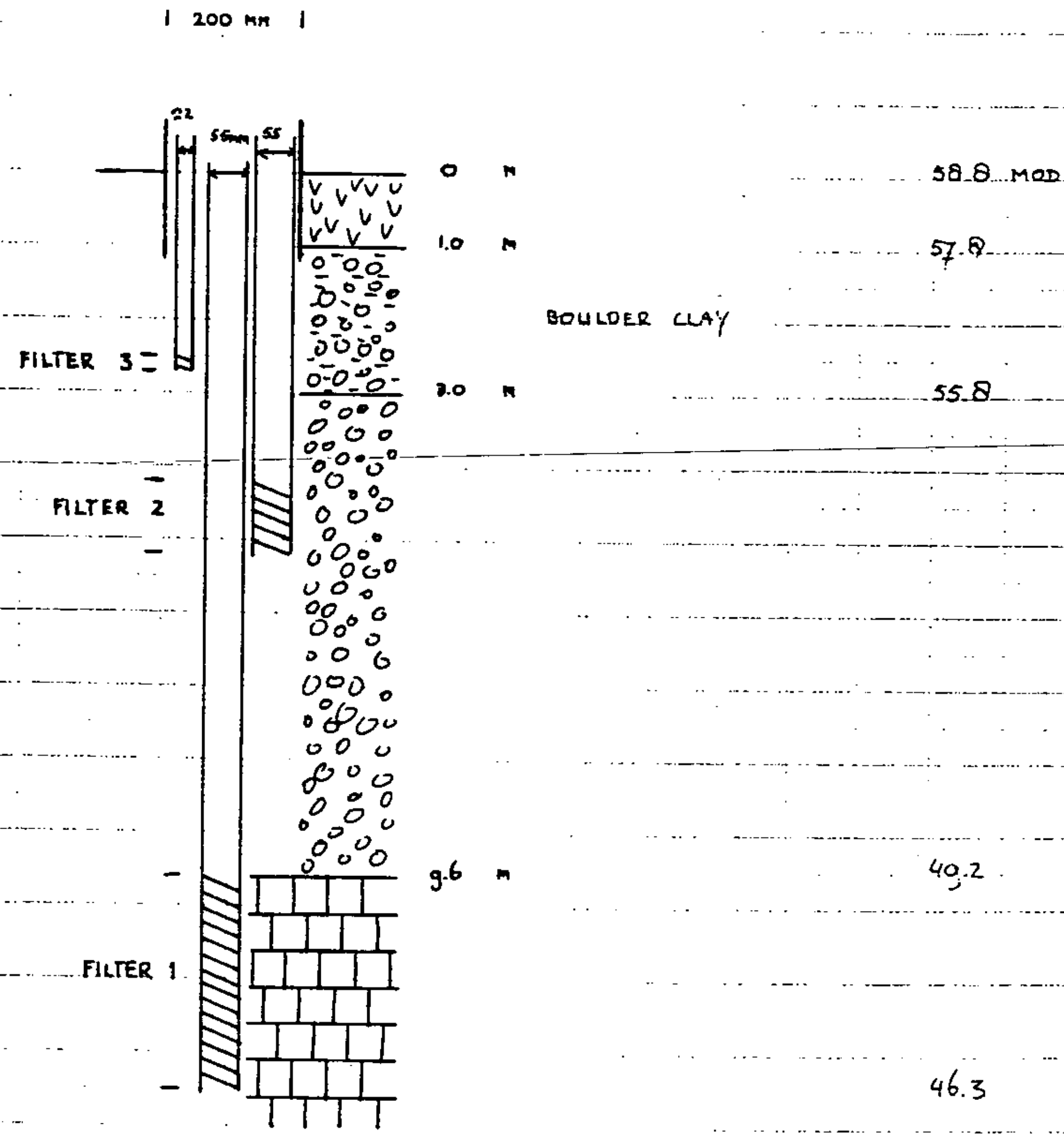


200 MM
55MM
55MM
22
FILTER 3
FILTER 2
FILTER 1
0 M
0.5 M
1.5 M
4.25 M
6.0 M
8.6 M
LACUSTRINE CLAY
BOULDER CLAY
GRAVELLY SAND
PEBBLY SAND
57.7 MOD
57.2
56.2
53.5
51.7
49.2
44.7

CLBH 3

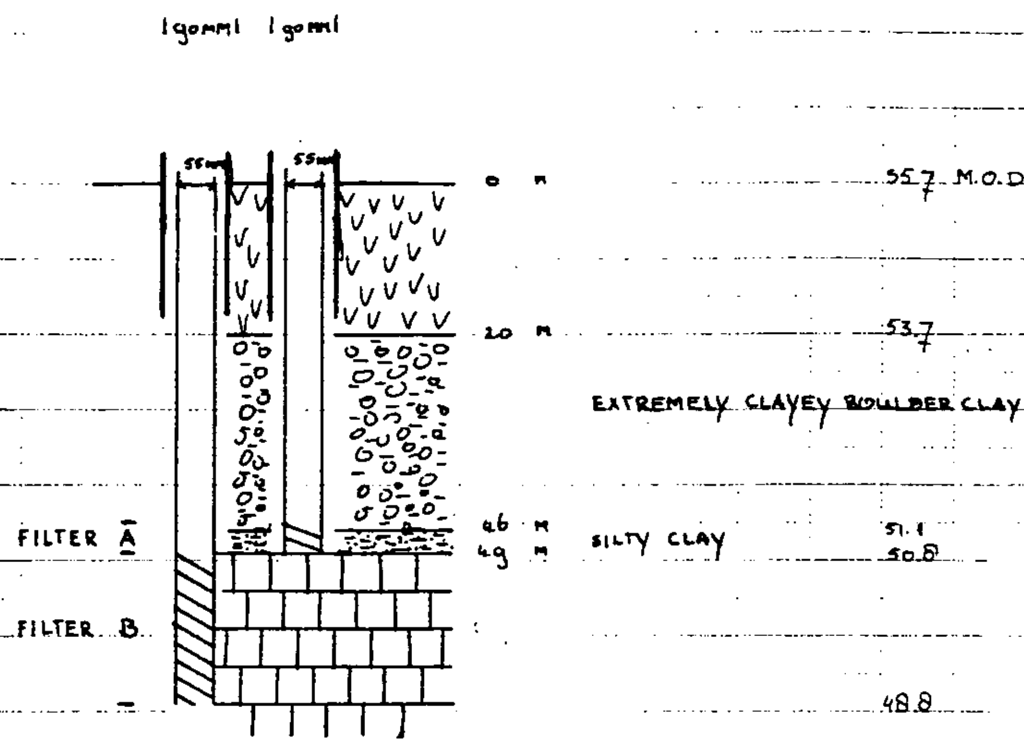

1.15 mm I
0 M
0.5 M
1.0 M
BROWN, CLAYEY TOPSOIL
63.8 M.O.D.
63.3
62.8
5.25 M
58.5
7.85 M
56.0
FILTER
13.2 M
50.6

CLBH 4

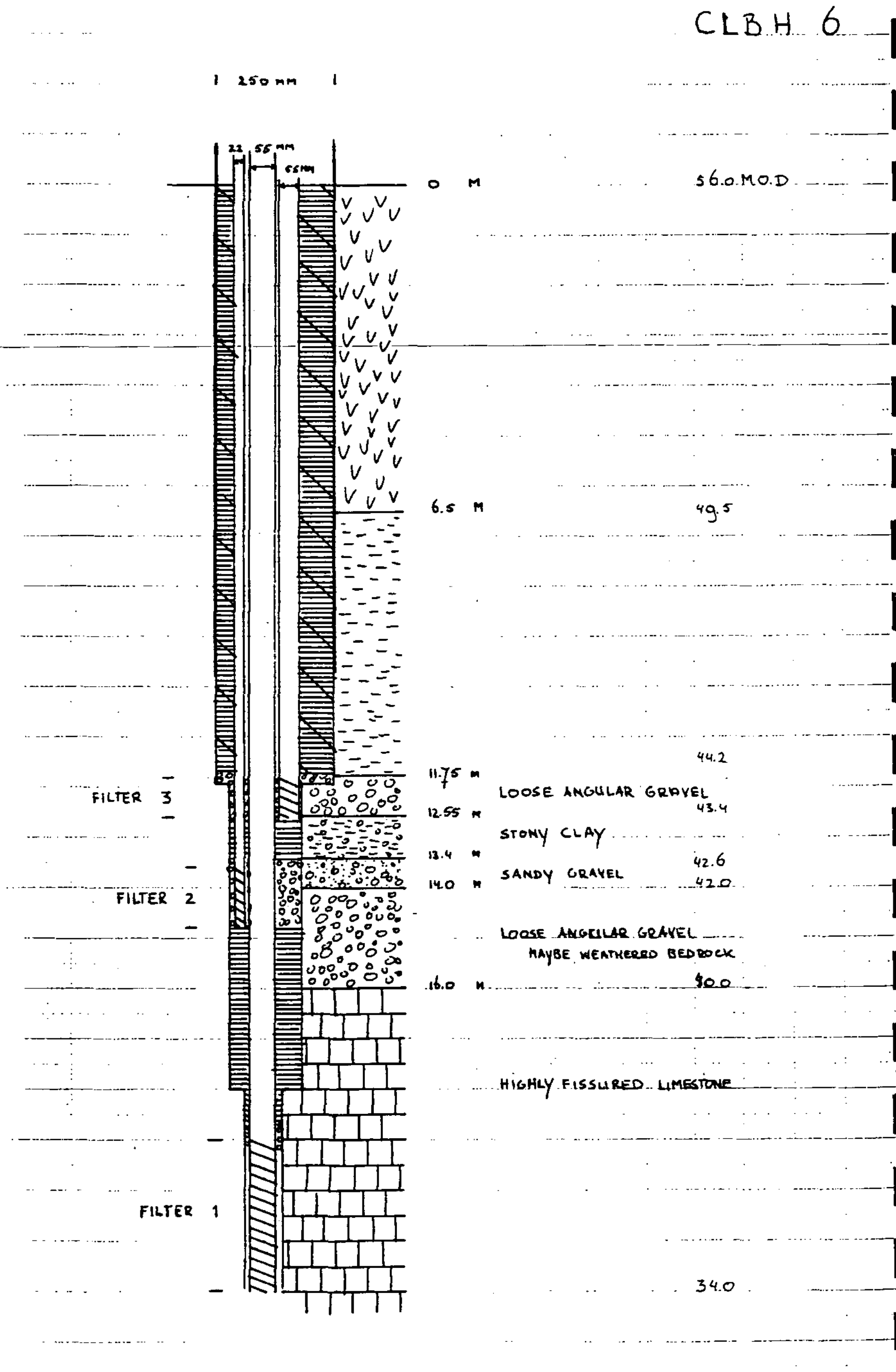


200 MM
22
56mm
55
0 M
1.0 M
BOULDER CLAY
3.0 M
9.6 M
FILTER 3
FILTER 2
FILTER 1
58.8 MOD
57.8
55.8
40.2
46.3

CLBH 5

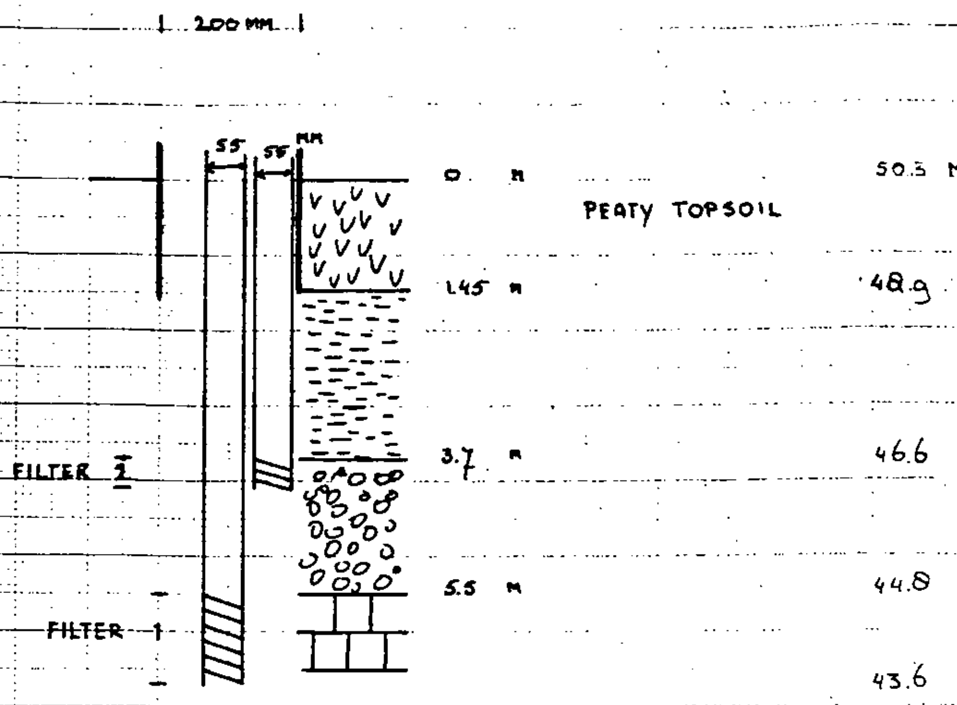


190mm 190mm
55mm
55mm
0 m
20 m
46 m
49 m
FILTER A
FILTER B
55.7 M.O.D.
53.7
EXTREMELY CLAYEY BOULDER CLAY
SILTY CLAY
51.1
50.8
48.8

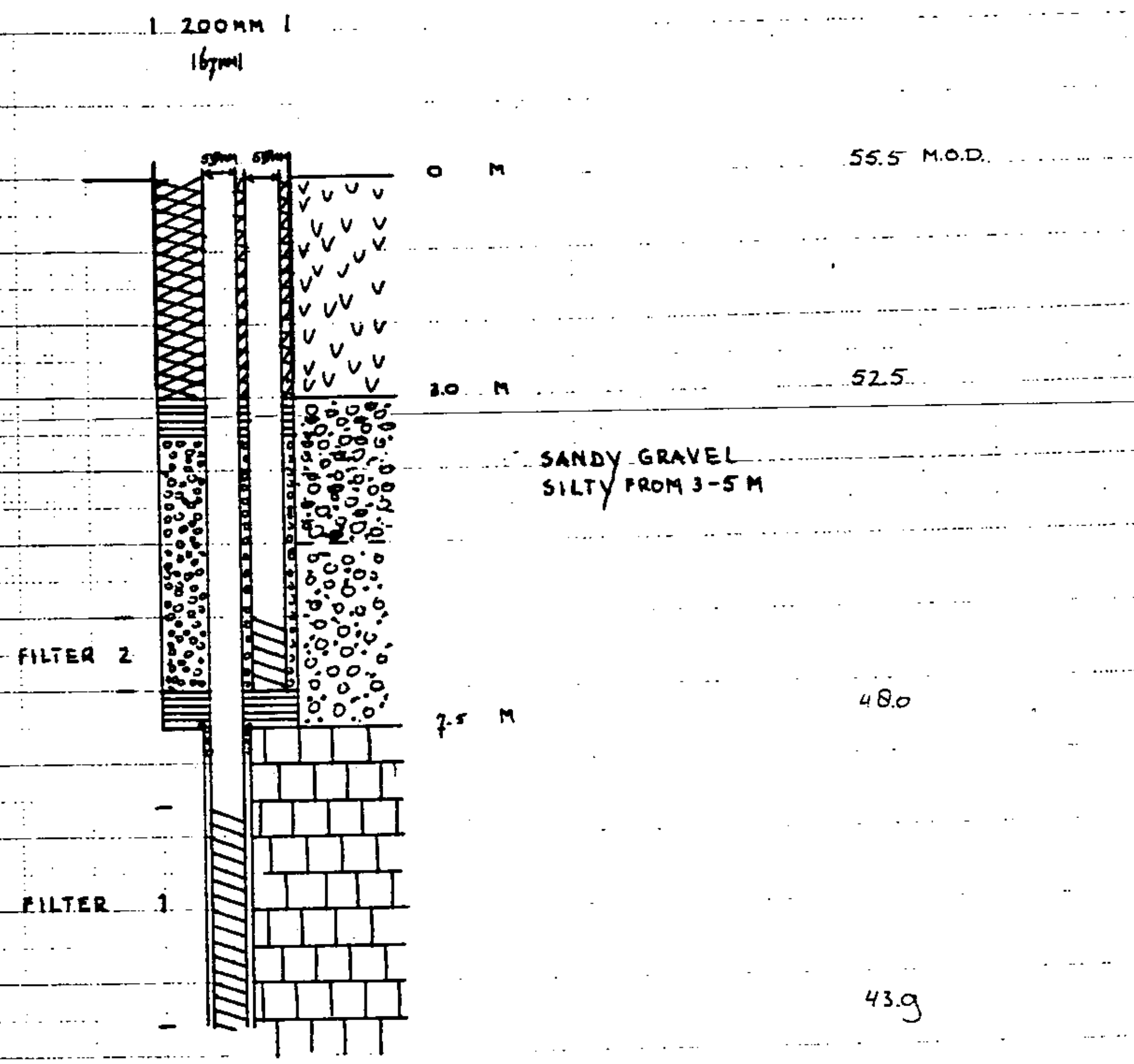


CLBH 6
250 MM
22
55 MM
65MM
0 M
56.0 M.O.D
6.5 M
49.5
44.2
11.75 M
LOOSE ANGULAR GRAVEL
43.4
12.55 M
STONY CLAY
13.4 M
42.6
SANDY GRAVEL
14.0 M
42.0
LOOSE ANGULAR GRAVEL
MAYBE WEATHERED BEDROCK
16.0 M
40.0
HIGHLY FISSURED LIMESTONE
34.0
FILTER 3
FILTER 2
FILTER 1

CLBH 7

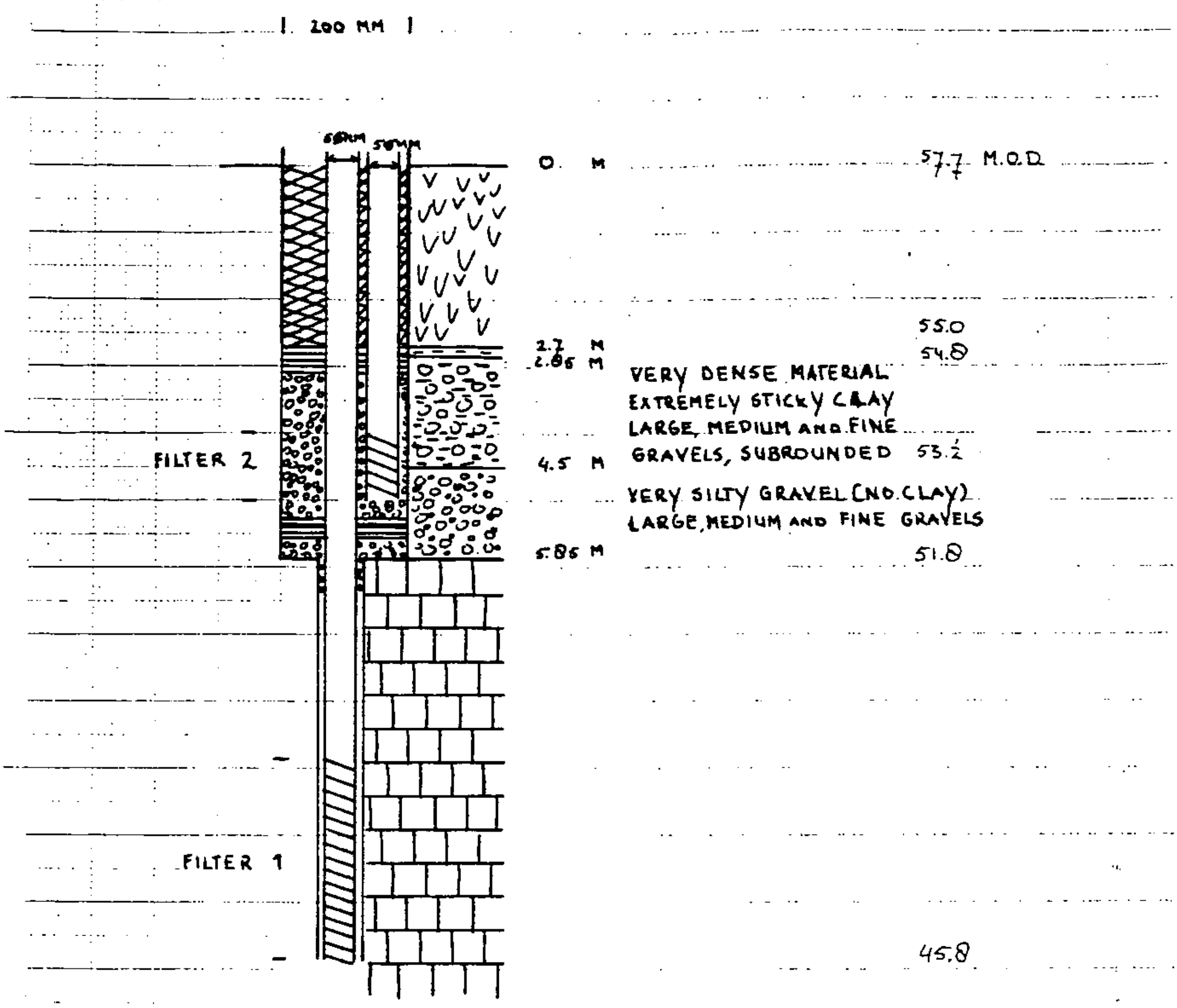

200 MM
55
55
MM
0 M
50.5 M.O.D.
PEATY TOPSOIL
1.45 M
48.9
3.7 M
46.6
FILTER 2
5.5 M
44.8
FILTER 1
43.6

CLBH 8

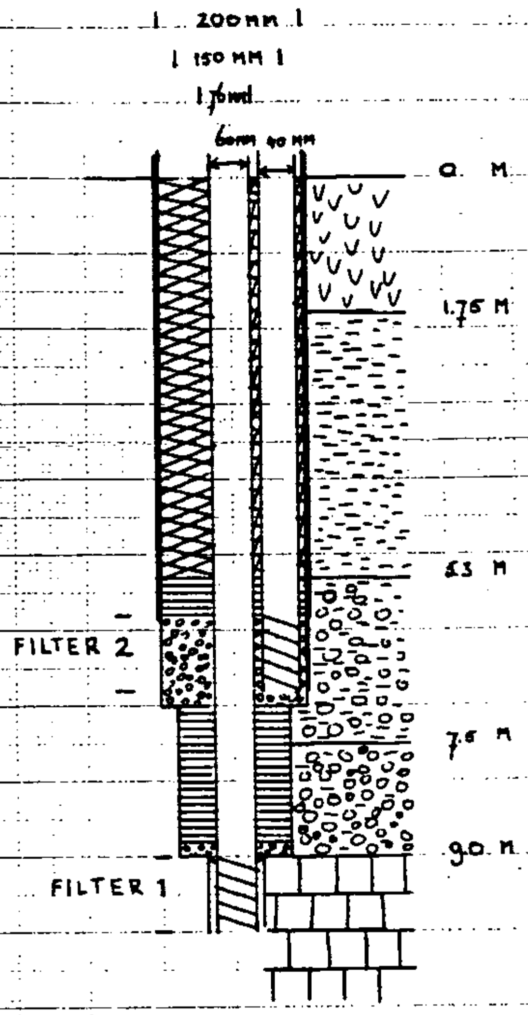


200MM
167mm
59mm
59mm
0 M
55.5 M.O.D.
3.0 M
52.5
SANDY GRAVEL
SILTY FROM 3-5 M
FILTER 2
7.5 M
48.0
FILTER 1
43.9

CLBH 9


200 MM
0. M
57.7 M.O.D.
55.0
2.7 M
2.85 M
54.8
VERY DENSE MATERIAL
EXTREMELY STICKY CLAY
LARGE, MEDIUM AND FINE
GRAVELS, SUBROUNDED
4.5 M
53.2
FILTER 2
VERY SILTY GRAVEL (NO CLAY)
LARGE, MEDIUM AND FINE GRAVELS
5.85 M
51.8
FILTER 1
45.8

CLBH 10

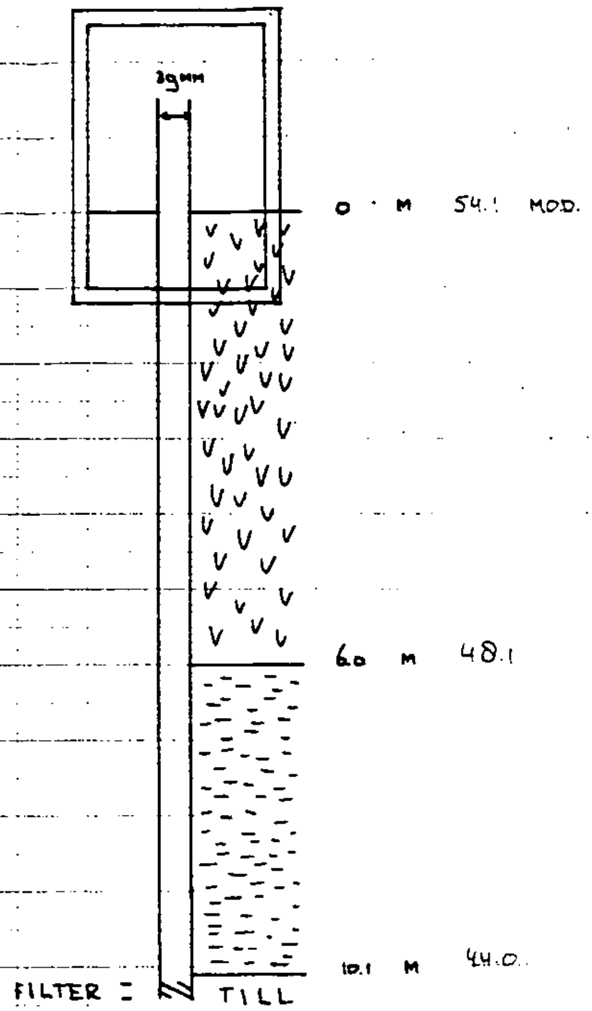


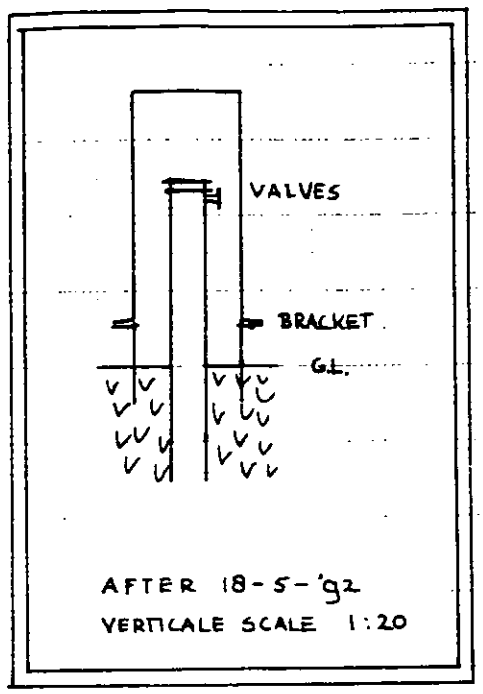
VERY STIFF

MEDIUM DENSE, VERY SILTY CLAY WITH LARGE COBBLES, BECOMING MORE GRAVEL RICH AT DEPTH (LESS SILTY)
CLASTS MAINLY ANGULAR.

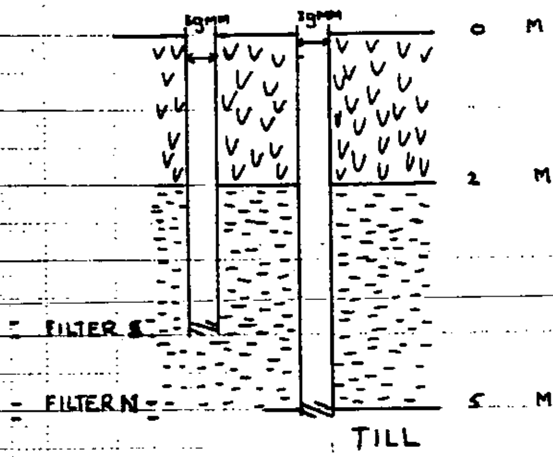
CLEAN LIMESTONE WITH FEW FISSURES

CLCD 1


39MM
0 M 54.1 MOD.
6.0 M 48.1
10.1 M 44.0
FILTER
TILL


VALVES
BRACKET
G.L.
AFTER 18-5-'92
VERTICALE SCALE 1:20

CLCD 2

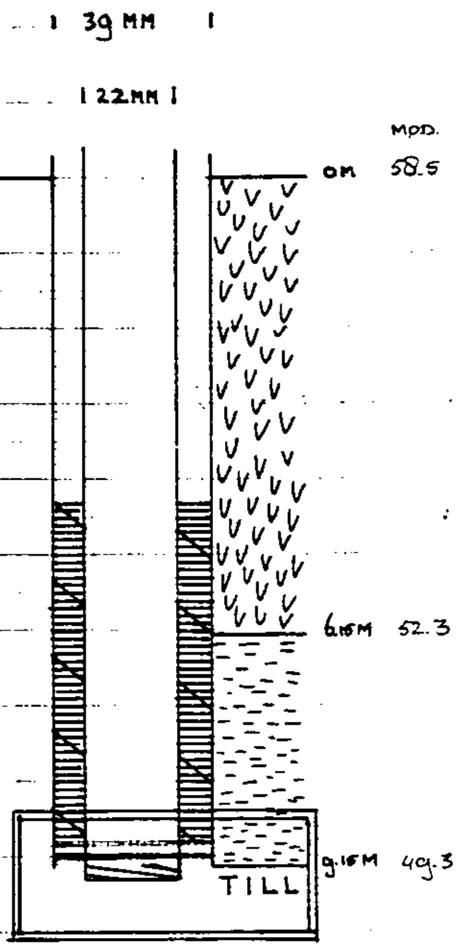


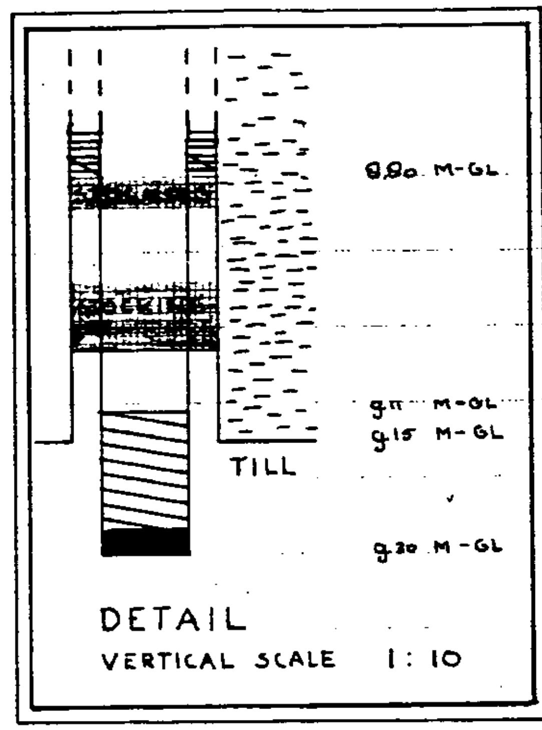
51.7 M.O.D.

49.7

46.7

CLCD 3


39 MM
22 MM
MOD.
0M 58.5
6.15M 52.3
9.15M 49.3
TILL


8.80 M-GL
9.11 M-GL
9.15 M-GL
TILL
9.30 M-GL
DETAIL
VERTICAL SCALE 1 : 10

APPENDIX II

COORDINATES AND LEVELS

		Page
A	*SHORT DESCRIPTION;*	*31*
B	*PRINT OUT OF LOTUS FILES;*	*32*
C	*CONTOURLINES OF CLARA BOG;*	*36*
D	*LEVELS OF CROSS-SECTION A*.*	*37*

APPENDIX IIA SHORT DESCRIPTION

Introduction

The Irish Office of Public Works (OPW) have installed wooden stakes over the bog which has established a surveyed grid reference system. The grid has a 100 metre interval and is parallel to the bog-road. A combination of letters for eastings/westings and numbers for northings is used. The origin is at the northern end of the Bog road. This, so called OPW grid, can only be found on the bog itself. As in this study the region of Clara Bog is the subject, the National grid has been used. This grid has a interval of 1 km.
In Oscar's file GRID.WK3 a calculation is given for the transition from OPW-coordinates to coordinates of the National grid. Some small mistakes were discovered in his file and they have been changed. The alterations made are:
Step 4: calculation is alright but in the explanation wrong figures are used;
Step 5: the wrong coordinates for C have been taken;
These changes can be find in the file GRID_M.WK3 which also gives more explanations about the used method.

Wells

The locations are known from a map of Richard Henderson. With help of this map coordinates are estimated.

Boreholes, cobra-drillings and weirs

Coordinates of the boreholes, cobradrillings and weirs are just taken from a fieldmap. They were pointed out on the map by measuring the distance in the field in footsteps (and converted to metres) and than read of the map. The readings were done to 10 metres but the values are not that accurate. The maximum difference will be approximately 50 metres.

Bog-piezometers

Coordinates of the tubes on Clara West are calculated from given OPW-coordinates. The coordinates of 905 are very inaccurate because of the very wet area and the lack of pegs.
There are two maps with the locations of those piezometers. One, hand-drawn map, made by students of the Agricultural University of Wageningen and a typed map from the Dutch National Forestry Service (SBB). The latter differs with the hand-drawn map and the coordinates. Those last two data-sets are taken as correct, which means that the following numbers have been changed on the SBB-map:

48, 53, 68, 72, 73, 74, 90, 91, 97.

The OPW-coordinates of the tubes on Clara East have been estimated by Iain Blackwell in the summer of 1992.

APPENDIX II.B PRINT OUT LOTUS FILES

COORDINATES CLARA BOG WEST

*X Nat. = X Nat.(0,0 OPW) - sin (alfa+beta) * distance to (0,0 OPW)*
*Y Nat. = Y nat.(0,0 OPW) - cos (alfa+beta) * distance to (0,0 OPW)*

X Nat. (0,0 OPW) = 225108.1
Y Nat. (0,0 OPW) = 230877.5
Beta = 0.308748 pi
Distance to (0,0 OPW):
*V [(X opw * X opw) + (Y opw * Y opw)]*
Vectorcorner C with Y opw-as, Alfa:
Inv [Tan(X opw / Y opw)]

	OPW Grid				Nat. Grid	
TUBE NO.	X-Coord.	Y-Coord.	Dist.	Alfa	X-Coord.	Y-Coord.
46	772.3	1226.6	1449.5	0.56	223999.6	229943.6
47	803.7	1213.9	1455.8	0.58	223973.6	229965.2
48	843.9	1197.7	1465.1	0.61	223940.2	229992.8
49	941.0	1188.0	1515.5	0.67	223850.6	230031.6
50	840.5	1095.3	1380.6	0.65	223974.6	230089.4
51	720.4	1254.5	1446.6	0.52	224040.6	229901.2
52	693.0	1242.0	1422.3	0.51	224070.5	229904.8
53	701.0	1132.0	1331.5	0.55	224096.3	230012.0
54	602.2	1178.8	1323.7	0.47	224176.2	229937.4
55	591.0	1048.0	1203.2	0.51	224226.6	230058.6
56	673.0	1010.0	1213.7	0.59	224160.1	230119.7
57	865.7	1247.5	1518.5	0.61	223904.3	229952.0
58	808.0	1276.0	1510.3	0.56	223950.6	229907.3
59	772.0	1308.0	1518.8	0.53	223975.2	229865.9
60	732.0	1337.0	1524.3	0.50	224004.5	229826.1
61	698.1	1355.7	1524.9	0.48	224031.1	229798.0
62	681.0	1368.0	1528.1	0.46	224043.6	229781.1
63	664.0	1378.0	1529.6	0.45	224056.8	229766.4
64	769.1	1357.3	1560.1	0.52	223963.0	229818.1
65	767.7	1387.6	1585.8	0.51	223955.1	229788.8
66	766.4	1412.2	1606.8	0.50	223948.9	229764.9
67	765.4	1432.7	1624.3	0.49	223943.6	229745.1
68	764.8	1447.4	1637.0	0.49	223939.7	229730.9
69	772.0	1463.0	1654.2	0.49	223928.1	229718.2
70	808.7	1066.6	1338.5	0.65	224013.6	230107.0
70s	802.9	1068.5	1336.5	0.64	224018.5	230103.5
71	763.9	1451.3	1640.1	0.48	223939.4	229726.9
72	763.8	1450.2	1639.0	0.48	223939.8	229727.9
73	764.1	1448.7	1637.9	0.49	223940.0	229729.5
74	1884.1	1663.7	2513.5	0.85	222807.6	229865.0
75	1883.2	1663.1	2512.4	0.85	222808.6	229865.3
76	1881.9	1662.3	2510.9	0.85	222810.1	229865.6
77	1877.7	1659.4	2505.9	0.85	222815.0	229867.1
78	1871.9	1655.4	2498.9	0.85	222821.7	229869.2
79	773.0	1472.0	1662.6	0.48	223924.4	229710.0
80	?	?	ERR	ERR	ERR	ERR
81	9.0	950.0	950.0	0.01	224810.9	229975.1
82	15.0	950.0	950.1	0.02	224805.2	229977.0
83	25.0	950.0	950.3	0.03	224795.6	229980.0
84	45.0	950.0	951.1	0.05	224776.6	229986.1
85	70.0	950.0	952.6	0.07	224752.8	229993.7
86	100.0	950.0	955.2	0.10	224724.2	230002.8
87	200.0	950.0	970.8	0.21	224628.9	230033.2
88	300.0	950.0	996.2	0.31	224533.6	230063.6
89	400.0	990.0	1067.8	0.38	224426.2	230055.8
90					223275.0	230050.0

	OPW Grid				Nat. Grid	
TUBE NO.	X-Coord.	Y-Coord.	Dist.	Alfa	X-Coord.	Y-Coord.
91	550.0	1150.0	1274.8	0.45	224234.7	229949.0
92	800.0	1000.0	1280.6	0.67	224042.1	230167.9
93	950.0	1000.0	1379.3	0.76	223899.2	230213.4
94	1100.0	1000.0	1486.6	0.83	223756.3	230259.0
95	1250.0	1000.0	1600.8	0.90	223613.4	230304.6
96	1400.0	1000.0	1720.5	0.95	223470.5	230350.2
97	1500.0	1200.0	1920.9	0.90	223314.4	230190.0
98	1600.0	1400.0	2126.0	0.85	223158.4	230029.9
99	1750.0	1550.0	2337.7	0.85	222969.9	229932.5
901	800.0	800.0	1131.4	0.79	224102.9	230358.4
902	800.0	900.0	1204.2	0.73	224072.5	230263.1
903	998.5	1247.0	1597.5	0.68	223777.9	229992.9
904	1300.0	1300.0	1838.5	0.79	223474.6	230034.0
905	1400.0	1520.0	2066.5	0.74	223312.5	229854.8
P101	728.5	1380.3	1560.7	0.49	223994.7	229783.8
Rossum weir						
P103	625.0	1076.0	1244.3	0.53	224185.7	230042.3
Soak gauge						
P105	771.0	1455.0	1646.7	0.49	223931.5	229725.6
Cutaway gauge						
P10?	804	1060	1330.4	0.65	224020.1	230111.9
Groundwater recorder						
CLCD3	811.5	1041	1319.9	0.66	224018.7	230132.3

BENCHMARKS
WEST

A, Soak	600	1130	1279.4	0.49	224193.1	229983.2
B, Mount	840	1235	1493.6	0.60	223932.6	229956.1
D, Rossum	728.5	1380.3	1560.7	0.49	223994.7	229783.8

COORDINATES CLARA BOG EAST

X Nat. = X Nat.(0,0 OPW) - sin (alfa+beta) * distance to (0,0 OPW)
Y Nat. = Y nat.(0,0 OPW) - cos (alfa+beta) * distance to (0,0 OPW)

X Nat. (0,0 OPW) = 225108.1
Y Nat. (0,0 OPW) = 230877.5
Beta = 0.308748 pi
Distance to (0,0 OPW):
V [(X opw * X opw) + (Y opw * Y opw)]
Vectorcorner C with Y opw-as, Alfa:
Inv [Tan(-X opw / Y opw)]

	OPW Grid				Nat. Grid	
TUBE NO.	X-Coord.	Y-Coord.	Dist.	Alfa	X-Coord.	Y-Coord.
101	295	40	297.7	-1.44	225377.0	230749.7
102	295	44	298.3	-1.42	225375.8	230745.9
103	295	49	299.0	-1.41	225374.3	230741.2
104	298	65	305.0	-1.36	225372.3	230725.0
105	255	60	262.0	-1.34	225332.8	230742.8
106	304	84	315.4	-1.30	225372.2	230705.1
107	314	109	332.4	-1.24	225374.2	230678.2
108	330	168	370.3	-1.10	225371.5	230617.1
109	359	278	454.1	-0.91	225365.7	230503.5
110	407	341	531.0	-0.87	225392.3	230428.9
111	436	422	606.8	-0.80	225395.3	230342.9
112	419	505	656.2	-0.69	225353.9	230269.0
113	474	600	764.6	-0.67	225377.4	230161.8

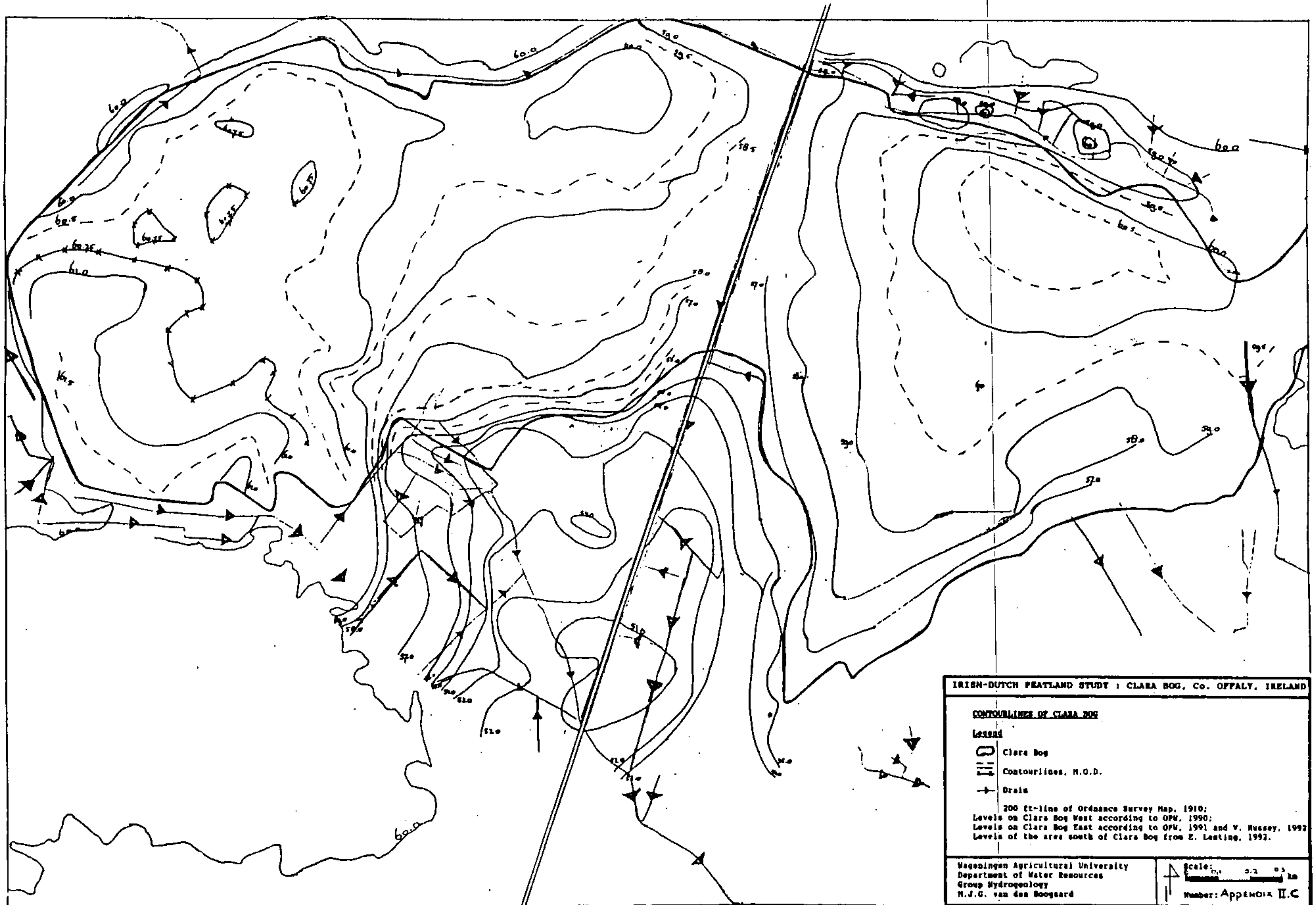
	OPW Grid				Nat. Grid	
TUBE NO.	X-Coord.	Y-Coord.	Dist.	Alfa	X-Coord.	Y-Coord.
114	552	663	862.7	-0.69	225432.6	230078.1
119	651	692	950.1	-0.75	225518.1	230020.4
120	804	755	1102.9	-0.82	225644.7	229913.9
121	774	510	926.9	-0.99	225690.6	230156.4
122	772	280	821.2	-1.22	225758.5	230376.1
123	800	194	823.2	-1.33	225811.4	230449.6
124	916	66	918.4	-1.50	225960.8	230536.3
125	965	159	978.0	-1.41	225979.2	230432.8
126	1000	225	1025.0	-1.35	225992.5	230359.2
127	1029	420	1111.4	-1.18	225960.9	230164.7
128	1147	250	1173.9	-1.36	226124.9	230290.8
129	1124	173	1137.2	-1.42	226126.4	230371.1
130	1094	76	1096.6	-1.50	226127.3	230472.6
131	1089	61	1090.7	-1.51	226127.1	230488.5
141	295	42	298.0	-1.43	225376.4	230747.8
142	295	46	298.6	-1.42	225375.2	230744.0
143	295	56	300.3	-1.38	225372.2	230734.5
151	497	181	528.9	-1.22	225526.6	230554.0
152	639	200	669.6	-1.27	225656.1	230492.8
153	586	322	668.6	-1.07	225568.6	230392.6
154	657	457	800.3	-0.96	225595.2	230242.4
BENCHMARKS						
EAST						
A (TBMA)	510.0	552.5	751.9	-0.75	225426.1	230196.1
B (TBMP)	587.5	1150.0	1291.4	-0.47	225318.4	229603.3
C (TBMB)	967.5	261.3	1002.2	-1.31	225950.5	230334.6
D (TBM3I)	880.0	680.0	1112.1	-0.91	225739.9	229962.2
E (TBM2K)	1140.0	237.5	1164.5	-1.37	226122.1	230304.8

COORDINATES TUBES OF J. BELL, CLBH, CLCD, WELLS, WEIRS & GAUGES

	Nat. Grid		According to
	X-Coord.	Y-Coord.	
NE1	225280	230550	Judy Bell
NE2	225120	230520	Judy Bell
NE3	225060	230510	Judy Bell
NE4	225020	230500	Judy Bell
NW1	224680	230840	Judy Bell
NW2	224800	230710	Judy Bell
NW3	224910	230570	Judy Bell
NW4	224950	230530	Judy Bell
NW5	224980	230500	Judy Bell
SE1	225190	230080	Judy Bell
SE2	224960	230030	Judy Bell
SE3	224890	230020	Judy Bell
SE4	224850	230010	Judy Bell
SW1	224440	230420	Judy Bell
SW2	224590	230260	Judy Bell
SW3	224750	230090	Judy Bell
SW4	224780	230060	Judy Bell
SW5	224810	230020	Judy Bell

	Nat. Grid X-Coord.	Y-Coord.	According to
CLBH2	225360	230760	Mary Smyth
CLBH3	225410	230930	Mary Smyth
CLBH4	223535	230940	Mary Smyth
CLBH5	223975	229606	Mary Smyth
CLBH6	224950	230320	Mary Smyth
CLBH7	224670	228370	Mary Smyth
CLBH8	226110	229460	Manon van den Boogaard
CLBH9	223070	229480	Manon van den Boogaard
CLBH10	224700	229430	Manon van den Boogaard
CLCD1	224850	230100	Manon van den Boogaard
CLCD2	224560	229240	Manon van den Boogaard
CLCD3	224019	230132	Manon van den Boogaard
CLCD4	225025	228990	Ray Flynn
CLCD5	225190	228940	Ray Flynn
CLCD6	224270	228860	Ray Flynn
Well_00	223590	228980	
Well_01	223620	231030	
Well_02	223750	231250	
Well_03	224050	231600	
Well_05	226110	230780	
Well_06	226290	230750	
Well_07	226440	230730	
Well_08	226570	230755	
Well_09	226840	231000	
Well_11	222740	228865	
Well_12	224020	228220	
Well_15	222000	228950	
Well_16	221450	230370	
Well_18	225500	231380	
Well_19	225350	231420	
Well_20	222880	227880	
Well_21	222485	228250	
Well_22	227220	228840	
Well_23	222150	229500	

	Nat. Grid X-Coord.	Y-Coord.	According to
Gauge Brosna River	226060	232210	Manon van den Boogaard
Gauge Silver River	225110	227350	Manon van den Boogaard
Gauge Deep drain	224830	228300	Manon van den Boogaard
Weir 921	224820	230000	Manon van den Boogaard
Weir 922	224860	230040	Manon van den Boogaard
Weir 923 (former)	225110	230820	Manon van den Boogaard
Weir 923 (new)	225100	230800	Manon van den Boogaard
Weir 100 (former)	225420	230750	Manon van den Boogaard

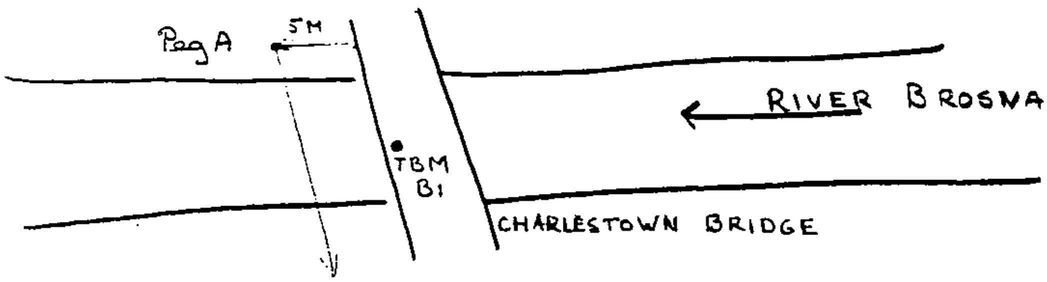

IRISH-DUTCH PEATLAND STUDY : CLARA BOG, Co. OFFALY, IRELAND
CONTOURLINES OF CLARA BOG
Legend
Clara Bog
Contourlines, M.O.D.
Drain
200 ft-line of Ordnance Survey Map, 1910;
Levels on Clara Bog West according to OPW, 1990;
Levels on Clara Bog East according to OPW, 1991 and V. Hussey, 1992
Levels of the area south of Clara Bog from E. Lenting, 1992.
Wageningen Agricultural University
Department of Water Resources
Group Hydrogeology
M.J.G. van den Boogaard
Scale:
km
Number: Appendix II.C

APPENDIX II.D LEVELS OF CROSS-SECTION A (MAP 2A*)*

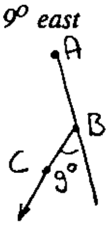
CROSS-SECTIONS CLARA BOG BY PADRAIC McGOWAN

13-July-1992, BM-Mill near Brosna River to Clara Bog east (peg G'1)
by Padraic McGowan, John and Manon

BM-Mill at River Brosna	*57.180*	*mod*
TBM B1, Charlestown Bridge	*60.742*	*mod*
Peg A, angle 140°.05' to Charlestown	*58.542*	*mod*
Peg A, distance to Charlestown Bridge	*5*	*m*
Start at Peg A		
End at Peg G'1 (OPW-grid) Nat.X-Coord.	*225745*	
Nat.Y-Coord.	*230570*	



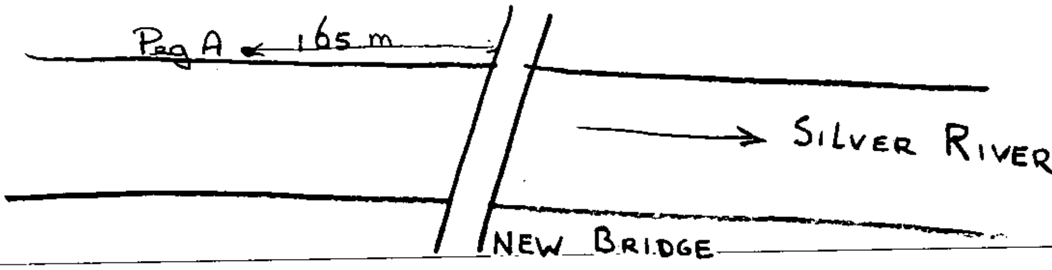
	Distance	*Dist. to Peg A*	*Reduced level (mod)*
Peg A	*0*	*0*	*58.54*
	27	*27*	*57.85*
	94	*94*	*59.36*
	111	*111*	*61.63*
	165	*165*	*52.52 !! 52=62 ??*
	251	*251*	*72.54*
	277	*277*	*80.51*
Top of Hill	*304*	*304*	*83.58*
	378	*378*	*82.19*
Peg C, 9° east	*378*	*378*	*82.20*
Peg B, 9° east	*0*	*304*	*83.58*
	95	*399*	*76.54*
	107	*411*	*74.61*
	113	*417*	*75.25*
	121	*425*	*76.92*
	179	*483*	*71.56*
	237	*541*	*69.76*
Peg D	*593*	*897*	*72.01*
Peg C	*0*	*378*	*82.20*
	578	*955*	*71.48*
	605	*982*	*67.99*
	757	*1135*	*63.81*
	812	*1190*	*65.22*
	1114	*1492*	*57.99*
	1124	*1501*	*58.63*
	1164	*1542*	*58.63*
	1210	*1588*	*59.94*
Top Peg G'1 (OPW)	*1247*	*1625*	*61.10*



Check onto CLBH2	*58.27*	*mod*
Other leveldata	*58.35*	*mod*
ERROR	*0.08*	*m*

14-July-1992, New Bridge (River Silver) to Clara Bog south-east
by Padraic McGowan, John and Manon

TBM at New Bridge		*51.20*	*mod*
Peg A,	*distance to New Bridge 165 m at Left Bank*		
Start at Peg a			
End peg	*Nat. X-Coord*	*224992*	
	Nat. Y-Coord	*228839*	



	Distance	*Dist. to Peg A*	*Reduced level (mod)*
Peg A	0	0	48.51
Bank of River	7	7	48.43
	9	9	47.46
Did not get bed	10	10	47.33
	17	17	47.63
	22	22	48.05
Bank of River	23	23	48.69
	96	96	48.75
	143	143	48.70
	302	302	48.78
	368	368	49.44
	444	444	49.27
	501	501	49.29
	604	604	50.13
Peg B, edge road	608	608	51.18
Peg B	0	608	51.18
Road	7	614	49.38
	114	721	49.59
	122	730	49.43
	186	794	50.78
Beside road	276	884	50.68
Peg C, 11° east	280	888	50.96
Peg D	324	932	50.67
Peg C	0	888	50.96
	23	911	50.77
	170	1058	51.09
	220	1108	51.25
	294	1182	52.03
	354	1242	52.61
	402	1290	54.88
Peg D	0	932	50.67
	415	1347	53.28
End peg	463	1395	53.76
Middle of drain, edge of Bog	465	1397	51.57

Check Bolt 14 in Bog Road	53.84	*mod*
Other leveldata	53.87	*mod*
ERROR	0.03	*m*

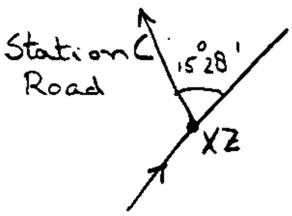
15/16/17-July-1992, New Bridge (Silver River) to Clara Bog west(peg G14)

15 July: From TBM, pole at house to Bog Road (station C)
by Padraic McGowan, John and Manon
16 July: From Bog Road (station C) to Clara Bog west (peg G14)
by Padraic McGowan, John and Vincent
17 July: From TBM, pole at house to New Bridge
by Padraic McGowan, John and Vincent

TBM New Bridge		*51.20*	*mod*
Peg G14 (OPW-grid)	*Nat.X-Coord.*	*224016*	
	Nat.Y-Coord.	*229756*	

	Distance	*Dist. to New Bridge*	*Reduced level (mod)*
Start at New Bridge			
	463.2		*47.36*
Side Silver River	*463.5*		*47.59*
Side Silver River	*464*		*48.07*
Left Bank Silver R	*465*	*0*	*48.64*
	452		*47.28*
	451		*47.87*
Right Bank Silver	*450*	*15*	*48.70*
	397	*68*	*48.34*
	293	*172*	*48.47*
Ditch	*212*	*253*	*48.79*
	147	*318*	*49.16*
	123	*342*	*50.84*
	36	*429*	*51.17*
	34	*431*	*51.10*
TBM, Pole at house	*0*	*465*	*55.78*
TBM, Pole at house	*0*	*465*	*55.78*
	138	*603*	*49.57*
	286	*751*	*50.14*
	377	*842*	*50.78*
	424	*889*	*51.00*
	466	*931*	*50.85*
	507	*972*	*51.69*
	544	*1009*	*50.05*
	569	*1034*	*50.52*
	600	*1065*	*50.62*
	625	*1090*	*50.47*
	668	*1133*	*51.00*
Road, Station B	*670*	*1135*	*51.06*
	734	*1199*	*50.50*
	756	*1221*	*50.39*
XZ	*761*	*1226*	*50.38*
Station B	*0*	*1135*	*51.06*
Drain (1)	*99*	*1234*	*48.72*
Drain (1)	*101*	*1236*	*48.56*
Edge drain (1)	*102*	*1237*	*48.86*
Left bank Drain(1)	*105*	*1240*	*50.11*
	120	*1255*	*50.03*
Left bank Drain(2)	*127*	*1262*	*49.74*
Middle drain (2)	*128*	*1263*	*48.98*
Right bank drain(2)	*133*	*1268*	*49.53*
	134	*1269*	*50.10*
	150	*1285*	*50.12*
	239	*1374*	*50.30*
	292	*1427*	*50.52*
Bog Road at Bridge	*479*	*1614*	*52.30*

Station C, 15^{o} 28' west of XZ	Distance	Dist. to New Bridge	Reduced level (mod)
XZ	0	1226	50.34
Peg R in field	471	1697	50.60



Station C	0	1614	52.30
	47	1661	50.36
Left bank drain	51	1665	50.22
Middle drain	53	1667	49.04
Right bank drain	56	1670	50.28
	99	1713	50.63
Right bank drain	130	1744	51.16
Middle drain	136	1750	49.47
Left bank drain	144	1758	50.98
	234	1848	50.70
	333	1947	51.44
	427	2041	51.75
	451	2065	51.84
	605	2219	57.68 !! 57=51???
peg R, 9^{o} east	0	1697	50.60
	471	2168	52.70
	574	2271	55.30
Edge of Bog	662	2359	55.14
Middle drain, edge	667	2364	53.95
Top peg G14			58.01

Check TBM OPW-weir	58.079	mod
Other leveldata	58.066	mod
ERROR	0.013	m

APPENDIX III

HYDRAULIC HEADS AND STAGES

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CLARA BOREHOLES and COBRADRILLINGS

PERIOD:	2 AUGUST 1990 - 30 OCTOBER 1992		
PIEZOM_NR:	CLBH2.1 - CLara BoreHole 2, Piezom. nr. 1		
METHOD OF MEASUREMENT:			
	E - Electrical contact meter (in most cases)		S - Steel tape
	Ru - Ruler	- No information	
WATERLEVEL STATUS:	P - Pumping wl	R - Recovering wl	S - Static waterlevel
WTRLVL:	m below casing/tube top		
WATERLEVEL:	mod		

NUMBER	CAS_LVL	MID_FIL_1	MID_FIL_2	MID_FIL_3
CLBH2	58.36	46.7	52.5	55.6
CLBH3	64.30	51.6	WELLSCREEN	
CLBH4	59.52	47.8	54.1	56.2
CLBH5	56.21	51.0	49.8	
CLBH6	56.78	35.5	41.8	43.8
CLBH7	50.79	44.3	46.4	
CLBH8	55.72	45.4	49.0	
CLBH9	57.90	47.3	53.2	
CLBH10	52.03	42.2	45.4	

NUMBER	TOP_TUBE	MID_FILTER	
CLCD1	55.62	43.4	Before 18 May 1992
CLCD1	54.23	43.4	After 18 May 1992
CLCD2_N	51.81	46.7	
CLCD2_S	51.72	47.8	
CLCD3	58.89	49.3	

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel
CLBH2.1			19900919	0.86	57.50
CLBH2.1			19901017	0.87	57.49
CLBH2.1			19901114	0.87	57.49
CLBH2.1			19901212	0.93	57.43
CLBH2.1			19910116	0.63	57.73
CLBH2.1			19910129	0.66	57.70
CLBH2.1			19910228	0.64	57.72
CLBH2.1			19910313	0.55	57.81
CLBH2.1			19910325	0.55	57.81
CLBH2.1			19910410	0.58	57.78
CLBH2.1			19910424	0.58	57.78
CLBH2.1			19910522	0.66	57.70
CLBH2.1			19910612	0.65	57.71
CLBH2.1			19910710	0.67	57.69
CLBH2.1			19910724	0.62	57.73
CLBH2.1			19910807	0.66	57.70
CLBH2.1		S	19910821	0.73	57.63
CLBH2.1	E	S	19911021	0.83	57.53
CLBH2.1	E	S	19911114	0.62	57.74
CLBH2.1	E	S	19911222	0.51	57.85
CLBH2.1	S	S	19920417	0.53	57.82
CLBH2.1	S	S	19920430	0.49	57.87
CLBH2.1	S	S	19920514	0.49	57.87
CLBH2.1	E	S	19920528	0.54	57.82
CLBH2.1	E	S	19920611	0.51	57.84 Sampled 4 June
CLBH2.1	E	S	19920625	0.60	57.75
CLBH2.1	E	S	19920709	0.63	57.72
CLBH2.1	S	S	19920723	0.68	57.67
CLBH2.1			19920821	0.75	57.61
CLBH2.1			19920904	0.80	57.56 Sampled 2 Sept.

