IRISH-DUTCH PEATLAND STUDY

GEOHYDROLOGY AND ECOLOGY

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HYDROLOGICAL FIELD WORK ON CLARA AND RAHEENMORE BOGS

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APRIL 1991

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

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PREVIEW

This report contains a description of my practical period in Ireland, from 25 June 1990 until 23 November 1990. The practical period described, is part of my study Cultuurtechniek, Land and Water management, at the Agricultural University in Wageningen, the Netherlands.

This practical period could not have taken place without the help of many others. I would like to thank Jos Schouwenaars, Sake van der Schaaf (Agricultural University Wageningen) and Donal Daly (Geological Survey Ireland) for supervising; Roel Dijksma (Agricultural University Wageningen) for his technical advice and help with the equipment; John Cross (Wildlife Service Ireland) and Jan Streefkerk (Dutch National Forestry Service) for organizing and general supervising the whole project.

Also thanks to my fellow students Ray Flynn, Richard Henderson, Lara Kelly, Henk Lensen and Mary Smith and to Jan van Dijk for their company and help in Clara.

Thanks to Henri Rijnders for his help during his holiday in Clara and in Wageningen, when I was writing this report.

At last I would like to wish Wildlife Service the best for conserving the bog as it is now: an interesting nature reserve, with all it's aspects.

Wageningen 1991,
Desirée Huisman

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CHAPTER 1: INTRODUCTION

In the past raised bogs were landscape features of frequent occurrence in whole northern Europe. Nowadays most raised bogs have disappeared as a result of turf cutting. In the Netherlands there are only a few bog remnants left. In the midlands of Ireland raised bogs still occur. These bogs are still threatened by turf cutting. Wildlife Service preserves some of these bogs including Raheenmore bog and Clara bog. Raheenmore bog is a classic example of a raised bog in a deep basin, with a developed dome. of about 270 ha. Clara bog is a raised bog. with soak systems, of about 665 ha and is one of the largest relatively intact raised bogs remaining in Ireland. Raheenmore bog and Clara bog form the research area of the Clara bog project.

In general the hydrological problems in and around bogs can be divided into two categories (anonymous, 1989):

* drainage problems:
  ** superficial drainage by ditches cut in the surface of the bog
  ** drainage of marginal zones as a result of peat cutting
  ** marginal drainage by deep ditches
* conservation problems:
  in the safeguarding of bogs, problems arise in identifying and analyzing the hydrological conditions for conservation. These problems are, for example, the lack of specific hydrological knowledge and the lack of specific knowledge regarding the effects of hydrological interventions.

Clara bog project is a collaboration of Dutch and Irish scientists and students to study the hydrology, ecology and geology aspects of raised bogs. The Irish authorities involved are: Wildlife Service, Office of Public Works, Geological Survey of Ireland, Trinity College Dublin, University College Galway and Sligo Regional Technical College. The Dutch authorities involved are: Dutch State Forestry, University of Amsterdam and the Agricultural University of Wageningen.

The information gathered by the project will enable Wildlife Service to make appropriate management programmes for raised bogs and will help the Dutch Government to regenerate bog growth in the Netherlands. The project started in October 1989 and will last for 3 years. This report is part of the project and describes the hydrology survey done during the period June - November 1990.

This report is a description of the fieldwork done in this period and an attempt of analyzing some of the hydrological information gathered by the project until November 1990. The results and conclusions in this report are not final, but will be used in further studies.

In chapter 2 the study sides are described. Chapter 3 gives a description of the fieldwork and other research methods. Chapter 4 contains the analyzes of some of the hydrological information. Chapter 5 contains the management of the data.

CHAPTER 2: THE STUDY SIDES

2.1 Introduction

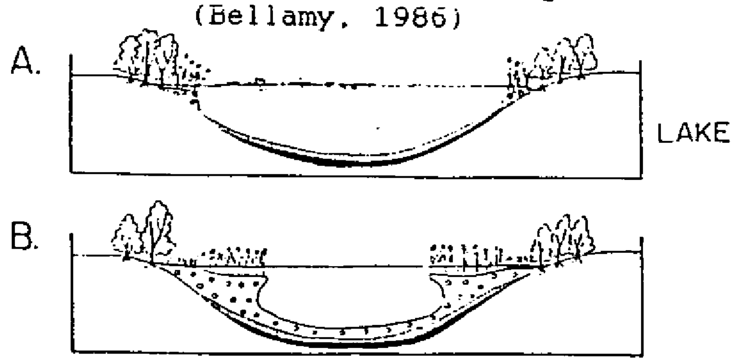
The study sides examined by the project are Raheenmore bog and Clara bog. These bogs are situated in the midlands of Ireland as shown in figure 2.1. Both bogs are raised bogs.

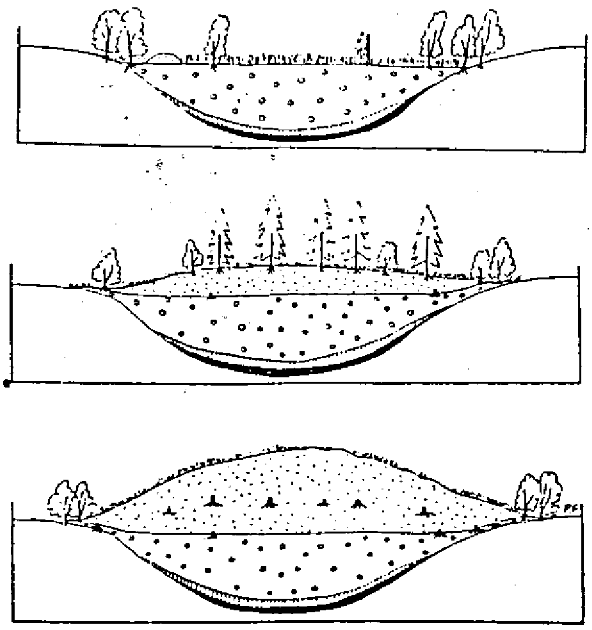
Figure 2.1 The study sides located in Ireland.

2.2 The origin of raised bogs

Raised bogs have developed from an open lake or a waterlogged depression. Five stages can be distinguished in the development of a raised bog from an open lake (Cross, 1990). The stages are given in figure 2.2. In stage A, peat forms on lake beds or in waterlogged depressions, where the ground water is nutrient-rich. In stage B beds of reeds develop and their dead remnants accumulate. In stage C, called fen, reeds are replaced by rushes, sedges, grasses, attractive herbs and sometimes trees and shrubs. Fen peat is dark and fibrous. At this stage Sphagnum, mosses able to survive on rain water which is nutrient-poor, colonize the fen. In stage D accumulation of Sphagnum forms light coloured spongy peat situated above the influence of the ground water. Fen plants are replaced by species which can survive in much poorer acid conditions and stage E, raised bog, is reached.

Figure 2.2: The development stages from a lake to a raised bog (Bellamy, 1986)





2.3 Clara bog

Clara bog is some 665 ha in extent and is one of the largest relatively intact raised bogs remaining in Ireland. Clara bog is intersected by a road, which divides the bog in an eastern and a western half. The drainage along the road caused a shrinkage of the peat of about 5 meter: this is shown in figure 2.3.

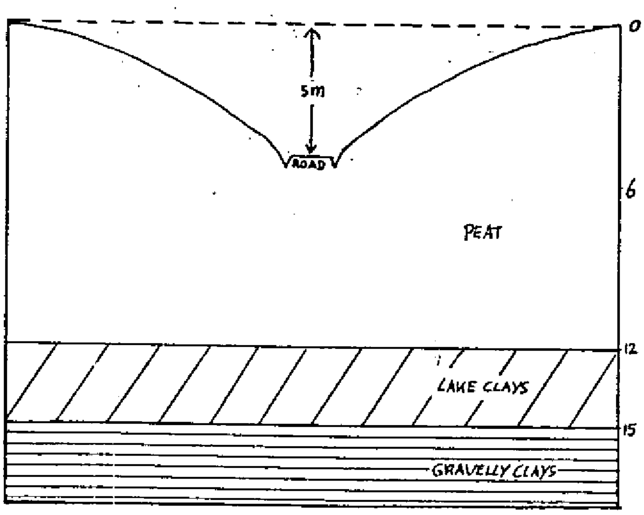


Figure 2.3: Subsidence of the road due to drainage

The eastern part has a drainage system of shallow drains of about 40 cm deep. These drains were made by Bord na Mona in 1983 to prepare Clara bog for peat production. Since Wildlife Service bought about 460 ha of the bog in 1986 attempts are made to block the drains. At the edges of Clara bog, which are privately owned, the turf cutting still continuous. Figure 2.4 shows Clara bog and the cutaway area.

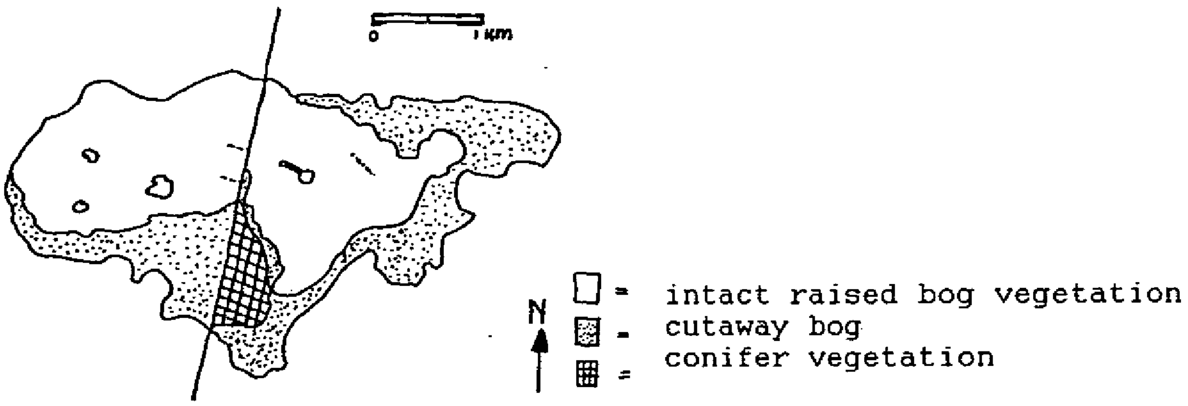


Figure 2.4: Map of Clara bog (IPCC, 1990)

Clara bog is famous for the occurrence of soaks. A soak is richer in nutrients than the other parts of the bog, as a result of which plants characteristic of fens occur. Such areas often have an open lake. The peat depth measured at Clara bog has a maximum of about 13.5 meter. This depth was measured by measuring the length of the deep piezometers, installed in the area around the soak (paragraph 3.3.7).

2.4 Raheenmore bog

Raheenmore bog is much smaller than Clara bog, about 270 ha. This bog is a good example of a raised bog with a well developed dome. This bog suffers from drainage by deep ditches around the bog, made to drain the agricultural lands around the bog. These drains were made about eight years ago.

At both bogs there are no lagzones left. These are zones with specific vegetation between the bog and the meadows. This is a result of the turfcutting and the cultivation of the agricultural land around the bogs.

To study the hydrology of the bogs transects of piezometer sets were installed. The location of the piezometer sets is given in appendix A2, A3 and A4, the composition in appendix C. The transects installed before June 1990 are described in Gloudemans (1990), the piezometers installed in the period June 1990 - November 1990 are described in chapter 3.

CHAPTER 3: THE FIELDWORK

3.1 Introduction

To gather information of the bog hydrology, fieldwork was done. The fieldwork contained the monitoring and levelling of piezometersets and recorders, improvement of the measuring network, retention- and conductivity measurements. The methods, problems and solutions of the fieldwork are described in this chapter.

3.2 Monitoring

3.2.1 The hydraulic heads

Every fortnight the phreatic water levels and the hydraulic heads of all piezometers have been measured. With a dipper or a ruler the water level has been measured. Until 20 August 1990 a dipper with a chain has been used, after this date a dipper with measuring tape has been used (figure 3.1). The chain dipper had an inaccuracy: 2.20 m at the chain is equal to 2.28 m in reality. All data gathered before 20 August 1990 have been corrected with a factor 1.04. The measuring tape dipper can be read in mm, instead of cm. Readings in mm are not accurate in mm, but more accurate in cm than readings in cm. Problems rise when the water level in a phreatic tube is low, because it is hard to hear the dipper in a perforated tube. This gives low phreatic water levels a certain inaccuracy.

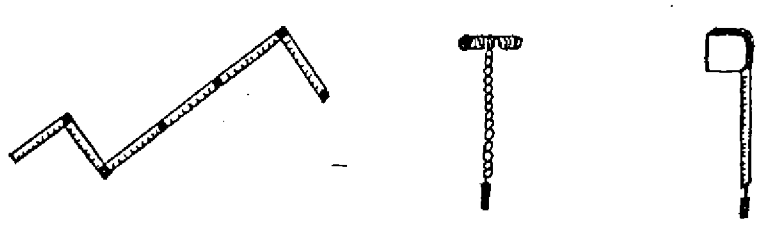


Figure 3.1 Ruler, chain dipper and measuring tape dipper.

3.2.2 The recorders and v-notches

On Clara bog and Raheenmore bog automatic recorders have been installed to measure the discharge and the ground water level continuously (E. Gloudemans, 1990). The recorders and the raingauges have been checked weekly.

Two SEBA recorders have been installed at the v-notches to measure the discharge, but they didn't work properly. There was to much friction in the mechanism, which caused a slow response of the recorder.

In July 1990 these recorders have been replaced by Ott recorders and the stilling wells have been replaced (figure 3.2). The stilling wells at the ground water recorders have been replaced in August 1990. When the discharge increased at the end of August 1990, it appeared that the recorders didn't work properly because the tubing was not perforated enough. This problem has been solved in the beginning of September 1990 by the technicians of the GSI. From september 1990 the recorders are functioning, all with a circulation time of 32 days and a wind clock. Changing the clock rates to a circulation time of 16 should give a more accurate chart, but new clock rates are very expensive.

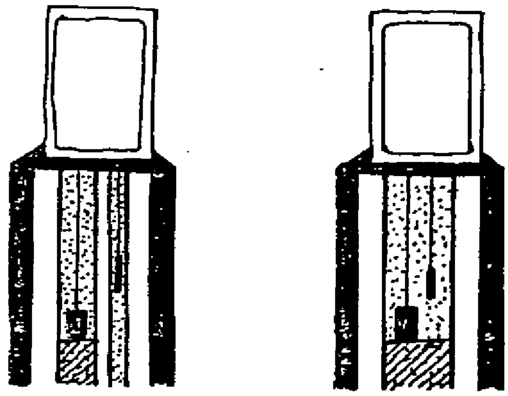


Figure 3.2: Replacement stilling well recorders.

In November 1990 a fifth Ott recorder has been installed near the second v-notch at Clara bog west. This recorder has been connected with the foundation of the v-notch, probably more steady than the other recorders (figure 3.3).

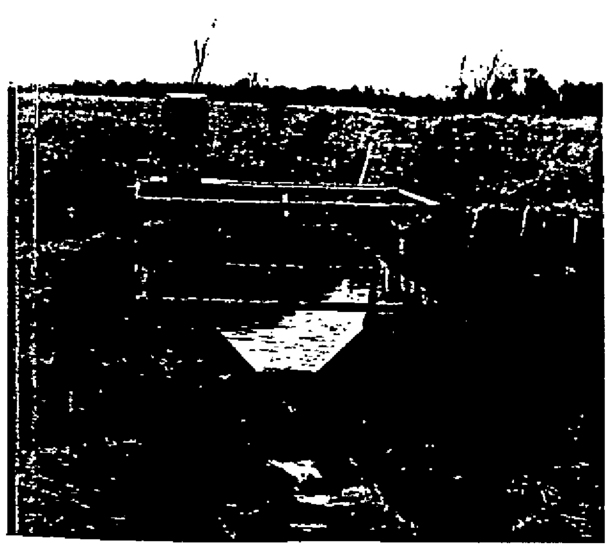


Figure 3.3: New v-notch Clara bog west.

The second v-notch has been positioned at the eastern drain in Clara bog west, to measure the discharge of Clara bog west together with the first v-notch (appendix A4). This new v-notch has a v-shape of 90 degrees and a sharp edge. A general formula for this type of 90 ° Thomson-notch is:

$$Q = 1.38 \times h^{2.48} \qquad (m^3/s) \qquad (1)$$

When the discharge is low, this formula can't be used while water sticks to the v-notch. A calibration of this v-notch will be made in Wageningen with a copy of this v-notch.

The charts of the recorders of the period starting in September 1990, are not digitised yet, but will be digitised at OPW in Dublin by Timothy Joyce.

Rainfall was measured with the tipping bucket, syphon recorder and handgauges on Clara bog and Raheenmore bog (Gloudemans, 1990). The rainfall data are given in appendix B. In general the handgauges collect more rainfall than the recorders register. In summer a lot of the water collected in the handgauges evaporated. In this period there was no check of the recorders possible. It might be a solution to paint the handgauges white, to reflect the sunlight, but the handgauges will not be English standard any longer. The syphon recorder is not able to deal with heavy showers, which causes the gaps in the daily rainfall table.

3.3 Extension and improvement of the measuring network

3.3.1 Introduction

After more than half a year of monitoring the measuring network, the data showed some gaps in information, which had to be improved by changing the network. All new installed phreatic tubes and piezometers are constructed the same as described by Gloudemans (1990). The existing network at the end of November 1990 is given in appendix C.

3.3.2 Changing piezometers in filterdepth

There was a lack of information about the waterflow in the lower layers of the peat. The peatdepth varies from about four meter at the edge to about fifteen meter in the middle of both bogs. The piezometers in the peat were originally installed at 1.50 m (B), 3.00 m (C) and 4.50 m (D) beyond the surface. To get more information of the deeper layers and not to extend the network, the piezometers of 1.50 (B) were pushed down to 6.00 m (E), if the peat was deep enough. The piezometer sets changed at the end of June 1990 or the begin of July 1990 from A, B, C and D to A, E, C and D.

3.3.3 Installing gauges and piezometers near the cutaway area

To collect information on the water table in the drain along the cut-away bank in Clara bog west and the drain to the v-notch in Raheenmore bog, gauges have been installed in the drains at the beginning of July 1990. These gauges have been pushed down in the peat minimal 1.00 m. Still the gauge in the drain at Clara bog west does not remain vertical. Because this gauge is hard to reach, it is hard to put this gauge in the right position. This must be taken into account when the data are used.

In the cut-away area near the bank of Clara bog west two new piezometer stations have been installed to get more information of the flow beyond the cut-away zone from the bog to the surroundings. Both piezometer stations (69 and 79) have a phreatic tube and a piezometer with the filter at the bottom of the peat. These piezometer sets have been installed in October 1990 and will probably be removed next summer when the turf cutting starts again.

3.3.4 Installing piezometer sets to compare an old facebank and a fresh facebank

To be able to compare the ground water flow of an old cut-away bank to a fresh cut-away bank, piezometer stations have been installed at an old bank (near grid peg S16, appendix A2 coördinate 19/16) and at a fresh bank (at the end of transect B-B') at Clara bog west. A situation sketch is shown in Appendix A5. The piezometer stations content a phreatic tube, a piezometer with a filter at 1.50 m beyond the surface and a piezometer with a filter at 3.00 m beyond the surface. It was hard to find an old bank, because most banks have been cut away as a result of continuing turf cutting. Approximately this bank is 10 years old, and is still in connection with the bog over a distance of 30 meter.

3.3.5 Installing the phreatic grid at Raheenmore bog

The only area that reminds of a lagzone is situated at Raheenmore bog west. It is a small part of the bog with a relatively regular change in vegetation from the bog to the meadow. Hydrological information was needed to support the ecology study at the lagzone. This area has been drained a lot in the past. Therefore the hydrology is not easy to describe. It might take a lot of time to get an idea of the ground water flow in this area. It might even be impossible to get an idea. To find out if it is useful to do a detailed hydrological study at this side, an intensive irregular phreatic grid has been installed. This grid will be monitored monthly for half a year. After this period it will be decided if the work will be continued or not. The situation sketch of this grid is given in appendix A6.

Among the students there has been a lot of discussion about this part of the project. Along Raheenmore bog an deep drain has been made about six years ago. The influence of this drain on the vegetation in this area is not very noticeable yet. The lag between change in hydrological conditions and change in vegetation seems to be a long period. This period might cover a longer period than the duration of the project, which makes this study useless for the project. This has to be taken into account when the decision of continuing or not has to be made.

3.3.6 Piezometers in stations equal in level and connected with timber

Probably as a result of shrinkage and swelling of the peat, the piezometer sets looked messy (figure 3.4). It was hard to compare the readings of the hydraulic heads at the spot and every top of the tube had to be levelled separately. Therefore all tubes have been topped to equal the height of the tubes and connected with timber, to keep the tubes at the same height (figure 3.4). The topping of the tubes has been done at

13

14 August 1990 at Clara bog west, 15 August 1990 at transect C-C'at Raheenmore bog and 1 and 6 November 1990 at N-S transect at Raheenmore bog.

Figure 3.4: The face lift of the piezometer sets

3.3.7 <u>Installing deep piezometers at the bottom of the peat</u>

Not only the tubes positioned in the piezometer sets moved by shrinkage and swelling of the peat, but also the phreatic tubes around the soak. To be able to keep these tubes at the same depth in the peat, deep piezometers at the bottom of the peat (F) have been installed next to the phreatic tubes and connected with each other by timber, as described in 3.3.6, in October 1990. These piezometers can also be used as new observation wells.

At the transects at Raheenmore bog more information was needed of the hydraulic heads at the bottom of the peat. In October 1990 at station 324, 327, 330, 333, 209 and 211 piezometers (F) have been pushed down to the bottom of the peat. After a month these piezometers were still not measurable. This can be caused by very low conductivity of the peat at this depth or by a closed filter caused by under pressure in the pipe. The last possibility can be solved by putting some water in the piezometer when the piezometers are installed.

3.3.8 <u>Installing swelling and shrinkage tools</u>

To get an idea of swelling and shrinkage of the peat, timber has been put around the piezometer sets last winter (figure 3.5). This method did not work, because the shrinkage and swelling has been not measured, but the starvation of the vegetation below the timber.

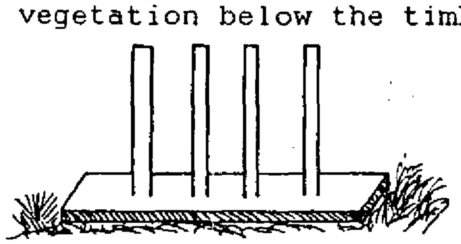


Figure 3.5: Old method

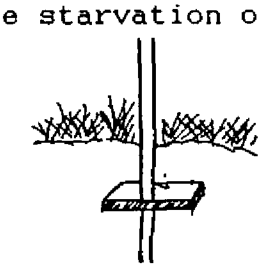


Figure 3.6: New method

At the beginning of July 1990 new timber was installed below the roots of the vegetation (figure 3.6) at Clara east (temporal benchmarks AR, BR, CR), Clara west (57E, 59E, 61E, 65E, 67E) and Raheenmore (202D, 206E, 209E and 330C). It might be useful to extend these measurements, with new timber around the deep piezometers installed in October 1990.

3.4 Levelling

3.4.1 Introduction

The absolute level of the bog surface is not constant in time. Shrinkage and swelling of the peat causes seasonal fluctuations and when the bog is influenced by drainage, the surface might go down in a period of several years.

The piezometers are positioned in the peat and fluctuate together with the bog surface. The water tables are measured every fortnight from the top of the tube. To know the water tables and hydraulic heads relative to an absolute datum and not relative to the top of the tube, the absolute height of the top of the tube has to be known at every time in the year.

3.4.2 The frequency of levelling

Approximately the range of changes in level as a result of shrinkage and swelling is 10 cm. This estimation can be verified with the measurements of paragraph 4.6.2, in which the range in 4 months is about 5 cm. The water tables have been measured in mm. The accuracy of these measurements is lost, when the absolute level of the top of the tube is not known. Therefore the tops of the tubes have to be levelled regularly. To get the most accurate data, the levelling has to be done together with every measurement of the water table. In practice this is not possible. But at least the levelling should be done every summer, autumn, winter and spring.

The first levelling survey of the piezometers on the transects A,B and C, the plots A,B and C and the random phreatic tubes around the soak has been done in December 1989 (Gloudemans, 1990). The first levelling survey of the North South transect on Raheenmore bog has been done after the instalment in 1987. The levelling data available were related to the bottom of the drain at the southern end of the transect. This makes this levelling not comparable with absolute level in meters above sea level. The second levelling has been done in the period of July 1990 until October 1990 for all transects and new installations.

3.4.3 The equipment

The equipment used in the second levelling survey is different from the equipment used in the first one. The type of the levelling instrument used the first time is a Carl Zeiss Jena NI 030. The type of the levelling instrument used the second levelling survey is GK1 KERN. This is a simple version with a bubble to approximate the vertical and a split bubble for fine adjustment adapted by a slope screw (figure 3.7). This levelling instrument has been used in combination with an upright staff. This instrument should be used with a reversed staff, which was not available.

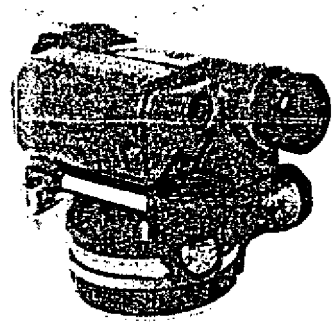


Figure 3.7: Levelling instrument GK1 KERN

3.4.4 Problems and possible solutions

Levelling of the top of the tubes is of no use when it is not done properly. The accuracy of the levelling done until November 1990 is dubious. The problems are due to the equipment, the measuring system and the circumstances.

The equipment

The staff used caused the equipment problems. Since there is no level on the back, it is hard to keep the staff vertical. While the staff is not reversed, measurements have been taken upside down, which is very hard to read. And there was no staff tiltlevel to account for slopes on the bog. This can be solved by using a reversed staff with a level on the back and a tiltlevel.

The measuring system

Accurate levelling of the top of the tubes and the benchmarks can only be done by putting the staff on the top of the tube, not beside the tube on the surface with an estimation of the tubehight. This is shown in figure 3.8.

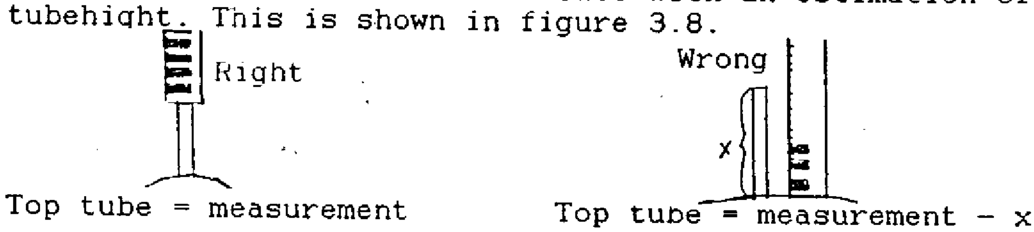


Figure 3.8: Method of measuring the tubelevel

The level of the top of the tubes is of more use than the surface level. The surface level changes and it is not clear what the surface exactly is. When a piezometer set looks like what is shown in figure 3.9 what is the surface level? The best thing to do is measure the top of the tubes and the distance of the tubes above surface level and derive an estimated surface level of it. This is shown in figure 3.9.

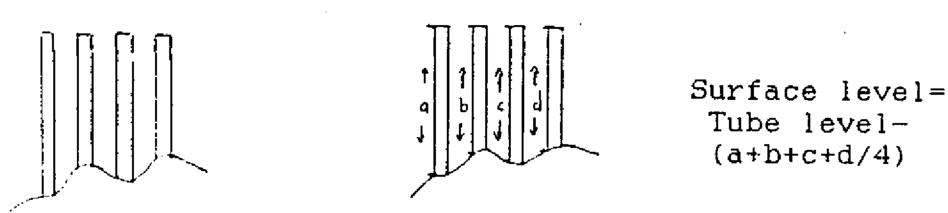


Figure 3.9: Method to measure the surface level

The circumstances

The weather circumstances can be awkward. When it is raining, levelling is impossible because the instrument is not waterproof; when wind is blowing, it is very hard to hold the staff vertical; when it is warm, heat waves disturb the view and when it is warm and humid midgets and other insects disturb the view as well.

The levelling tour has to start and end at a benchmark. The level of the benchmark should remain constant in time, what means that the benchmark should be positioned outside the bog or anchored in the layers beyond the peat. In November 1990 there are only benchmarks of this type on the road at Clara, at the plots on Clara bog east, at the v-notches and at Tinkers Bridge in Raheenmore bog. While the benchmarks are far away from the piezometer stations the levelling tours are very long. To level a long tour on a bog is very hard. During the levelling the bubble of the levelling-instrument is out of level by every movement of the reader. The errors of levelling are about 3-6 cm in a levelling tour of 1-2 km. But these errors are defined by comparison of the begin and the end value. During the levelling tour the error can be equalized. The absolute levels which are needed have to be accurate to at least centimeters. This is not the right way of levelling.

The best solution to this problem would be if there were benchmarks installed near the piezometer stations on the bog.

To get an acceptable accuracy of the measurement the distance between the levelling-instrument and the staff must not exceed 100 meters, at normal circumstances. In my opinion the distance should not exceed 50 meters on bog circumstances. Whenever the levelling-instrument is moved, the accuracy of the measurement will decrease. Therefore benchmarks are needed every 100 meters. To decrease this amount of benchmarks, some available spots on the bog can have the function of benchmark. The v-notches, the boreholes (at the north side of Clara bog east and the north and south side of Raheenmore bog) and the temporal benchmarks at the plots on Clara bog east are steady. The deep piezometers to the bottom of the peat are not as steady as the other spots mentioned but can be used as steady spot between two benchmarks. This leads to the following new benchmarks (the coordinates are estimated, the positioning of the coordinates is given in appendix A):

Five benchmarks at Raheenmore bog, positioned at:

1) the middle of the north-south transect; coordinates 600/60
2) the middle of the east-west transect; coordinates 1070/-100
3) the east of the east-west transect; coordinates 1340/-260
4) the bog side of the lagzone; coordinates -225/-250
5) the meadow side of the lagzone; coordinates -300/-250

Two benchmarks at Clara bog west, positioned at:

1) between piezometer stations 48 and 57; coordinates 1235/840
2) near the soak between piezometer stations 54 and 56; coordinates 1230/600

Three or six benchmarks at Clara bog east. If the three existing temporal benchmarks at the plots are not anchored in the clay, these benchmarks have to be replaced. The positioning of the other three benchmarks depends on the installation of new piezometers in this area.

The benchmarks must be anchored in the (clay-) layers beyond the peat. This can be a problem because the peatdepth in the middle of the bog is about 15 meters. The benchmarks must be strong and remain vertical during the project. A possibility is to put long augers down in the clay and keep them in till the end of the project.

The new benchmarks together with the v-notches, the boreholes and the temporal benchmarks at the plots should be levelled every year from a benchmark outside the bog. Preferably with better equipment to get accurate absolute levels of the top of those benchmarks. At November 1990 the tops of the existing benchmarks have not been levelled accurate yet.

3.5 Retention measurements

3.5.1 Introduction

To find retention curves of the peat, the outflow method is used (van Gerven, 1990). Undisturbed peat samples had to be taken in the field. These samples had to be saturated, put under different pressure, saturated again and dried in the oven. Problems occurred with this method are described below.

3.5.2 The samples

The samples have been taken with a core sampler in sample cylinders. The samples should be undisturbed, because the structure of the sample affects the water retention. The peat samples mostly contained pieces of wood or roots, which cause holes in the samples. Often the peat is very soft and when an attempt is made to take the sample cylinder out of the peat, the cylinder is empty. Most samples taken are relatively undisturbed samples.

3.5.3 The equipment

Parts of the equipment have been taken to the Netherlands at the end of June 1990 to repair them. Therefore rubber rings have been needed. These rings were not as common as they were supposed to be, they had to be ordered. Unfortunately in summer firms have holidays what postponed this order till the end of August 1990. The parts arrived in Wageningen at the beginning of September 1990. At the end of the first week in September, the parcel has been sent to Clara. A month later the parcel arrived.

3.5.4 The measurements in progress

The samples have been put into the equipment and saturated. After the saturation, the pump has been switched on and there was pressure on the samples. A few days later, the electricity has been cut of, the bill of the ESB has not been paid. The pump stopped, the measurement stopped also. The electricity was back within one day. A few days after the electricity has been cut of, electricians started to install new storage heaters in the house. There was no electricity during the day, the test had to start again. The following two weeks, there were no problems (!). Until the pressure has been expanded to pF 2. The new rubber rings in four samples were not tight enough, four samples quit. Let's continue with 16 samples instead of 20. A week later there was another problem. The pump stuck over night, several times. Problems with the heating protection, told the manual. But it was nearly freezing in the basement. A probable cause of this problem is low voltage during the night, caused by the storage heaters which store electricity at night. To be able to use this method every season of the year, this problem has to be solved.

3.6 Horizontal and vertical conductivity

3.6.1 Introduction

In addition to the conductivity data gathered by van Gerven, permeability measurements were done at the piezometers installed at 6.00 m depth and at the old and new facebank at Clara bog west and Raheenmore bog. To measure the horizontal conductivity the piezometer method and the inversed augerhole method were used, to measure the vertical conductivity the tube method was used. The results of these measurements are given in paragraph 4.8 and 4.9. Measuring forms of these measurements are given in appendix D.

3.6.2 The inversed tube method

The inversed tube method can be described as follows. First an augerhole is made at about 60 and 120 cm depth beneath surface. A plastic tube without any perforation with a diameter of 3 inch (+/- 7.7 cm) was put into the hole and filled with water. The drop of the water table is measured in time. The formula to calculate the conductivity (appendix D2):

$$K = \frac{A'}{\bar{y}} \times \frac{\Delta y}{\Delta t} \qquad (m/day) \tag{2}$$

K	= vertical conductivity	(m/d)
A'	= $864\pi R^2/2.54A$	(-)
A	= area	(cm^2)
R	= radius of the tube	(cm)
y	= drop of the water table	(cm)
t	= time	(sec)

The tube method worked out to be very slow, the results are based on very small changes in the water table. This must be taken into account when these data are used.

3.6.3 The piezometer method

The piezometer method can be described as follows. The piezometers used did already exist in the measuring network. The water table in the piezometer has been lowered by pumping the water out and the rate at which the water rises is measured. The hydraulic conductivity is calculated as follows (app.D3):

$$K = \frac{\pi R^2}{A\bar{y}} \times \frac{\Delta y}{\Delta t} = \frac{A' R_2}{\bar{y}} \times \frac{\Delta y}{\Delta t} \qquad (m/day) \tag{3}$$

K	= vertical conductivity	(m/d)
A	= area	(cm^2)
A'	= $864\pi/A$	(cm^{-2})
R	= radius of the tube	(cm)
y	= drop of the water table	(cm)
t	= time	(sec)

The use of the piezometer method in peat research is dubious, as described in van Gerven, 1990 and Flynn, 1990.

3.6.4 The inversed augerhole method

The inversed augerhole method is an augerhole test above the water table. A hole is augered to about 1 m depth beneath the peat surface and a perforated iron tube with a diameter of 8 cm is put into the hole. This tube is filled with water and the rate of fall of the water table is measured. The hydraulic conductivity is calculated as follows (Appendix D4):

$$K = 1.15\, R\, \frac{\log(h_o + \frac{R}{2}) - \log(h_t + \frac{R}{2})}{t} \qquad (m/day) \tag{4}$$

K	= vertical conductivity	(m/d)
R	= radius of the tube	(cm)
t	= time	(sec)
h_o	= length of watercolumn at t=0	(cm)
h_t	= length of watercolumn at t=t	(cm)

This method worked pretty good at the old and fresh facebank this summer at Clara bog west, when the water level was about 100 cm below surface level.

3.6.5 The falling head method

The falling head method has been used to measure the saturated conductivity of peat samples. Relatively undisturbed peat samples have been taken and saturated. Afterwards the sample has been put in an installation as shown in figure 3.11.

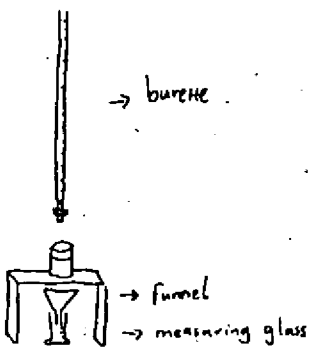


Figure 3.11: The falling head method (Lit. 10)

Darcy's law can be used to describe the ground water flow:

$$q = -k \times \frac{dH}{dz} \qquad (5)$$

q	= groundwater flux	(m/d)
k	= conductivity	(m/d)
H	= hydraulic head	(m)
z	= vertical space coordinate (height)	(m)

Water drops from the burette on the sample. The head of water on the sample rises until a certain height. Than the water drops out of the sample into the measuring glass. By measuring the volume V in the measuring glass every time period, the discharge Q is known. When Q is constant in time, q can be calculated by dividing Q through the area off the sample.

$$q = \frac{Q}{A} \quad (m/s) \qquad (6)$$

$$\frac{dH}{dz} = \frac{d_w + d_s}{d_s} \qquad (7)$$

d_w = head of water above sample
d_s = height of sample

$$k_{saturated} = \frac{-q \times dz}{dH} \quad (m/s) \qquad (8)$$

This method appeared not to be useful for peat samples. The conductivity is too low, which causes a very high head of water on the samples. This is a problem because it is very hard to keep the water in the plastic cylinder made of tape. Another problem with this method is the appearance of gaps between the peat and the cylinder. In this case water flows through the gaps instead of the peat and the conductivity is can not be measured.