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel	
CLBH2.1			19921002	0.87	57.49	
CLBH2.1			19921030	0.93	57.43	
CLBH2.2			19900919	0.84	57.52	
CLBH2.2			19901017	0.87	57.49	
CLBH2.2			19901114	0.88	57.48	
CLBH2.2			19901212	0.91	57.44	
CLBH2.2			19910116	0.59	57.77	
CLBH2.2			19910129	0.61	57.75	
CLBH2.2			19910228	0.63	57.73	
CLBH2.2			19910313	0.52	57.83	
CLBH2.2			19910325	0.48	57.88	
CLBH2.2			19910410	0.52	57.84	
CLBH2.2			19910424	0.53	57.83	
CLBH2.2			19910522	0.50	57.86	
CLBH2.2			19910612	0.49	57.87	
CLBH2.2			19910710	0.62	57.74	
CLBH2.2			19910724	0.58	57.77	
CLBH2.2			19910807	0.61	57.74	
CLBH2.2		S	19910821	0.69	57.67	
CLBH2.2	E	S	19911021	0.90	57.46	
CLBH2.2	E	S	19911114	0.69	57.67	
CLBH2.2	E	S	19911222	0.56	57.80	
CLBH2.2	S	S	19920417	0.72	57.64	
CLBH2.2	S	S	19920430	0.65	57.71	
CLBH2.2	S	S	19920514	0.68	57.68	
CLBH2.2	E	S	19920528	0.74	57.62	
CLBH2.2	E	S	19920611	0.68	57.68	Sampled 4 June
CLBH2.2	E	S	19920625	0.79	57.57	
CLBH2.2	E	S	19920709	0.76	57.60	
CLBH2.2	S	S	19920723	0.79	57.56	
CLBH2.2			19920821	0.83	57.53	
CLBH2.2			19920904	0.88	57.48	Sampled 2 Sept.
CLBH2.2			19921002	0.89	57.47	
CLBH2.2			19921030	0.98	57.38	
CLBH2.3			19900919	0.76	57.60	
CLBH2.3			19901017	0.83	57.53	
CLBH2.3			19901114	0.84	57.52	
CLBH2.3			19901212	0.87	57.49	
CLBH2.3			19910116	0.50	57.86	
CLBH2.3			19910129	0.50	57.86	
CLBH2.3			19910228	0.51	57.85	
CLBH2.3			19910313	0.29	58.06	
CLBH2.3			19910325	0.27	58.09	
CLBH2.3			19910410	0.31	58.05	
CLBH2.3			19910424	0.32	58.04	
CLBH2.3			19910522	0.29	58.07	
CLBH2.3			19910612	0.27	58.09	
CLBH2.3			19910710	0.43	57.93	
CLBH2.3			19910724	0.42	57.94	
CLBH2.3			19910807	0.46	57.89	
CLBH2.3		S	19910821	0.55	57.81	
CLBH2.3	E	S	19911021	0.89	57.47	
CLBH2.3	E	S	19911114	0.68	57.68	
CLBH2.3	E	S	19911222	0.56	57.80	
CLBH2.3	S	S	19920417	0.77	57.59	
CLBH2.3	S	S	19920430	0.69	57.67	
CLBH2.3	S	S	19920514	0.72	57.63	
CLBH2.3	E	S	19920528	0.73	57.62	
CLBH2.3	E	S	19920611	0.66	57.70	Sampled 4 June

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel
CLBH2.3	E	S	19920625	0.78	57.58
CLBH2.3	E	S	19920709	0.77	57.59
CLBH2.3	S	S	19920723	0.82	57.54
CLBH2.3			19920821	0.87	57.49
CLBH2.3			19920904	0.93	57.43 Sampled 2 Sept.
CLBH2.3			19921002	0.95	57.41
CLBH2.3			19921030	0.98	57.38
CLBH3.1		S	19900802	6.09	58.21
CLBH3.1		S	19900822	6.26	58.04
CLBH3.1		S	19900905	6.38	57.92
CLBH3.1		S	19900919	6.43	57.87
CLBH3.1		S	19901017	6.56	57.74
CLBH3.1		S	19901114	6.59	57.71
CLBH3.1		S	19901212	6.63	57.67
CLBH3.1		S	19910116	6.40	57.90
CLBH3.1		S	19910129	6.42	57.88
CLBH3.1		S	19910228	6.33	57.97
CLBH3.1		S	19910313	6.22	58.08
CLBH3.1		S	19910325	6.10	58.20
CLBH3.1		S	19910410	6.13	58.17
CLBH3.1		S	19910424	6.12	58.18
CLBH3.1		S	19910522	6.01	58.29
CLBH3.1		S	19910612	5.99	58.31
CLBH3.1		S	19910710	6.16	58.14
CLBH3.1		S	19910724	6.25	58.05
CLBH3.1		S	19910807	6.35	57.95
CLBH3.1		S	19910821	6.40	57.90
CLBH3.1	E	S	19911021	6.72	57.58
CLBH3.1	E	S	19911114	6.52	57.78
CLBH3.1	E	S	19920417	6.32	57.98
CLBH3.1	E	S	19920430	6.29	58.01
CLBH3.1	E	S	19920514	6.29	58.01
CLBH3.1	E	S	19920528	6.31	57.99
CLBH3.1	E	S	19920611	6.35	57.95
CLBH3.1	E	S	19920625	6.40	57.90
CLBH3.1	E	S	19920709	6.48	57.82
CLBH3.1	E	S	19920723	6.53	57.77
CLBH3.1			19920821	6.65	57.65
CLBH3.1			19920904	6.70	57.60 Sampled 2 Sept.
CLBH3.1			19921002	6.79	57.51
CLBH3.1			19921030	6.87	57.43
CLBH4.1	E	S	19911021	2.90	56.62
CLBH4.1	E	S	19911114	2.69	56.83
CLBH4.1	S	S	19920417	2.36	57.16
CLBH4.1	S	S	19920430	2.21	57.31
CLBH4.1	E	S	19911222	2.56	56.96
CLBH4.1	E	S	19920514	2.32	57.20
CLBH4.1	E	S	19920528	2.54	56.98
CLBH4.1	E	S	19920611	2.57	56.95
CLBH4.1	E	S	19920625	2.72	56.80
CLBH4.1	E	S	19920709	2.82	56.70
CLBH4.1	E	S	19920723	2.93	56.59
CLBH4.1			19920821	3.04	56.48
CLBH4.1			19920904	2.89	56.63 Sampled 2 Sept.
CLBH4.1			19921002	1.68	57.84
CLBH4.1			19921030	2.03	57.49
CLBH4.2	E	S	19911021	2.85	56.67
CLBH4.2	E	S	19911114	2.63	56.89

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel
CLBH4.2	E	S	19911222	2.52	57.00
CLBH4.2	S	S	19920417	2.30	57.22
CLBH4.2	S	S	19920430	2.13	57.39
CLBH4.2	E	S	19920514	2.27	57.25
CLBH4.2	E	S	19920528	2.51	57.02
CLBH4.2	E	S	19920611	2.51	57.01
CLBH4.2	E	S	19920625	2.70	56.82
CLBH4.2	E	S	19920709	2.82	56.71
CLBH4.2	E	S	19920723	2.89	56.63
CLBH4.2			19920821	2.99	56.53
CLBH4.2			19920904	2.82	56.70 Sampled 2 Sept.
CLBH4.2			19921002	0.41	59.11
CLBH4.2			19921030	2.80	56.72
CLBH4.3	E	S	19911021	2.35	57.17
CLBH4.3	E	S	19911114	2.20	57.32
CLBH4.3	E	S	19911222	2.11	57.41
CLBH4.3	S	S	19920417	2.06	57.46
CLBH4.3	S	S	19920430	1.62	57.90
CLBH4.3	E	S	19920514	1.95	57.57
CLBH4.3	E	S	19920528	2.46	57.06
CLBH4.3	E	S	19920611	1.78	57.74
CLBH4.3	E	S	19920625	2.67	56.85
CLBH4.3	E	S	19920709	1.79	57.73
CLBH4.3	E	S	19920723		< 56.10 DRY
CLBH4.3			19920821	1.99	57.53
CLBH4.3			19920904	1.81	57.71 Sampled 2 Sept.
CLBH4.3			19921002	3.24	56.28
CLBH4.3			19921030	2.98	56.55
CLBH5.A	S		19910905	1.38	54.83
CLBH5.A	S		19910919	1.37	54.84
CLBH5.A	S		19911004	1.33	54.89
CLBH5.A	S		19911018	1.16	55.05
CLBH5.A	S		19911030	1.23	54.98
CLBH5.A	S		19911114	0.92	55.29
CLBH5.A	S		19911128	0.99	55.22
CLBH5.A	S		19911212	1.09	55.12
CLBH5.A	S		19911226	0.98	55.23
CLBH5.A	S		19920109	0.89	55.32
CLBH5.A	S		19920123	1.13	55.08
CLBH5.A	S		19920206	1.19	55.02
CLBH5.A	S		19920220	1.20	55.01
CLBH5.A	S		19920305	1.13	55.08
CLBH5.A	S		19920319	1.07	55.14
CLBH5.A	S		19920402	1.03	55.18
CLBH5.A	S	S	19920417	1.10	55.11
CLBH5.A	S	S	19920501	1.01	55.21
CLBH5.A	E	S	19920514	1.10	55.11
CLBH5.A	E	S	19920528	1.20	55.01
CLBH5.A	E	S	19920611	1.26	54.95 Sampled 4 June
CLBH5.A	S	S	19920625	1.38	54.83
CLBH5.A	E	S	19920709	1.35	54.86
CLBH5.A	S	S	19920723	1.39	54.83
CLBH5.A			19920821	1.32	54.89
CLBH5.A			19920904	1.29	54.92 Sampled 2 Sept.
CLBH5.A			19921002	1.42	54.79
CLBH5.A			19921030	1.43	54.79
CLBH5.B	S		19910905	1.39	54.83
CLBH5.B	S		19910919	1.37	54.84

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel
CLBH5.B	S		19911004	1.34	54.87
CLBH5.B	S		19911018	1.17	55.04
CLBH5.B	S		19911030	1.24	54.97
CLBH5.B	S		19911114	0.93	55.28
CLBH5.B	S		19911128	0.99	55.23
CLBH5.B	S		19911212	1.10	55.11
CLBH5.B	S		19911226	0.96	55.25
CLBH5.B	S		19920109	0.88	55.33
CLBH5.B	S		19920123	1.13	55.09
CLBH5.B	S		19920206	1.20	55.01
CLBH5.B	S		19920220	1.20	55.01
CLBH5.B	S		19920305	1.14	55.08
CLBH5.B	S		19920319	1.07	55.14
CLBH5.B	S		19920402	1.03	55.18
CLBH5.B	S	S	19920417	1.12	55.10
CLBH5.B	S	S	19920501	1.01	55.20
CLBH5.B	E	S	19920514	1.10	55.11
CLBH5.B	E	S	19920528	1.20	55.01
CLBH5.B	E	S	19920611	1.27	54.94 Sampled 4 June
CLBH5.B	S	S	19920625	1.38	54.83
CLBH5.B	E	S	19920709	1.36	54.86
CLBH5.B	S	S	19920723	1.40	54.81
CLBH5.B			19920821	1.32	54.89
CLBH5.B			19920904	1.29	54.92 Sampled 2 Sept.
CLBH5.B			19921002	1.42	54.79
CLBH5.B			19921030	1.43	54.79
CLBH6.1	E	S	19911021	0.39	56.39
CLBH6.1	E	S	19911114	0.26	56.52
CLBH6.1	E	S	19911222	0.10	56.68
CLBH6.1	S	S	19920417	0.29	56.49
CLBH6.1	Ru	S	19920501	0.25	56.53
CLBH6.1	Ru	S	19920514	0.27	56.51
CLBH6.1	E	S	19920528	0.34	56.44
CLBH6.1	E	S	19920611	0.29	56.49 Sampled 4 June
CLBH6.1	E	S	19920625	0.36	56.42
CLBH6.1	E	S	19920709	0.36	56.42
CLBH6.1	S	S	19920723	0.41	56.37
CLBH6.1			19920821	0.36	56.42
CLBH6.1			19920904	0.37	56.41 Sampled 2 Sept.
CLBH6.1			19921002	0.34	56.44
CLBH6.1			19921030	0.36	56.43
CLBH6.2	E	S	19911021	0.39	56.39
CLBH6.2	E	S	19911114	0.26	56.52
CLBH6.2	E	S	19911222	0.10	56.68
CLBH6.2	S	S	19920417	0.29	56.49
CLBH6.2	Ru	S	19920501	0.25	56.53
CLBH6.2	Ru	S	19920514	0.27	56.51
CLBH6.2	E	S	19920528	0.33	56.45
CLBH6.2	E	S	19920611	0.29	56.49 Sampled 4 June
CLBH6.2	E	S	19920625	0.37	56.42
CLBH6.2	E	S	19920709	0.35	56.43
CLBH6.2	S	S	19920723	0.40	56.38
CLBH6.2			19920821	0.38	56.40
CLBH6.2			19920904	0.37	56.41 Sampled 2 Sept.
CLBH6.2			19921002	0.36	56.42
CLBH6.2			19921030	0.36	56.42
CLBH6.3	E	S	19911021	0.39	56.39
CLBH6.3	E	S	19911114	0.26	56.52

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel	
CLBH6.3	E	S	19911222	0.10	56.68	
CLBH6.3	S	S	19920417	0.28	56.50	
CLBH6.3	Ru	S	19920501	0.25	56.53	
CLBH6.3	Ru	S	19920514	0.26	56.52	
CLBH6.3	E	S	19920528	0.31	56.47	
CLBH6.3	E	S	19920611	0.29	56.49	Sampled 4 June
CLBH6.3	E	S	19920625	0.36	56.42	
CLBH6.3	E	S	19920709	0.36	56.43	
CLBH6.3	S	S	19920723	0.41	56.37	
CLBH6.3			19920821	0.37	56.41	
CLBH6.3			19920904	0.38	56.40	Sampled 2 Sept.
CLBH6.3			19921002	0.35	56.43	
CLBH6.3			19921030	0.37	56.42	
CLBH7.1		S	19911021	1.18	49.61	
CLBH7.1		S	19911114	0.90	49.89	
CLBH7.1		S	19911222	0.75	50.04	
CLBH7.1		S	19920410	0.82	49.97	
CLBH7.1	S	S	19920417	0.86	49.93	
CLBH7.1	S	S	19920501	0.70	50.09	
CLBH7.1	E	S	19920514	0.83	49.96	
CLBH7.1	E	S	19920528	1.50	49.29	
CLBH7.1	E	S	19920611	1.01	49.78	
CLBH7.1	E	S	19920625	1.22	49.57	
CLBH7.1	E	S	19920709	1.28	49.51	
CLBH7.1	E	S	19920723	1.40	49.39	
CLBH7.1			19920821	1.39	49.40	
CLBH7.1			19920904	1.25	49.54	Sampled 2 Sept.
CLBH7.1			19921002	1.02	49.77	
CLBH7.1			19921030	0.95	49.84	
CLBH7.2		S	19911021	1.23	49.56	
CLBH7.2		S	19911114	1.16	49.63	
CLBH7.2		S	19911222	0.82	49.97	
CLBH7.2		S	19920410	0.80	49.99	
CLBH7.2	S	S	19920417	0.85	49.94	
CLBH7.2	S	S	19920501	0.70	50.10	
CLBH7.2	E	S	19920514	0.83	49.96	
CLBH7.2	E	S	19920528	1.48	49.31	
CLBH7.2	E	S	19920611	1.01	49.78	
CLBH7.2	E	S	19920625	1.23	49.56	
CLBH7.2	E	S	19920709	1.28	49.52	
CLBH7.2	E	S	19920723	1.39	49.40	
CLBH7.2			19920821	1.38	49.41	
CLBH7.2			19920904	1.24	49.55	Sampled 2 Sept.
CLBH7.2			19921002	1.02	49.77	
CLBH7.2			19921030	0.93	49.86	
CLBH8.1	E	S	19920709	0.73	55.00	
CLBH8.1	E	S	19920723	0.74	54.98	
CLBH8.1			19920821	0.63	55.09	
CLBH8.1			19920904	0.58	55.14	Sampled 2 Sept.
CLBH8.1			19921002	0.70	55.02	
CLBH8.1			19921030	0.62	55.10	
CLBH8.2	E	S	19920709	0.72	55.00	
CLBH8.2	E	S	19920723	0.75	54.98	
CLBH8.2			19920821	0.61	55.11	
CLBH8.2			19920904	0.58	55.15	Sampled 2 Sept.
CLBH8.2			19921002	0.70	55.03	
CLBH8.2			19921030	0.62	55.10	

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel
CLBH9.1	E	S	19920723	1.01	56.89 from top piezomete
CLBH9.1			19920821	1.06	56.84
CLBH9.1			19920904	1.06	56.84 Sampled 2 Sept.
CLBH9.1			19921002	0.96	56.94
CLBH9.1			19921030	0.93	56.97
CLBH9.2	E	S	19920723	0.93	56.97 from top piezomete
CLBH9.2			19920821	1.05	56.85
CLBH9.2			19920904	1.04	56.86 Sampled 2 Sept.
CLBH9.2			19921002	0.95	56.95
CLBH9.2			19921030	0.93	56.98
CLBH10.1			19920821	0.78	51.25
CLBH10.1			19920904	0.76	51.27 Sampled 2 Sept.
CLBH10.1			19921002	0.71	51.32
CLBH10.1			19921030	0.70	51.34
CLBH10.2			19920821	0.74	51.29
CLBH10.2			19920904	0.75	51.28 Sampled 2 Sept.
CLBH10.2			19921002	0.67	51.36
CLBH10.2			19921030	0.68	51.36
CLCD1		S	19920410	0.44	55.18
CLCD1	S	S	19920417	0.47	55.15
CLCD1	S	S	19920430	0.47	55.15
CLCD1	S	S	19920514	0.47	55.14
CLCD1	Ru	S	19920528	-0.84	55.07
CLCD1	Ru	S	19920611	-0.99	55.22 Sampled 4 June
CLCD1	Ru	S	19920625	-0.98	55.21
CLCD1	Ru	S	19920709	-1.05	55.28
CLCD1	Ru	S	19920723	-0.94	55.16
CLCD1			19920821	-0.59	54.82
CLCD1			19920904	-0.81	55.04 Sampled 2 Sept.
CLCD1			19921002	-0.83	55.06
CLCD1			19921030	-0.81	55.04
CLCD2_N	S	S	19920417	0.70	51.11
CLCD2_N	S	S	19920430	0.64	51.17
CLCD2_N	S	S	19920514	0.62	51.19
CLCD2_N	S	S	19920528	0.64	51.17
CLCD2_N	S	S	19920611	0.59	51.21
CLCD2_N	E	S	19920625	0.60	51.21
CLCD2_N	S	S	19920709	0.60	51.21
CLCD2_N	S	S	19920723	1.07	50.74
CLCD2_N			19920821	0.88	50.93
CLCD2_N			19920904	1.12	50.69 Sampled 2 Sept.
CLCD2_N			19921002	0.78	51.03
CLCD2_N			19921030	0.75	51.06
CLCD2_S	S	S	19920417	0.54	51.18
CLCD2_S	S	S	19920430	0.52	51.20
CLCD2_S	S	S	19920514	0.50	51.22
CLCD2_S	S	S	19920528	0.69	51.03
CLCD2_S	S	S	19920611	0.66	51.06
CLCD2_S	E	S	19920625	0.68	51.04
CLCD2_S	S	S	19920709	0.73	50.99
CLCD2_S	S	S	19920723	0.85	50.87
CLCD2_S			19920821	0.79	50.93
CLCD2_S			19920904	0.82	50.90 Sampled 2 Sept.
CLCD2_S			19921002	0.69	51.03
CLCD2_S			19921030	0.61	51.11

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel
CLCD3		S	19920417		
CLCD3	S	S	19920501	1.83	57.07
CLCD3	S	S	19920514	1.84	57.05
CLCD3	S	S	19920528	1.90	57.00
CLCD3	S	S	19920611	1.94	56.95 Sampled 4 June
CLCD3	S	S	19920625	1.97	56.92
CLCD3	S	S	19920709	1.96	56.93
CLCD3	S	S	19920723	1.98	56.92
CLCD3			19920821		
CLCD3			19920904	2.00	56.89 Sampled 2 Sept.
CLCD3			19921002	1.94	56.96
CLCD3			19921030	1.95	56.95

Date: 30 October 1992	Top_tube	Wtrlvl	Waterlevel
CLCD4	52.77	0.28	52.49 TILL
CLCD5	55.76	2.09	53.67 TILL
CLCD6	51.50	1.54	49.96 CLAYEY TILL

WELLS

PERIOD:	21 OCTOBER 1991 - 30 OCTOBER 1992
NUMBER:	WELL 01 - Domestic well nr. 1
METHOD OF MEASUREMENT:	E - Electrical contact meter (in most cases)
WATERLEVEL STATUS:	Doubts about static waterlevel.
WTRLVL:	m below altitude
WATERLEVEL:	mod

NUMBER	Altitude	Depth	NUMBER	Altitude	Depth
0	67.00	32.96	13	62.75	
1	60.12	56.32	14		-3.80
2	58.53	55.58	15	54.07	37.97
3	57.71	53.98	16	51.15	47.38
4	53.98		17	61.26	
5	60.42	56.02	18	64.86	46.56
6	60.26	56.61	19	70.27	57.37
7	60.51	55.41	20	54.03	49.78
8	60.89	56.64	21	60.04	46.09
9	60.04	56.54	22	55.41	
11	70.01		23	57.85	
12	56.09	51.36			

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel
WELL_00	E	S	19920415	5.44	61.56
WELL_00	E	S	19920515	5.51	61.49
WELL_00	E	S	19920612	5.94	61.06
WELL_00	E	S	19920710	6.19	60.81
WELL_00			19920904	6.53	60.47
WELL_00			19921001	6.00	61.00
WELL_00			19921030		
WELL_01	E	S	19911021	3.60	56.52
WELL_01	E	S	19911114	3.46	56.66
WELL_01	E	S	19911222	3.31	56.81
WELL_01	E	S	19920122	3.45	56.67
WELL_02	E	S	19911021	2.83	55.70
WELL_02	E	S	19911114	2.64	55.89
WELL_02	E	S	19911222	2.55	55.98
WELL_02	E	S	19920122	2.43	56.10
WELL_02	E	S	19920430	2.12	56.41
WELL_02	E	S	19920515	2.15	56.38

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel
WELL_02	E	S	19920612	2.33	56.20
WELL_02	E	S	19920710	2.54	55.99
WELL_02			19920904	2.81	55.72
WELL_02			19921001	2.75	55.78
WELL_02			19921030	2.85	55.68
WELL_03	E	S	19911021	3.30	54.41
WELL_03	E	S	19911114	3.20	54.51
WELL_03	E	S	19911222	3.13	54.58
WELL_03	E	S	19920122	2.97	54.74
WELL_03	E	S	19920430	2.77	54.94
WELL_03	E	S	19920515	2.80	54.91
WELL_03	E	S	19920612	2.89	54.82
WELL_03	E	S	19920710	3.00	54.71
WELL_03			19920904	3.20	54.51
WELL_03			19921001	3.23	54.48
WELL_03			19921030	3.29	54.42
WELL_05	E		19911021	3.70	56.72 ABSTRACTION!!
WELL_05	E		19911114	3.57	56.85 ABSTRACTION!!
WELL_05	E		19911222	3.44	56.98 ABSTRACTION!!
WELL_05	E		19920122	3.28	57.14 ABSTRACTION!!
WELL_05	E		19920528	3.45	56.97 ABSTRACTION!!
WELL_05	E		19920611	3.45	56.97 ABSTRACTION!!
WELL_05	E		19920710	3.42	57.00 ABSTRACTION!!
WELL_05			19921001	3.76	56.66
WELL_05			19921030	3.84	56.58
WELL_06	E	S	19911021	3.65	56.61
WELL_06	E	S	19911114	3.51	56.75
WELL_06	E	S	19911222	3.43	56.83
WELL_06			19920122	3.30	56.96
WELL_06			19920528	2.41	57.85
WELL_06	E	S	19920612	2.55	57.71
WELL_06	E	S	19920709	2.75	57.51
WELL_07	E	S	19911021	4.00	56.51
WELL_07	E	S	19911114	3.72	56.79
WELL_07	E	S	19911222	3.59	56.92
WELL_07	E	S	19920122	3.42	57.09
WELL_07	E	S	19920430	3.02	57.49
WELL_07	E	S	19920515	3.11	57.40
WELL_07	E	S	19920528	3.28	57.23
WELL_07	E	S	19920612	3.06	57.45
WELL_07	E	S	19920710	3.42	57.09
WELL_07			19920904	3.78	56.73
WELL_07			19921001	3.74	56.77
WELL_07			19921030	3.73	56.78
WELL_08	E	S	19911021	3.90	56.99
WELL_08	E	S	19911114	3.81	57.08
WELL_08	E	S	19911222	3.63	57.26
WELL_08	E	S	19920122	3.48	57.41
WELL_08	E	S	19920430	3.38	57.51
WELL_08	E	S	19920515	3.39	57.50
WELL_08	E	S	19920528	3.39	57.50
WELL_08	E	S	19920612	3.45	57.44
WELL_08	E	S	19920709	3.56	57.33
WELL_08			19920904	3.80	57.09
WELL_08			19921001	3.84	57.05
WELL_08			19921030	3.96	56.93

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel	
WELL_09	E	S	19911021	3.10	56.94	
WELL_09	E	S	19911114	3.03	57.01	
WELL_09	E	S	19911222	2.92	57.12	
WELL_09	E	S	19920122	2.80	57.24	
WELL_09	E	S	19920430	2.08	57.96	
WELL_09	E	S	19920515	2.80	57.24	
WELL_09	E	S	19920612	2.83	57.21	
WELL_09	E	S	19920710	2.95	57.09	
WELL_09			19920904	3.22	56.82	
WELL_09			19921001	3.32	56.72	
WELL_09			19921010	3.38	56.66	
WELL_11			19921001	5.41	64.60	
WELL_11			19921030	5.56	64.45	
WELL_12	E	S	19911021	4.73	51.36	
WELL_12	E	S	19911114	4.62	51.47	
WELL_12	E	S	19911222	4.51	51.58	
WELL_12	E	S	19920122	4.28	51.81	
WELL_12	E	S	19920430	4.60	51.49	
WELL_12	E	S	19920515		< 51.36	DRY
WELL_12	E	S	19920612		< 51.36	DRY
WELL_12	E	S	19920710		< 51.36	DRY
WELL_12			19920904		< 51.36	DRY
WELL_14	E	S	19911021	3.10	-3.10	
WELL_14	E	S	19911114	3.09	-3.09	
WELL_14	E	S	19911222	3.02	-3.02	
WELL_14	E	S	19920122	2.78	-2.78	
WELL_15	E	S	19911021	3.05	51.02	
WELL_15	E	S	19911114	2.72	51.35	
WELL_15	E	S	19911222	2.69	51.38	
WELL_15	E	S	19920122	2.45	51.62	
WELL_15	E	S	19920430	0.48	53.59	
WELL_15	E	S	19920515	1.18	52.89	
WELL_15	E	S	19920612	1.57	52.50	
WELL_15	E	S	19920710	2.04	52.03	
WELL_15			19920904	2.55	51.52	
WELL_15			19921001	2.54	51.53	
WELL_15			19921030	2.33	51.74	
WELL_16	E	S	19911021	2.45	48.70	
WELL_16	E	S	19911114	2.42	48.73	
WELL_16	E	S	19911222	2.35	48.80	
WELL_16	E	S	19920122	2.18	48.97	
WELL_16	E	S	19920430	1.19	49.96	
WELL_16	E	S	19920515	1.67	49.48	
WELL_16	E	S	19920612	2.19	48.96	
WELL_16	E	S	19920710	2.62	48.53	
WELL_16			19920904	2.30	48.85	
WELL_16			19921001	2.22	48.93	
WELL_16			19921030	2.18	48.97	
WELL_18	E	S	19911021	18.30	46.56	
WELL_18	E	S	19911114	18.06	46.80	
WELL_18	E	S	19911222	17.76	47.10	
WELL_18	E	S	19920122	17.41	47.45	

PIEZOM_NR	Meth_meas	Level_sta	Date_meas	Wtrlvl	Waterlevel
WELL_19	E	S	19911021	12.90	57.37
WELL_19	E	S	19911114	12.81	57.46
WELL_19	E	S	19911222	12.76	57.51
WELL_19			19920122	12.32	57.95
WELL_19			19920430	12.20	58.07
WELL_19			19920515	12.31	57.96
WELL_19			19920612	12.33	57.94
WELL_19			19920710	12.40	57.87
WELL_19			19920904		< 57.37 DRY
WELL_19			19921001		< 57.37 DRY
WELL_19			19921030		< 57.37 DRY
WELL_20	E	S	19911021	4.17	49.86
WELL_20	E	S	19911114	4.03	50.00
WELL_20	E	S	19911222	3.89	50.14
WELL_20	E	S	19920122	3.51	50.52
WELL_20	E	S	19920430	3.13	50.90
WELL_20	E	S	19920515	3.28	50.75
WELL_20	E	S	19920612	3.68	50.35
WELL_20	E	S	19920710	3.90	50.13
WELL_20			19920904	4.22	49.81
WELL_20			19921001	4.23	49.80
WELL_20			19921030	4.12	49.91
WELL_21	E	S	19911021	3.21	56.83
WELL_21	E	S	19911114	3.02	57.02
WELL_21	E	S	19911222	2.95	57.09
WELL_21	E	S	19920122	2.45	57.59
WELL_21	E	S	19920430	2.54	57.50
WELL_21	E	S	19920515	2.65	57.39
WELL_21	E	S	19920612	3.09	56.95
WELL_21	E	S	19920710	3.46	56.58
WELL_21			19920904	3.70	56.34
WELL_21			19921001	3.46	56.58
WELL_21			19921030	2.83	57.21
WELL_22	E	S	19911021	2.97	52.44
WELL_22	E	S	19911114	2.46	52.95
WELL_22	E	S	19911222	2.36	53.05
WELL_22	E	S	19920122	2.16	53.25
WELL_22	E	S	19920430	2.40	53.01
WELL_22	E	S	19920515	2.54	52.87
WELL_22	E	S	19920612	2.46	52.95
WELL_22	E	S	19920710	2.70	52.71
WELL_22			19920904	2.72	52.69
WELL_22			19921001	2.55	52.86
WELL_22			19921030	2.54	52.87
WELL_23	E		19920430	4.28	53.57
WELL_23	E		19920515	4.30	53.55
WELL_23	E		19920612	4.88	52.97
WELL_23	E		19920710	5.12	52.73
WELL_23			19920904	5.28	52.57
WELL_23			19921001	5.14	52.71
WELL_23			19921030	5.13	52.72

DISCHARGES IN DRAINS and RIVERS NEAR CLARA BOG
PERIOD: 19 March 1992 - 23 July 1992

GAUGE IN DEEP DRAIN SOUTH-EAST OF CLARA BOG. 1 April 1992 - 23 July 1992
Bottom of the gauge: 48.80 mod EC: microSiemens/cm

DATE	TIME	Gauge (m/mod)		EC	$T(^0C)$	
01-04-92		0.280	49.08	310	6.6	
02-04-92		0.254	49.05	318	6.4	
06-04-92	11.11	0.235	49.04	340	7.6	
07-04-92	14.41	0.297	49.10	286	8.7	
09-04-92	9.05	0.240	49.04	305	6.4	
13-04-92	15.32	0.211	49.01	348	9.6	
14-04-92	15.20	0.220	49.02	345	10.3	
17-04-92	16.56	0.195	49.00	359	11.2	
18-04-92	12.30	0.191	48.99	361	11.1	
21-04-92	14.27	0.177	48.98	370	11.1	
22-04-92	17.15	0.177	48.98	366	10.1	
23-04-92	12.10	0.179	48.98	369	8.4	
26-04-92	13.06	0.300	49.10	273	10.8	
28-04-92	13.11	0.259	49.06			
29-04-92	10.28	0.234	49.03			
30-04-92	16.49	0.300	49.10			
01-05-92	10.01	0.311	49.11			
03-05-92	17.16	0.226	49.03			
04-05-92	15.23	0.212	49.01			
05-05-92	10.47	0.254	49.05			
06-05-92	17.13	0.224	49.02			
07-05-92	15.50	0.218	49.02			
08-05-92	17.44	0.202	49.00			
09-05-92	14.07	0.198	49.00			
11-05-92	13.05	0.210	49.01			
12-05-92	15.15	0.235	49.04			
13-05-92	14.20	0.210	49.01			
14-05-92	17.50	0.200	49.00			
17-05-92	17.00	0.163	48.96			
19-05-92	17.10	0.155	48.96			
20-05-92	16.00	0.151	48.95	Other Ec meter!		(18.00)
22-05-92	12.30	0.148	48.95	432	13.8	
23-05-92		0.144	48.94	435	10.9	
25-05-92	11.35	0.148	48.95	496	10.5	
28-05-92	12.05	0.139	48.94	467	9.8	
02-06-92	17.45	0.158	48.96			
08-06-92	11.15	0.140	48.94			
11-06-92	12.05	0.294	49.09	226	10.8	
15-06-92	18.45	0.140	48.94	384	12.7	
17-06-92	17.00	0.131	48.93			
25-06-92	17.35	0.124	48.92	459	12.4	
08-07-92		0.142	48.94			
09-07-92	Afternoon	0.135	48.94	437	11	
23-07-92	11/12.00	0.11	48.91			
21-08-92		0.21	49.01			
30-10-92		0.19	48.99			

DEEP DRAIN (1/4/92 - 23/7/92)	(mod)	EC
MEAN	49.00	366
MIN WATERLEVEL	48.91	
MAX WATERLEVEL	49.11	
MIN EC	49.09	226
MAX EC	48.95	496

GAUGE IN RIVER BROSNA AT CHARLESTOWN BRIDGE 8 April 1992 - 23 July 1992
Bottom of the gauge: 48.98 mod EC: microSiemens/cm

DATE	TIME	Gauge (m/mod)		EC	$T(^0C)$
08-04-92	10.55	1.29	50.27	560	
10-04-92		1.25	50.23		
14-04-92	15.00	1.25	50.23	486	9.5
17-04-92	18.10	1.25	50.23	527	10.4
18-04-92	12.56	1.20	50.18	528	10.6
21-04-92	15.14	1.20	50.18	516	10.3
26-04-92	13.48	1.35	50.33	534	10.6
28-04-92	13.46	1.35	50.33		
30-04-92	17.30	1.40	50.38		
01-05-92	9.46	1.37	50.35		
05-05-92	11.15	1.32	50.30		
07-05-92	16.13	1.29	50.27		
09-05-92	14.40	1.28	50.26		
12-05-92	15.05	1.28	50.26		
14-05-92	18.05	1.27	50.25		
19-05-92	17.40	1.20	50.18		
22-05-92	12.50	1.20	50.18	Other Ec meter!	
28-05-92	21.10	1.06	50.04	529	12.7
02-06-92	18.15	1.07	50.05		
11-06-92	15.00	1.01	49.99	547	12.4
17-06-92	17.00	1.16	50.14		
25-06-92	19.10	1.16	50.14	475	12.9
08-07-92		1.16	50.14		
09-07-92	21.00	1.13	50.11		
23-07-92	12.15	1.14	50.12		
30-10-92		1.19	50.17		

RIVER BROSNA (8/4/92 - 23/7/92)	(mod)	EC
MEAN	50.21	522
MIN WATERLEVEL	49.99	547
MAX WATERLEVEL	50.38	
MIN EC	50.14	475
MAX EC	50.27	560

GAUGE IN SILVER RIVER AT NEW BRIDGE *8 April 1992 - 23 July 1992*

Bottom of the gauge: 46.46 mod *EC: microSiemens/cm*

DATE	TIME	Gauge (m/mod)		EC	T(^{0}C)
10-04-92		0.48	46.94		
14-04-92	15.30	0.49	46.95	630	10.2
17-04-92	17.10	0.46	46.92	640	11.1
18-04-92	12.22	0.45	46.91	631	10.9
21-04-92	14.14	0.43	46.89	626	10.7
23-04-92	12.07	0.45	46.91	629	8.9
26-04-92	13.38	0.69	47.15	601	10.7
28-04-92	13.00	0.59	47.05		
30-04-92	16.55	0.65	47.11		
01-05-92	10.19	0.73	47.19		
03-05-92	17.05	0.55	47.01		
05-05-92	10.38	0.59	47.05		
07-05-92	15.42	0.51	46.97		
09-05-92	13.58	0.49	46.95		
11-05-92	13.10	0.51	46.97		
12-05-92	15.25	0.54	47.00		
14-05-92	18.10	0.49	46.95		
19-05-92	17.25	0.43	46.89		
22-05-92	12.40	0.44	46.90	Other Ec meter!	
25-05-92	11.45	0.44	46.90	692	10.3
28-05-92	11.55	0.43	46.89	694	9.8
02-06-92	17.50	0.43	46.89		
11-06-92	11.55	0.75	47.21	588	9.9
17-06-92	17.00	0.43	46.89		
25-06-92	18.00	0.41	46.87	689	11.0
08-07-92		0.42	46.88		
09-07-92	Afternoon	0.44	46.90	679	10.3
23-07-92	11/12.00	0.39	46.85		
21-08-92		0.54	47.00		
30-10-92		0.56	47.02		

SILVER RIVER (8/4/92 - 23/7/92)	(mod)	EC
MEAN	46.97	645
MIN WATERLEVEL	46.85	
MAX WATERLEVEL	47.21	588
MIN EC	47.21	588
MAX EC	46.89	694

WEIR NO. DEH 921 IN DRAIN WEST AT THE BOG ROAD — *19 March 1992 - 11 June 1992*

DEPTH : Distance from below the mark on stake to watersurface. — *EC: microSiemens/cm*

DATE	TIME	DEPTH (m)	EC	T (^oC)
19-03-92	14.19	0.97		
20-03-92	16.58	0.97		
21-03-92	17.12	0.91		
22-03-92	16.55	0.77		
23-03-92	14.51	0.85		
24-03-92	16.10	0.91	96	7.9
26-03-92	17.52	0.94	109	7.4
29-03-92	17.12	0.93		
31-03-92	11.07	0.94		
01-04-92	12.47	0.92	107	6.4
02-04-92	14.27	0.95	110	6.0
03-04-92	16.25	0.96	116	6.2
04-04-92	17.25	0.98	128	7.2
06-04-92	11.03	0.96	138	7.3
07-04-92	14.35	0.88	108	7.8
09-04-92	9.15	0.95	111	6.8
10-04-92	14.40	0.97		
13-04-92	15.27	0.98	138	8.3
14-04-92	15.14	0.96	142	8.8
15-04-92	13.35	0.97	136	7.9
17-04-92	16.42	0.98	145	9.4
18-04-92	12.42	0.98	149	9.8
19-04-92	18.13	0.99	150	10.1
21-04-92	14.43	0.99	158	9.4
22-04-92	17.24	0.99	160	8.9
23-04-92	12.15	0.99	165	8.2
26-04-92	13.01	0.87	97	9.3
28-04-92	13.24	0.93		
29-04-92	10.30	0.95		
30-04-92	16.30	0.87		
01-05-92	9.57	0.89		
03-05-92	17.29	0.96		
04-05-92	15.29	0.97		
05-05-92	11.00	0.92		
06-05-92	17.24	0.95		
07-05-92	15.55	0.96		
08-05-92	17.58	0.97		
09-05-92	14.20	0.98		
11-05-92	13.08	0.96		
12-05-92	15.40	0.93		
13-05-92	14.00	0.95		
14-05-92	17.45	0.97		
16-05-92	20.50	1.00		
17-05-92	16.30	1.00		
19-05-92	17.00	1.01		
20-05-92	15.45	1.01 Other Ec meter!		
21-05-92	16.00	1.02		
22-05-92	12.48	1.02	189	8.8 (18.40)
25-05-92	11.35	1.02	196	8.9
01-06-92	12/13	1.00	211	8.9
11-06-92	12/13	0.90	109	9.8

WEIR 921 (19/3/92 - 11/6/92)	(mod)	EC
MEAN	0.95	138
MIN WATERLEVEL	0.77	
MAX WATERLEVEL	1.02	189
MIN EC	0.91	96
MAX EC	1.00	211

WEIR NO. DEH 922 IN DRAIN SOUTH-EAST AT THE BOG ROAD — *19 March 1992 - 11 June 1992*

DEPTH : Distance from below the mark on stake to watersurface. — *EC: microSiemens/cm*

DATE	TIME	DEPTH (m)	EC	T (°C)
19-03-92	14.20	0.79		
20-03-92	16.56	0.78		
21-03-92	17.13	0.68		
22-03-92	16.55	0.67		
23-03-92	14.51	0.61		
24-03-92	16.13	0.68	259	8.0
26-03-92	17.49	0.73	299	7.8
29-03-92	17.12	0.72		
31-03-92	11.09	0.74		
01-04-92	12.50	0.70	260	5.9
02-04-92	14.30	0.74	288	5.2
03-04-92	16.28	0.77	324	6.1
04-04-92	17.19	0.78	375	7.3
06-04-92	11.00	0.76	332	7.0
07-04-92	14.28	0.67	241	8.1
09-04-92	9.17	0.74	299	6.4
10-04-92	14.40	0.77		
13-04-92	15.24	0.78	364	8.1
14-04-92	15.10	0.78	356	9.1
15-04-92	13.30	0.77	325	7.0
17-04-92	16.40	0.80	378	10.1
18-04-92	12.44	0.80	393	10.3
19-04-92	18.15	0.80	397	11.2
21-04-92	14.47	0.81	416	9.8
22-04-92	17.25	0.81	422	9.4
23-04-92	12.17	0.81	407	8.2
26-04-92	13.00	0.65	219	9.8
28-04-92	13.26	0.72		
29-04-92	10.33	0.75		
30-04-92	16.10	0.65		
01-05-92	9.55	0.67		
03-05-92	17.30	0.76		
04-05-92	15.30	0.78		
05-05-92	11.00	0.72		
06-05-92	17.25	0.76		
07-05-92	15.56	0.77		
08-05-92	17.59	0.79		
09-05-92	14.22	0.79		
11-05-92	13.00	0.77		
12-05-92	15.40	0.72		
13-05-92	14.00	0.75		
14-05-92	17.45	0.79		
16-05-92	20.45	0.82		
17-05-92	16.30	0.82		
19-05-92	17.00	0.85		
20-05-92	15.30	0.86	Other Ec meter!	
21-05-92	16.00	0.86		
22-05-92	12.50	0.87	507	9.7 (18.42)
25-05-92	11.35	0.87	512	9.9
01-06-92	12/13	0.85	481	9.6
11-06-92	12/13	0.66	199	10.6

WEIR 922 (19/3/92 - 11/6/92)	(mod)	EC
MEAN	0.76	350
MIN WATERLEVEL	0.61	
MAX WATERLEVEL	0.87	510
MIN EC	0.66	199
MAX EC	0.87	512

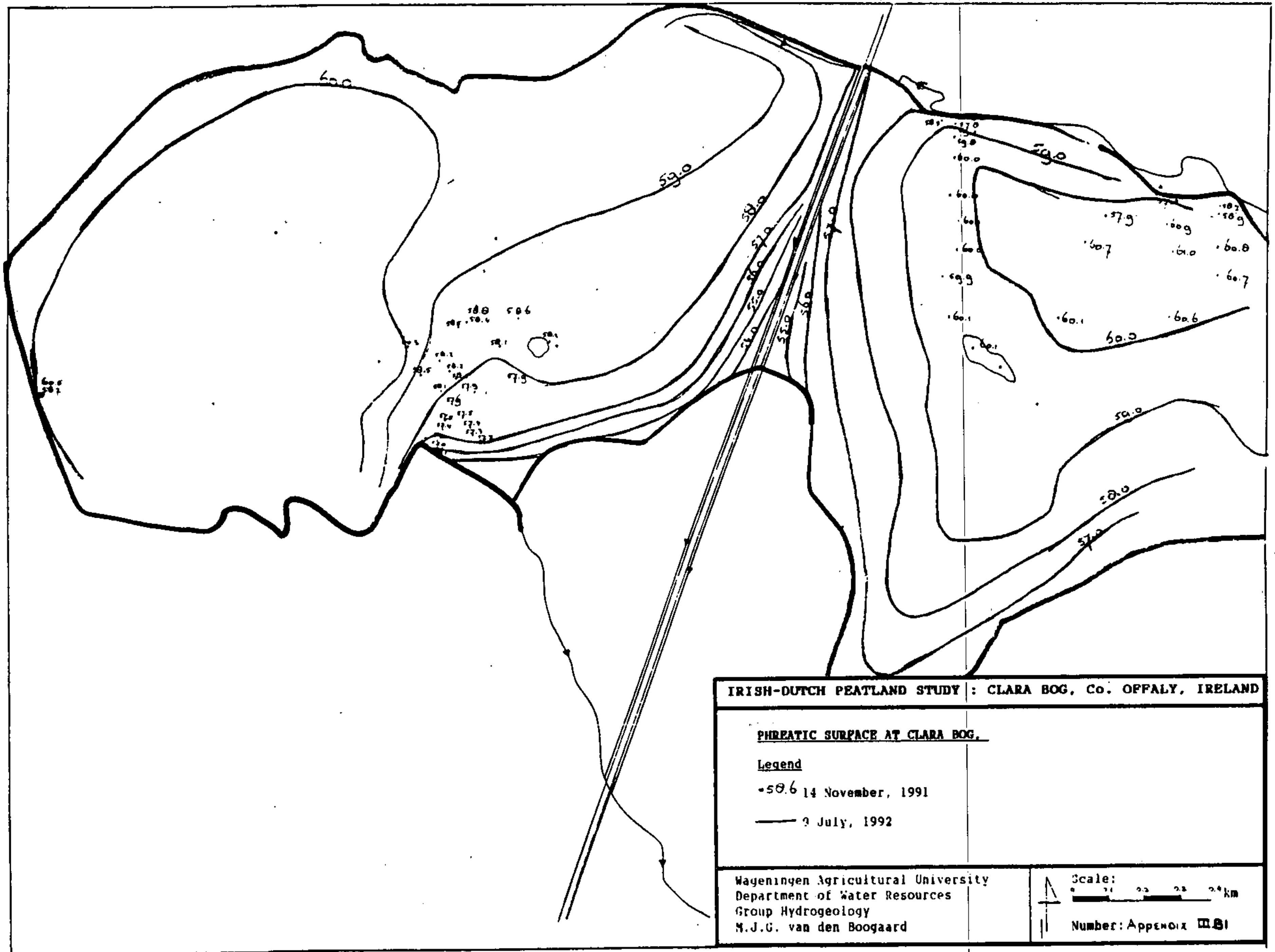
WEIR NO. DEH 923E IN DRAIN NORTH-EAST AT THE BOG ROAD *19 March 1992 - 14 May 1992*
DEPTH : Distance from below the mark on stake to watersurface. *EC: microSiemens/cm*

DATE	TIME	DEPTH (m)	EC	T (^oC)	
19-03-92	14.00	0.445			
20-03-92	16.53	0.440			
21-03-92	17.17	0.364			
22-03-92	16.55				
23-03-92		MORE PLASTIC INSTALLED			
24-03-92	16.17		334	8.5	
26-03-92	16/7.55?	0.402	369	8.5	
29-03-92	17.15	0.405			
31-03-92	11.12	0.415			
01-04-92	12.55	0.385	331	6.2	
02-04-92	14.03	0.413	348	6.0	
03-04-92	16.32	0.434	396	7.3	
04-04-92	17.13	0.450	412	9.0	
06-04-92	10.56	0.427	402	7.5	
07-04-92	14.15	0.360	292	8.6	
09-04-92	9.20	0.420	373	5.9	
10-04-92	14.45	0.441			
13-04-92	15.16	0.445	416	9.7	
14-04-92	15.07	0.441	418	10.7	
15-04-92	13.30	0.434	386	8.8	
17-04-92	15.15	0.452	428	11.2	
18-04-92	12.49	0.456	451	11.3	
19-04-92	18.19	0.461	453	12.8	
21-04-92	14.59	0.468	468	11.6	
22-04-92	17.30	0.465	468	10.1	
23-04-92	12.21	0.461	460	8.4	
26-04-92	12.55	0.341	280	11.2	WATER VERY HIGH, V ALMOST REACHED.
28-04-92	13.33	0.392			
29-04-92	10.30	0.415			
30-04-92	16.00	0.350			WATER VERY HIGH, V ALMOST REACHED.
01-05-92	9.51	0.355			WATER VERY HIGH, V ALMOST REACHED.
03-05-92	17.37	0.431			
04-05-92	15.33	0.439			
05-05-92	11.06	0.395			
06-05-92	17.34	0.421			
07-05-92	16.00	0.428			
08-05-92	18.05	0.443			
09-05-92	14.29	0.447			
11-05-92	12.55	0.438			
12-05-92	15.35	WEIR REMOVED			

WEIR 923 (19/3/92 - 14/5/92)	(mod)	EC
MIN WATERLEVEL	0.34	
MAX WATERLEVEL	0.47	
MIN EC		280
MAX EC		468

WATER NEAR WEIR NO. DEH 923E

DATE	TIME	EC (microS/cm)	T (^oC)
25-03-92	10.47	635	9.5
09-04-92	9.21	581	6.5
13-04-92	15.16	570	10.6
17-04-92	15.16	560	11.4
18-04-92	12.50	578	11.8
19-04-92	18.20	576/619	12.6
21-04-92	15.00	582	12.3
22-04-92	17.31	552	9.9



IRISH-DUTCH PEATLAND STUDY : CLARA BOG, Co. OFFALY, IRELAND

PHREATIC SURFACE AT CLARA BOG.

Legend

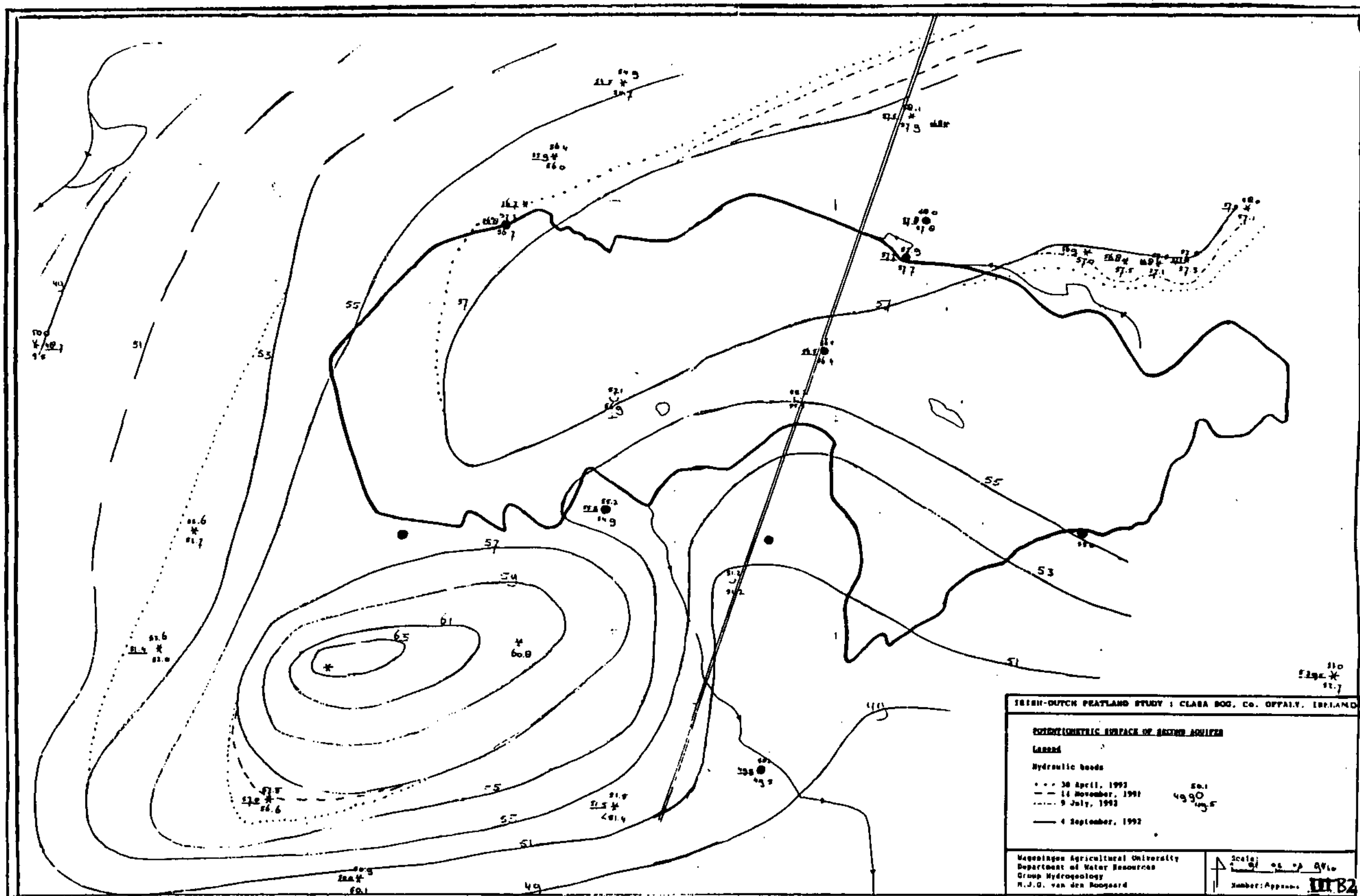
•58.6 14 November, 1991

——— 9 July, 1992

Wageningen Agricultural University
Department of Water Resources
Group Hydrogeology
M.J.G. van den Boogaard

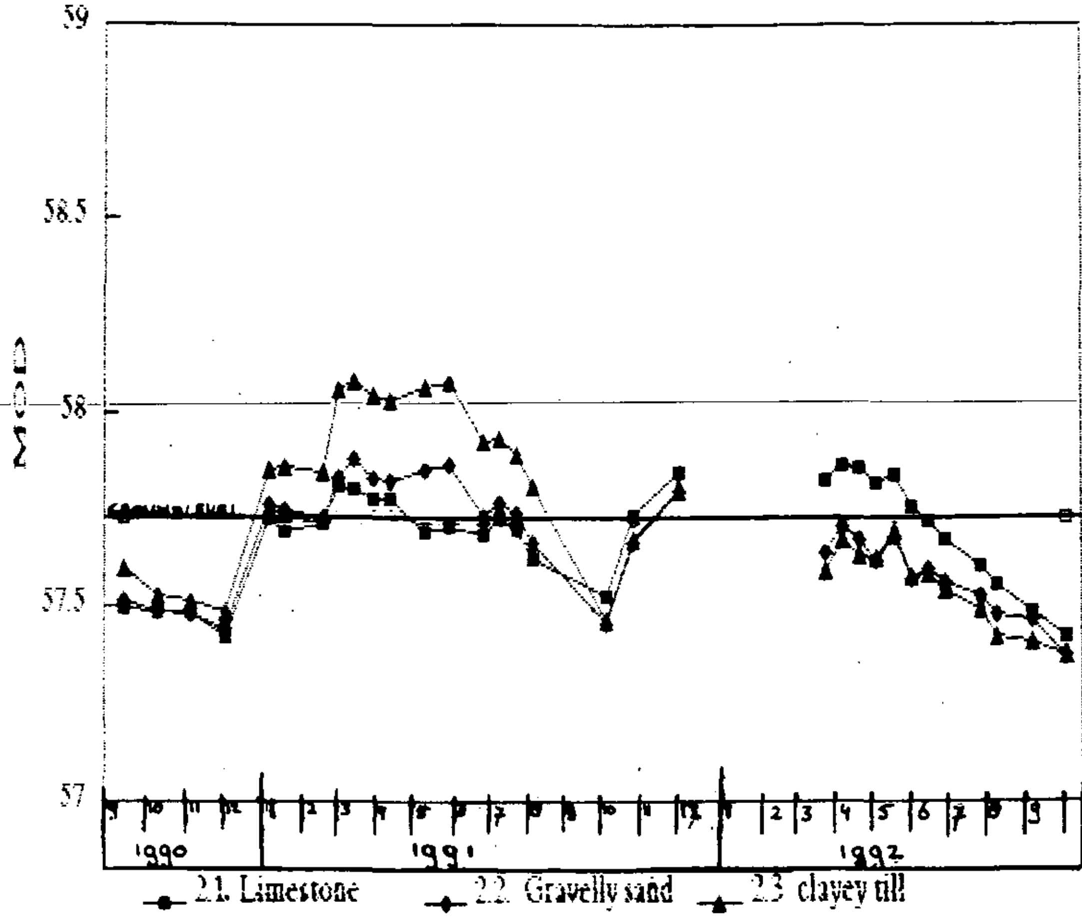
Scale: km

Number: Appendix III.8


IRISH-DUTCH PEATLAND STUDY : CLARA BOG, Co. OFFALY, IRELAND
POTENTIOMETRIC SURFACE OF SECOND AQUIFER
Legend
Hydraulic heads
30 April, 1992
14 November, 1991
9 July, 1992
4 September, 1992
Wageningen Agricultural University
Department of Water Resources
Group Hydrogeology
R.J.G. van den Boogaard
Scale:
Number: Appendix III B2

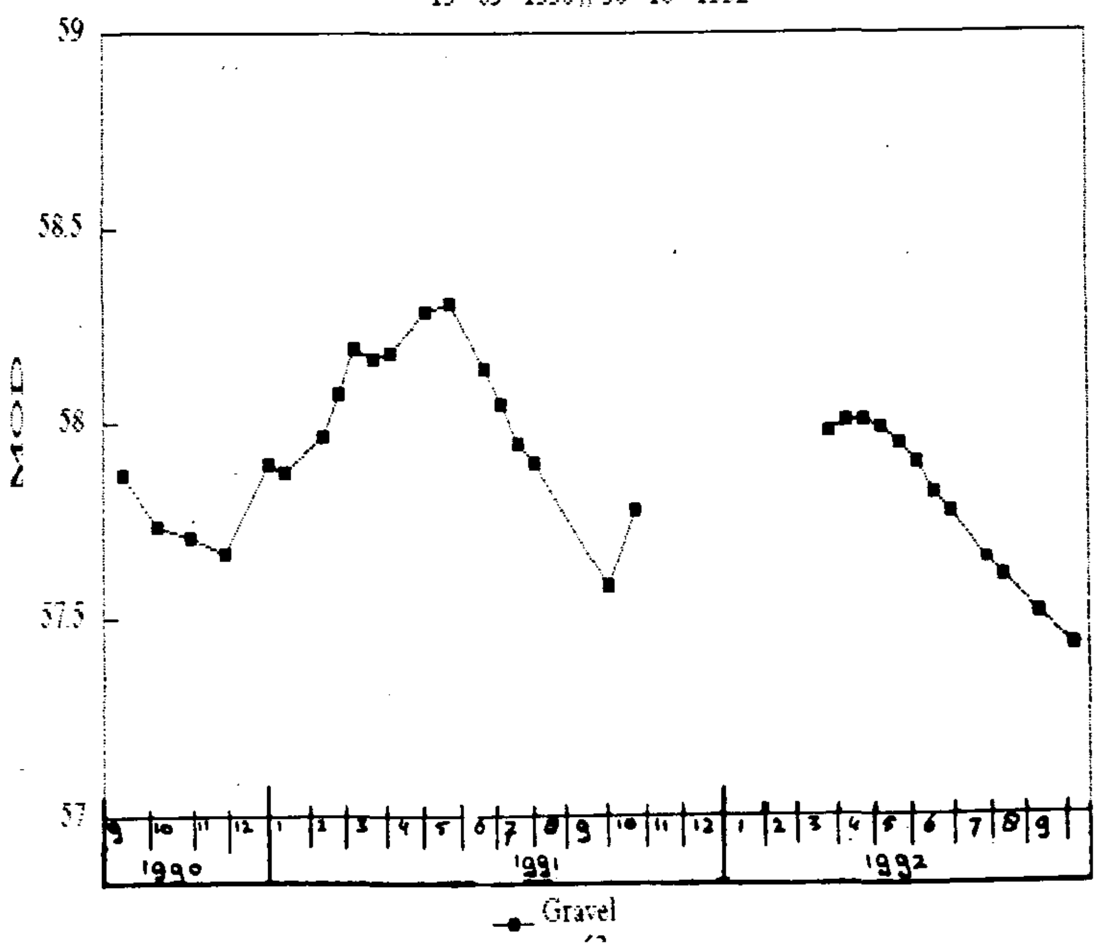
Hydraulic heads CLBH2

19-09-1990 // 30-10-1992



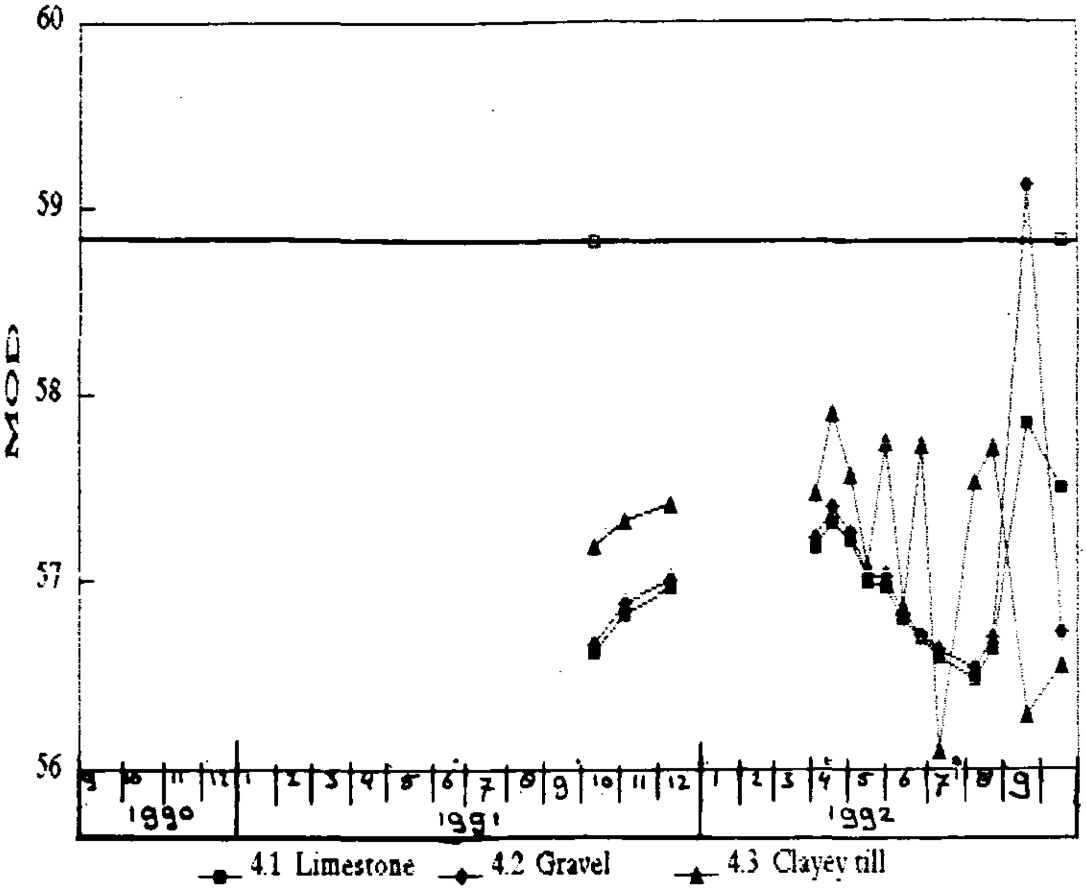
Hydraulic heads CLBH3

19-09-1990 // 30-10-1992



Hydraulic heads CLBH4

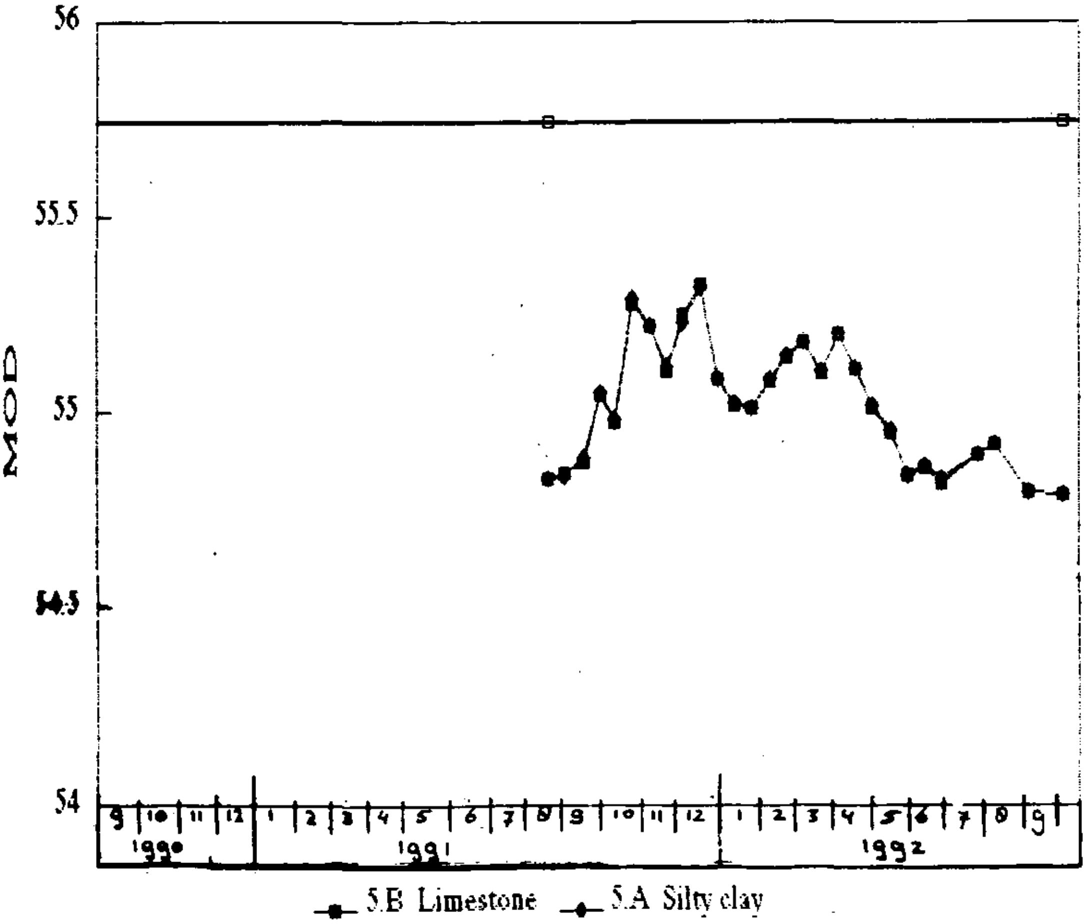
21-10-1991 // 30-10-1992



Y-as: 4m in stead of 2m.

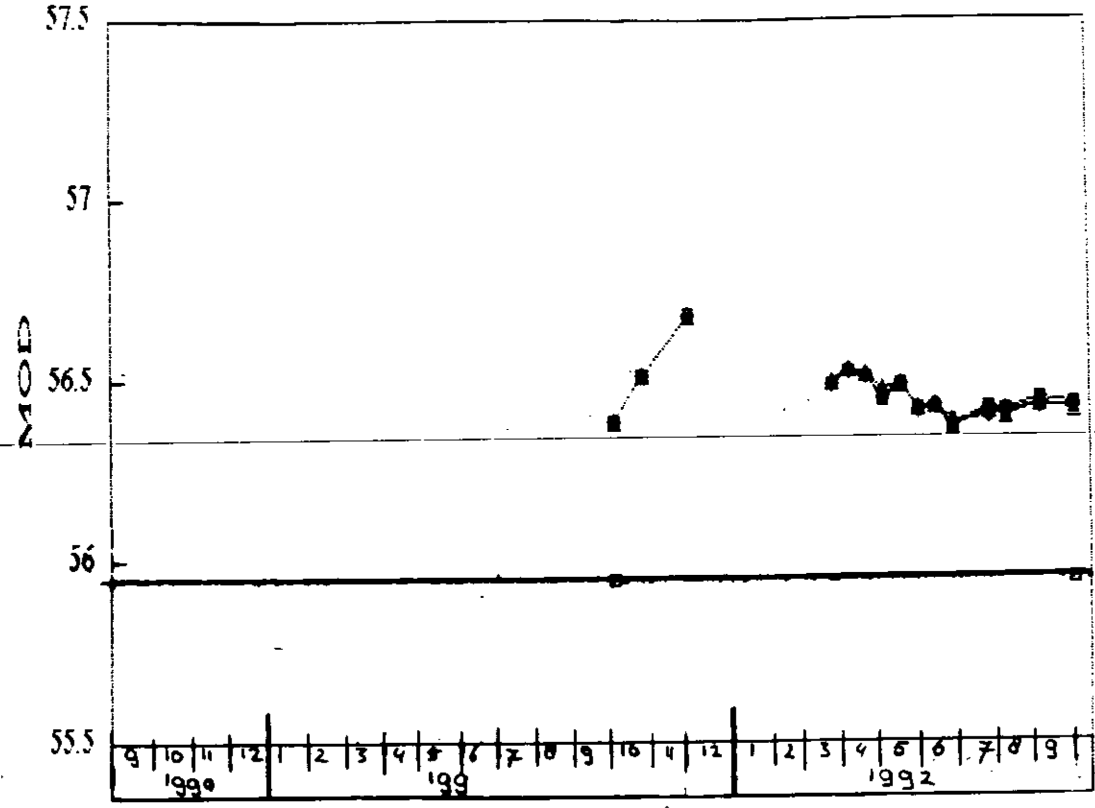
Hydraulic heads CLBH5

05-09-1991 // 30-10-1992



Hydraulic heads CLBH6

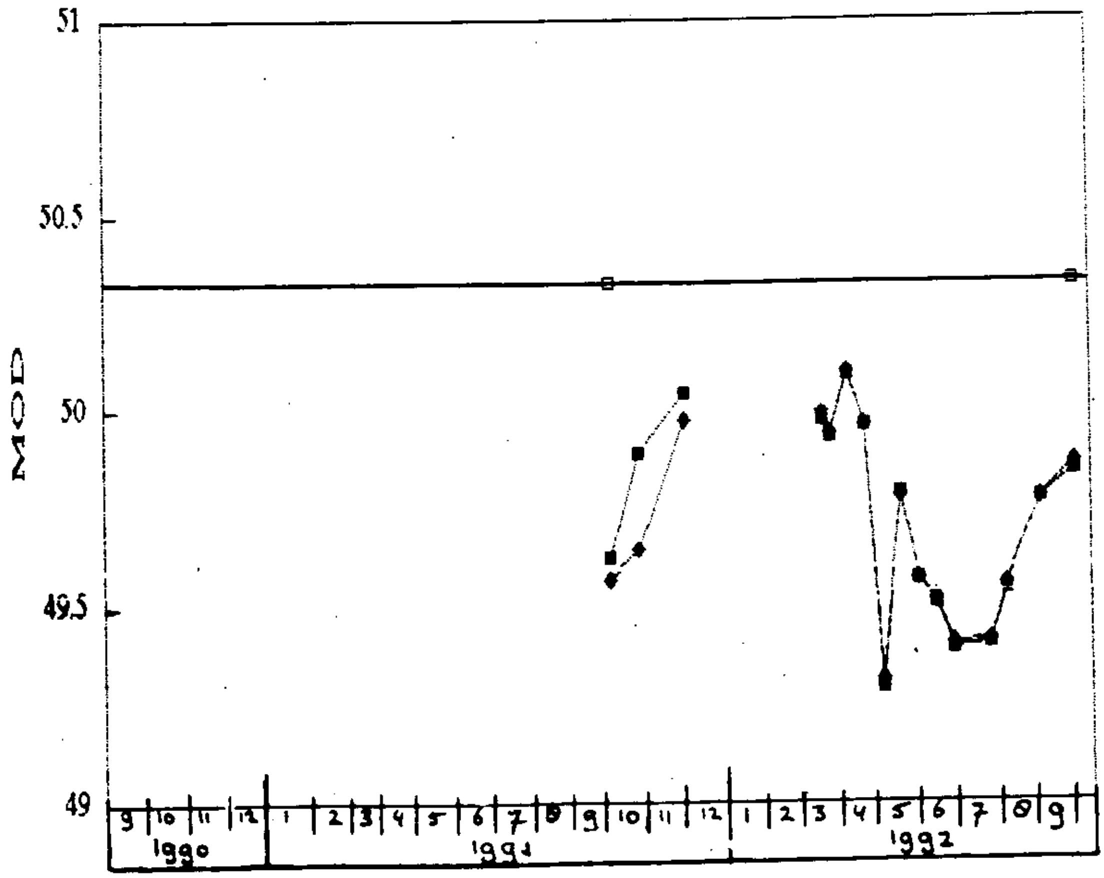
21-10-1991 // 30-10-1992



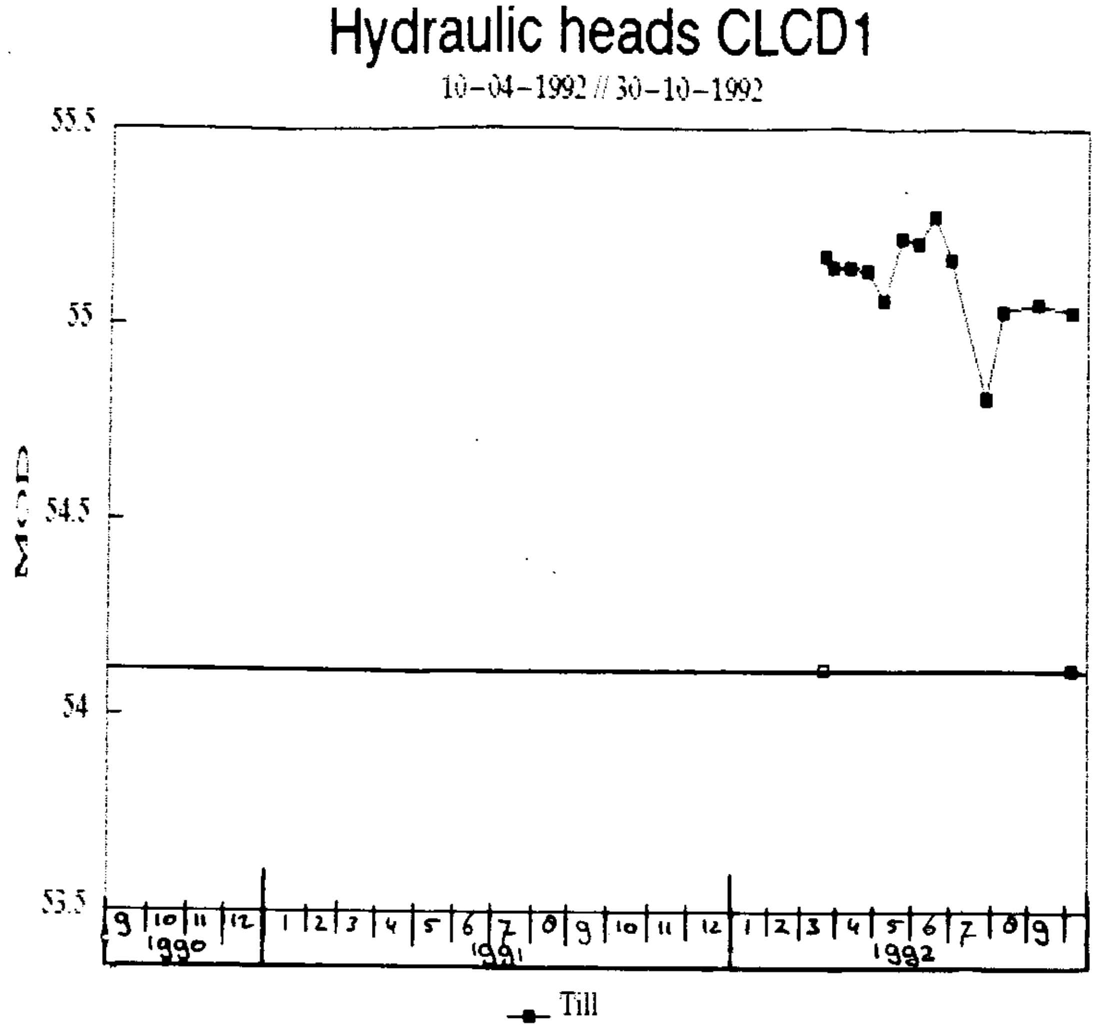
6.1 Limestone
6.2 Gravel
6.3 Gravel direct beneath lac. clay

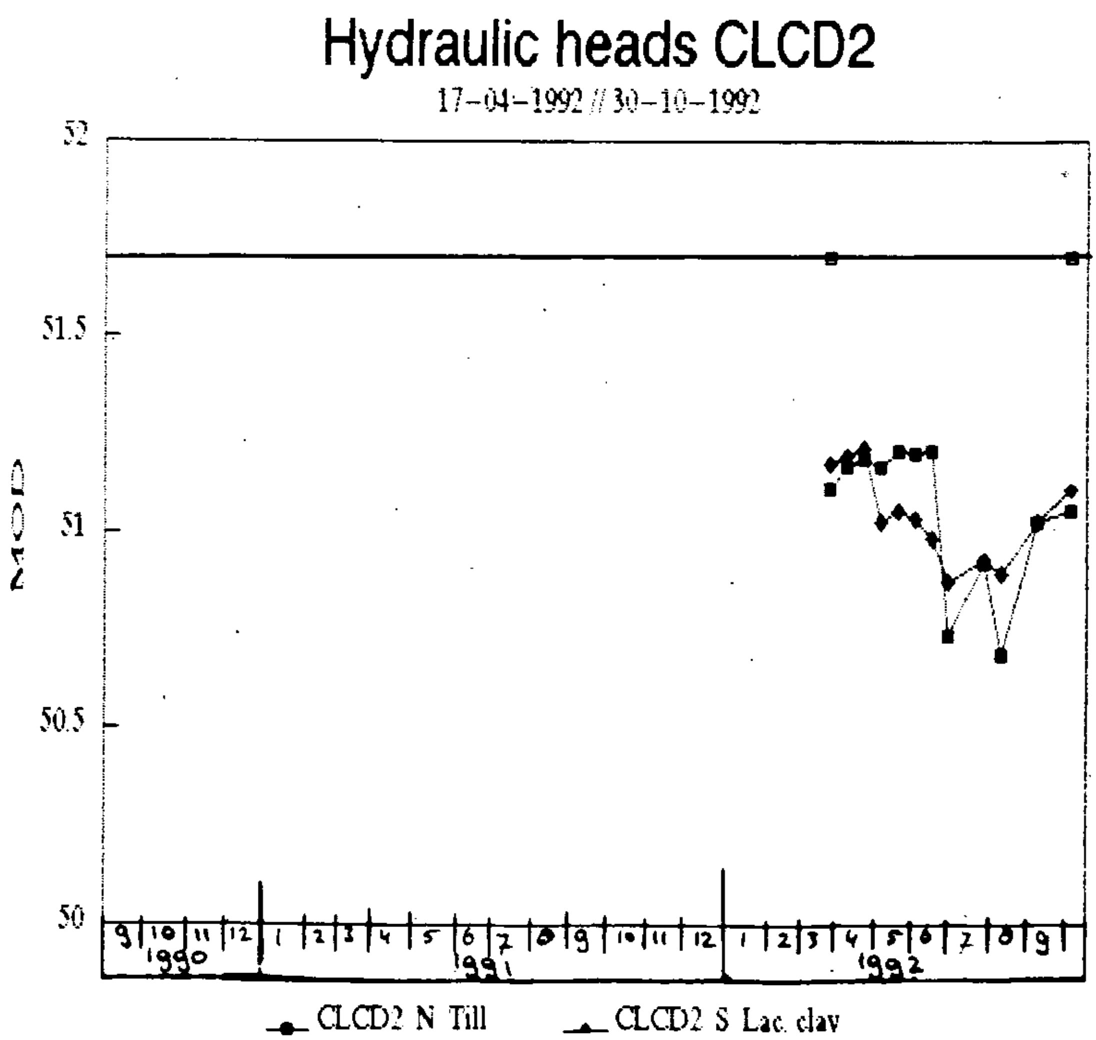
Hydraulic heads CLBH7

21-10-1991 // 30-10-1992



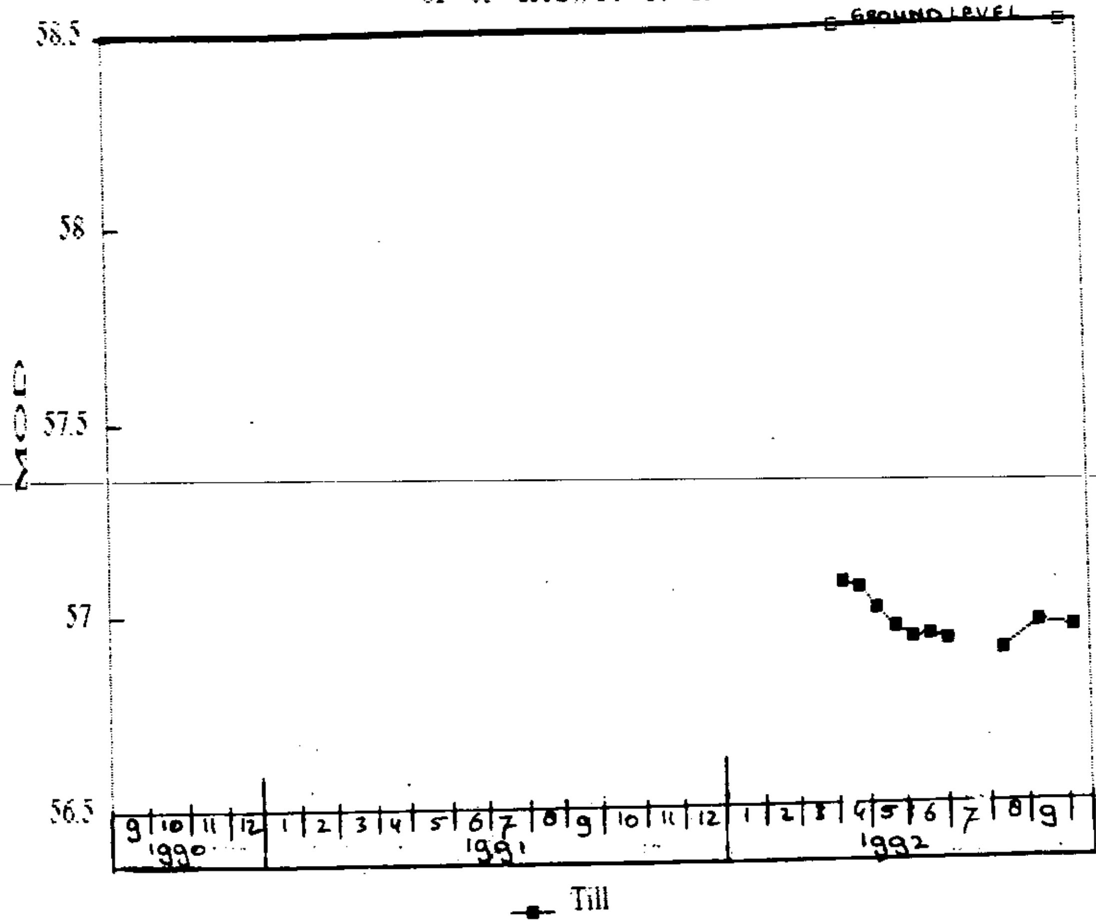
7.1 Limestone
7.2 Gravel


Hydraulic heads CLCD1
10-04-1992 // 30-10-1992
55.5
55
54.5
54
53.5
MOD
9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9
1990
1991
1992
Till


Hydraulic heads CLCD2
17-04-1992 // 30-10-1992
52
51.5
51
50.5
50
MOD
9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9
1990
1991
1992
CLCD2 N Till
CLCD2 S Lac. clay

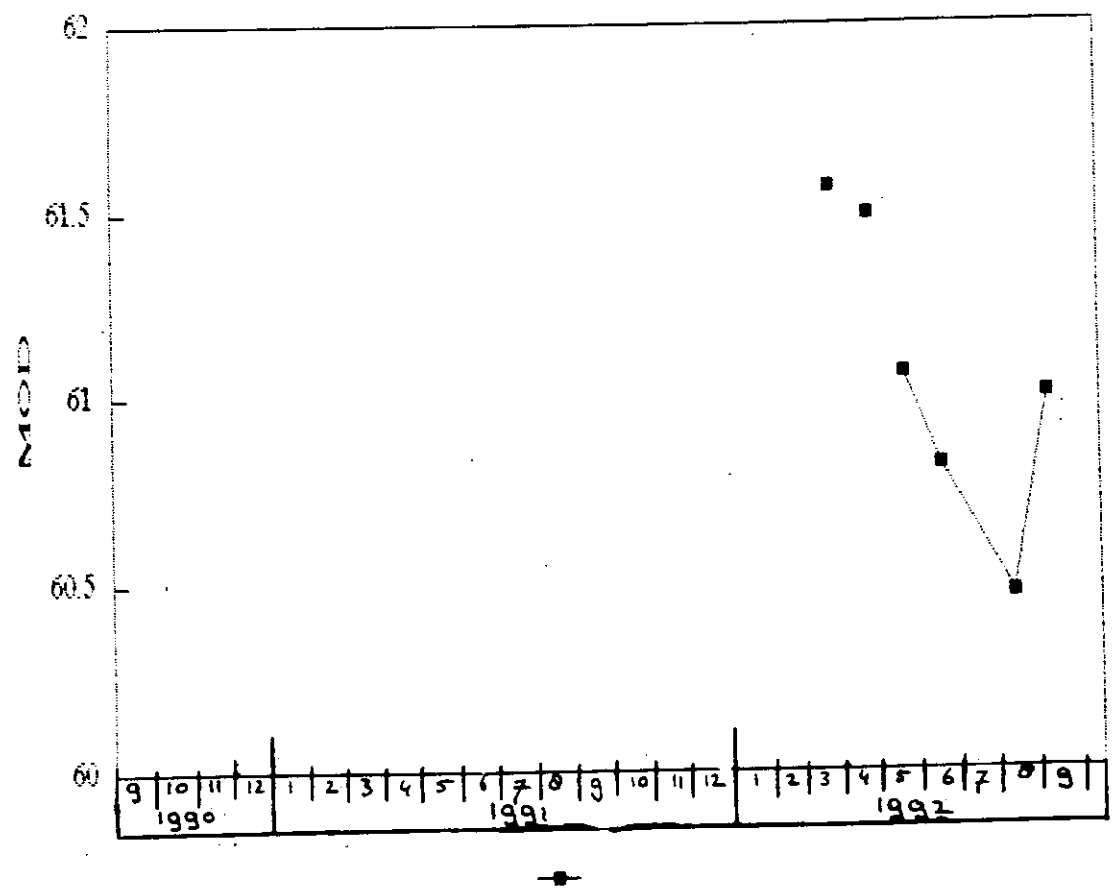
Hydraulic heads CLCD3

01-05-1992 // 30-10-1992



Hydraulic heads WELL_00

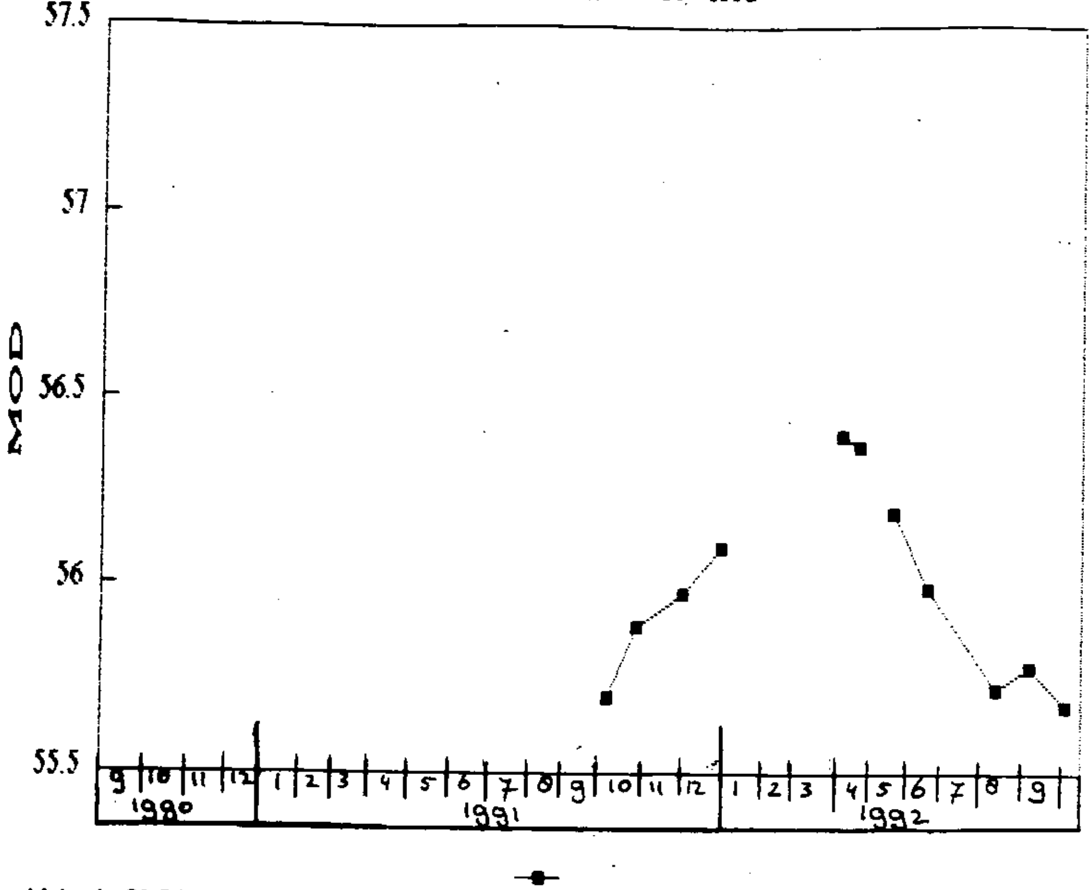
01-05-1992 // 30-10-1992



Altitude 67.0 MOD

Hydraulic heads WELL_02

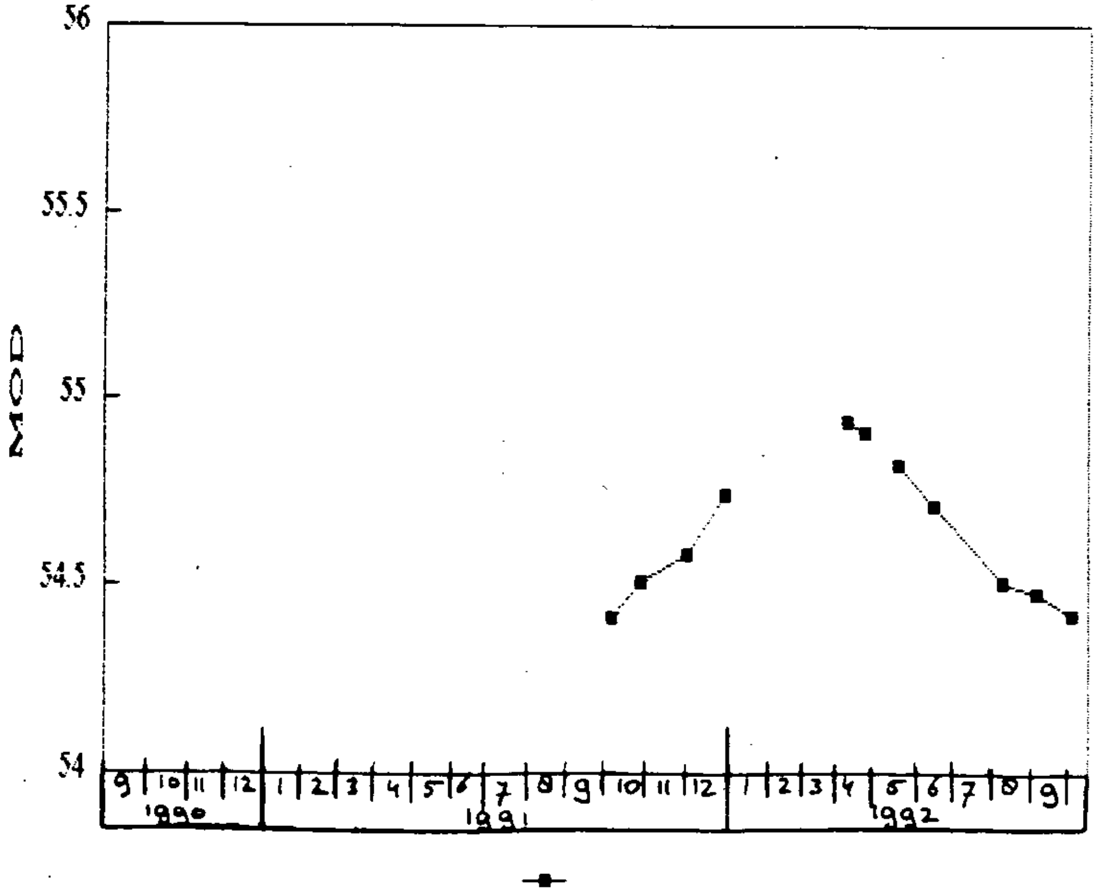
01-05-1992 // 30-10-1992



Altitude 58.5 MOD

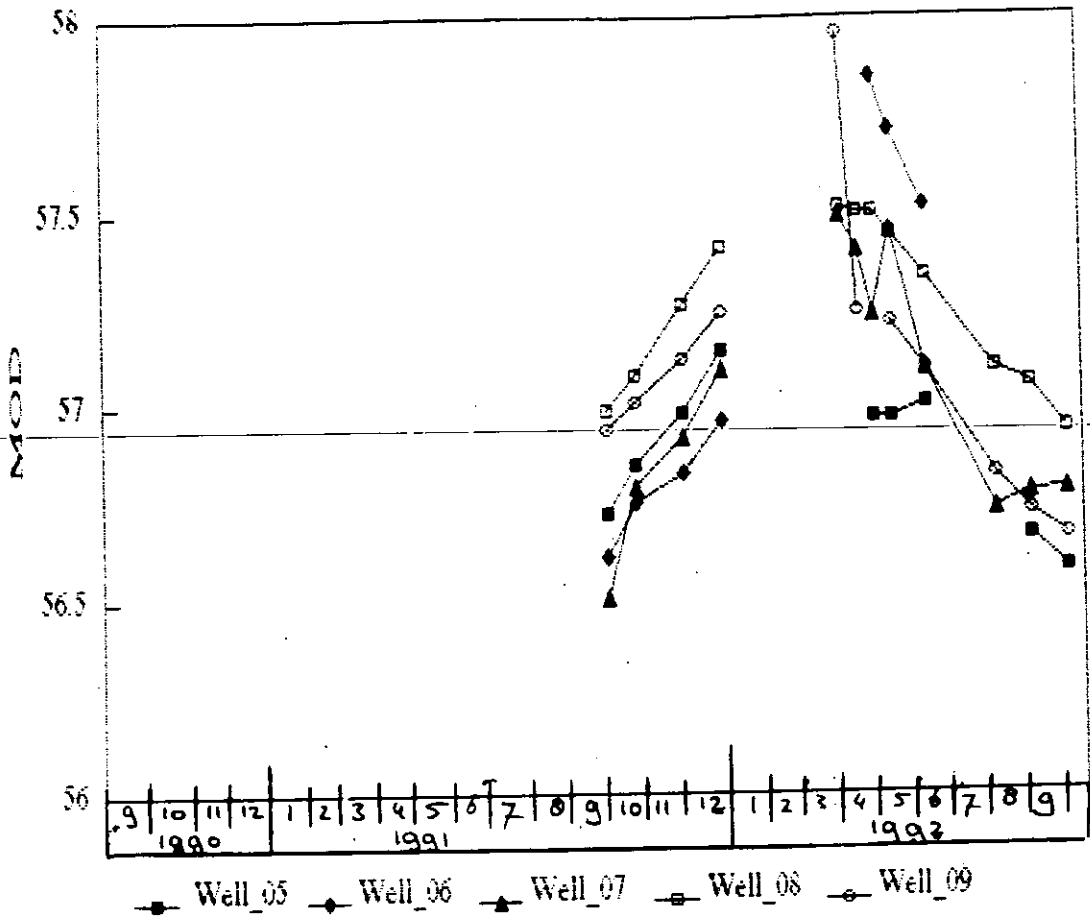
Hydraulic heads WELL_03

01-05-1992 // 30-10-1992



Altitude 57.7 MOD

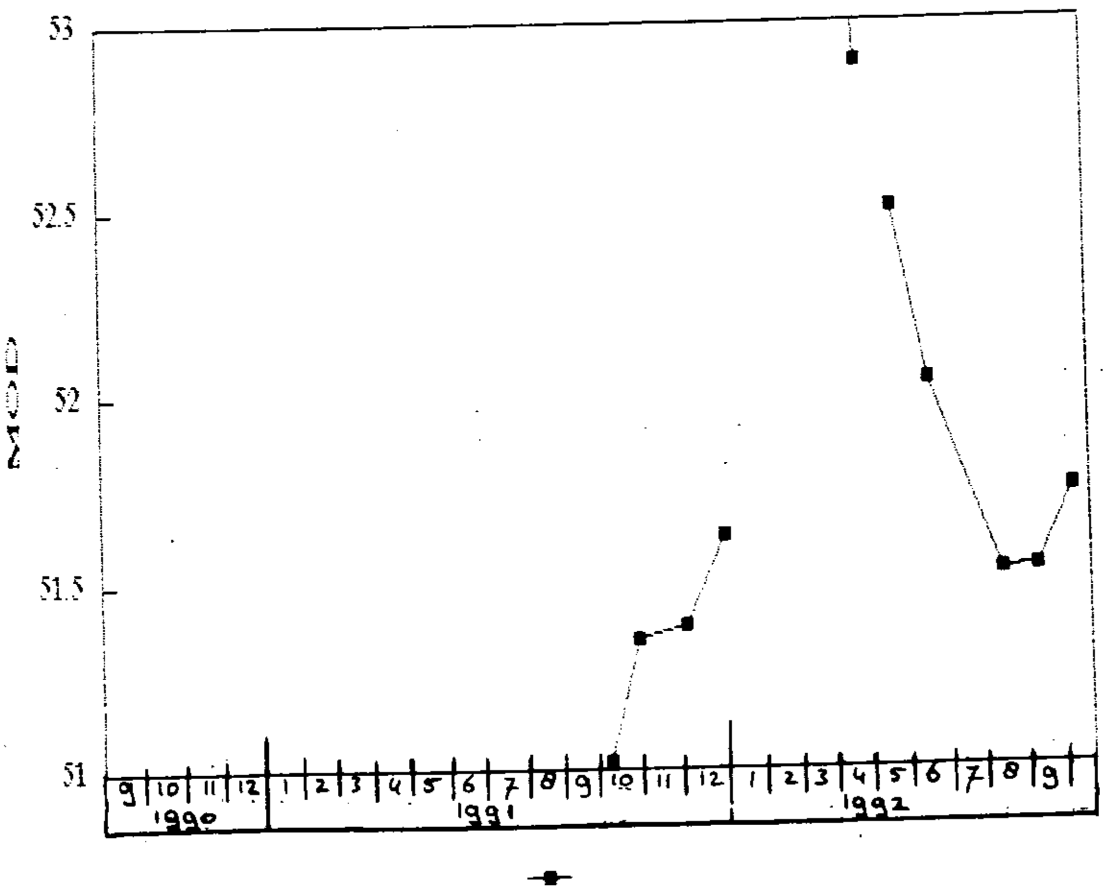
Hydraulic heads WELLS, north – east of Clara Bog
01 – 05 – 1992 // 30 – 10 – 1992