CHAPTER 4: RESULTS AND ANALYSES

4.1 Introduction

In this chapter an attempt is made to analyze some of the information, gathered as described in chapter 3. Succeeding students will analyze the data in further detail.

4.2 Fluctuation of the phreatic water levels and the hydraulic heads

4.2.1 Introduction

One of the things that can derived from the monitoring data is the fluctuation of the water level and the hydraulic heads during the year. The fluctuation graphs of some of the piezometer stations are given in appendix E. The data used to make these graphs have been corrected to an equal level of the tube in time, because some of the levelling data of succeeding periods varied too much. Transect north-south at Raheenmore bog is let out of this paragraph because the levelling data were not reliable (par. 3.4).

4.2.2 The soaksystem at Clara bog west

Phreatic tubes have been installed random around the soak in 1989 (Gloudemans, 1990), to survey the relation between the vegetation and the water level during the year. The fluctuation of the phreatic water table at most spots around the soak is given in appendix E2. The vegetation types are described in table 4.1.

Table 4.1: Vegetation types (van Gerven, 1990 (extended))

46	Sphagnum/Ling heather
47	Sphagnum/Ling heather
48	Sphagnum
50	Calluna/Sphagnum
52	Molinia tussocks
53	Birch grove with Sphagnum (near soak)
54	Sphagnum
55	Sphagnum palustre (near soak)

The location of the phreatic tubes is given in appendix A2.

In winter 46, 47, 48, 50, 52 and 53 fluctuate equal, about 10 to 15 cm. In May, the beginning of the dry period, the water level at 48, 50, 53 and 55 dropped further and at the end of June the water level rose more at these spots. The fluctuation of the water level between the wet period and the dry period is about 20 to 25 cm. After September the water levels equalled again at all spots. The stations 48, 50 and 55 are situated in wet areas with sphagnum. The sensitivity of sphagnum to desiccation seems to be higher. This has been found also in the Netherlands (Schouwenaers, 1990). The evapotranspiration of calluna and sphagnum and birch trees (53) has to be higher than the evapotranspiration of calluna and molinia. Evapotranspiration differences of vegetation types will be studied in 1991 with lysimeters.

4.2.3 Along the transects at Clara bog west

The fluctuation graphs of piezometer station 57, situated central on the bog, and piezometer station 68, situated at the edge of the bog, is given in appendix E3. The phreatic water level at piezometer station 57 shows a more capricious path than the other stations. This can be caused by worse hydraulic contact with the toplayer, than the other stations. Piezometers A, B, C, E and D follow each other well. The fluctuation of the phreatic water level is about 45 cm, of the hydraulic heads about 37 cm. In comparison with the phreatic tubes around the soak, 4.2.2, the water level at this spot fluctuates much more. A reason can be the location of this station at the foot of the hill. The influence of this hill on the hydrology can be important.

The phreatic water level at piezometer station 68 fluctuates about 100 cm, the hydraulic head at 1.50 m depth about 70 cm and the hydraulic head at 3.00 m depth about 120 cm. The giant fluctuation at 3.00 m depth is probably a result of the facebank which has nearly the same depth. The fluctuation at 4.00 m depth will probably be less, because this filter is situated beneath the disturbance. At this depth there are not enough measurements yet to measure the fluctuation. Interesting is the fact that nearly all levels are recovering after one year. If levelling of the tubes can be done more accurate in the following periods, more certain conclusions can be derived next year.

The fluctuation of the water level is less inside the soaksystem than outside the soaksystem. The soaksystem has a function of a buffer, which keeps the water in the system. By evaporation of water out of the soaksystem nutrients will accumulate and the water table will not drop too much because of the buffer mechanism. It would be interesting to find out more about the buffer mechanism of the soaksystem and it's relation to the occurrence of the specific vegetation.

4.2.4 Along transect C-C' at Raheenmore bog

Of piezometer station 201, located in the dug edge, 206, located 200 m from the edge and 212, in the middle of the bog, fluctuation graphs are given in appendix E4. The phreatic water level and the hydraulic head at 1.50 m depth at station 201 follow each other well. The fluctuation is about 22 cm. The hydraulic heads at 3.00 m depth and at 3.62 m depth follow each other as well, with a fluctuation of about 25 cm. At station 206 and 212 all graph lines follow each other with a fluctuation of about 25 cm.

At Raheenmore bog all fluctuations are nearly equal. In comparison with the fluctuations along the transects at Clara bog west, this fluctuation is limited. Possible causes for this difference are the occurrence of turfcutting at facebanks at the edge of Clara bog, a totally different conductivity pattern of the bog or a difference in amount of water collecting vegetation. The first cause seems the most reasonable, further research has to find the real cause.

Differences in fluctuations are more comparable when the standarddeviation of the mean waterlevel is calculated. In table 4.2 the standarddeviation is given for the piezometers of the graphs in appendix E. A large standarddeviation stands for much fluctuation.

Table 4.2: Standarddeviation of the waterlevel at both bogs

Number	Mean w.l. (m)	Standarddeviation	Classification
46	57.98	0.07	**
47	57.99	0.07	**
48	58.04	0.10	**
50	58.30	0.10	**
52	57.72	0.05	*
53	57.95	0.08	**
54	57.80	0.07	**
55	58.08	0.09	**
57A	58.04	0.14	***
57B	58.02	0.08	**
57C	57.90	0.06	**
57D	57.88	0.06	**
57E	57.79	0.05	*
68A	56.70	0.26	***
68B	56.33	0.19	***
68C	55.48	0.39	***
68D	55.10	0.15	***
103P	58.13	0.04	*
201A	99.86	0.06	**
201B	99.74	0.06	**
201C	99.07	0.06	**
201D	99.02	0.06	**
206A	103.83	0.09	**
206B	103.80	0.03	*
206C	103.71	0.05	*
206D	103.65	0.05	*
206E	103.61	0.08	**
206S	103.65	0.07	**
212A	106.22	0.04	*
212B	106.21	0.03	*
212C	106.19	0.03	*
212D	106.17	0.02	*
212E	106.14	0.02	*

The classification : standarddeviation 0- 5 cm -> *
standarddeviation 5-10 cm -> **
standarddeviation 10 cm -> ***

In general the standarddeviation at Clara bog is larger than at Raheenmore bog. The standarddeviation at the edge of the bogs are larger than in the middle of the bogs. These results are equal to the analyses of the graphs.

4.3 Equipotential images of the transects

4.3.1 Introduction

To get an impression of the direction of the ground water flow in the peat equipotential images of the transects at different dates are made. The dates chosen are dates with the first and last available data of the transects, the wettest date (28 February or 1 March) and the driest date (14 or 15 August) of 1990. The water flows perpendicular to the equipotential lines, from the highest equipotential line to the lowest. The piezometer filters are located at the images with marks, together with the values of the hydraulic heads. The images are made with the computer program Surfer; inter- and extrapolation faults are not out of the question and must be taken into account. The images are given in appendix F.

4.3.2 Phreatic tubes around the soak at Clara bog west (F2)

The first image is dated at 14 August 1990, because some of the phreatic tubes were not levelled before July 1990. At both dates the phreatic ground water from the soaksystem flowed towards the cutaway area, in south eastern direction. There is no contraction of the equipotential lines at this edge, but this can be expected since only phreatic ground water is measured. Data from wetter periods are necessary to get a better impression of the flow during the year. This information can be used in the catchment studies, which will be described by Lensen.

4.3.3 Transect A-A'(F3) and B-B'(F4) at Clara bog west

The general flow of this transect at all dates is towards the cutaway area, situated beyond piezometer station 63. In the driest period the flow is more in horizontal direction than in the wetter periods. Since a new piezometer at piezometer station 63 has been installed at 4.50 m depth, a certain contraction can be seen in the edge. By using Darcy's law (formula 5) this suggests a lower conductivity or a larger discharge flowing out of that area. One should expect that in this case compaction of the peat near the cutaway causes a lower conductivity of the peat. Piezometers at 6.00 m depth do not change the image a lot.

Transect B-B' shows also the same general flow at the different dates. In the middle of the bog, station 59, some of the ground water is flowing downwards, the rest is flowing more or less horizontal towards the facebank near station 68. The contraction of the equipotential lines at the facebank is at all dates clear. Image B+ (F7) shows the equipotential lines with the new installed sets in the cutaway. The contraction at the edge must be due to a lowering of the conductivity, if there was a larger flow the equipotential lines at the cutaway side would not be that far from each other.

4.3.4 Transect C-C' at Raheenmore bog (F5)

The general direction of the flow is equal at all dates. The mean flow is more or less horizontal towards the edge. There is some vertical flow in the middle of the bog. The contraction at the edge is obvious at all images. The adoption of piezometers at 6.00 m depth do not influence the images much, but the new installed deep piezometers do. The equipotential lines towards the middle of the bog are turned off towards the centre of the bog, which suggests more downward flow. How important the downward flow in quantitative sense is, can only be said when the conductivity of the deeper layers of the peat is known. Hopefully there are possibilities to measure the conductivity at by example 10 m depth.

4.3.5 North South transect at Raheenmore bog (F8)

Since the levelling data of 1987 available are not comparable with later levelling data, the first date used is 26 September 1990. The images of the two given dates do not differ much. In the middle of the bog water flow is downwards, at the edges towards the drains. At image +, the data of the boreholes are used as well. The boreholes are located at both edges of the bog and have filters beyond the peat in respectively bolder-clay, gravel and limestone. A detailed description of the boreholes is given by Henderson (1990). The only difference of this image and the image without the boreholes is a turn off of the equipotential lines at the northern end. But this turn off is beyond the peat in the bolderclay. This is a locked layer with very low permeability and the interaction between the ground water in the peat and the ground water beyond the peat is probably very poor.

4.4 Rainfall

4.4.1 Introduction

Since November 1989 rainfall has been measured at Clara, since December 1989 at Raheenmore. The rainfall data, measured with the tipping bucket and the syphon recorder, corrected to the handgauge measurements, are given in appendix B. In comparison with table 4.3 this year, with a year sum of 850 mm rainfall at Clara (table 4.4), was a relatively dry year.

Table 4.4:
a) Rainfall Clara bog 19 November 1989 - 19 November 1990
b) Rainfall Raheenmore bog 5 December 1989 - 19 November 1990

Nov	Dec	Jan	Feb	Mrch	Apr	May	June	July	Aug	Sep	Oct	Nov
3	51	111	179	29	35	31	87	58	82	22	113	49
	76	99	173	26	41	47	88	70	88	47	111	46

Table 4.3 : Monthly and annual averages of rainfall of weather stations of Ireland in the period 1951-1980

County-Station	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Carlow-Bagenalstown	101	73	67	59	69	55	63	71	90	99	69	105	941
Cavan-Bailieboro	105	70	70	62	69	69	60	66	94	99	96	106	1007
Clare-Ennis	112	76	75	65	67	67	76	90	108	105	120	131	1094
Cork-Airport	146	106	103	70	87	64	73	90	115	120	115	139	1229
Donegal-Glenties	164	108	107	81	86	92	109	115	145	115	166	172	1498
Dublin-Glasnevin	64	51	48	46	56	52	55	71	70	66	68	77	724
Galway-Letterfrack	175	113	124	83	92	99	105	121	155	161	172	177	1575
Kerry-Killarney	217	147	145	96	103	76	91	97	142	169	184	210	1678
Kildare-Lullymore	80	55	55	54	63	59	64	78	66	82	80	86	834
Kilkenny-Callan	97	70	64	55	67	49	64	70	84	83	86	101	890
Laois-Portlaoise	91	65	60	59	68	57	67	73	88	87	83	99	897
Leitrim-Dromahair	121	85	81	67	76	87	101	106	115	120	130	132	1223
Limerick-Ballyneety	97	68	62	62	62	62	78	89	92	90	101	110	972
Longford-Lanesboro	87	60	63	55	63	61	71	80	87	90	87	93	896
Louth-Dundalk	99	70	71	60	65	65	75	90	86	92	93	102	967
Mayo-Castlebar	163	107	112	67	93	100	103	124	140	153	166	181	1529
Meath-Kells	90	60	62	56	63	60	67	80	64	64	91	91	878
Monaghan-Clones	88	66	62	53	65	69	72	86	85	88	88	96	917
Offaly-Birr	76	52	53	55	62	52	68	76	79	80	77	86	816
Roscommon-Boyle	111	75	74	60	71	69	79	86	99	105	106	115	1049
Sligo-Markree Castle	115	77	77	65	74	80	87	96	108	113	122	125	1139
Tipperary-Cashel	101	76	66	61	70	56	65	82	91	89	90	105	951
Waterford-Dungarvan	127	97	92	70	78	55	67	86	103	105	106	126	1112
Westmeath-Athlone	85	61	60	56	64	60	73	87	88	87	86	96	901
Wexford-Foulkesmills	107	79	76	61	69	57	69	87	93	100	102	106	1005
Wicklow-Glen of Imaal	141	102	101	82	96	79	91	102	118	120	129	150	1309
Carlow-Bagenalstown													

4.4.2 Clara and Raheenmore compared with nearest weather stations

In comparison with Athlone and Birr, the nearest weather stations to Clara, the months of January, February, June and October 1990 were wetter and the other months much drier than Clara. According to table 4.2, the rainfall is spread equal over the months in Birr and Athlone. According to table 4.3 it is not in Clara and partly in Raheenmore. But are the data gathered at Birr and Athlone comparable with the data gathered at Clara and or Raheenmore?

To get an answer to this question daily data of Clara, Raheenmore, Birr and Mullingar (Athlone was not available) have been compared. The histograms of these data are given in appendix B3. The regression of these data was calculated for the period April 1990 until July 1990. This is a very short period, but it was the only period of which all data off all weather stations were available.

Table 4.4: Regression analysis daily rainfall data April - July 1990

	Correlation coefficients:	Linear Regression lines:
Clara-Mullingar	0.87	$x(c) = 0.21 + 0.75x(m)$
Clara-Birr	0.77	$x(c) = 0.16 + 0.99x(b)$
Raheen-Mullingar	0.89	$x(r) = 0.23 + 0.96x(m)$
Raheen-Birr	0.90	$x(r) = -0.25 + 1.53x(b)$
Raheen-Clara	0.92	$x(r) = 0.07 + 1.22x(c)$

N.B. $x(c)$ = amount of rainfall at Clara in mm.

The correlation between Clara and Birr is not very well. A probable cause could be the location of Birr near the Slieve Bloom mountains, which disturbes the rainfall pattern. According to table 4.4 the best weather station to compare Clara with is Mullingar, Raheenmore can be compared with Mullingar as well as Birr. If the annual data of all weather stations are known, it would be interesting to calculate the regression data again.

4.5 The plots at Clara bog east

4.5.1 Introduction

The eastern part of Clara bog has been drained by Bord na Mona in 1986. The drains cover the whole surface with a mutual distance of about 20 meters. These drains have been blocked with peat in 1989, to stop the drainage of this part of the bog. At a wet (A), medium (B) and dry (C) spot phreatic tubes have been installed to get an impression of the effect of blocking the drains and the shrinkage of the peat between the drains (Gloudemans, 1990).

The surface level of the bog has been measured five times this year: 12 December 1989, 22 January, 8 May, 25 September and 13 November 1990. The water levels have been measured fortnightly.

After one full year of monitoring, an first attempt to analyze the data is made. Graphs of the surface level and phreatic water level at the plots are given in appendix G.

4.5.2 Analyses of the graphs of the plots

If the graph shows a straight water level in a plot (type 1), the drains don't function any more. The water level in the peat is equal to the water level in the drains. If the graph shows a convex water level in a plot (type 2), the drains still function. Water flows from the peat to the drains, and the bog will loose water quickly. If the graph shows a concave water level (type 3), seepage occurs from the drains to the peat. This might occur in summer after a heavy shower, when peat is very dry. The rain will fall on the surface, runoff the surface into the drains, which won't drain because of the blockage and finally the water will seep into the peat. Plot A1 is shown in appendix G2, plot A2 in G5, plot A3 in G8, plot B1 in G13, plot B2 in G16, plot B3 in G19, plot C1 in G24, plot C2 in G27 and plot C2 in G30.

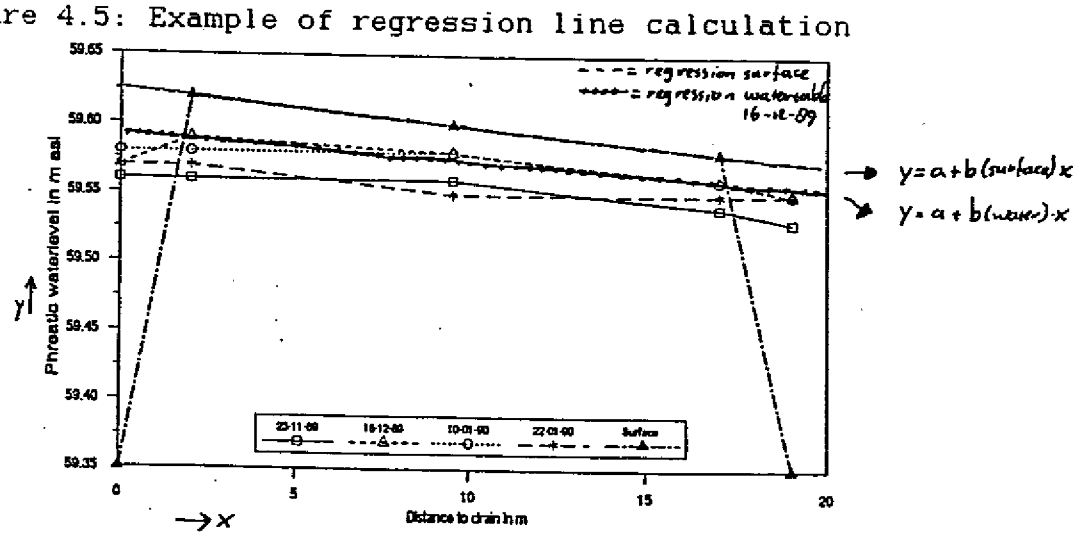
Plot A1 (tube 1-5):	Type 1 in winter, autumn and early spring
	Type 2 at 20 June 1990
	Type 3 in summer
Plot A2 (tube 6-10):	Type 1 in winter, autumn and early spring
	Type 2 in summer
	Type 3 in summer
Plot A3(tube 11-15):	Type 1 whole year
Plot B1(tube 16-20):	Type 1 (drain 20) whole year
	Type 2 (drain 16) whole year
Plot B2(tube 21-25):	Type 1 (drain 25) in winter and autumn
	Type 2 (drain 25) in spring and summer

Type 2 (drain 21) whole year
Plot B3(tube 26-30): Type 1 (drain 26) at 25 April 1990
Type 2 (drain 26) nearly whole year
Type 1 (drain 30) at 8 December 1989, 8 May 1990 and 14 August 1990
Type 2 (drain 30) the rest of the year
Type 3 (drain 30) in summer
Plot C1(tube 31-35): Type 1 winter and spring, 6 July and 28 August 1990
Type 2 May and 14 August 1990
Type 3 at 23 May, July, and September 1990,
Plot C2(tube 36-40): Type 1 (drain 36) at 19 July 1990
Type 2 nearly whole year
Type 3 (drain 36) at 25 April 1990 (drain 40) at 23 May 1990
Plot C3(tube 41-45): Type 2 whole year

According to this the drains in plot A are effectively blocked. The photographs of the drains (appendix G) show the drains all blocked and full of water, which is expected by previous reasoning. Drain 16, 21 and 26 of plot B (G22) are not effectively blocked. The photograph of drain 16 shows a drain with less blocks than at plot A (G11), the photographs of drain 21 and 26 show partly overgrown drains, which unfortunately still function. At plot C (G33) there are blocks but probably not enough to keep the water in the bog.

Another attempt to analyze the data of the plots has been done by calculating the regression lines of water table and the surface level of the three tubes in the middle of the plots. This is shown in figure 4.5.

Figure 4.5: Example of regression line calculation



In general a (regression-)line can be written as:

$$y = a + b(x) \tag{9}$$

In table 4.5 the coefficient a and b are given of the regression lines of the surface level of a period and the variation in coefficient b is given of the water level during a period. The variation of the coefficient b is given as the maximum and minimum coefficient b(water) of a period. The periods refer to the periods of measurements at the plots given in appendix G.

With this analyze, it might be possible to conclude following. If b(water) = b(surface) at a plot in a period, the slope of the surface = the slope of the watertable. In this case the shape of the water table is caused by the shape of the surface, not by drainage. This is not the case if drainage caused a change of shape of the surface. If b(water) = b(surface) there is influence of drainage.

Calculating the regression line between three points gives a certain error, because the best fitting straight line is calculated. When the three points are not situated in a straight line, the best fitting straight line can give a totally other figure than the original figure.

Table 4.5: Regression analyses plots Clara bog east

Plot	Period	b(surface)	b(water) variation	a(surf)
A1	1	-0.00267	-0.002 - -0.00133	59.63
A1	2	-0.002	-0.00133 - -0.00067	59.64
A1	3	-0.00267	-0.004 - -0.00107	59.65
A1	4	-0.00533	-0.004 - 0.00193	59.63
A1	5	-0.00467	-0.00002	59.62
A2	1	-2.0E-15	-4.0E-15 - 0.00067	59.49
A2	2	-0.00067	-0.00267 - -2.0E-15	59.53
A2	3	-0.00133	-0.00333 - -0.00133	59.53
A2	4	-0.00267	-0.002 - -0.0002	59.49
A2	5	-0.00267	-0.00266	59.50
A3	1	-0.00467	-0.00304 - -0.00213	59.23
A3	2	-0.004	-0.002 - -0.00067	59.22
A3	3	-0.00467	-0.006 - -0.002	59.25
A3	4	-0.00027	-0.00027 - 0.00047	59.21
A3	5	-0.002	-2.0E-15	59.21
B1	1	0.00733	0.00533 - 0.00667	59.07
B1	2	0.00467	0.00133 - 0.00533	59.18
B1	3	0.006	0.00533 - 0.0074	59.16
B1	4	0.00333	0.00467 - 0.00653	59.19
B1	5	0.00533	0.004	59.19
B2	1	-0.002	0.002 - 0.004	59.46
B2	2	-0.00333	-0.00533 - 0.00667	59.48
B2	3	-0.002	0.004 - 0.01002	59.47
B2	4	-2.0E-15	0.00333 - 0.00467	59.38
B2	5	-0.00067	0.00133	59.39
B3	1	-0.002	0.00067 - 0.00267	59.60
B3	2	-0.004	-0.00133 - 0.00104	59.55
B3	3	-0.00333	0.00072 - 0.00265	59.59
B3	4	0.002	0.00033 - 0.00133	59.44
B3	5	-2.0E-15	0.00067	59.49
C1	1	0.00267	0.00133 - 0.00467	59.17
C1	2	0.00267	0.00267 - 0.00467	59.17
C1	3	0.00333	0.00133 - 0.00467	59.11

C1	4	0.00267	0.00247 - 0.00413	59.05
C1	5	0.00533	0.00333	59.03
C2	1	0.00267	-0.00067 - 0.00267	59.49
C2	2	-0.00067	-0.005 - -0.002	59.52
C2	3	0	-0.00487 - 0.00133	59.51
C2	4	0.00133	-0.00213 - -0.00307	59.47
C2	5	0.00267	-0.00133	59.46
C3	1	-0.01067	-0.01067 - -0.00667	59.17
C3	2	-0.01067	-0.012 - -0.00867	59.17
C3	3	-0.00333	-0.01 - -0.00467	59.13
C3	4	-0.01067	-0.008 - -0.0044	59.14
C3	5	-0.01047	-0.01133	59.20

At plot A the direction coefficients (b) of the regression lines of the water table do not differ much from the direction coefficient of the regression lines of the surface level. The water does not flow in another direction than suspected by the shape of the surface level. At plot B they do. The figures of plot B in appendix G show the shape of the surface as a top of a mountain. This could point out to more desiccation at plot B, than at plot A which means more drainage. Plot C1 is comparable with plot A and plot C2 and C3 is comparable with plot B, regarding to table 4.2. But the figures of plot C in appendix G24 are more like plot B.

4.5.3 Shrinkage of the peat between the drains

The last column of table 4.5 gives the location coefficient, a of formula 9, of the regression lines of the surface level of the plots. These data give an indication of shrinkage and swelling of the plots. The plots were also installed to get an impression of the shrinkage of the peat between the drains (Gloudemans,1990).

It is obvious that at plot A the fluctuation is much smaller than at the other two plots. Plot B2, B3, C1 and C2 do not return to the same height as the year before. Only plot B1 recovers in height. But it seems that the surface level measured in the first period is a bit too low. This could be a fault.

Comparing this data with the figures of appendix G. the same conclusions can be made. Calculating regression lines is useful to get an impression of the shrinkage between the drains at Clara bog east.

4.6 Shrinkage and swelling of the peat

4.6.1 Introduction

The surface level of the bog varies during the different seasons. In wet periods the peat is swelling, the absolute levels will be higher. In dry periods the peat is shrinking. To get an idea about the amount of shrinkage and swelling small pieces of timber were installed around the deepest piezometers of the transects under the root zone (chapter 2). Every month the distance of the top of the piezometer to the wood has been measured.

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4.6.2 Analyses of the shrinkage and swelling figures

The figures 4.1 - 4.3 show the fluctuations of the surface of the peat from July 1990 until November 1990. At Clara bog west the maximum fluctuation appears, 5 cm. Probably the fluctuation will be larger over a year, because the measurements started in summer and ended in autumn. The most central stations measured at Clara bog, 59 and 61 have less fluctuation. The wettest plot at Clara bog east(A) fluctuates the most, the driest plot (C) less. This means the driest plot doesn't swell as much as it should. That is what was expected, because the driest plot is disturbed the most. At Raheenmore bog the effect of shrinkage and swelling is not as obvious. This could mean this bog is more disturbed than Clara bog.....
This survey should be continued during the project.

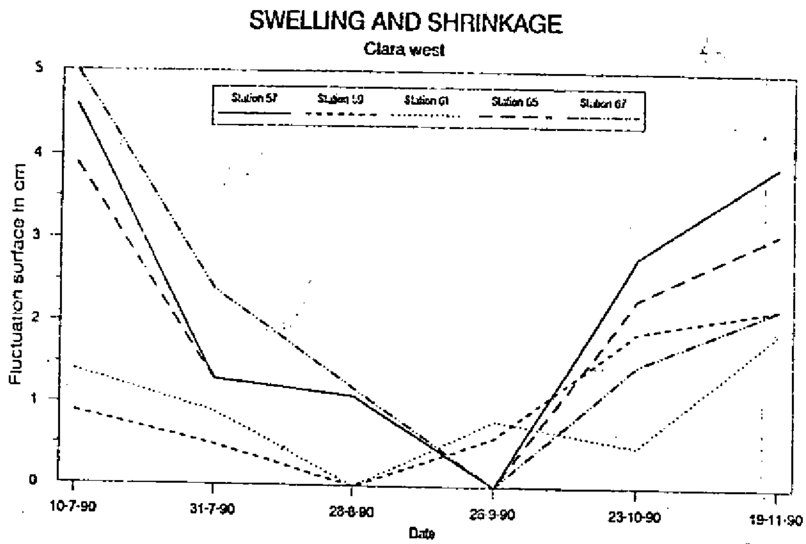

Figure 4.1 Shrinkage and swelling at Clara bog west

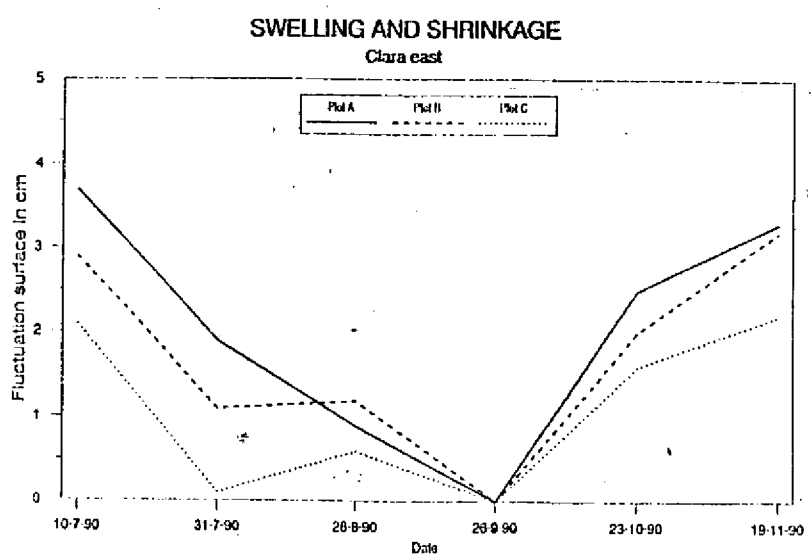

Figure 4.2 Shrinkage and swelling at Clara bog

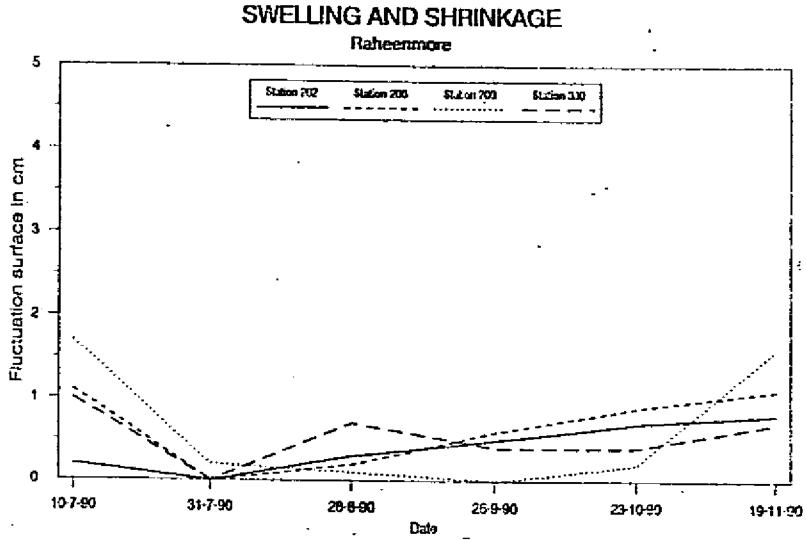

Figure 4.3 Shrinkage and swelling at Raheenmore bog

4.7 Raheenmore Boundary Survey

4.7.1 Introduction

At Raheenmore bog the first attempt to find the catchment boundary has been done at the beginning of this project. There has been an attempt to map the topographic boundary. The following survey has been carried out to see if this topographic boundary is equal to the hydrologic boundary.

At four different spots in the topographic boundary (appendix A2) transects of three phreatic tubes have been installed (appendix A4). At each transect one phreatic tube has been installed inside the catchment, one phreatic tube on the topographic boundary and one outside the catchment. These phreatic tubes have been monitored from July 1990 and levelled in September 1990. The graphics of these data are given in appendix H.

4.7.2 Analyses of the data

Figure RBS 1 (H2) shows the topographic boundary not equal to the hydrologic boundary. The surface level of RBS1B (on the topo-graphic boundary) is definitely higher than RBS1A (inside the catchment area) and RBS1C (outside the catchment area).

Figure RBS 2 (H3) shows that this spot is not situated at the boundary at all. Therefore the boundary must be more in the bog, before RBS2A.

Figure RBS 3 (H4) shows that the boundary can differ in time. At 29 August 1990, the topographic boundary was equal to the hydrologic boundary. The other data the hydrologic boundary was more inside the bog. The boundary varies in time.

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Figure RBS 4 (H5) shows that the topographic boundary can be equal to the hydrologic boundary, also at different dates.

To find the catchment area is not only a matter of levelling the surface. If an accurate catchment area is needed, this kind of survey should be done and succeeded. On the other hand, when the boundary is not constant in time, it is very difficult to know what the catchment is at a certain period. The catchment boundary is still a mystery.

4.8 Facebank research at Clara bog west

4.8.1 Introduction

What is the effect of the cutting of the turf at the facebank at the drainage of the bog? What will happen when the cutting of the turf at the facebanks stops? To answer these questions information is needed of permeability, equipotential patrons, storage coefficient, particle size distribution, retention etcetera of an old and a fresh facebank. Therefore a new survey has started at Clara bog west (situation explained in chapter 3).

4.8.2 The permeability of the facebanks

The permeability has been measured with the piezometer method, the tube method and the inversed augerhole method (chapter 3). The constant head method (Flynn, 1990) still has to be done. Results are given in table 4.6.

Table 4.6: Permeability in m/d of facebanks at Clara bog west

	OLD FACEBANK				FRESH FACEBANK	
	74	75	76	77	78	68
Inversed auger-hole method	0.71		0.20			0.06
Tube method						
60 cm depth	0.007		0.0008			0.00004
120 cm depth	0.0002		0.00005			0.000002
Piezometer-method						
150 cm depth			0.004	0.04	0.05	0.002
300 cm depth	0.0007	0.002	0.0007	0.004	0.01	0.001

According to these measurements, the horizontal and vertical conductivity of the old bank is larger than the conductivity of the fresh bank. If there are no other factors which influence conductivity, this could mean the drainage of the bog is getting worse after stopping the cutting, because the peat is more permeable when it is dried out. An succeeding survey at this subject is necessary. The measurements are taken during summer, the situation could be different in winter. The constant head method could give other, maybe better, results (Flynn, 1990).

4.8.3 Retention of the facebanks

Samples have been taken from both banks to survey the storage coefficient, retention, particle size distribution and density of the peat. The samples have been taken up to 2.00 m depth. At the old bank the layering of the peat was obvious. The problems described in chapter 3 were the reason why no results came out of this survey. This survey should be repeated.

4.8.4 Equipotential images of the facebanks

The equipotential patterns of the facebanks at 11 September 1990 and 19 November 1990 are given in appendix F11 and F12. Near to the facebank, the equipotential lines are plane, nearly horizontal, at the new facebank and still sloping at the old facebank. This doesn't change when the water table has risen about 30 cm. Together with the higher conductivity at the old bank, this should suggest the old bank is draining more than the fresh bank. If this is the situation, the bog won't be saved by stopping the turfcutting. All turfbanks will become older = more permeable = more drainage. There is no proof of this yet, succeeding survey is necessary to proof it.

4.9 The conductivity of the peat at 6.00 m depth

The conductivity has been measured with the piezometer method (chapter 2) at the D and E piezometers in Clara bog west and Raheenmore bog. The results are given in table 4.7 and 4.8 together with the conductivity measurements of other depths (van Gerven, 1990).

Table 4.7: Conductivity at Clara and Raheenmore bog (rising head)

Filterdepth / Piezometer station	80	110	150	300	450	600	840
57			0.01	0.2	0.4	0.04	
59	0.04	0.02	0.01	0.002	0.003	0.001	
61			0.01	0.03	0.03	0.001	
63			0.03	0.008	0.003		
65			0.09	0.007	0.001	0.001	
67			0.009	0.009	0.02	0.01	
68			0.004	0.003	0.002		
70			0.2	0.003	0.02	0.001	0.00
Filterdepth / Piezometer station	**80**	**110**	**150**	**300**	**450**	**600**	**660**
202	0.06	0.02	0.08	0.001	0.004		
204	0.20	0.07	0.007	0.001	0.03	0.02	
206	0.003	0.004	0.01	0.08	0.02	0.02	0.04
209	0.10	0.2	0.03	0.2	0.02	0.04	
210						0.03	
211						0.06	
212			0.03	0.1	0.02	0.04	

The horizontal conductivity measured at 4.50 or 6.00 m depth does not vary much from the other measurements. The permeability is reducing in depth, but regularly. It could be interesting to measure the horizontal conductivity at the deeper installed F piezometers.

CHAPTER 5: DATA MANAGEMENT

5.1 Introduction

Gathering data is of no use if no one is able to know what data are available, to retrieve the data and to use the data for further analyses. Good organized data management is a must. The computer program Dbase III+ can be a great help to store the data, but a certain data structure is needed first.

5.2 The directory structure

All data are related to the study sides Clara bog, Raheenmore bog or the surroundings of these study sides. The data of the surroundings are the meteorological data of Birr and Mullingar. The data of Clara bog and Raheenmore bog can be subdivided in general data (geology, peatdepth, humification, acrotelm/catotelm, etcetera), hydrology data and data of soil physics (conductivity, retention, pore size distribution etcetera). General data and data of soil physics are all fixed data. Hydrology data can be subdivided in data gathered with tubes, rainfall data, evapo(transpi)ration data, discharge data and ground water data (from the ground water recorder).

The following directory tree is made regarding to this structure. The info directories contain information about the division of the files at that tree branch.

```
HYDRO─┬─INFO
      ├─SURROUND─┬─INFO
      │          ├─BIRR─────┬─RAINFALL
      │          │          └─EVAPOTRA
      │          └─MULINGAR─┬─RAINFALL
      │                     └─EVAPOTRA
      ├─CLARA────┬─INFO
      │          ├─GENERAL
      │          ├─HYDROLOG─┬─TUBES
      │          │          ├─RAINFALL
      │          │          ├─EVAPOTRA
      │          │          ├─DISCHARGE
      │          │          └─GRWATER
      │          └─SOILPHYS
      └─RAHEEN───┬─INFO
                 ├─GENERAL
                 ├─HYDROLOG─┬─TUBES
                 │          ├─RAINFALL
                 │          ├─EVAPOTRA
                 │          ├─DISCHARGE
                 │          └─GRWATER
                 └─SOILPHYS
```

5.3 The file structure

Hydrology data are related to a specific area or a specific spot. An area as well as a spot can be described by coordinates. A catchment area can be situated by several X, Y coordinates, a spot by one X, Y, Z coordinate. The piezometers installed at the study sides can all be located at the bog with X and Y coordinates, which do not change in time. These are **fixed** data, which do not change in time. By shrinkage and swelling of the bog the Z coordinate, the top of the tube above sea level, changes during the year. While these changes are measured periodic, Z coordinates are **period** data. Period data change periodic. Water tables and hydraulic heads are measured every fortnight and called **monitoring** data. Ground water recorders, rainfall recorders and v-notch recorders gather information continuously, this are **continuous** data. All different types of data, described above, are stored in different files.