Altitude 60.0 – 60.9 MOD

Hydraulic heads WELL_15

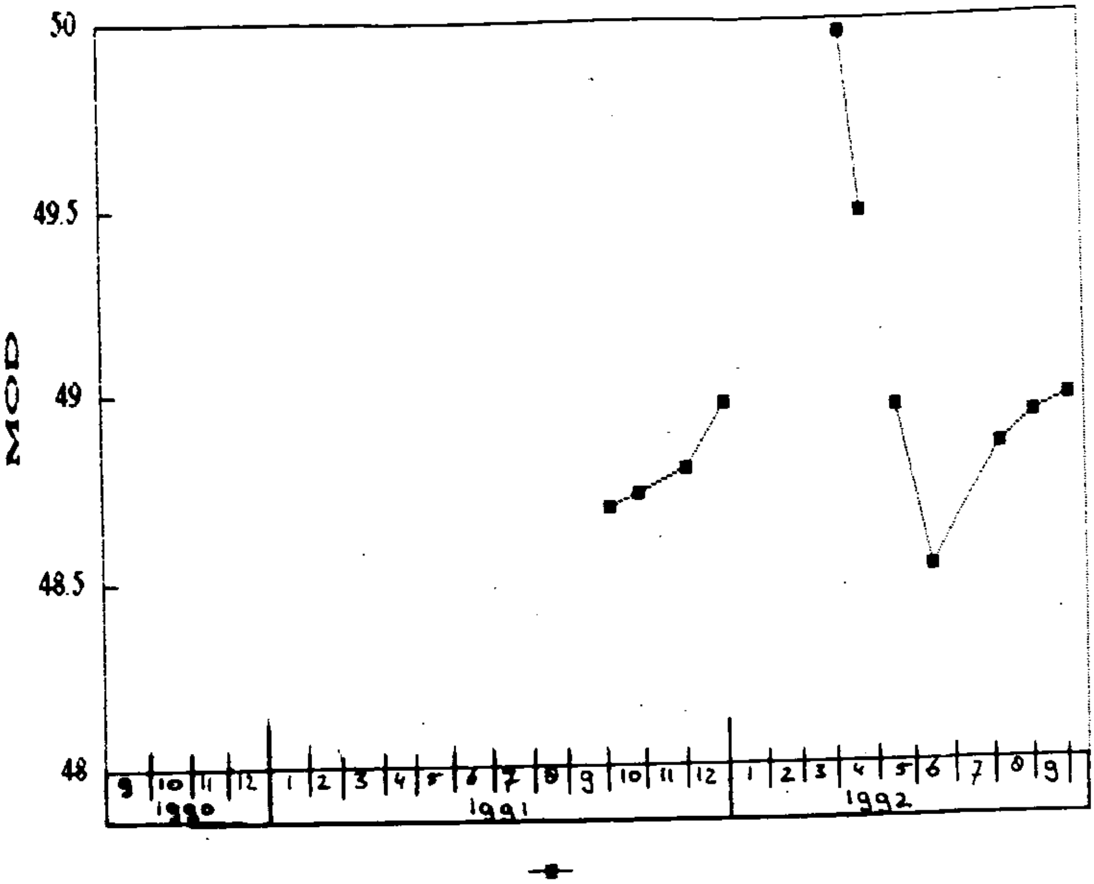
01 – 05 – 1992 // 30 – 10 – 1992



Altitude 54.1 MOD

Hydraulic heads WELL_16

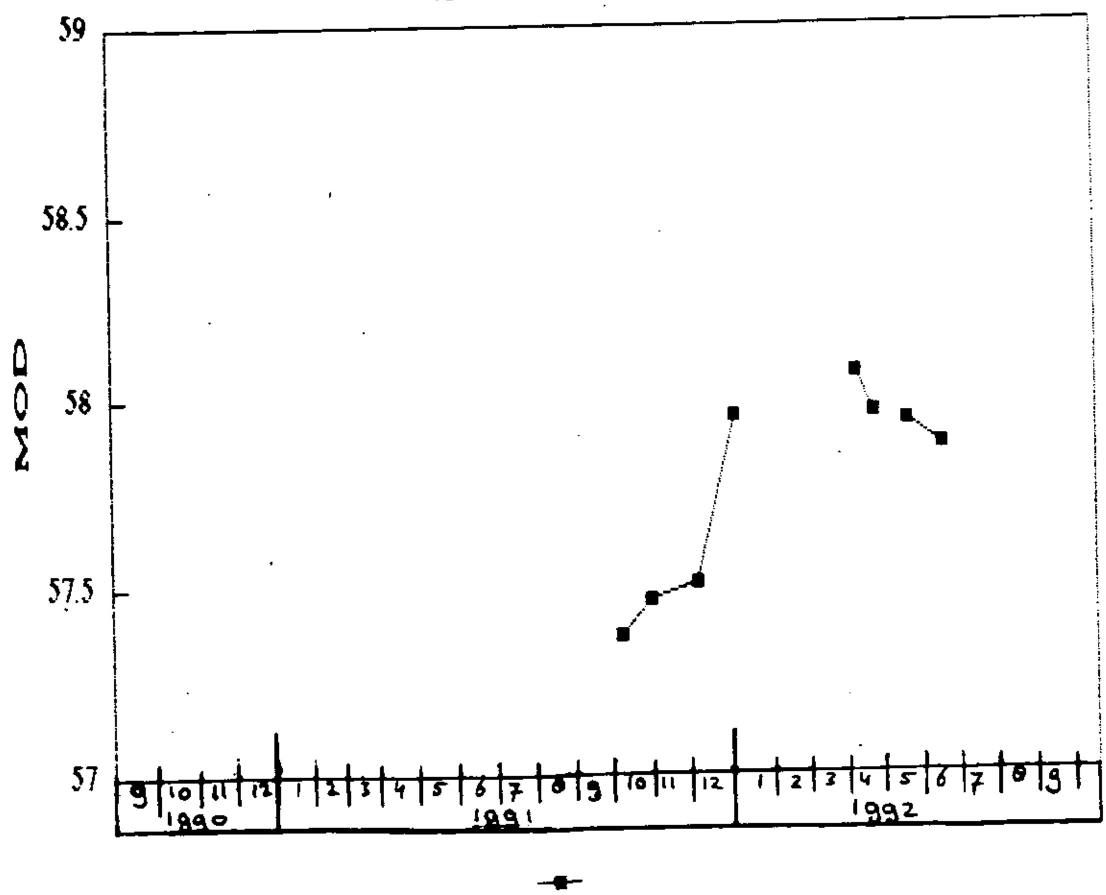
01-05-1992 // 30-10-1992



Altitude 51.15 MOD

Hydraulic heads WELL_19

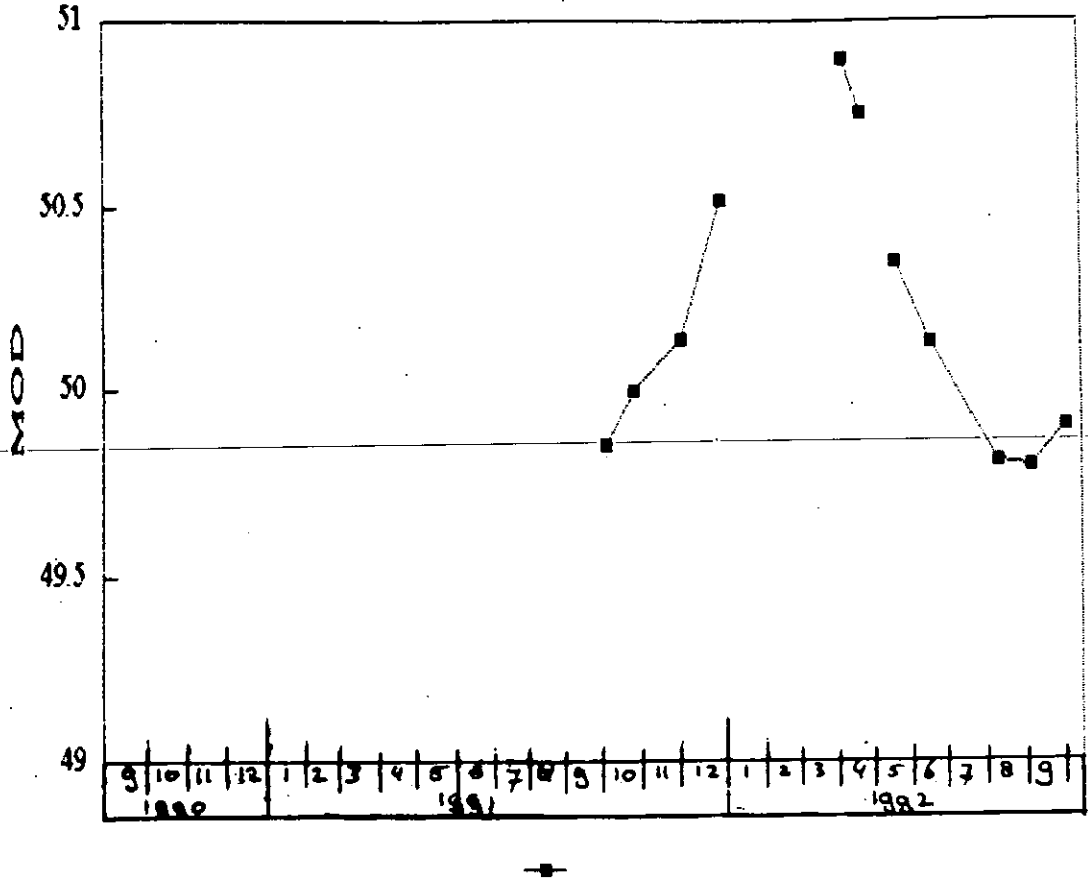
01-05-1992 // 30-10-1992



Altitude 70.3 MOD

Hydraulic heads WELL_20

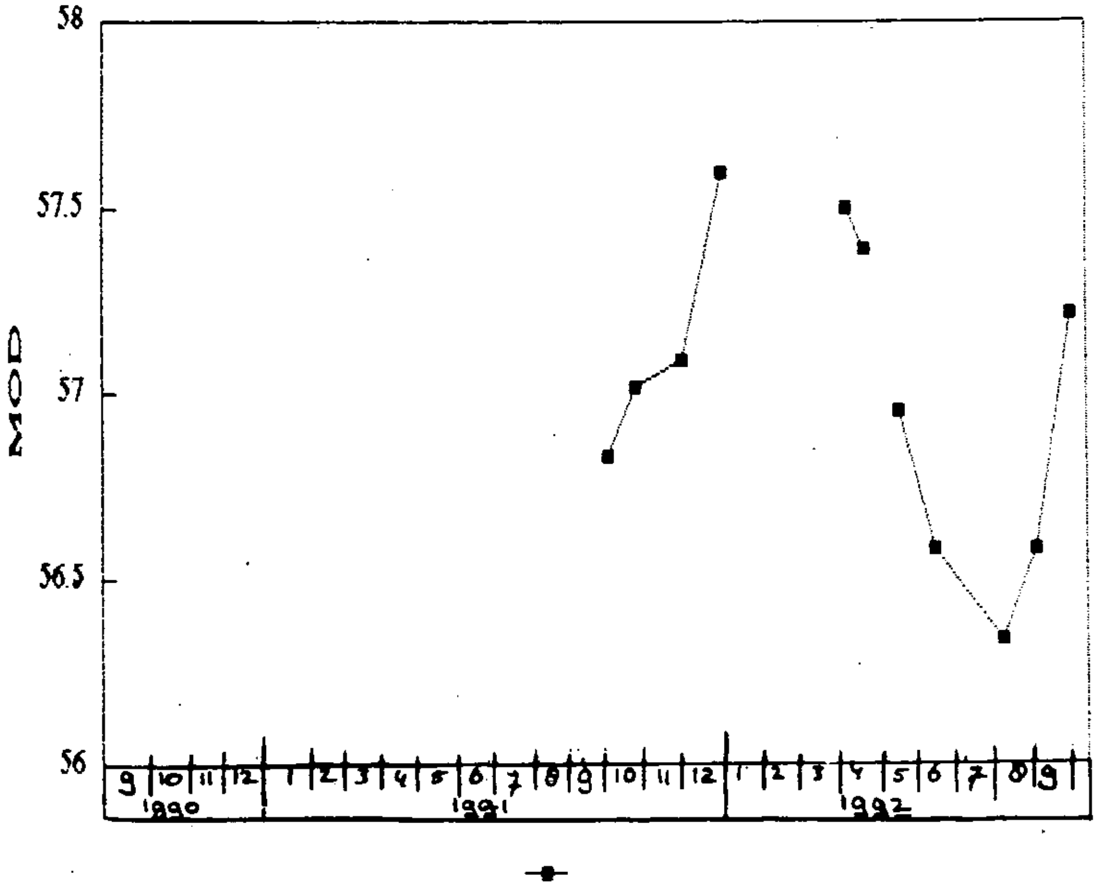
01-05-1992 // 30-10-1992



Altitude 54.03 MOD

Hydraulic heads WELL_21

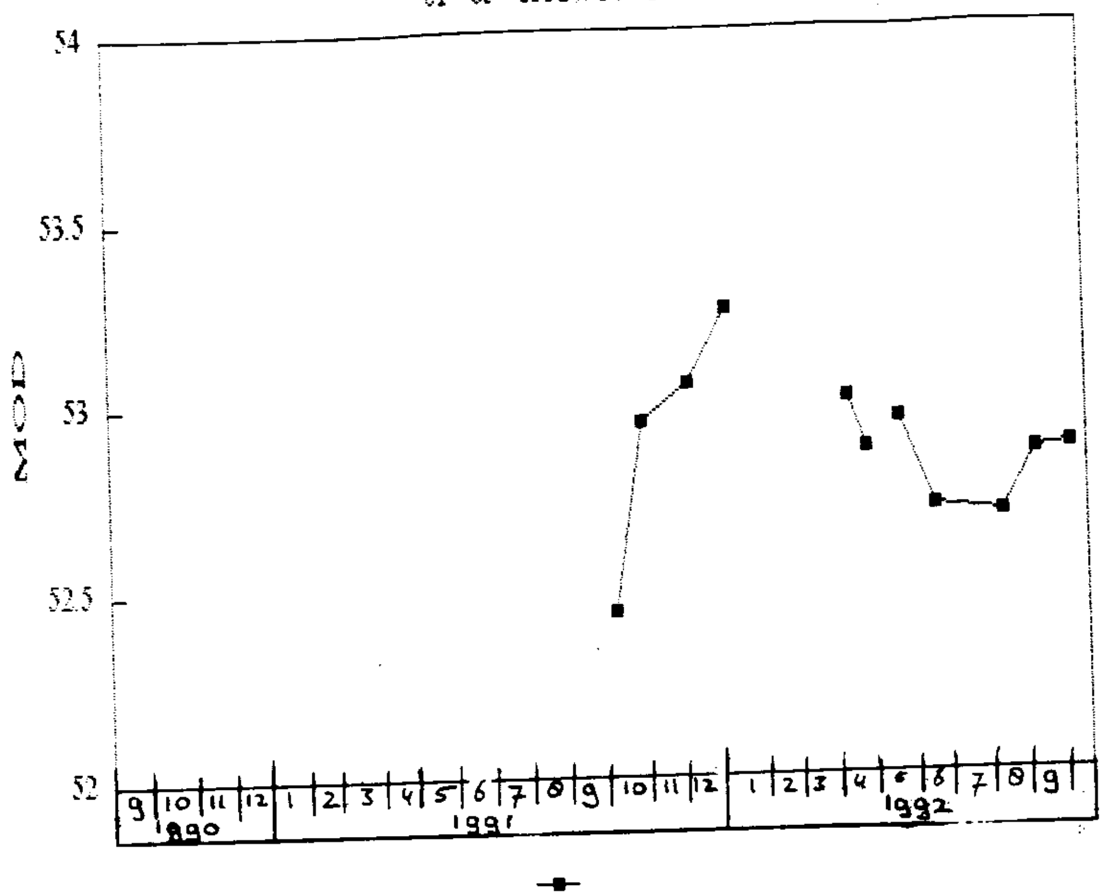
01-05-1992 // 30-10-1992



Altitude 60.04 MOD

Hydraulic heads WELL_22

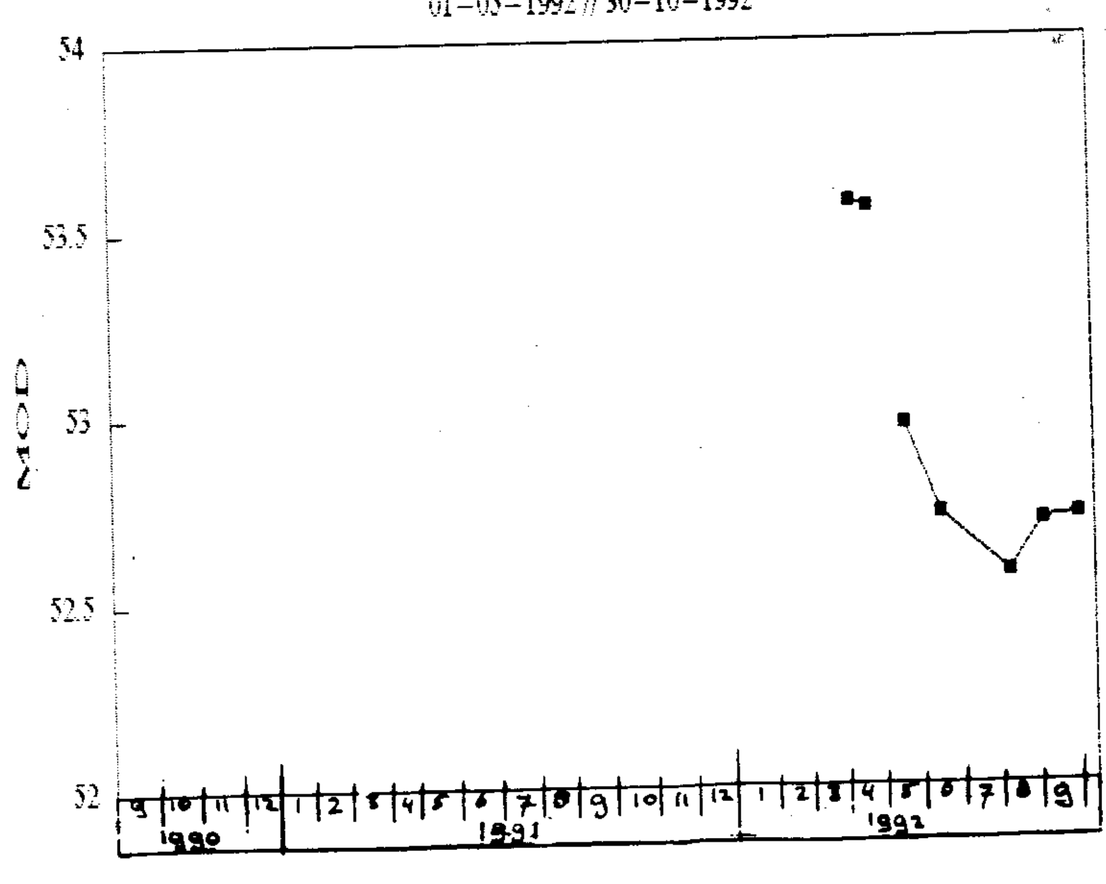
01-05-1992 // 30-10-1992



Altitude 55.41 MOD

Hydraulic heads WELL_23

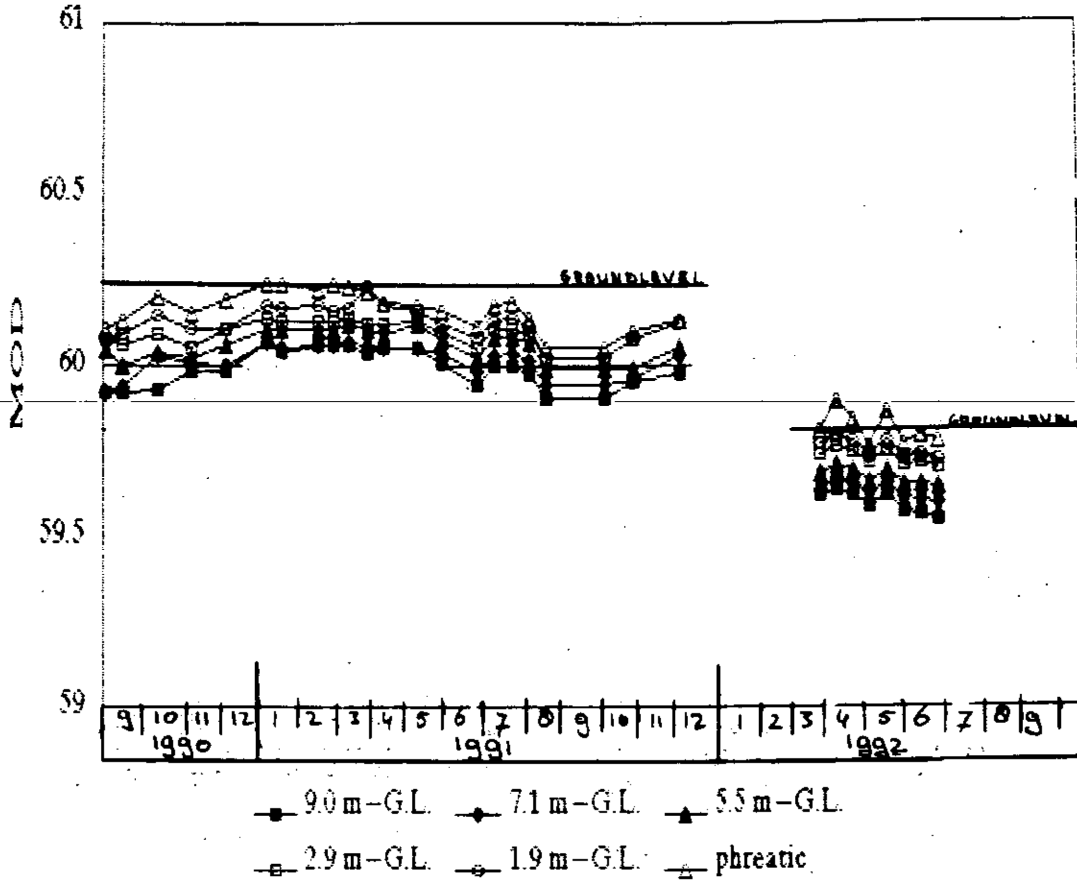
01-05-1992 // 30-10-1992



Altitude 57.85 MOD

Hydraulic heads 113, CLARA EAST

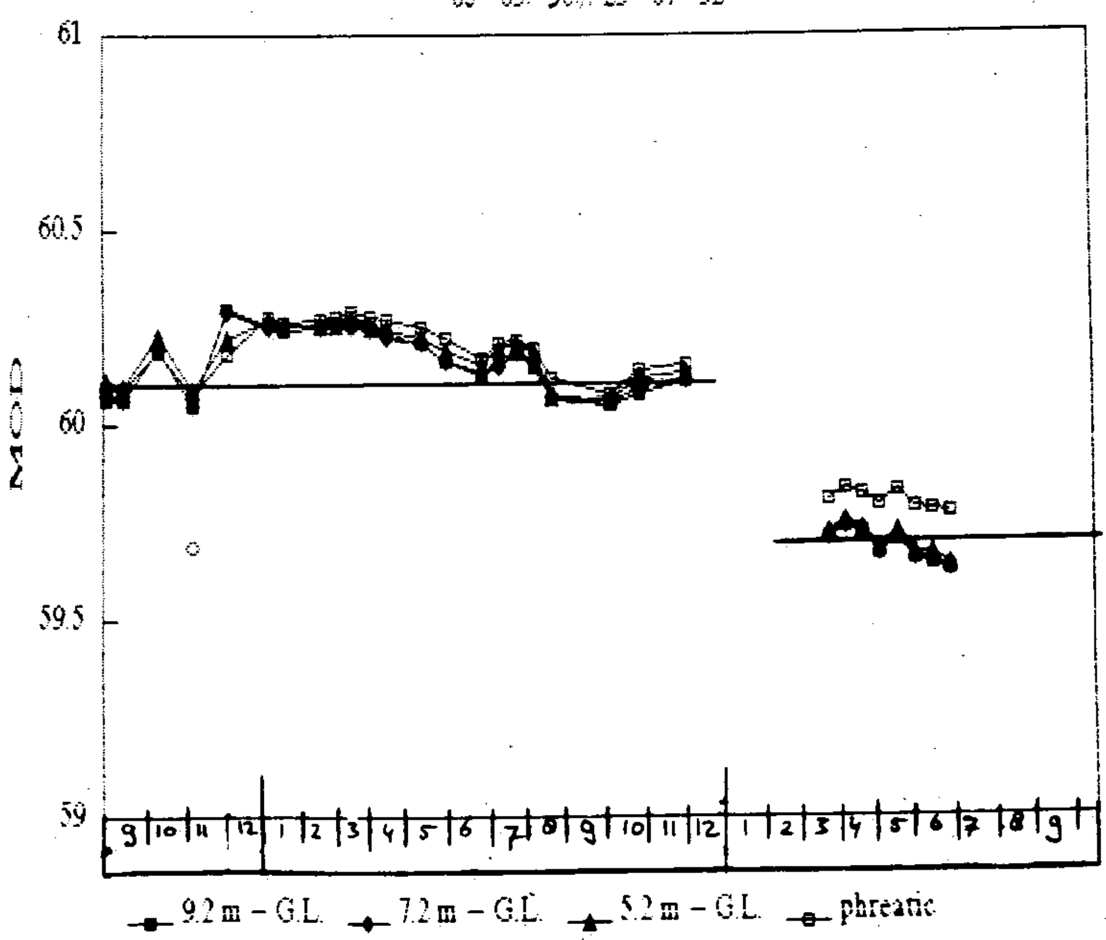
05-09-90 // 23-07-92



Altitude 59.8 MOD

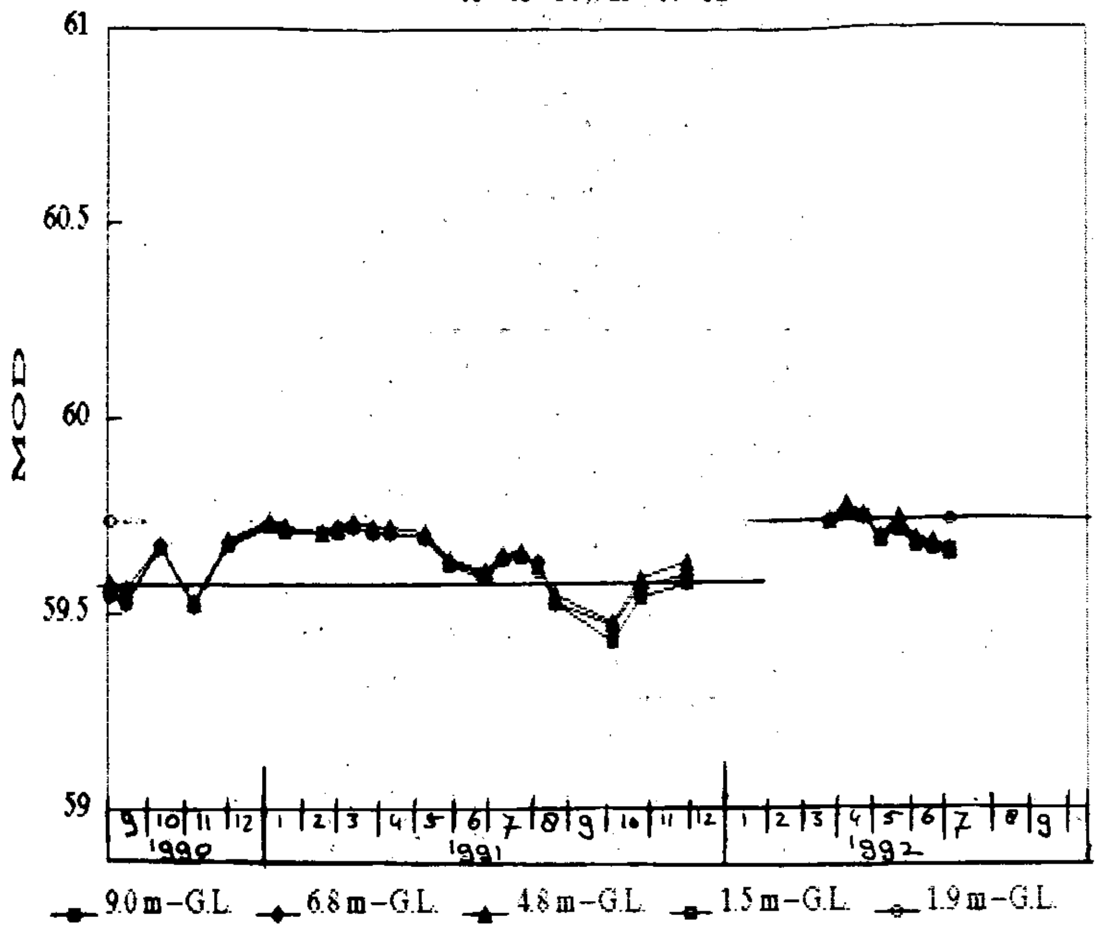
Hydraulic heads 114, CLARA EAST

05-09-90 // 23-07-92



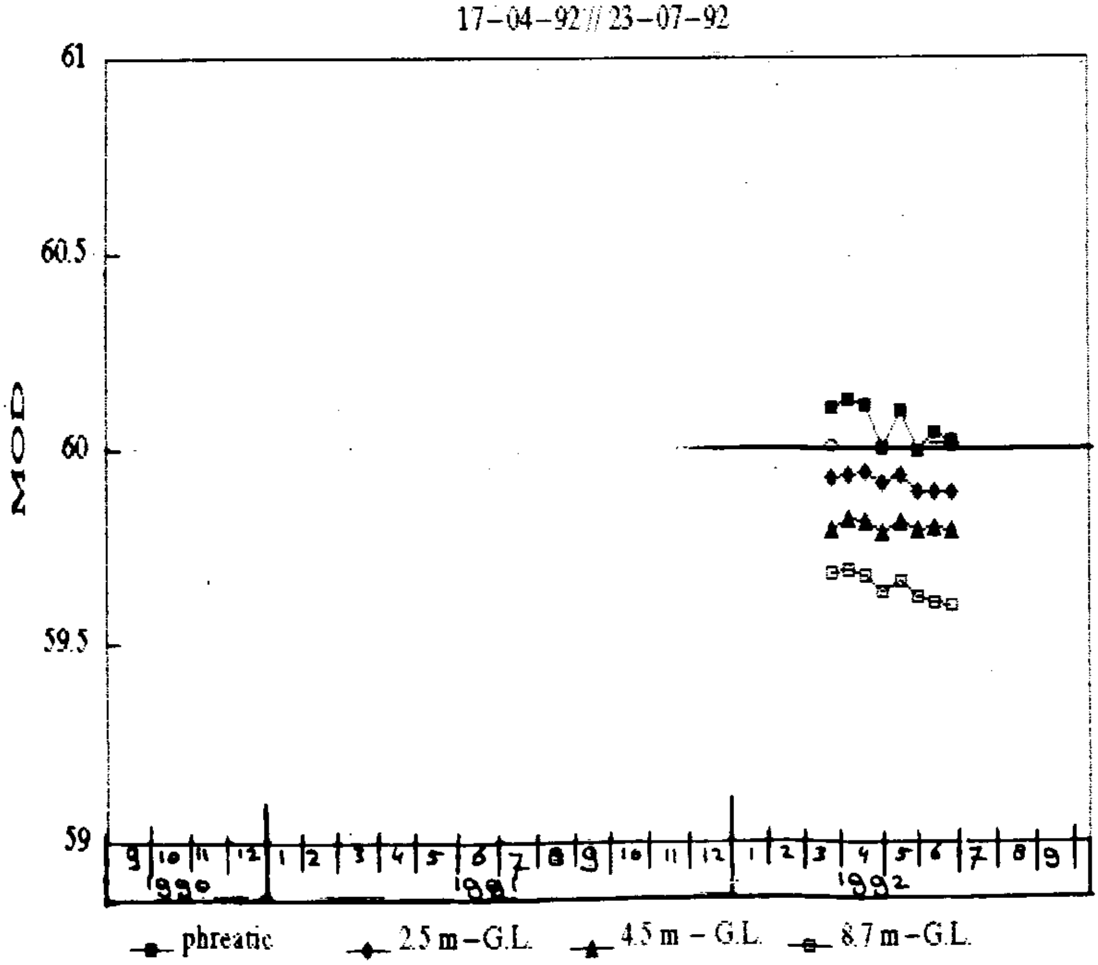
Hydraulic heads 119, CLARA EAST

05-09-90 // 23-07-92



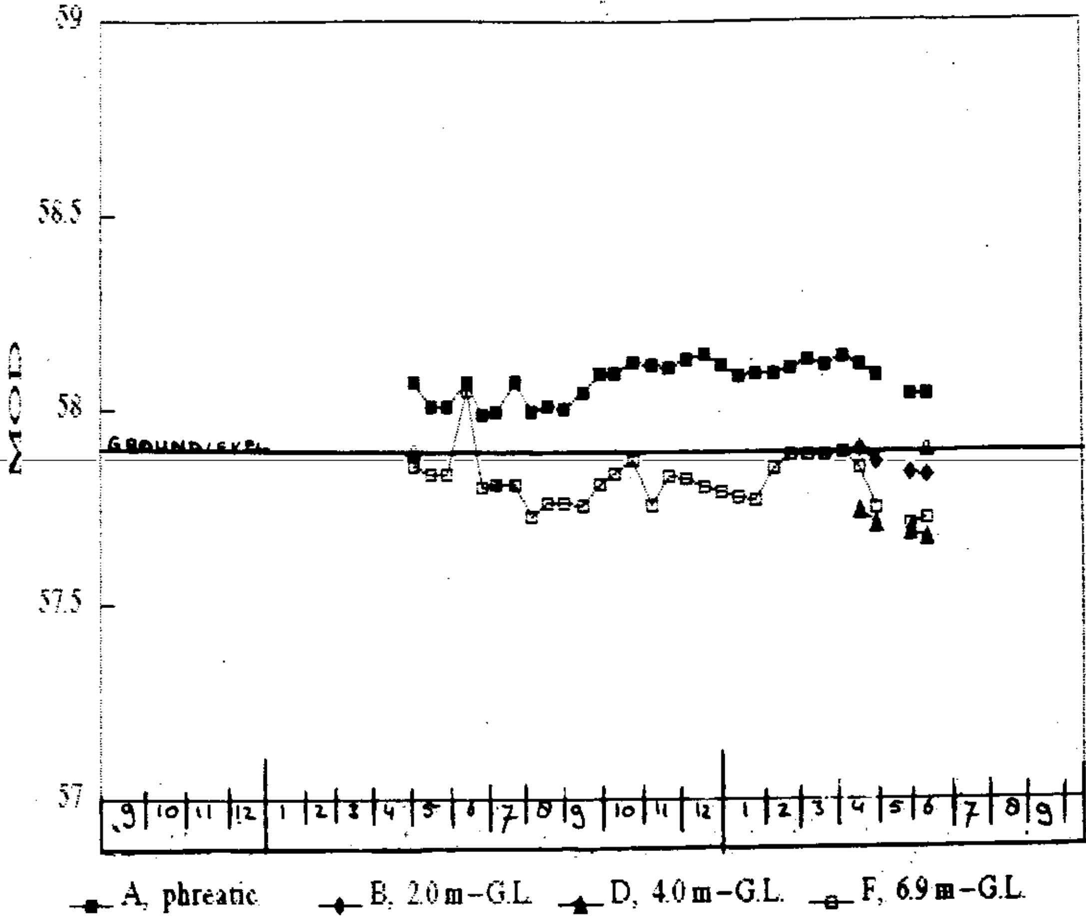
Hydraulic heads 120, CLARA EAST

17-04-92 // 23-07-92



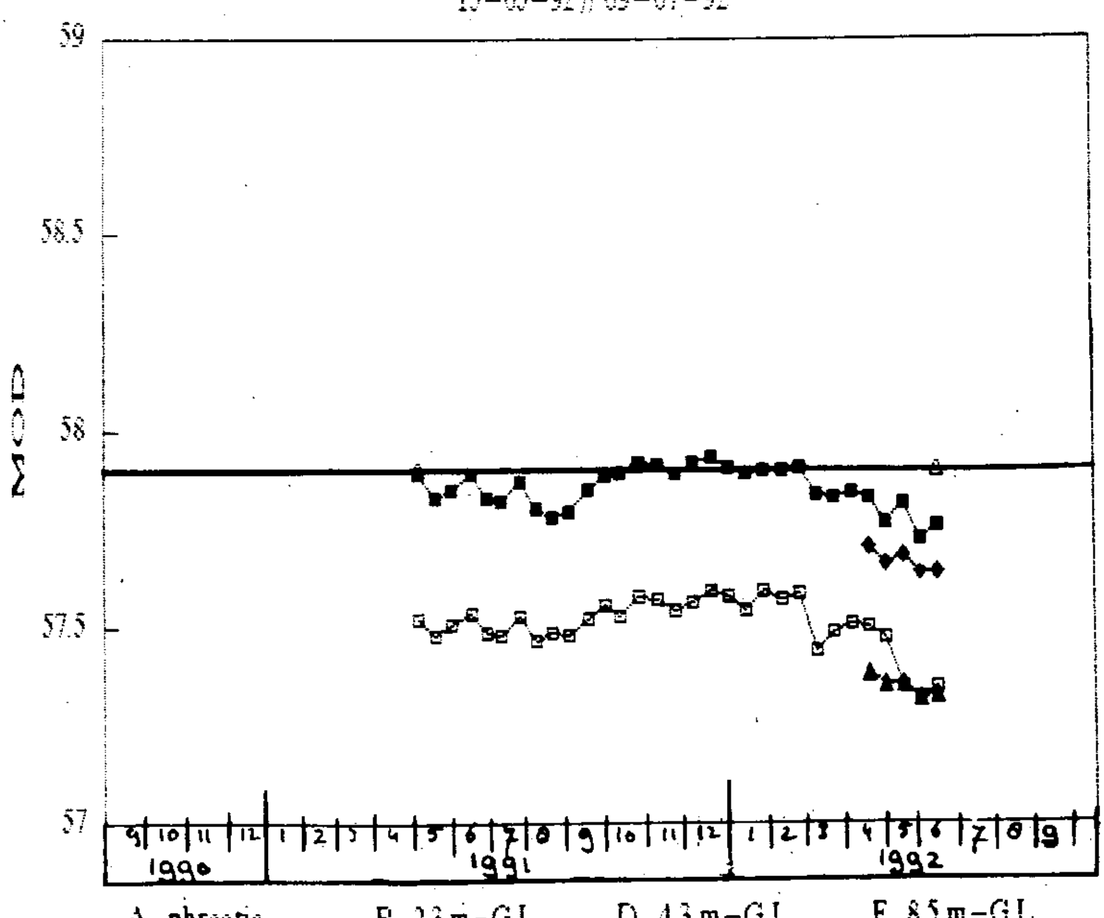
Hydraulic heads 46, CLARA WEST

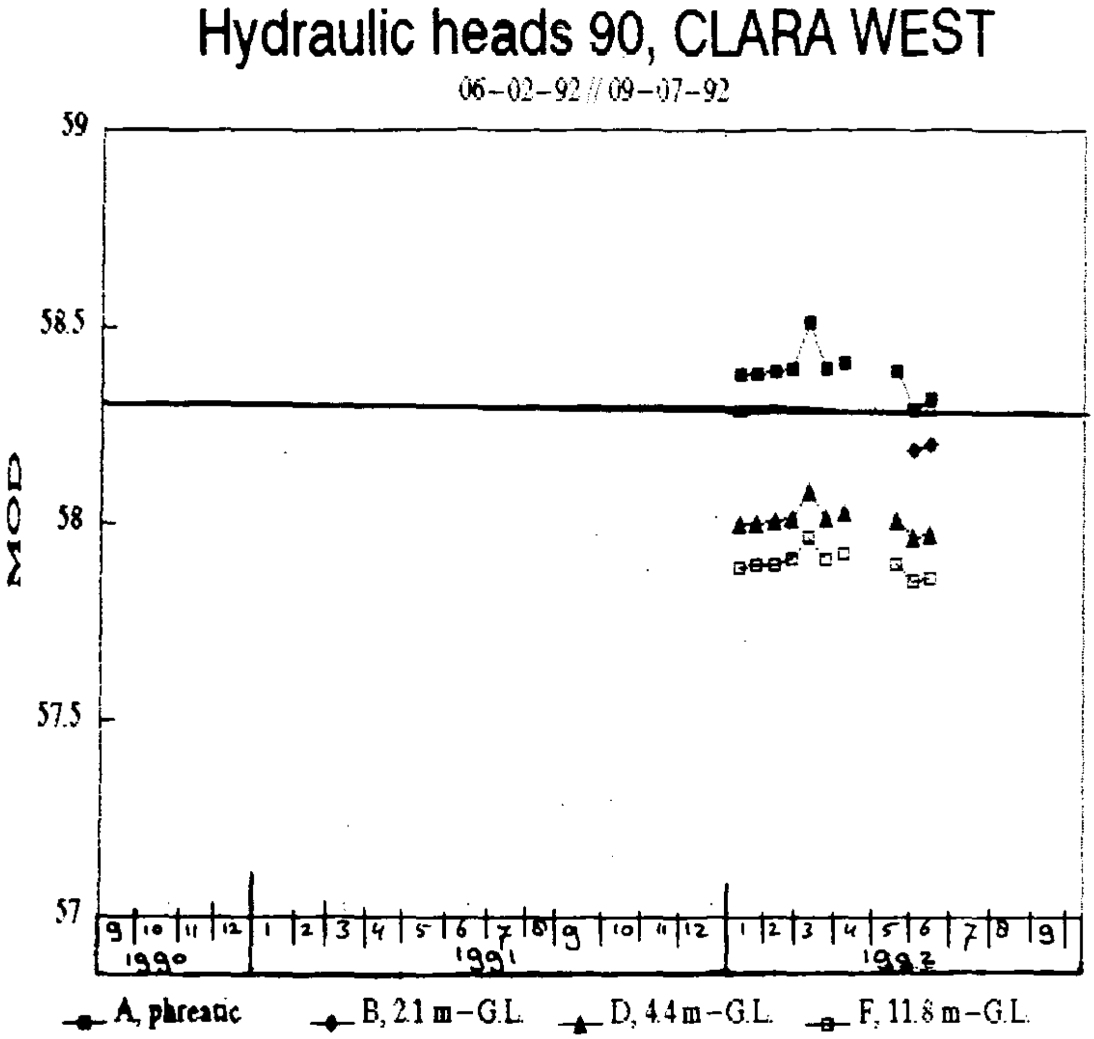
15-05-91 // 09-07-92



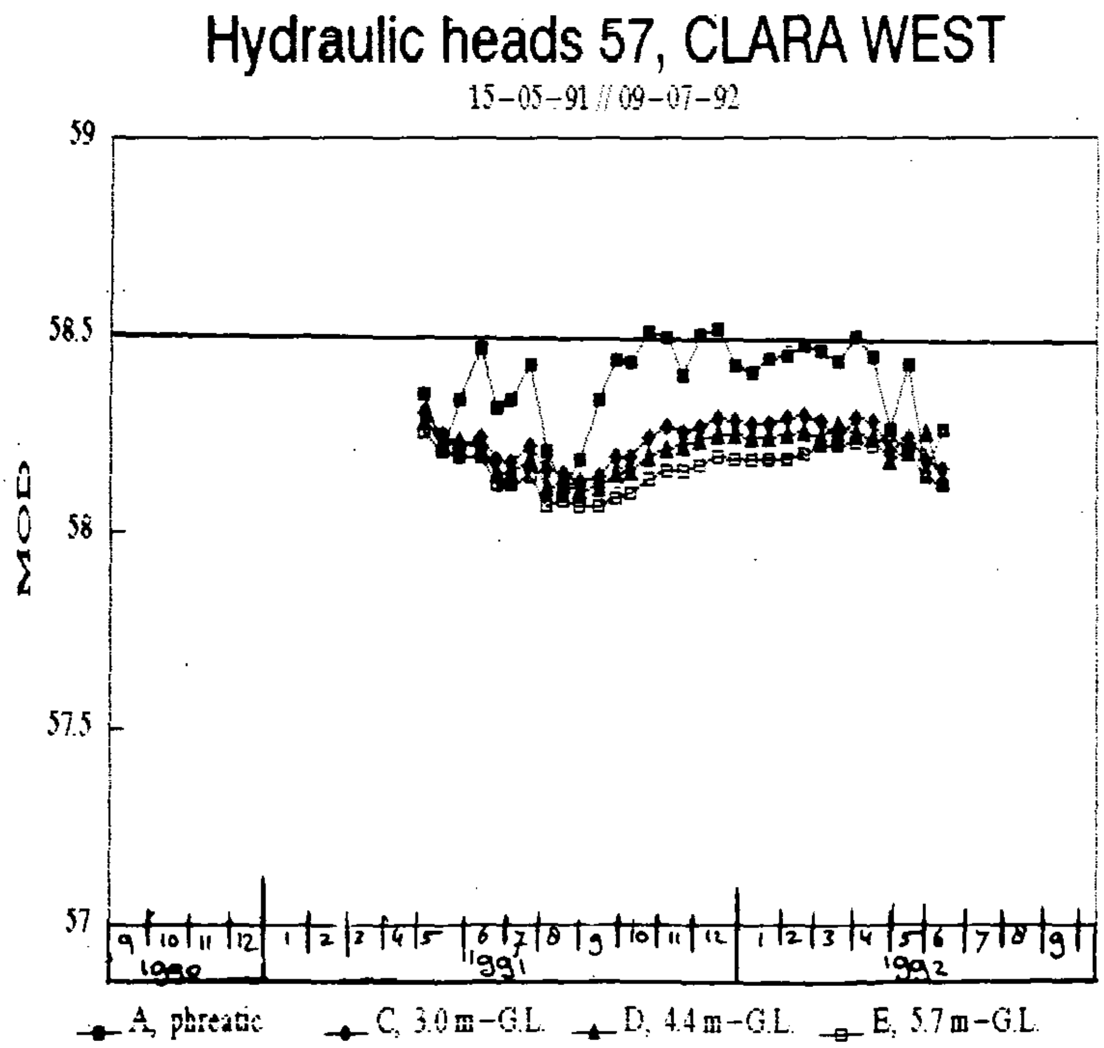
Hydraulic heads 54, CLARA WEST

15-05-92 // 09-07-92





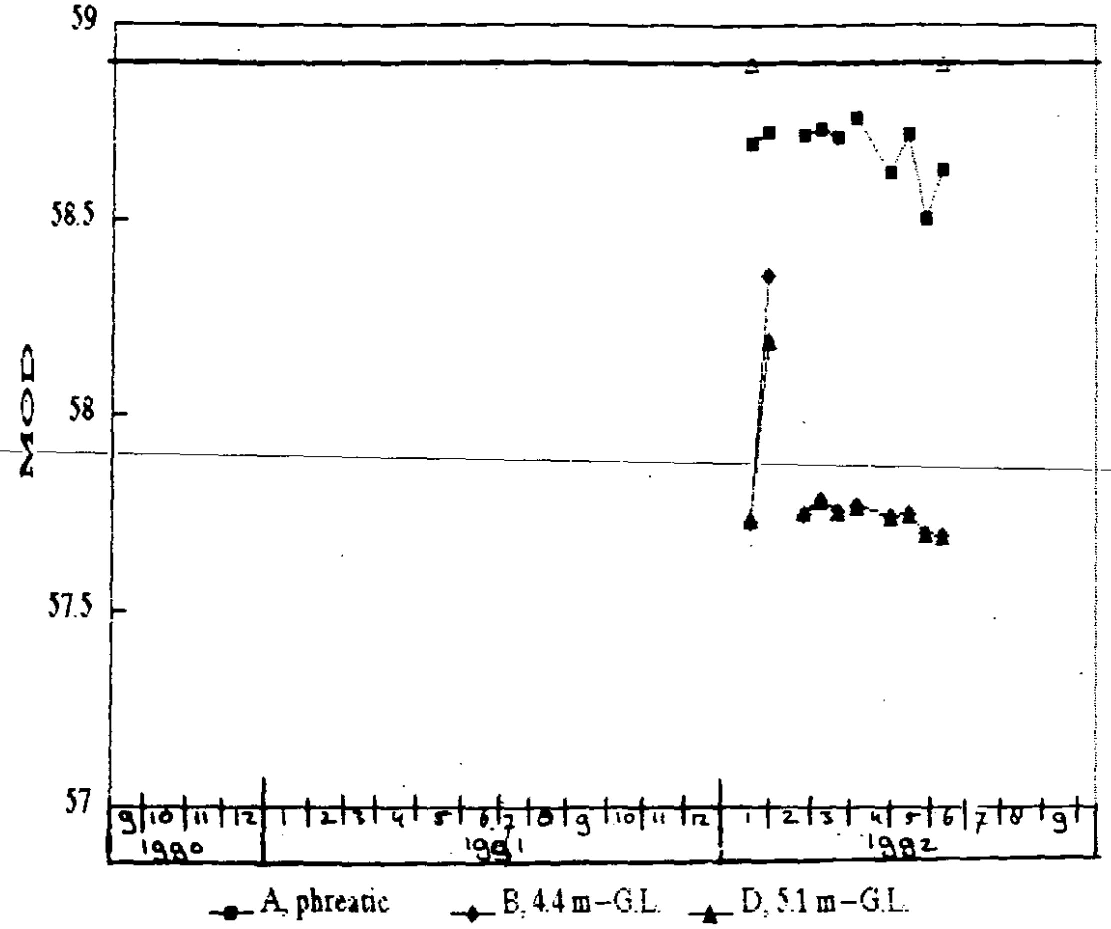
Hydraulic heads 90, CLARA WEST
06-02-92 // 09-07-92
59
58.5
58
57.5
57
MOD
9
10
11
12
1990
1991
1992
A, phreatic
B, 2.1 m-G.L.
D, 4.4 m-G.L.
F, 11.8 m-G.L.



Hydraulic heads 57, CLARA WEST
15-05-91 // 09-07-92
59
58.5
58
57.5
57
MOD
1990
1991
1992
A, phreatic
C, 3.0 m-G.L.
D, 4.4 m-G.L.
E, 5.7 m-G.L.

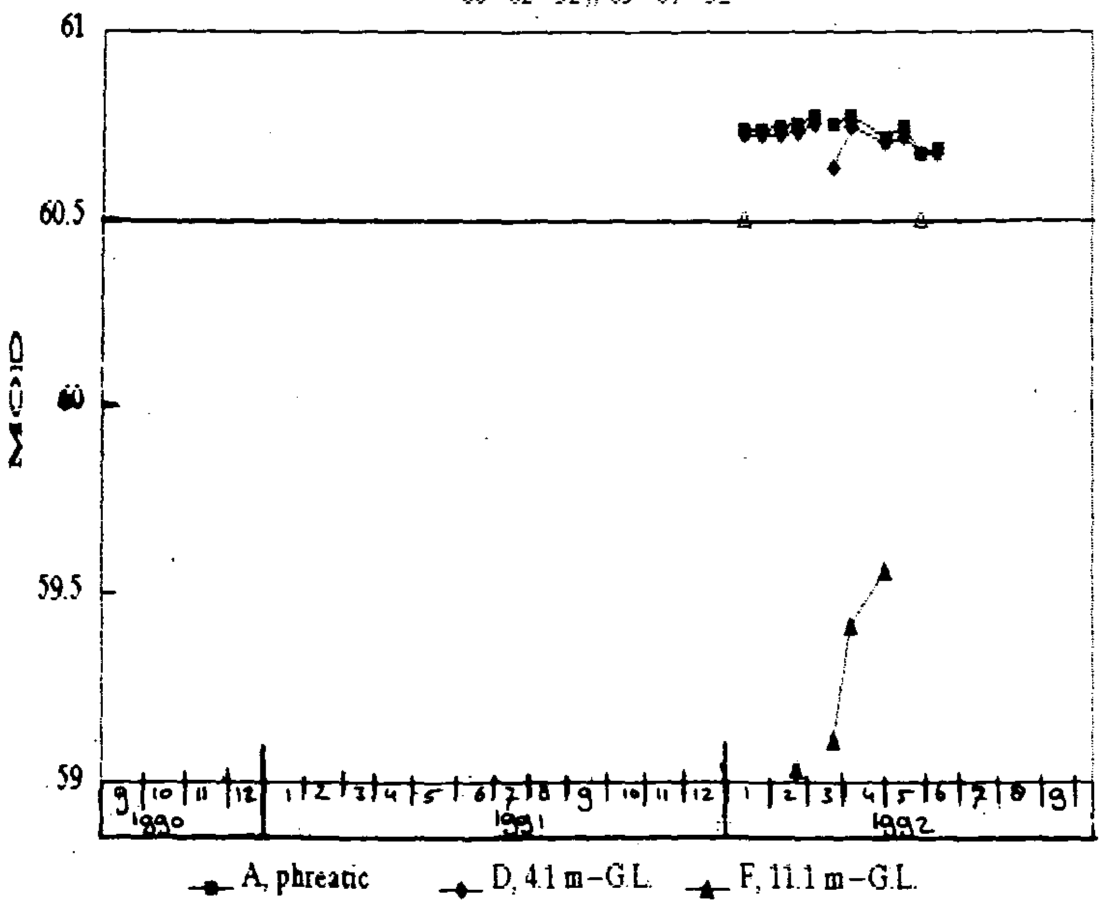
Hydraulic heads 92, CLARA WEST

06-02-92 // 09-07-92

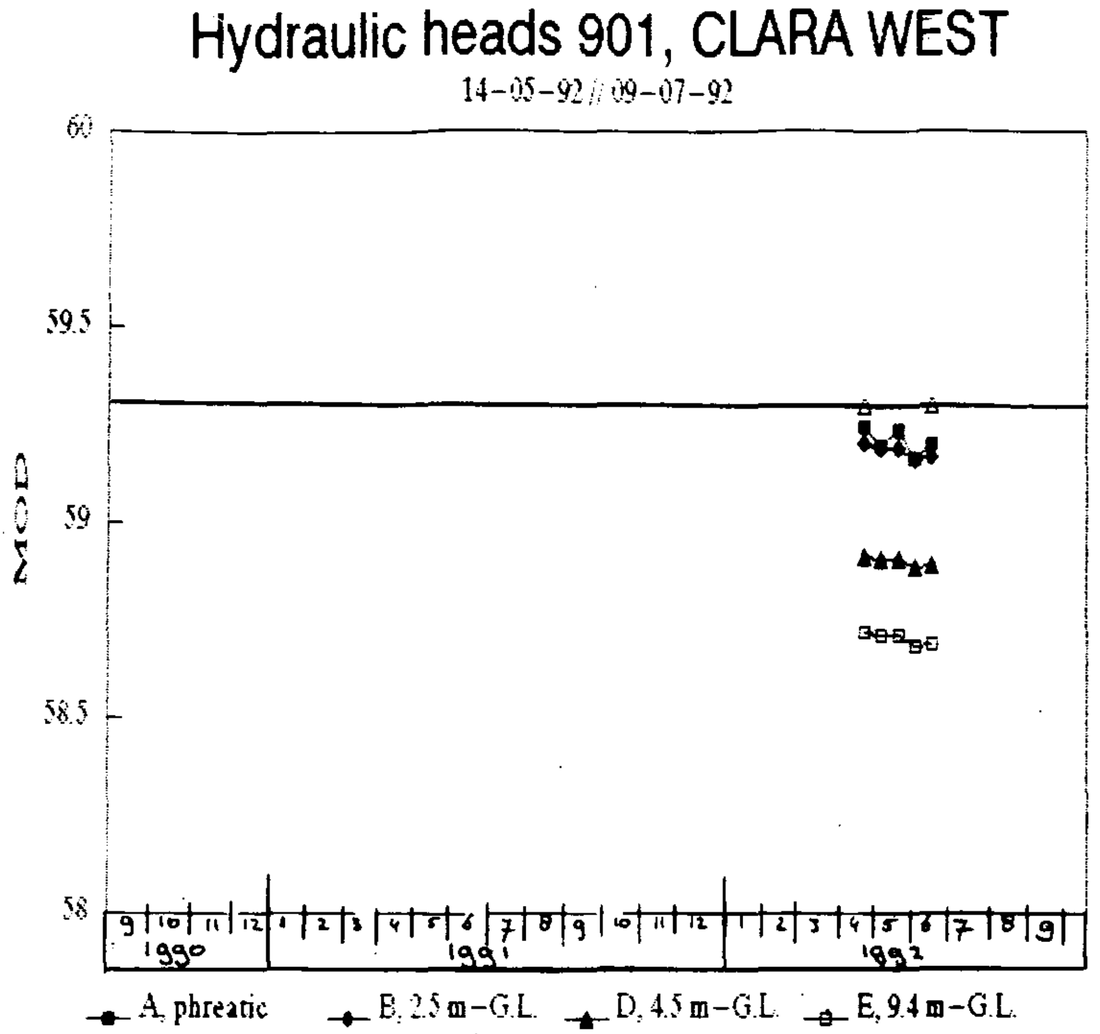


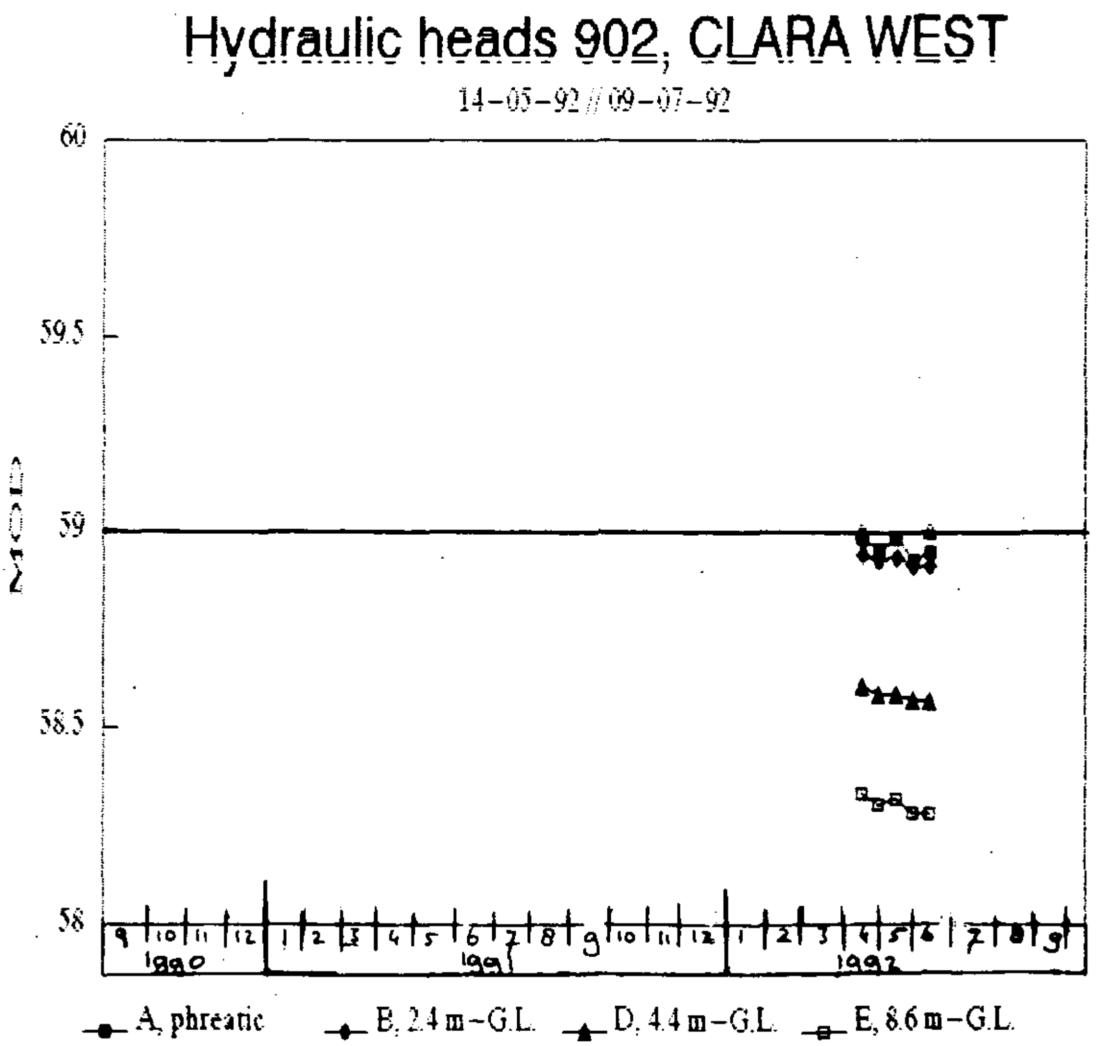
Hydraulic heads 96, CLARA WEST

06-02-92 // 09-07-92



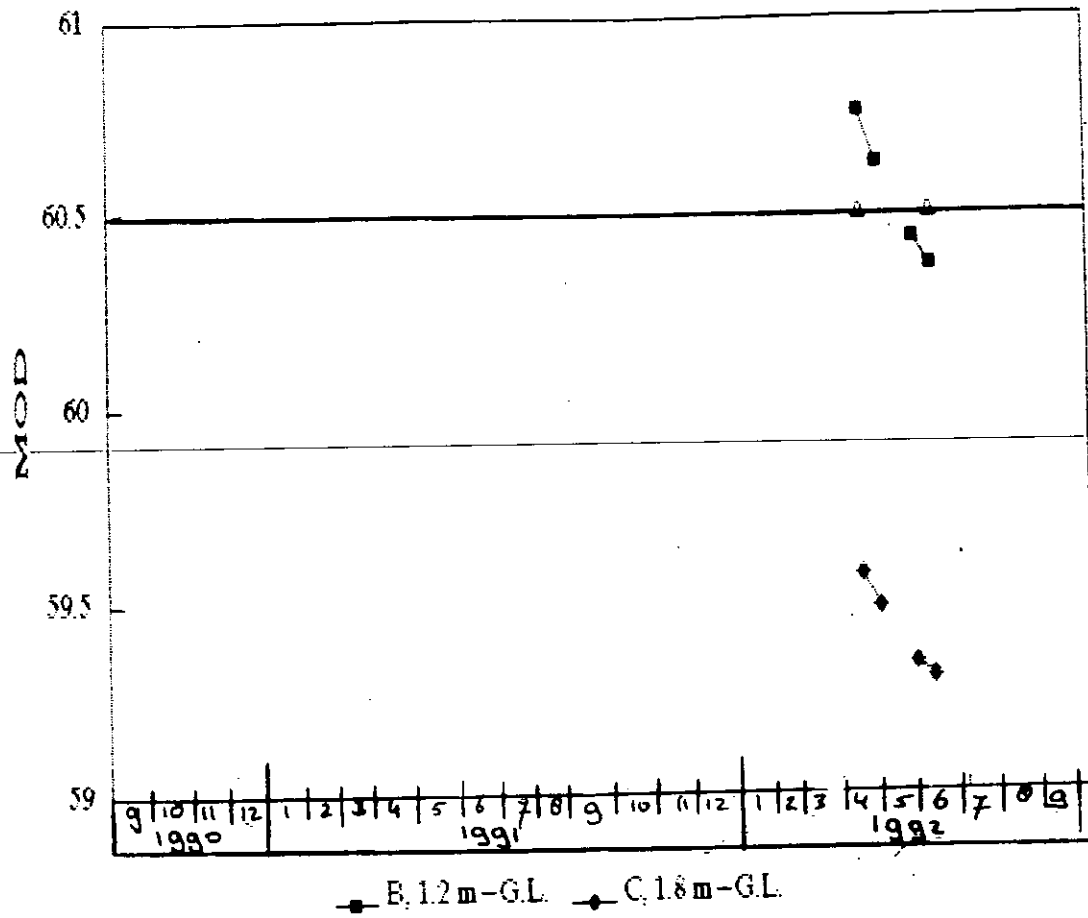
First data of 96.F are not used.


Hydraulic heads 901, CLARA WEST
14-05-92 // 09-07-92
MOD
60
59.5
59
58.5
58
1990
1991
1992
A, phreatic
B, 2.5 m-G.L.
D, 4.5 m-G.L.
E, 9.4 m-G.L.


Hydraulic heads 902, CLARA WEST
14-05-92 // 09-07-92
MOD
60
59.5
59
58.5
58
1990
1991
1992
A, phreatic
B, 2.4 m-G.L.
D, 4.4 m-G.L.
E, 8.6 m-G.L.

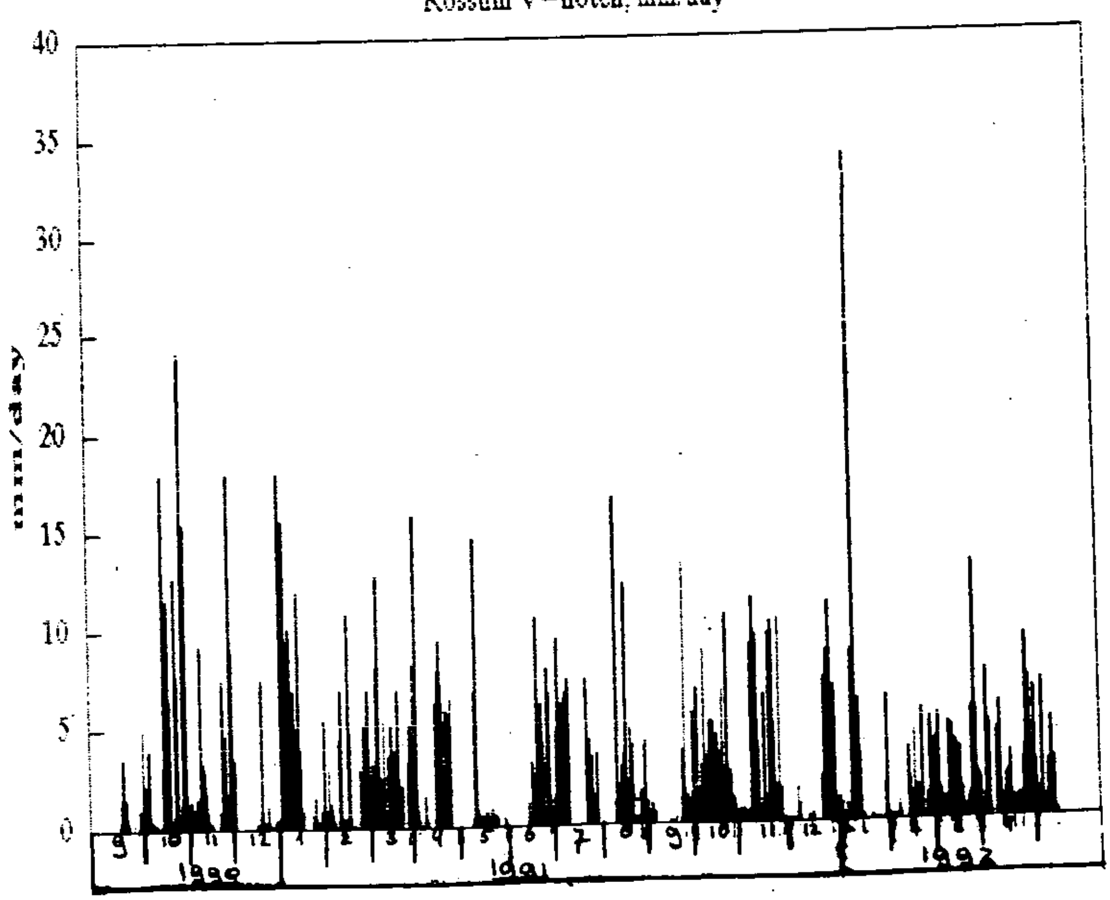
Hydraulic heads 903, CLARA WEST

14-05-92 // 09-07-92



PRECIPITATION CLARA BOG

Rossum V-notch, mm/day

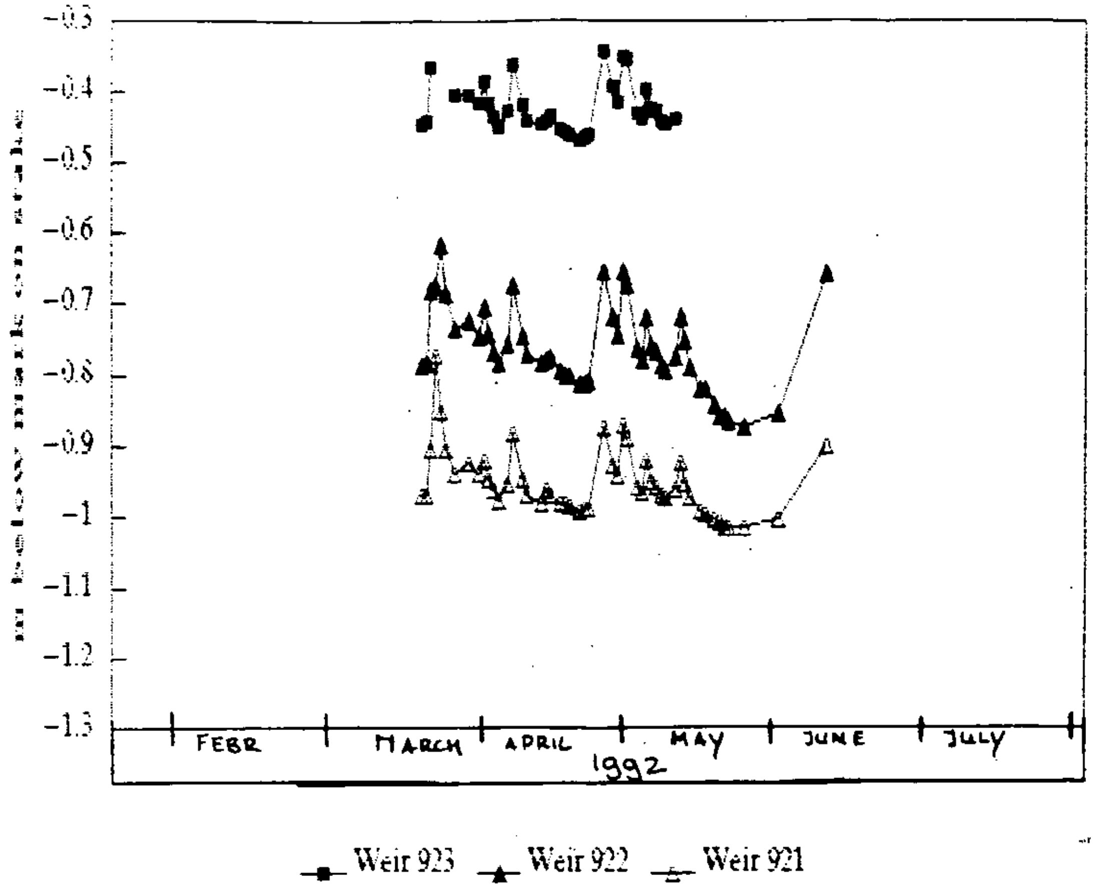


DATA FROM S. VAN DER SCHAAF

03 Sept. '90// 15 May '92

Waterlevels in drains along the Bogroad

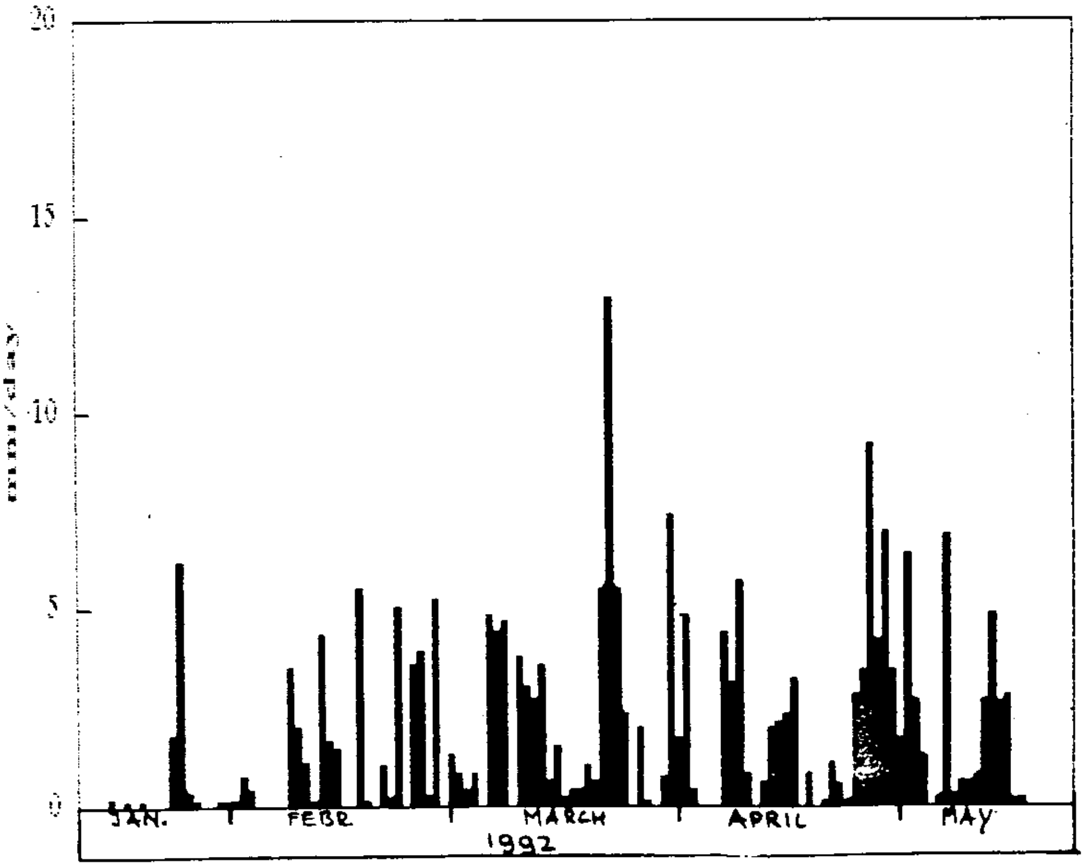
19-03-92 // 11-06-92



Every weir has it's own stake!

Precipitation Clara Bog

Rossum V-notch, mm/day

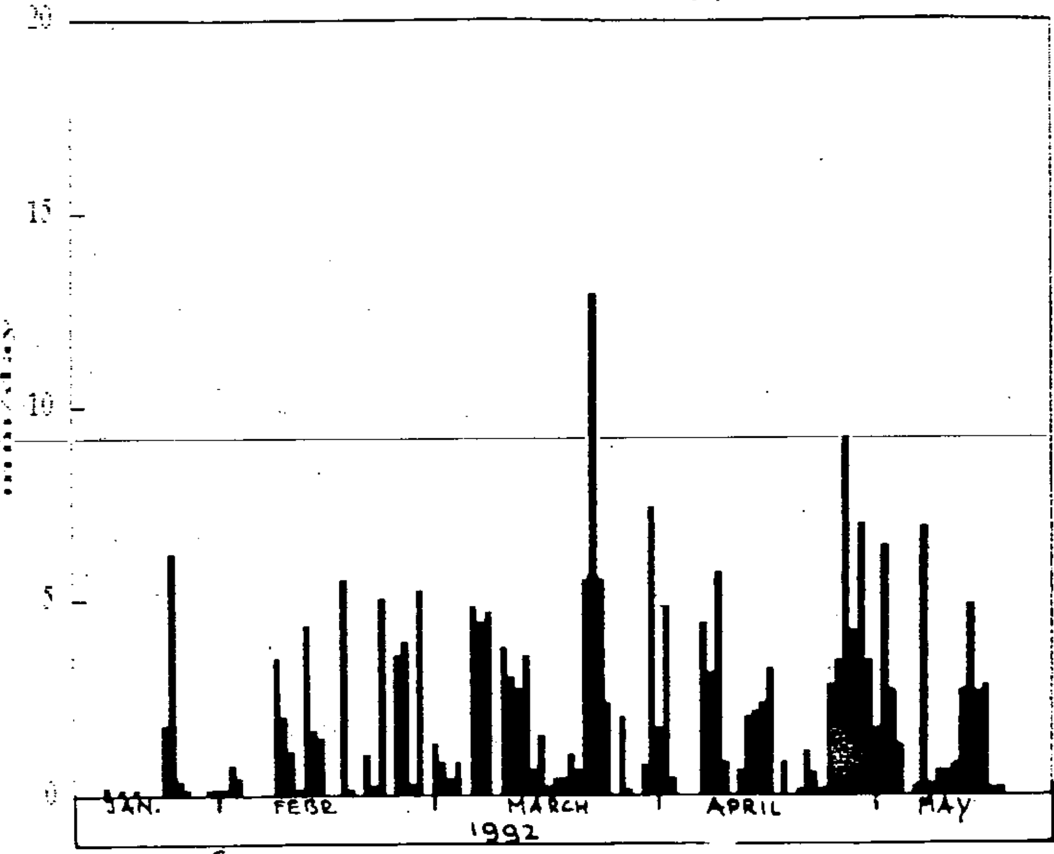


16 Jan.'92/15 May '92

DATA FROM S. VAN DER SCHAAF

Precipitation Clara Bog

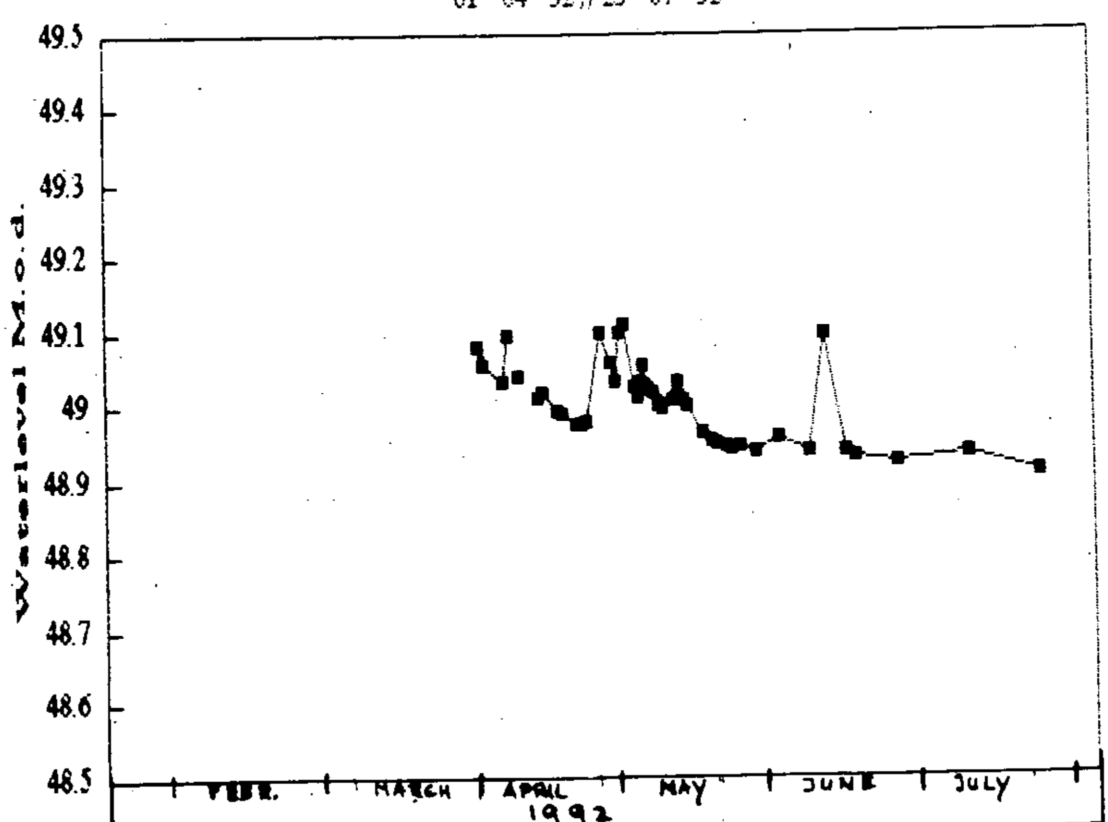
Rosum V-notch, mm/day



DATA FROM S. VAN DER SCHAAF

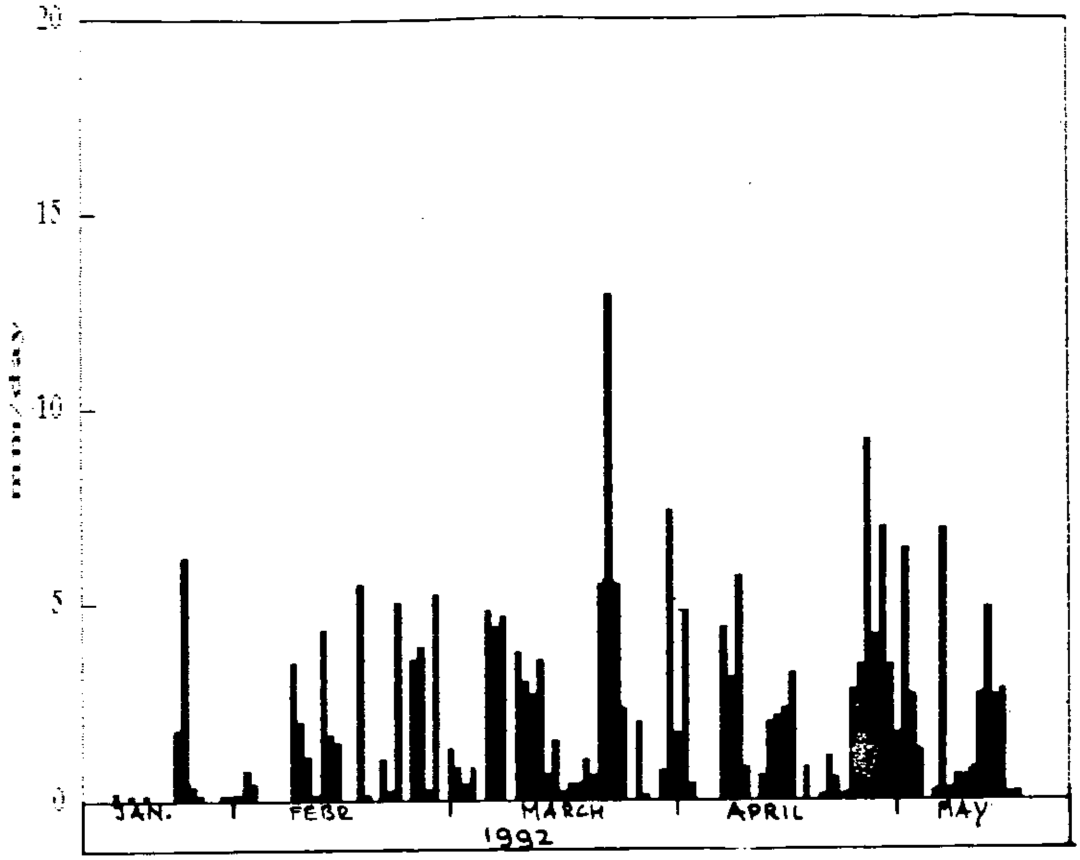
Waterlevels Deep drain

01-04-92 // 23-07-92



Precipitation Clara Bog

Rossum V-notch, mm/day

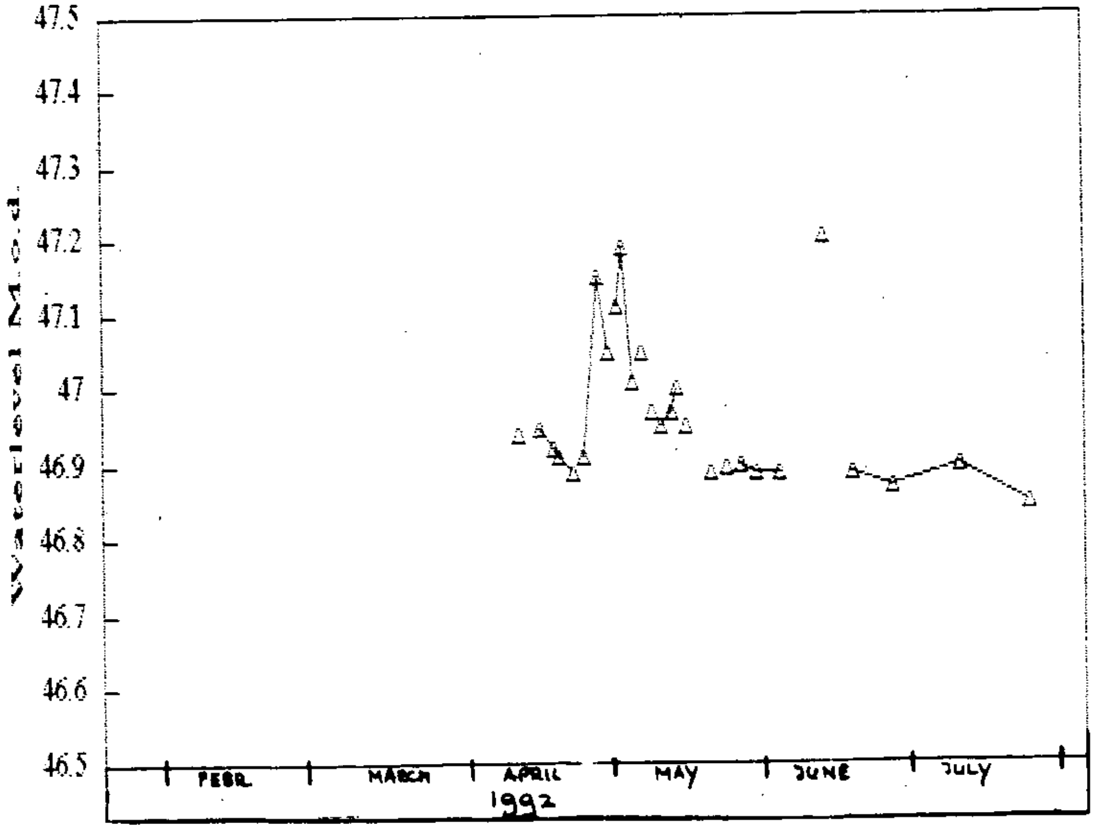


16 Jan.'92//15 May '92

DATA FROM S. VAN DER SCHAAF

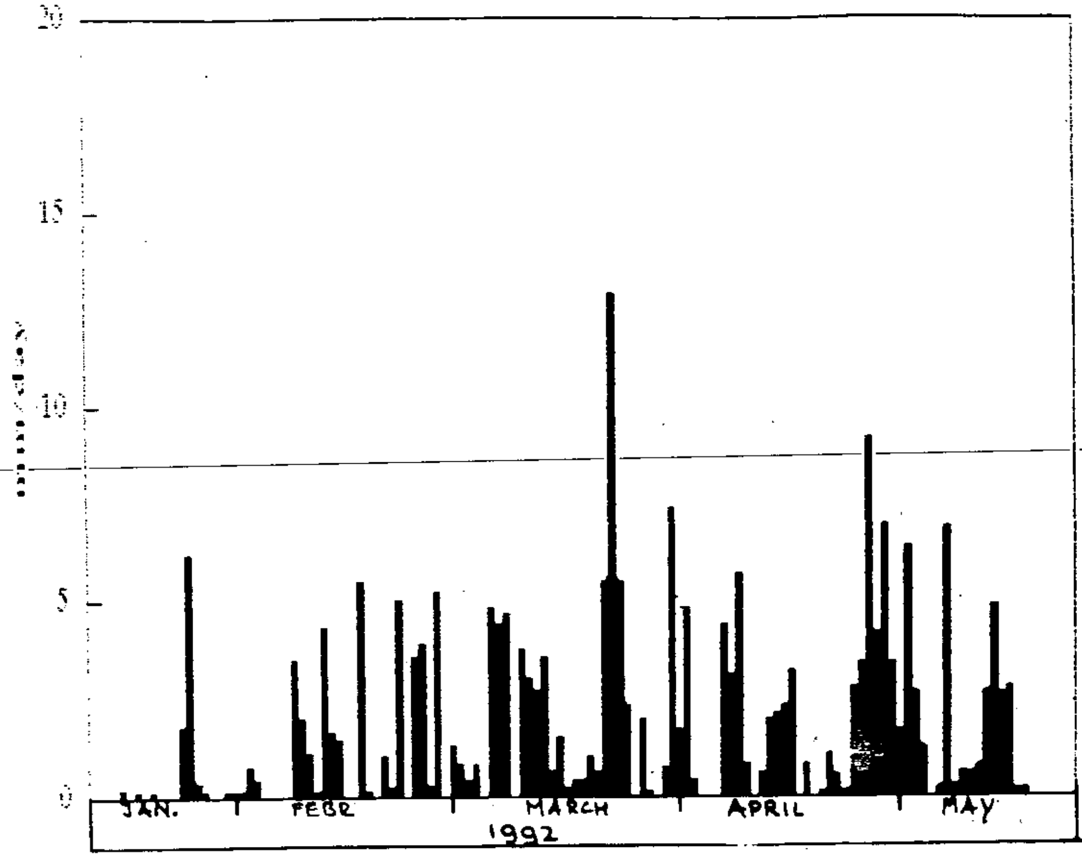
Waterlevels Silver River

01-04-92 // 23-07-92



Precipitation Clara Bog

Rossum V–notch, mm/day

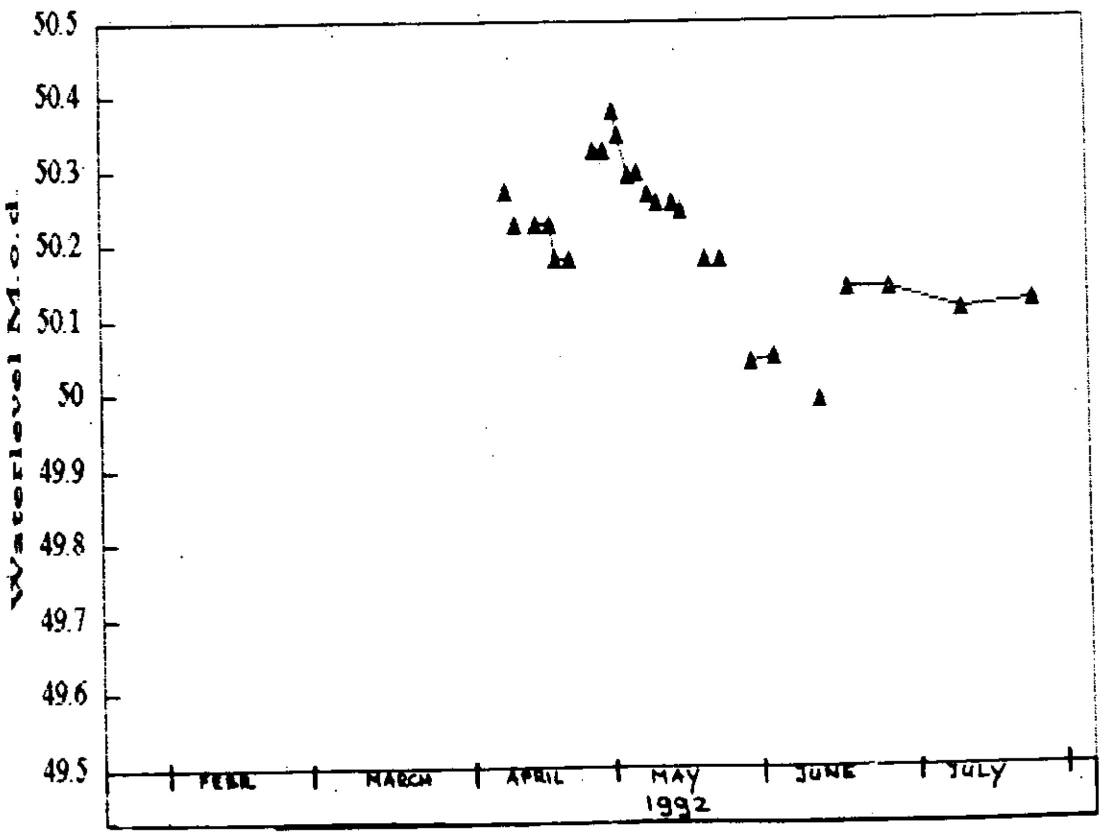


16 Jan.'92//15 May'92

DATA FROM S. VAN DER SCHAAF

Waterlevels River Brosna

01–04–92 // 23–07–92



DISCHARGE MEASUREMENTS WITH THE TRACER METHOD (continue)

LOCATION:	*Deep drain southeast of Clara Bog.*
DATE:	*23 May 1992*
OBSERVERS:	*Henny, Marco and Manon.*
REMARKS:	*Level at gauge: 0.144 m*
	Using 2 Mariotte vessels.
	Saltwater ca. 1.2 kg NaCl in ca. 25 liter: 0.05 kg/l

	EC	T (°C)
Streamwater	435 MicroS.	10.9
Saltwater	60.9 MilliS.	10.9

UPSTREAM: ***Total mean q = 0.03***

Vessel 1

EC: 62.9 milliS. before
63.2 milliS. after.

t(sec)	liters	q(l/sec)
0	9.3	
7	9.0	0.043
78	8.0	0.014
140	7.0	0.016
200	6.0	0.017
265	5.0	0.015
335	4.0	0.014
405	3.5	0.007
Total	5.8	
Mean		0.014

Vessel 5

EC: 62.8 milliS. before
63.0 milliS. after.

t(sec)	liters	q(l/sec)
0	9.2	
21	9.0	0.010
85	8.0	0.016
156	7.0	0.014
230	6.0	0.014
305	5.0	0.013
375	4.0	0.014
405	3.0	0.033
Total	6.2	
Mean		0.015

DOWNSTREAM

t(sec)	EC(MicroS./cm)
0	439
10	439
30	439
50	439
60	439
70	439
100	448
115	468
120	487
135	518
150	530
170	542
190	545
210	544
240	545
270	548
300	552
330	552
360	549
390	557
405	556

DILUTION

30 ml from Mariotte vessel

Add(l)	EC
1	3.1 milliS./cm
2	1.8 milliS./cm
3	1.4 milliS./cm
4	1.1 milliS./cm
5	1015 microS./cm
6	923 microS./cm
7	853 microS./cm
8	802 microS./cm
9	763 microS./cm
10	731 microS./cm
11	704 microS./cm
12	683 microS./cm
13	665 microS./cm

1 liter seperate and diluted : EC = 683

0.250	614
0.500	588
0.750	566
0.978	551

So for 13 l another 12.714 liter: TOTAL 25.7 liter

Dilution factor R: 25.7/0.03 = 857
Mean q: 0.03 l/sec
Q = q/R = 25 l/sec

LOCATION:	*Drain east of Clara Bog (Fig.4.1.)*	
DATE:	*23 May 1992*	
OBSERVERS:	*Henny, Marco and Manon.*	
REMARKS:	*Saltwater ca. 1.2 kg NaCl in ca. 25 liter:*	*0.05 kg/l*
	Same saltwater as in deep drain.	

Streamwater *607 MicroS.* *10.5 Celsius*

UPSTREAM: ***Mean q = 0.013***

Vessel

t(sec)	*liters*	*q(l/sec)*
0	7.7	
62	7.0	0.011
144	6.0	0.012
224	5.0	0.013
295	4.0	0.014
373	3.0	0.013
447	2.0	0.014
Total	5.7	
Mean		0.013

DOWNSTREAM

t(sec)	*EC (MicroSiemens/cm)*
0	610
10	610
20	620
30	672
40	726
50	722
70	730
80	763
90	758
100	726
110	760
120	750
130	726
140	725
150	736
170	751
180	705
200	732
210	747
220	763
240	768
260	763
280	806
300	760
330	850
350	830
360	830
390	860
420	812
447	850

DILUTION

15 ml from Mariotte vessel

Add(l)	*EC*
1.0	1.7 milliS.
2.0	1293 microS.
3.0	1071 microS.
4.0	961 microS.
5.0	888 microS.
6.0	843 microS.
6.250	833 microS.

Dilution factor R: 6.23 / 0.015 = 417
Mean q: *0.013 l/sec*
Q = q*R = ***5 l/sec***

FLOW MEASUREMENTS TAKEN AT GAUGE DEEP DRAIN

DATE	S.G.R.	METER TYPE	Q(m³/s.)	MEASURED BY.	REM
29/5/92	0.140	59239-6	0.0219	P. Mc G.	
6/2/92	0.180	104201-2	0.0405	" " "	
18/2/92	0.200	104201-2	0.0346	" " "	
10/6/92	0.175	59239-6	0.0296	" " "	
10/6/92	0.175	104201-2	0.0361	" " "	
10/6/92	0.175	107369-3	0.0303	" " "	
17/6/92	0.135	59239-6	0.0178	" " "	
17 '92	0.135	104201-2	0.0222	" " "	
17/6/92	0.135	107369-3	0.0196	" " "	
17/6/92	0.135	95922-1	0.0219	F. Q.	
17/6/92	0.135	107322-3	0.0202	F. Q.	

FLOW MEASUREMENTS TAKEN AT NEW BRIDGE (SILVER RIVER)

DATE	S.G.R.	METER TYPE	Q(m³/s.)	MEASURED BY.	REMK
6/2/92	0.410	104201-2	0.8606	P. Mc G.	
18/ 92	0.440	104201-2	0.9604	" " "	

(P. MacGowan, O.P.W.)

APPENDIX IV

TEMPERATURE MEASUREMENTS

		Page
A	BECKMAN AND IWACO;	89
B	PRINT OUT OF LOTUS FILES;	91
C	ISOTHERMIC TRANSECTS;	105
D	TEMPERATURE PROFILE AND TEMPERATURE GRADIENT.	112

BECKMAN TABLE		*TEMP. WITH IWACO-FORMULA*		
Res. Ohms	*Temp °C*	*Temp °C*	*Absl. error*	*Relative error*
75.79K	-40	-43.17	-3.17	0.08
54.66K	-35	-37.57	-2.57	0.07
39.86K	-30	-32.03	-2.03	0.07
29.38K	-25	-26.55	-1.55	0.06
21.87K	-20	-21.14	-1.14	0.06
16.43K	-15	-15.77	-0.77	0.05
12.46K	-10	-10.48	-0.48	0.05
9534	- 5	- 5.25	-0.25	0.05
7355	0	- 0.08	-0.08	ERR
6990	1	0.95	-0.05	-0.05
6645	2	1.97	-0.03	-0.01
6319	3	2.99	-0.01	-0.00
6011	4	4.01	0.01	0.00
5720	5	5.02	0.02	0.00
5444	6	6.04	0.04	0.01
5184	7	7.05	0.05	0.01
4937	8	8.06	0.06	0.01
4704	9	9.06	0.06	0.01
4483	10	10.06	0.06	0.01
4273	11	11.06	0.06	0.01
4075	12	12.06	0.06	0.00
3887	13	13.05	0.05	0.00
3708	14	14.05	0.05	0.00
3539	15	15.04	0.04	0.00
3379	16	16.02	0.02	0.00
3226	17	17.01	0.01	0.00
3082	18	17.98	-0.02	-0.00
2944	19	18.97	-0.03	-0.00
2814	20	19.94	-0.06	-0.00
2690	21	20.92	-0.08	-0.00
2572	22	21.89	-0.11	-0.01
2460	23	22.86	-0.14	-0.01
2354	24	23.82	-0.18	-0.01
2253	25	24.78	-0.22	-0.01
2156	26	25.75	-0.25	-0.01
2065	27	26.70	-0.30	-0.01
1977	28	27.66	-0.34	-0.01
1894	29	28.61	-0.39	-0.01
1815	30	29.56	-0.44	-0.01
1740	31	30.50	-0.50	-0.02
1668	32	31.45	-0.55	-0.02
1599	33	32.40	-0.60	-0.02
1534	34	33.33	-0.67	-0.02
1471	35	34.28	-0.72	-0.02
1412	36	35.21	-0.79	-0.02
1355	37	36.15	-0.85	-0.02
1301	38	37.08	-0.92	-0.02
1249	39	38.01	-0.99	-0.03
1200	40	38.93	-1.07	-0.03
1153	41	39.85	-1.15	-0.03
1108	42	40.77	-1.23	-0.03
1065	43	41.68	-1.32	-0.03
1024	44	42.59	-1.41	-0.03
984.2	45	43.52	-1.48	-0.03

946.6	46	44.43	-1.57	-0.03
910.6	47	45.33	-1.67	-0.04
876.2	48	46.24	-1.76	-0.04
843.2	49	47.14	-1.86	-0.04
811.7	50	48.04	-1.96	-0.04
672.9	55	52.51	-2.49	-0.05
560.7	60	56.91	-3.09	-0.05
469.4	65	61.26	-3.74	-0.06
394.9	70	65.55	-4.45	-0.06
333.5	75	69.79	-5.21	-0.07
283.1	80	73.95	-6.05	-0.08
241.3	85	78.06	-6.94	-0.08
206.5	90	82.11	-7.89	-0.09
177.5	95	86.09	-8.91	-0.09
153.2	100	90.01	-9.99	-0.10
132.7	105	93.87	-11.13	-0.11
115.4	110	97.67	-12.33	-0.11
100.6	115	101.43	-13.57	-0.12
88.1	120	105.11	-14.89	-0.12
77.4	125	108.74	-16.26	-0.13
68.2	130	112.31	-17.69	-0.14
60.2	135	115.87	-19.13	-0.14
53.4	140	119.32	-20.68	-0.15
47.4	145	122.78	-22.22	-0.15
42.3	150	126.12	-23.88	-0.16

In range 12 -21 degrees Celsius the rel. error is zero.

Between 2 and 30 degrees Celsius the rel. error is 0.01 C.

The IWACO-FORMULA is used for the BECKMAN-APPARATUS as the relative error will never be larger than 0.01 C.

Table IV.1. Location, date and time of the temperature measurements.

APRIL 1992 IWACO-Apparatus			JUNE 1992 BECKMAN-Apparatus		
Site	a.m./p.m.	Day	Site	a.m./p.m.	Day
46	p.m.	06	46	a.m.	26
54	p.m.	06	54	a.m.	26
57	p.m.	06	57	a.m.	26
67	a.m	06			
71	a.m.	06			
85	p.m.	07			
90	p.m.	06	90	a.m.	26
92	p.m.	06	92	a.m.	26
901	p.m.	06	901	a.m.	26
903	p.m.	06			
104	a.m.	03			
106	p.m.	03			
107	a.m.	03			
108	a.m.	03	108	p.m.	25
109	a.m.	03			
110	p.m.	03			
111	p.m.	03	111	p.m.	25
112	p.m.	02	112	p.m.	25
113	p.m.	02	113	a.m.	25
114	p.m.	02	114	a.m.	25
119	p.m.	02	119	p.m.	25
120	p.m.	02	120	p.m.	25
CLBH2	a.m.	01	CLBH2	p.m.	25
CLBH3	a.m	01			
CLBH4	p.m.	01	CLBH4	p.m.	25
CLBH5	p.m.	01	CLBH5	p.m.	25
CLBH6	p.m.	01	CLBH6	p.m.	25
CLBH7	p.m.	01	CLBH7	p.m.	25
CLCD1	p.m.	01			
CLCD2	p.m.	01			

TEMPERATURE LOG FORM April and June 1992

April 1992: IWACO-Apparatus
June 1992: Beckman-Apparatus

CLBH2.1 April 57.73 : Groundlevel 57.73 Mod.

CLARA BOG - BOREHOLES Date 01/04/92 and 25/06/92

CLBH2.1 Depth m gl.	April Depth mamsl	57.73 Temp. Celsius	Gradient C/m	CLBH2.1 Depth m-gl.	June Depth mamsl	Temp. Celsius	Gradient C/m
0.1	57.8			-0.1	57.9		
				0.4	57.4	14.6	
-0.9	56.8	8.34		0.9	56.9	12.9	2.8
				1.4	56.4	11.8	1.7
-1.9	55.8	8.63	-0.3	1.9	55.9	11.2	1.0
				2.4	55.4	10.8	0.7
-2.9	54.8	8.95	-0.3	2.9	54.9	10.5	0.5
				3.4	54.4	10.3	0.4
-3.9	53.8	9.27	-0.3	3.9	53.9	10.1	0.2
				4.4	53.4	10.1	0.1
-4.9	52.8	9.57	-0.3	4.9	52.9	10.0	0.1
				5.4	52.4	9.9	
-5.9	51.8	9.82	-0.2	5.9	51.8		
-6.9	50.8	10.02	-0.2	6.9	50.8		
-7.9	49.8	10.14	-0.1	7.9	49.8		
-8.9	48.8	10.26	-0.1	8.9	48.8		
-9.9	47.8	10.29	-0.0	9.9	47.8		
-10.9	46.8	10.34	-0.0	10.9	46.8		
-11.9	45.8	10.37	-0.0	11.9	45.8		
-12.7	45.1	10.38		12.7	45.1		

CLBH4.1 Depth m gl.	April Depth mamsl	58.82 Temp. Celsius	Gradient C/m	CLBH4.1 Depth m-gl.	June Depth mamsl	Temp. Celsius	Gradient C/m
				-0.2	59.0		
				0.4	58.5		
				0.9	58.0		
				1.4	57.5		
				1.9	57.0		
-2.5	56.3	7.59		2.4	56.5	11.0	
				2.9	56.0	10.3	1.0
-3.5	55.3	7.58	-0.0	3.4	55.5	9.9	0.5
				3.9	55.0	9.8	0.3
-4.5	54.3	7.59	-0.0	4.4	54.5	9.6	0.2
				4.9	54.0	9.5	0.3
-5.5	53.3	7.63	-0.1	5.4	53.5	9.3	
-6.5	52.3	7.76	-0.1	6.5	52.3		
-7.5	51.3	7.79	-0.1	7.5	51.3		
-8.5	50.3	8.00	-0.3	8.5	50.3		
-9.5	49.3	8.32	-0.4	9.5	49.3		
-10.5	48.3	8.75	-0.3	10.5	48.3		
-11.5	47.3	8.92	-0.3	11.5	47.3		
-12.5	46.3	9.30	-0.6	12.5	46.3		
-12.6	46.2	9.55		12.6	46.2		

CLBH5.	April	55.74		CLBH5.	June		
Depth m gl.	Depth mamsl	Temp. Celsius	Gradient C/m	Depth m-gl.	Depth mamsl	Temp. Celsius	Gradient C/m
				0.0	55.7		
				0.5	55.2		
				1.0	54.7	12.0	
-1.5	54.2	9.15		1.5	54.2	10.5	2.1
				2.0	53.7	9.9	0.8
-2.5	53.2	9.62	-0.3	2.5	53.2	9.7	0.3
				3.0	52.7	9.6	0.1
-3.5	52.2	9.70	-0.1	3.5	52.2	9.6	0.0
				4.0	51.7	9.6	0.0
-4.5	51.2	9.75	-0.1	4.5	51.2	9.6	-0.0
				5.0	50.7	9.6	-0.1
-5.5	50.2	9.95	-0.1	5.5	50.2	9.7	
-6.5	49.2	10.05	-0.1	6.5	49.2		
-7.5	48.2	10.08	-0.1	7.5	48.2		
-8.5	47.2	10.15	-0.1	8.5	47.2		
-8.8	46.9	10.18		8.8	46.9		

CLBH6.3	April	55.95		CLBH6.3	June		
Depth m gl.	Depth mamsl	Temp. Celsius	Gradient C/m	Depth m-gl.	Depth mamsl	Temp. Celsius	Gradient C/m
0.3	56.2	8.02		-0.3	56.3		
				0.2	55.8	16.5	
-0.7	55.2	8.16	-0.5	0.7	55.3	13.3	5.0
				1.2	54.8	11.5	3.0
-1.7	54.2	8.99	-0.5	1.7	54.3	10.3	1.7
				2.2	53.8	9.8	0.6
-2.7	53.2	9.23	-0.3	2.7	53.3	9.7	0.0
				3.2	52.8	9.7	0.0
-3.7	52.2	9.61	-0.3	3.7	52.3	9.7	-0.1
				4.2	51.8	9.8	-0.2
-4.7	51.2	9.79	-0.2	4.7	51.3	9.9	-0.1
				5.2	50.8	9.9	
-5.7	50.2	9.92	-0.1	5.7	50.2		
-6.7	49.2	10.05	-0.1	6.7	49.2		
-7.7	48.2	10.17	-0.1	7.7	48.2		
-8.7	47.2	10.16	-0.0	8.7	47.2		
-9.7	46.2	10.23	-0.1	9.7	46.2		
-10.7	45.2	10.29	-0.0	10.7	45.2		
-11.7	44.2	10.31	-0.0	11.7	44.2		
-12.3	43.6	10.34		12.3	43.6		

CLBH7.1 Depth m gl.	April Depth mamsl	50.33 Temp. Celsius	Gradient C/m	CLBH7.1 Depth m-gl.	June Depth mamsl	Temp. Celsius	Gradient C/m
				0.1	50.3		
				0.6	49.8		
				1.1	49.3	12.0	
-1.3	49.1	9.01		1.3	49.1		
				1.6	48.8	11.3	1.2
				2.1	48.3	10.8	1.0
-2.3	48.1	9.22	-0.2	2.3	48.1		
				2.6	47.8	10.4	0.7
				3.1	47.3	10.1	0.3
-3.3	47.1	9.42	-0.2	3.3	47.1		
				3.6	46.8	10.0	0.1
				4.1	46.3	10.0	0.0
-4.3	46.1	9.66	-0.4	4.3	46.1		
				4.6	45.8	10.0	0.0
				5.1	45.3	10.0	
-5.3	45.1	10.14		5.3	45.0		

CLARA BOG EAST - TUBES   Date 02/04/92   112/13/14/19/20
03/04/92   104/6/7/8/9/10/11
25/06/92

108.1	April	59.69		108.1	June		
Depth m gl.	Depth mamsl	Temp. Celsius	Gradient C/m	Depth m-gl.	Depth mamsl	Temp. Celsius	Gradient C/m
-0.6	59.1	7.58		0.5	59.2	13.9	
-1.1	58.6	8.09	-0.9	1.0	58.7	11.5	3.9
-1.6	58.1	8.50	-0.9	1.5	58.2	10.0	2.0
-2.1	57.6	9.00	-1.0	2.0	57.7	9.5	0.7
-2.6	57.1	9.50	-0.8	2.5	57.2	9.3	0.0
-3.1	56.6	9.76	-0.5	3.0	56.7	9.4	-0.2
-3.6	56.1	9.97	-0.3	3.5	56.2	9.6	-0.3
-4.1	55.6	10.06	-0.1	4.0	55.7	9.7	-0.2
-4.6	55.1	10.09	-0.0	4.5	55.2	9.8	-0.2
-5.1	54.6	10.08	0.0	5.0	54.7	9.9	
-5.6	54.1	10.08	0.0	5.5	54.2		
-6.1	53.6	10.08	-0.0	6.1	53.6		
-6.6	53.1	10.09	-0.0	6.6	53.1		
-7.1	52.6	10.09	-0.0	7.1	52.6		
-7.2	52.5	10.11		7.2	52.5		

111.1	April	59.76		111.1	June		
Depth m gl.	Depth mamsl	Temp. Celsius	Gradient C/m	Depth m-gl.	Depth mamsl	Temp. Celsius	Gradient C/m
-0.7	59.1	7.68		0.7	59.1	13.2	
-1.2	58.6	7.71	-0.2	1.2	58.6	11.1	3.4
-1.7	58.1	7.89	-0.6	1.7	58.1	9.8	2.0
-2.2	57.6	8.36	-0.9	2.2	57.6	9.1	1.1
-2.7	57.1	8.75	-0.7	2.7	57.1	8.8	0.4
-3.2	56.6	9.05	-0.5	3.2	56.6	8.7	-0.1
-3.7	56.1	9.28	-0.4	3.7	56.1	8.9	-0.3
-4.2	55.6	9.44	-0.3	4.2	55.6	9.0	-0.3
-4.7	55.1	9.54	-0.2	4.7	55.1	9.2	-0.3
-5.2	54.6	9.60	-0.1	5.2	54.6	9.3	-0.2
-5.7	54.1	9.66	-0.1	5.7	54.1	9.4	
-6.2	53.6	9.72	-0.1	6.2			
-6.7	53.1	9.78	-0.1	6.7			
-7.2	52.6	9.84	-0.2	7.2			
-7.7	52.1	9.93	-0.1	7.7			
-8.2	51.6	9.97		8.2			

Depth:
* April x.x8, June x.x4
For graph x.x6

112.1	April	59.8		112.1	June		
Depth m gl.	Depth mamsl	Temp. Celsius	Gradient C/m	Depth m-gl.	Depth mamsl	Temp. Celsius	Gradient C/m
-0.7	59.1	7.84		0.7	59.1	13.3	
-1.2	58.6	8.18	-0.8	1.2	58.6	11.0	3.5
-1.7	58.1	8.62	-0.9	1.7	58.1	9.8	1.6
-2.2	57.6	9.09	-0.9	2.2	57.6	9.4	0.5
-2.7	57.1	9.53	-0.7	2.7	57.1	9.3	-0.0
-3.2	56.6	9.80	-0.5	3.2	56.6	9.4	-0.2
-3.7	56.1	9.98	-0.3	3.7	56.1	9.6	-0.3
-4.2	55.6	10.05	-0.1	4.2	55.6	9.7	-0.2
-4.7	55.1	10.05	0.0	4.7	55.1	9.8	-0.1
-5.2	54.6	10.05	0.0	5.2	54.6	9.8	-0.1
-5.7	54.1	10.03	0.1	5.7	54.1	9.9	
-6.2	53.6	10.00	0.0	6.2	53.6		
-6.7	53.1	10.00	-0.0	6.7	53.1		
-7.2	52.6	10.00	-0.0	7.2	52.6		
-7.7	52.1	10.01	-0.0	7.7	52.1		
-8.2	51.6	10.03	-0.0	8.2	51.6		
-8.7	51.1	10.05	-0.0	8.7	51.1		
-9.2	50.6	10.07	-0.1	9.2	50.6		
-9.3	50.5	10.08		9.3	50.5		

113.1	April	59.79		113.1	June		
Depth m gl.	Depth mamsl	Temp. Celsius	Gradient C/m	Depth m-gl.	Depth mamsl	Temp. Celsius	Gradient C/m
				0.1	59.7		
-0.6	59.2	7.94		0.6	59.2	13.5	
				1.1	58.7	11.5	3.4
-1.6	58.2	8.42	-0.7	1.6	58.2	10.1	2.1
				2.1	57.7	9.4	0.9
-2.6	57.2	9.33	-0.7	2.6	57.2	9.2	0.2
				3.1	56.7	9.2	-0.1
-3.6	56.2	9.77	-0.3	3.6	56.2	9.3	-0.2
				4.1	55.7	9.4	-0.2
-4.6	55.2	9.88	-0.0	4.6	55.2	9.5	-0.2
				5.1	54.7	9.6	-0.1
-5.6	54.2	9.86	0.0	5.6	54.2	9.6	
-6.6	53.2	9.83	0.0	6.6	53.2		
-7.6	52.2	9.83	-0.0	7.6	52.2		
-8.6	51.2	9.86	-0.0	8.6	51.2		
-9.1	50.7	9.88		9.1	50.7		

114.1	April	59.69		114.1	June		
Depth m gl.	Depth mamsl	Temp. Celsius	Gradient C/m	Depth m-gl.	Depth mamsl	Temp. Celsius	Gradient C/m
				0.1	59.6	15.9	
-0.7	59.0	7.35		0.6	59.1	13.8	4.2
-1.2	58.5	7.86	-0.8	1.1	58.6	11.7	3.6
-1.7	58.0	8.18	-0.8	1.6	58.1	10.2	2.4
-2.2	57.5	8.62	-0.9	2.1	57.6	9.3	1.0
-2.7	57.0	9.07	-0.8	2.6	57.1	9.1	0.2
-3.2	56.5	9.43	-0.6	3.1	56.6	9.1	-0.1
-3.7	56.0	9.64	-0.3	3.6	56.1	9.3	-0.2
-4.2	55.5	9.75	-0.1	4.1	55.6	9.3	-0.2
-4.7	55.0	9.78	-0.1	4.6	55.1	9.4	-0.2
-5.2	54.5	9.80	-0.0	5.1	54.6	9.5	-0.2
-5.7	54.0	9.79	0.0	5.6	54.1	9.6	
-6.2	53.5	9.77	0.0	6.2	Depth:		
-6.7	53.0	9.75	0.0	6.7	April x.x6. June x.x0		
-7.2	52.5	9.75	-0.0	7.2	For graph x.x3		
-7.7	52.0	9.77	-0.0	7.7			
-8.2	51.5	9.79	-0.0	8.2			
-8.7	51.0	9.81	-0.0	8.7			
-9.2	50.5	9.83	-0.1	9.2			
-9.4	50.3	9.85		9.4			

119.1	April	59.74		119.1	June		
Depth m gl.	Depth mamsl	Temp. Celsius	Gradient C/m	Depth m-gl.	Depth mamsl	Temp. Celsius	Gradient C/m
-0.6	59.2	7.79		0.6	59.1	13.9	
				1.1	58.6	11.8	3.8
-1.6	58.2	8.50	-0.8	1.6	58.1	10.2	2.3
-2.1	57.7	9.05	-1.0	2.1	57.6	9.5	0.9
-2.6	57.2	9.47	-0.6	2.6	57.1	9.3	0.2
-3.1	56.7	9.68	-0.4	3.1	56.6	9.3	-0.1
-3.6	56.2	9.86	-0.2	3.6	56.1	9.4	-0.2
-4.1	55.7	9.92	-0.1	4.1	55.6	9.5	-0.2
-4.6	55.2	9.94	-0.0	4.6	55.1	9.6	-0.2
-5.1	54.7	9.93	0.0	5.1	54.6	9.7	-0.1
-5.6	54.2	9.93	0.0	5.6	54.1	9.8	
-6.1	53.7	9.92	-0.0	6.1	53.7		
-6.6	53.2	9.93	-0.0	6.6	53.2		
-7.1	52.7	9.92	-0.0	7.1	52.7		
-7.6	52.2	9.95	-0.1	7.6	52.2		
-8.1	51.7	9.97	-0.1	8.1	51.7		
-8.6	51.2	10.00	-0.1	8.6	51.2		
-9.0	50.8	10.03		9.0	50.8		

120.E Depth m gl.	April Depth mamsl	60.01 Temp. Celsius	Gradient C/m	120.E Depth m-gl.	June Depth mamsl	Temp. Celsius	Gradient C/m
				0.3	59.7		
-0.8	59.2	7.65		0.8	59.2	12.4	
-1.3	58.7	8.15	-1.0	1.3	58.7	10.4	3.1
-1.8	58.2	8.66	-1.0	1.8	58.2	9.4	1.3
-2.3	57.7	9.10	-0.7	2.3	57.7	9.0	0.4
-2.8	57.2	9.41	-0.5	2.8	57.2	9.0	-0.1
-3.3	56.7	9.60	-0.3	3.3	56.7	9.1	-0.2
-3.8	56.2	9.68	-0.1	3.8	56.2	9.2	-0.2
-4.3	55.7	9.70	-0.0	4.3	55.7	9.3	-0.2
-4.8	55.2	9.70	0.0	4.8	55.2	9.4	-0.1
-5.3	54.7	9.69	0.0	5.3	54.7	9.5	-0.1
-5.8	54.2	9.66	0.0	5.8	54.2	9.5	
-6.3	53.7	9.66	-0.0	6.3	53.7		
-6.8	53.2	9.66	-0.0	6.8	53.2		
-7.3	52.7	9.67	-0.0	7.3	52.7		
-7.8	52.2	9.69	0.0	7.8	52.2		
-8.3	51.7	9.67	-0.0	8.3	51.7		
-8.8	51.2	9.72		8.8	51.2		

CLARA BOG WEST - TUBES Date 06/04/92 07/04/92 26/06/92 46,54,57,67,71,90,92,901,90 85

46.F Depth m gl.	April Depth mamsl	57.9 Temp. Celsius	Gradient C/m	46.F Depth m-gl.	June Depth mamsl	Temp. Celsius	Gradient C/m
-0.3	57.6	8.03		0.3	57.7		
-0.8	57.1	8.02	-0.4	0.8	57.2	13.6	
-1.3	56.6	8.40	-0.9	1.3	56.7	11.3	3.6
-1.8	56.1	8.87	-0.9	1.8	56.2	10.0	1.8
-2.3	55.6	9.34	-0.8	2.3	55.7	9.5	0.6
-2.8	55.1	9.64	-0.6	2.8	55.2	9.4	0.1
-3.3	54.6	9.90	-0.4	3.3	54.7	9.4	-0.1
-3.8	54.1	10.00	-0.1	3.8	54.2	9.5	-0.7
-4.3	53.6	10.00	-0.1	4.3	53.7	10.1	-0.7
-4.8	53.1	10.07	-0.1	4.8	53.2	10.2	-0.1
-5.3	52.6	10.06	0.0	5.3	52.7	10.2	0.1
-5.8	52.1	10.02	0.0	5.8	52.2	10.1	
-6.3	51.6	10.05	-0.0	6.3	51.6		
-6.8	51.1	10.03	0.0	6.8	51.1		
-7.2	50.7	10.01		7.2	50.7		

54.F Depth m gl.	April Depth mamsl	57.9 Temp. Celsius	Gradient C/m	54.F Depth m-gl.	June Depth mamsl	Temp. Celsius	Gradient C/m
-0.8	57.1	8.79		0.8	57.1	13.0	
-1.3	56.6	8.59	-0.1	1.3	56.6	11.2	3.0
-1.8	56.1	8.87	-0.6	1.8	56.1	10.1	1.6
-2.3	55.6	9.21	-0.7	2.3	55.6	9.6	0.6
-2.8	55.1	9.54	-0.6	2.8	55.1	9.5	0.0
-3.3	54.6	9.79	-0.4	3.3	54.6	9.5	-0.1
-3.8	54.1	9.96	-0.3	3.8	54.1	9.6	-0.2
-4.3	53.6	10.05	-0.1	4.3	53.6	9.7	-0.2
-4.8	53.1	10.07	-0.0	4.8	53.1	9.8	-0.1
-5.3	52.6	10.08	0.0	5.3	52.6	9.8	-0.1
-5.8	52.1	10.06	0.0	5.8	52.1	9.9	
-6.3	51.6	10.06	-0.0	6.3	51.6		
-6.8	51.1	10.07	-0.0	6.8	51.1		
-7.3	50.6	10.08	-0.0	7.3	50.6		
-7.8	50.1	10.09	-0.0	7.8	50.1		
-8.3	49.6	10.10	-0.1	8.3	49.6		
-8.6	49.3	10.13		8.6	49.3		

57.E Depth m gl.	April Depth mamsl	58.5 Temp. Celsius	Gradient C/m	57.E Depth m-gl.	June Depth mamsl	Temp. Celsius	Gradient C/m
-0.9	57.7	8.22		0.8	57.7	12.8	
-1.4	57.2	8.15	-0.2	1.3	57.2	10.8	3.0
-1.9	56.7	8.44	-0.8	1.8	56.7	9.8	1.5
-2.4	56.2	8.90	-1.0	2.3	56.2	9.3	0.5
-2.9	55.7	9.45	-0.8	2.8	55.7	9.3	-0.0
-3.4	55.2	9.71	-0.5	3.3	55.2	9.4	-0.2
-3.9	54.7	9.90	-0.3	3.8	54.7	9.5	-0.3
-4.4	54.2	10.03	-0.2	4.3	54.2	9.7	-0.3
-4.9	53.7	10.10	-0.1	4.8	53.7	9.8	-0.2
-5.4	53.2	10.11	-0.0	5.3	53.2	9.9	-0.2
-5.9	52.7	10.12		5.8	52.7	10.0	

Depth:
April x.85, June x.75
For graph x.8

90.F Depth m gl.	April Depth mamsl	58.3 Temp. Celsius	Gradient C/m	90.F Depth m-gl.	June Depth mamsl	Temp. Celsius	Gradient C/m
-0.7	57.6	8.50		0.8	57.6	12.9	
-1.2	57.1	8.28	-0.0	1.3	57.1	11.0	3.1
-1.7	56.6	8.51	-0.6	1.8	56.6	9.8	1.6
-2.2	56.1	8.90	-0.8	2.3	56.1	9.3	0.5
-2.7	55.6	9.27	-0.7	2.8	55.6	9.3	0.0
-3.2	55.1	9.58	-0.5	3.3	55.1	9.3	-0.1
-3.7	54.6	9.77	-0.3	3.8	54.6	9.4	-0.2
-4.2	54.1	9.87	-0.2	4.3	54.1	9.5	-0.2
-4.7	53.6	9.92	-0.1	4.8	53.6	9.6	-0.1
-5.2	53.1	9.96	-0.1	5.3	53.1	9.6	-0.1
-5.7	52.6	9.97	-0.0	5.8	52.6	9.7	
-6.2	52.1	9.98	0.0	6.2	52.1		
-6.7	51.6	9.97	0.0	6.7	51.6		
-7.2	51.1	9.94	0.0	7.2	51.1		
-7.7	50.6	9.96	-0.0	7.7	50.6		
-8.2	50.1	9.96	-0.0	8.2	50.1		
-8.7	49.6	10.00	-0.0	8.7	49.6		
-9.2	49.1	9.99	-0.0	9.2	49.1		
-9.7	48.6	10.01	-0.1	9.7	48.6		
-10.2	48.1	10.05	-0.1	10.2	48.1		
-10.7	47.6	10.09	-0.1	10.7	47.6		
-11.2	47.1	10.14	-0.1	11.2	47.1		
-11.7	46.6	10.20	-0.1	11.7	46.6		
-11.9	46.4	10.23		11.9	46.4		

92.F Depth m gl.	April Depth mamsl	58.8 Temp. Celsius	Gradient C/m	92.F Depth m-gl.	June Depth mamsl	Temp. Celsius	Gradient C/m
-1.2	57.6	8.62		1.3	57.6	11.3	
-1.7	57.1	8.68	-0.4	1.8	57.1	10.0	1.8
-2.2	56.6	9.06	-0.8	2.3	56.6	9.5	0.6
-2.7	56.1	9.48	-0.7	2.8	56.1	9.4	-0.0
-3.2	55.6	9.80	-0.5	3.3	55.6	9.5	-0.3
-3.7	55.1	10.01	-0.4	3.8	55.1	9.7	-0.3
-4.2	54.6	10.15	-0.2	4.3	54.6	9.8	-0.2
-4.7	54.1	10.17	-0.1	4.8	54.1	9.9	-0.2
-5.1	53.7	10.22		5.1	53.7		
				5.3	53.6	10.0	
				5.8	53.1		

901.E Depth m gl.	April Depth mamsl	59.3 Temp. Celsius	Gradient C/m	901.E Depth m-gl.	June Depth mamsl	Temp. Celsius	Gradient C/m
-0.8	58.5	8.68		0.8	58.5	12.7	
-1.3	58.0	8.49	-0.1	1.3	58.0	11.0	2.9
-1.8	57.5	8.77	-0.7	1.8	57.5	9.8	1.6
-2.3	57.0	9.18	-0.8	2.3	57.0	9.4	0.4
-2.8	56.5	9.56	-0.6	2.8	56.5	9.4	-0.1
-3.3	56.0	9.82	-0.4	3.3	56.0	9.5	-0.2
-3.8	55.5	9.98	-0.3	3.8	55.5	9.6	-0.3
-4.3	55.0	10.08	-0.1	4.3	55.0	9.8	-0.2
-4.8	54.5	10.12	-0.1	4.8	54.5	9.8	-0.2
-5.3	54.0	10.13	-0.0	5.3	54.0	9.9	-0.1
-5.8	53.5	10.15	-0.0	5.8	53.5	10.0	
-6.3	53.0	10.16	-0.0	6.3	53.0		
-6.8	52.5	10.17	-0.0	6.8	52.5		
-7.3	52.0	10.18	-0.0	7.3	52.0		
-7.8	51.5	10.20	-0.0	7.8	51.5		
-8.3	51.0	10.20	-0.0	8.3	51.0		
-8.8	50.5	10.22	-0.1	8.8	50.5		
-9.3	50.0	10.25	-0.0	9.3	50.0		
-9.5	49.8	10.25		9.5	49.8		

67.E Depth m-gl.	April Depth mamsl	56.8 Temp. Celsius	Gradient C/m	85.F Depth m-gl.	April Depth mamsl	55.4 Temp. Celsius	Gradient C/m
				0.8	54.6	8.06	
1.2	55.6	8.42		1.3	54.1	8.17	-0.5
1.7	55.1	8.49	-0.4	1.8	53.6	8.52	-0.8
2.2	54.6	8.78	-0.5	2.3	53.1	8.94	-0.9
2.7	54.1	8.97	-0.4	2.8	52.6	9.40	-0.6
3.2	53.6	9.18	-0.4	3.3	52.1	9.59	-0.4
3.7	53.1	9.36	-0.4	3.8	51.6	9.78	-0.6
4.2	52.6	9.53		4.3	51.1	10.18	-0.2
				4.8	50.6	9.94	0.2
				5.3	50.1	9.99	-0.1
				5.8	49.6	10.00	-0.0
				5.9	49.5	10.00	

CLBH3 Depth m-gl.	April Depth mamsl	63.83 Temp. Celsius	Gradient C/m
6.0	57.9		
7.0	56.9	9.54	
8.0	55.9	9.57	-0.0
9.0	54.9	9.55	-0.0
10.0	53.9	9.61	-0.0
11.0	52.9	9.64	-0.0
12.0	51.9	9.65	-0.1
12.8	51.1	9.79	

CLCD1 Depth m-gl.	April Depth mamsl	54.12 Temp. Celsius	Gradient C/m
-1.4	55.5		
-0.4	54.5	5.77	
0.6	53.5	6.99	-1.2
1.6	52.5	8.13	-1.0
2.6	51.5	8.96	-0.7
3.6	50.5	9.51	-0.3
4.6	49.5	9.65	-0.2
5.6	48.5	9.88	-0.2
6.6	47.5	10.06	-0.1
7.6	46.5	10.08	-0.0
8.6	45.5	10.09	-0.0
9.6	44.5	10.12	-0.0
10.2	43.9	10.14	

CLCD2_N Depth m-gl.	April Depth mamsl	51.7 Temp. Celsius	Gradient C/m
0.6	51.1		
1.6	50.1	9.37	
2.6	49.1	9.82	-0.3
3.6	48.1	10.01	-0.1
4.6	47.1	10.06	-0.3
5.2	46.5	10.45	

71.C Depth m gl.	April Depth mamsl	Temp. Celsius	Gradient C/m
-1.6		8.27	
-2.1		8.21	-0.2
-2.4		8.47	

903.C Depth m gl.	April Depth mamsl	60.5 Temp. Celsius	Gradient C/m
-2.3	58.3	9.69	
-2.8	57.8	9.62	0.0
-3.1	57.5	9.68	

104.1	April	58.68	
Depth m gl.	Depth mamsl	Temp. Celsius	Gradient C/m
-0.6	58.1	8.91	
-1.1	57.6	8.10	0.4
-1.6	57.1	8.48	-0.8
-2.1	56.6	8.94	-0.9
-2.6	56.1	9.41	-0.7
-3.1	55.6	9.69	-0.5
-3.6	55.1	9.90	-0.2
-4.1	54.6	9.90	-0.2
-4.2	54.5	10.04	

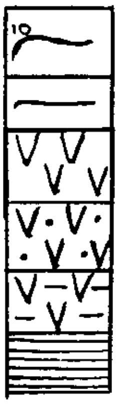
106.1	April	59.46	
Depth m gl.	Depth mamsl	Temp. Celsius	Gradient C/m
-0.6	58.9	7.61	
-1.1	58.4	8.03	-0.9
-1.6	57.9	8.47	-1.0
-2.1	57.4	9.02	-1.1
-2.6	56.9	9.57	-0.8
-3.1	56.4	9.86	-0.5
-3.6	55.9	10.03	-0.2
-4.1	55.4	10.03	-0.1
-4.4	55.1	10.12	

107.1	April	59.54	
Depth m-gl.	Depth mamsl	Temp. Celsius	Gradient C/m
0.6	59.0	7.64	
1.1	58.5	8.03	-0.8
1.6	58.0	8.46	-0.9
2.1	57.5	8.94	-0.9
2.6	57.0	9.41	-0.8
3.1	56.5	9.69	-0.5
3.6	56.0	9.92	-0.4
4.1	55.5	10.05	-0.2
4.2	55.3		
4.4	55.2		
4.6	55.0	10.08	-0.0
5.1	54.5	10.09	-0.0
5.2	54.4	10.10	

109.1	April	59.73	
Depth m-gl.	Depth mamsl	Temp. Celsius	Gradient C/m
0.6	59.2	7.64	
1.1	58.7	8.12	-0.9
1.6	58.2	8.55	-1.0
2.1	57.7	9.07	-1.0
2.6	57.2	9.51	-0.8
3.1	56.7	9.84	-0.5
3.6	56.2	10.04	-0.3
4.1	55.7	10.13	-0.1
4.6	55.2	10.15	-0.0
5.1	54.7	10.17	-0.0
5.6	54.2	10.17	-0.0
6.1	53.7	10.17	-0.0
6.6	53.2	10.18	-0.0
7.1	52.7	10.18	-0.0
7.3	52.5	10.19	

110.1	April	59.81	
Depth m-gl.	Depth mamsl	Temp. Celsius	Gradient C/m
0.6	59.2	7.71	
1.1	58.7	8.15	-0.8
1.6	58.2	8.55	-0.9
2.1	57.7	9.01	-0.9
2.6	57.2	9.49	-0.8
3.1	56.7	9.79	-0.5
3.6	56.2	10.00	-0.3
4.1	55.7	10.08	-0.1
4.6	55.2	10.12	-0.0
5.1	54.7	10.13	-0.0
5.6	54.2	10.13	0.0
6.1	53.7	10.12	0.0
6.6	53.2	10.13	-0.0
7.1	52.7	10.15	-0.0
7.3	52.6		
7.6	52.2	10.17	-0.0
8.1	51.7	10.19	-0.0
8.6	51.2	10.19	-0.1
9.1	50.7	10.24	

<u>*LEGEND*</u>



Isotherm $10^{0}C$

Border of geological layer

Young Sphagnum peat

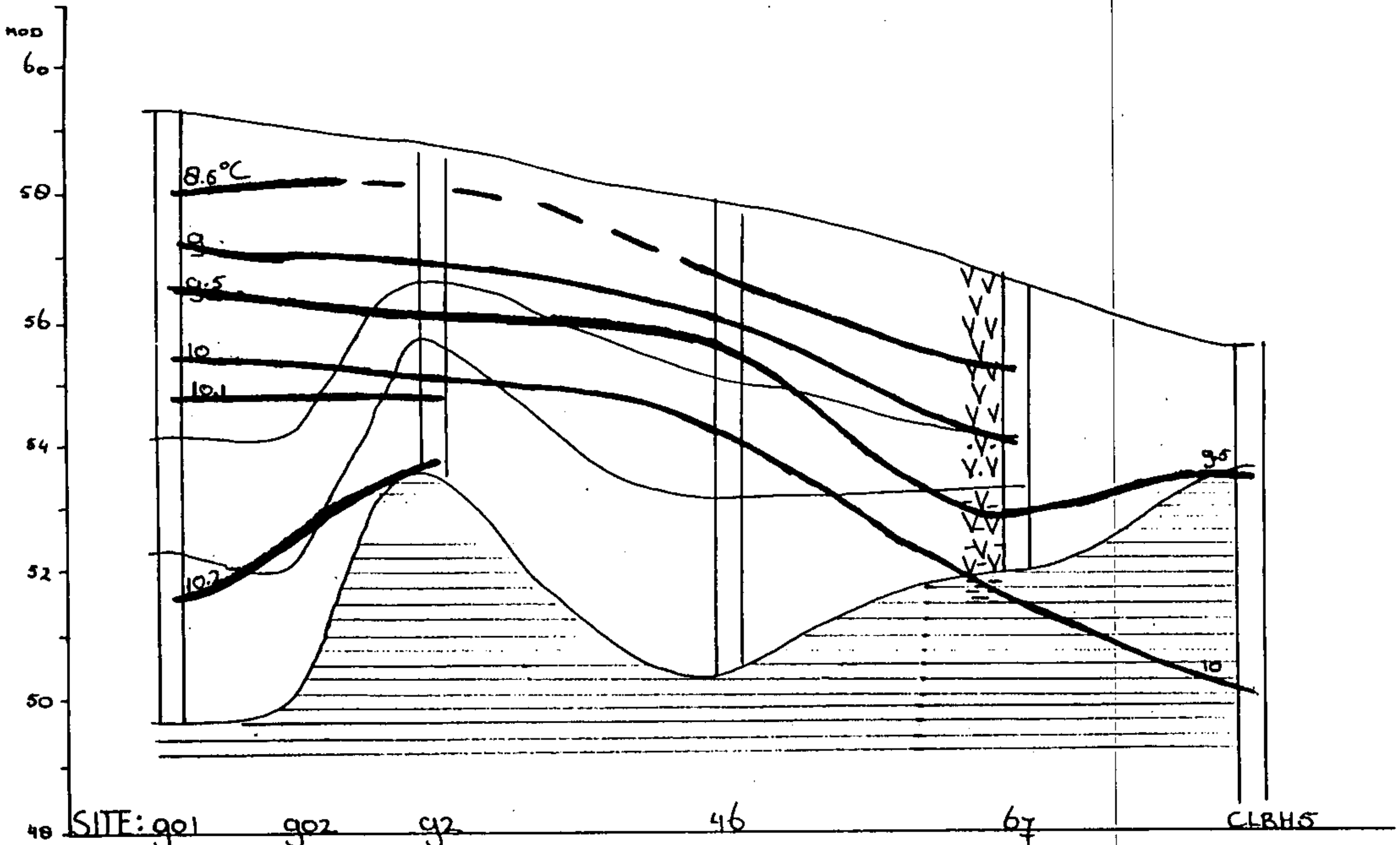
Old Sphagnum peat

Fenpeat

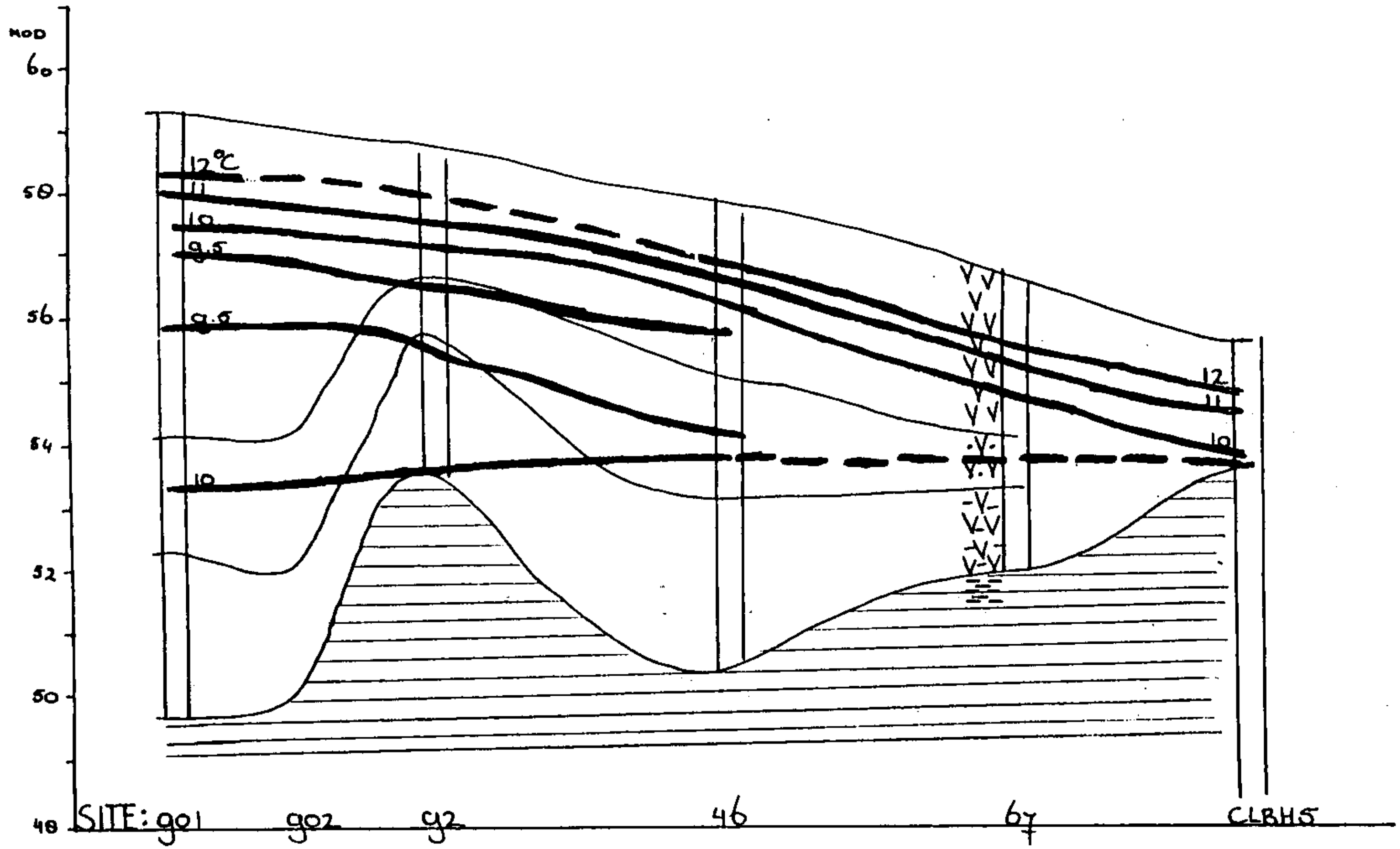
Mineral subsoil

Horizontal scale

*Vertical exaggeration 50 **



APPENDIX IV.C	ISOTHERMS	April 1992
Transect 1	Clara west	(Site 901-CLBH5)

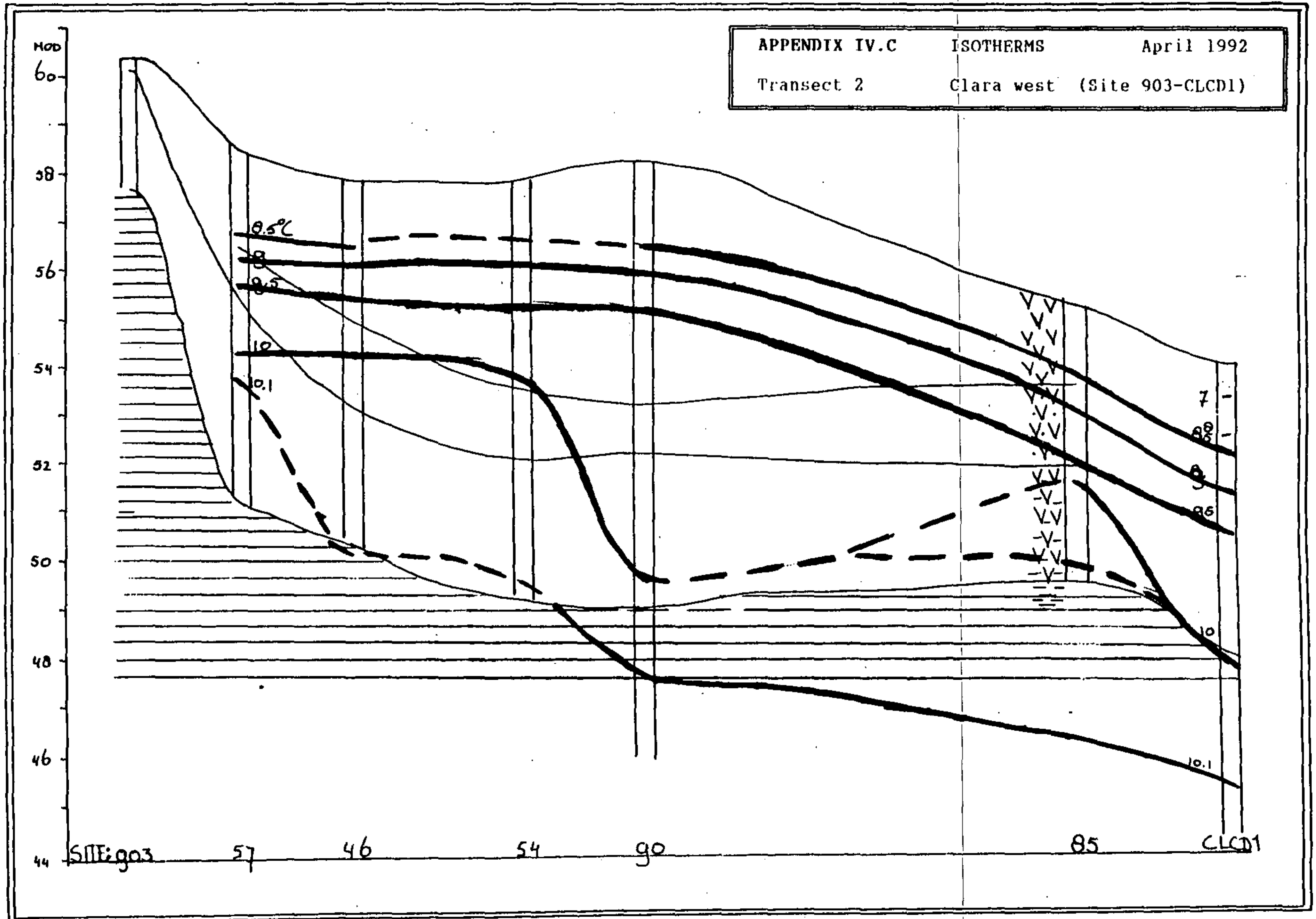


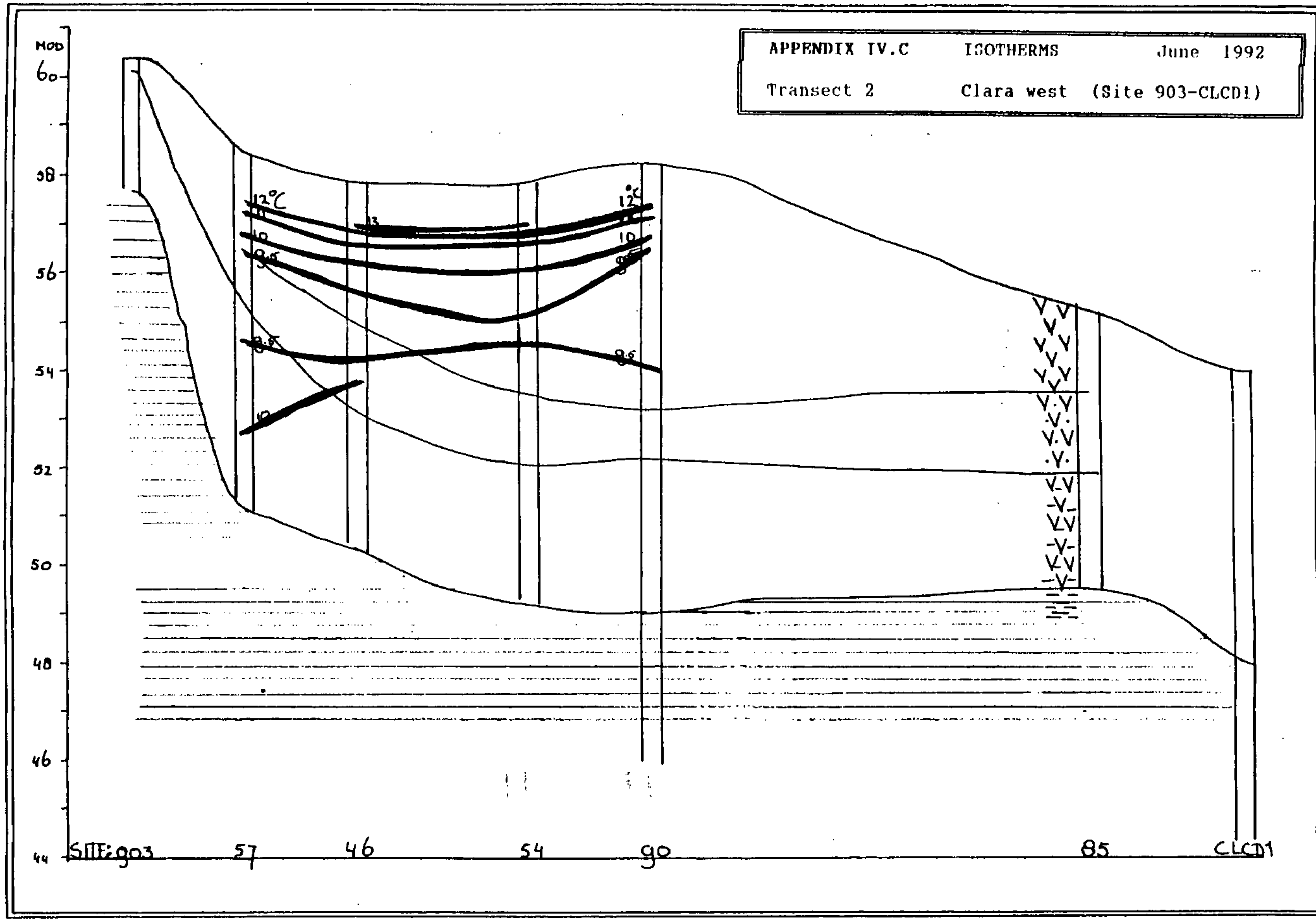
APPENDIX IV.C ISOTHERMS June 1992

Transect 1 Clara west (Site 901-CLBH5)

APPENDIX IV.C ISOTHERMS April 1992

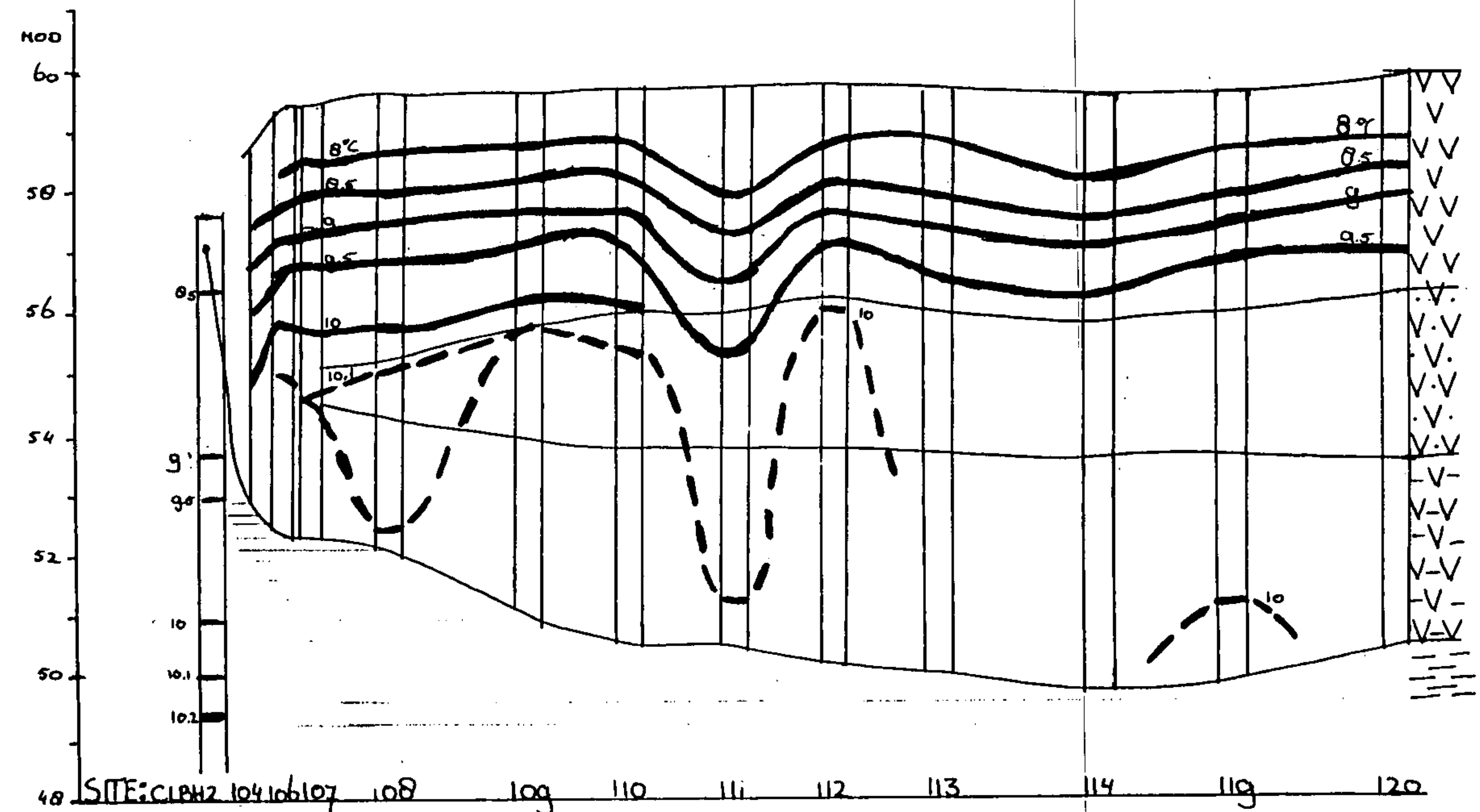
Transect 2 Clara west (Site 903-CLCD1)



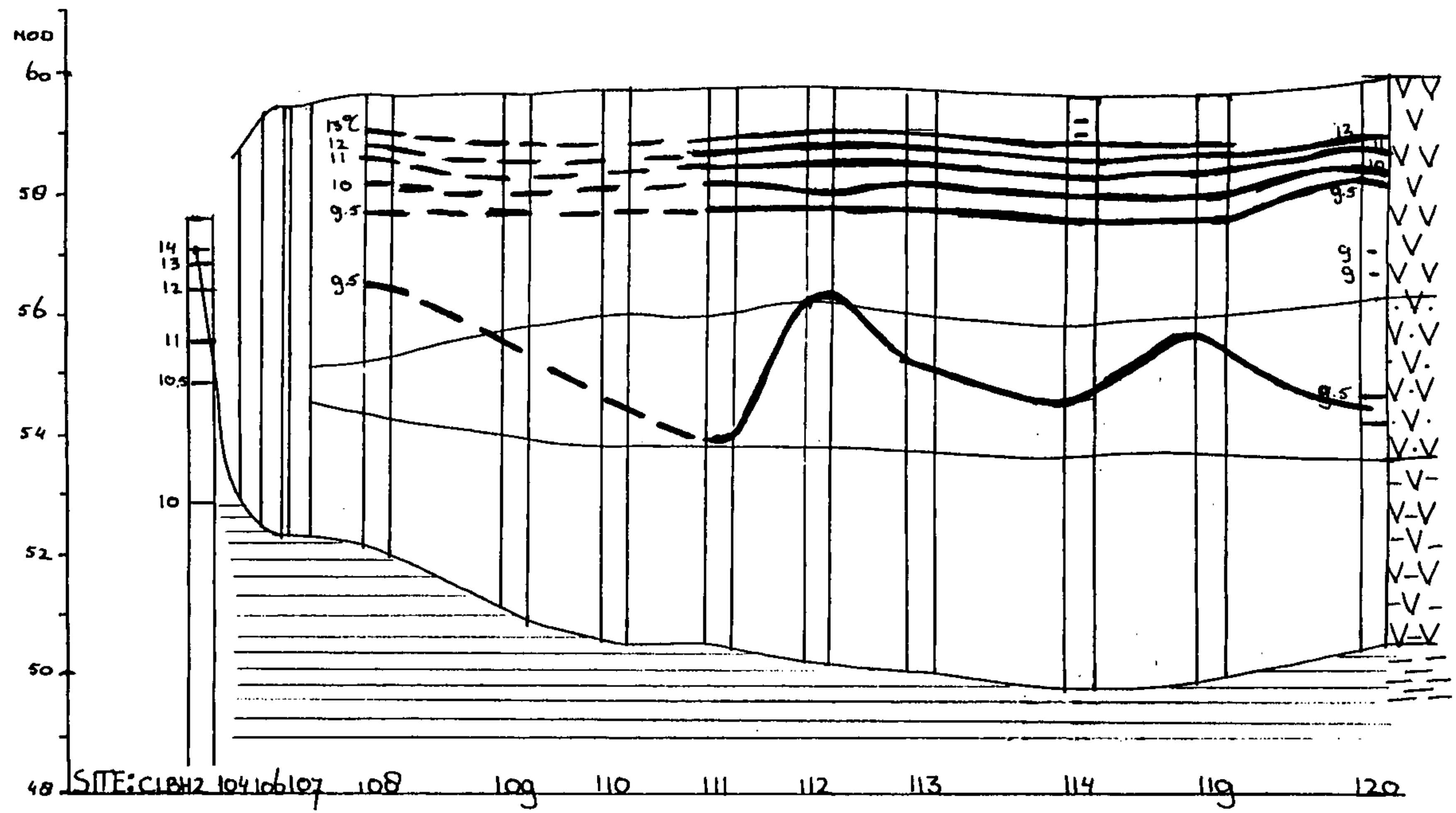


APPENDIX IV.C ISOTHERMS June 1992

Transect 2 Clara west (Site 903-CLCD1)

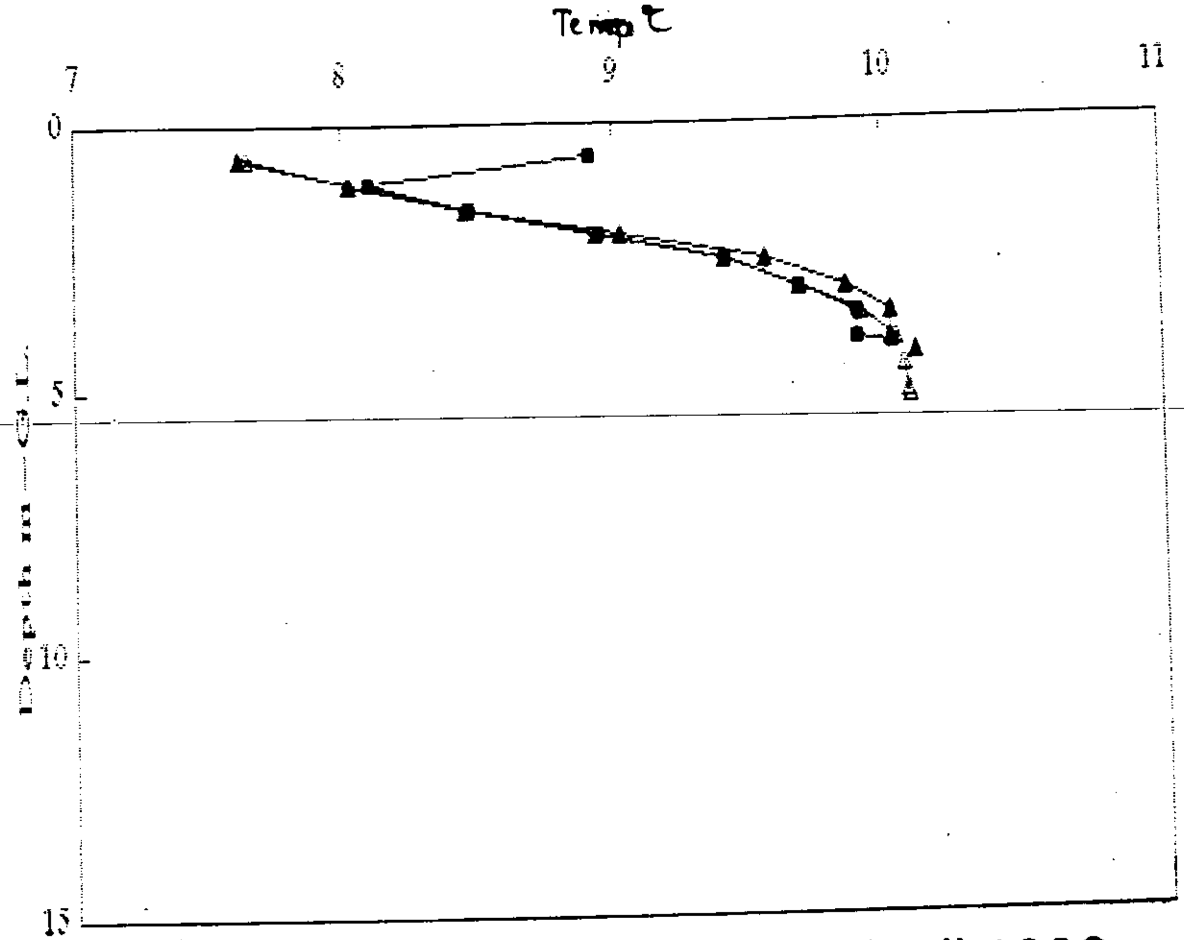


APPENDIX IV.C	ISOTHERMS	April 1992
Transect 3	Clara east (Site 104-120)	

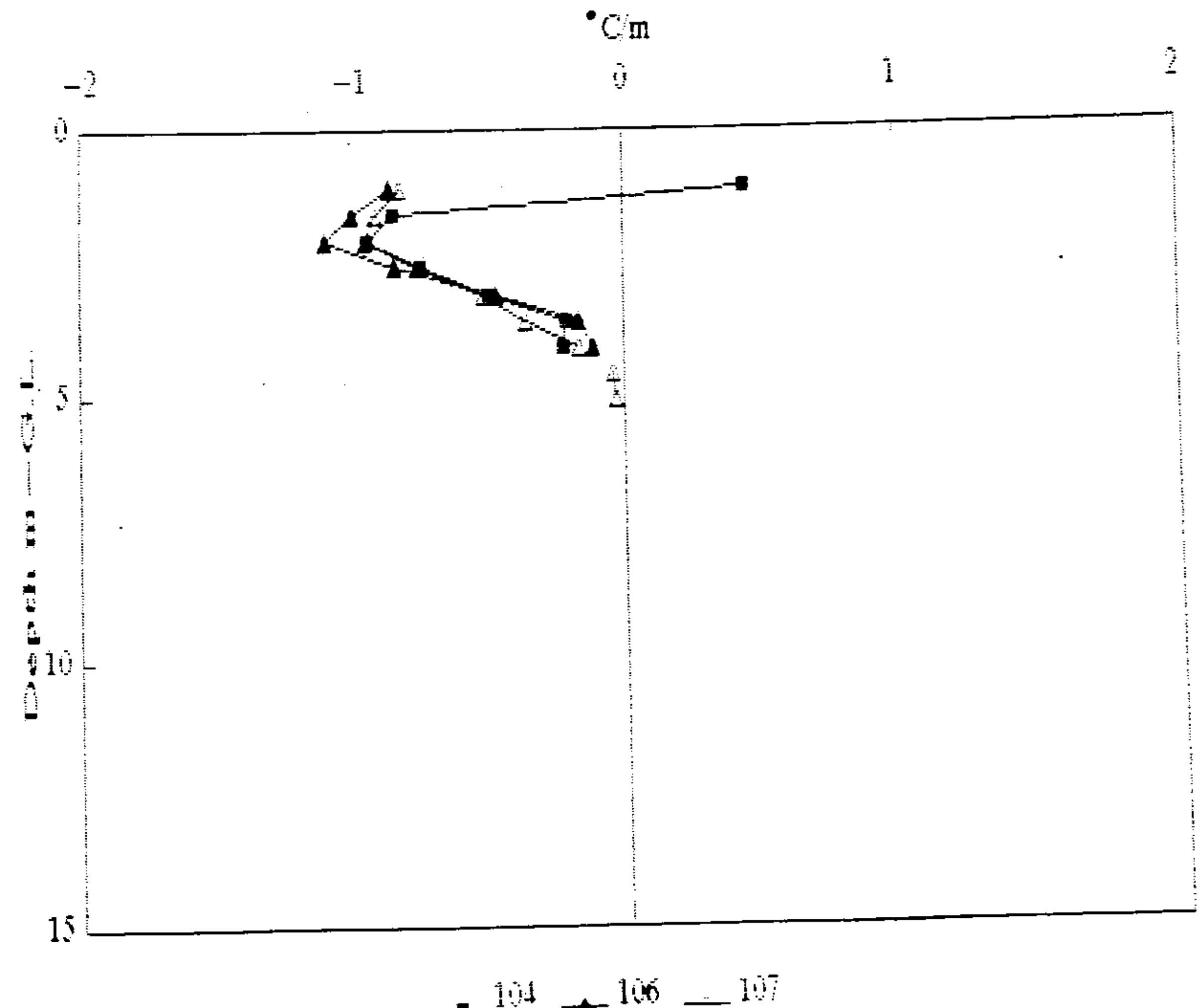


APPENDIX IV.C	ISOTHERMS	June 1992
Transect 3	Clara east	(Site 104-120)