The file structure can be retrieved in the file name. All files, except the files stored in sub-sub directory HYDROLOG which start with the following character, start with the character H from HYDRO. The second character stands for the study sides: S from SURROUND, C from CLARA and R from RAHEEN. The following character stands for a) the subarea or the transect:

Surroundings:	Clara:	Raheenmore:
B from BIRR	A from transect A-A'	C from transect C-C'
M from MULLINGAR	B from transect B-B'	N from N-S transect
	F from facebanks	B from boundary survey
	P from plot A,B;C	L from Lagzone
	S from soak	

or b) the sub-sub directory

GEN from GENERAL
INF from INFO
SOIL from SOILPHYS

In previous case a) the following combination of characters stands for the sub-sub directory:

RAIN from RAINFALL	TUB from TUBES
EVAP from EVAPOTRA	DIS from DISCHARGE
GRW from GRWATER	

The following character stands for the data type:

C from continuous data
F from fixed data
M from monitoring data
P from period data

The last character contains a period or a version number. To conclude an example: CATUBF01.DBF contains Fixed data tubes transect A-A' Clara version 1.

LITERATUR

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11 Vakgroep Hydraulica, 1987. Veldpracticum Hydrologie. Agricultural University Wageningen.

12 Werkgroep Herziening Cultuurtechnisch Vademecum, 1988. Cultuurtechnisch vademecum. Cultuurtechnische vereniging, Utrecht.

APPENDIX A

Maps and situation sketches of the study sides.

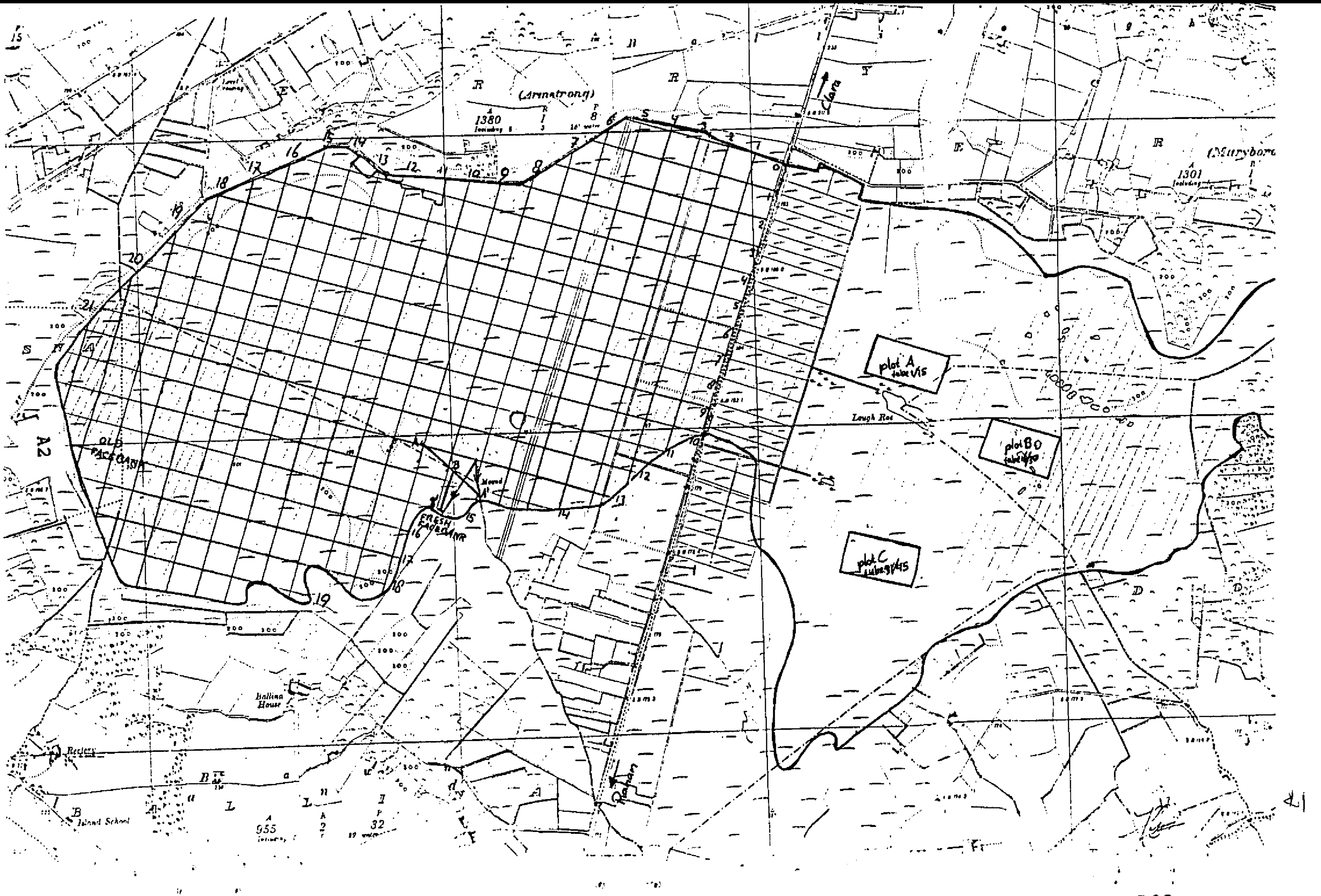
A2 Map of Clara bog

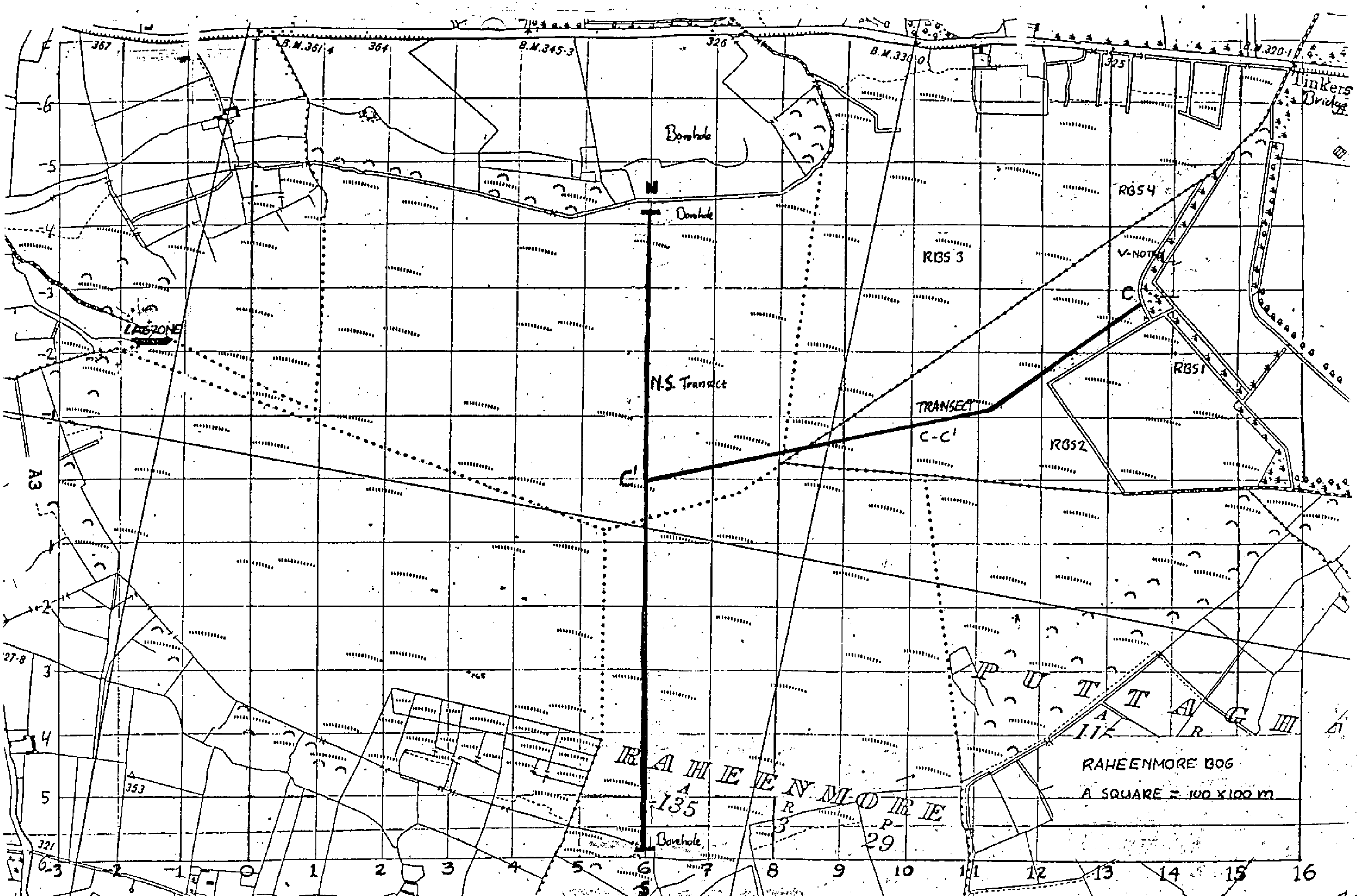
A3 Map of Raheenmore bog

A4 Positioning tubes of Clara bog west and Raheenmore bog

A5 Situation sketches of the old and fresh bank at Clara bog

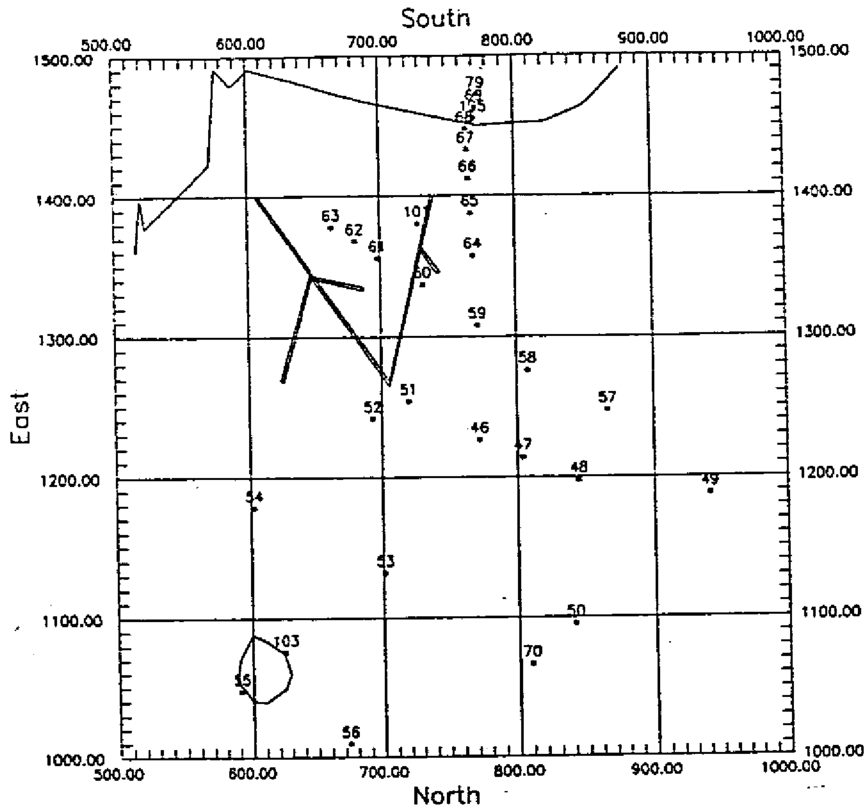
A6 Situation sketch of the phreatic grid at Raheenmore bog


(Armstrong)
1380
(Murybore
1301
Clara
plot A
plot B
plot C
Lough Roe
OLD FACE BANK
FRESH FACE BANK
A2
Mound
Ballina House
Rectory
Island School
955
32

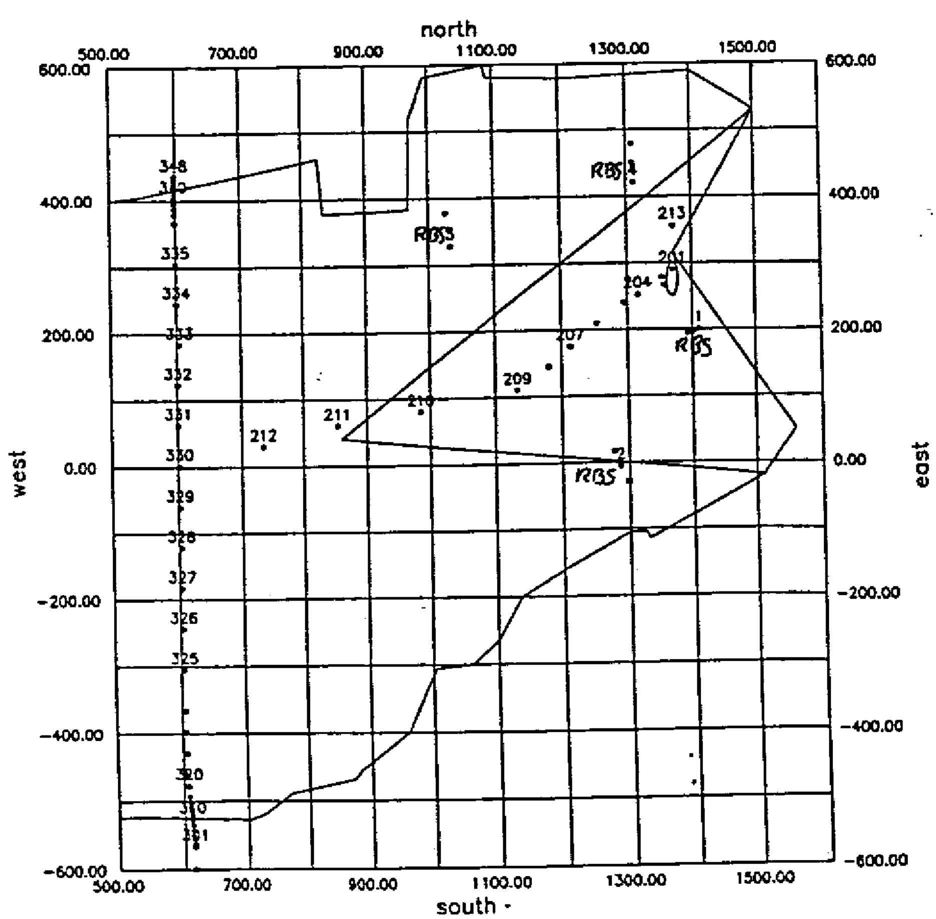


RAHEENMORE BOG
A SQUARE = 100 X 100 m
Tinkers Bridge
Borehole
N
S
N.S. Transect
TRANSECT
C-C'
C
C'
RBS 1
RBS 2
RBS 3
RBS 4
V-NOTCH
LAGZONE
PUTTAGH
RAHEENMORE
B.M. 361·4
B.M. 345·3
B.M. 330·0
B.M. 320·1
367
364
326
325
353
321
A3

Positioning tubes Clara West



Positioning tubes Raheenmore



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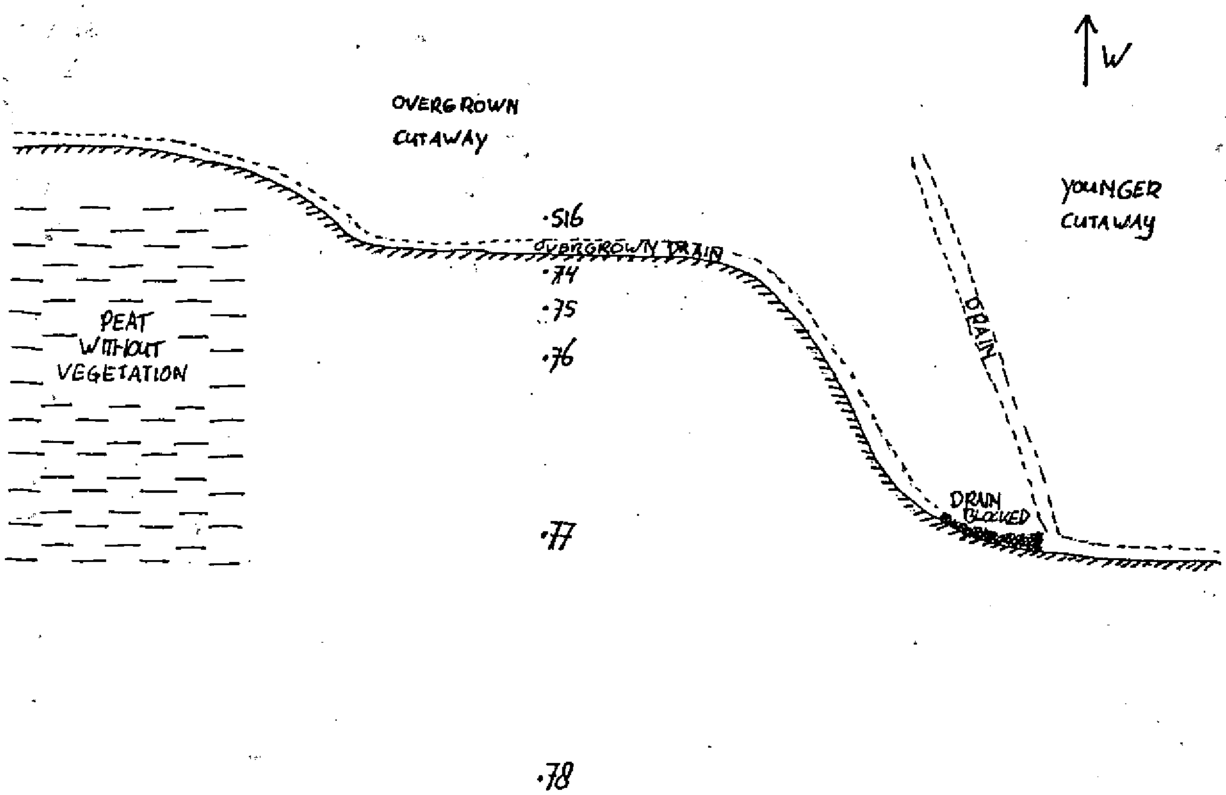
Situation sketch Old facebank Clara West

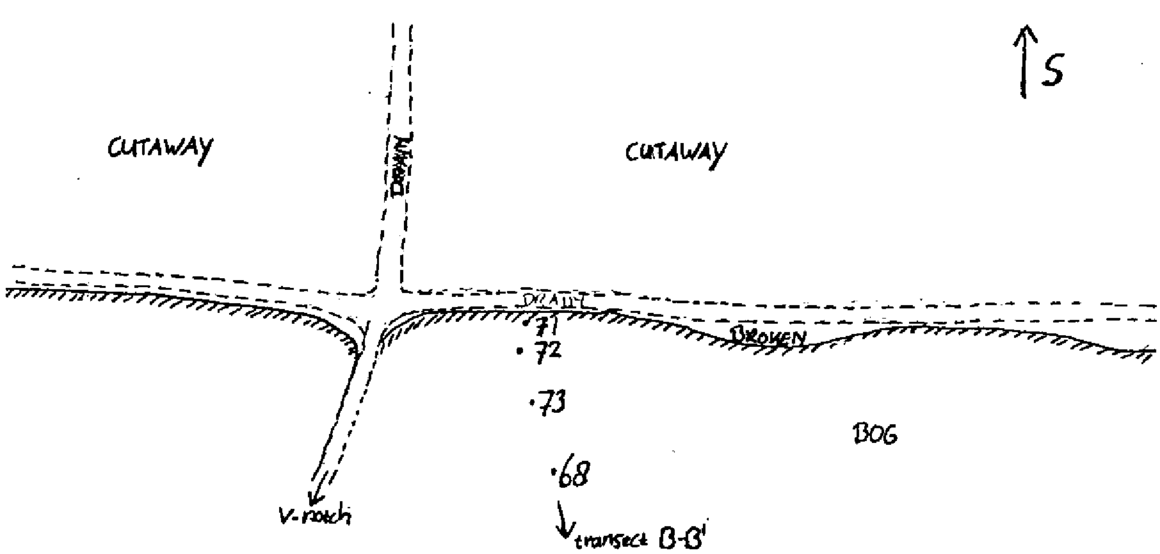


Distances:

74 - bank	= 0,50 m
74 - 75	= 1,00 m
75 - 76	= 1,50 m
76 - 77	= 5,00 m
77 - 78	= 7,00 m

All stations: A = phreatic
B = 1,50 m filterdepth - surface
C = 3,00 m filterdepth - surface

Situation sketch Fresh Facebank Clara West



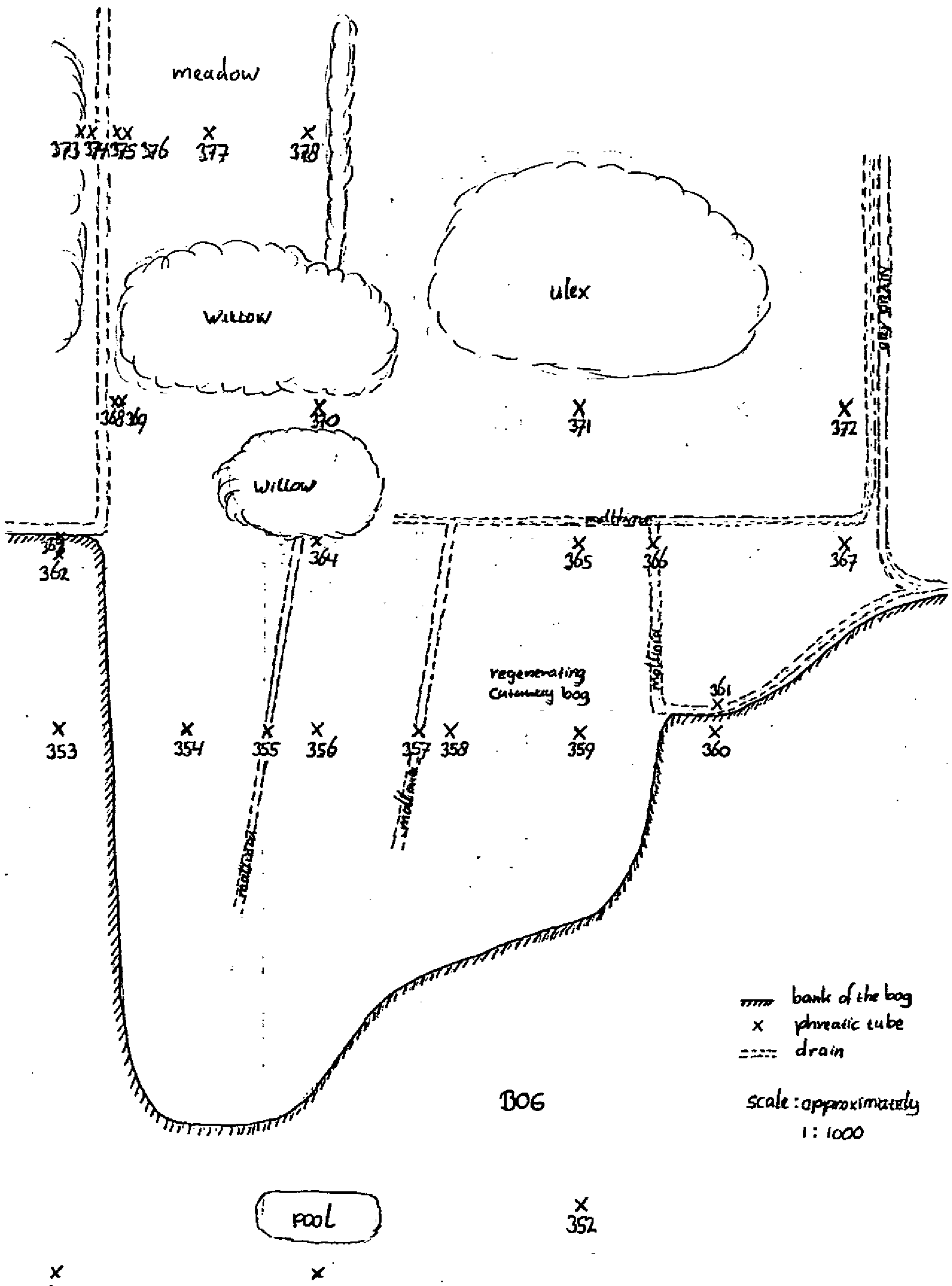
Distances:

71 - bank	= 0,50 m
71 - 72	= 1,00 m
72 - 73	= 1,50 m
73 - 68	= 3,00 m

71, 72, 73 A, B and C

A5 68 A, B, C and D

Situation sketch Raheenmore lagzone



APPENDIX B

Daily rainfall measured at the study sides

Table 1: Daily rainfall at Clara bog in mm, measured with the Tipping bucket rainfall recorder

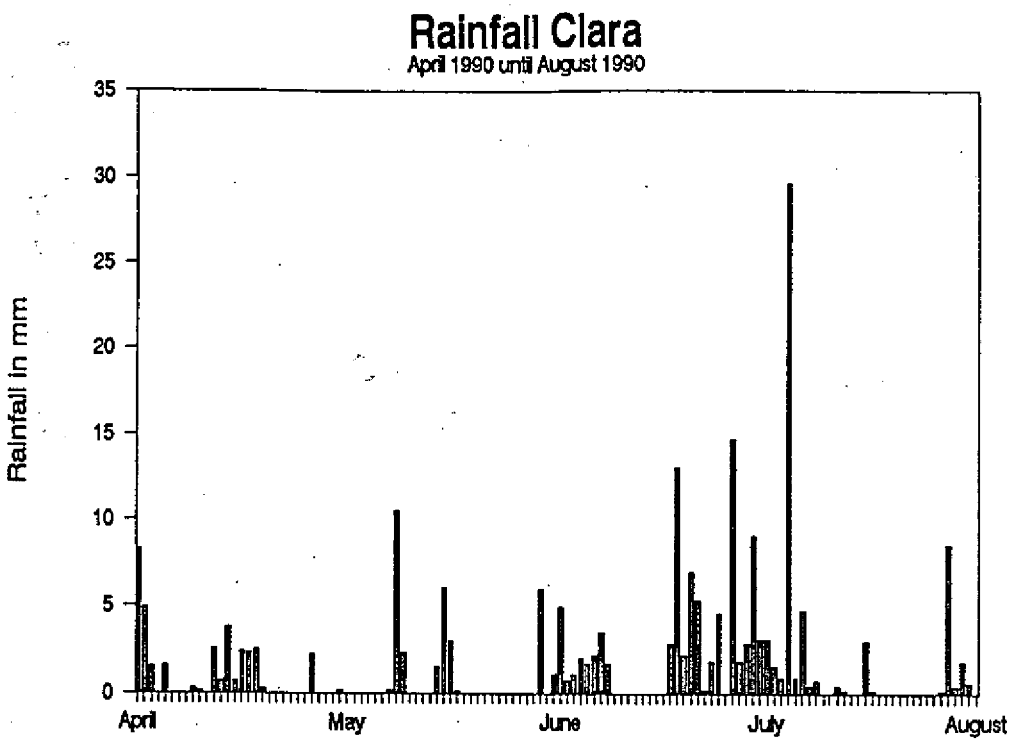
	1989		1990										
Day	Nov	Dec	Jan	Feb	Mrc	Apr	May	June	July	Aug	Sep	Oct	Nov
1		0.0	2.0	–	5.2	8.3	0.0	5.0	3.1	0.0	0.0	1.9	0.8
2		0.2	4.6	(22.5)	0.0	4.9	0.0	0.7	1.6	0.0	0.0	13.9	0.2
3		0.2	1.6	–	0.0	1.5	0.0	1.1	0.9	0.0	0.4	10.5	0.2
4		0.0	0.0	–	6.0	0.0	0.0	2.0	29.7	0.0	1.0	1.9	0.2
5		0.0	0.2	–	0.2	1.6	0.0	1.7	0.9	0.0	3.6	12.2	0.0
6		0.0	1.9	–	0.2	0.0	0.0	2.2	4.8	0.0	1.4	9.8	0.0
7		0.0	11.0	(52.7)	0.4	0.0	0.2	3.5	0.4	0.0	0.4	0.2	0.0
8		0.0	0.5	–	1.2	0.0	10.5	1.7	0.7	0.4	0.0	0.2	0.0
9		0.0	0.0	–	0.4	0.3	2.3	0.0	0.0	2.4	0.2	0.7	0.4
10		0.0	2.8	–	1.2	0.2	0.0	0.0	0.0	0.2	0.0	7.9	0.8
11	–	2.9	0.5	–	1.4	0.0	0.0	0.0	0.4	1.6	0.0	14.2	1.2
12	–	5.0	0.2	–	0.6	2.6	0.0	0.0	0.2	1.2	0.0	0.0	7.0
13	–	16.2	0.2	–	3.1	0.7	0.0	0.0	0.0	0.0	0.2	0.0	4.7
14	–	0.6	0.8	(36.0)	0.3	3.8	1.5	0.0	0.0	7.6	0.0	2.2	0.2
15	–	0.0	2.6	–	0.2	0.7	6.1	0.0	3.0	5.0	0.0	26.6	0.6
16	–	8.6	6.0	–	0.0	2.4	3.0	0.0	0.2	1.4	0.6	1.8	11.5
17	–	0.2	2.0	–	0.0	2.3	0.2	2.9	0.0	6.0	1.2	15.8	16.9
18	(3.2)	0.0	1.8	–	0.2	2.5	0.0	13.1	0.0	3.2	5.6	1.0	1.0
19	0.6	0.2	8.0	–	0.0	0.3	0.0	2.2	0.0	10.4	1.4	0.0	3.5
20	2.0	0.8	0.0	–	0.2	0.0	0.0	7.0	0.0	1.0	0.4	1.2	
21	0.6	3.0	0.6	(31.6)	1.4	0.0	0.0	5.3	0.0	0.0	0.6	1.0	
22	0.0	0.0	4.0	0.0	0.6	0.0	0.0	0.2	0.0	0.4	4.2	0.0	
23	0.0	4.2	20.2	2.0	1.7	0.0	0.0	1.8	0.0	18.7	0.2	0.8	
24	0.0	7.2	7.9	10.1	3.9	0.0	0.0	4.6	0.0	3.7	0.2	0.0	
25	0.2	1.2	10.0	7.9	0.2	0.0	0.0	0.0	0.0	0.0	0.2	1.0	
26	0.0	0.0	3.9	8.8	0.0	2.2	0.0	14.7	0.2	3.9	0.2	1.4	
27	0.0	0.2	0.8	4.1	0.4	0.0	0.0	1.8	8.6	3.7	0.2	7.8	
28	0.0	0.2	2.8	14.3	0.0	0.0	0.0	2.9	0.4	0.0	0.0	2.4	
29	0.0	0.2	3.0		0.0	0.0	6.0	9.1	1.8	5.6	0.0	1.4	
30	0.0	0.0	–		0.0	0.2	0.0	3.1	0.6	2.4	0.0	4.4	
31		–	–		0.0		1.1		0.0	3.2		2.0	

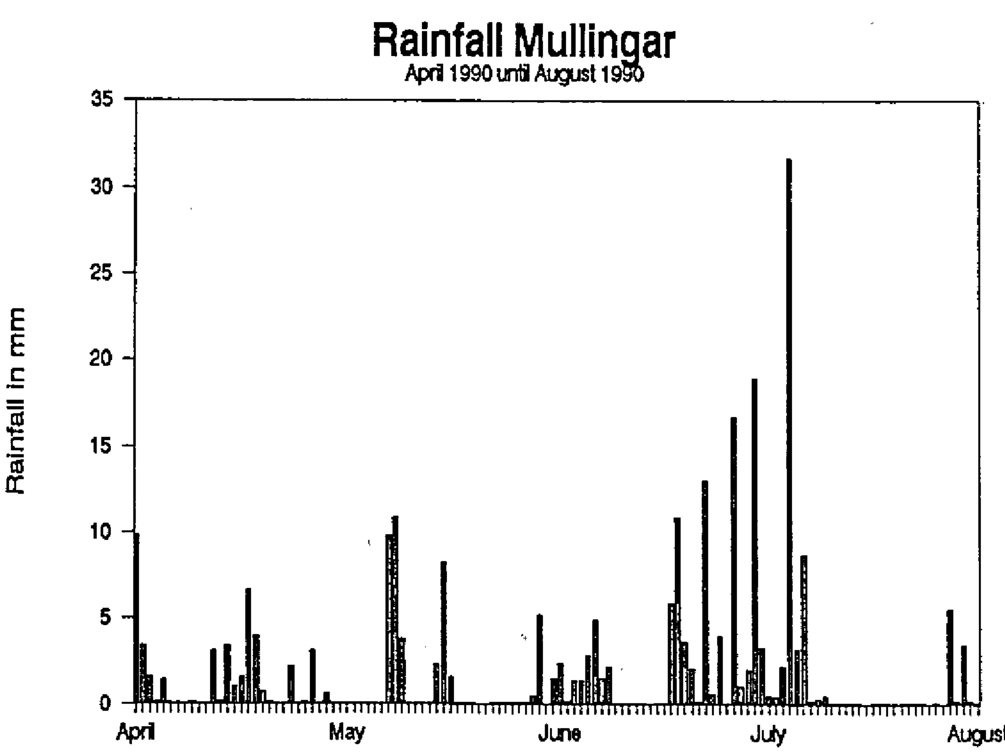
– : Rainfall is not registered that day by the recorder
(....): Handgauge measurements for the missing days

Table 2: Daily rainfall at Raheenmore bog in mm, measured with the Syphonrecorder

	1989	1990										
Day	Dec	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct	Nov
1		–	–	(47.9)	12.9	0.2	4.5	–	0.0	0.0	2.5	0.3
2		–	–	–	4.3	0.0	0.0	–	0.0	0.0	–	0.2
3		–	–	–	1.8	0.0	3.5	–	0.0	0.6	(27.6)	0.3
4		(13.7)	–	–	0.2	0.0	1.3	–	0.0	1.1	1.9	0.2
5	–	–	–	–	3.1	0.0	2.7	(62.9)	0.0	1.9	13.1	0.2
6	–	–	–	–	0.1	0.0	5.2	5.6	0.0	0.6	6.7	0.5
7	–	–	–	(6.9)	0.1	3.4	3.2	1.1	0.0	0.0	0.0	0.0
8	–	–	(85.4)	–	0.6	3.6	2.3	1.1	0.0	0.0	0.0	0.0
9	–	–	–	–	0.4	2.7	0.0	1.1	1.8	0.0	0.3	0.0
10	–	–	–	–	0.1	0.0	0.0	0.0	0.0	0.0	–	0.8
11	(0.1)	–	–	–	0.0	0.0	0.0	0.0	0.5	0.0	–	7.5
12	–	–	–	–	0.8	0.0	0.0	0.0	2.3	0.0	–	0.2
13	–	(18.8)	–	–	6.0	0.1	0.0	0.0	0.3	0.0	–	4.3
14	–	–	–	–	3.2	3.1	0.0	0.0	1.7	0.0	–	0.3
15	–	–	(25.4)	–	1.0	9.0	0.0	0.0	13.7	0.0	–	0.7
16	–	–	–	(5.1)	1.3	4.8	0.0	0.0	1.9	0.7	–	13.3
17	–	–	–	–	4.0	0.0	4.8	0.0	4.9	0.4	(69.1)	14.3
18	–	–	–	–	3.1	0.0	6.7	0.0	2.3	5.7	0.7	0.2
19	(51.0)	–	–	–	0.2	0.0	1.4	0.0	10.9	1.5	0.2	3.9
20	–	–	–	–	0.0	0.0	7.6	0.0	0.9	0.7	0.7	0.2
21	–	(21.4)	–	–	0.0	0.0	1.3	0.0	0.0	1.3	0.0	
22	–	–	(19.6)	(1.2)	0.0	0.0	0.8	0.0	0.0	3.3	0.0	
23	–	–	–	3.1	0.0	0.0	1.2	0.0	–	0.0	4.8	
24	–	–	–	2.9	0.0	0.0	4.4	0.0	–	0.0	0.0	
25	–	–	–	0.2	0.0	0.0	0.0	0.0	–	0.5	4.2	
26	(19.5)	–	–	0.3	0.6	0.0	9.7	0.0	–	0.1	0.2	
27	–	(42.9)	–	0.1	0.0	0.0	0.8	18.6	–	0.0	9.0	
28	–	–	–	0.1	0.0	0.0	16.1	0.7	–	0.0	2.3	
29	–	–		0.0	0.0	19.6	–	5.7	(56.8)	1.2	5.0	
30	–	–		0.0	0.0	0.0	–	0.2	4.15	0.3	1.8	
31	–	(12.0)		0.1		0.2		0.0	5.09		1.0	

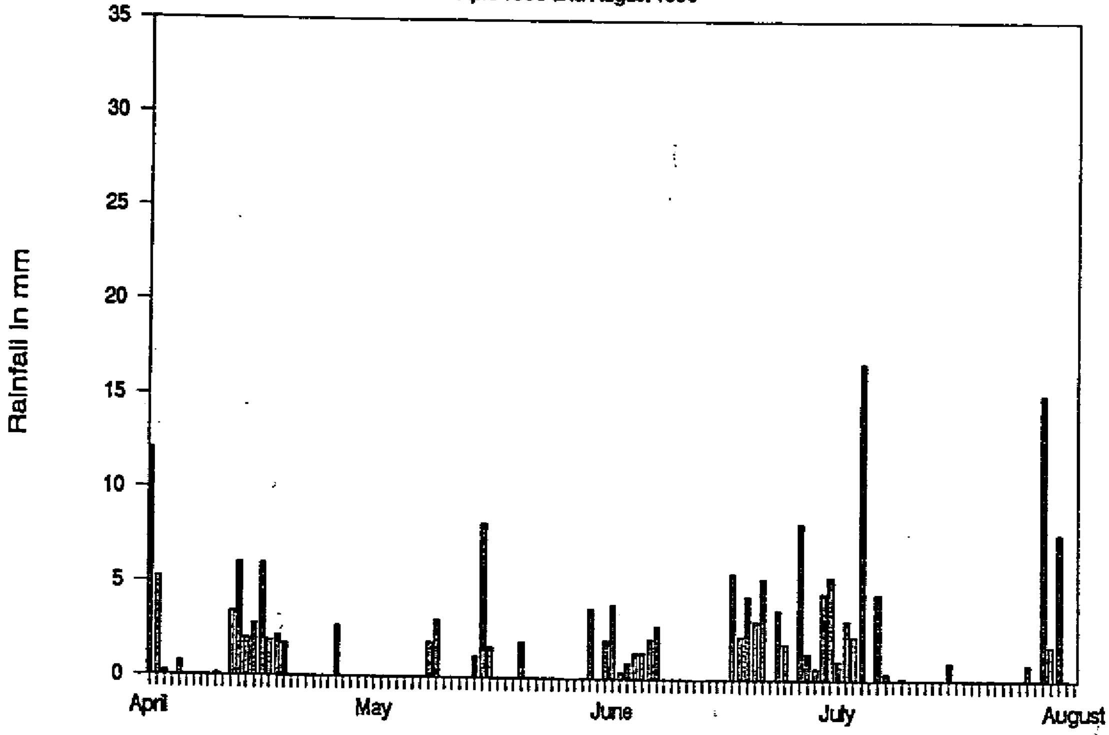
– : Rainfall is not registered that day by the recorder
(....): Handgauge measurements for the missing days


Rainfall Clara
April 1990 until August 1990
Rainfall in mm
35
30
25
20
15
10
5
0
April
May
June
July
August


Rainfall Mullingar
April 1990 until August 1990
Rainfall in mm
35
30
25
20
15
10
5
0
April
May
June
July
August

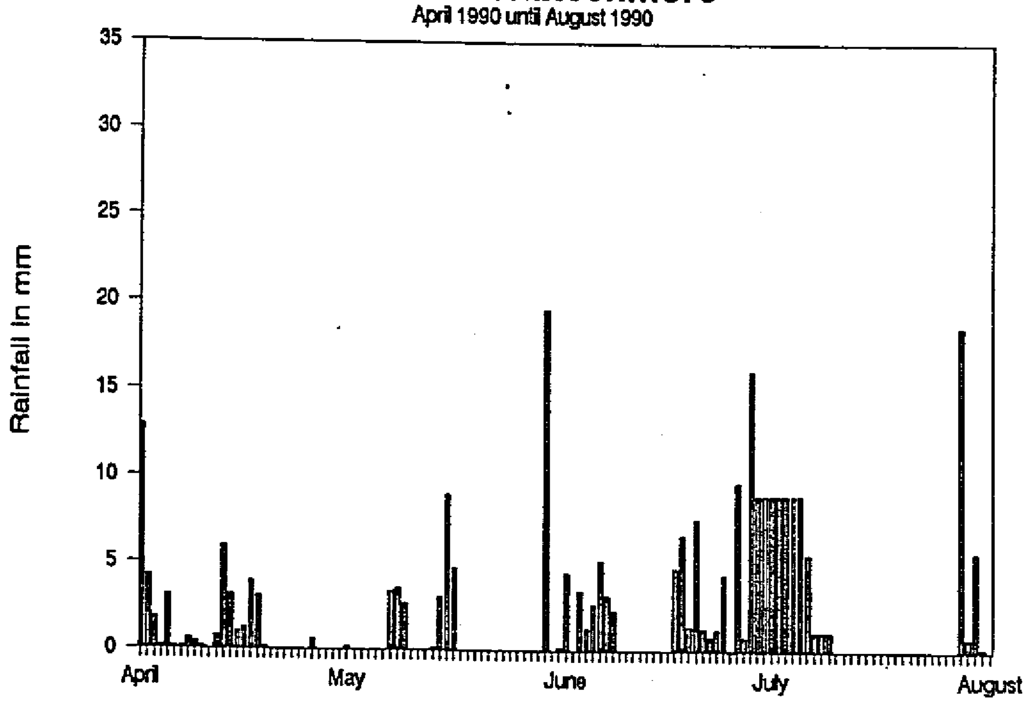
Rainfall Birr

April 1990 until August 1990



Rainfall Raheenmore

April 1990 until August 1990



APPENDIX C

THE MEASURING NETWORK

November 1990

The contents of the transect at Clara Bog and Raheenmore Bog

Filterdepth in m from top tube to bottom filter.