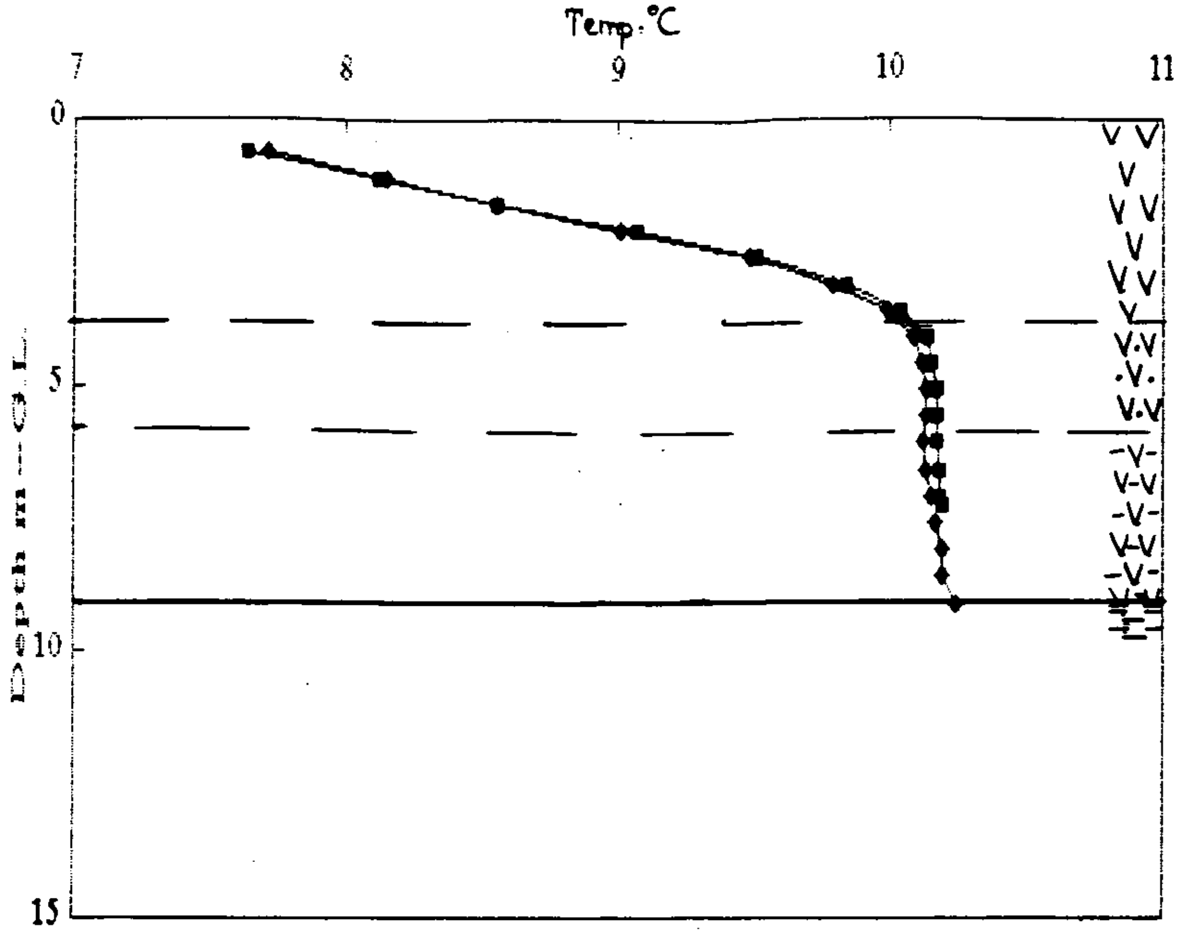
TEMPERATURE PROFILE April 1992



TEMPERATURE GRADIENT April 1992



TEMPERATURE PROFILE April 1992



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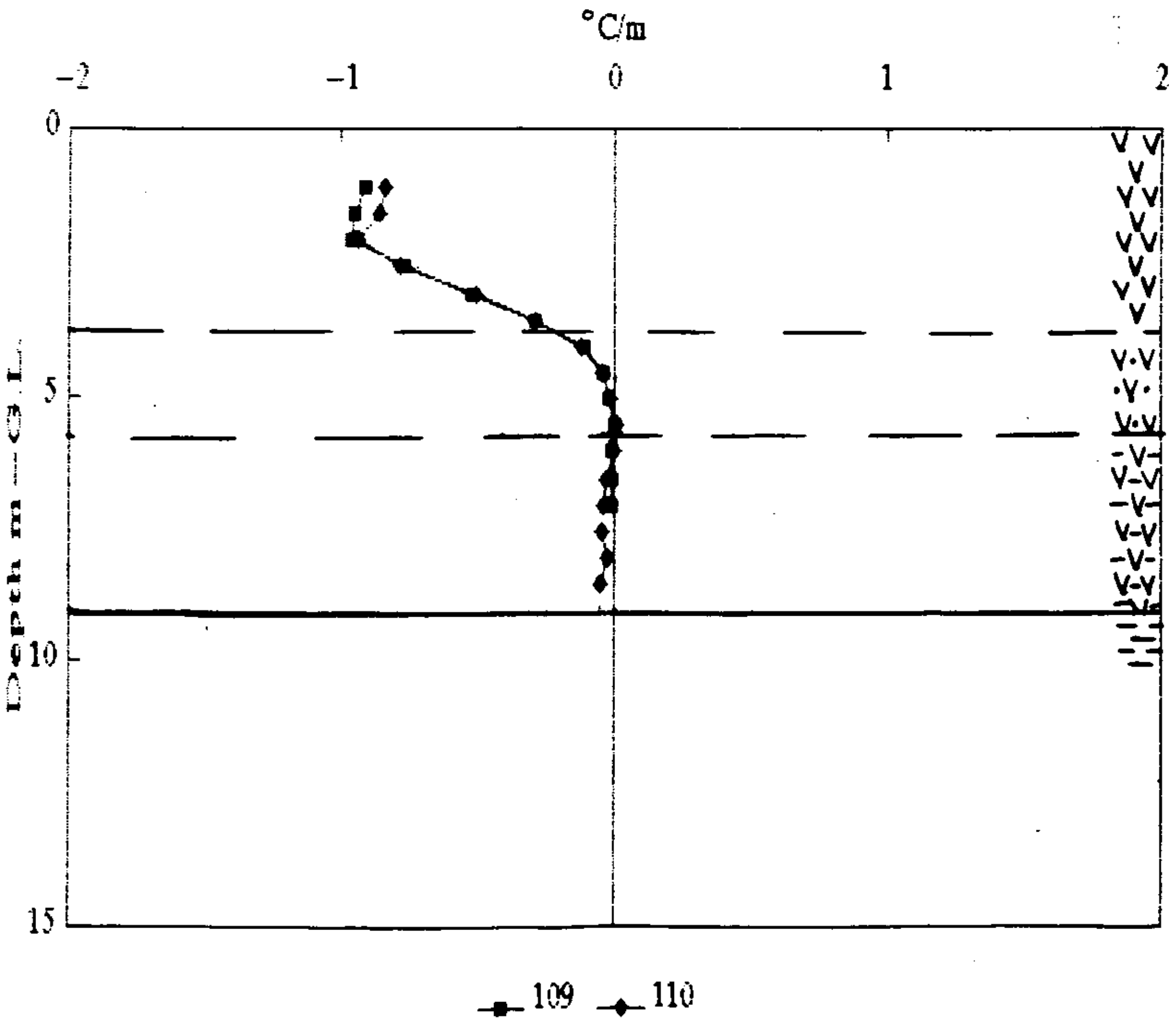

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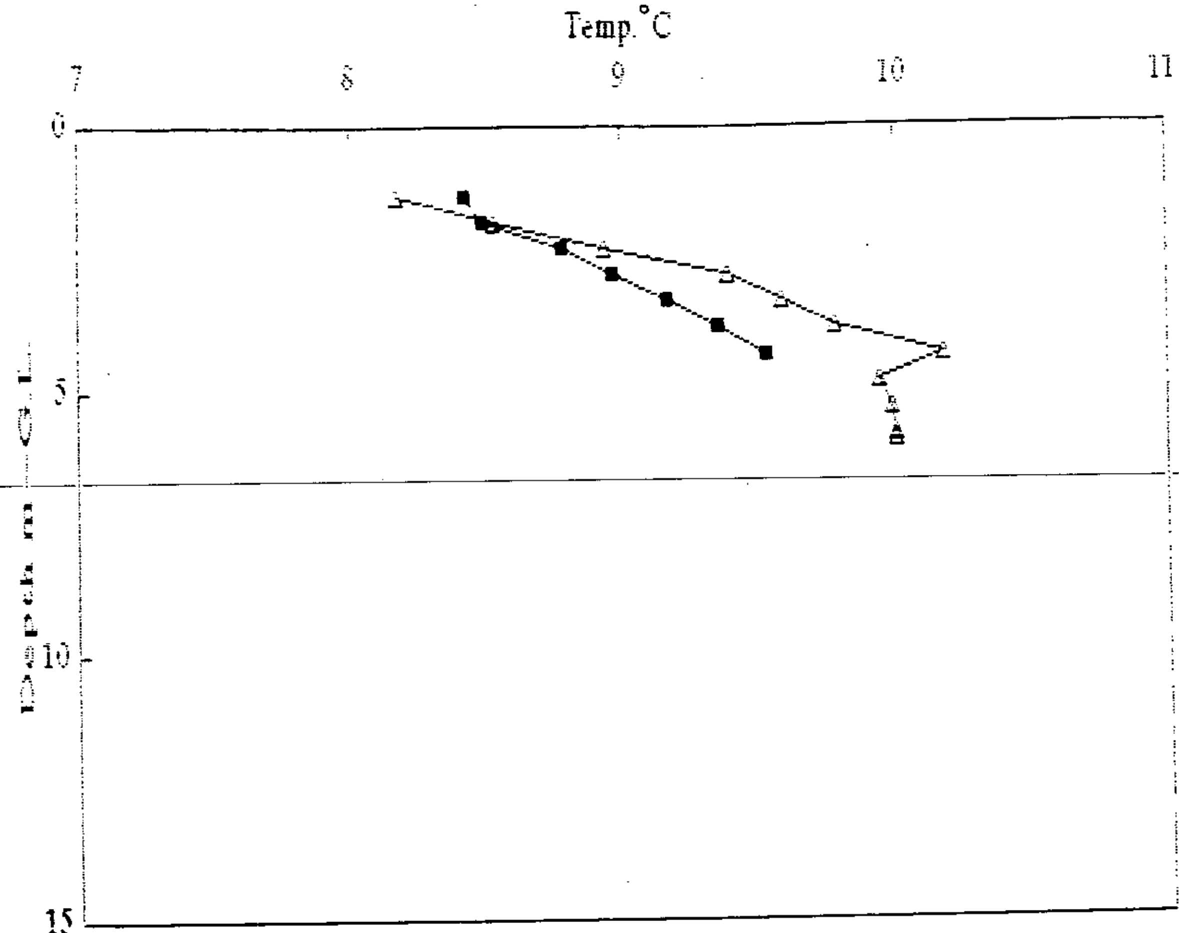

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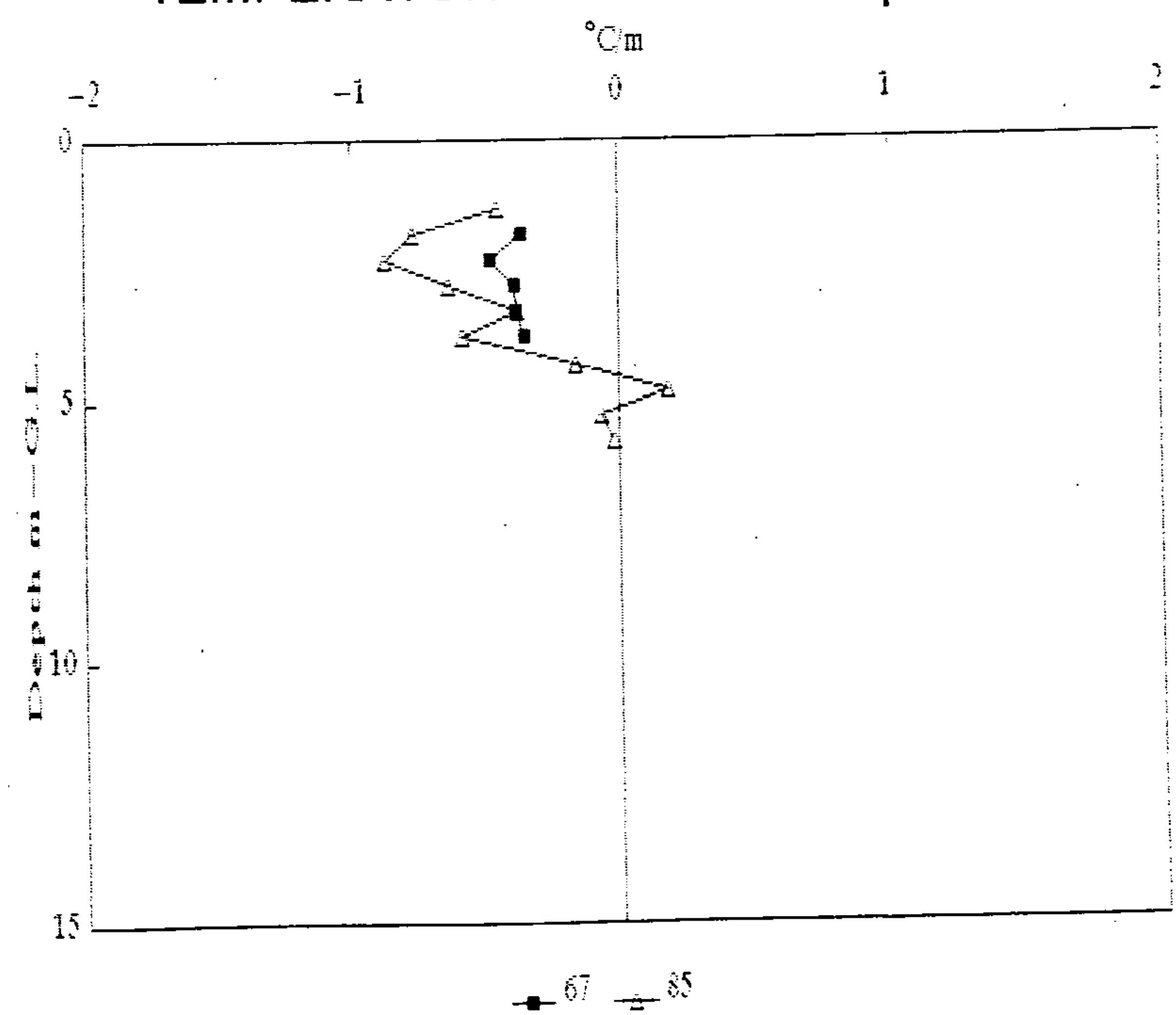
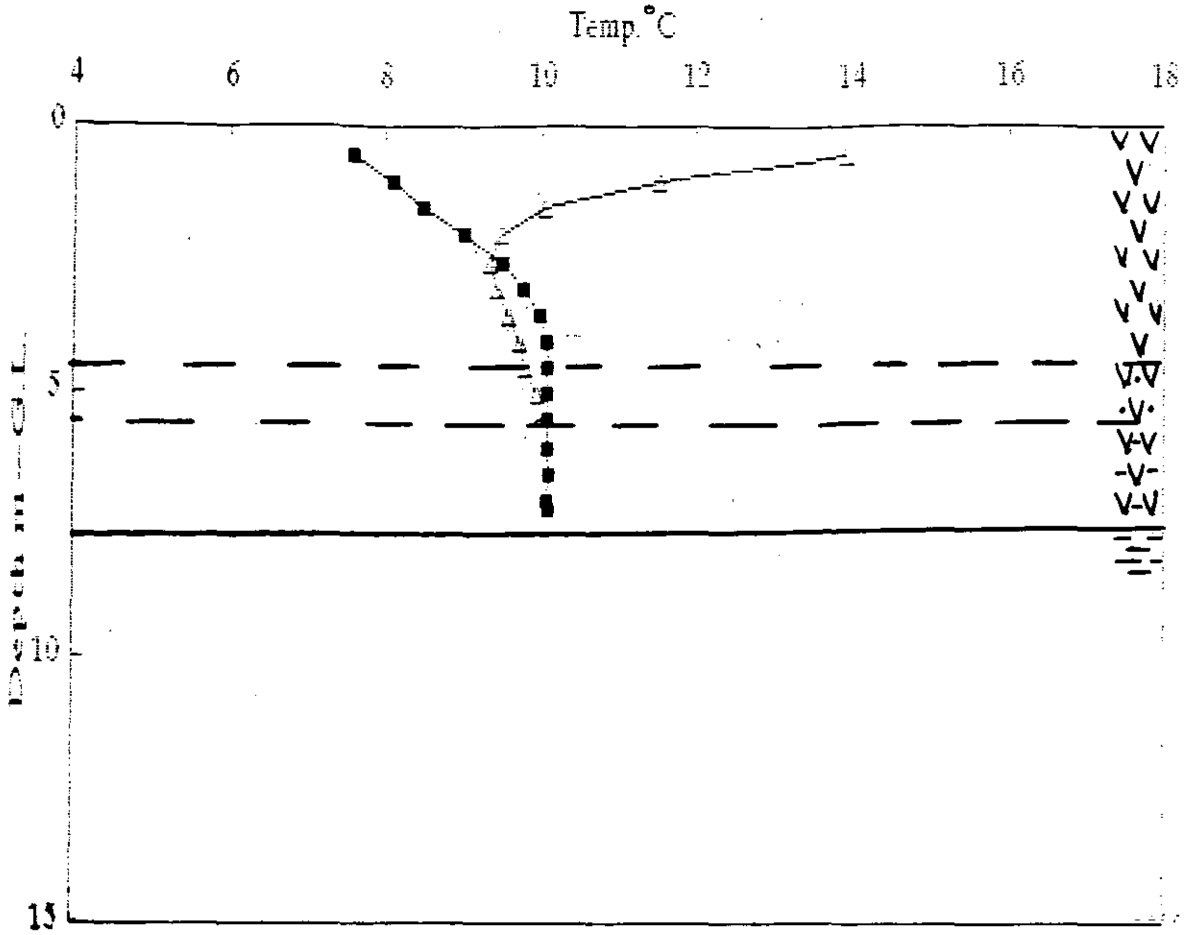
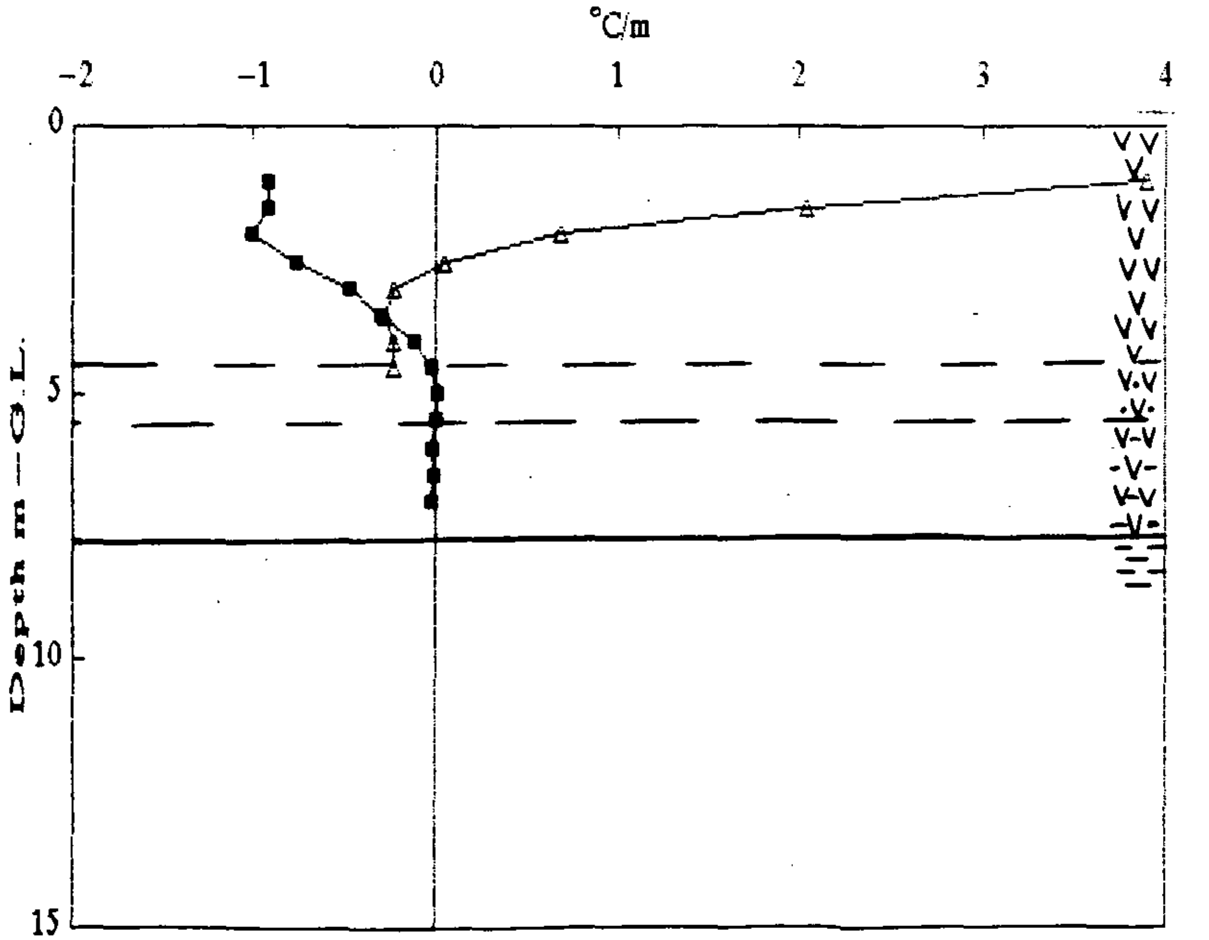


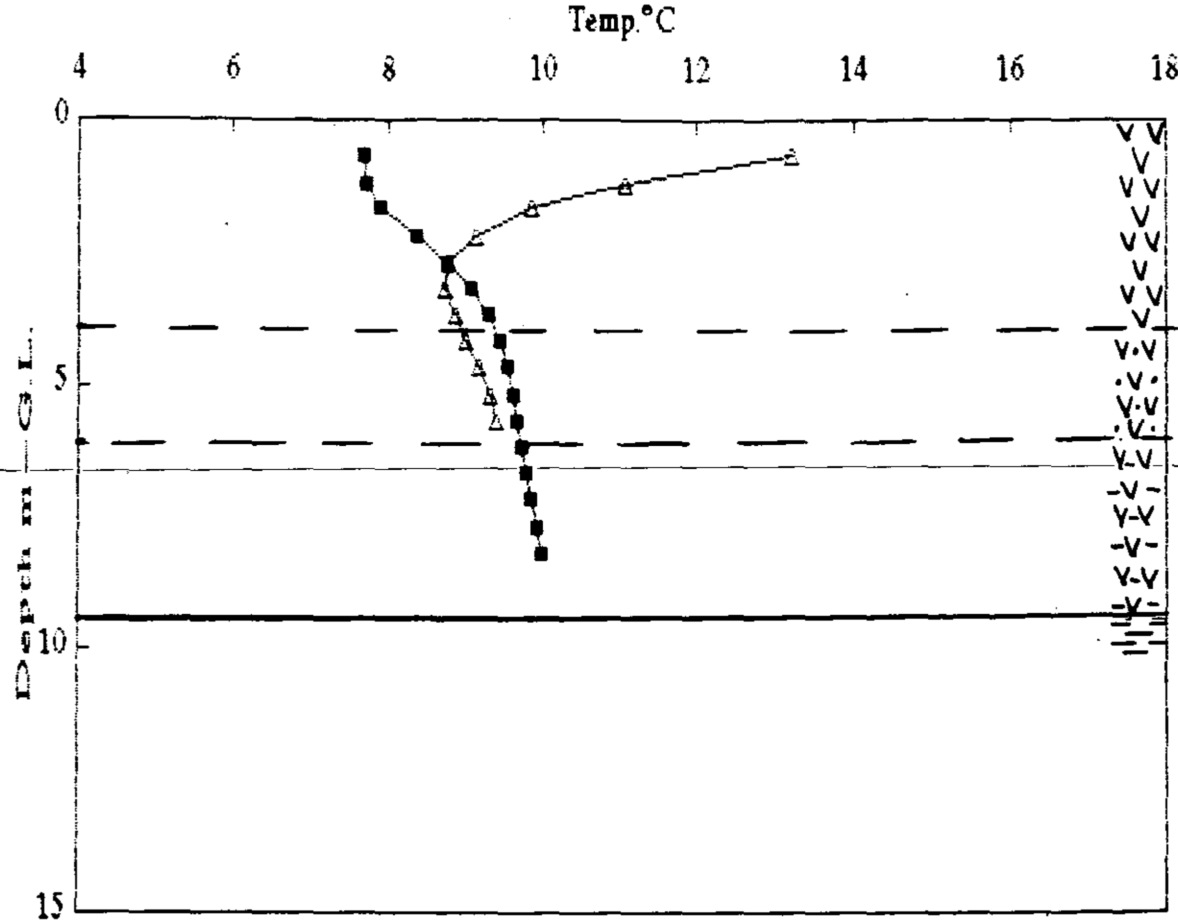
TEMPERATURE PROFILE Tube 108



TEMPERATURE GRADIENT Tube 108



TEMPERATURE PROFILE Tube 111



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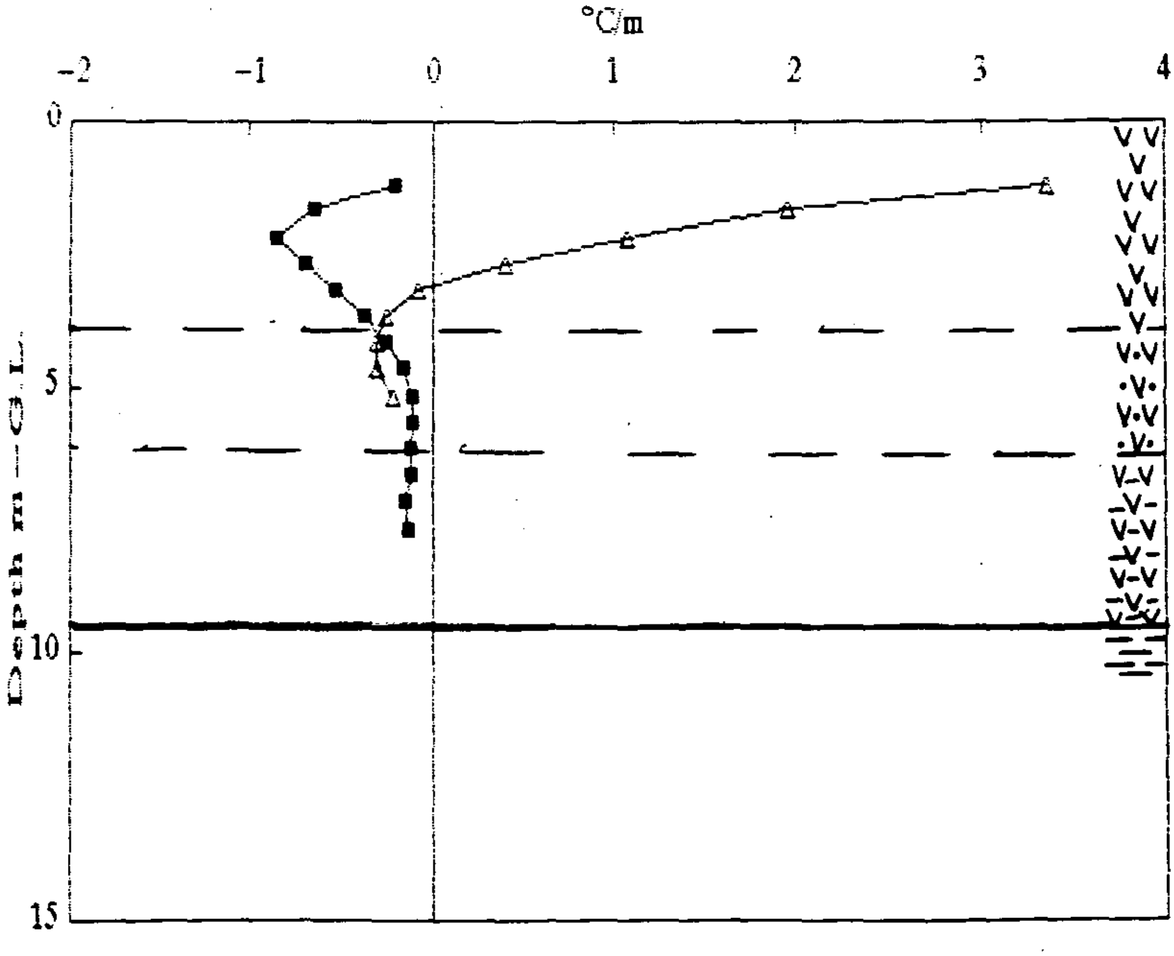
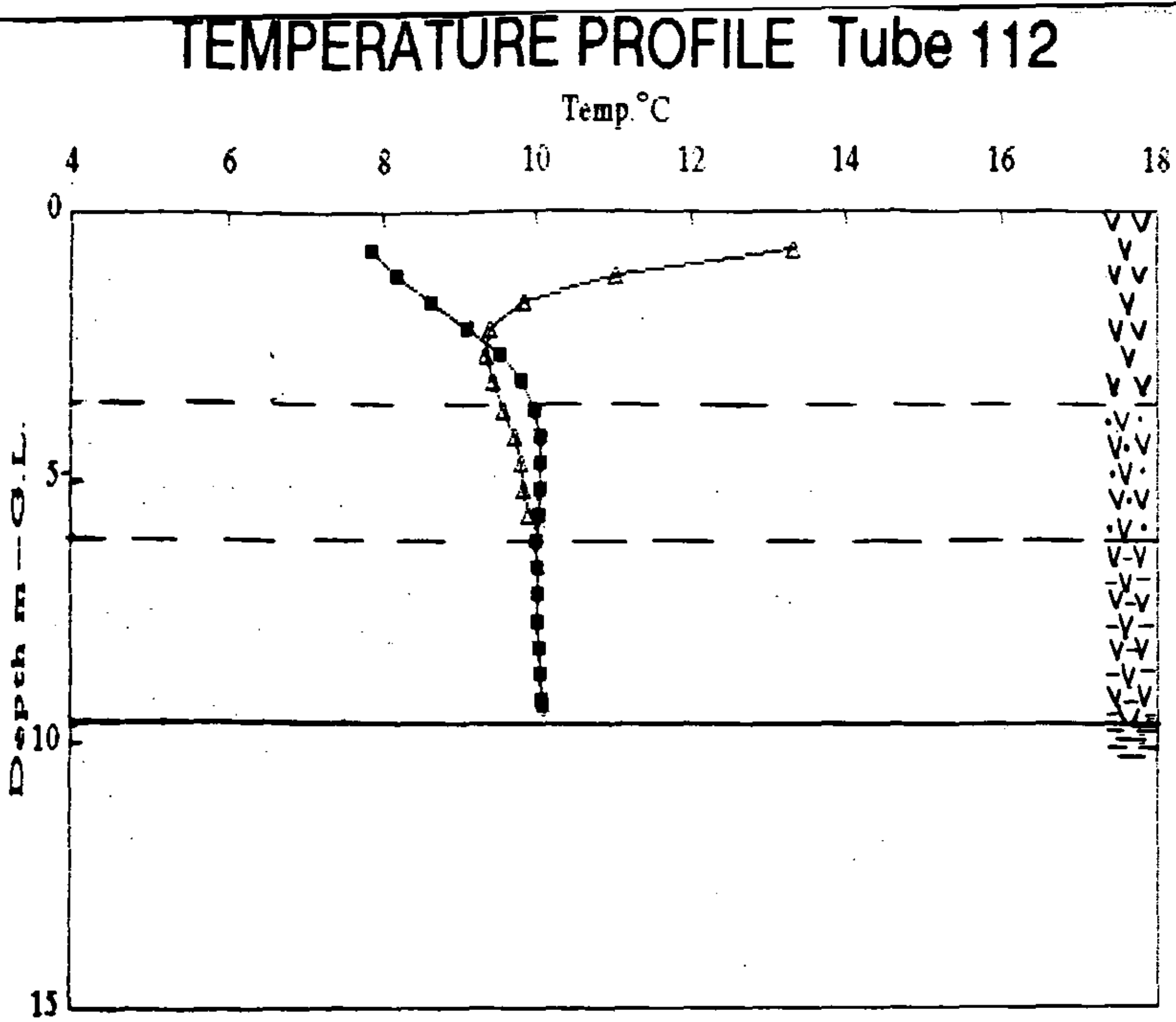
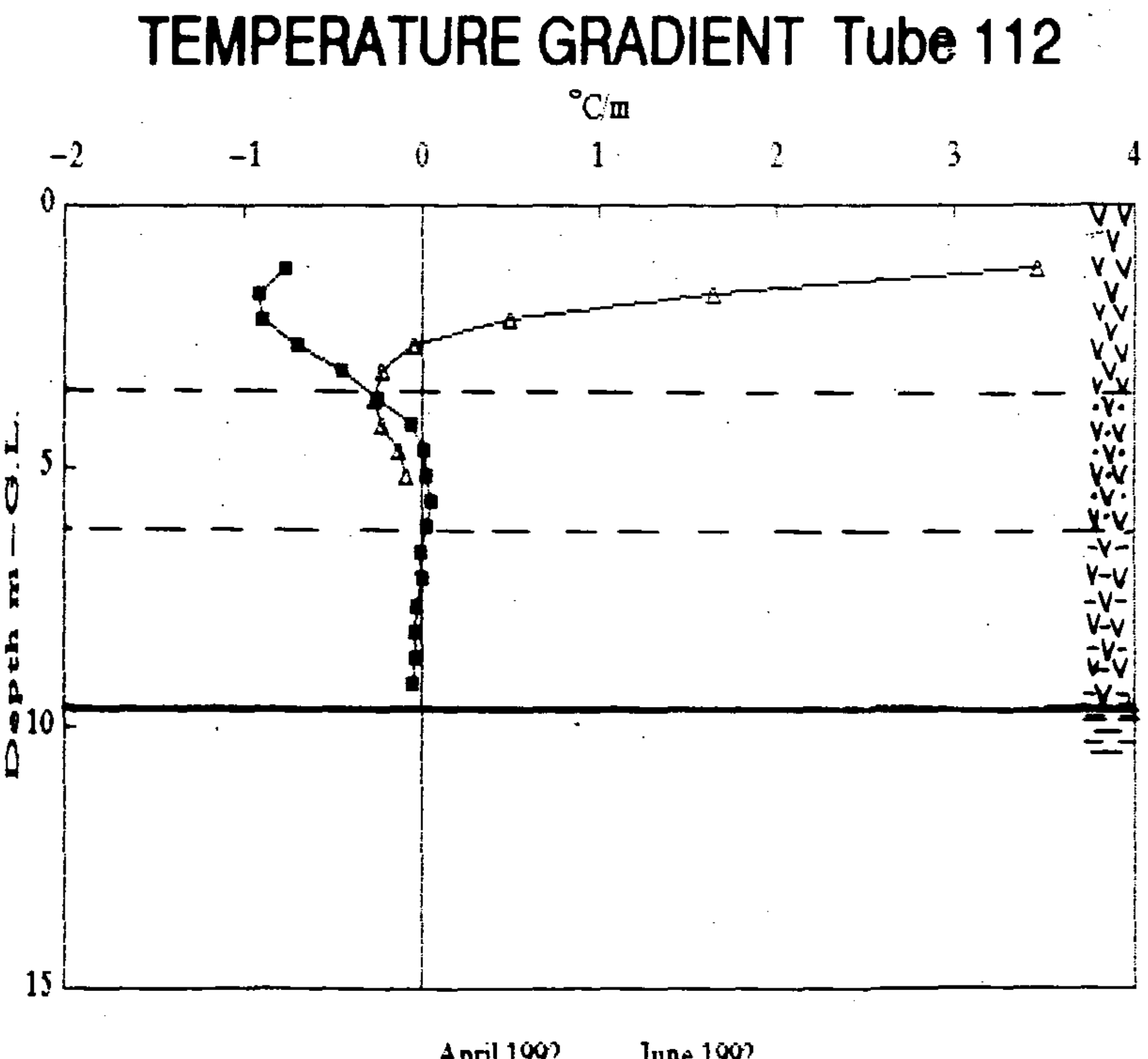


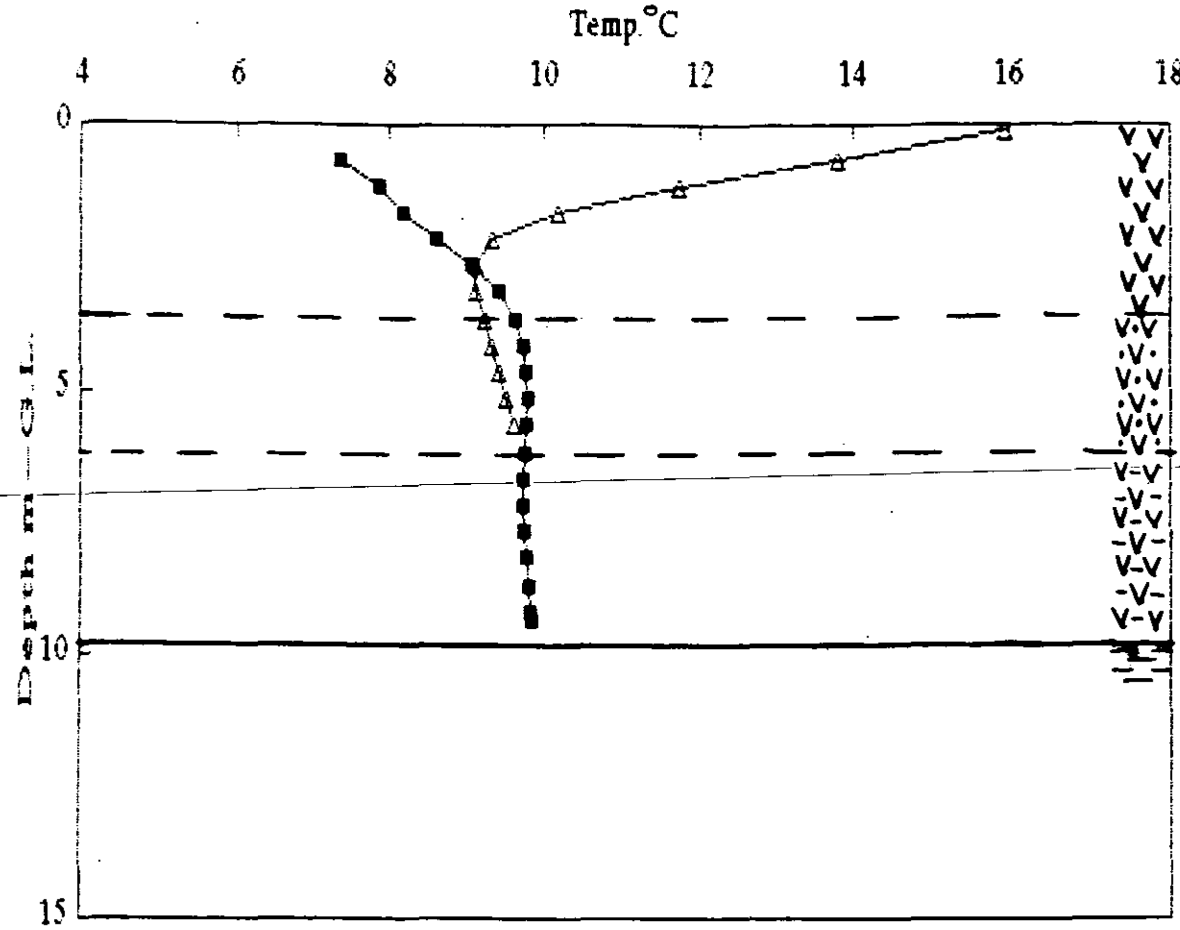


TEMPERATURE PROFILE Tube 112
Temp.°C
4
6
8
10
12
14
16
18
0
5
10
15
Depth m — G.L.

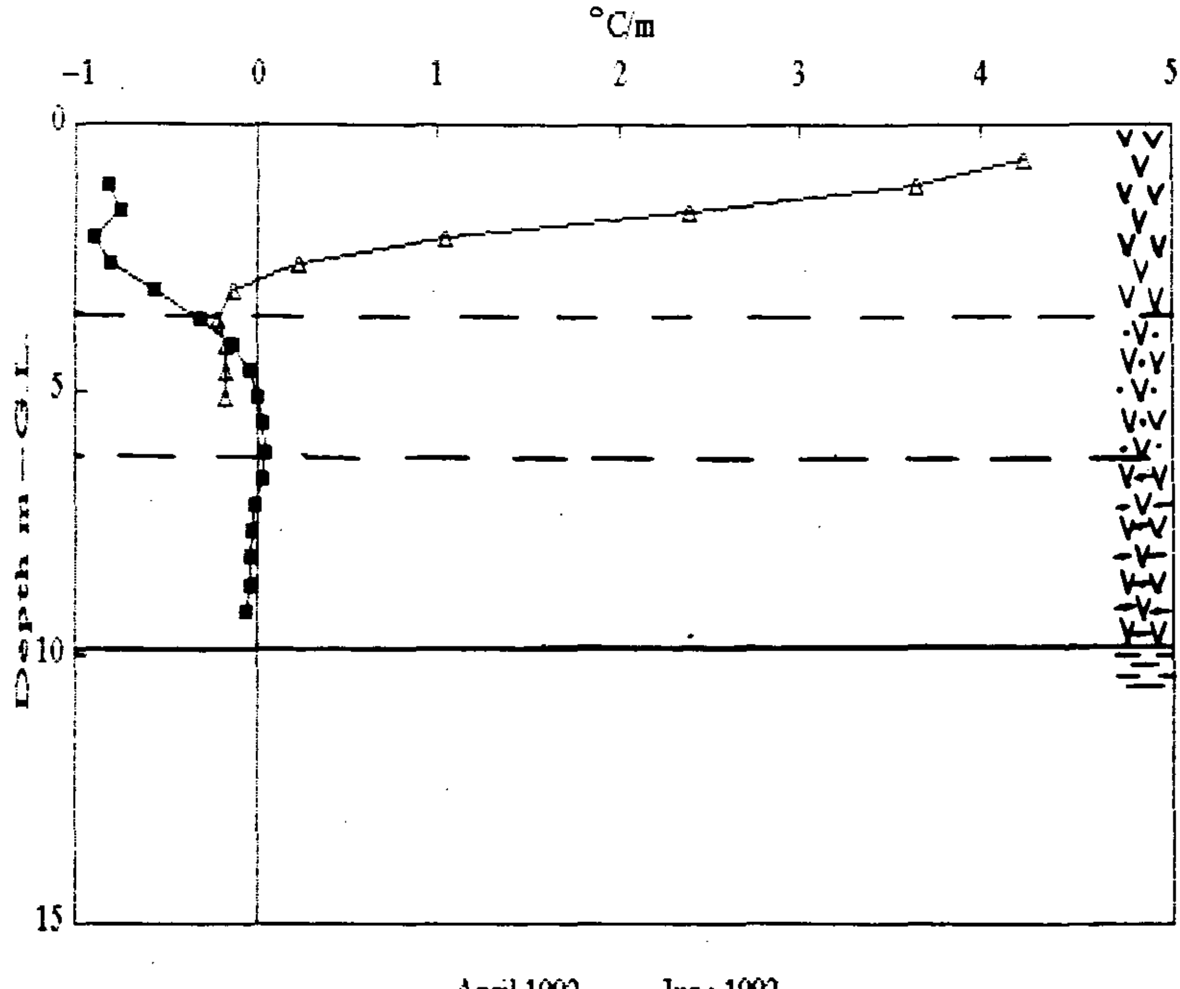


TEMPERATURE GRADIENT Tube 112
°C/m
-2
-1
0
1
2
3
4
0
5
10
15
Depth m — G.L.
April 1992
June 1992

TEMPERATURE PROFILE Tube 114

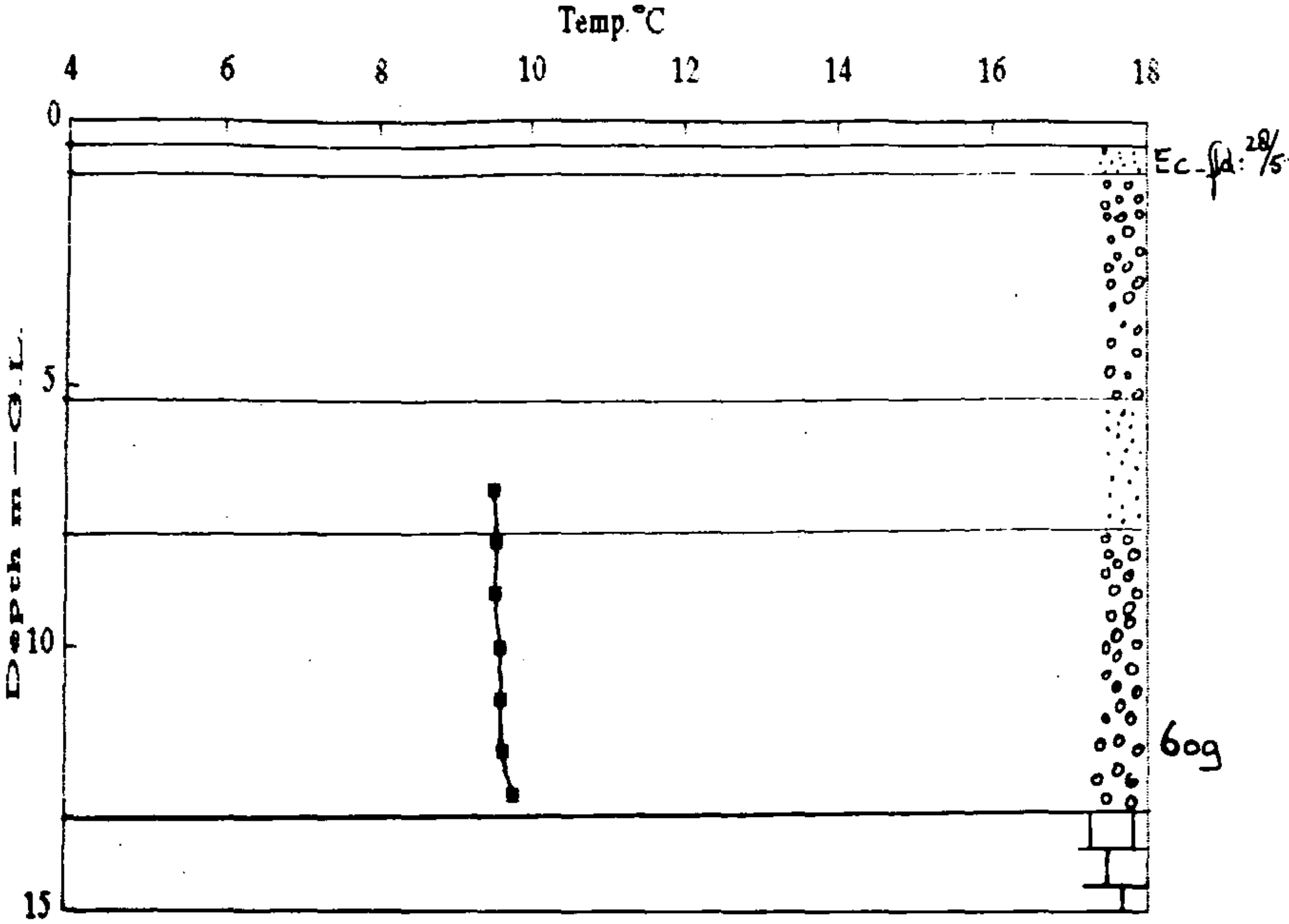


TEMPERATURE GRADIENT Tube 114



April 1992 June 1992

TEMPERATURE PROFILE CLBH3



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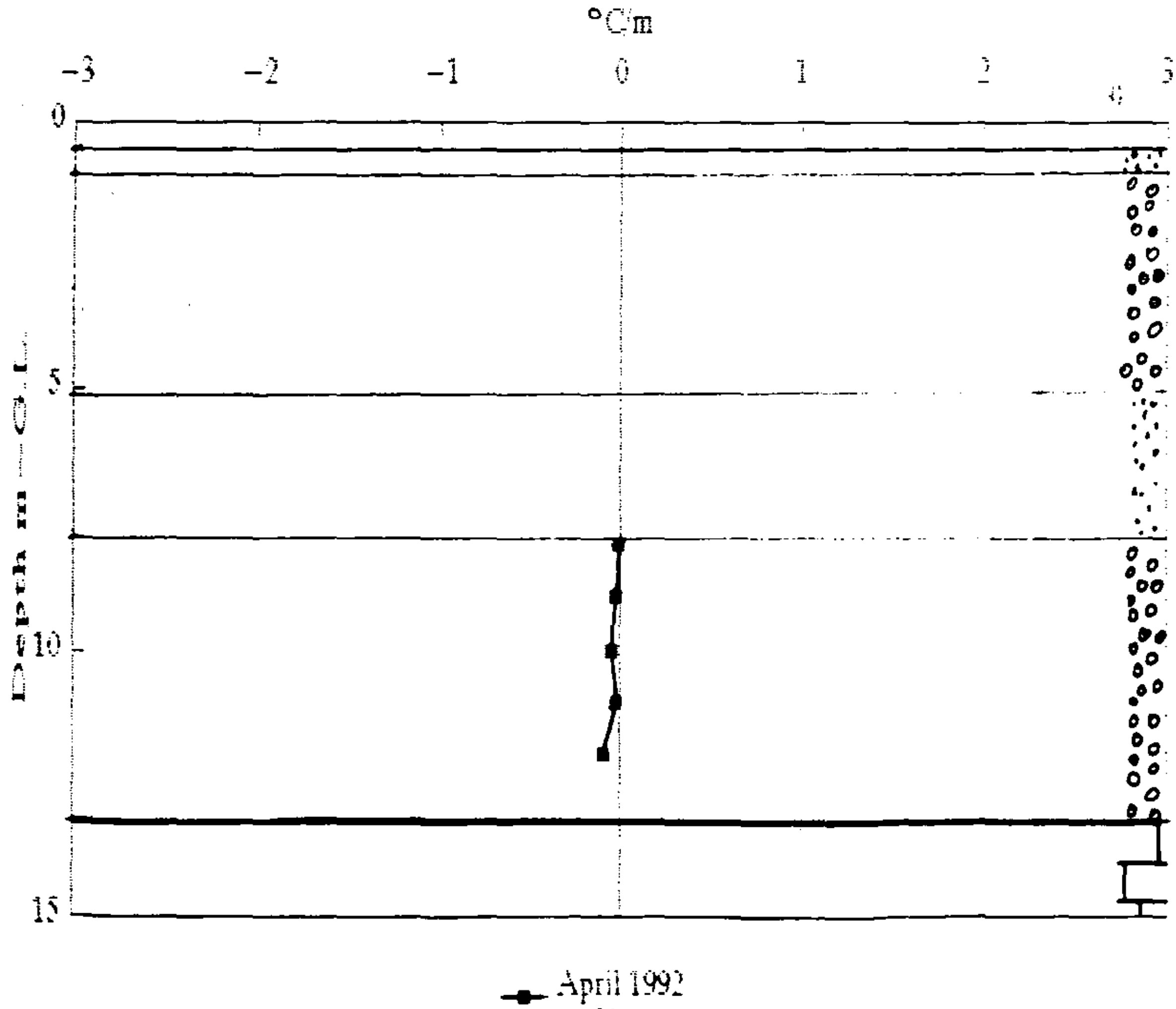
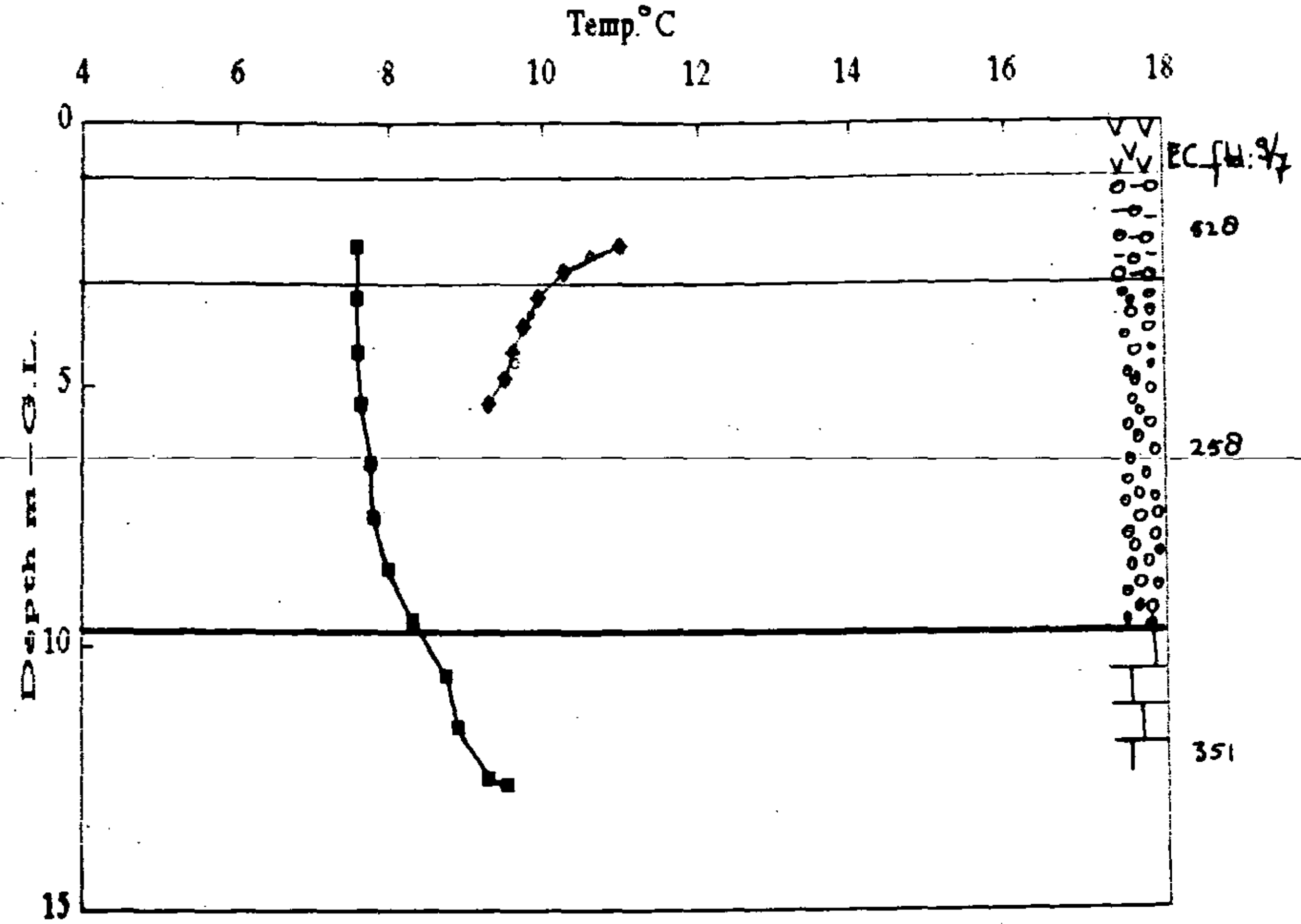
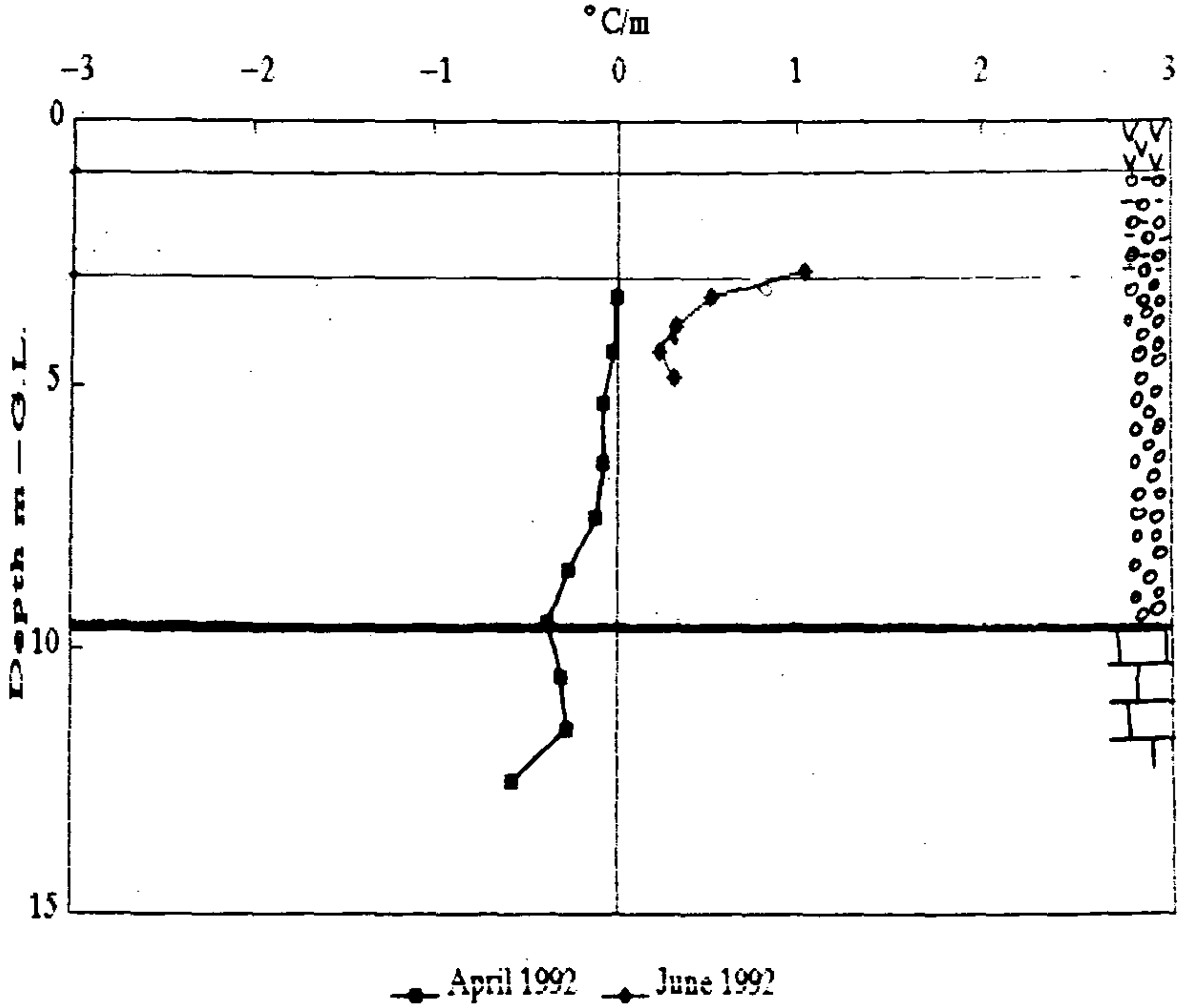


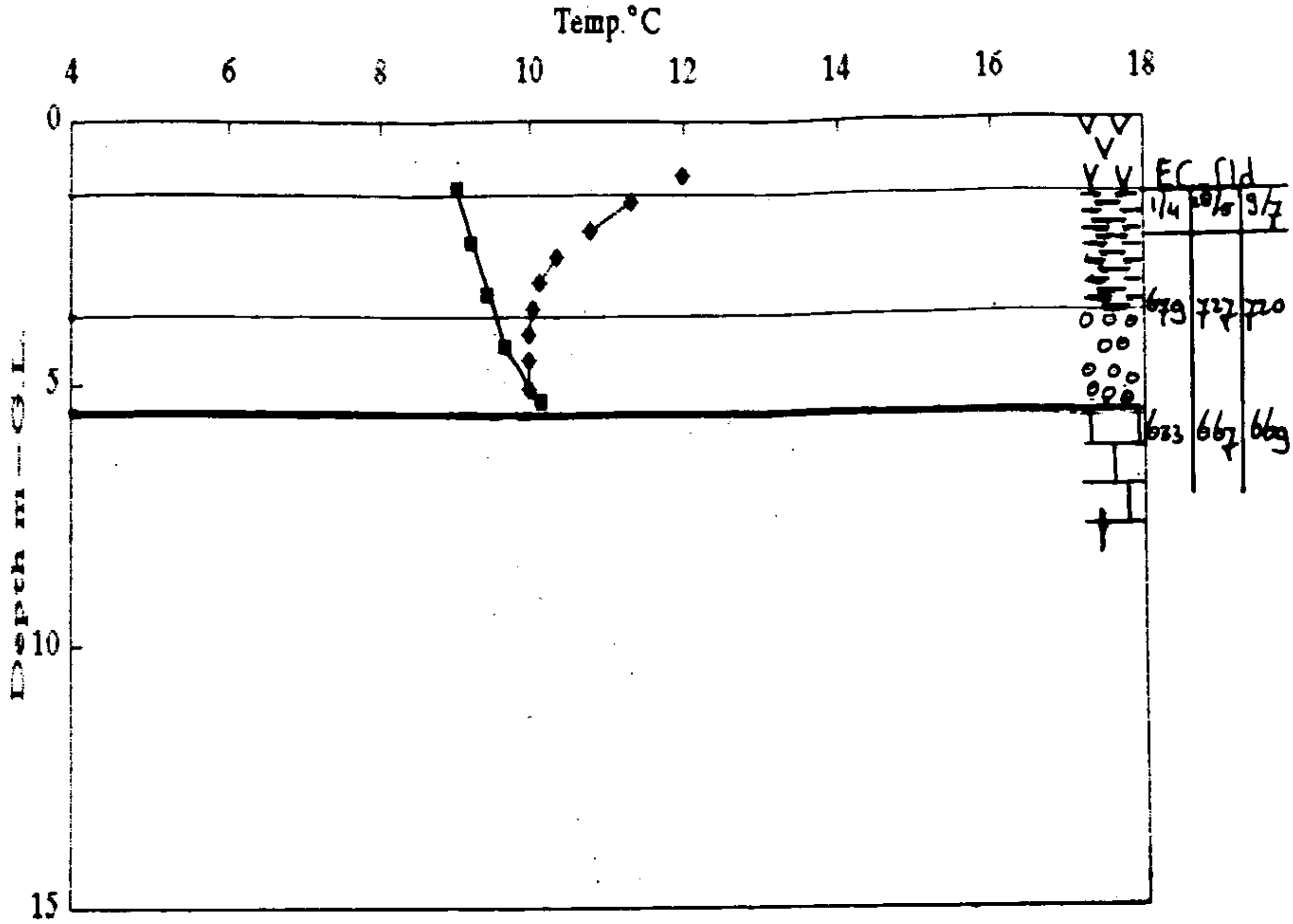
TEMPERATURE PROFILE CLBH4



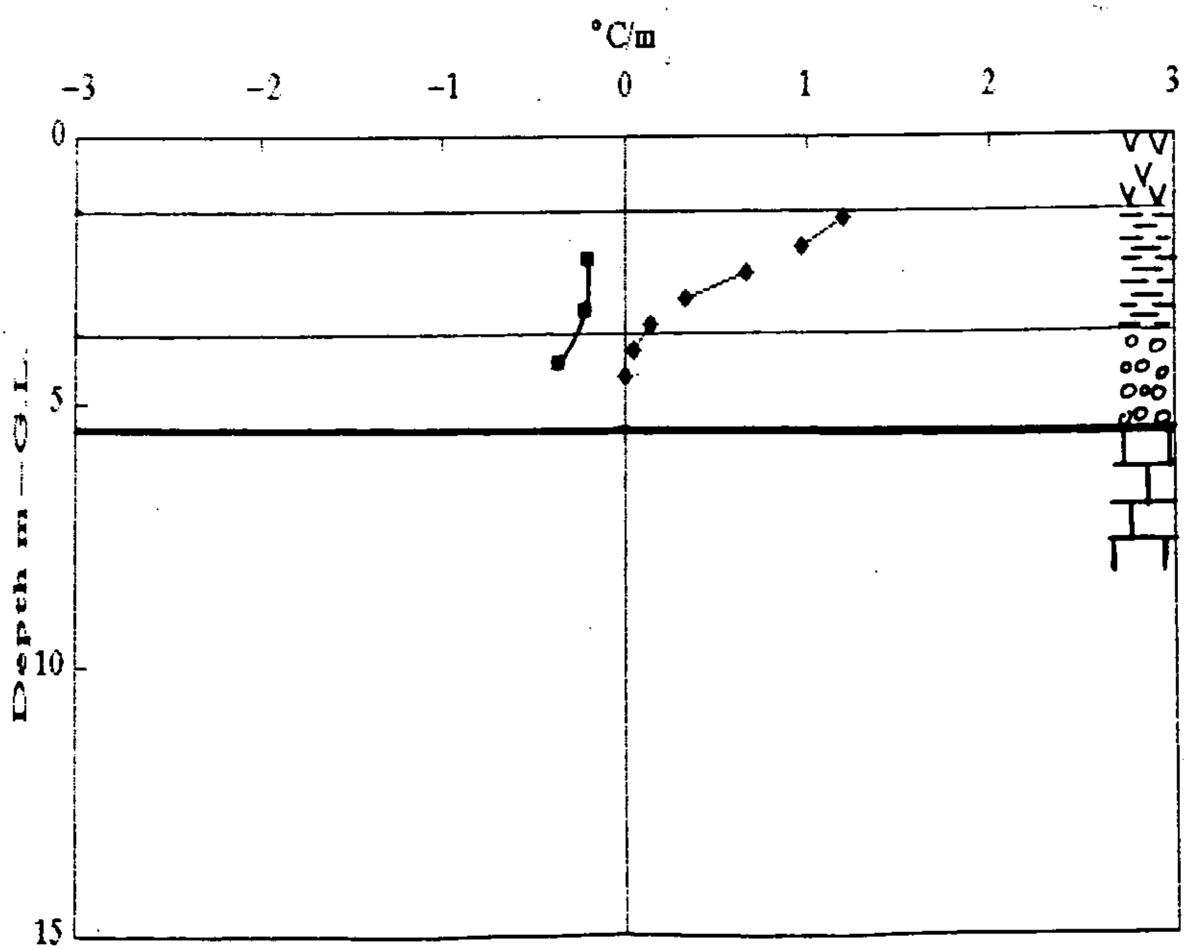
TEMPERATURE GRADIENT CLBH4



TEMPERATURE PROFILE CLBH7

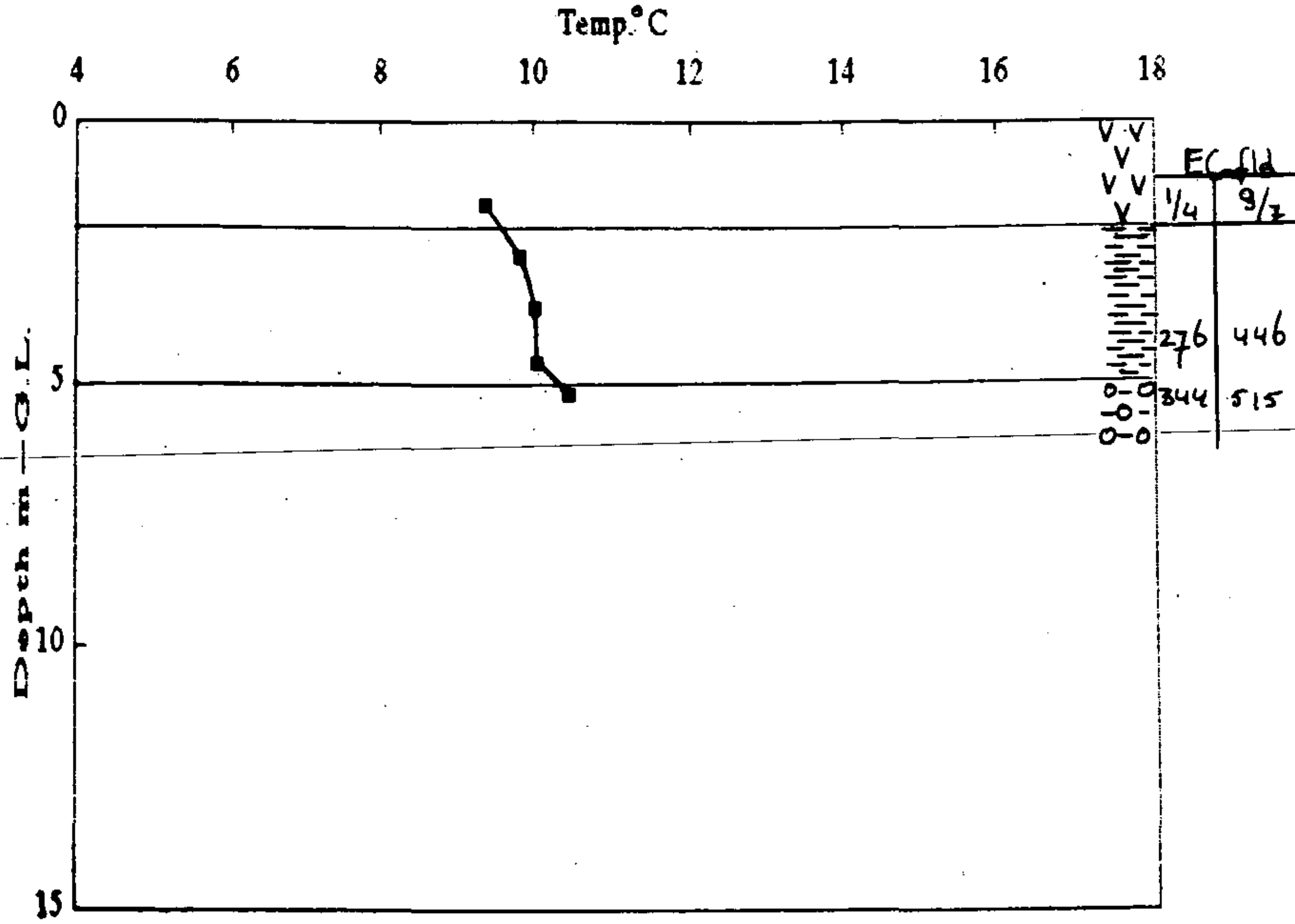


TEMPERATURE GRADIENT CLBH7

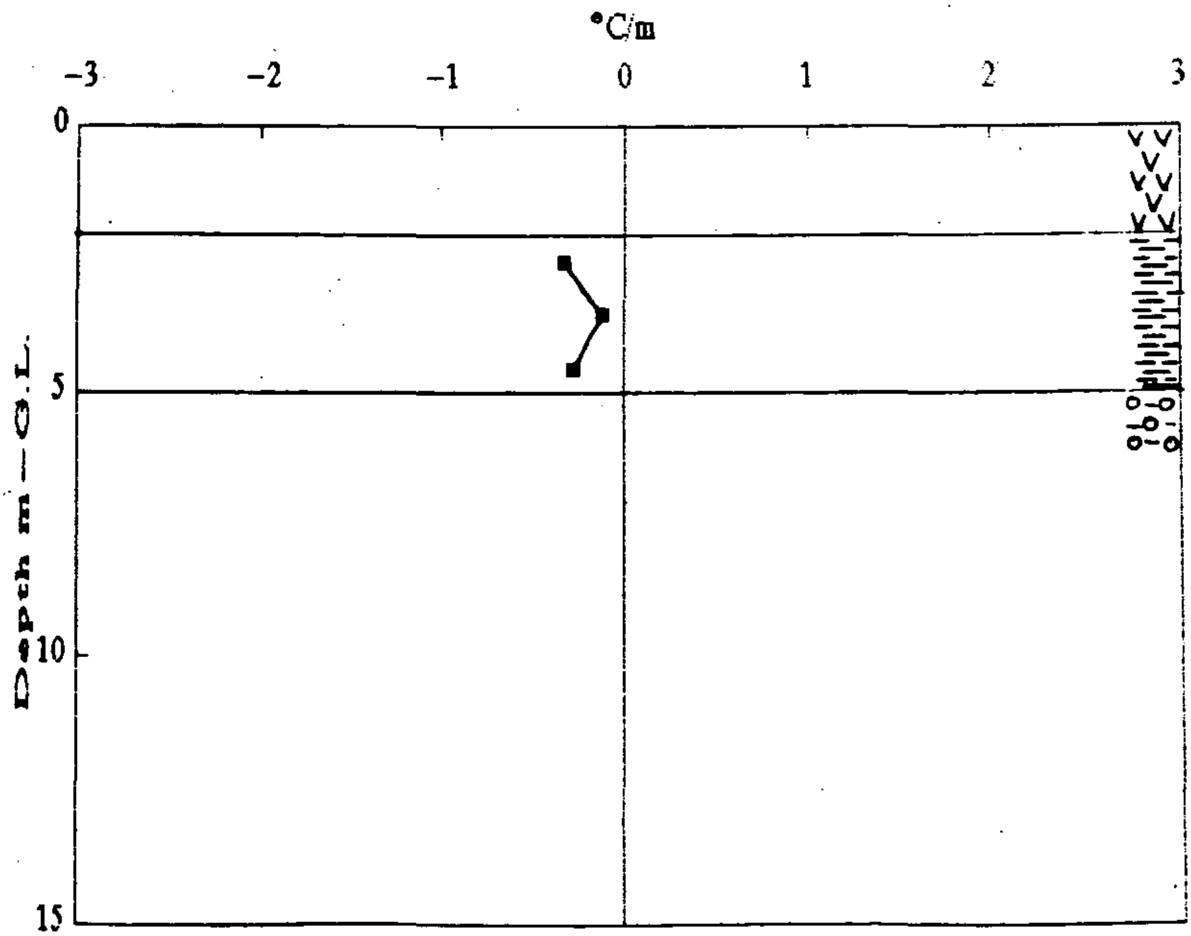


April 1992 June 1992

TEMPERATURE PROFILE CLCD2



TEMPERATURE GRADIENT CLCD2



April 1992

APPENDIX V

ELECTRIC CONDUCTIVITY DATA

CONDUCTIVITY 1 APRIL 1992

EC-Meter:WTW (Silver)