Filterlength phreatic (phr) = 1.00 m filter
Filterlength phreatic (phr+)= 1.50 m filter
Filterlength piezometer = 0.15 m filter
Filterlength piezometer S = 0.10 m filter

Clara East:

All tubes are phreatic with a filterlength of 1.00 m.

Plot A: tubes 1-15 AR = temporally benchmark
Plot B: tubes 16-30 BR = temporally benchmark
Plot C: tubes 31-45 CR = temporally benchmark

Clara West:

Soak

NUMBER	A	B	C	D	E	F	S
46	phr					7.39	
47	phr					9.75	
48	phr					8.53	
49	phr						
50	phr					7.73	
51	phr					10.97	
52	phr					9.75	
53	phr					10.25	
54	phr					8.84	
55	phr					13.57	
56	phr					9.54	
70	phr		3.25	4.74	6.24		9.22

Transect A-A'

NUMBER	A	B	C	D	E	F	S
57	phr		3.19	4.68	5.97		
58	phr						
59	phr		3.23	4.73	6.24		
60	phr						
61	phr		3.25	4.75	6.24		
62	phr						
63	phr		3.22	4.75			

Transect B-B'

NUMBER	A	B	C	D	E	F	S
59	phr		3.23	4.73	6.24		
64	phr						
65	phr		3.22	4.73	5.89		
66	phr						
67	phr		3.21	4.66	5.33		
68	phr	1.71	3.17	4.16			
69	phr					3.99	
79	phr					3.17	

Facebank

NUMBER	A	B	C	D	E	F	S
71	phr	1.75	3.25				
72	phr	1.75	3.25				
73	phr	1.75	3.25				
74	phr+	1.75	3.25				
75	phr	1.75	3.25				
76	phr	1.75	3.25				
77	phr	1.75	3.25				
78	phr	1.75	3.25				

Raheenmore:

Transect C-C'

NUMBER	A	B	C	D	E	F	S
201	phr	1.75	3.22	3.82			
202	phr		3.22	4.75			
203	phr						
204	phr		3.22	4.74	6.22		
205	phr						
206	phr		3.23	4.72	6.23		6.85
207	phr						
208	phr						
209	phr		3.24	4.75	6.24	13.96	
210	phr		3.23	4.75	6.23		
211	phr		3.18	4.69	6.22	14.64	
212	phr		3.24	4.75	6.25		
213							5.60

Raheenmore Boundary Survey

All phreatic tubes: nr RBS1 (A,B,C) - RBS4 (A,B,C)

<u>Raheenmore Lagzone</u>

All phreatic tubes: nr 350 - 378; nr 360 and 363 with 1.50 m filterlength.

<u>North-South transect</u>

NUMBER	GD	A	B	C	D	E	F	GW
301	stick							
303		1.95	2.74					phr
304								phr
305		1.20	1.68	2.42				phr
306	phr							
307	phr	1.20	1.69	2.43				phr
308	phr							
309	phr							
310	phr	1.19	1.95	2.80				
311	phr							
312	phr							
313	phr	1.20	2.20	2.95	3.95			phr
314								phr
315	phr	1.19	2.20	3.20	4.35			phr
316	phr							
317	phr	1.19	2.20	3.60	4.94			phr
318	phr							
319	phr							
320	phr							
321	phr	1.20	2.19	3.69	5.18	7.78		
322	phr							
323	phr							
324	phr	1.20	2.00	3.50	5.00		9.71	
325	phr							
326	phr							
327	phr	1.20	2.20	3.70	5.20		13.84	
328	phr							
329	phr							
330	phr	1.19	2.18	3.68	5.19	12.26	12.75	
331	phr							
332	phr							
333	phr	1.18	2.19	3.69	5.20		15.74	
334	phr							
335	phr							
336	phr	1.20	2.20	3.68	5.17	5.22		
337	phr							
338	phr							
339	phr							
340	phr	1.20	2.09	2.84	3.94			
341	phr							
342	phr	1.20	2.19	3.15				phr
343	phr							
344		1.20	1.99	2.94				phr
345								phr
346		1.70	2.24					phr
348	stick							

APPENDIX D

Measuring formulars of conductivity measurements

(Practicum hydrology, 1987)

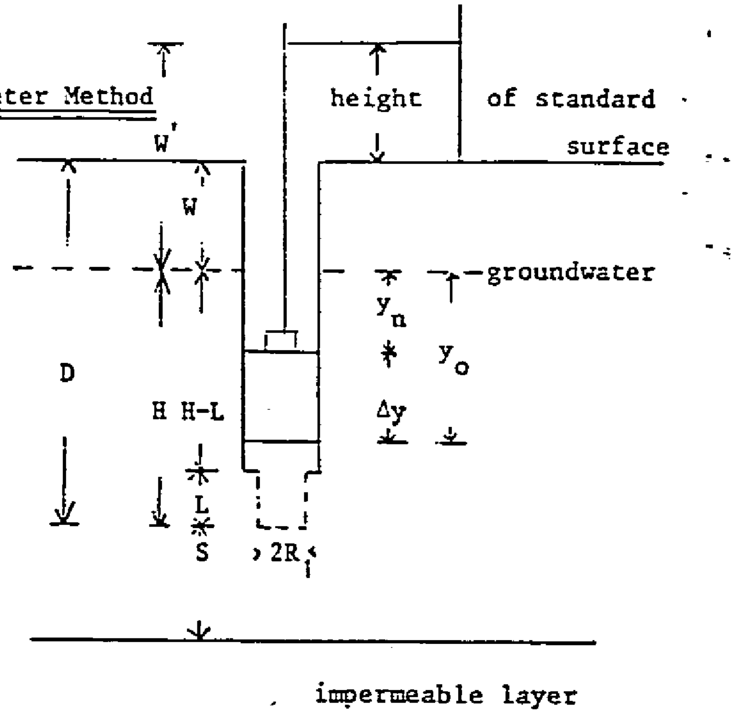
D2 The piezometer method

D3 The tube method

D4 The inversed augerhole method

D5 Graphs to be used with the formulars

Piezometer Method



Location :

No :

Date :

Observer :

Depth D : cm

Groundwater level W: cm

Layer measured : - cm

K :

W' = cm

height = cm –

W = cm

D = cm

W = cm –

H = cm

L = cm

H - L = cm; H - L> L and S > L

---

time t | water table after pumping y'_t | Δy_t

$y_o = y_o' - W' =$

$\Delta y = y_o' - y_n' =$

$\bar{y} = y_o - \frac{1}{2}\Delta y =$

L = cm

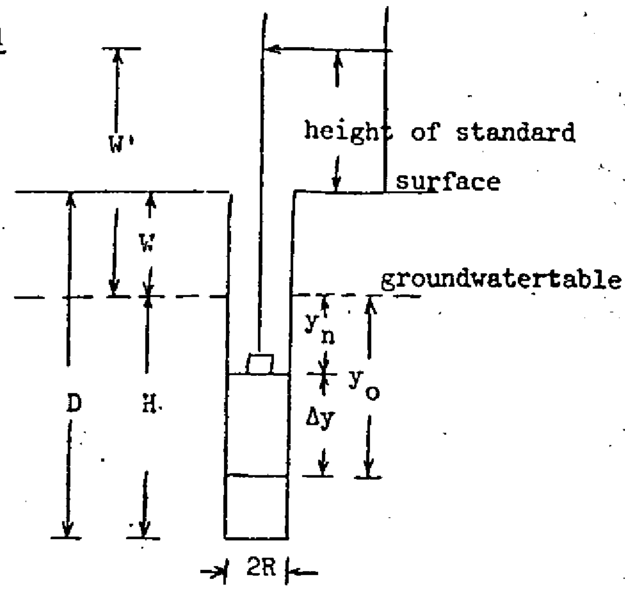
R_1 = cm A' = (from graph)

R_2 = cm

$\frac{\Delta y}{\Delta t}$ = ——— = cm/sec

$K = \frac{A' R_2^2}{\bar{y}} \times \frac{\Delta y}{\Delta t} =$ x = m/day

<u>Tube Method</u>



Location :

No :

Date :

Observer :

Depth D : cm

Groundwater table W : cm

K : m/day

W' = cm

height = cm

W = cm

D = cm

W = cm

H = cm

time water table after pumping

t y_t' Δy_t

$y_o = y_o' - W' =$

$\Delta y = y_o' - y_n' =$

$\bar{y} = y_o - \frac{1}{2}\Delta y =$

R = cm

A' = (from graph)

$\frac{\Delta y}{\Delta t} = \frac{\qquad}{\qquad} =$ cm/sec

$K = \frac{A'}{\bar{y}} \times \frac{\Delta y}{\Delta t} = \quad \times \quad =$ m/day

Inversed Auger Hole Test

Location :

No :

Date :

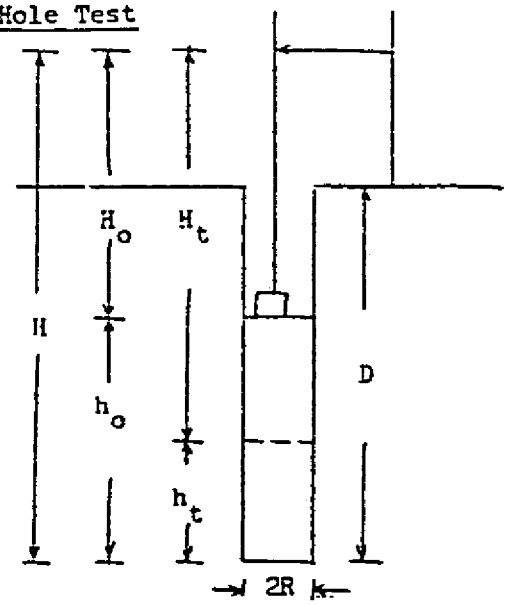
Observer :

R : cm

Depth D : cm

Layer measured : - cm

K : m/day



t	H	H_t	h_t	h_t+R/2	t	H	H_t	h_t	h_t+R/2

tan α =

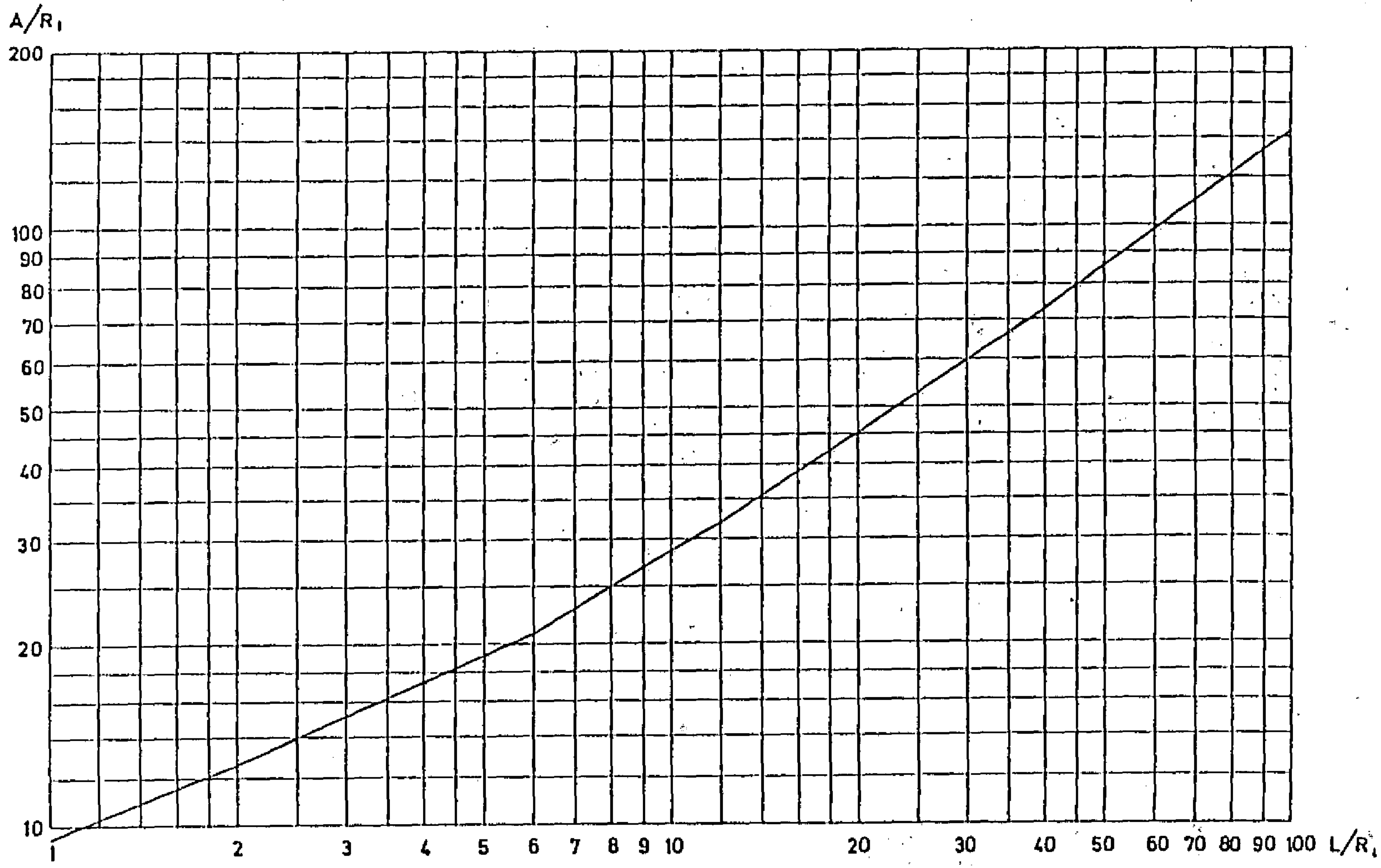
K: = 1.15 R tan α =

If tan α is very small and cannot be determined accurately from the graph, calculate: log (h_o + R/2) = , log (h_t + R/2) =

$$K = 1.15\ R\ \frac{\log\ (h_o + R/2) - \log\ (h_t + R/2)}{t} =$$

If K is calculated in cm/sec or in cm/min, the value has to be multiplied respectively by 864 or 14.4 in order to obtain K in m/day.

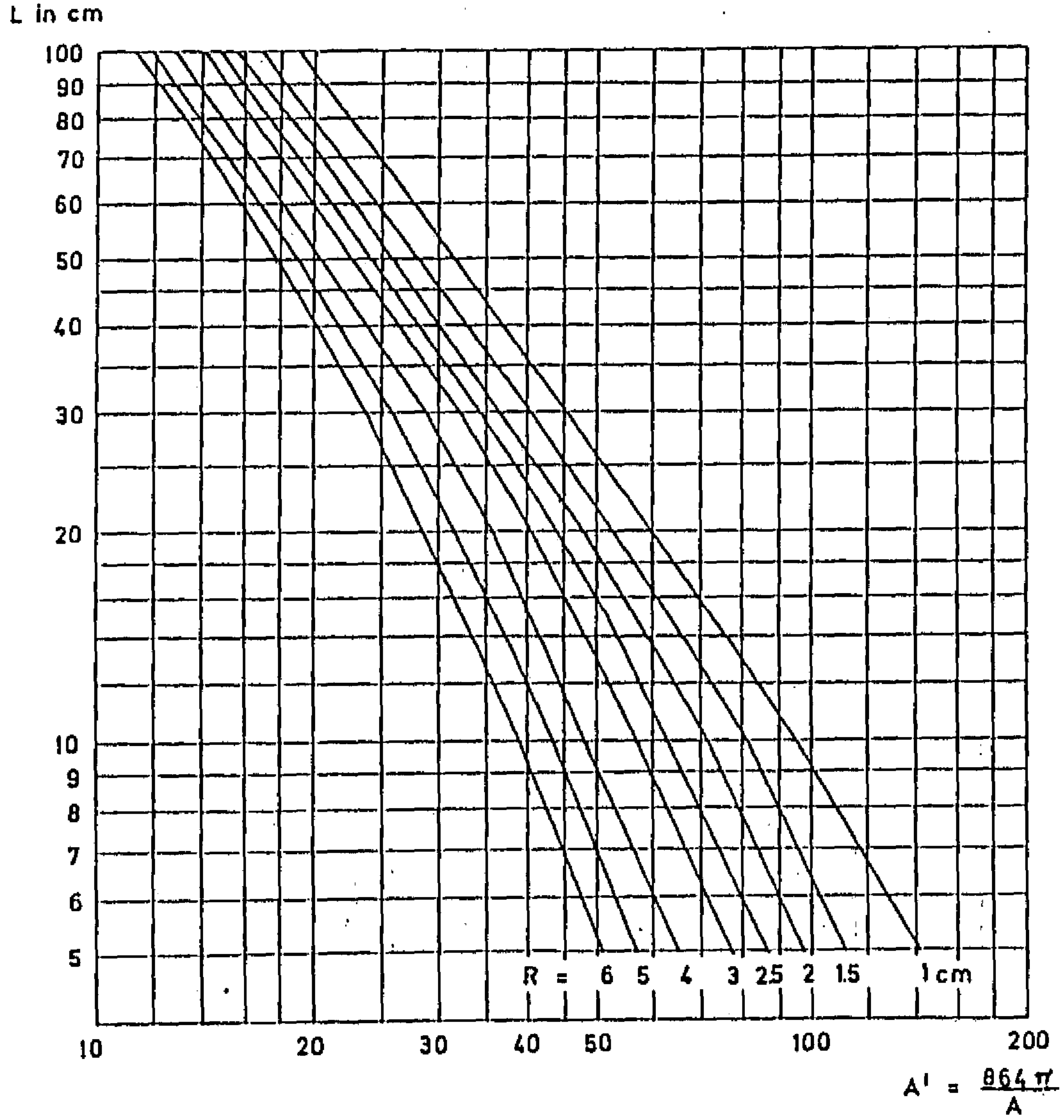
Graph 1. Relation between L/R_1 and A/R_1 for the piezometer method.



D5

He – 244/3

Graph 2. Relation between L, R, and A' for the piezometer method.



Ho-244/4

D6

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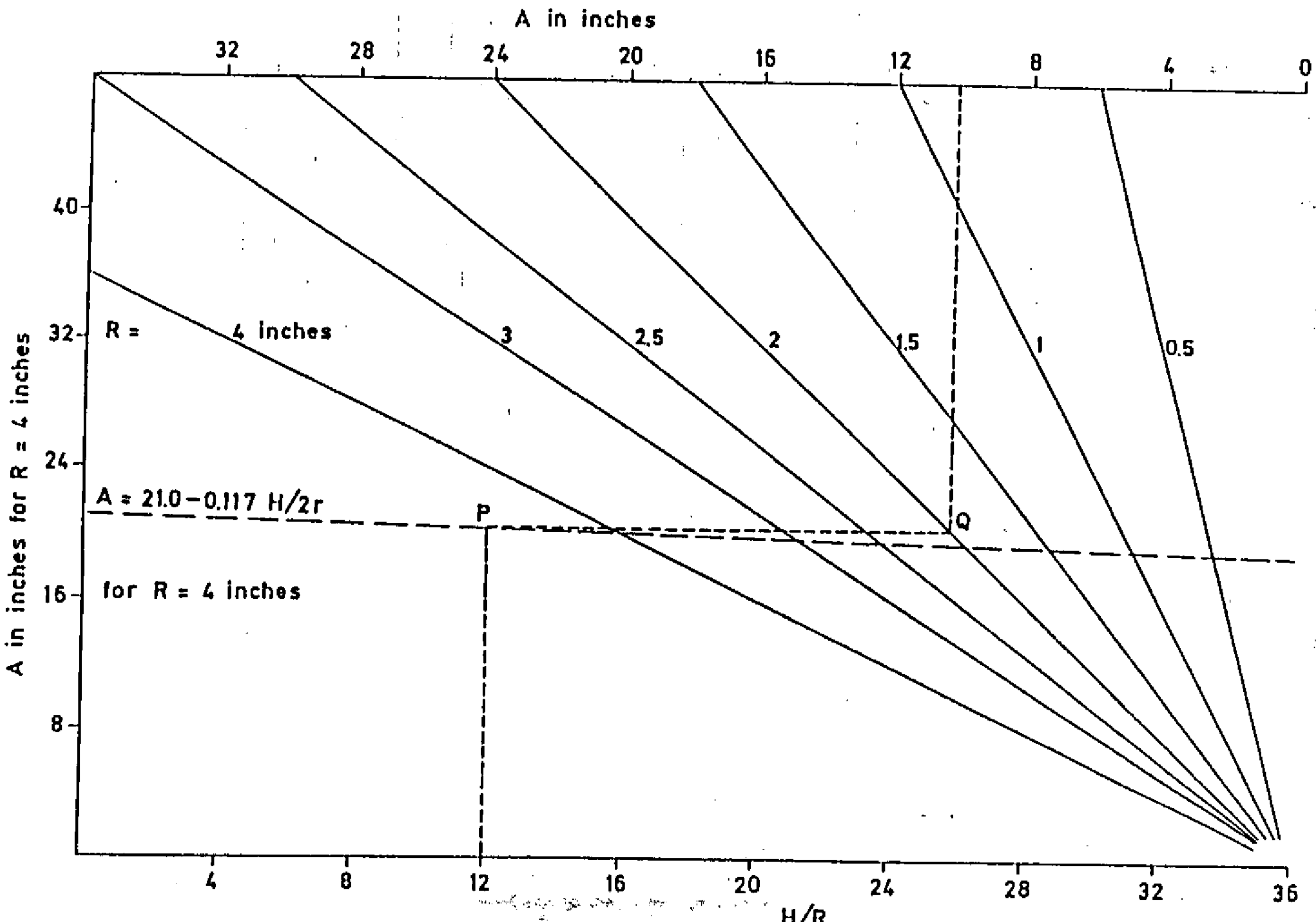
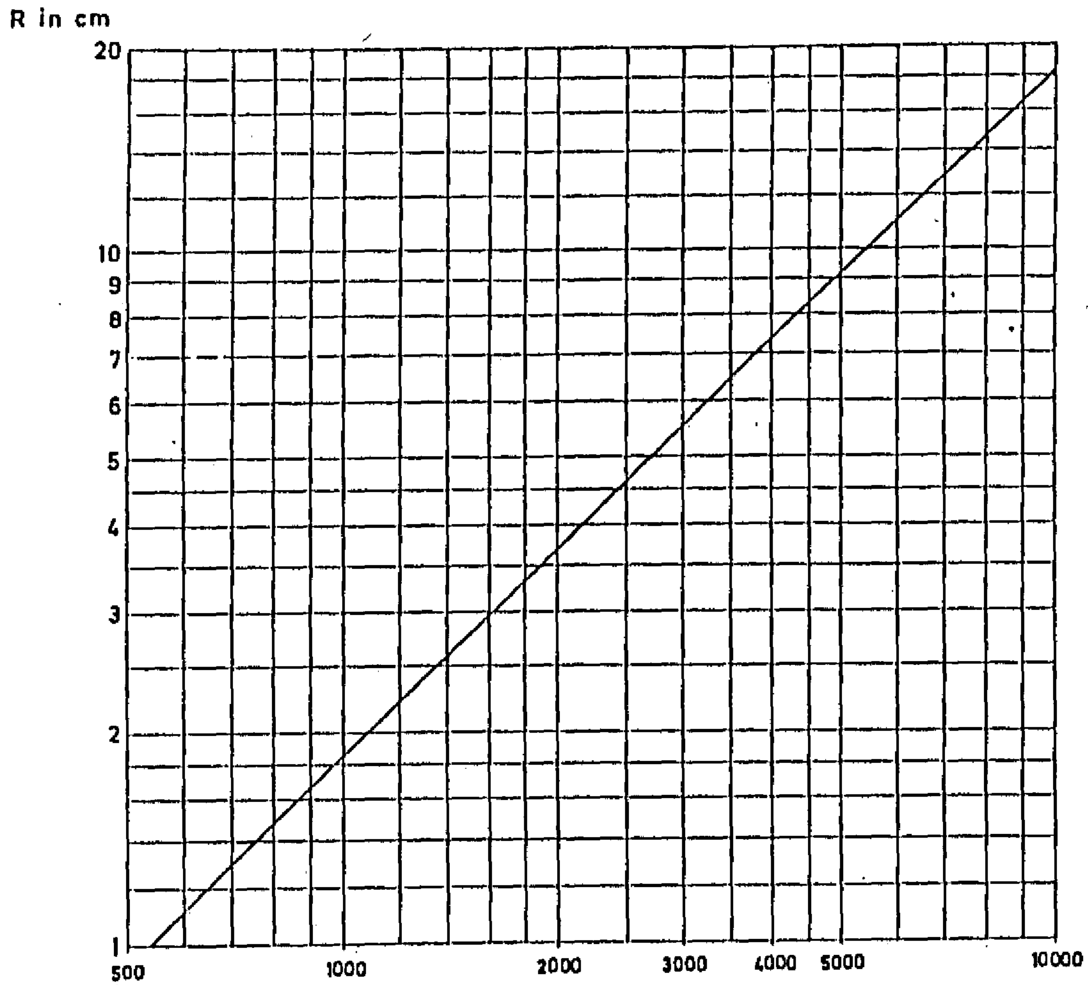
Graph 3 Relation between H/R and A for the tube method.



Ho – 244/5

Graph 4. Relation between R and A' for the tube method.



$A' = \frac{864 \pi R^2}{2.54 A}$

Ho - 244/6

DB

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APPENDIX E

Fluctuation of the water table and hydraulic heads

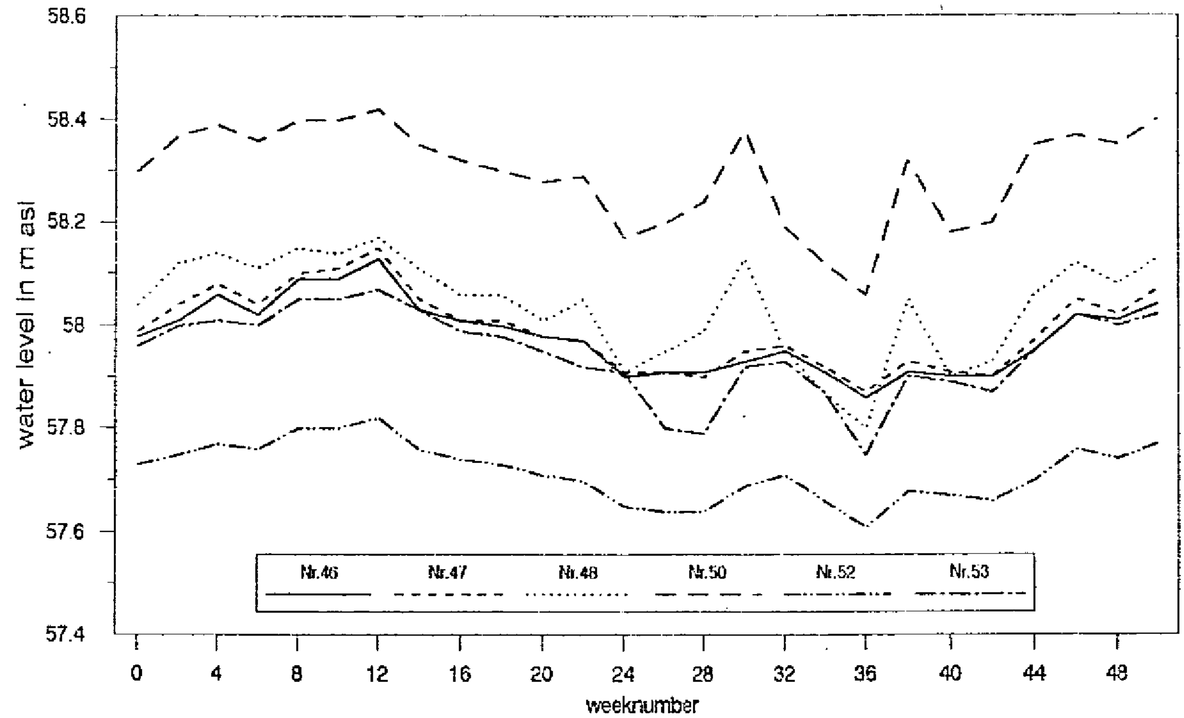
E2 The soaksystem at Clara bog west

E3 Along the transects A-A' and B-B' at Clara bog west

E4 Along transect C-C' at Raheenmore bog

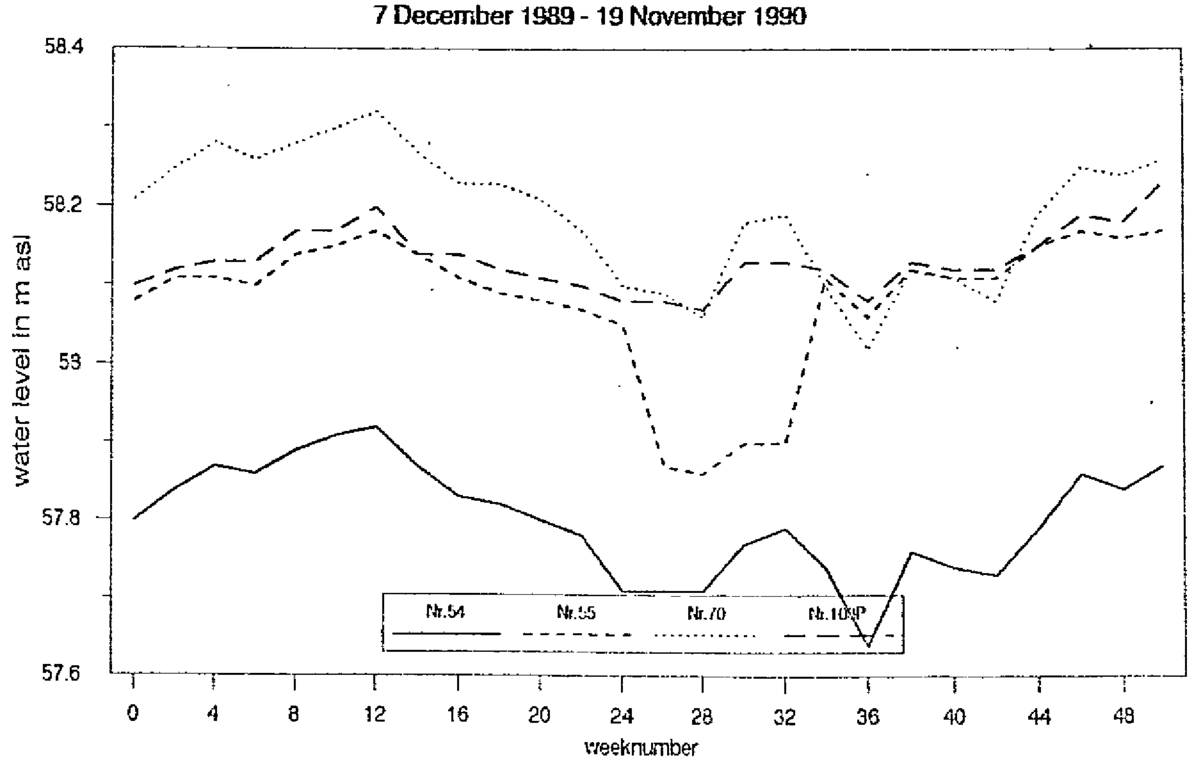
Phreatic waterlevels at the soak of Clara West

7 December 1989 - 19 November 1990

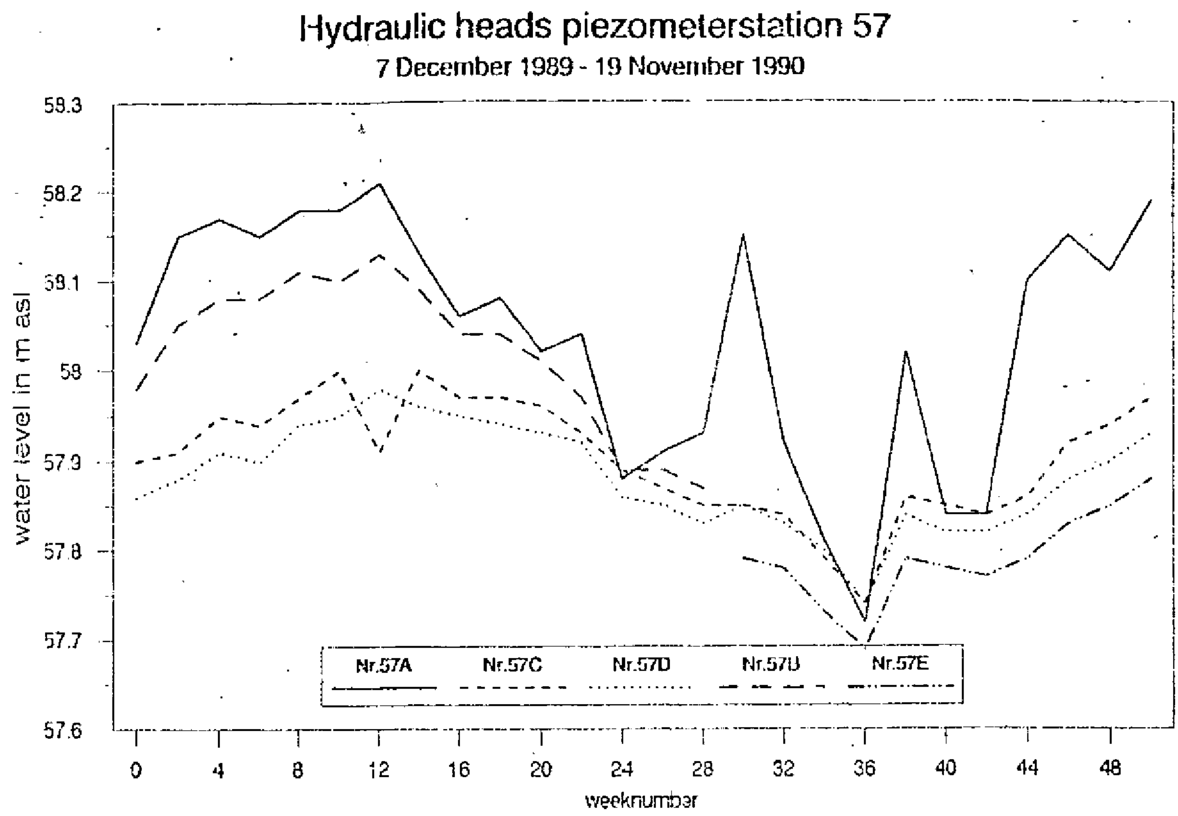


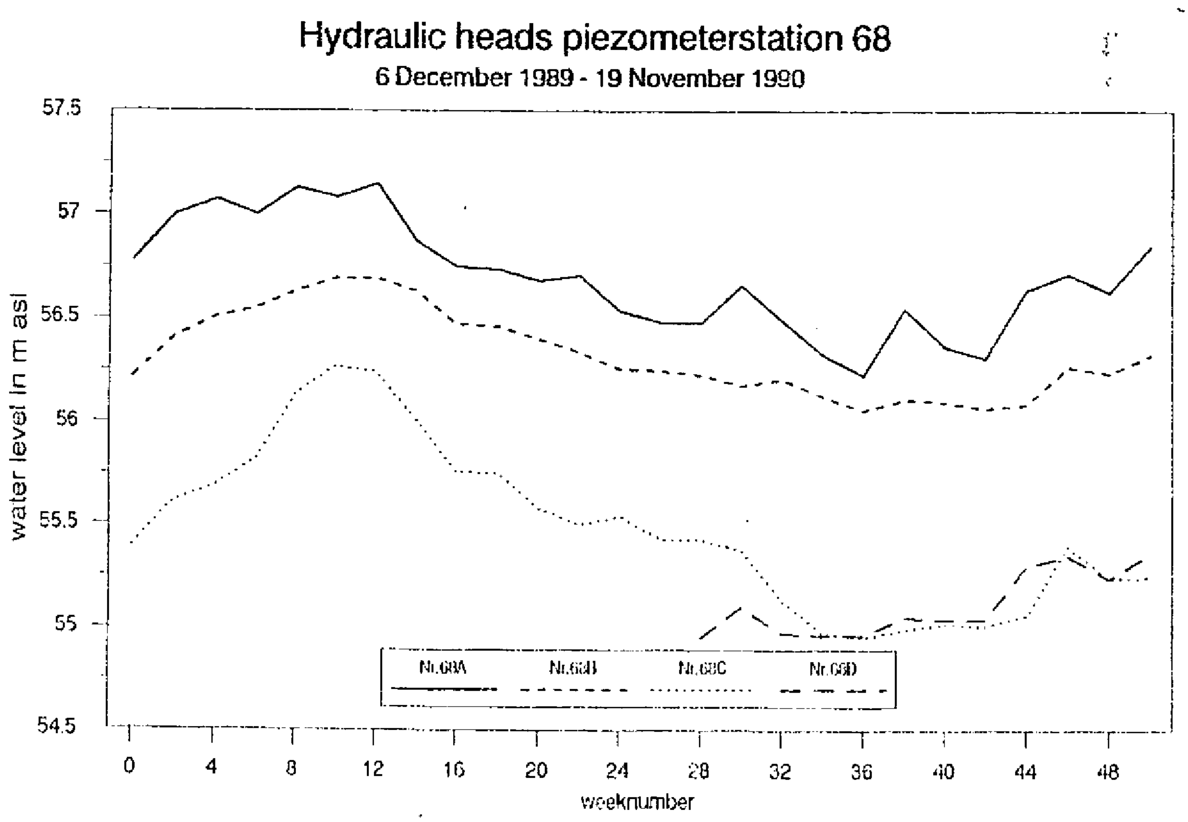
Phreatic waterlevels at the soak of Clara West

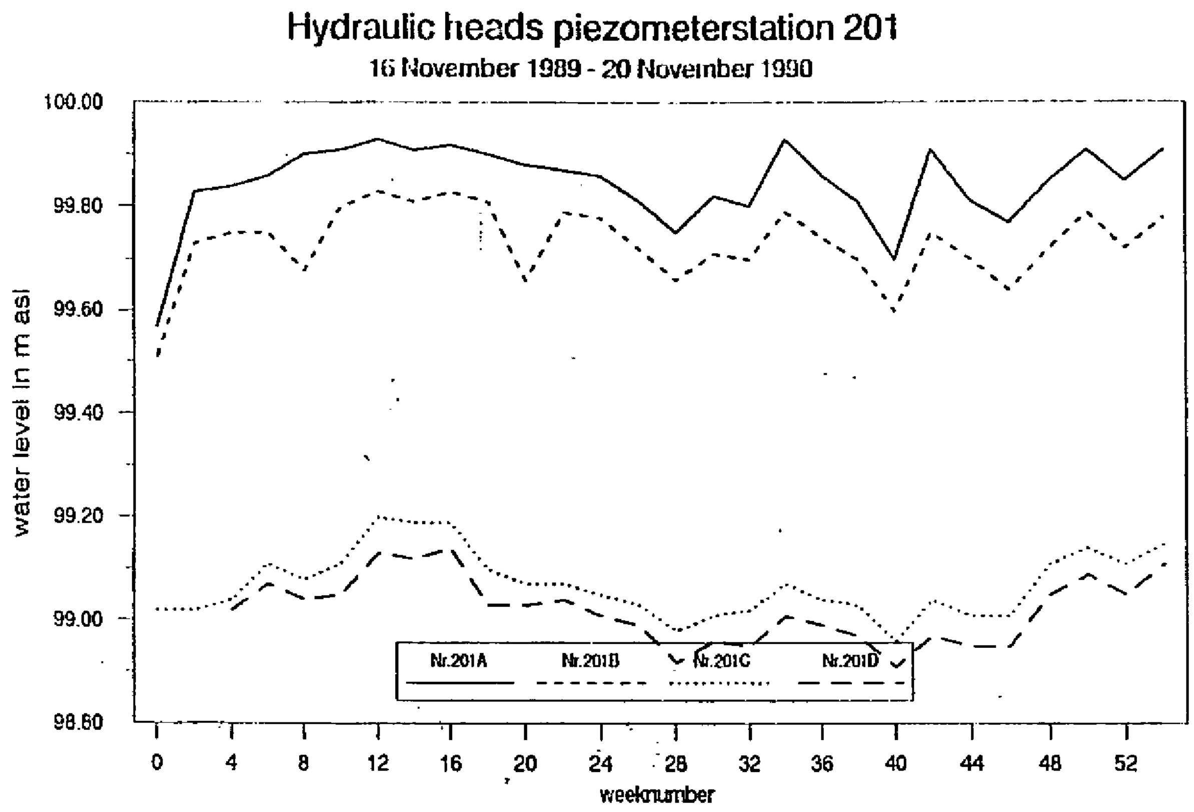
7 December 1989 - 19 November 1990

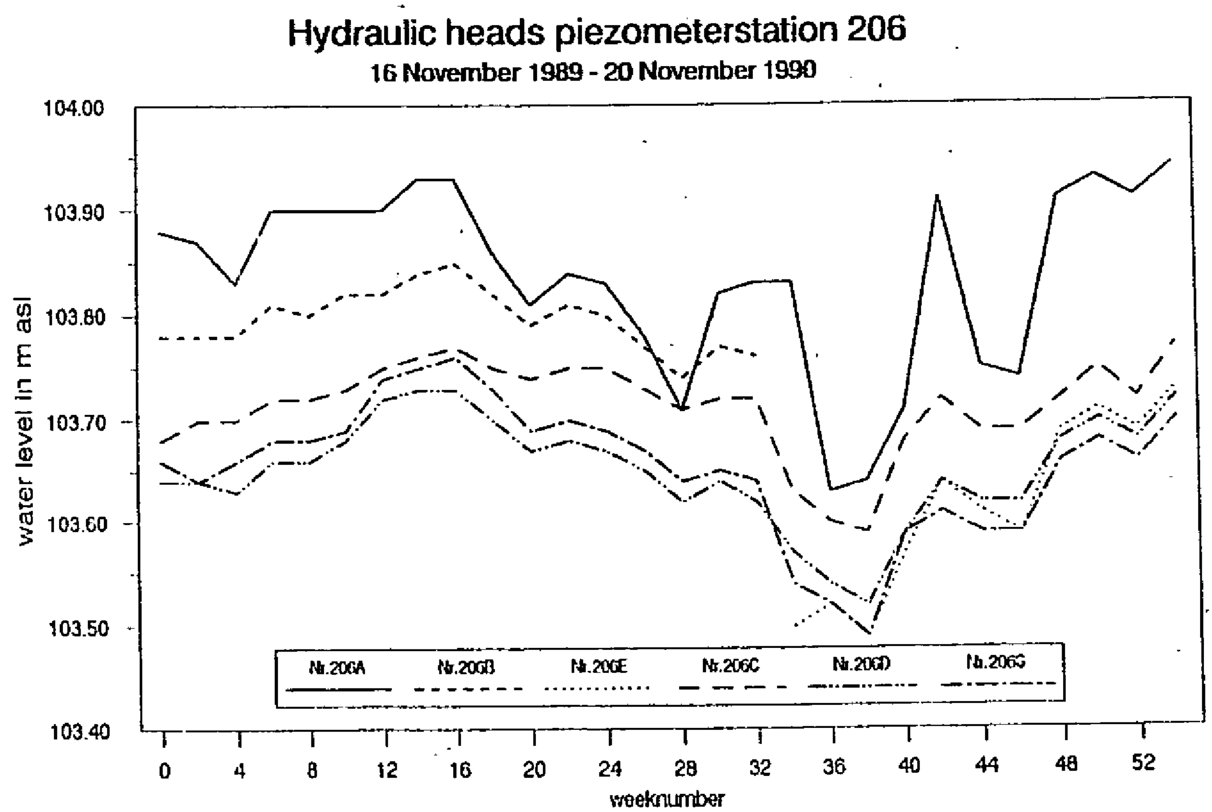


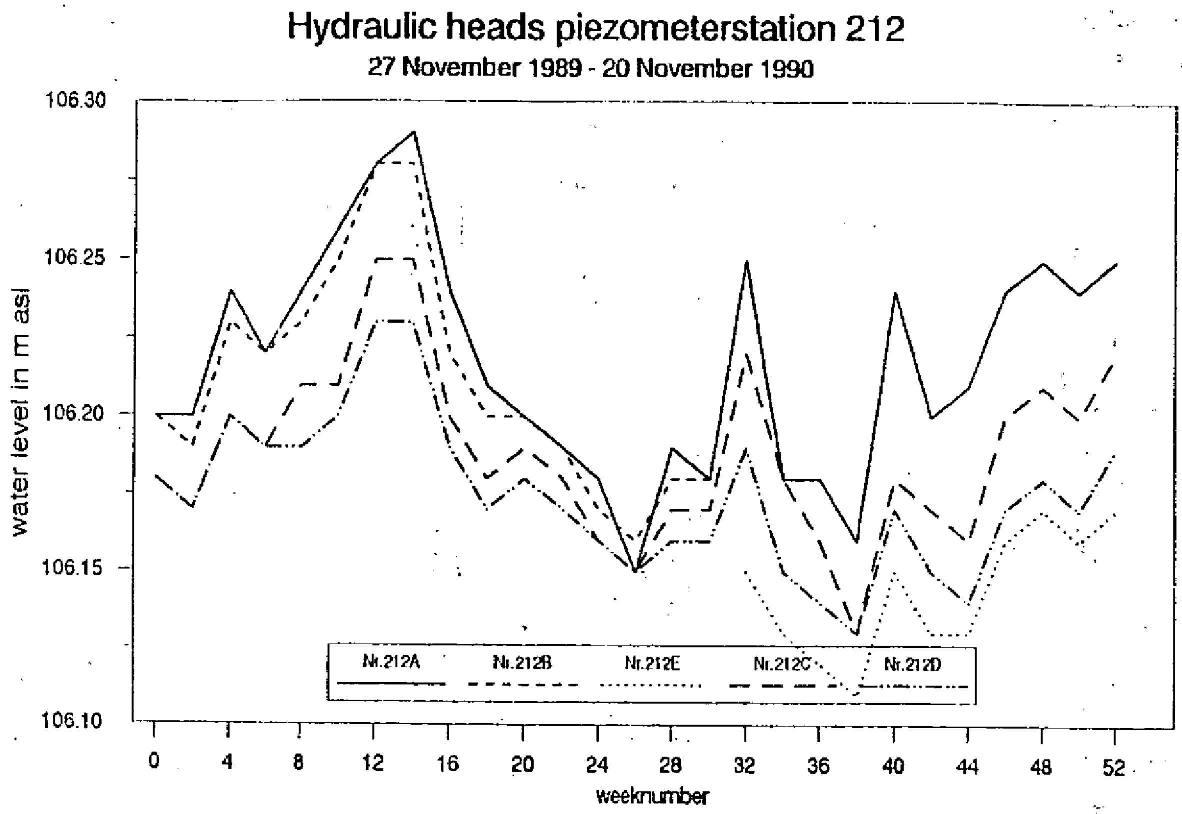
62


Hydraulic heads piezometerstation 57
7 December 1989 - 19 November 1990
water level in m asl
58.3
58.2
58.1
58
57.9
57.8
57.7
57.6
0
4
8
12
16
20
24
28
32
36
40
44
48
weeknumber
Nr.57A
Nr.57C
Nr.57D
Nr.57B
Nr.57E


Hydraulic heads piezometerstation 68
6 December 1989 - 19 November 1990
water level in m asl
57.5
57
56.5
56
55.5
55
54.5
0
4
8
12
16
20
24
28
32
36
40
44
48
weeknumber


Hydraulic heads piezometerstation 201
16 November 1989 - 20 November 1990
water level in m asl
100.00
99.80
99.60
99.40
99.20
99.00
98.60
weeknumber
0
4
8
12
16
20
24
28
32
36
40
44
48
52
Nr.201A
Nr.201B
Nr.201C
Nr.201D


Hydraulic heads piezometerstation 206
16 November 1989 - 20 November 1990
water level in m asl
104.00
103.90
103.80
103.70
103.60
103.50
103.40
weeknumber
0
4
8
12
16
20
24
28
32
36
40
44
48
52
Nr.206A
Nr.206B
Nr.206E
Nr.206C
Nr.206D
Nr.206G



Hydraulic heads piezometerstation 212
27 November 1989 - 20 November 1990
106.30
106.25
106.20
106.15
106.10
water level in m asl
0
4
8
12
16
20
24
28
32
36
40
44
48
52
weeknumber
Nr.212A
Nr.212B
Nr.212E
Nr.212C
Nr.212D

APPENDIX F

Equipotential images

F2 Around the soak at Clara bog west

F3 Transect A-A' at Clara bog west

F4 Transect B-B' at Clara bog west

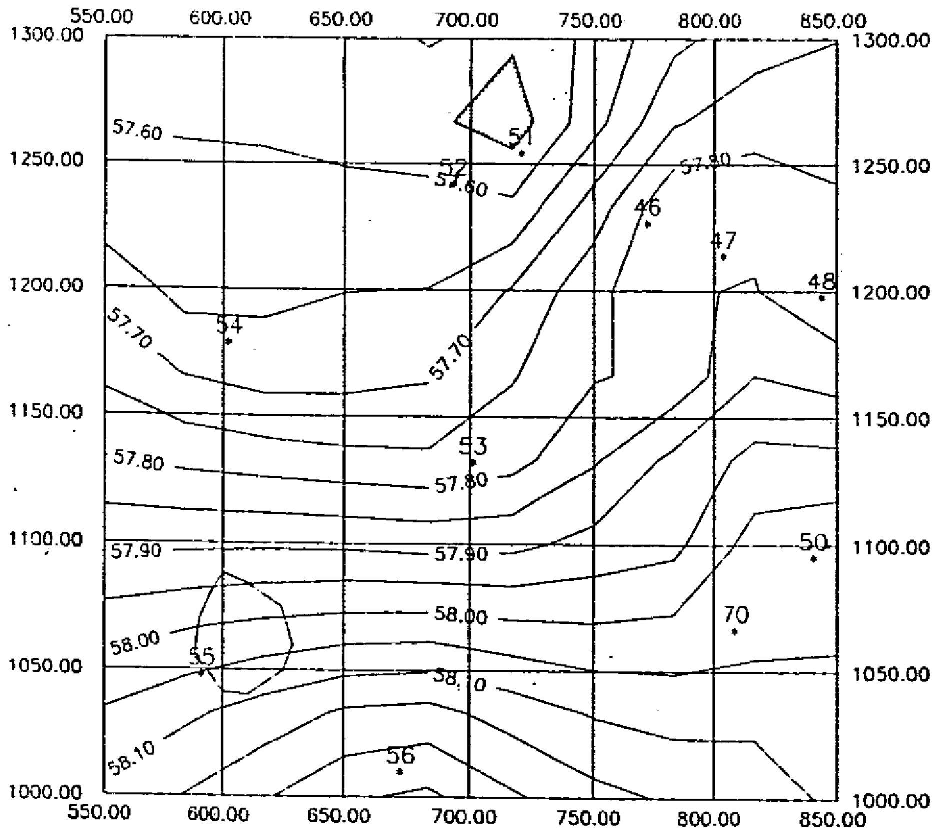
F5 Transect C-C' at Raheenmore bog

F8 North south transect at Raheenmore bog

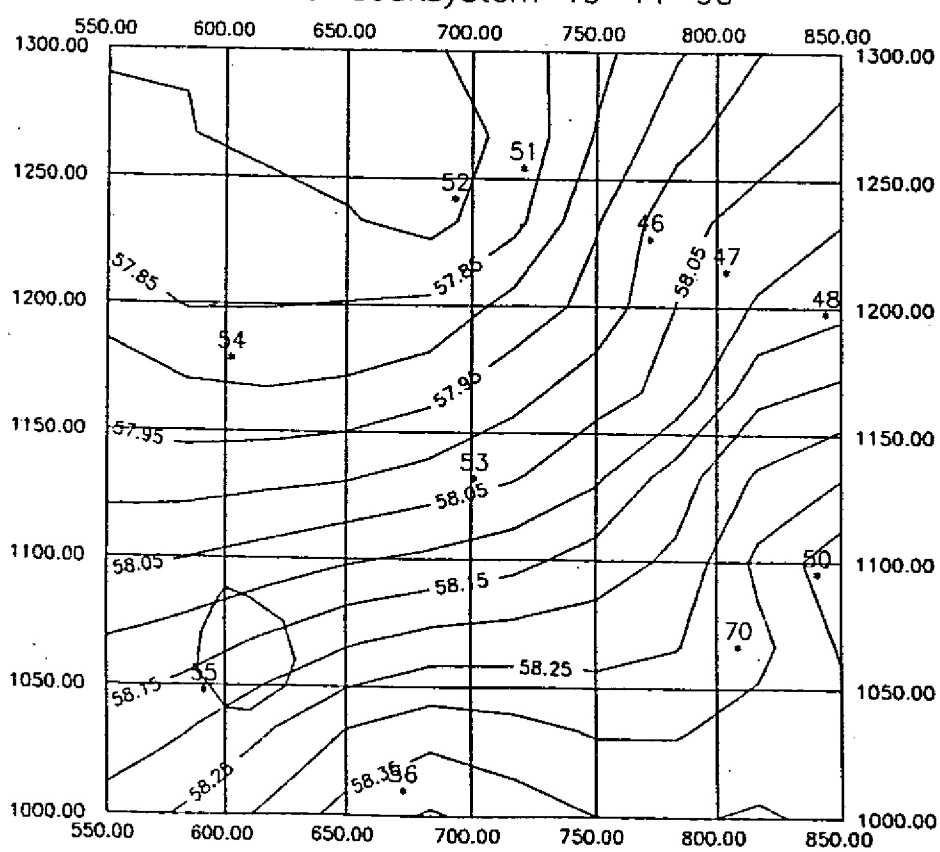
F11 Old facebank at Clara bog west

F12 New facebank at Clara bog west

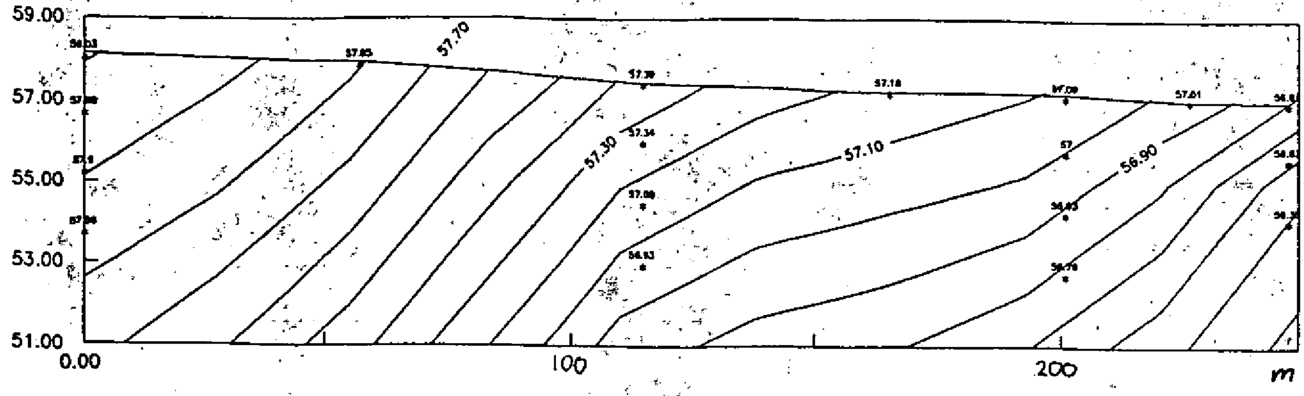
Phreatic level soaksystem 14-8-90



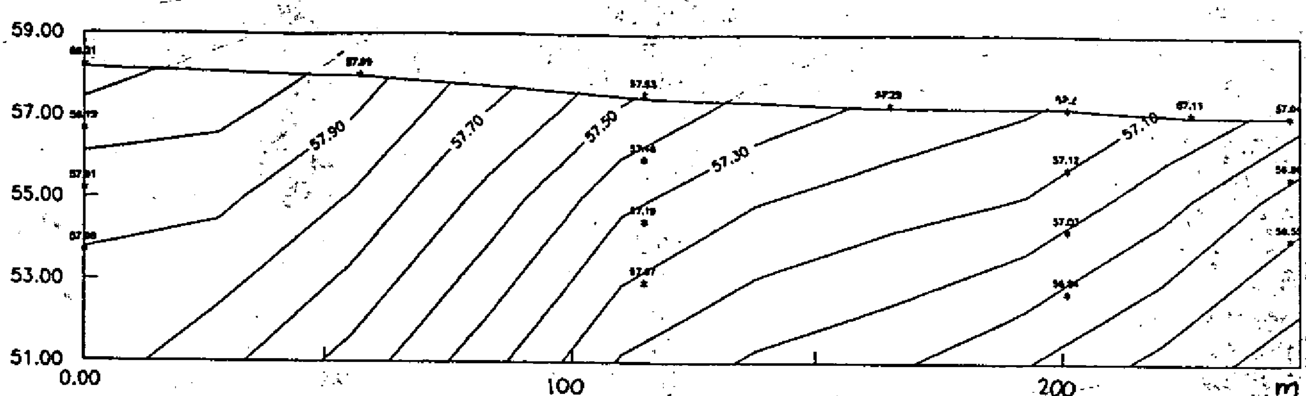
Phreatic level soaksystem 19-11-90



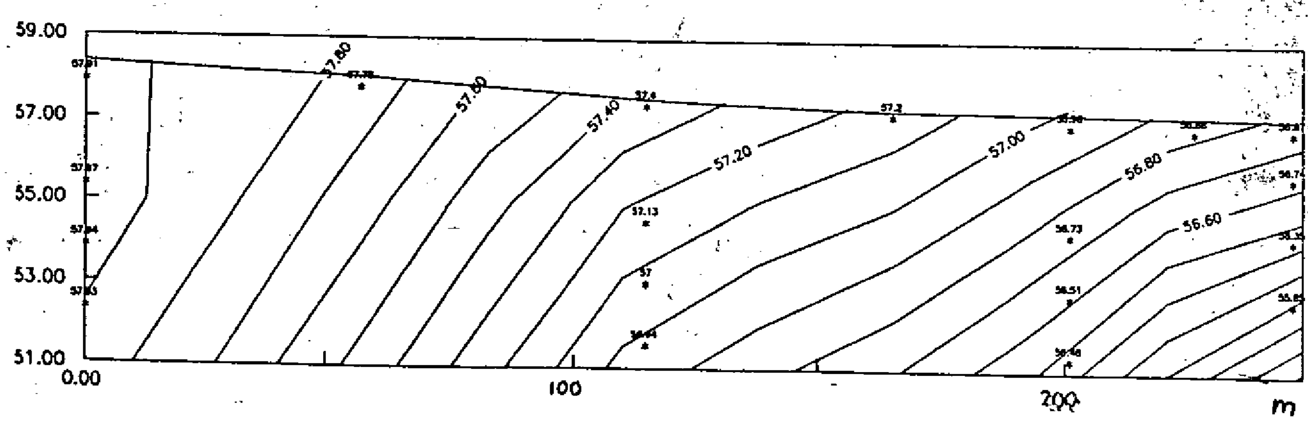
Equipotential lines transect A 7-12-89



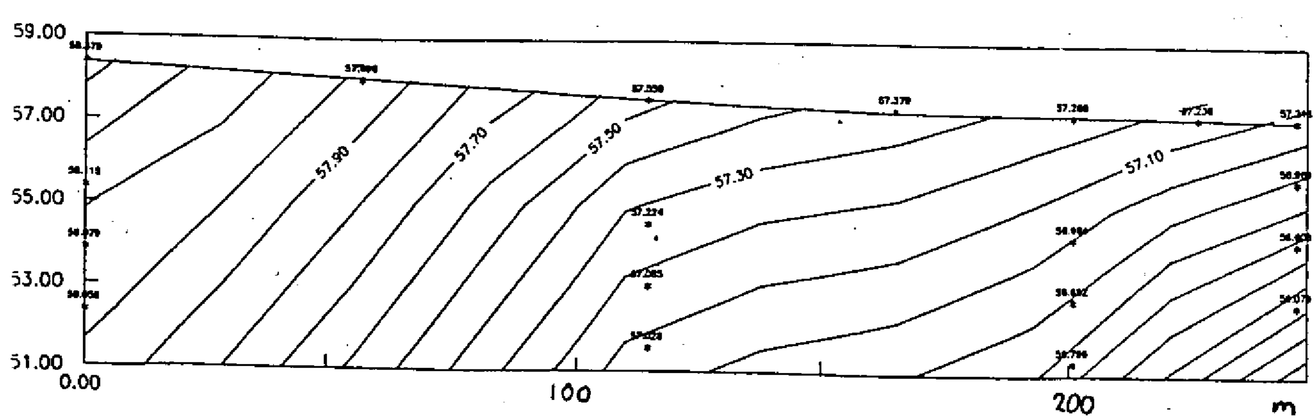
Equipotential lines transect A 28-2-90



Equipotential lines transect A 14-8-90

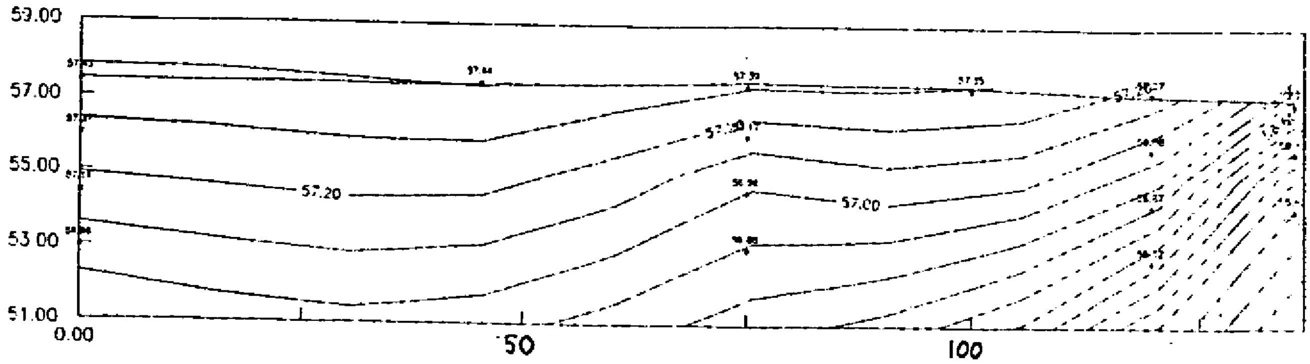


Equipotential lines transect A 19-11-90

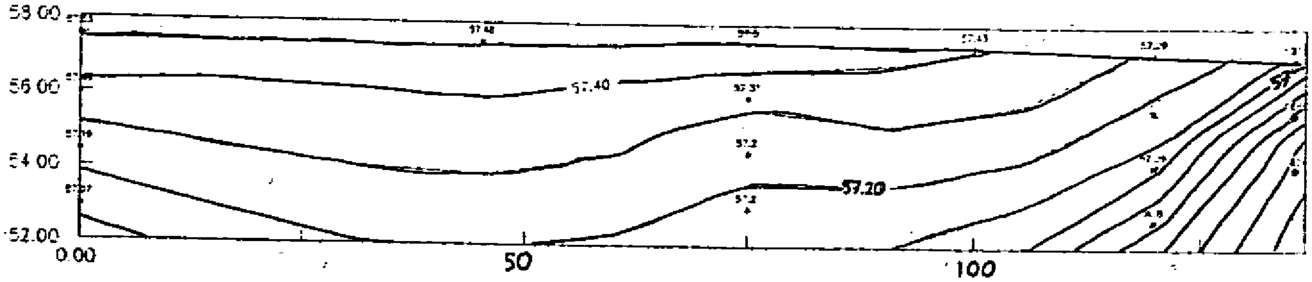


F3

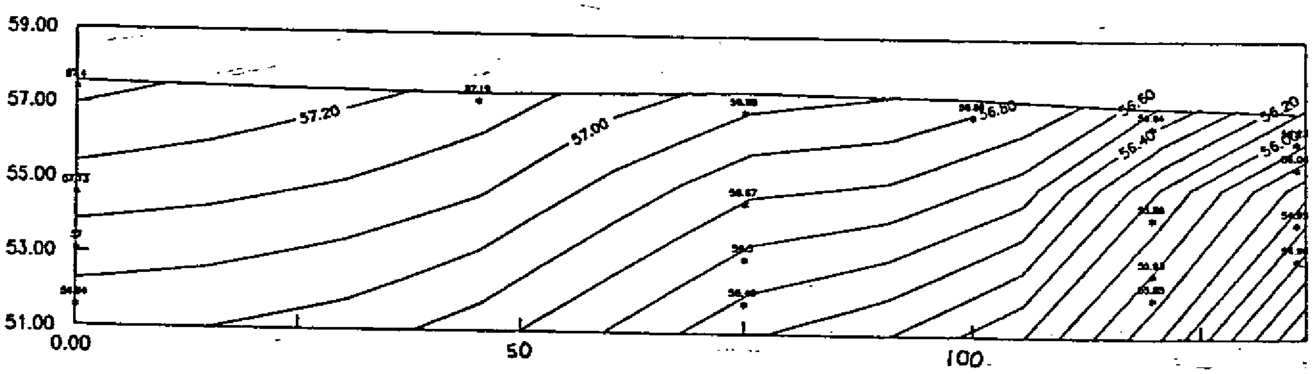
Equipotential lines transect B 18-12-89



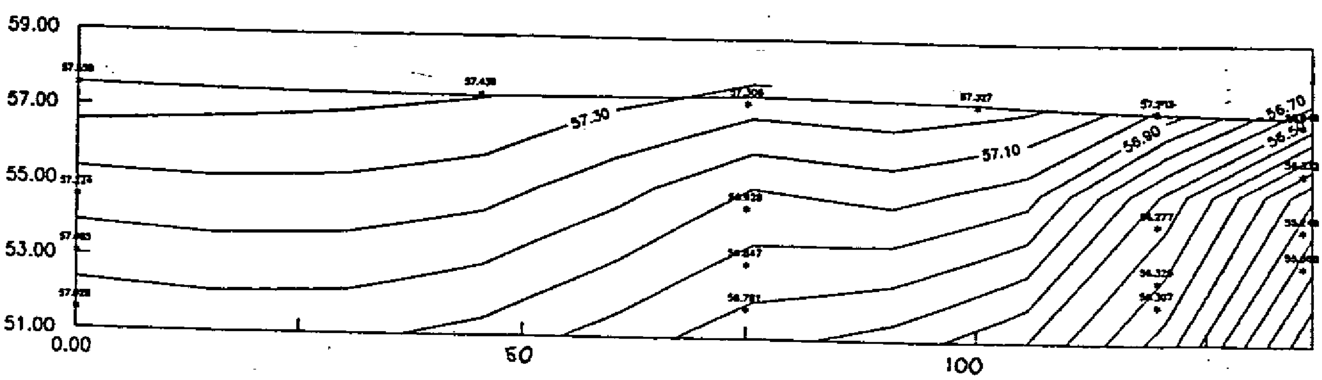
Equipotential lines transect B 28-2-90



Equipotential lines transect B 14-8-90

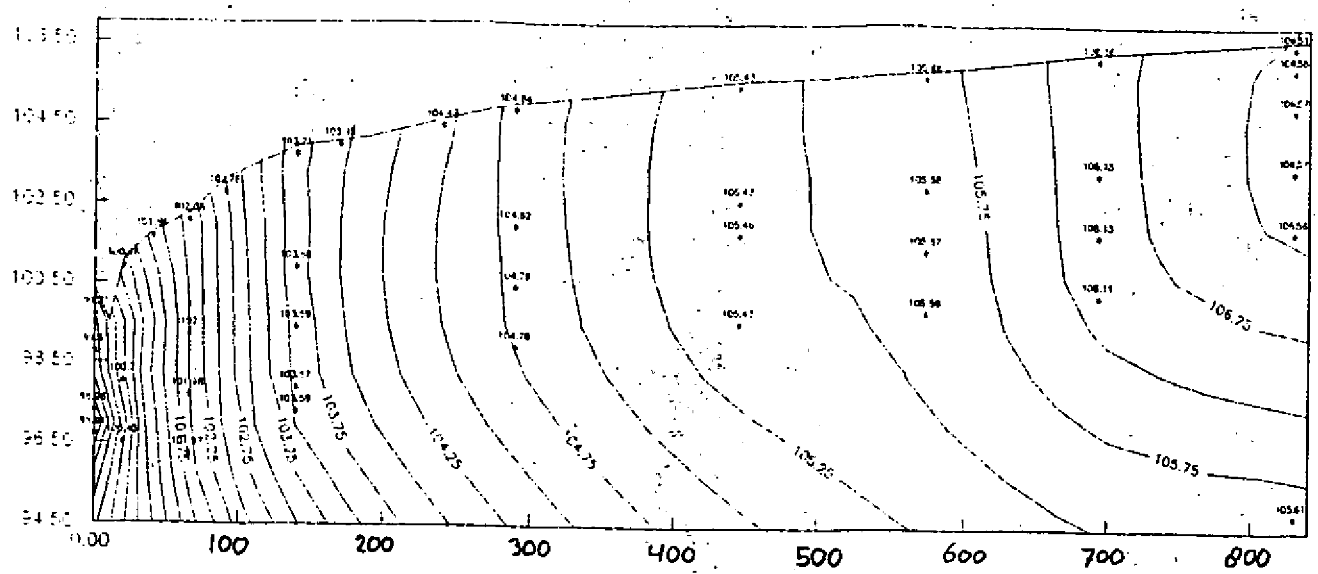


Equipotential lines transect B 19-11-90

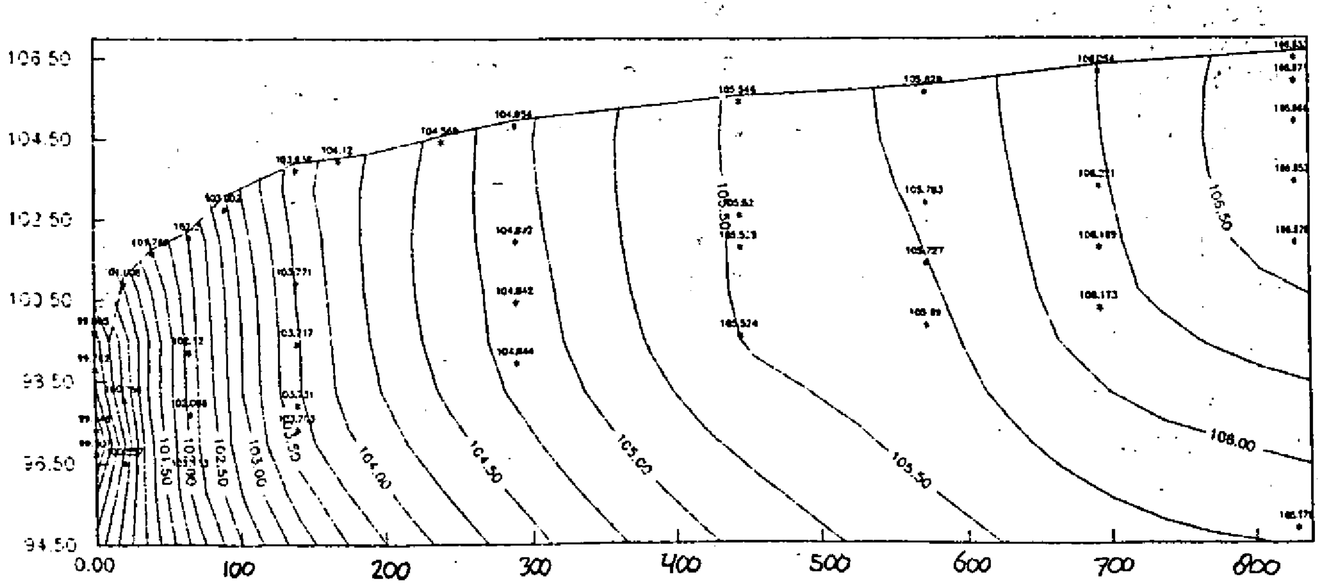


F4

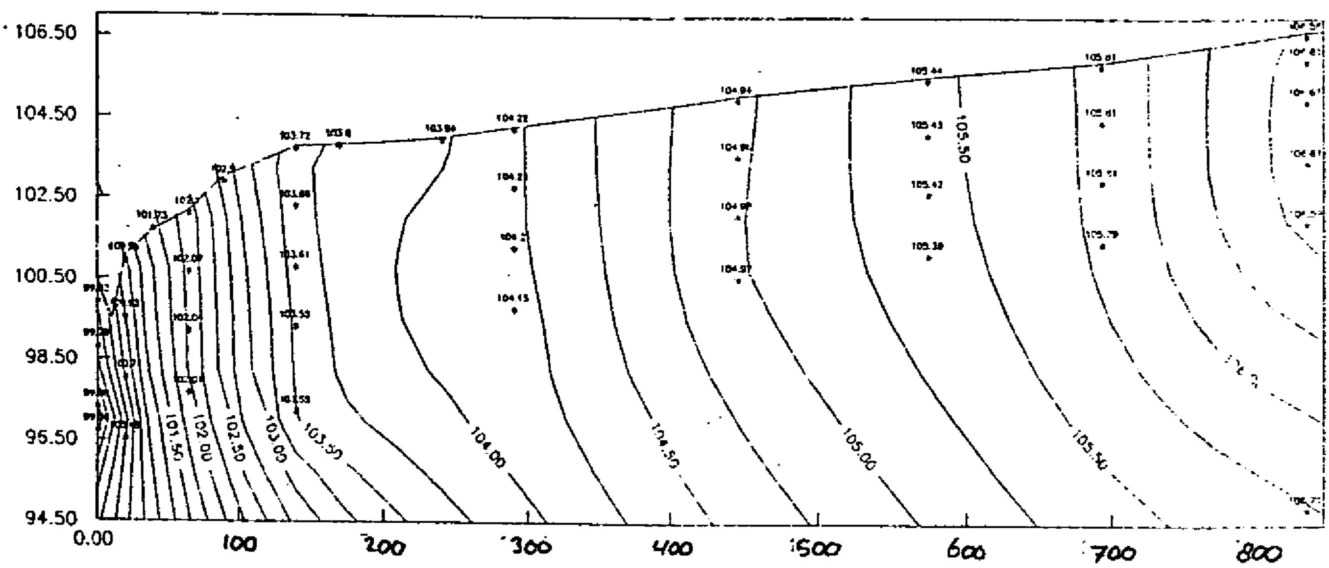
Equipotential lines transect C–C' 15–8–90