NO.	MicrS./cm	T	
Deepdrain	310	6.6	
Weir_921	107	6.4	
Weir_922	260	5.9	
Weir_923(	331	6.2	
CLBH2.1	279	7.9	
CLBH2.2	284	7.7	
G100(Ditc	313	5.6	
CLBH5.A	504	8.8	(apparatus of Ben)
CLBH5.B	773	8.8	(apparatus of Ben)
Ditch CLB	339	7.3	
CLBH6.1	575	7.1	
CLBH6.2	526	6.5	
CLBH6.3	492	7.7	
Ditch CLB	316	5.9	
CLBH7.1	633	8.7	
CLBH7.2	679	8.5	
CLCD1	580	5.7	
DitchW,CL	112	6.5	
DitchE,CL	262	6.2	
CLCD2_N	344	8.6	
CLCD2_S	276	7.5	
DitchW,CL	148	6.5	
DitchE,CL	257	6.3	
DitchS,CL	150	6.5	

CONDUCTIVITY 6 APRIL 1992
85.F, 7 April
EC-Meter:WTW (Silver)

NO.	MicrS./cm	T
Deepdrain	340	7.6
Weir_921	138	7.3
Weir_922	332	7.0
Weir_923(	402	7.5
46.F	73	8.9
54.F	77	10.3
57.E	152	8.9
85.F	100	8.4
90.F	453	8.2
92.F	287	9.3
901.E	303	9.3

CONDUCTIVITY 28 MAY 1992
TIME:
EC-Meter:WTW LF 91 (HE 1/T)

NO.	MicrS./cm	T
CLBH2.1	297	9.7
CLBH2.2	309	8.5
CLBH2.3	1590	8.2
CLBH3	609	
CLBH7.1	667	7.9
CLBH7.2	727	7.7

CONDUCTIVITY 9 JULY 1992
TIME: 11.45-18.00
EC-Meter:WTW LF 91 (HE 1/T)

NO.	MicrS./cm	T
Deepdrain	437	11.0
CLBH2.1	564	10.1
CLBH2.2	717	9.4
CLBH2.3	1798	10.4
CLBH4.1	351	8.9
CLBH4.2	258	8.3
CLBH4.3	528	8.5
CLBH5.A	643	7.9
CLBH5.B	796	7.9
CLBH6.1	607	8.0
CLBH6.2	649	8.0
CLBH6.3	400	7.7
CLBH7.1	669	8.2
CLBH7.2	720	8.0
CLBH8.1	560	8.5
CLBH8.2	492	8.9
CLCD1	668	8.5
CLCD2_N	515	8.3
CLCD2_S	446	7.9
110.1	113	8.7
110.2	96	8.7
110.3	88	9.7
110.4	80	9.1
110.5	79	9.4
110.6	96	10.5
111.1	118	9.8
111.2	71	8.8
111.3	57	9.1
111.4	64	9.5
111.5	56	9.6
111.6	79	10.0
112.1	82	8.5
112.2	79	9.1
112.3	75	9.1
112.4	59	9.4
112.5	65	10.1
112.6	96	10.4
114.1	173	9.7
114.2	128	9.8
114.3	156	10.0
114.4	89	10.2
115.1	106	9.3
119.1	750	8.4
119.2	435	9.6
119.3	215	9.7
119.4	321	9.9
120.A		
120.B	116	9.7
120.D	149	8.7
120.E	120	8.3

CONDUCTIVITY 16 JULY 1992

TIME: 14.15-17.00
EC-Meter:WTW LF 91 (HE 1/T)

NO.	MicrS./cm	T	REMARKS
46.A	77	12.3	
46.B	83	9.9	
46.D	111	8.3	
46.F	77	10.0	
54.A	80	12.6	
54.B	79	11.2	
54.D	124	8.8	
54.F	80	8.4	
57.A	77	10.3	
57.C	109	8.9	
57.D	159	8.4	
57.E	158	9.2	
90.A	82	10.2	
90.B	84	8.9	
90.D	118	8.1	
90.F	766	8.1	
92.A	92	9.1	
92.B	86	8.8	
92.D	230	8.3	
92.F	392	7.8	
94.A	115	8.8	
94.D	150	8.3	
94.F	163	8.0	
96.A	89	8.9	
96.B	66	10.6	
96.D	72	8.2	
96.F	603	7.0	
901.A	84	9.4	
901.B	111	10.6	
901.D	147	9.1	
901.F	313	8.7	
902.A	85	9.1	
902.B	117	9.2	
902.D	171	7.9	
902.F	630	8	
903.C	96	8.7	
Water nea	95	15.2	

CONDUCTIVITY 20 JULY 1992

TIME: 16.05-16.50
EC-Meter:WTW LF 91 (HE 1/T)

NO.	MicrS./cm	T
Drain (fo	584	13.2
101.1	768	9.3
101.2	680	9.7
101.3	425	10.2
101.4	358	10.6
102.1	766	7.9
102.2	724	8.3
102.3	428	9.6
102.4	126	9.8
103.1	535	10.7
103.2	133	10.2
103.3	92	10.1
103.4	70	10.2
104.1	107	9.3
104.2	97	8.5
104.3	91	9.5
104.4	71	11.3
106.1	87	8.2
106.2	72	9.5
106.3	63	10.2
106.4	34	12.1
108.1	109	9.0
108.2	76	8.6
108.3	73	8.8
108.4	70	9.1
108.5	85	11.4

WATERSAMPLING 25/26 MARCH 1992
pH-Meter:Microprocessor WTW pH 196
EC-Meter:WTW LF 91 (LS 1/T-1.5)

TUBE_NO.	AT HOME MicrS./cm	pH
46.A		
46.B		
46.D		
46.F		
54.A	76	4.31
54.B	100	5.31
54.D	133	5.47
54.F	76	4.66
57.A		
57.C		
57.D		
57.E		
90.A	100	6.19
90.B	96	5.21
90.D	106	5.33
90.F	780	6.94
SOAK	71	4.23
92.A	81	5.21
92.B	104	5.29
92.D	202	6.26
92.F	340	6.35
96.A		
96.B		
96.D		
96.F		
901.A	112	5.75
901.B	123	5.24
901.D	157	5.30
901.E	No sample	
902.A	133	5.59
902.B	121	5.16
902.D	161	5.17
902.E	No sample	
903.B		
903.C		
904.A		
904.B		
904.D		
904.E		

TAPWATER 19-07-1992

WTW LF 91 (HE 1/T)
632 14.8

WTW LF 91 (LS 1/T-1.5)
637 19.8

WATERSAMPLING 4 JUNE 1992
pH-Meter:Microprocessor WTW pH 196
EC-Meter:WTW LF 91 (LS 1/T-1.5)

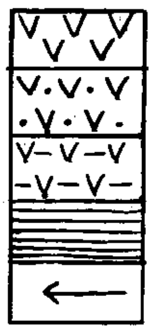
TUBE_NO.	AT HOME MicrS./cm	pH
46.A	74	5.40
46.B	82	5.35
46.D	147	6.04
46.F	100	5.81
54.A	74	4.46
54.B	132	5.52
54.D	117	5.50
54.F	109	5.55
57.A	91	4.45
57.C	101	5.56
57.D	823	6.61
57.E		
90.A	81	4.20
90.B	82	5.18
90.D	354	5.87
90.F	255	5.99
SOAK	70	4.59
92.A	80	5.67
92.B	89	5.16
92.D		
92.F	445	6.44
96.A	79	4.32
96.B	67	4.78
96.D	209	6.14
96.F	85	5.60
901.A	85	5.40
901.B	112	4.66
901.D	497	6.16
901.E	297	5.83
902.A	73	4.82
902.B	111	5.14
902.D	455	5.92
902.E	203	5.44
903.B	84	4.83
903.C	187	5.98
905.A	90	4.37
905.B	129	5.01
905.D	215	5.81
905.E	219	5.59
113.1	92	5.06
113.3	440	6.30
113.4	75	5.23
113.6	86	4.31
119.1	784	6.48
119.2	287	5.82
119.3	165	5.45
119.4	490	6.05
120.A	75	4.33
120.B	115	4.80
120.D	164	5.16
120.E	137	5.93
CLBH 1	673	6.79
" 2.1	285	6.91
" 2.2	479	8.10
" 2.3	1960	11.53
" 3	748	6.63
" 5.A	339	6.12
" 5.B	239	5.86
" 6.1	587	6.94
" 6.2	652	8.66
" 6.3	408	8.31
SILVER	608	7.52
DRAIN	337	7.55
921	145	7.40
922	315	6.60
923	367	6.93
924	350	7.00
BROSNA	537	7.92

APPENDIX VI

TEMPERATURE AND HYDROCHEMICAL DATA

LEGEND

Lithological profile



Young Sphagnum peat

Old Sphagnum peat

Fenpeat

Mineral subsoil

Indication for hydraulic head in second aquifer

(Information derived from data Bloetjes (1992) and pers. comm. ten Dam & Spieksma)

Lines in pH- and EC-graphs:

— — —	*March 1992 (EC_lab)*
———	*June 1992 (EC_fld)*
— • — •	*September 1992 (EC_fld)*

EC in μS/cm

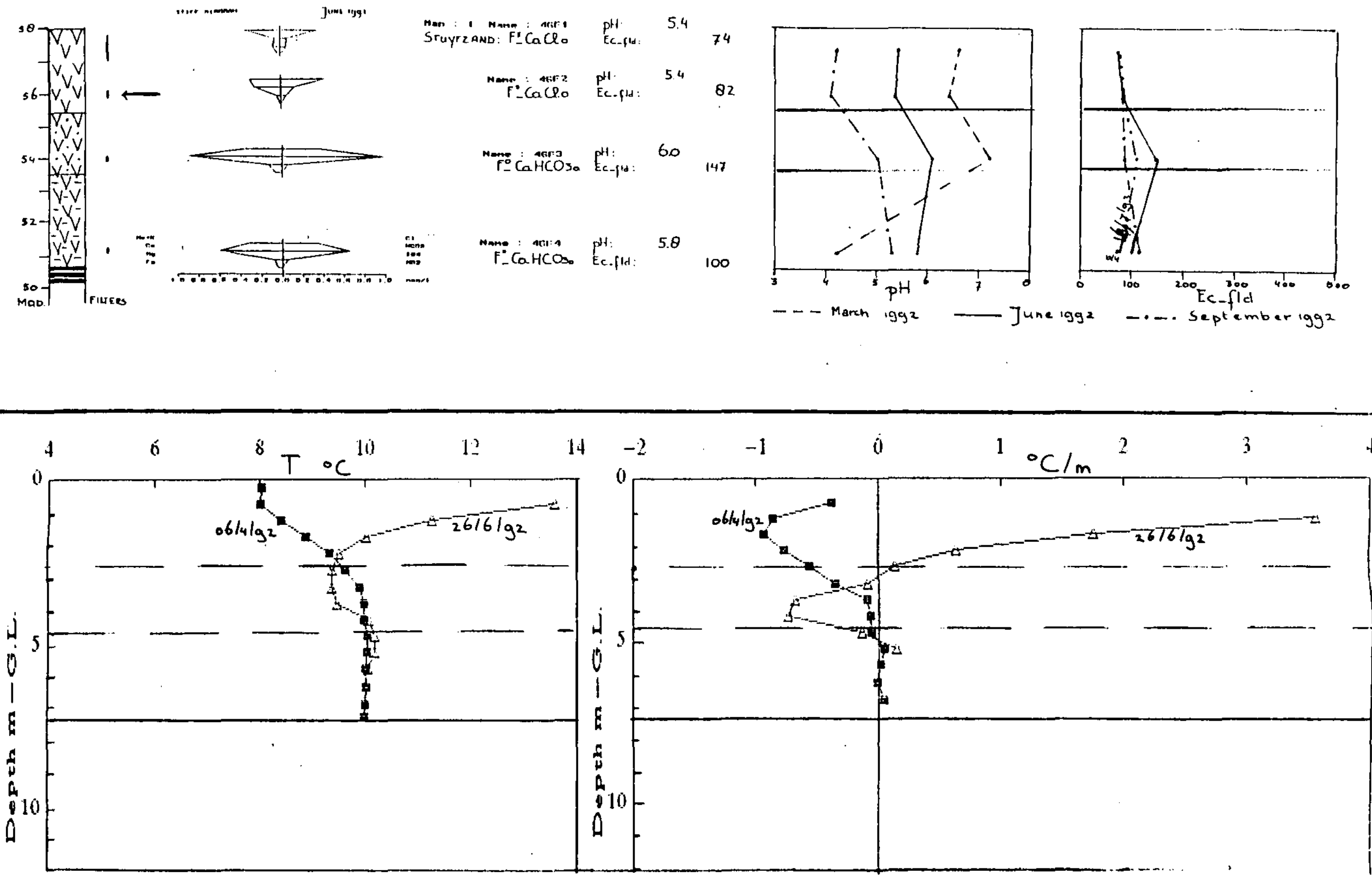
Remarks

March 1992:
- *sample 901.F2, Ca estimated;*
- *Alkalinity ($CaCO_3$) from laboratory analysis * 1.22 = HCO_3 which is used in Chemproc.*

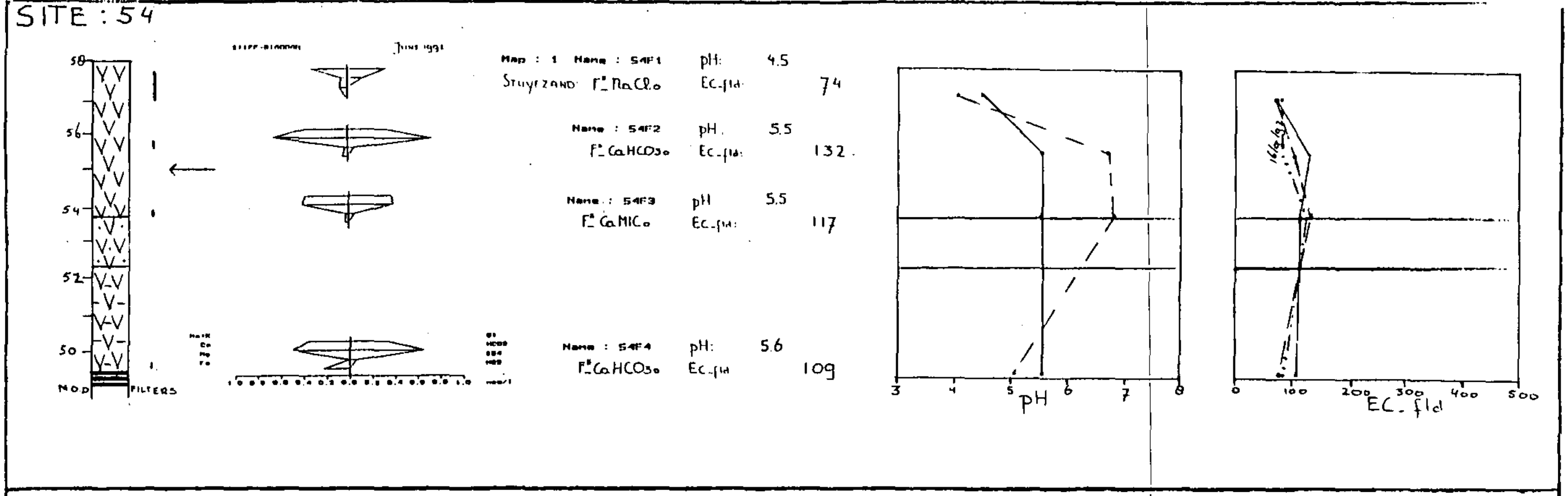
June 1992:
- *HCO_3 for all samples estimated;*

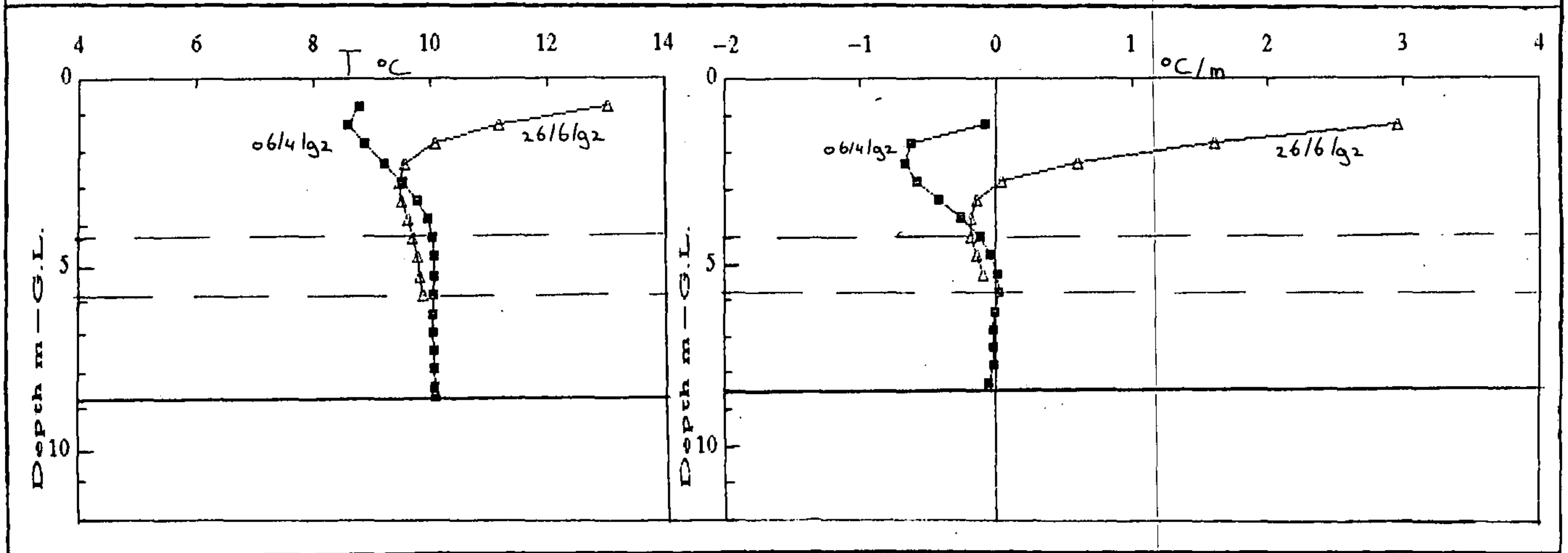
September 1992:
- *Alkalinity ($CaCO_3$) from laboratory analysis * 1.22 = HCO_3 which is used in Chemproc;*
- *HCO_3 < 10 mg/l, than value estimated (according to IB_ERR standards);*
- *other ions with a concentration smaller than certain limit are not used.*

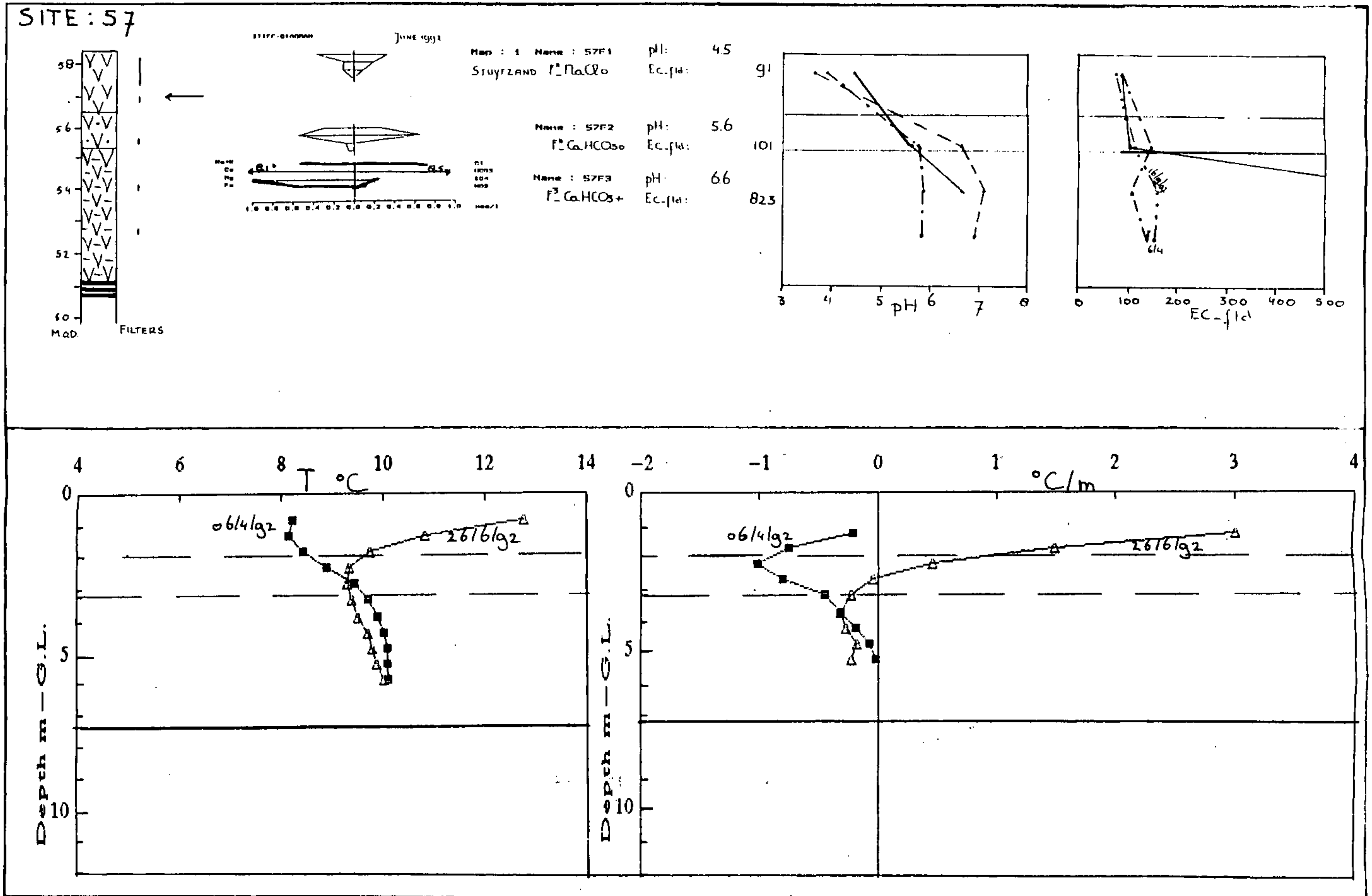
SITE: 46



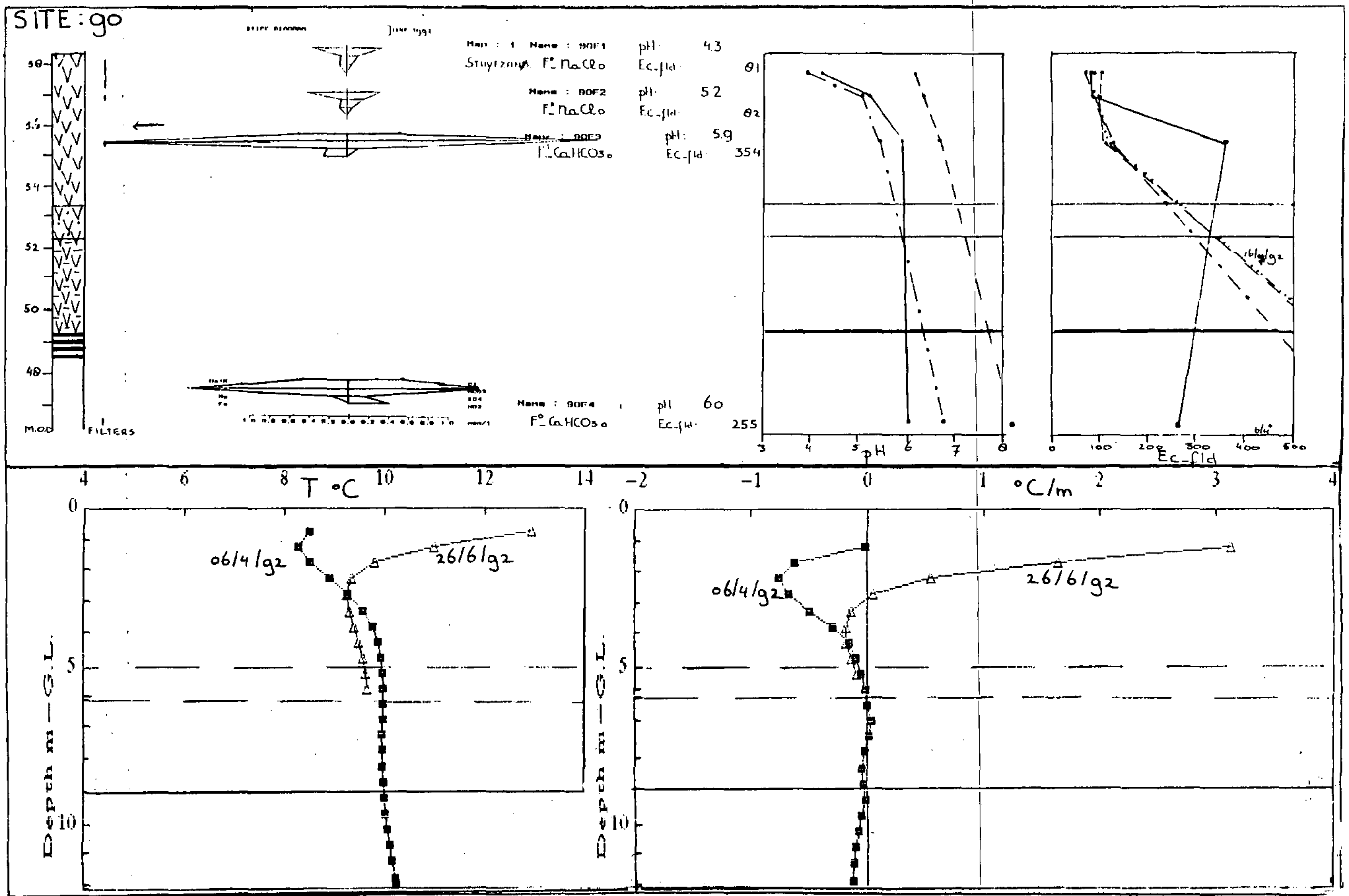
June 1991
Stuyrzand: $F_1^-CaCl_0$
pH: 5.4
Ec_fld: 74
Name: 46F2
$F_1^-CaCl_0$
pH: 5.4
Ec_fld: 82
Name: 46F3
$F_1^0CaHCO_{3a}$
pH: 6.0
Ec_fld: 147
Name: 46F4
$F_1^-CaHCO_{3a}$
pH: 5.8
Ec_fld: 100
Filters
pH
Ec_fld
March 1992
June 1992
September 1992
T °C
°C/m
Depth m — G.L.
06/4/92
26/6/92


SITE : 54
Map : 1 Name : 54F1 pH: 4.5
STUYFZAND F*2 NaCl0 EC-fld 74
Name : 54F2 pH: 5.5
F*2 CaHCO30 EC-fld 132
Name : 54F3 pH 5.5
F*2 CaMIC0 EC-fld 117
Name : 54F4 pH: 5.6
F*2 CaHCO30 EC-fld 109
N.O.P.
FILTERS
pH
EC-fld


T °C
06/4/92
26/6/92
Depth m — G.L.
°C/m
06/4/92
26/6/92
Depth m — G.L.

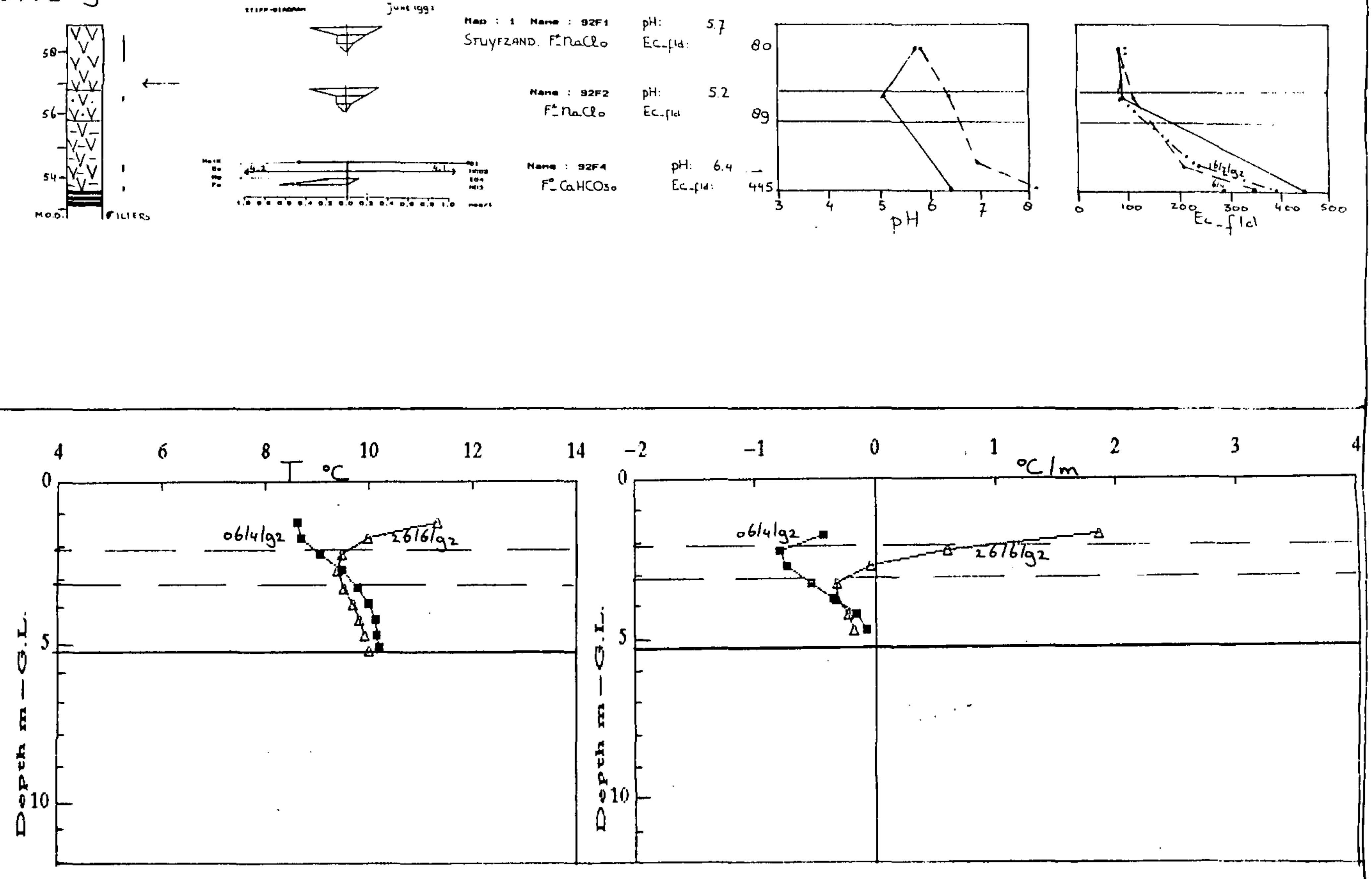


SITE : 57
JUNE 1992
Map : 1 Name : 57F1
STUYFZAND F1 NaClo
pH: 4.5
Ec-fld:
Name : 57F2
F2 CaHCO3o
pH: 5.6
Ec-fld:
Name : 57F3
F3 CaHCO3+
pH 6.6
Ec-fld:
M.O.D.
FILTERS
91
101
823
pH
EC-fld
T °C
°C/m
06/4/92
26/6/92
Depth m — G.L.

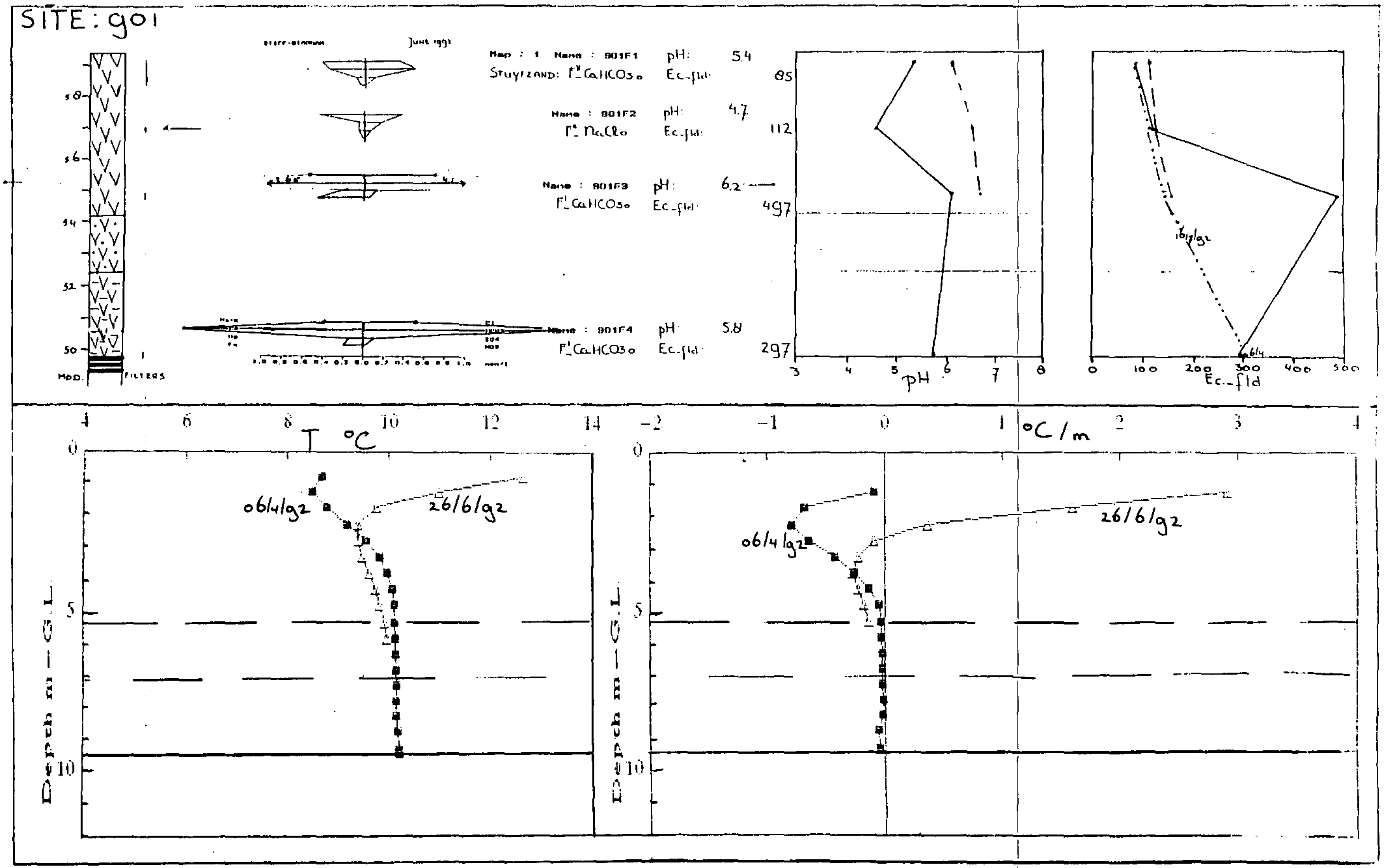


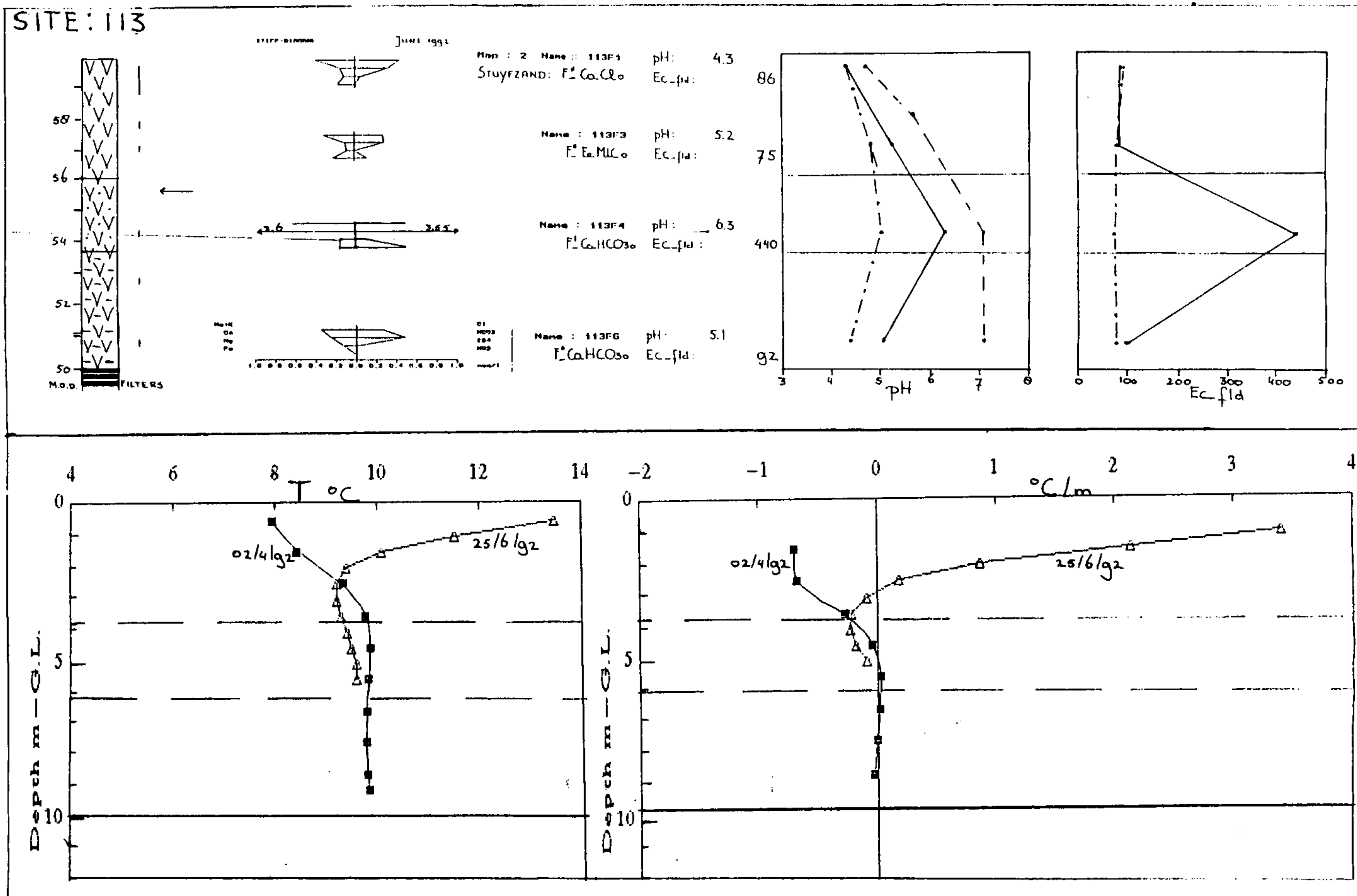
SITE : 90
Name : 90F1
pH 4.3
Stuyfzand F° NaClo
Ec-fld
Name : 90F2
pH 5.2
F° NaClo
Ec-fld
Name : 90F3
pH: 5.9
F° CaHCO3o
Ec-fld 354
Name : 90F4
pH 6.0
F° CaHCO3o
Ec-fld 255
M.O.D
FILTERS
pH
Ec-fld
T °C
°C/m
06/4/92
26/6/92
Depth m — G.L.

SITE: g2

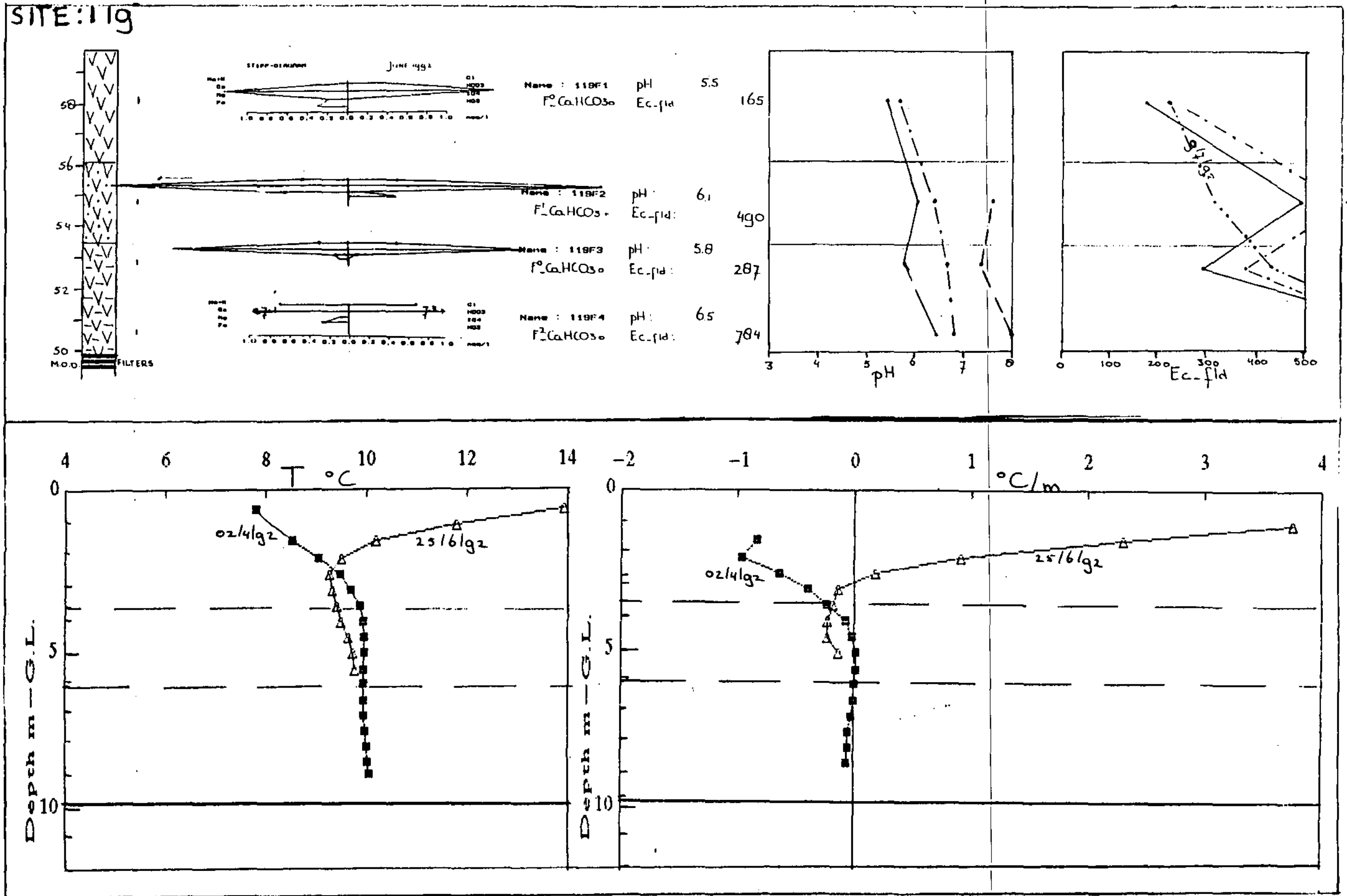


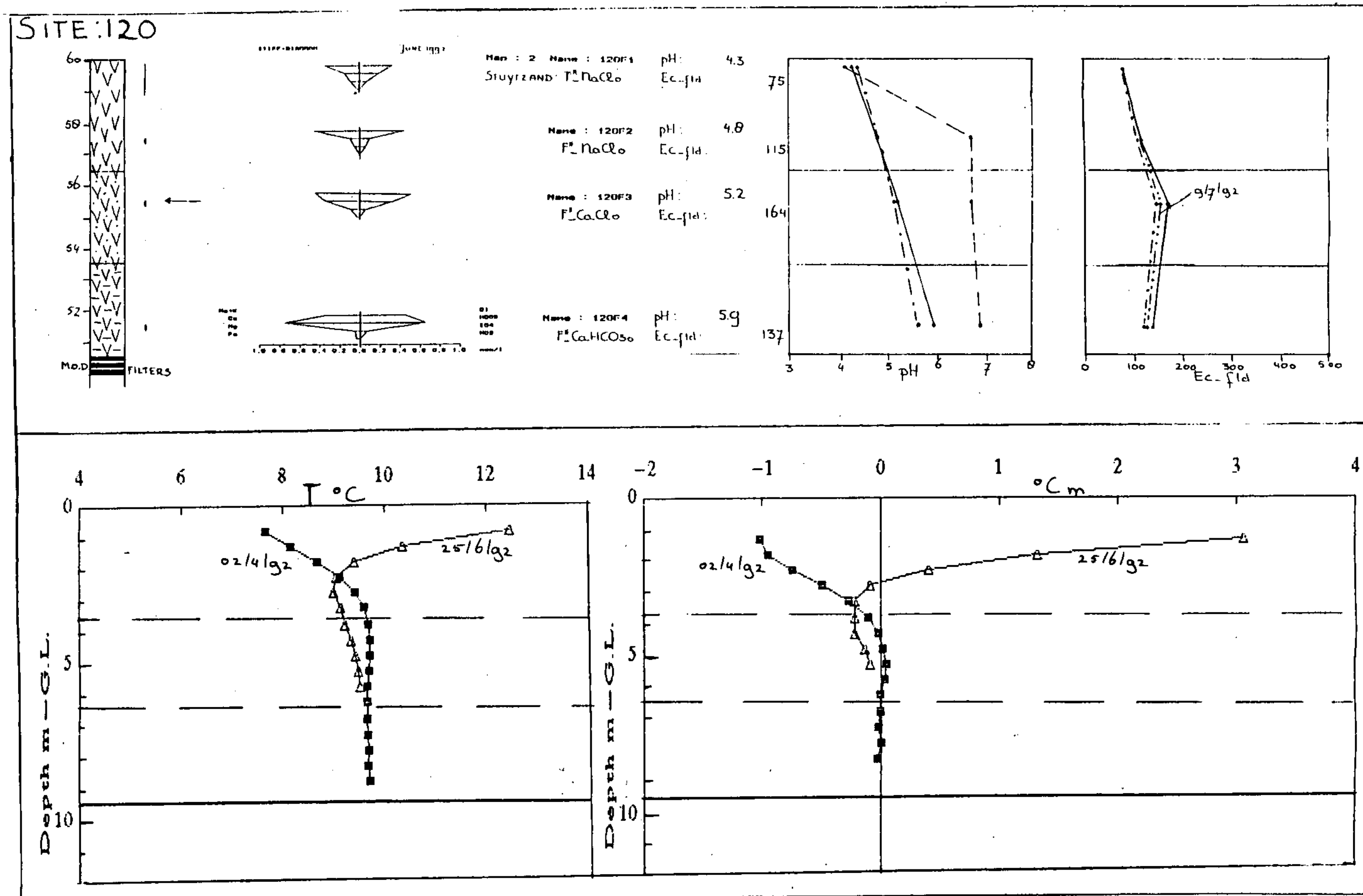
June 1992
Map : 1 Name : 92F1
STUYFZAND. F⁺NaCl0
pH: 5.7
Ec-fld:
Name : 92F2
F⁺NaCl0
pH: 5.2
Ec-fld
Name : 92F4
F⁰CaHCO30
pH: 6.4
Ec-fld:
M.O.D.
FILTERS
pH
Ec-fld
T °C
0614/g2
2616/g2
°C/m
Depth m — G.L.

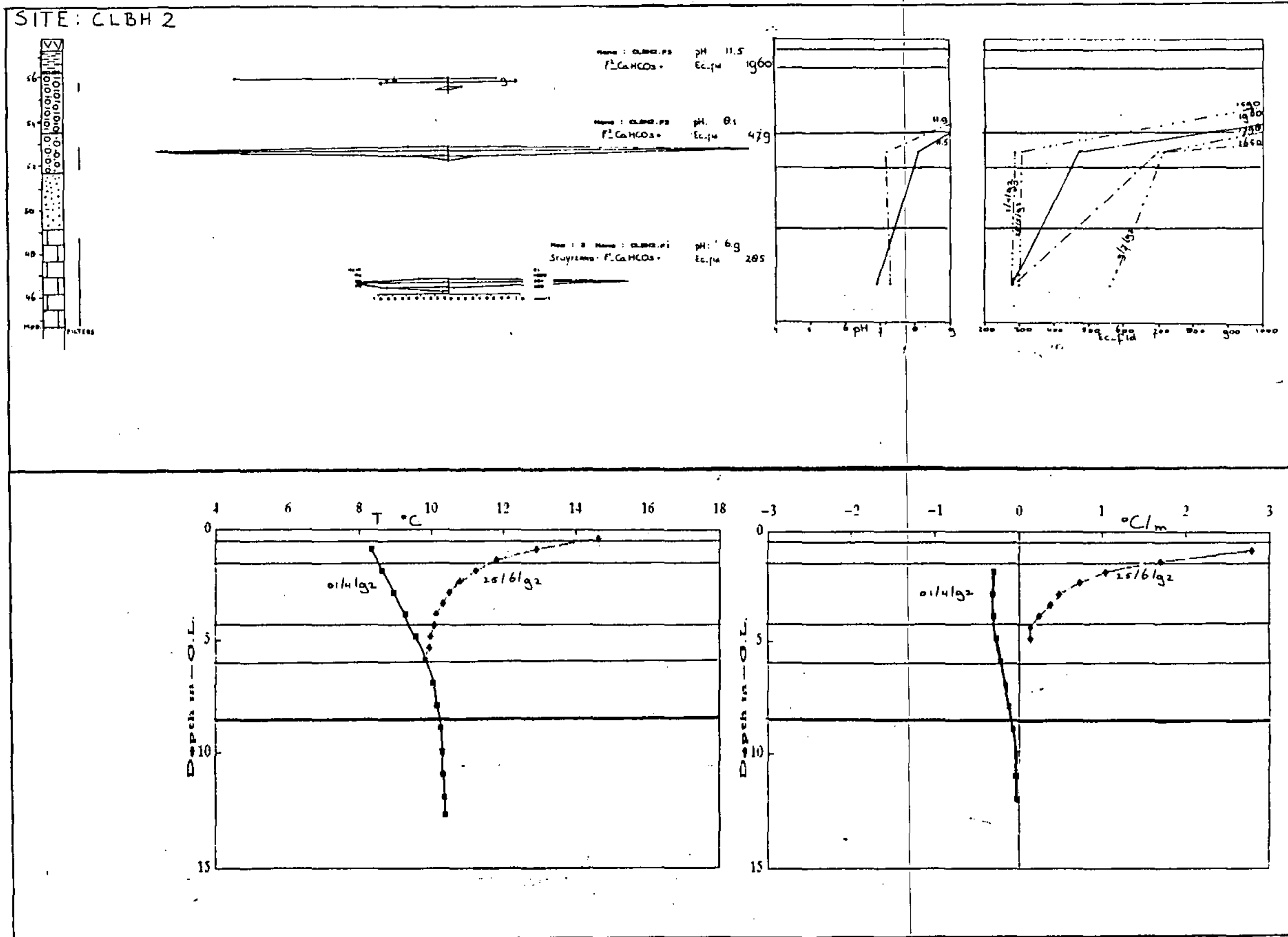

SITE: 901
June 1992
Map : 1 Name : 901F1
STUYFZAND: F1 CaHCO3 o
pH: 5.4
Ec-fld: 85
Name : 901F2
F1 NaCl o
pH: 4.7
Ec-fld: 112
Name : 901F3
F1 CaHCO3 o
pH: 6.2
Ec-fld: 497
Name : 901F4
F1 CaHCO3 o
pH: 5.8
Ec-fld: 297
MOD.
FILTERS
pH
Ec-fld
T °C
°C/m
Depth m - G.L.
06/4/92
26/6/92

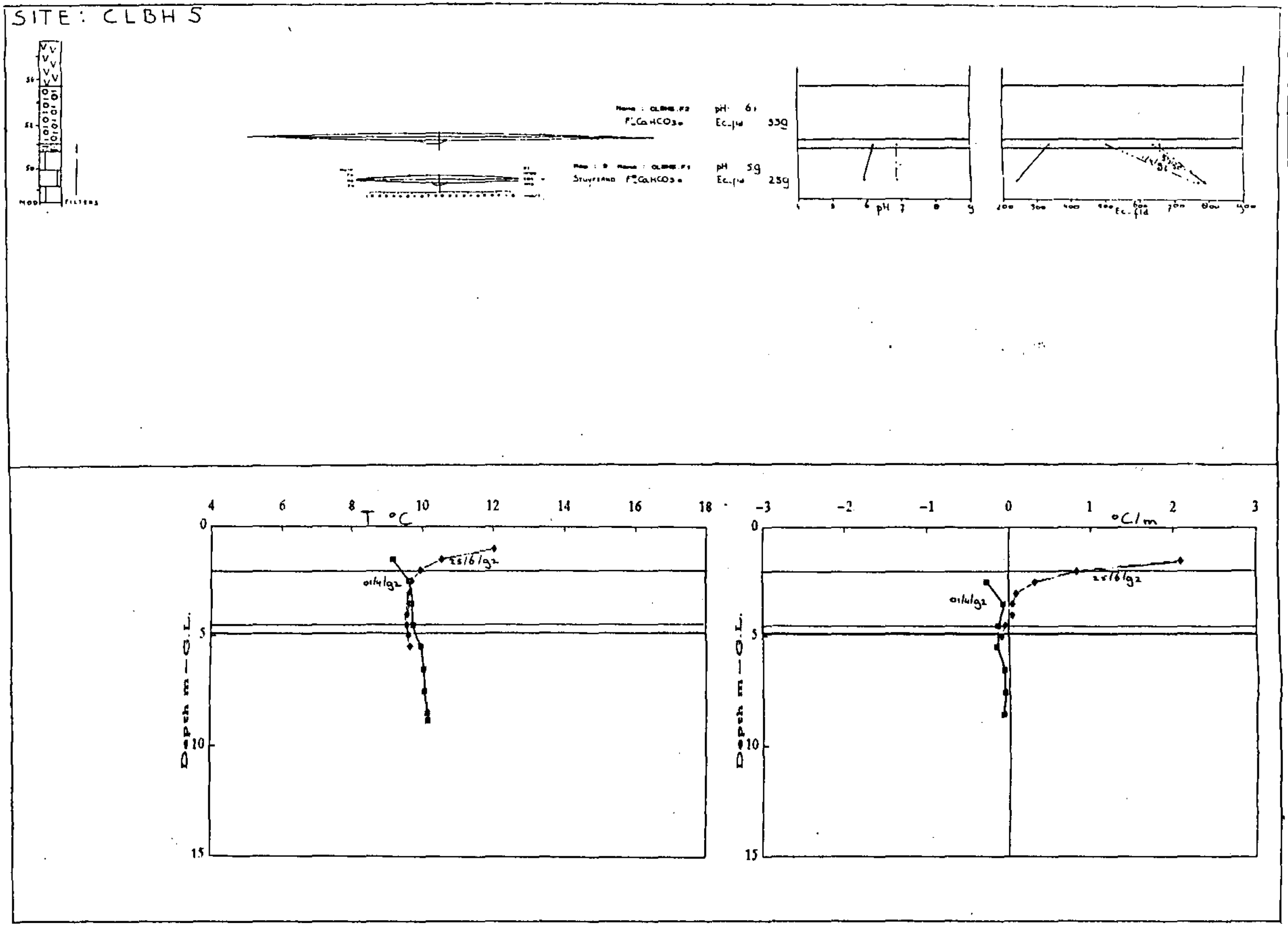


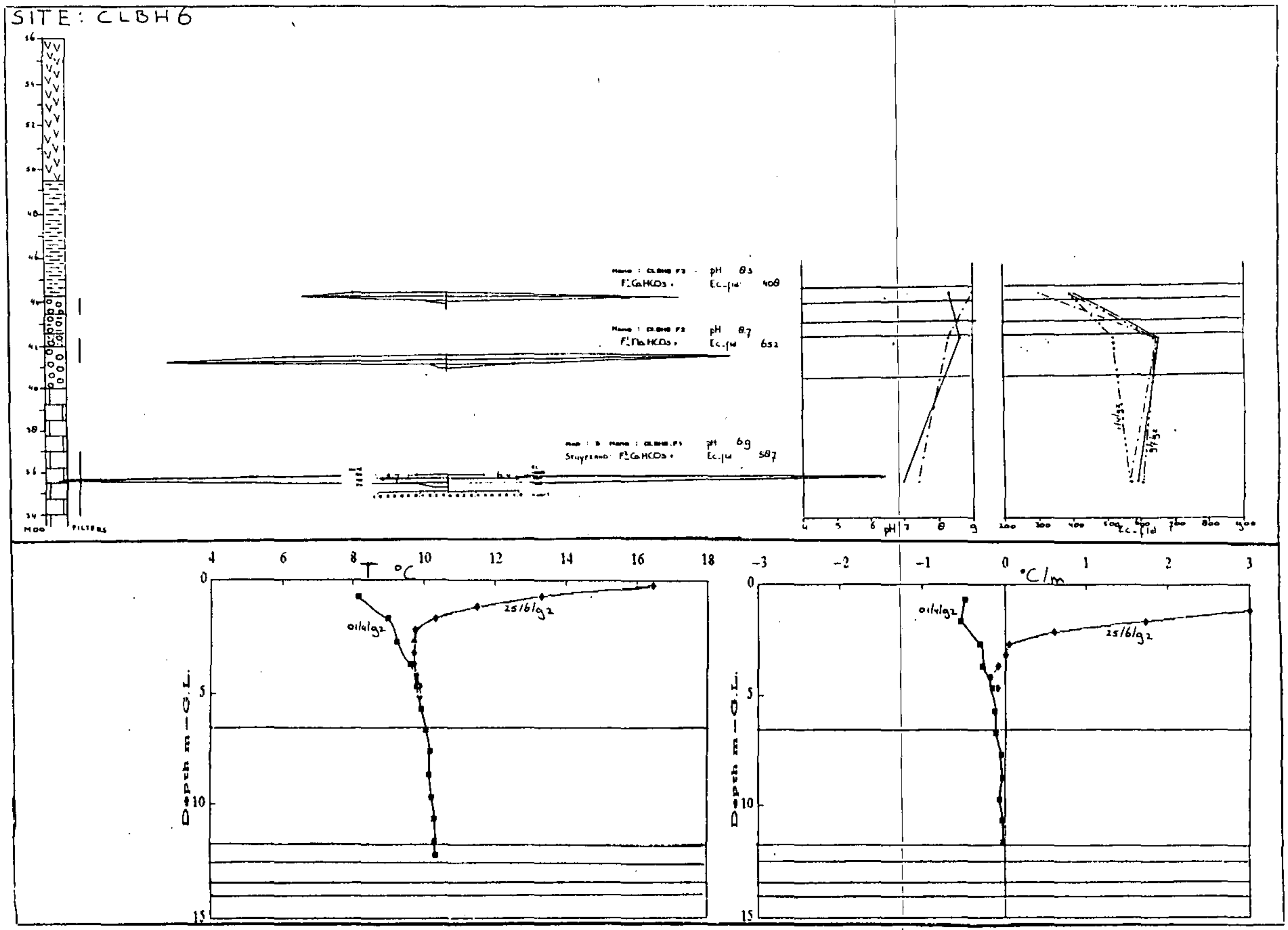
SITE : 113
June 1992
Name : 113F1
STUYFZAND: F1 CaCl0
pH: 4.3
Ec_fld:
Name : 113F3
F1 Ca-MIX0
pH: 5.2
Ec_fld:
Name : 113F4
F1 CaHCO30
pH: 6.3
Ec_fld:
Name : 113F6
F1 CaHCO30
pH: 5.1
Ec_fld:
FILTERS
86
75
440
92
pH
Ec_fld
T °C
02/4/92
25/6/92
Depth m — G.L.
°C/m

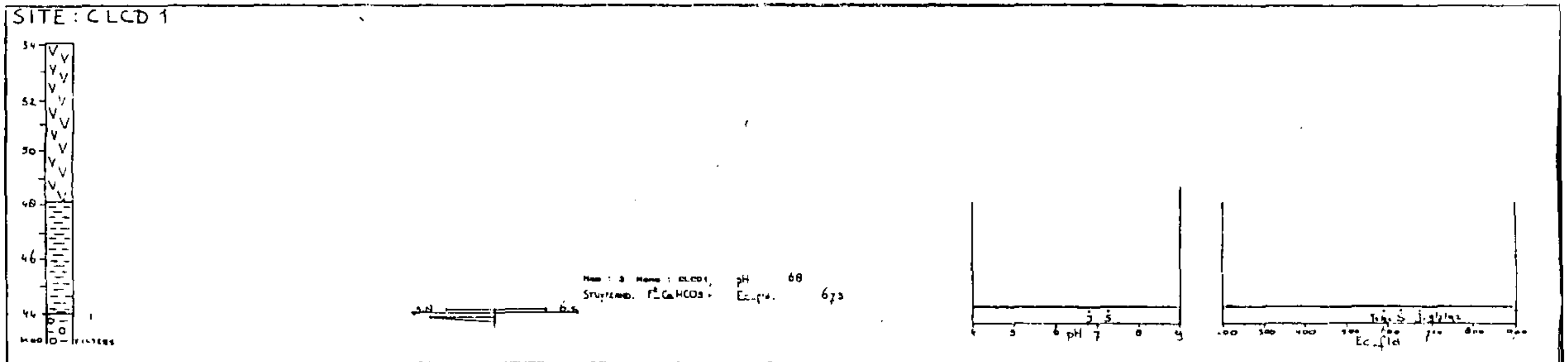

SITE: 11g
FILTERS
M.O.D.
Name : 11gF1
F°_CaHCO3o
pH 5.5
Ec_fld
Name : 11gF2
F¹_CaHCO3+
pH 6.1
Ec_fld:
Name : 11gF3
F°_CaHCO3o
pH 5.8
Ec_fld:
Name : 11gF4
F²_CaHCO3o
pH 6.5
Ec_fld:
165
490
287
784
pH
Ec_fld
9/7/92
T °C
02/4/92
25/6/92
°C/m
Depth m — G.L.