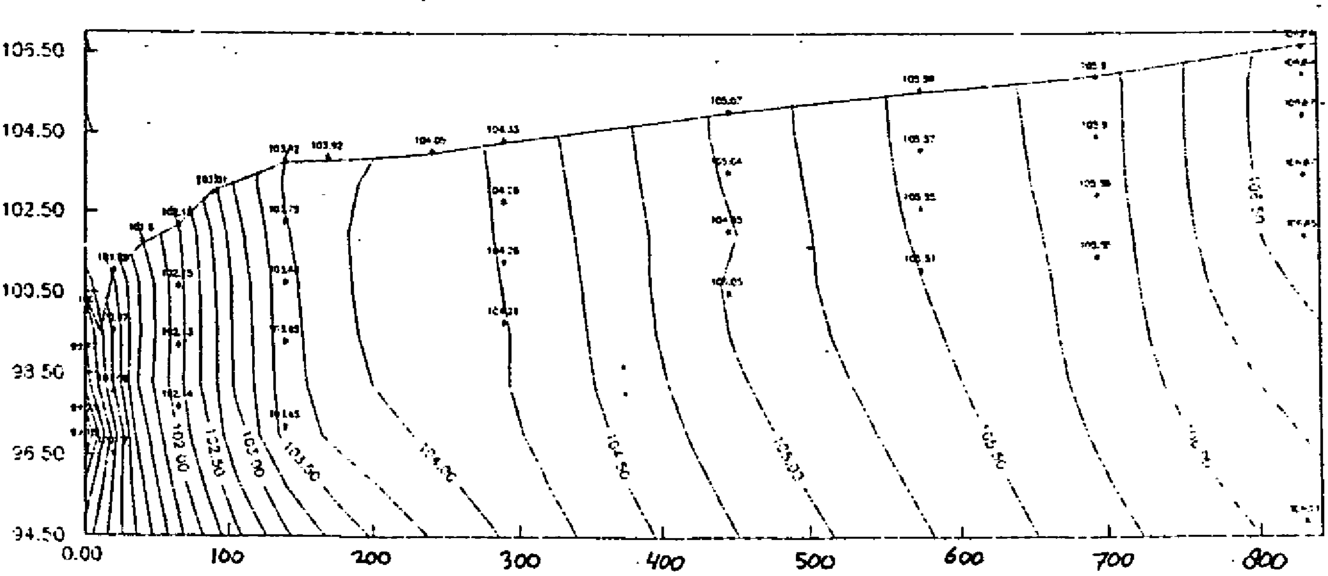
Equipotential lines transect C–C' 20–11–90



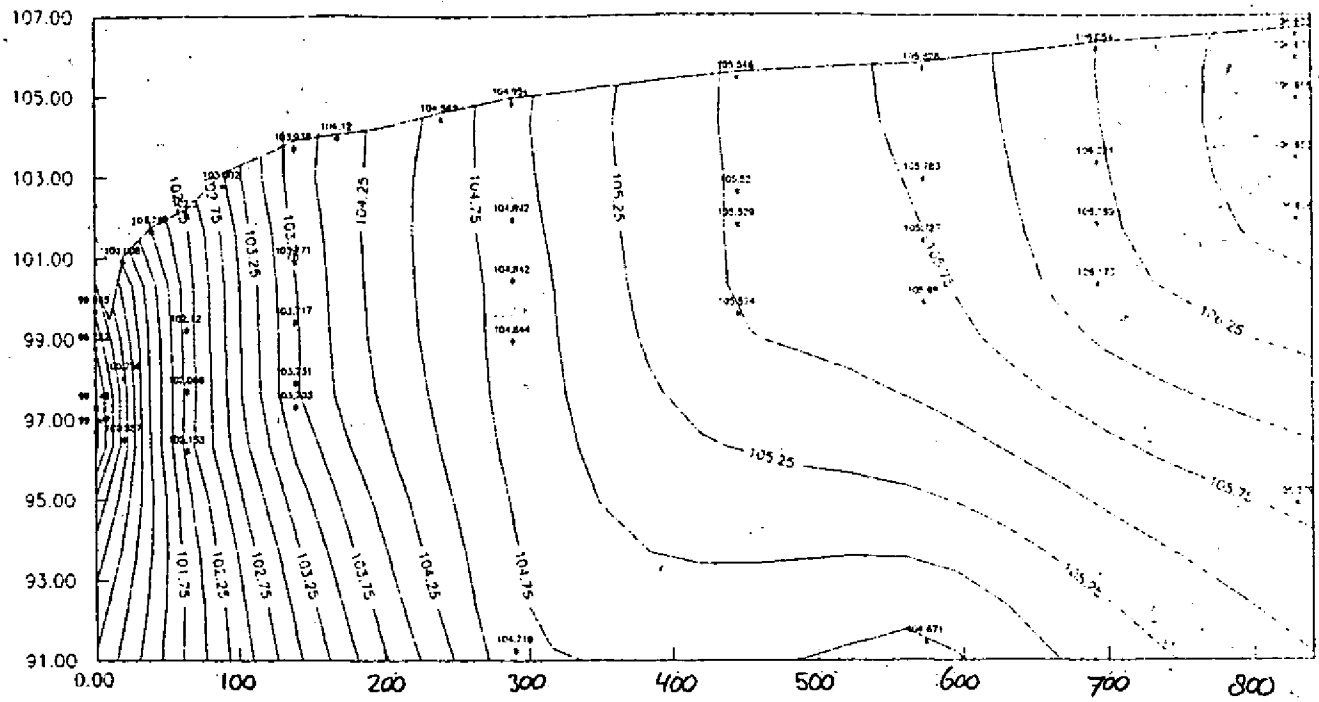
Equipotential lines transect C–C' 11–12–89



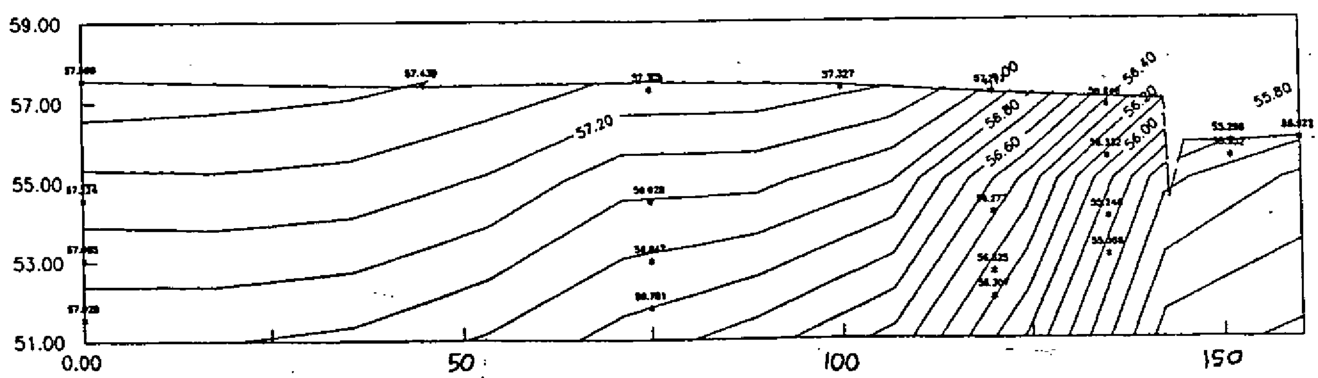
Equipotential lines transect C–C' 1–3–90



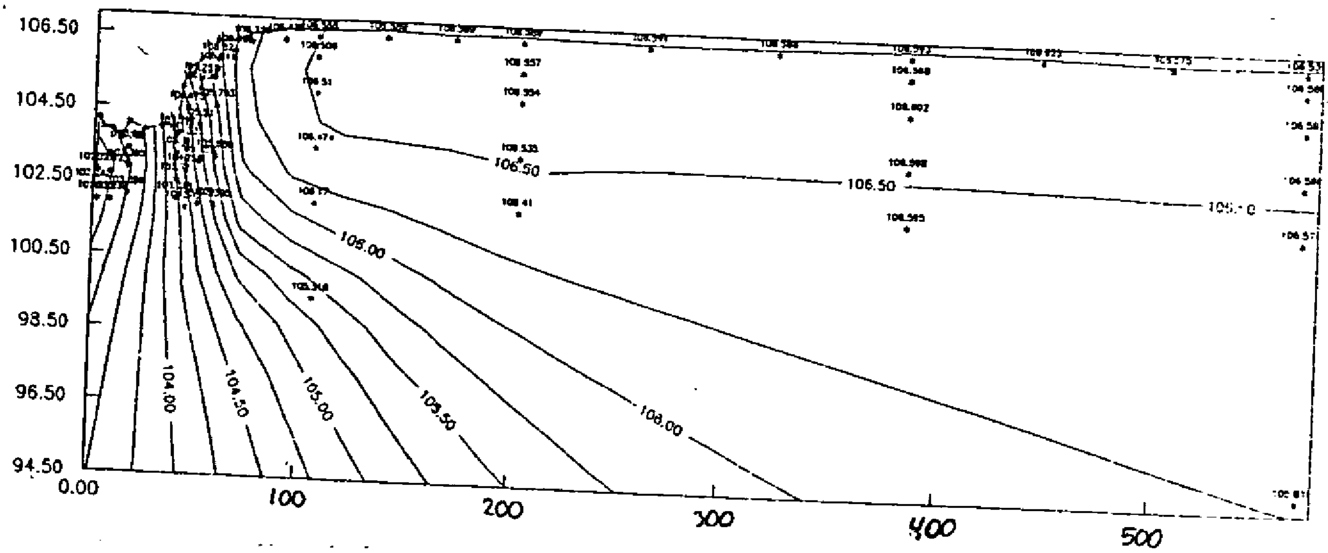
Equipotential lines transect C-C+ 20-11-90



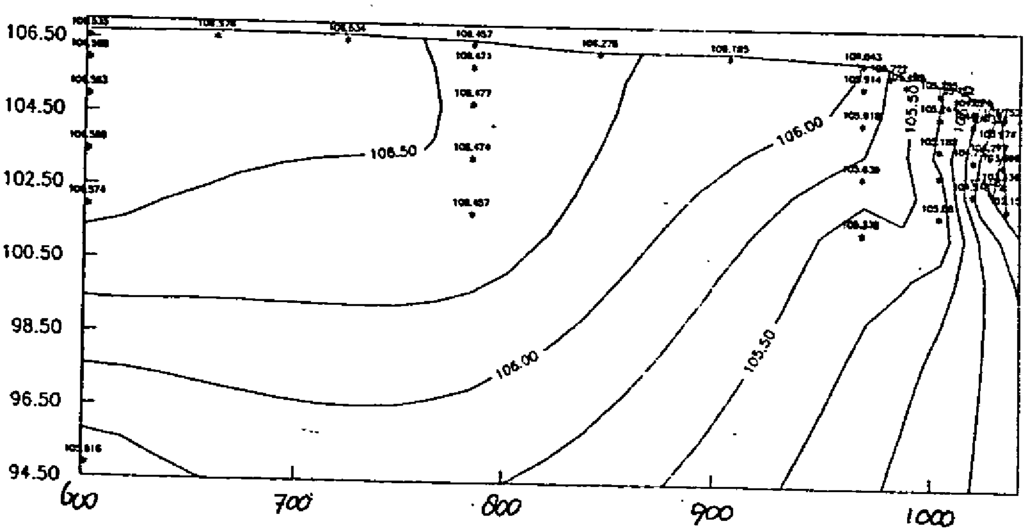
Equipotential lines transect B+ 19-11-90



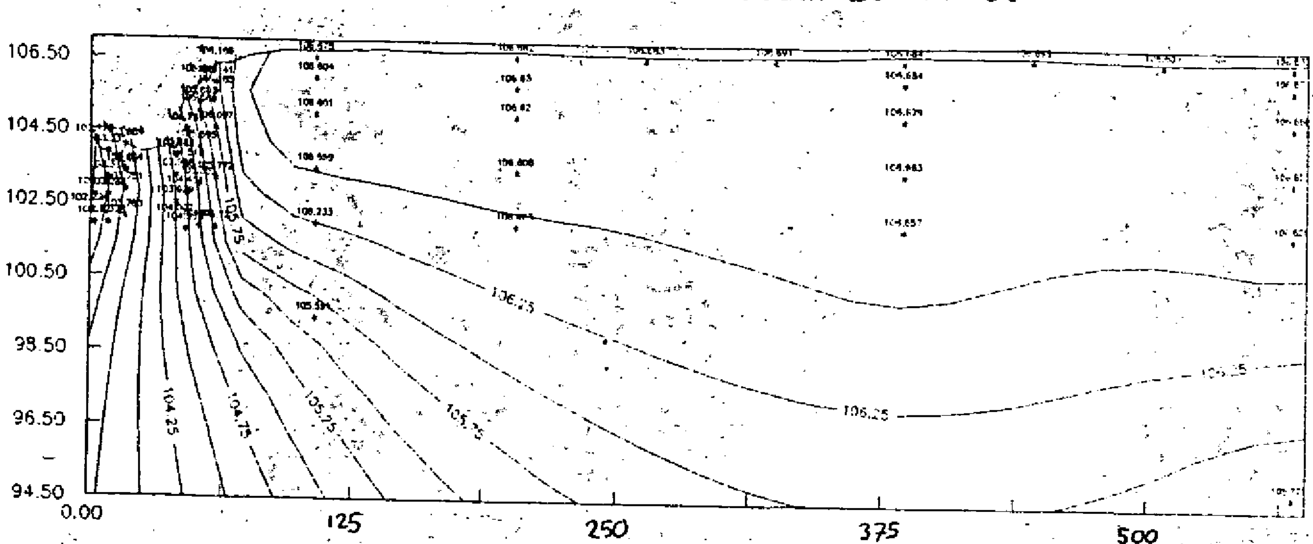
Equipotential lines NS transect south 26-9-90



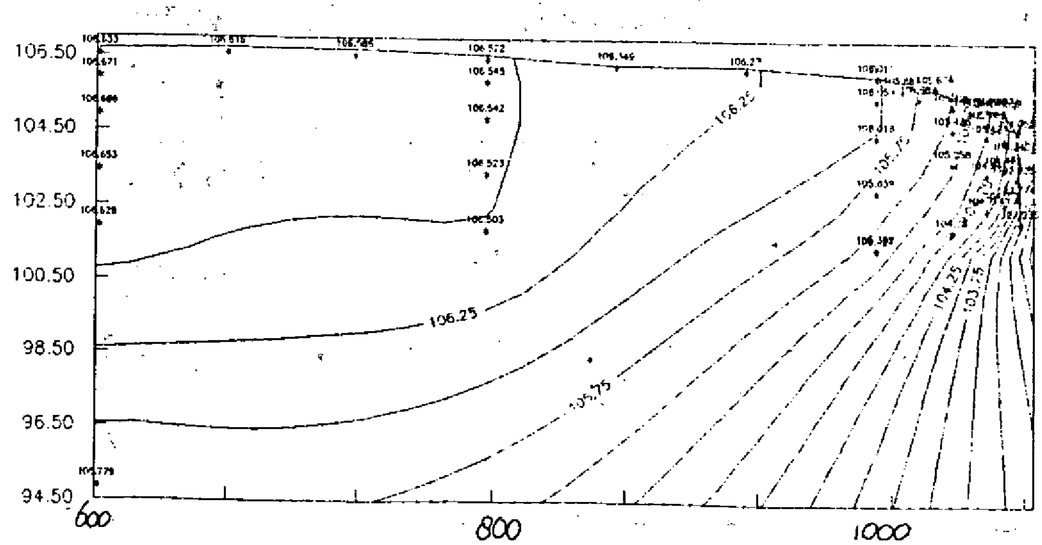
Equipotential lines NS transect north 26-9-90



Equipotential lines NS transect south 20-11-90

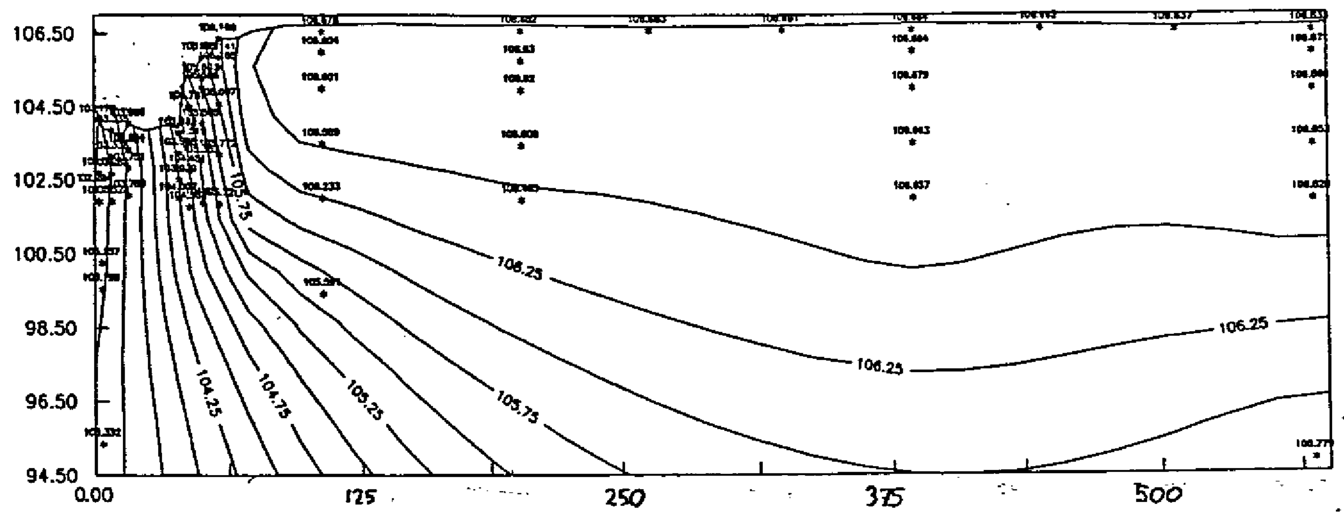


Equipotential lines NS transect north 20-11-90

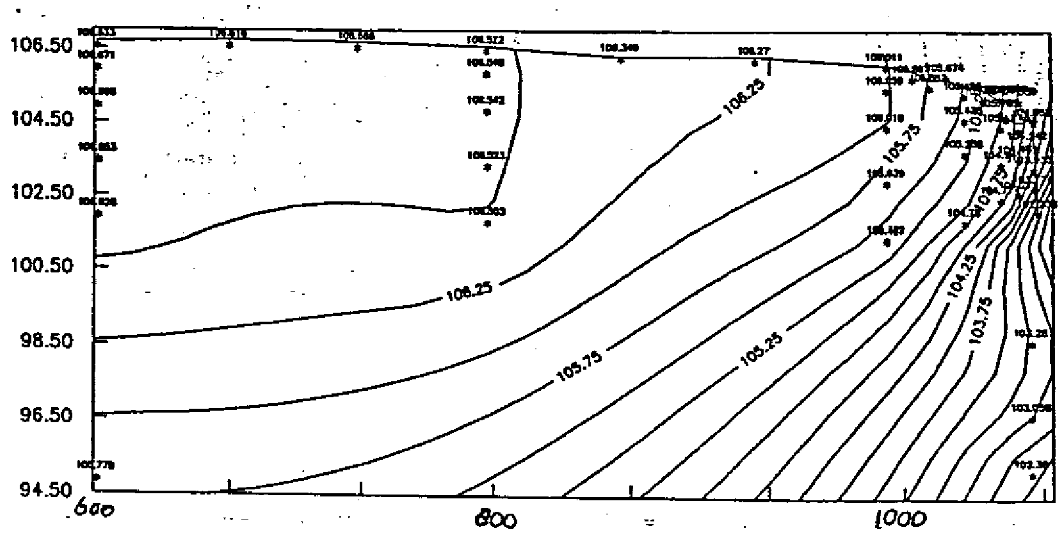


F9

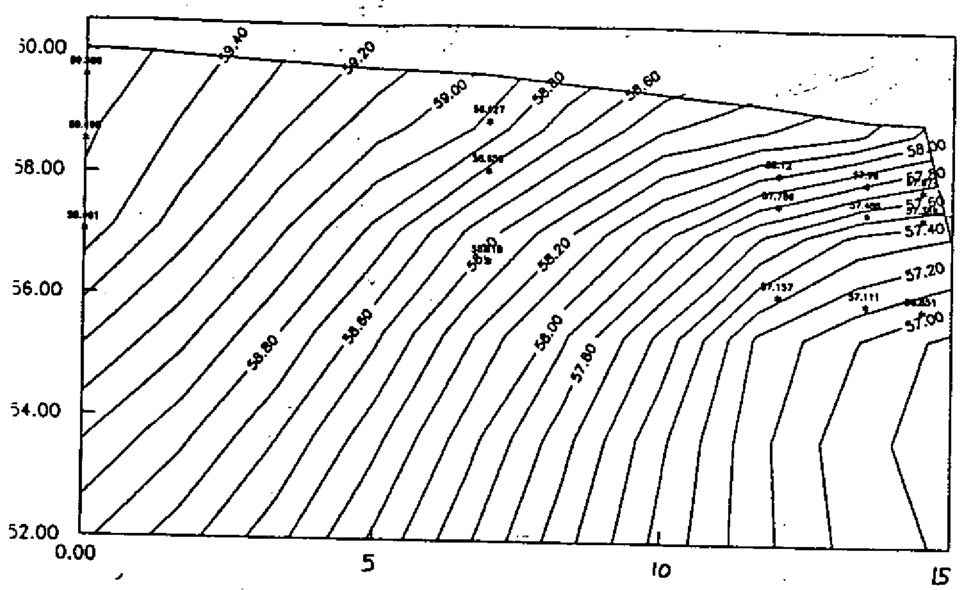
Equipotential lines NS transect south+ 20-11-90



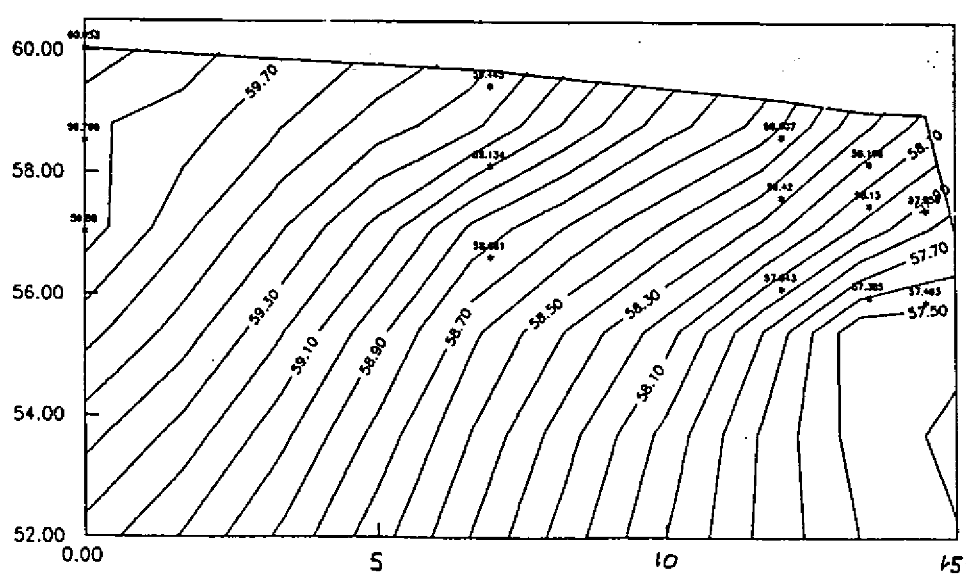
Equipotential lines NS transect north+ 20-11-90



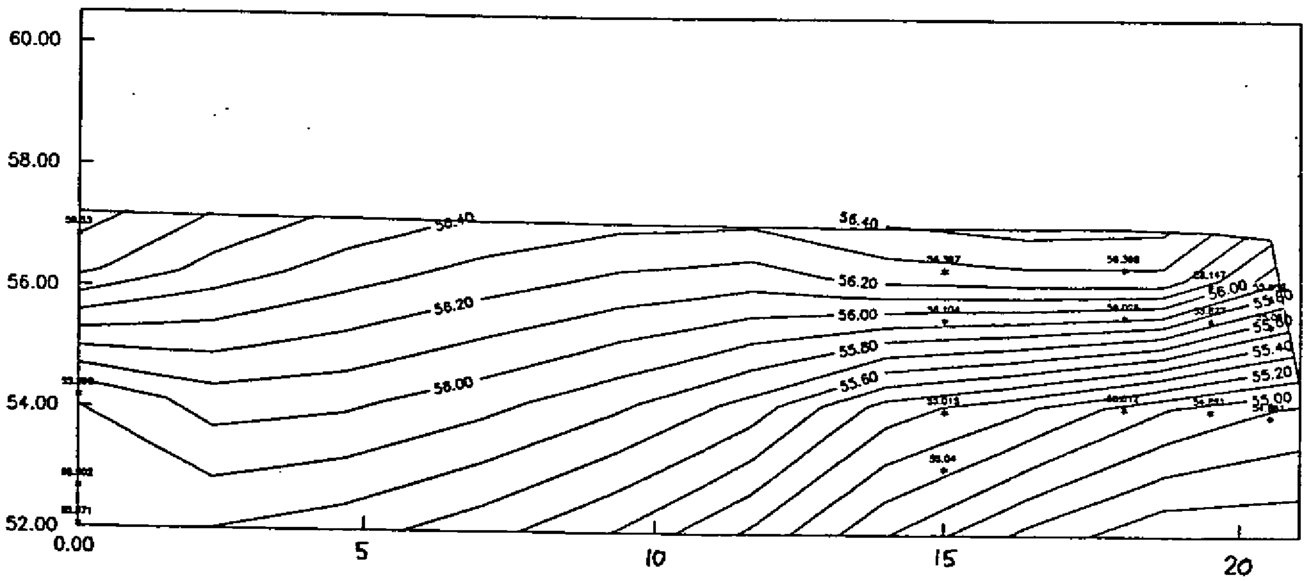
Equipotential lines old facebank 11-9-90



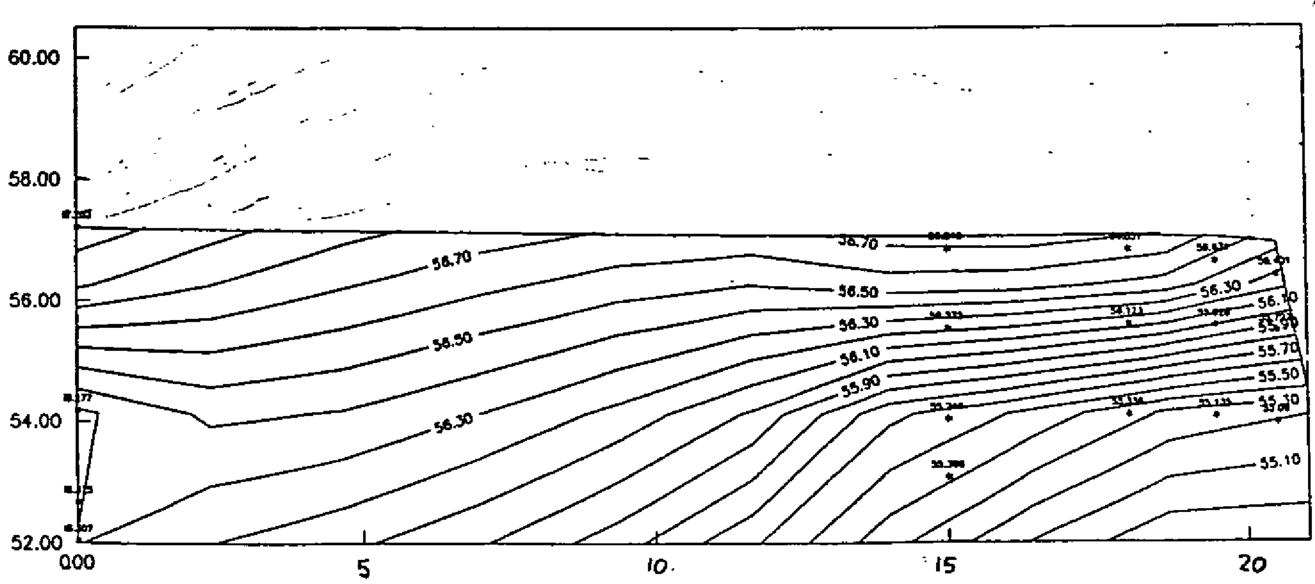
Equipotential lines old facebank 19-11-90



Equipotential lines new facebank 11-9-90



Equipotential lines new facebank 19-11-90



APPENDIX G

The plots at Clara east

G2 Plot A1 (tubes 1-5)

G5 Plot A2 (tubes 6-10)

G8 Plot A3 (tubes 11-15)

G11 Photographs of plot A

G13 Plot B1 (tubes 16-20)

G16 Plot B2 (tubes 21-25)

G19 Plot B3 (tubes 26-30)

G22 Photographs of plot B

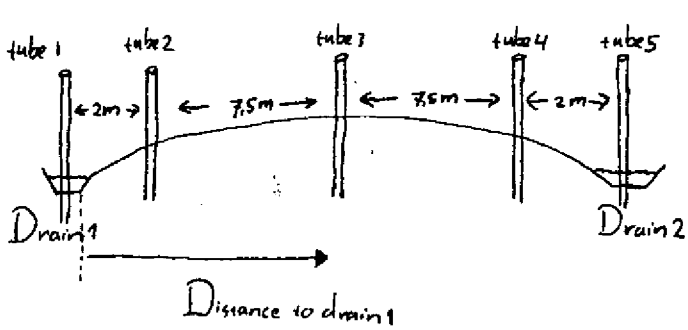
G24 Plot C1 (tubes 31-35)

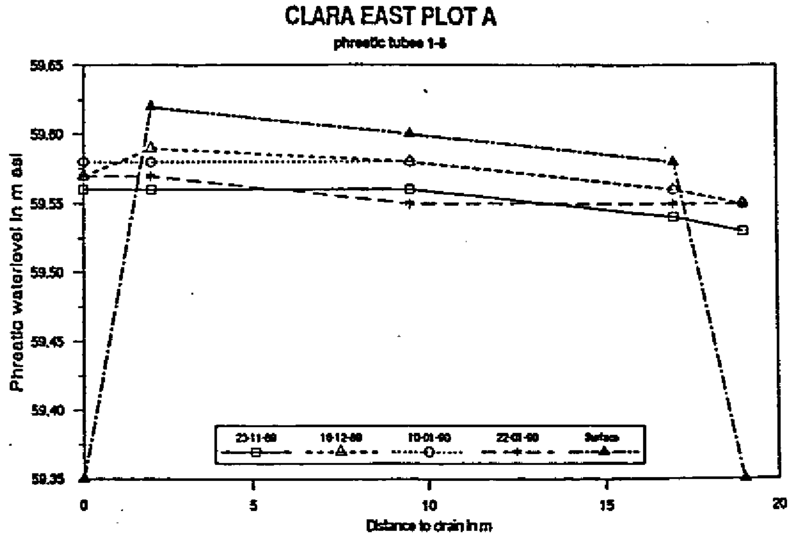
G27 Plot C2 (tubes 36-40)

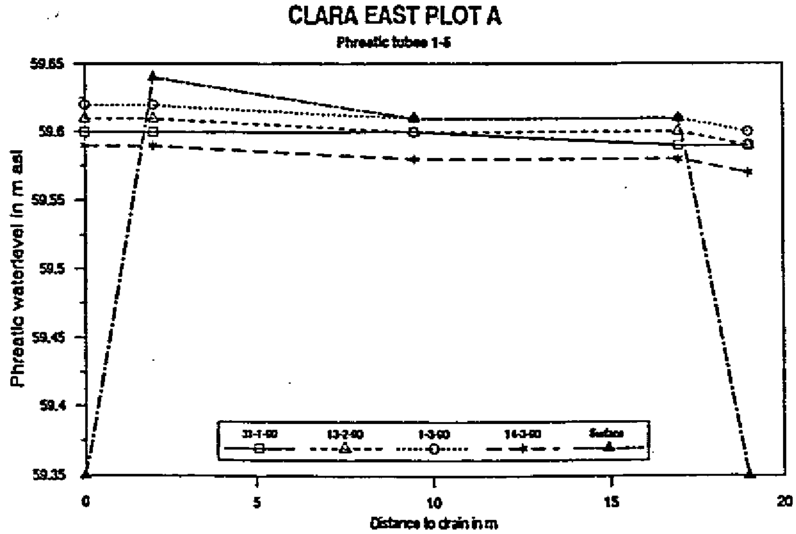
G30 Plot C3 (tubes 41-45)

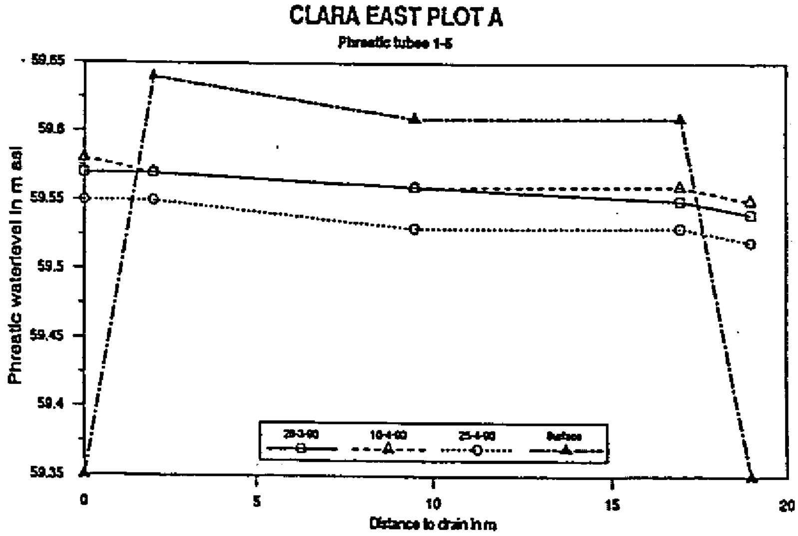
G33 Photographs of plot C

Situation



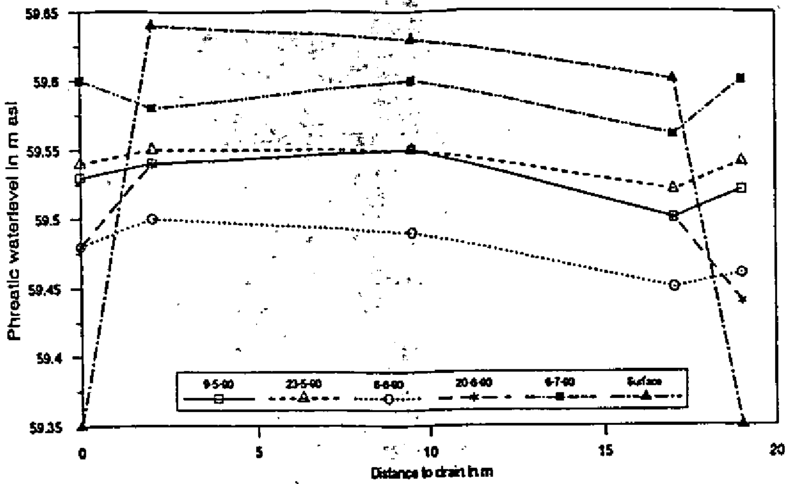

CLARA EAST PLOT A
phreatic tubes 1-5
Phreatic waterlevel in m asl
59.65
59.60
59.55
59.50
59.45
59.40
59.35
0
5
10
15
20
Distance to drain in m
10-01-90
22-01-90
Surface


CLARA EAST PLOT A
Phreatic tubes 1-5
Phreatic waterlevel in m asl
59.65
59.6
59.55
59.5
59.45
59.4
59.35
0
5
10
15
20
Distance to drain in m
13-2-90
1-3-90
14-3-90
Surface


CLARA EAST PLOT A
Phreatic tubes 1-5
Phreatic waterlevel in m asl
59.65
59.6
59.55
59.5
59.45
59.4
59.35
0
5
10
15
20
Distance to drain in m
29-3-90
10-4-90
25-4-90
Surface

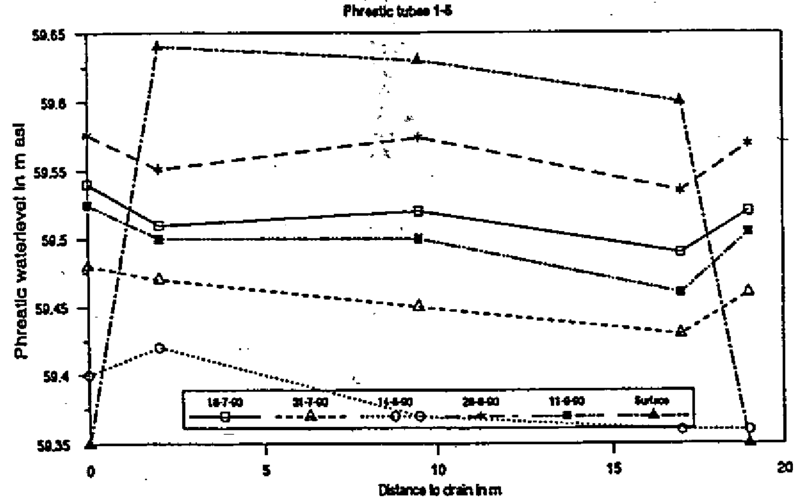
CLARA EAST PLOT A

phreatic tubes 1-5



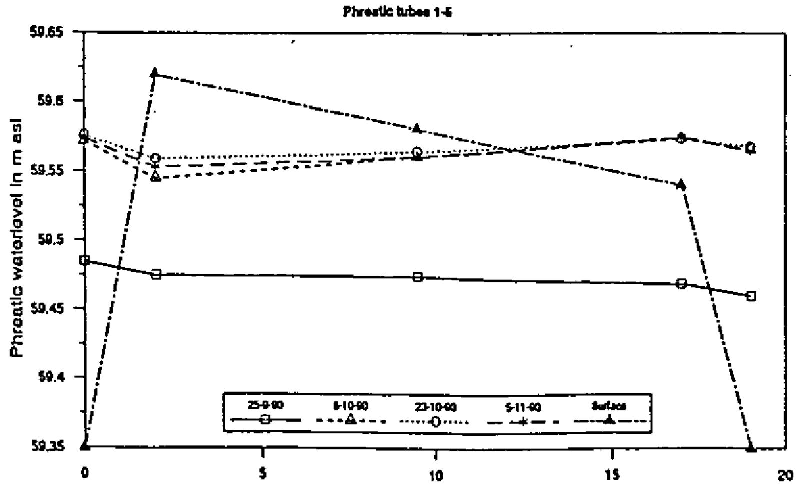
CLARA EAST PLOT A

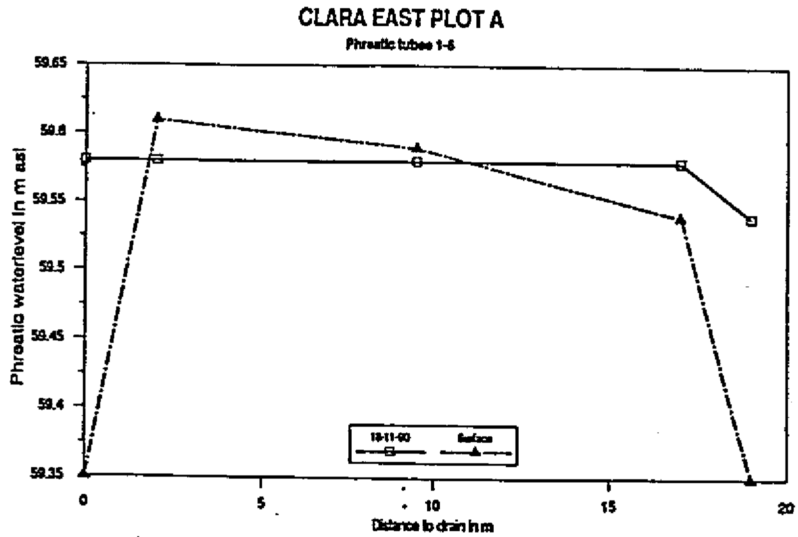
Phreatic tubes 1-5

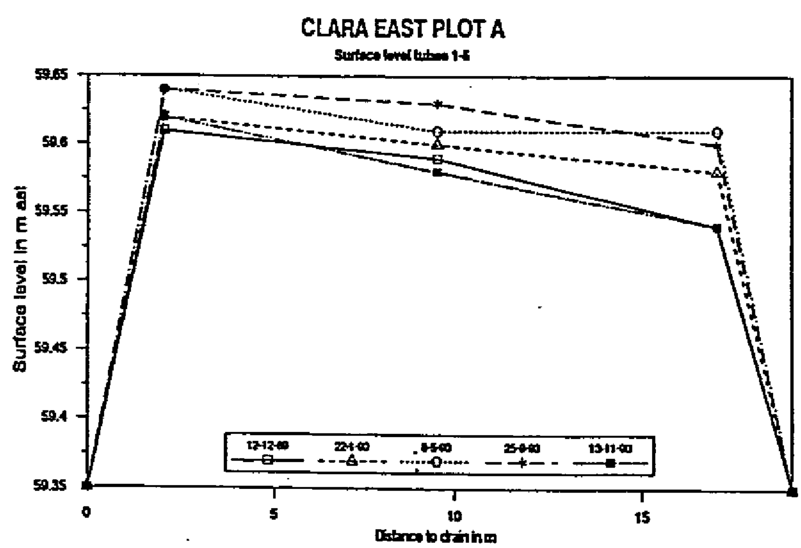


CLARA EAST PLOT A

Phreatic tubes 1-5



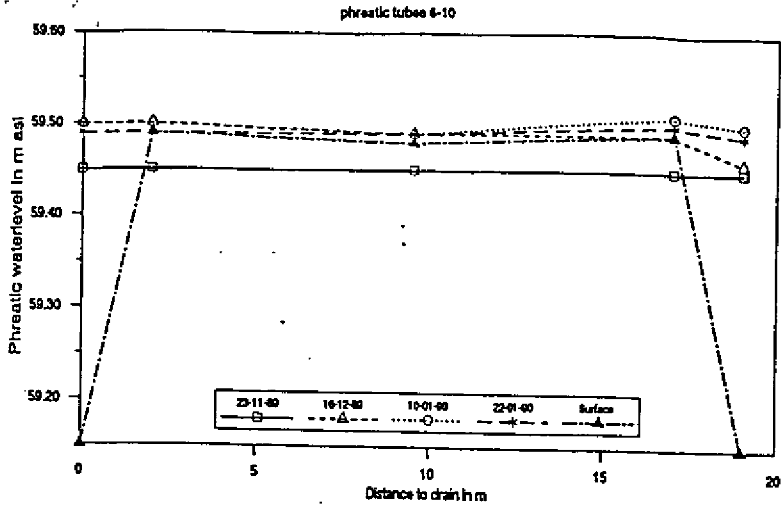

CLARA EAST PLOT A
Phreatic tubes 1-6
Phreatic waterlevel in m asl
59.65
59.6
59.55
59.5
59.45
59.4
59.35
0
5
10
15
20
Distance to drain in m
Surface


CLARA EAST PLOT A
Surface level tubes 1-6
Surface level in m asl
59.65
59.6
59.55
59.5
59.45
59.4
59.35
0
5
10
15
Distance to drain in m

81

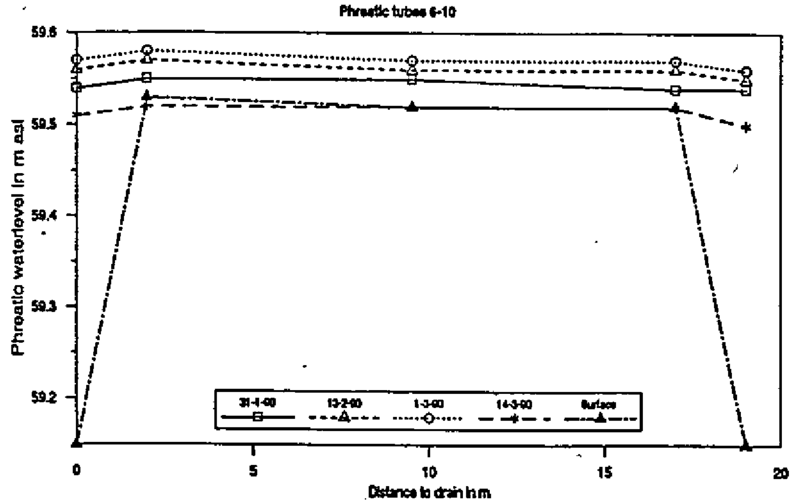
CLARA EAST PLOT A

phreatic tubes 6-10



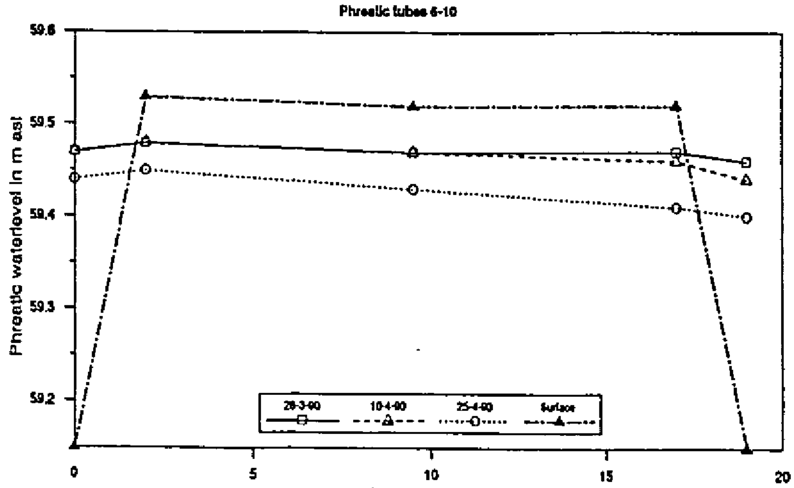
CLARA EAST PLOT A

Phreatic tubes 6-10



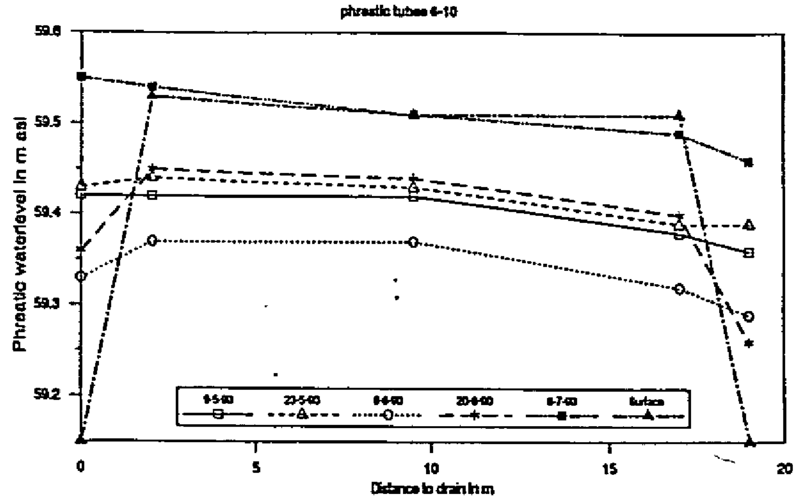
CLARA EAST PLOT A

Phreatic tubes 6-10



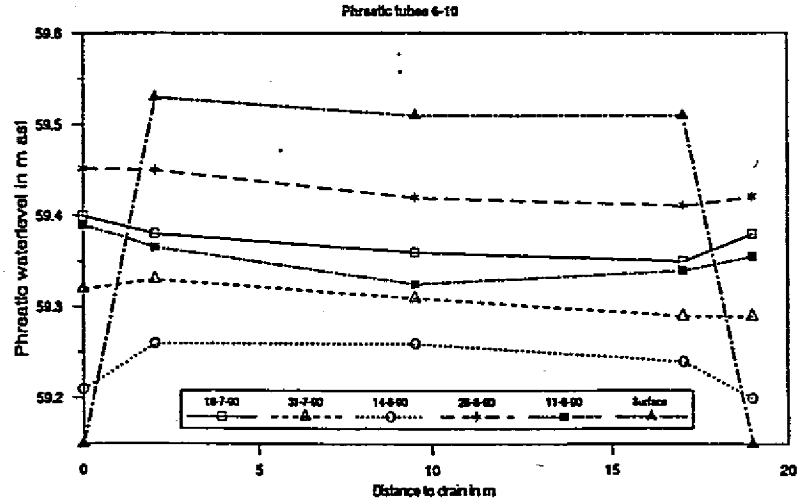
CLARA EAST PLOT A

phreatic tubes 6-10



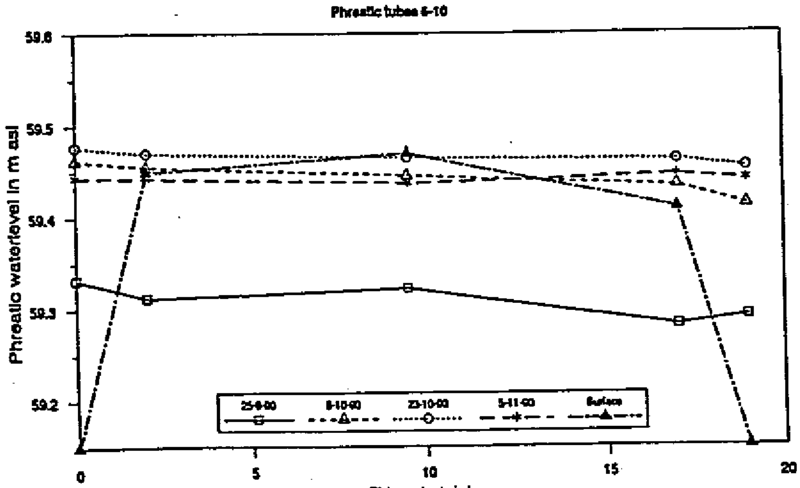
CLARA EAST PLOT A

Phreatic tubes 6-10



CLARA EAST PLOT A

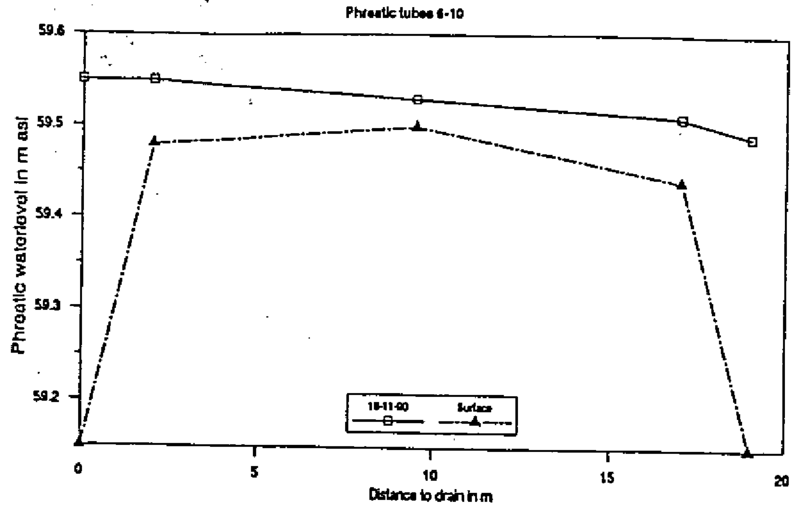
Phreatic tubes 6-10



G6

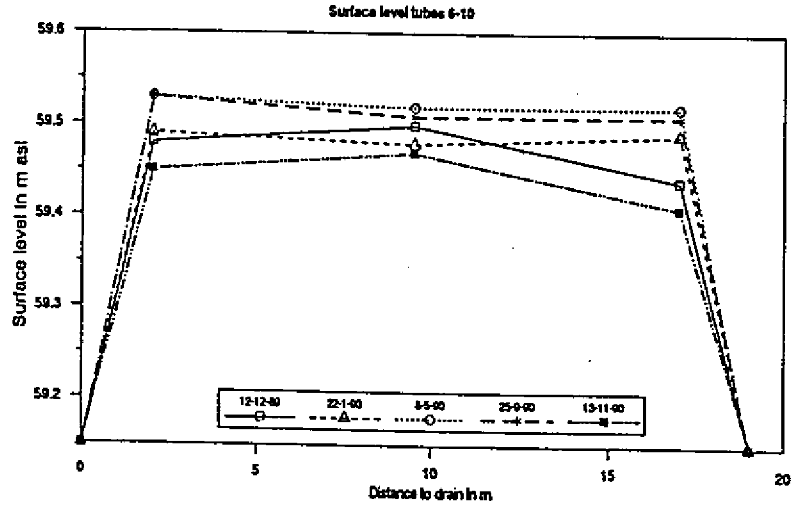
CLARA EAST PLOT A

Phreatic tubes 6-10



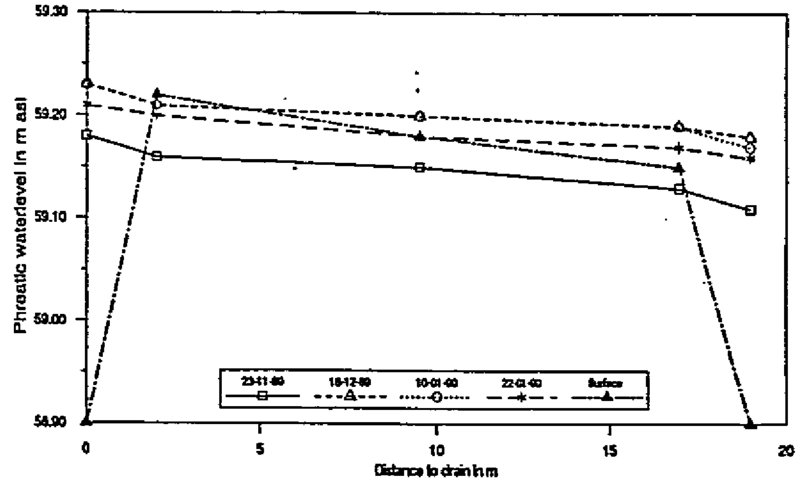
CLARA EAST PLOT A

Surface level tubes 6-10



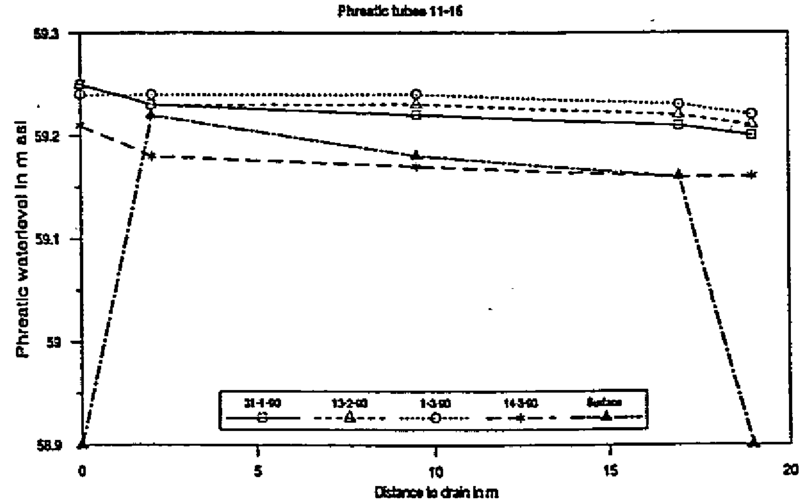
CLARA EAST PLOT A

phreatic tubes 11-16



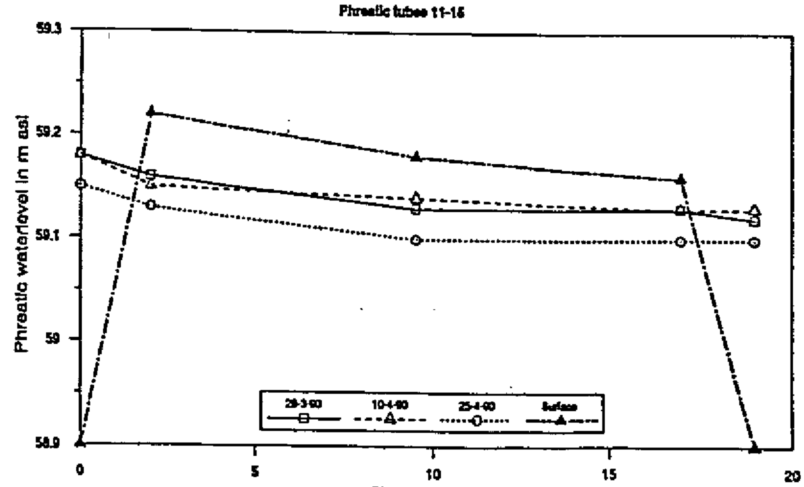
CLARA EAST PLOT A

Phreatic tubes 11-16



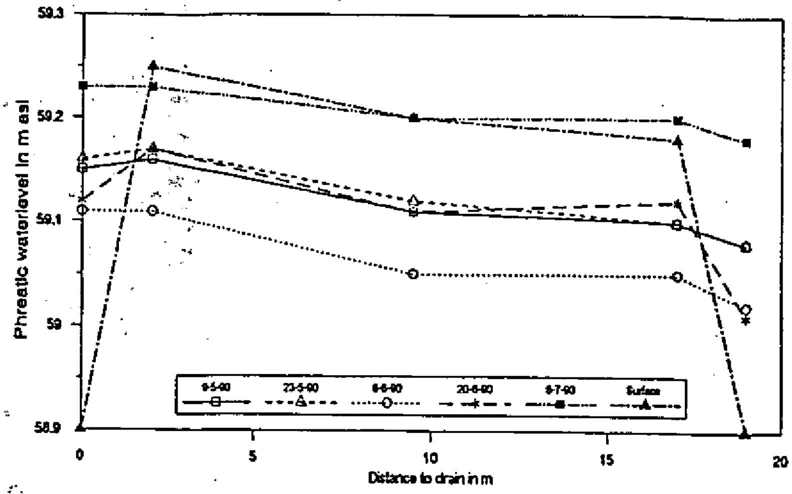
CLARA EAST PLOT A

Phreatic tubes 11-16



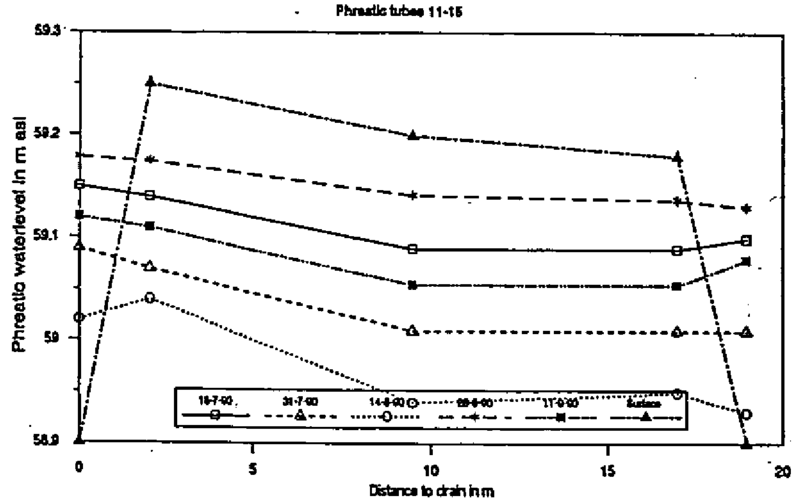
CLARA EAST PLOT A

phreatic tubes 11-15



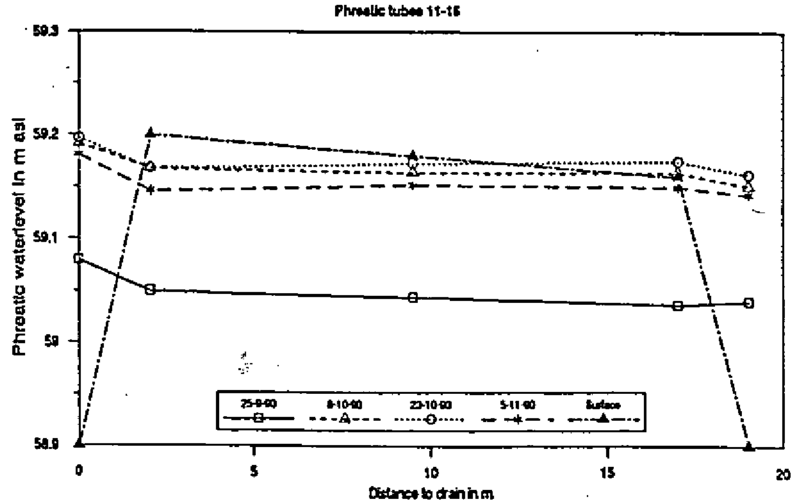
CLARA EAST PLOT A

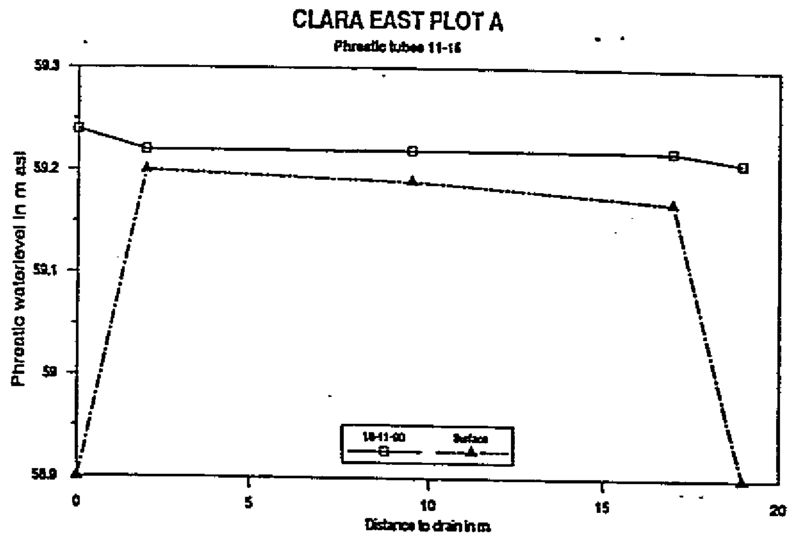
Phreatic tubes 11-15

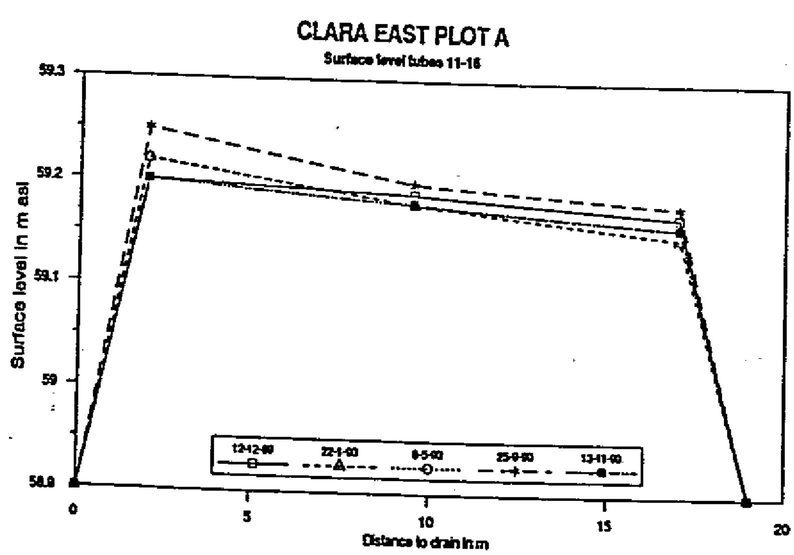


CLARA EAST PLOT A

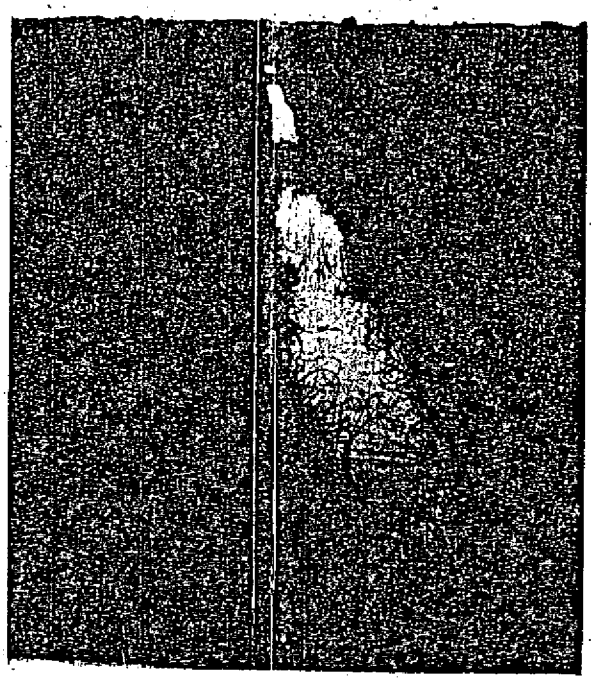
Phreatic tubes 11-15




CLARA EAST PLOT A
Phreatic tubes 11-16
59.3
59.2
59.1
59
58.9
Phreatic waterlevel in m asl
0
5
10
15
20
Surface
Distance to drain in m

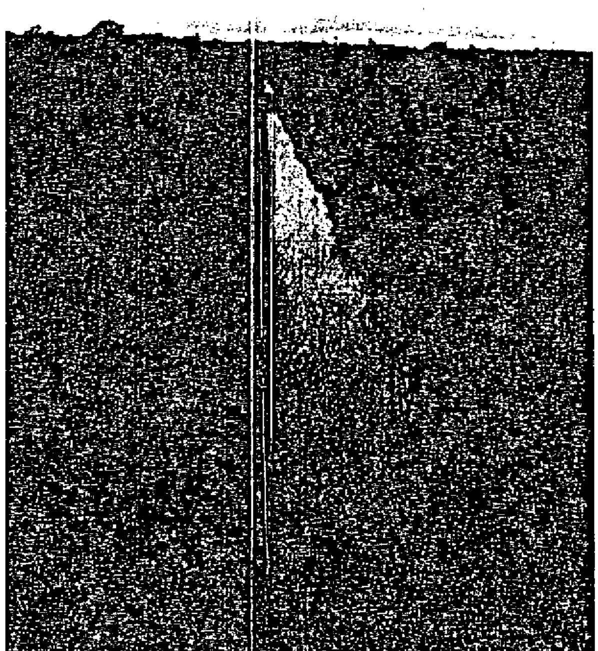

CLARA EAST PLOT A
Surface level tubes 11-16
59.3
59.2
59.1
59
58.9
Surface level in m asl
0
5
10
15
20
Distance to drain in m