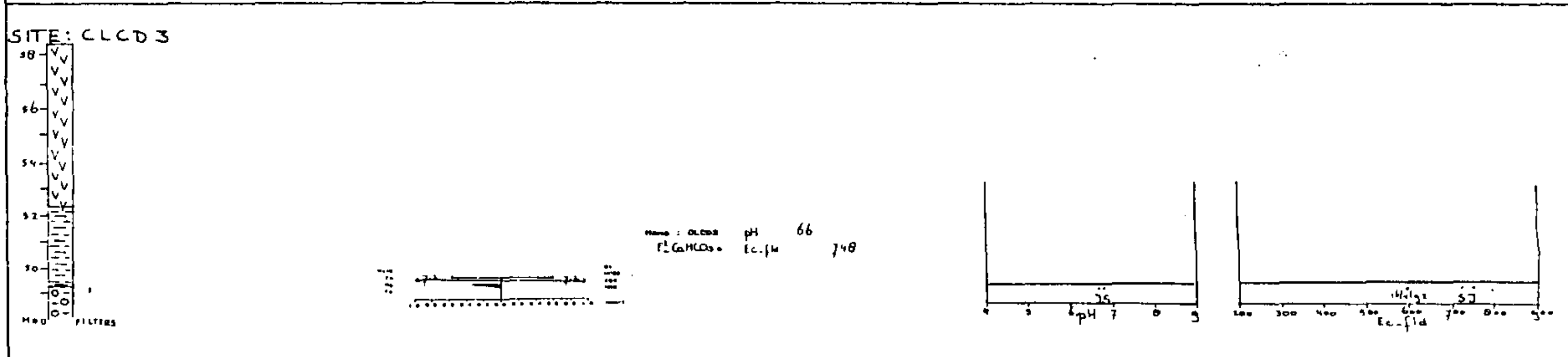

SITE: 120
June 1992
Map : 2 Name : 120F1 pH: 4.3
STUYFZAND: T*NaCl0 Ec-fld
Name : 120F2 pH: 4.8
F*NaCl0 Ec-fld
Name : 120F3 pH: 5.2
F*CaCl0 Ec-fld
Name : 120F4 pH: 5.9
F*CaHCO3 Ec-fld
M.O.D
FILTERS
pH
Ec-fld
9/7/92
T °C
°C m
02/4/92
25/6/92
Depth m – G.L.

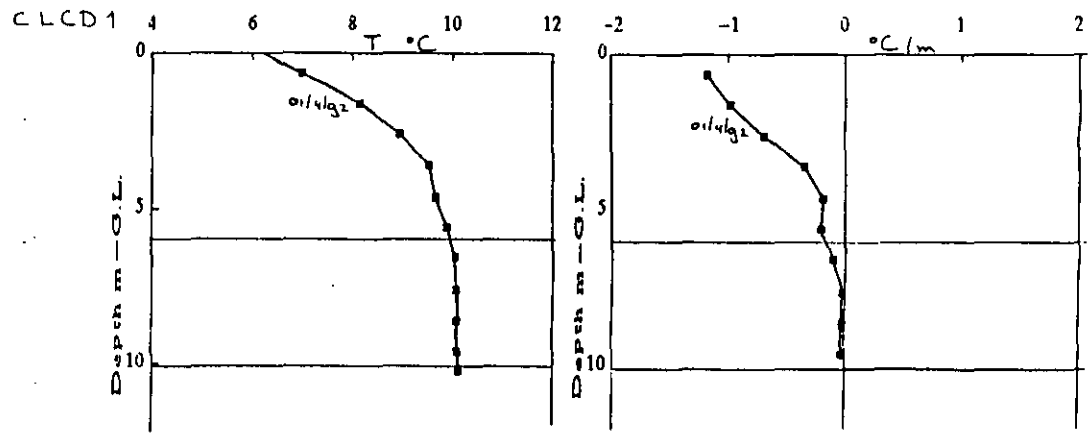

SITE: CLBH 2
T °C
°C/m
Depth in — O.L.
01/4/92
25/6/92
pH
Ec-fld
4 6 8 10 12 14 16 18
-3 -2 -1 0 1 2 3
0 5 10 15

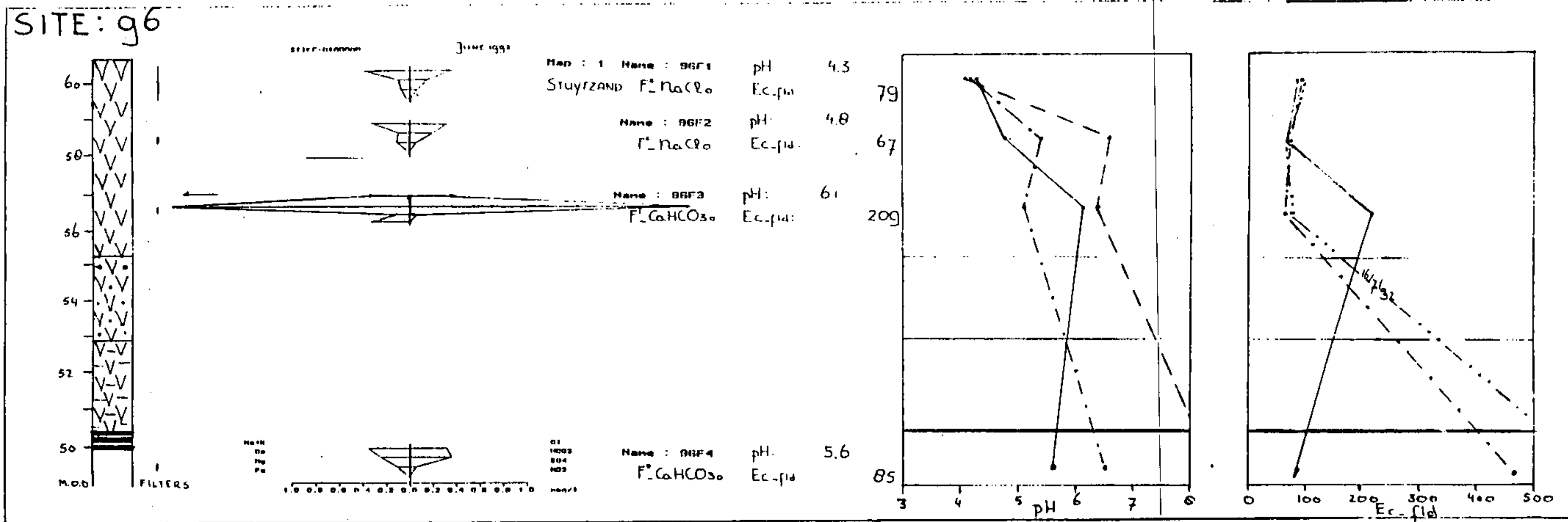

SITE: CLBH 5
pH
Ec-fld
T °C
°C/m
Depth m - G.L.
01/4/g2
25/6/g2

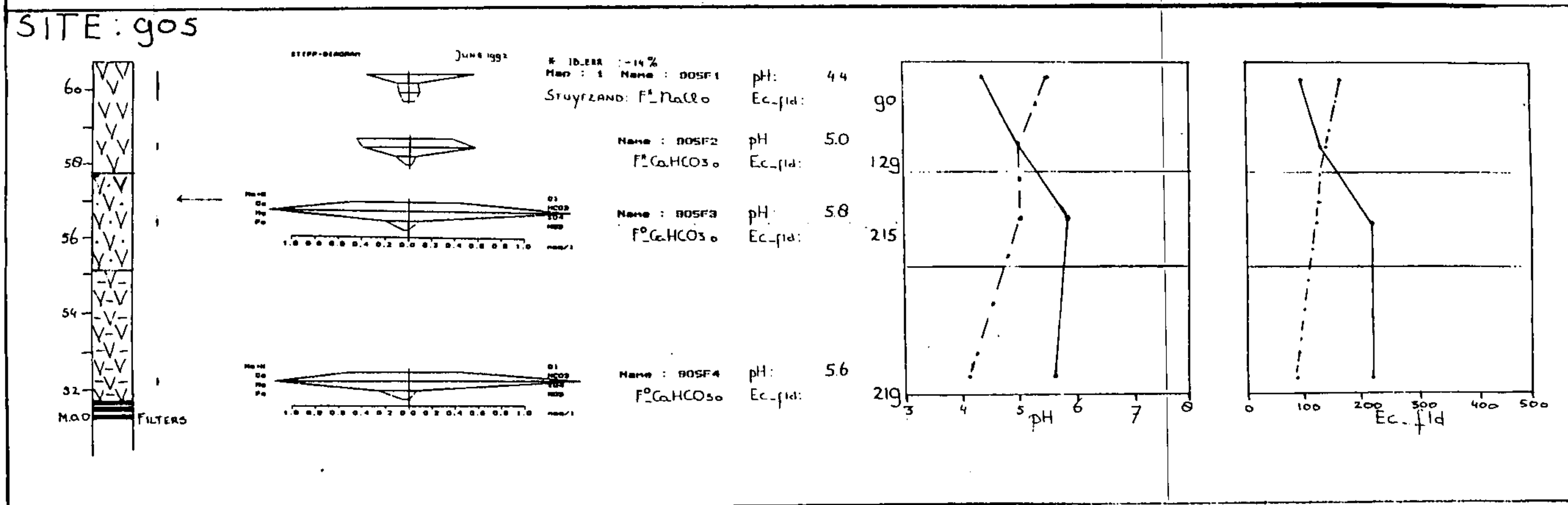

SITE: CLBH6
FILTERS
pH 8.3
Ec.μs 408
pH 8.7
Ec.μs 652
pH 6.9
Ec.μs 587
pH
Ec.μs
T °C
°C/m
Depth m – G.L.
01/4/92
25/6/92


SITE : CLCD 1
pH
Ec-fld

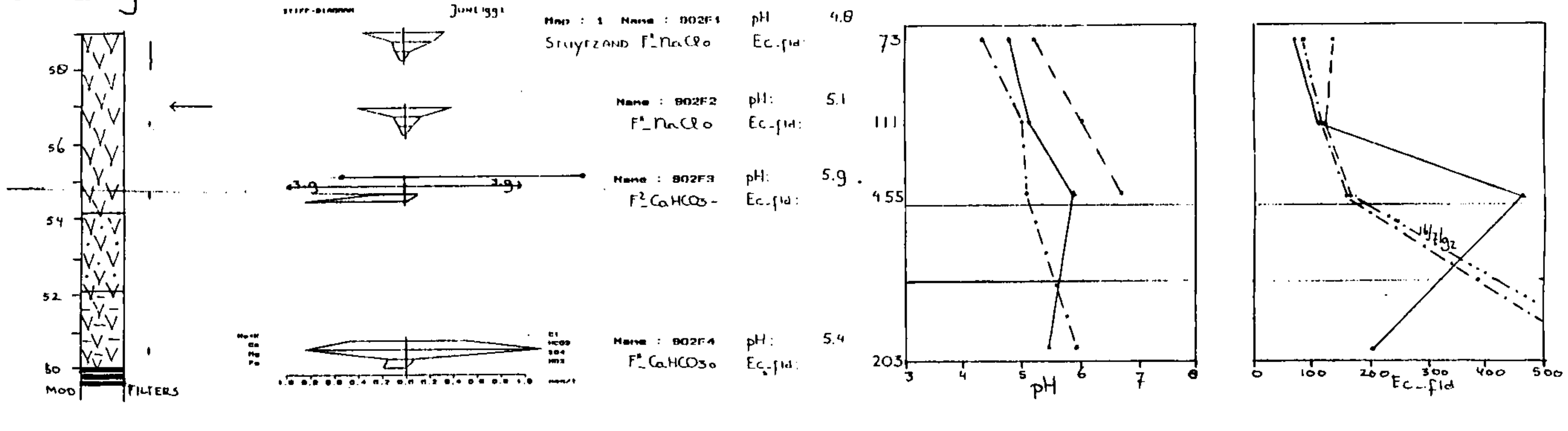

SITE : CLCD 3
pH
Ec-fld


CLCD 1
T °C
°C/m
Depth m - G.L.
01/4/92

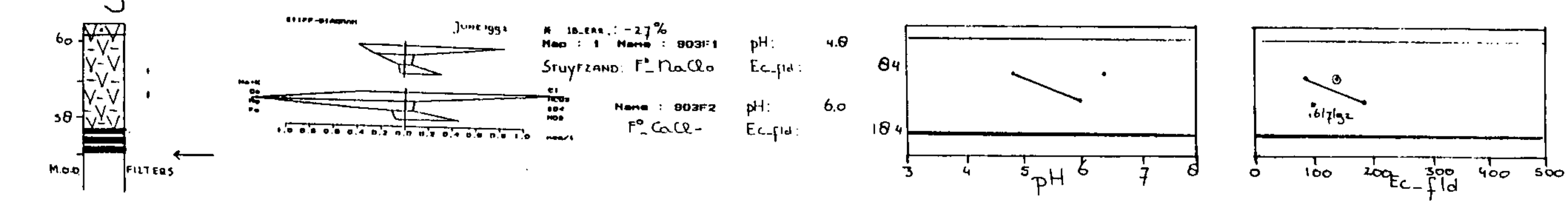

SITE: 96
June 1992
Map : 1 Name : 96F1
Stuyfzand F1_NaCl0
pH 4.3
Ec_fld
Name : 96F2
F1_NaCl0
pH 4.8
Ec_fld
Name : 96F3
F1_CaHCO30
pH: 6.1
Ec_fld:
Name : 96F4
F1_CaHCO30
pH 5.6
Ec_fld
79
67
209
85
M.O.D
FILTERS
pH
Ec_fld

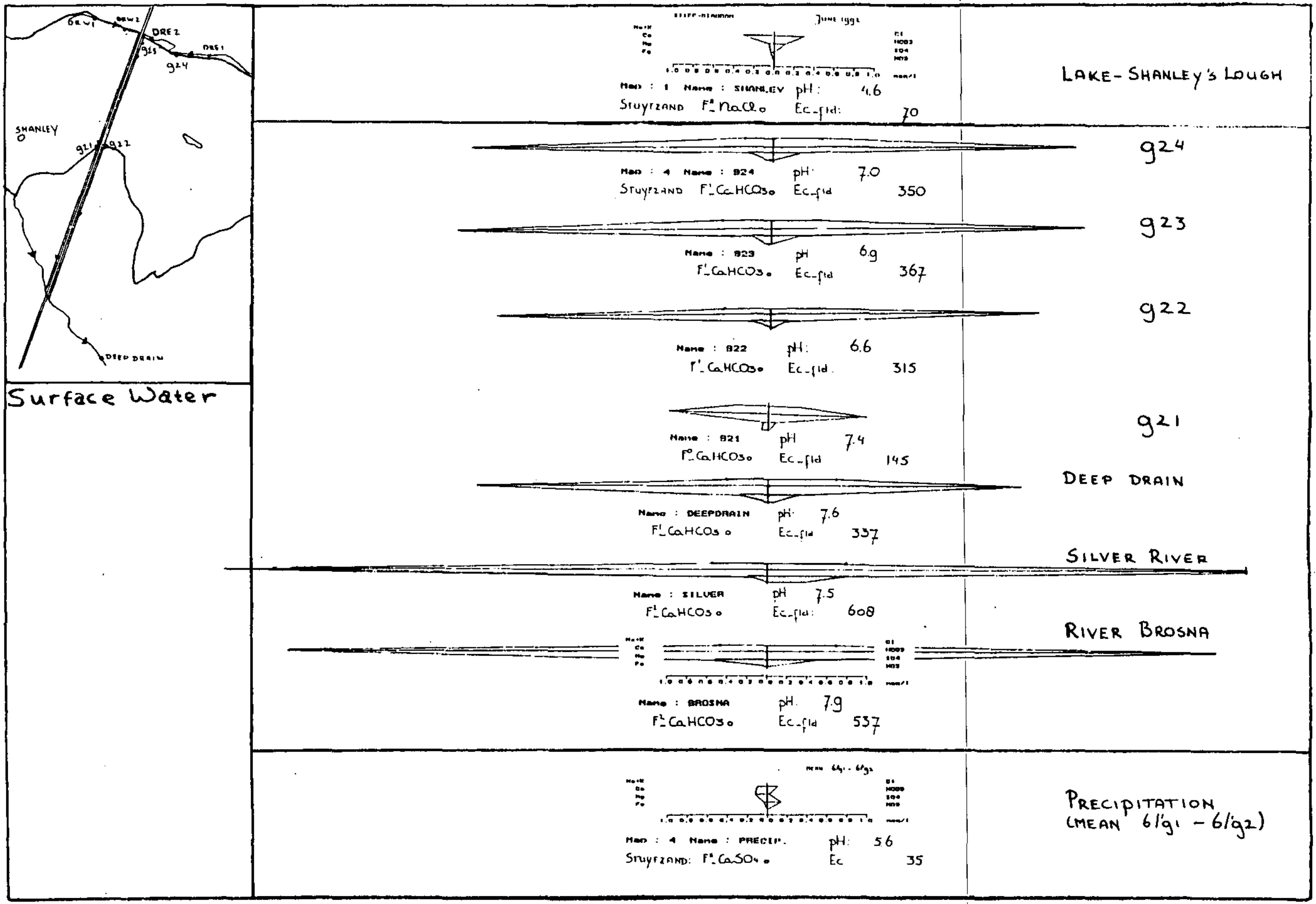

SITE: 90S
June 1992
Map : 1 Name : 90SF1
Stuyfzand: F1_NaCl0
pH: 4.4
Ec_fld:
Name : 90SF2
F1_CaHCO30
pH 5.0
Ec_fld:
Name : 90SF3
F0_CaHCO30
pH 5.8
Ec_fld:
Name : 90SF4
F0_CaHCO30
pH: 5.6
Ec_fld:
90
129
215
219
M.O.D
FILTERS
pH
Ec_fld

SITE: 902



SITE: 903





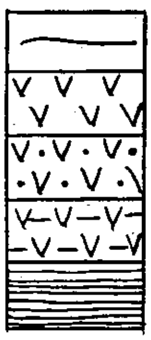
GRW1
GRW2
DRE2
DRE1
g23
g24
SHANLEY
g21
g22
DEEP DRAIN
Surface Water
June 1991
Map : 1 Name : SHANLEY pH: 4.6
Stuyfzand F*_NaCl₀ Ec-fld: 70
LAKE-SHANLEY'S LOUGH
Map : 4 Name : G24 pH: 7.0
Stuyfzand F1_CaHCO3₀ Ec-fld 350
g24
Name : G23 pH 6.9
F1_CaHCO3₀ Ec-fld 367
g23
Name : G22 pH: 6.6
F1_CaHCO3₀ Ec-fld 315
g22
Name : G21 pH 7.4
F0_CaHCO3₀ Ec-fld 145
g21
Name : DEEPDRAIN pH: 7.6
F1_CaHCO3₀ Ec-fld 337
DEEP DRAIN
Name : SILVER pH 7.5
F1_CaHCO3₀ Ec-fld: 608
SILVER RIVER
Name : BROSNA pH 7.9
F1_CaHCO3₀ Ec-fld 537
RIVER BROSNA
Map : 4 Name : PRECIP. pH: 5.6
Stuyfzand: F1_CaSO4₀ Ec 35
PRECIPITATION
(MEAN 6/91 - 6/92)

APPENDIX VII

ELECTRIC CONDUCTIVITY AND STUYFZAND CLASSIFICATION

LEGEND

.	*Filterdepth*
.440	*EC (μS/cm)* *March 1992 laboratory data* *June, July and September 1992, field data*
$.F^1CaHCO_3$	*Stuyfzand-classification*



Border of geological layer

Young Sphagnum peat

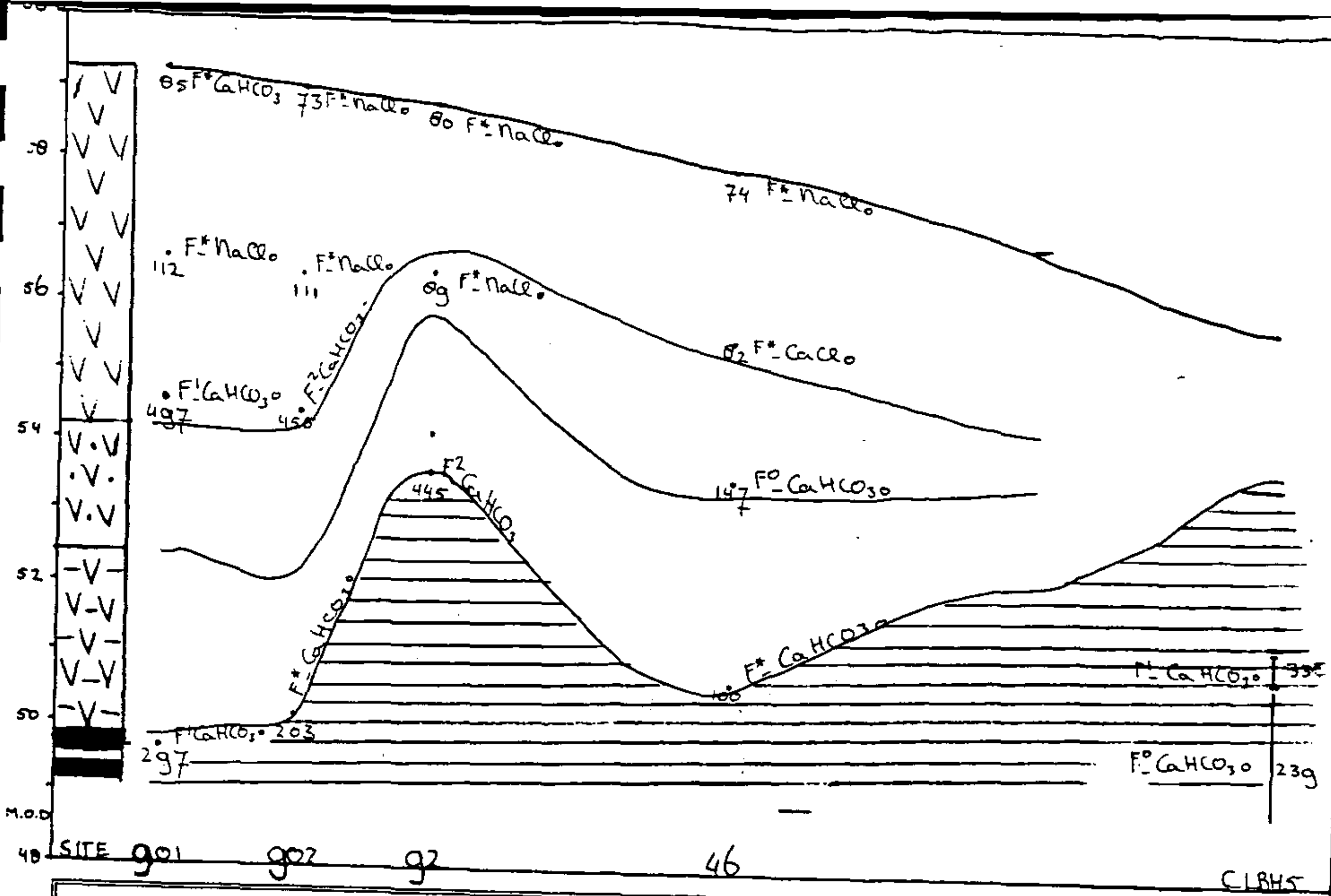
Old Sphagnum peat

Fenpeat

Mineral subsoil

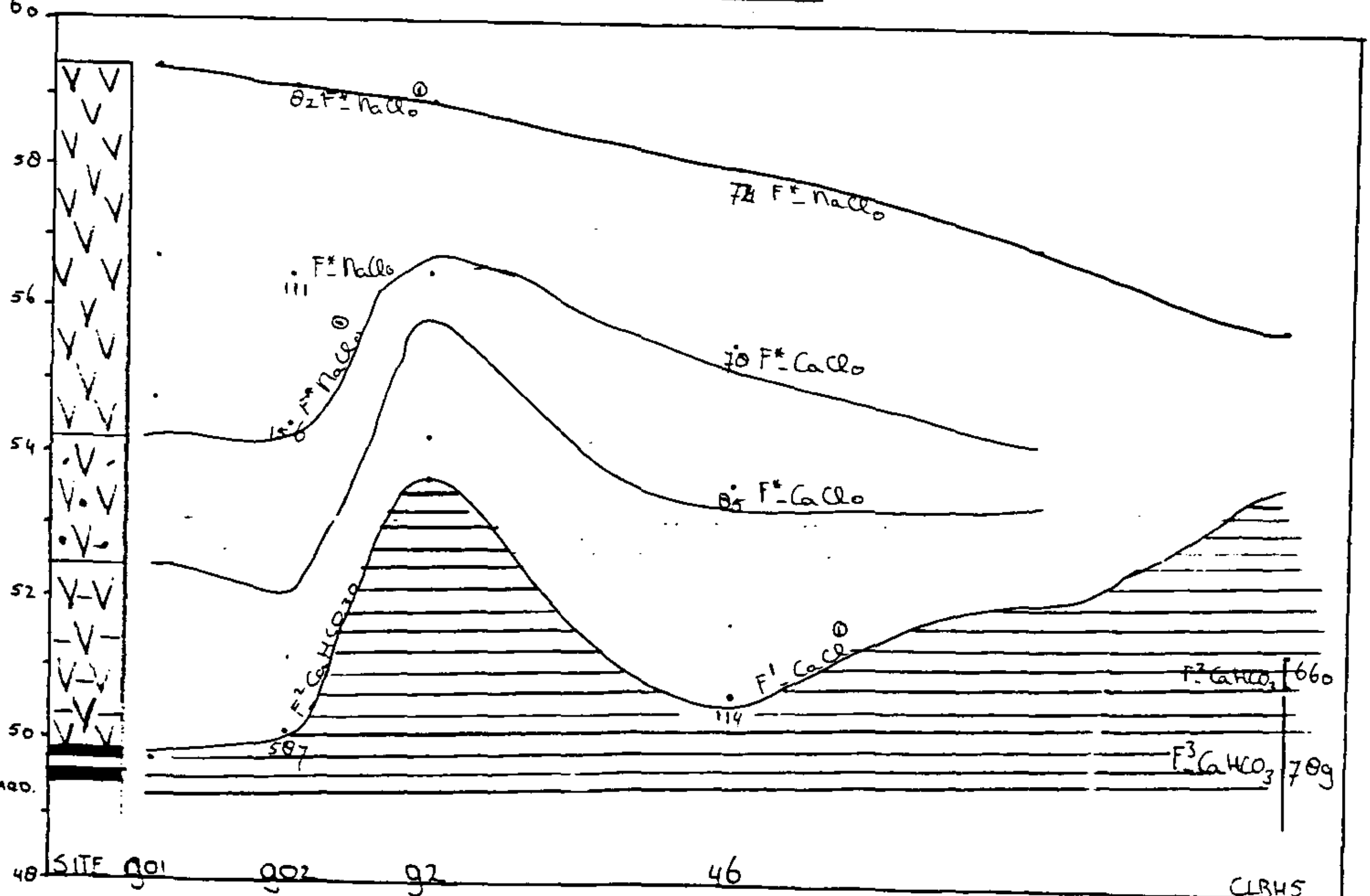
Horizontal scale

*Vertical exaggeration 50 **



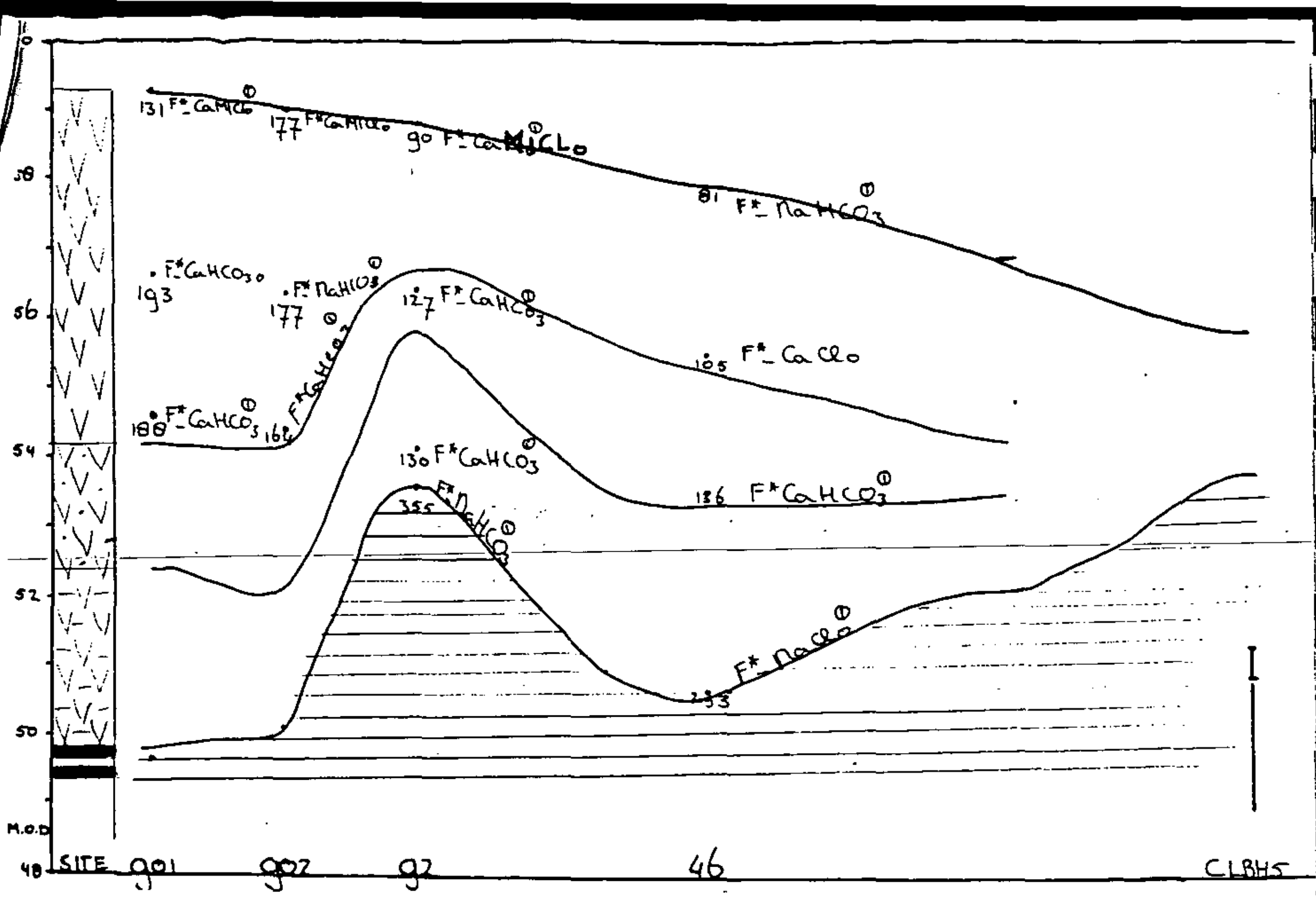
APPENDIX VII EC-fld/Stuyfzand June 1992

Transect 1 Clara west (Site 901-CLBH5)



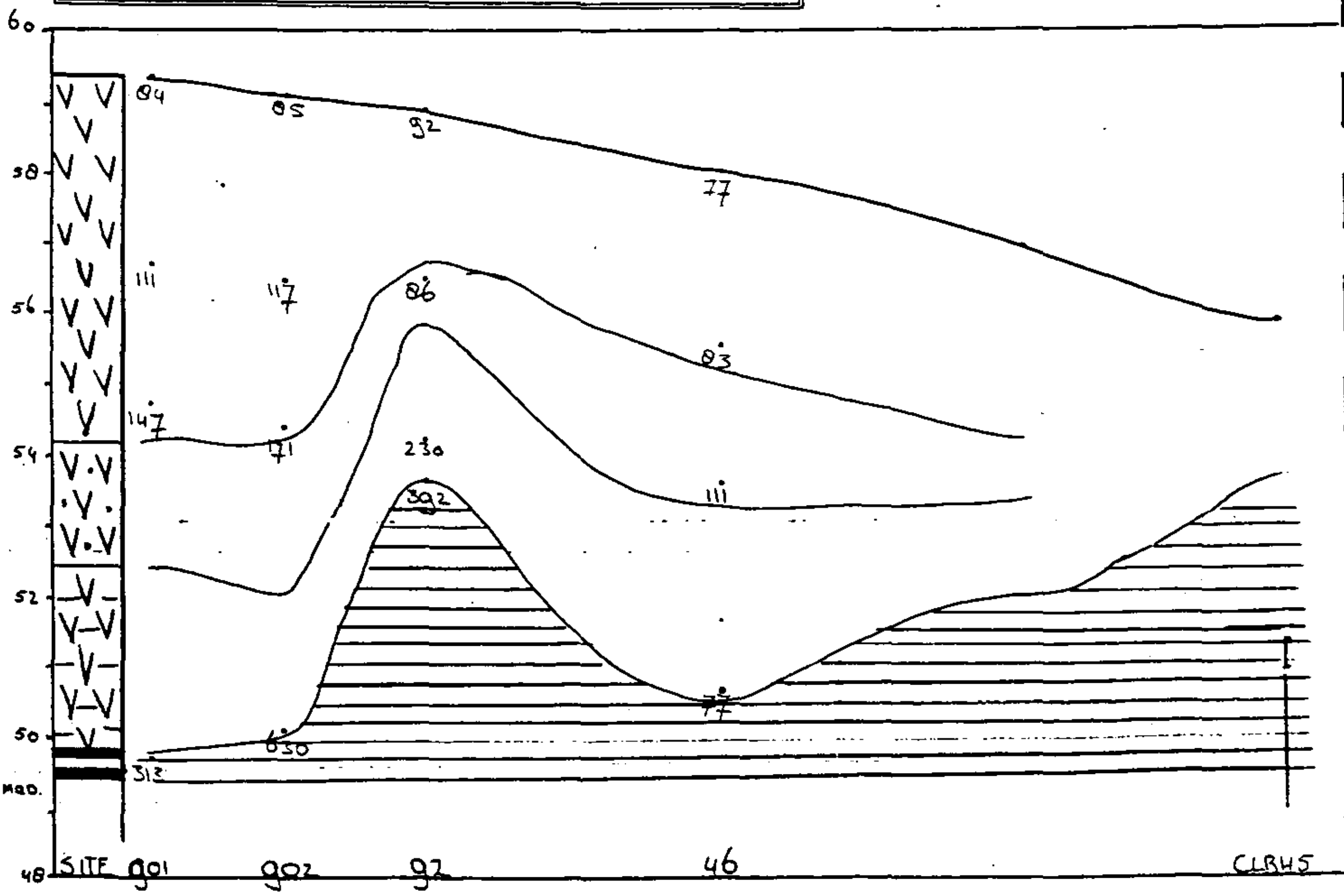
APPENDIX VII EC-fld/Stuyfzand Sept. 1992

Transect 1 Clara west (Site 901-CLBH5)



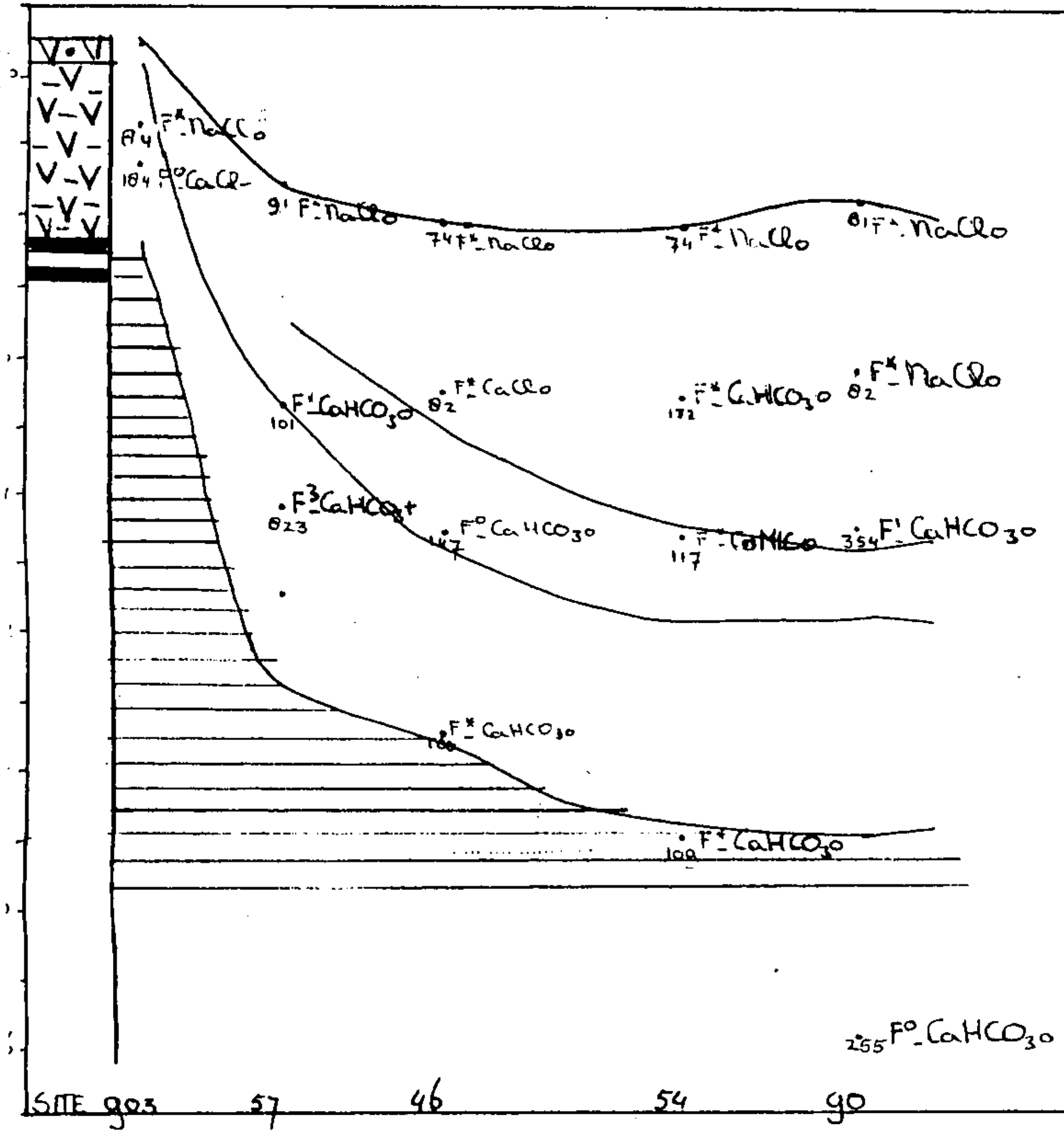
APPENDIX VII EC-lab/Stuyfzand March 1992

Transect 1 Clara west (Site 901-CLBH5)



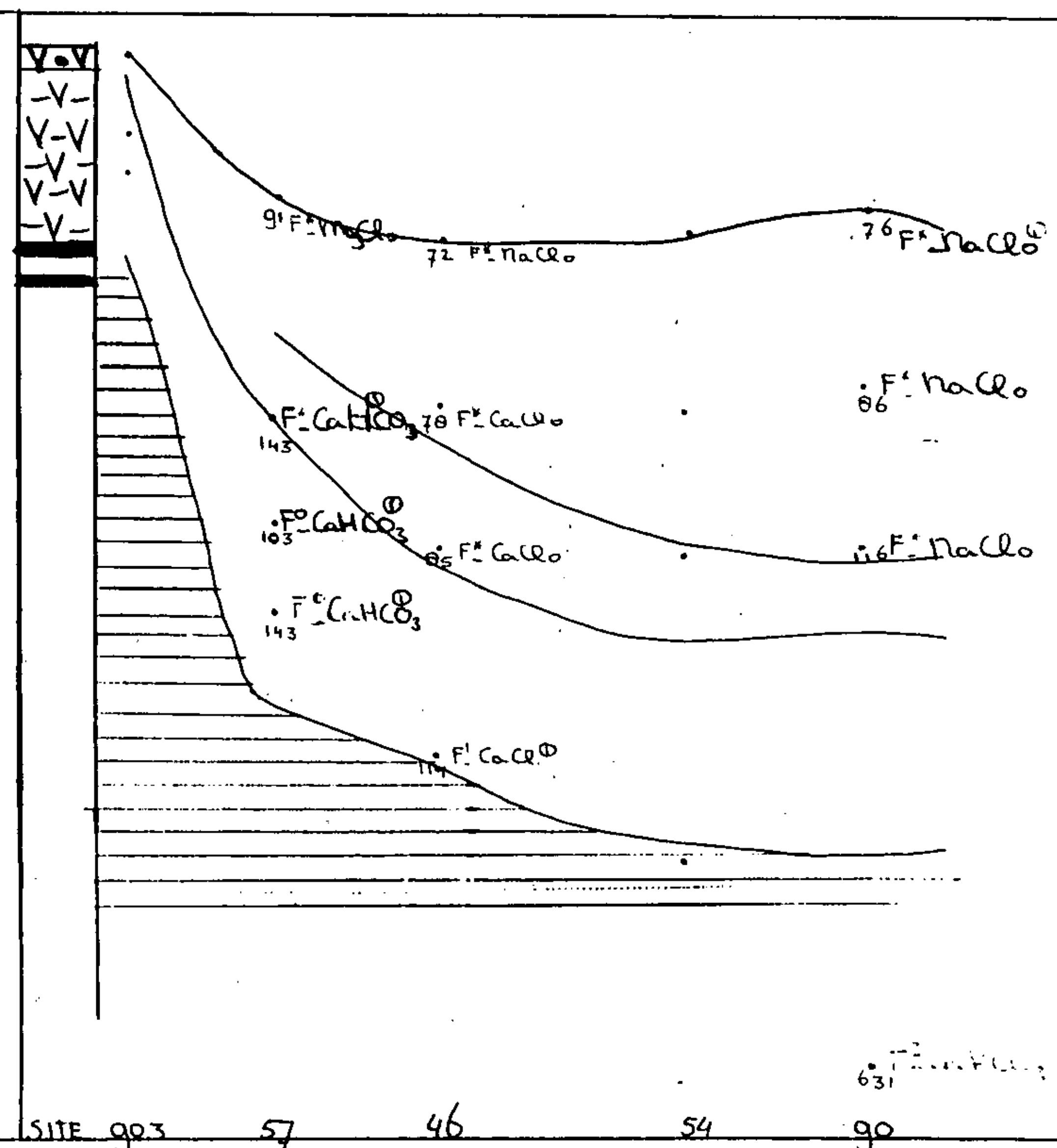
APPENDIX VII EC-fld/Stuyfzand July 1992

Transect 1 Clara west (Site 901-CLBH5)



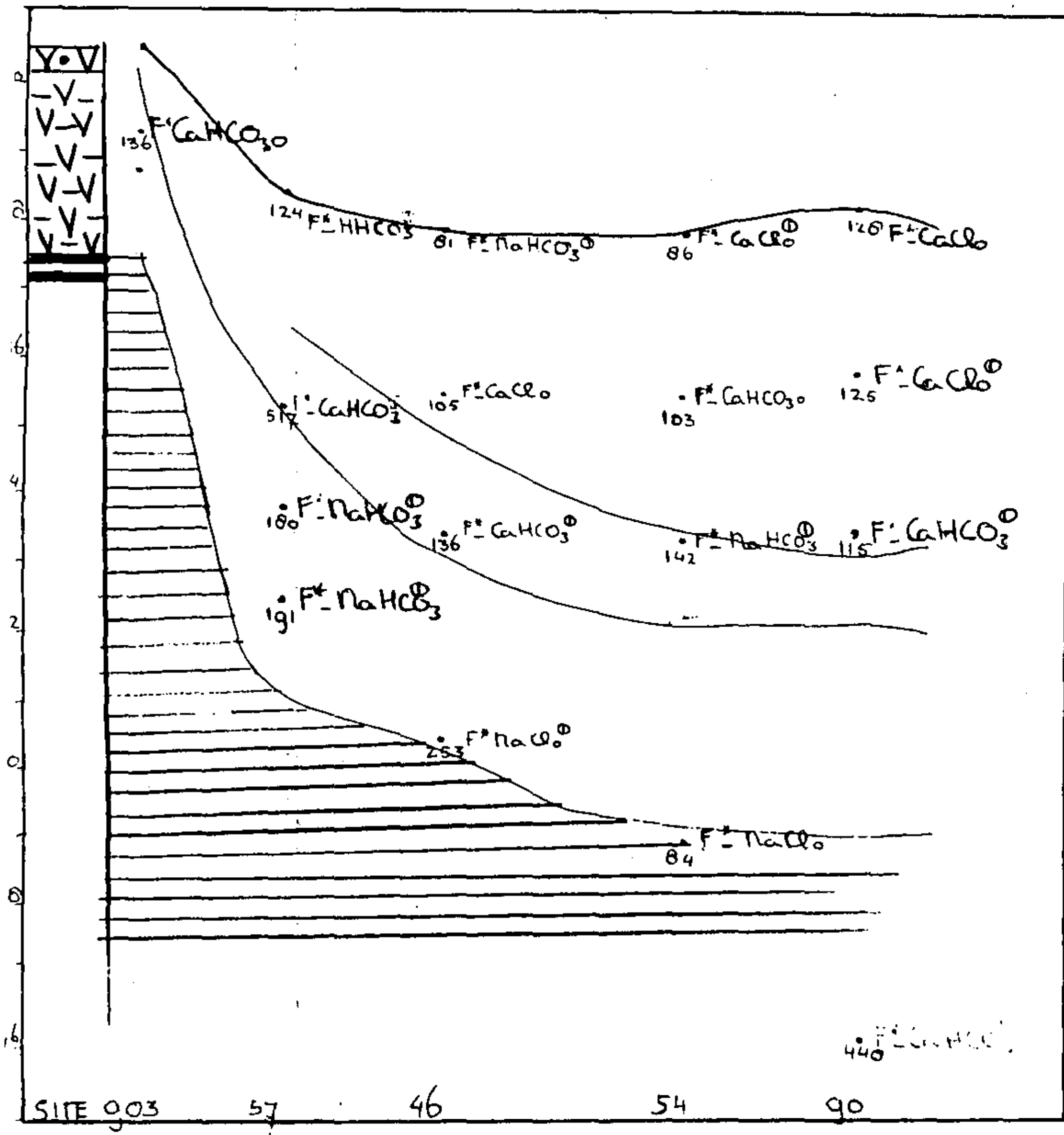
APPENDIX VII EC-fld/Stuyfzand June 1992

Transect 2 Clara west (Site 903-CLCD1)

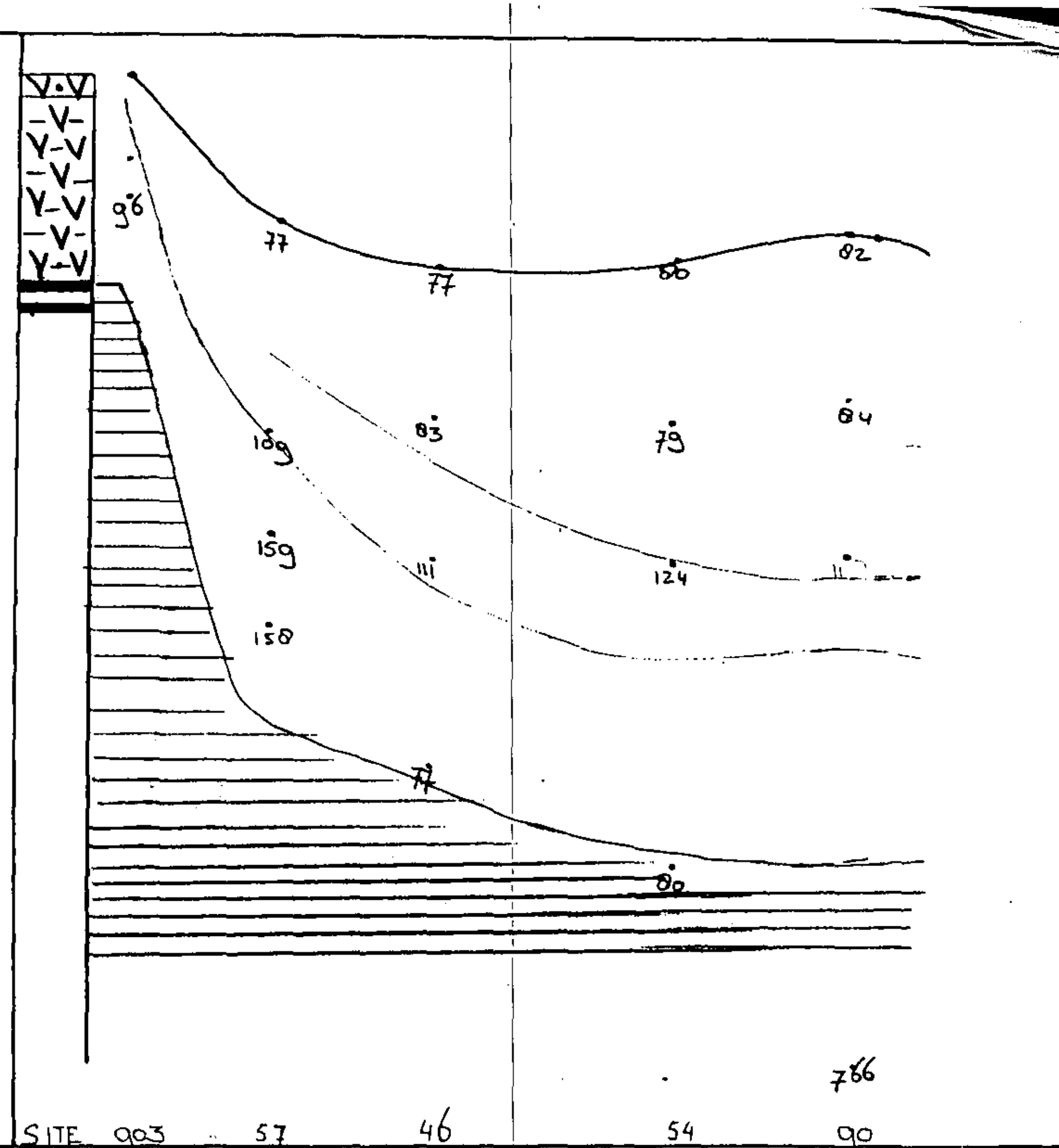


APPENDIX VII EC-fld/Stuyfzand Sept. 1992

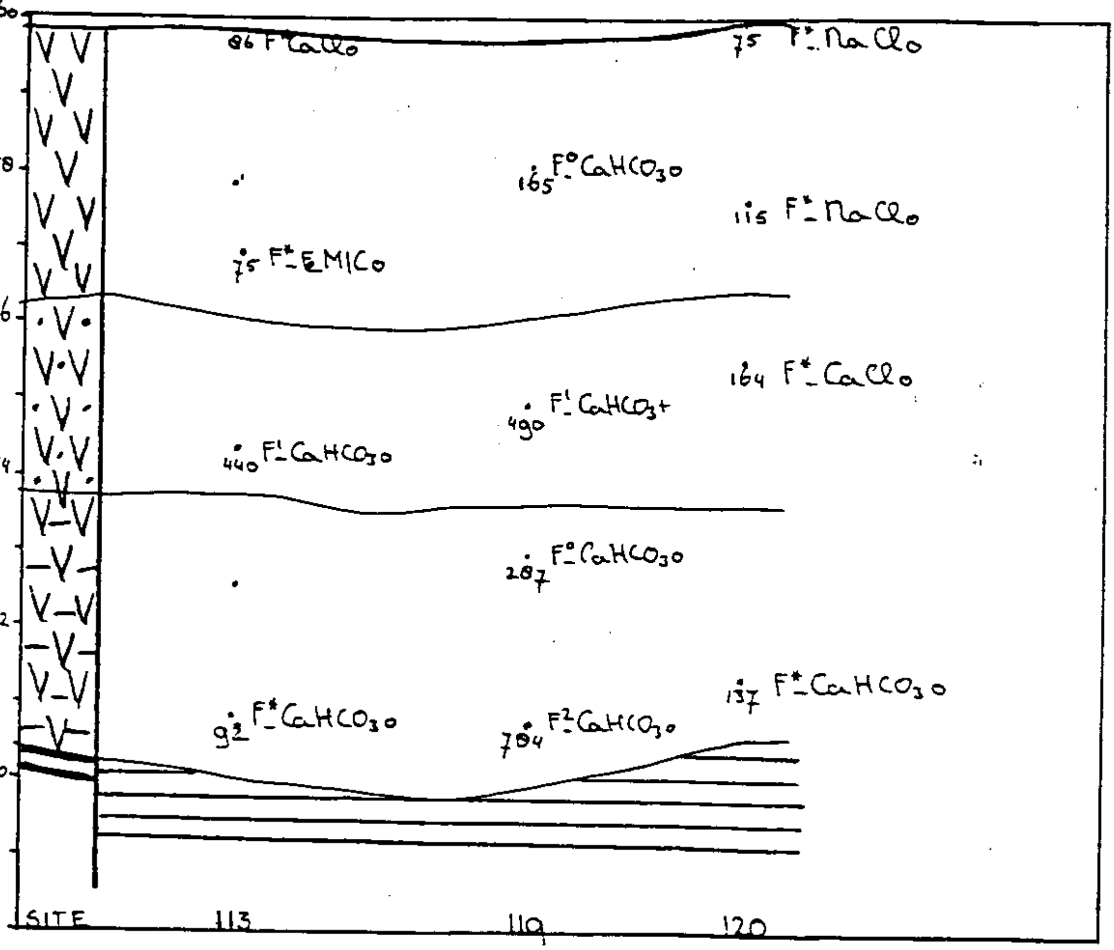
Transect 2 Clara west (Site 903-CLCD1)



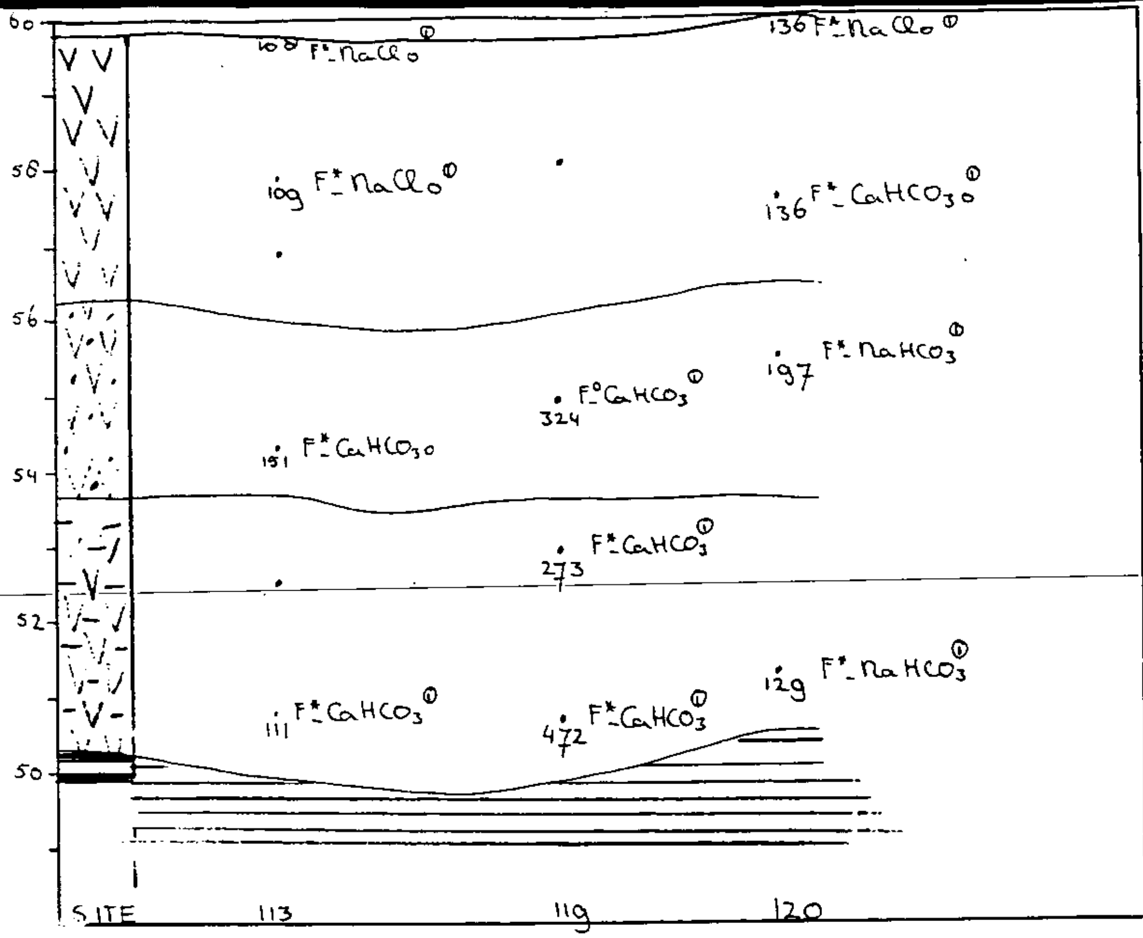
APPENDIX VII EC-lab/Stuyfzand March 1992
Transect 2 Clara west (Site 903-CLCD1)



APPENDIX VII EC-fld/Stuyfzand July 1992
Transect 2 Clara west (Site 903-CLCD1)

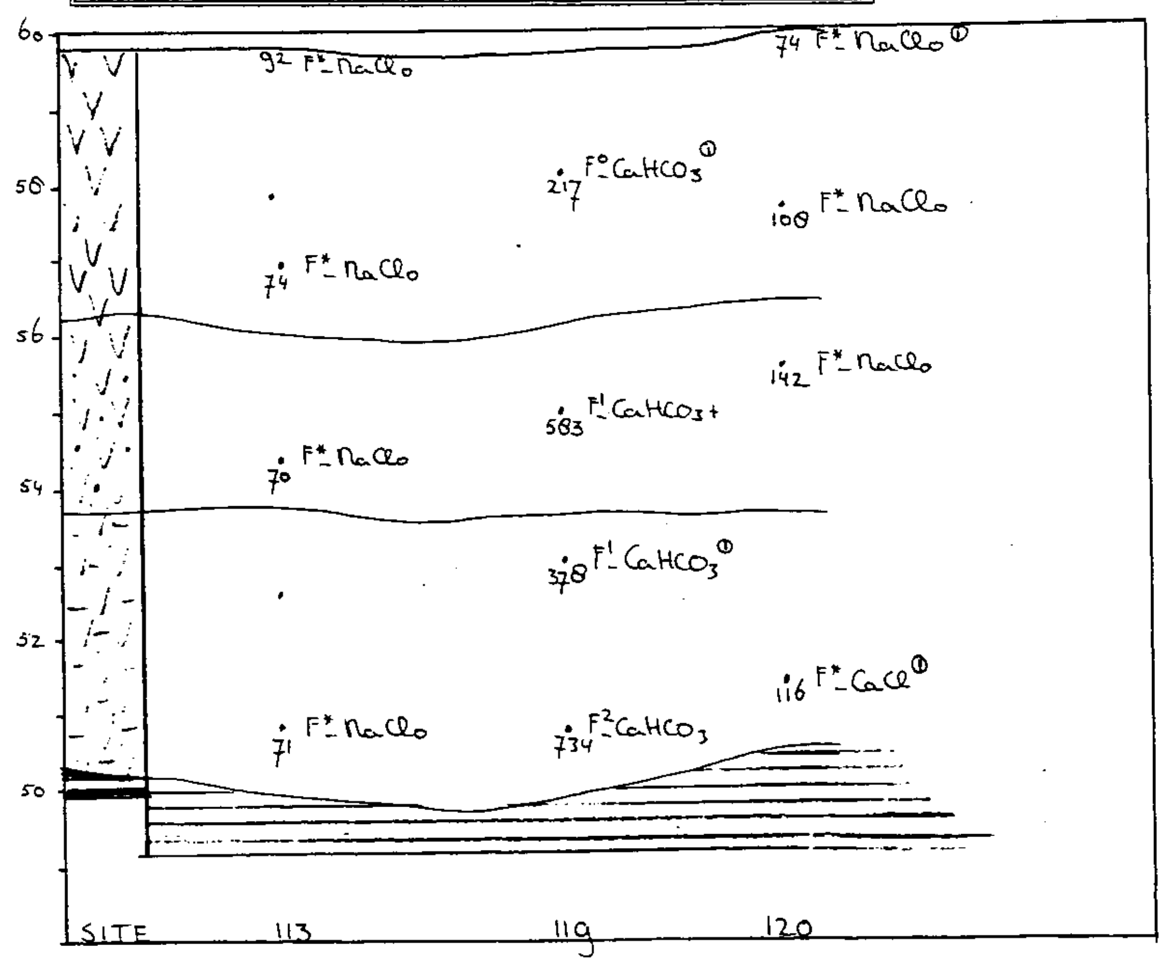


APPENDIX VII	EC-fld/Stuyfzand	June	1992
Transect 3	Clara east (Site 104-120)		



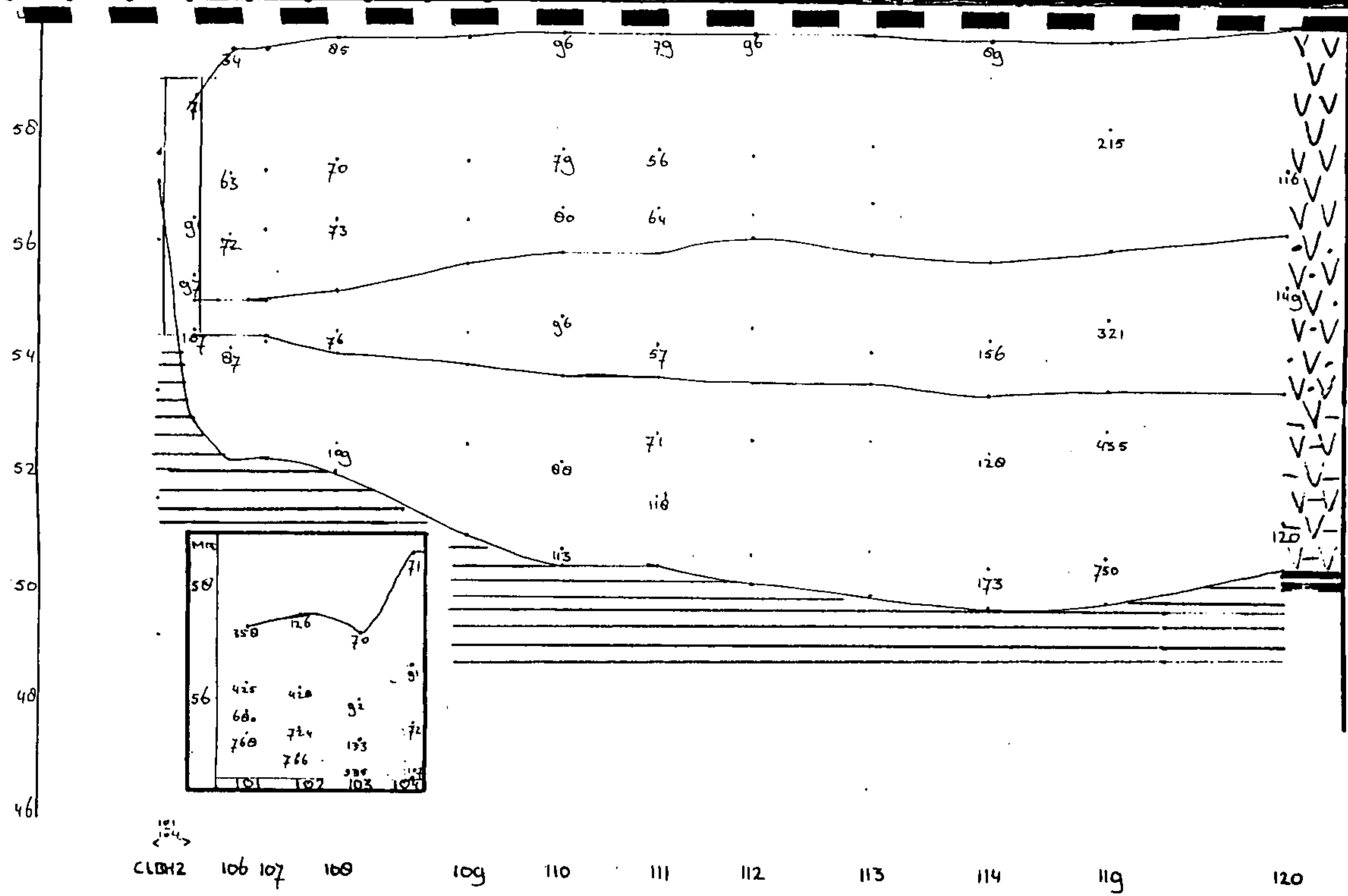
APPENDIX VII EC-lab/Stuyfzand March 1992

Transect 3 Clara east (Site 104-120)



APPENDIX VII EC-fld/Stuyfzand Sept. 1992

Transect 3 Clara east (Site 104-120)



APPENDIX VII FC-Fld/Stuyfzand July 1992

Transect 3 Clara east (Site 104-120)