G10

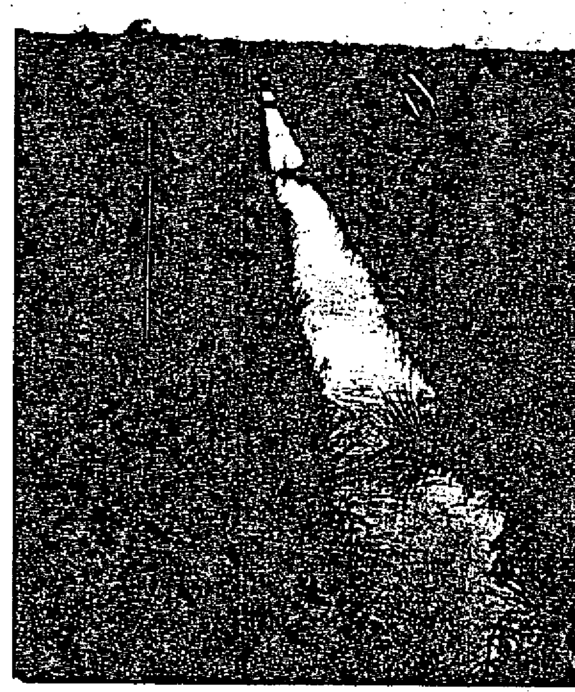


A1, drain 1

A1, drain 5

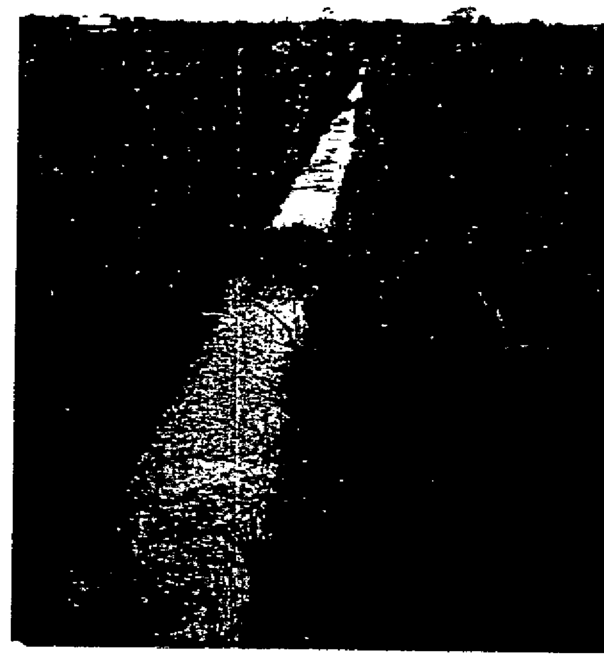


A2, drain 6



A2, drain 10

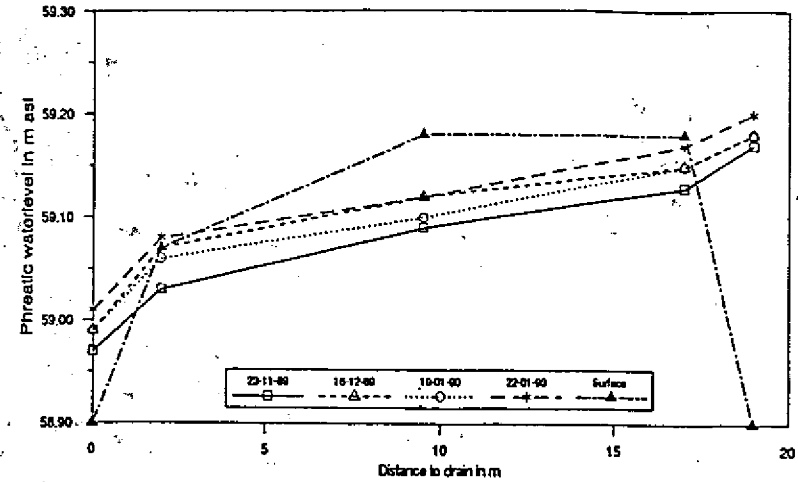
A3, drain 11



A3, drain 15

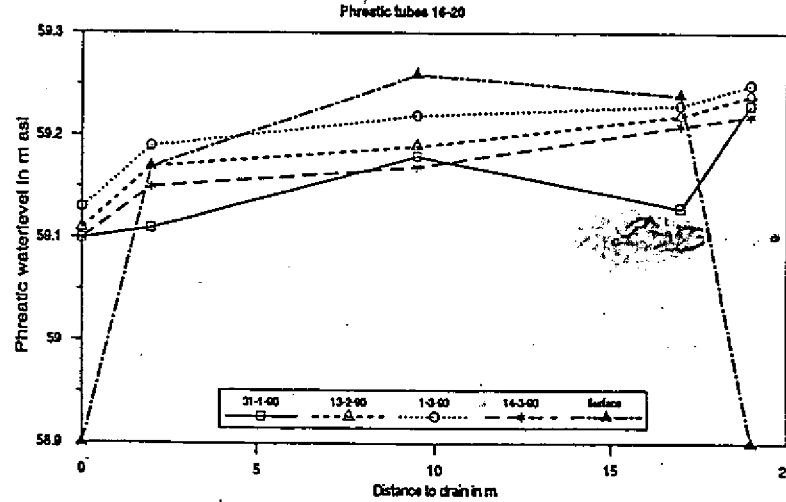
CLARA EAST PLOT B

phreatic tubes 16-20



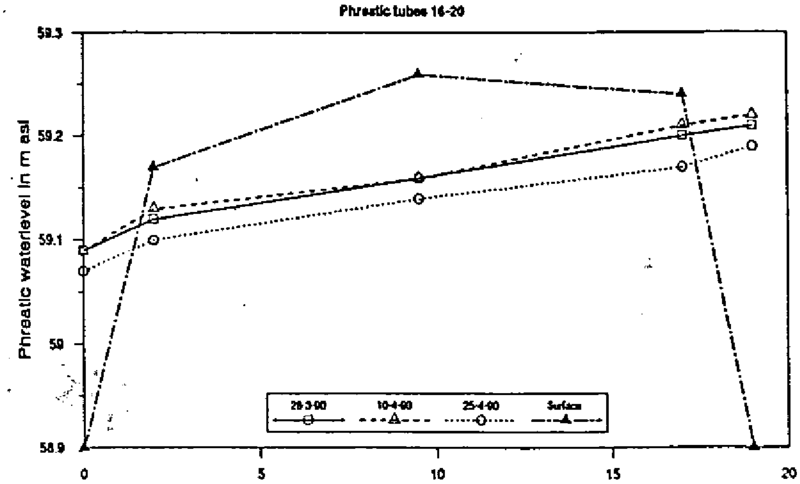
CLARA EAST PLOT B

Phreatic tubes 16-20



CLARA EAST PLOT B

Phreatic tubes 16-20

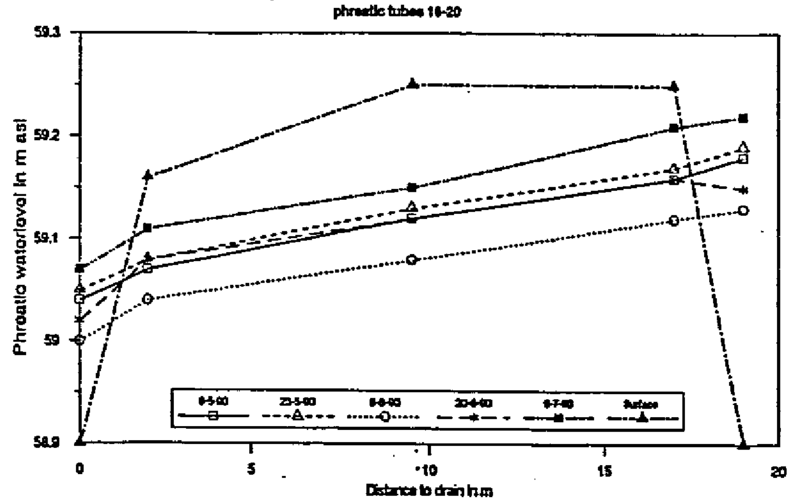


G13

90

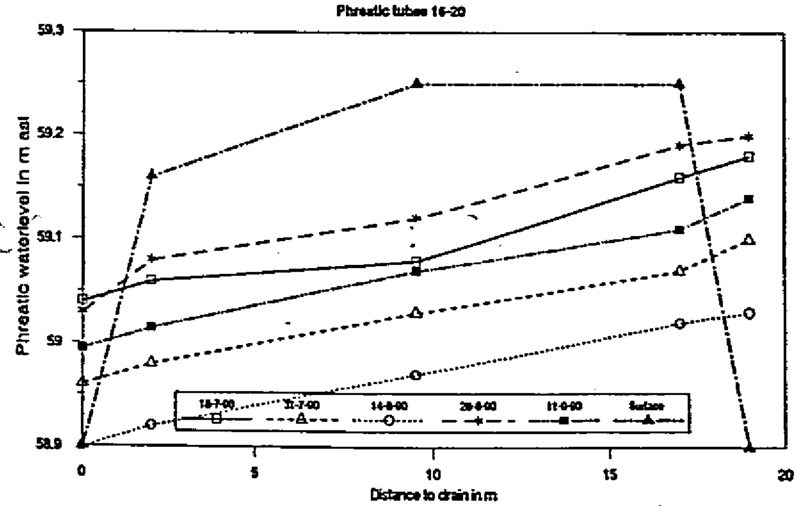
CLARA EAST PLOT B

phreatic tubes 16-20



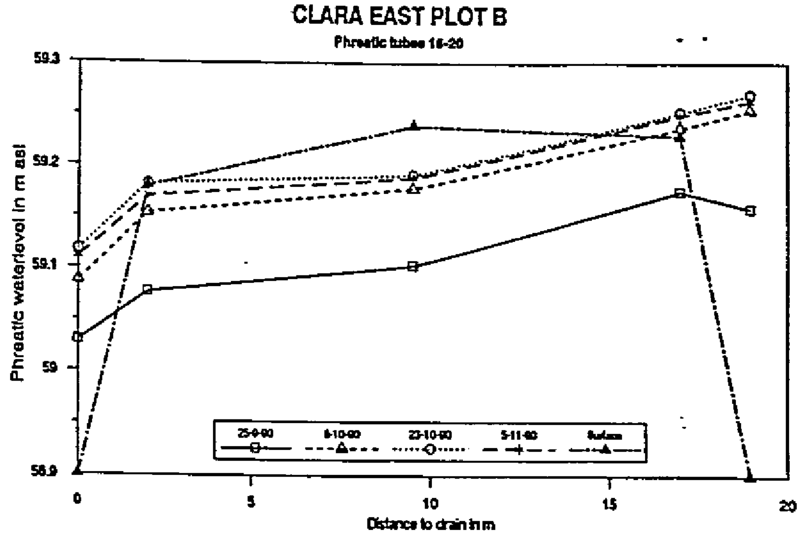
CLARA EAST PLOT B

Phreatic tubes 16-20



CLARA EAST PLOT B

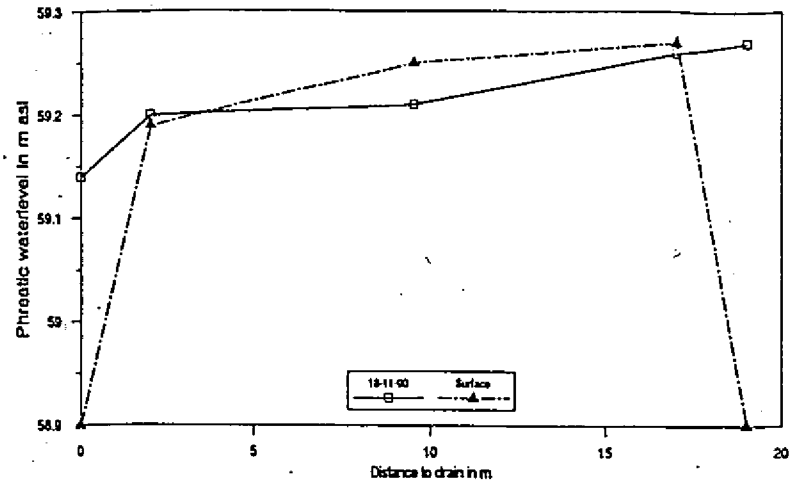
Phreatic tubes 16-20



G14

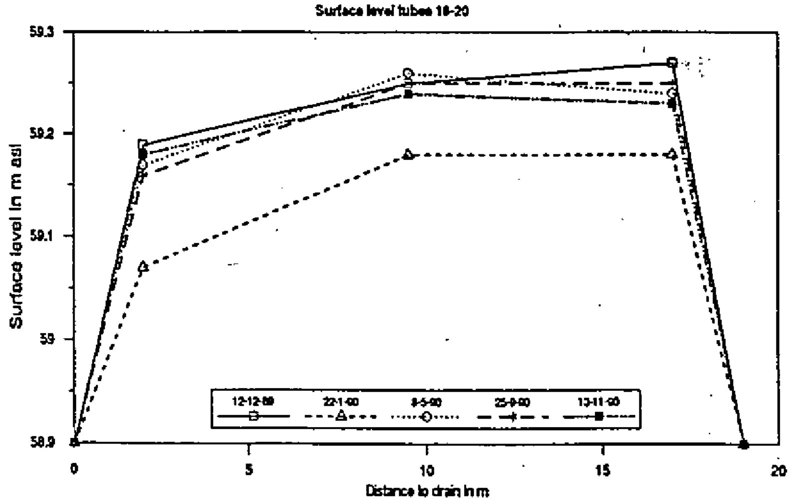
CLARA EAST PLOT B

Phreatic tubes 16-20



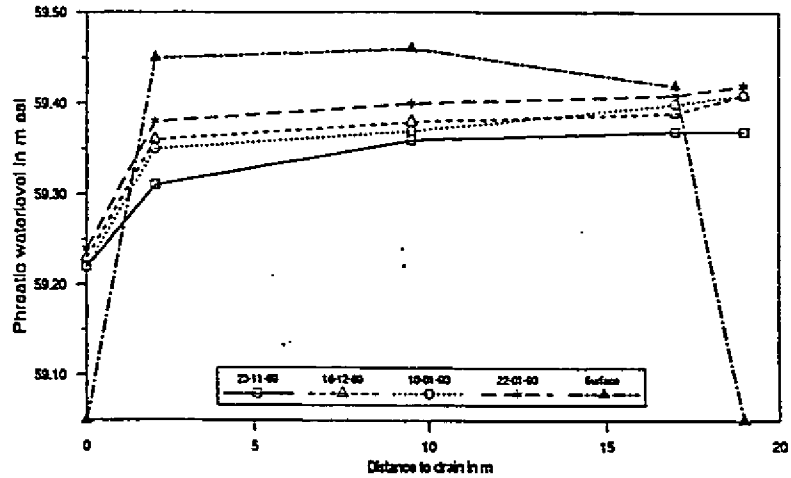
CLARA EAST PLOT B

Surface level tubes 16-20



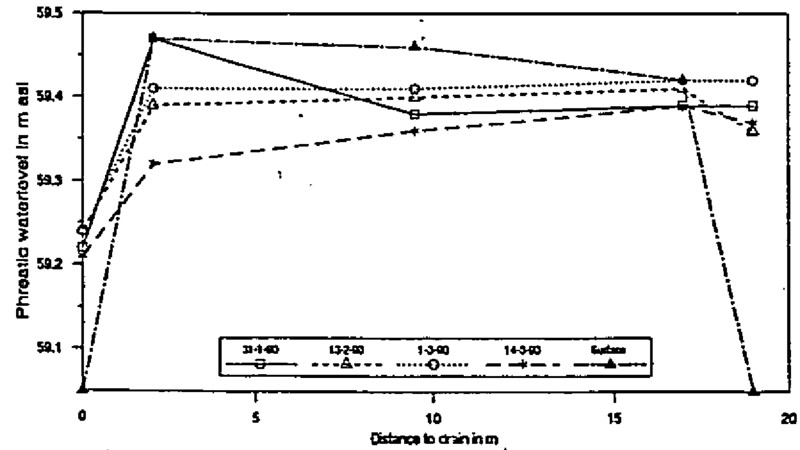
CLARA EAST PLOT B

phreatic tubes 21-25



CLARA EAST PLOT B

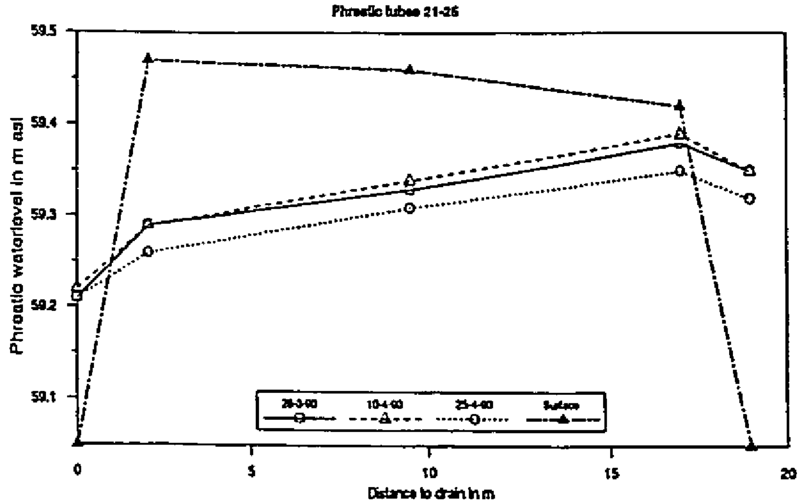
Phreatic tubes 21-25



The water level measured at 31-1-00 is probably a measuring fault

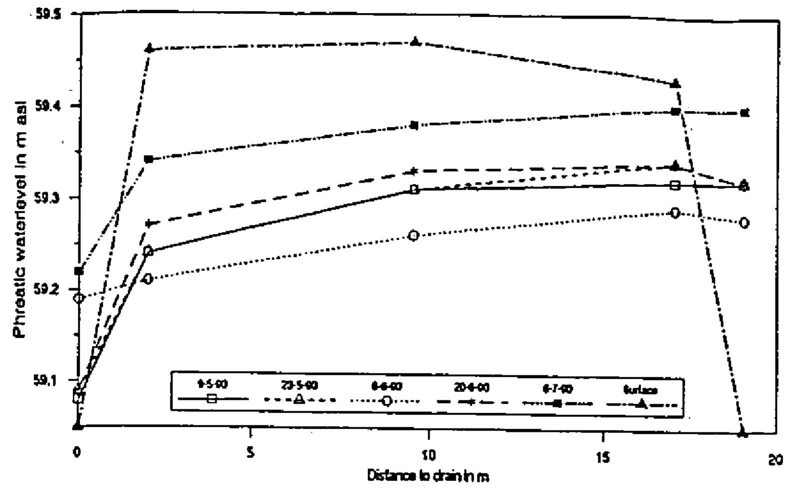
CLARA EAST PLOT B

Phreatic tubes 21-25

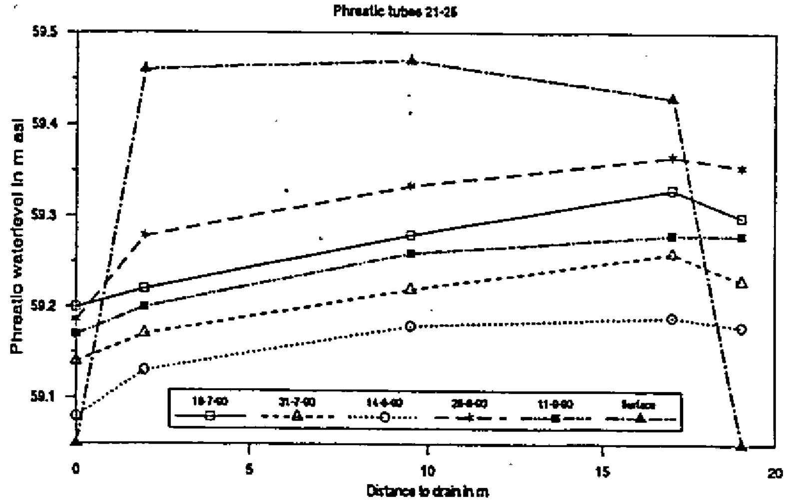


G16

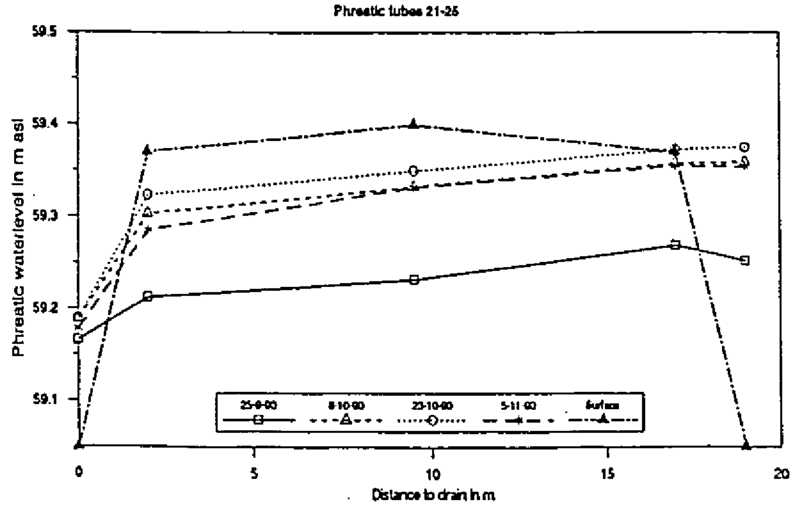
CLARA EAST PLOT B
phreatic tubes 21-25



CLARA EAST PLOT B
Phreatic tubes 21-25



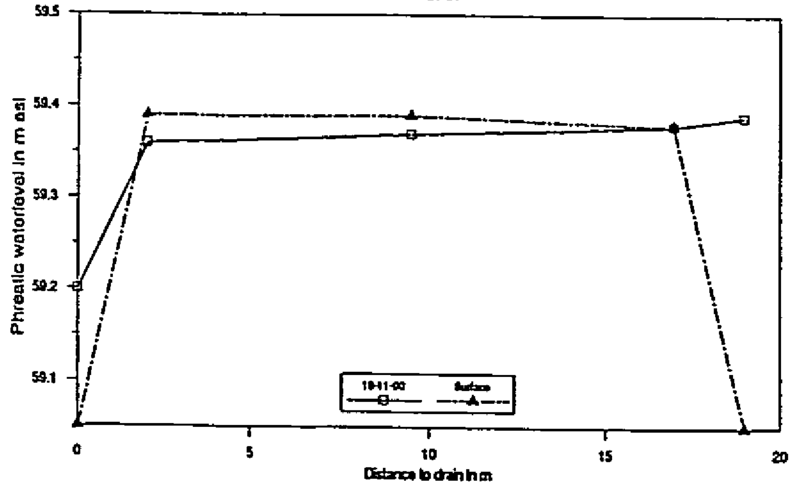
CLARA EAST PLOT B
Phreatic tubes 21-25



G17

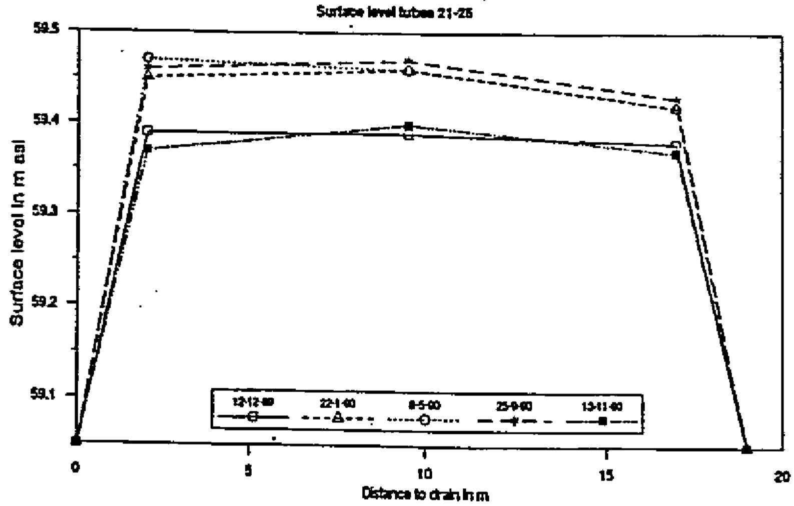
CLARA EAST PLOT B

Phreatic tubes 21-25



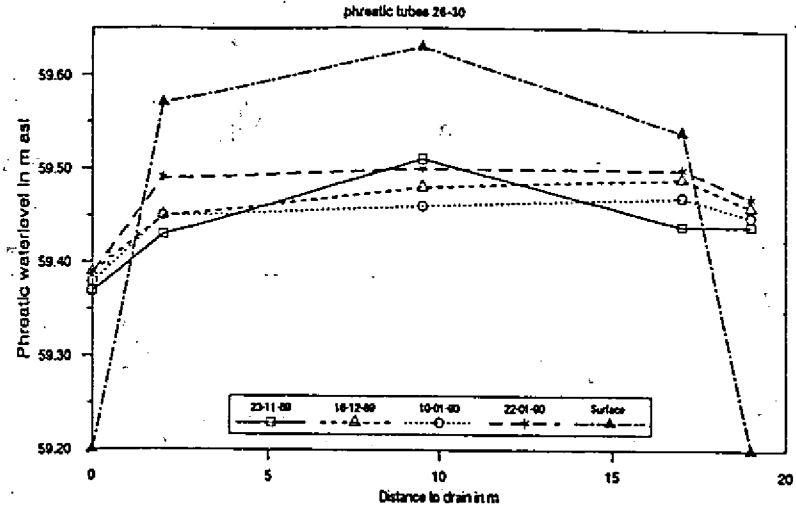
CLARA EAST PLOT B

Surface level tubes 21-25



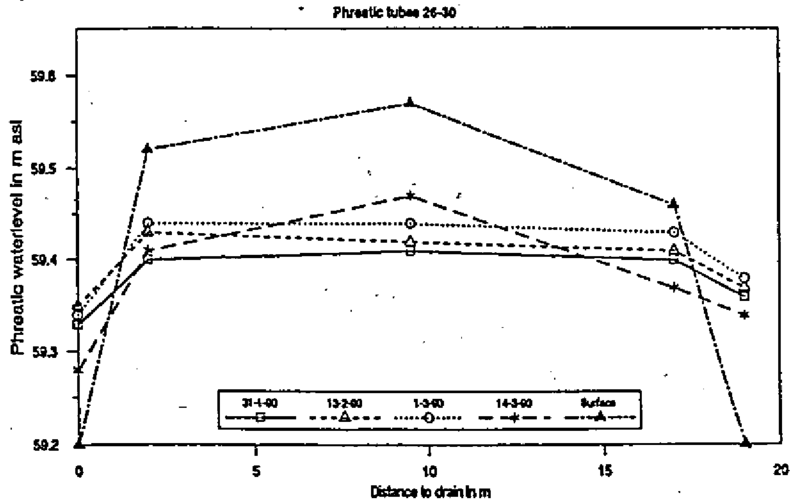
CLARA EAST PLOT B

phreatic tubes 26-30



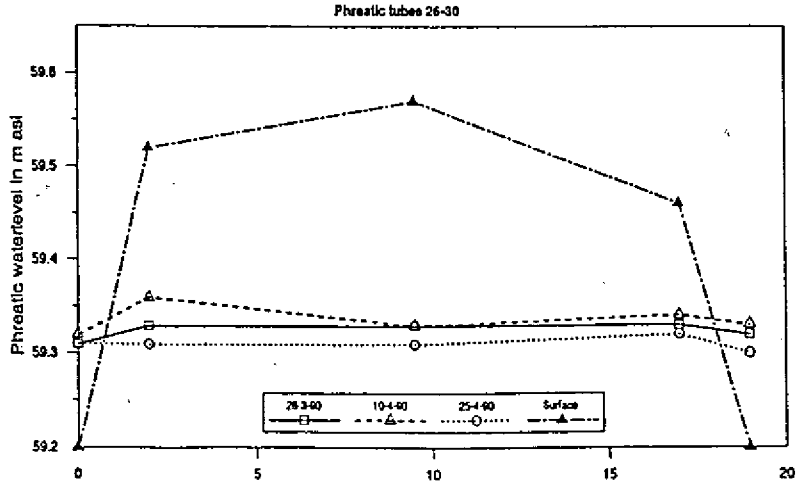
CLARA EAST PLOT B

Phreatic tubes 26-30



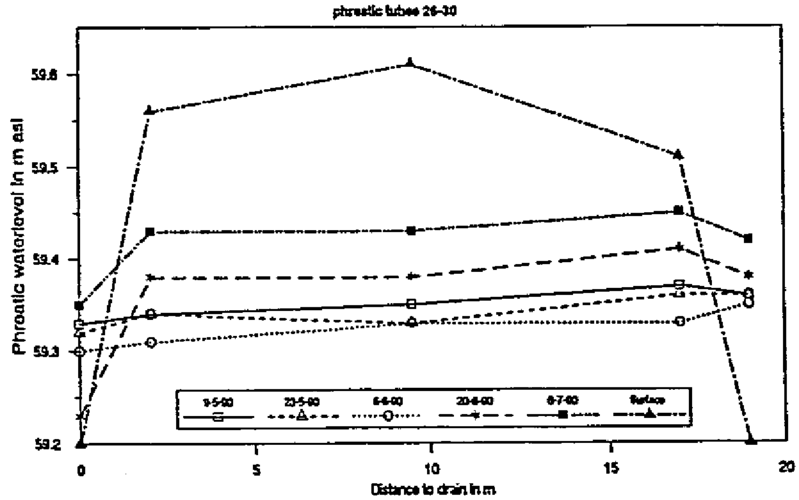
CLARA EAST PLOT B

Phreatic tubes 26-30



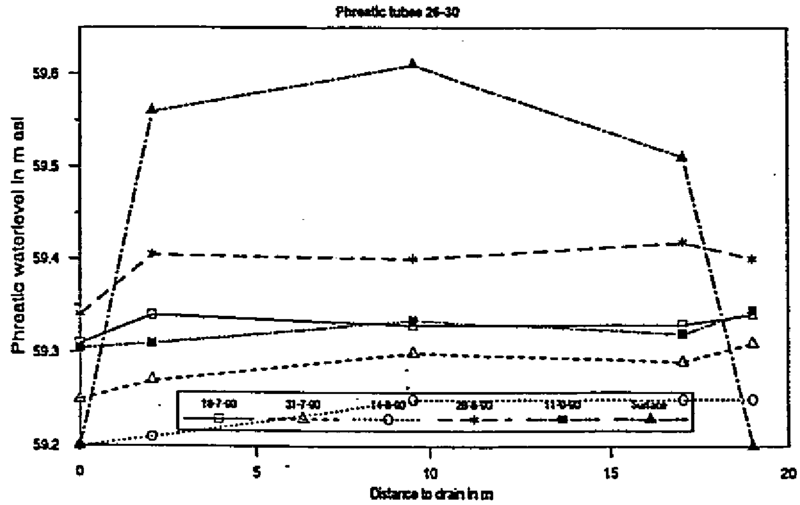
CLARA EAST PLOT B

phreatic tubes 26-30



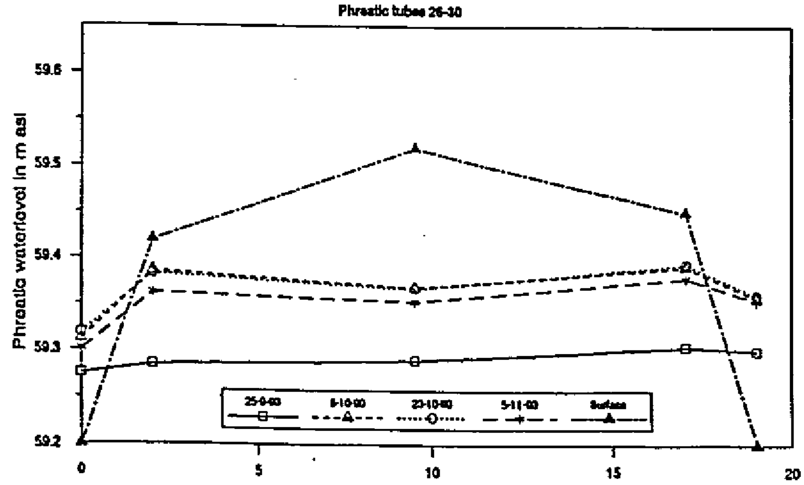
CLARA EAST PLOT B

Phreatic tubes 26-30



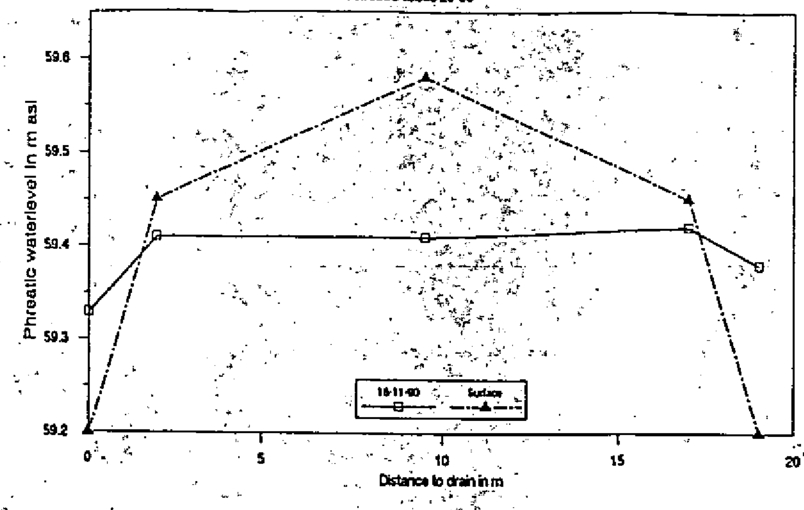
CLARA EAST PLOT B

Phreatic tubes 26-30



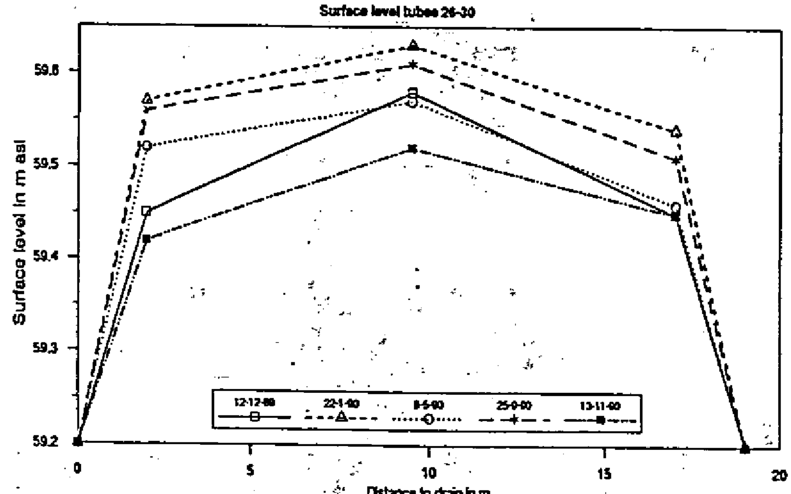
CLARA EAST PLOT B

Phreatic tubes 26-30

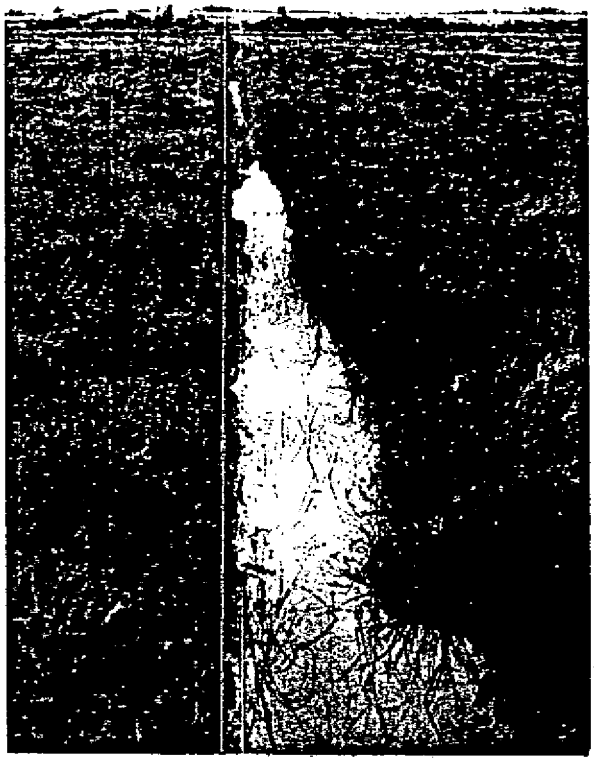


CLARA EAST PLOT B

Surface level tubes 26-30

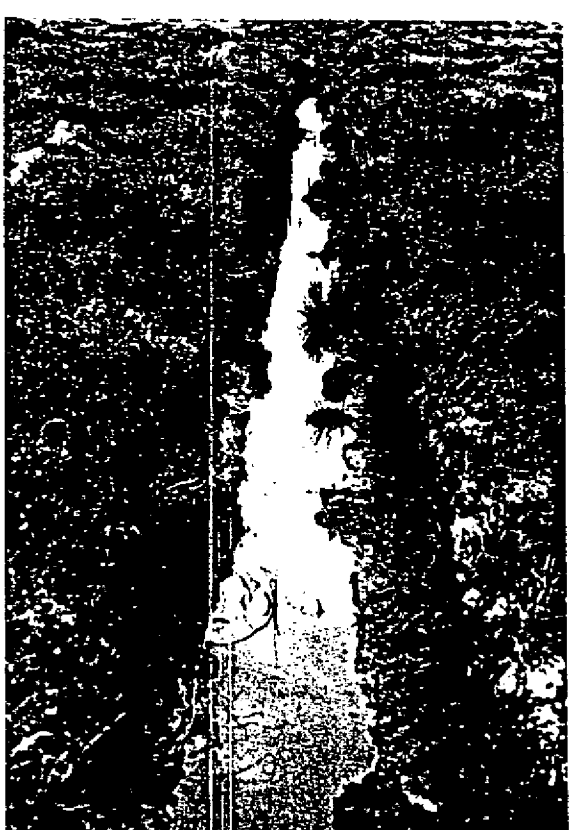


98

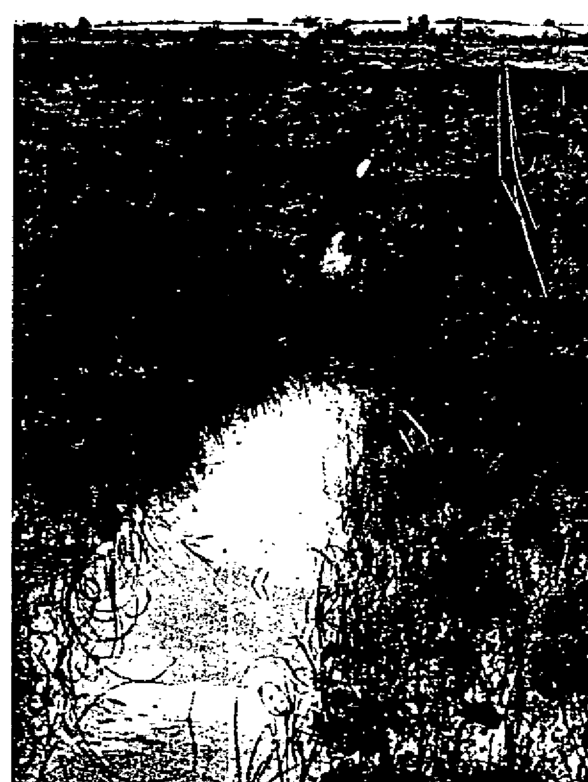


B1, drain 16

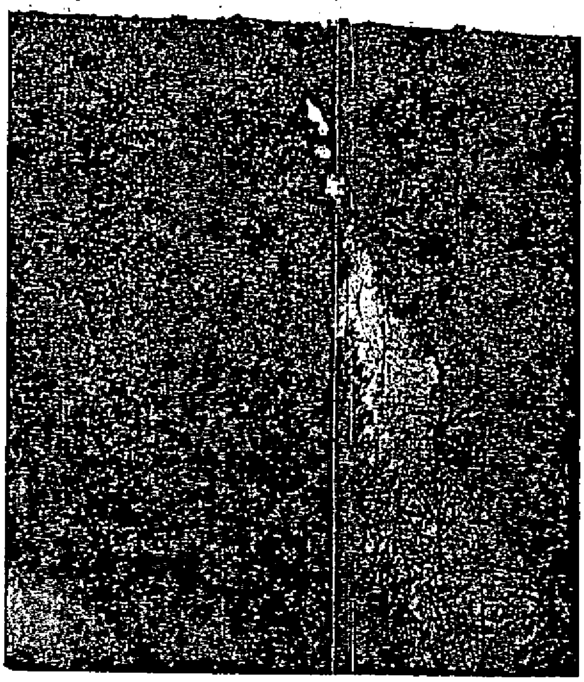
B1, drain 20



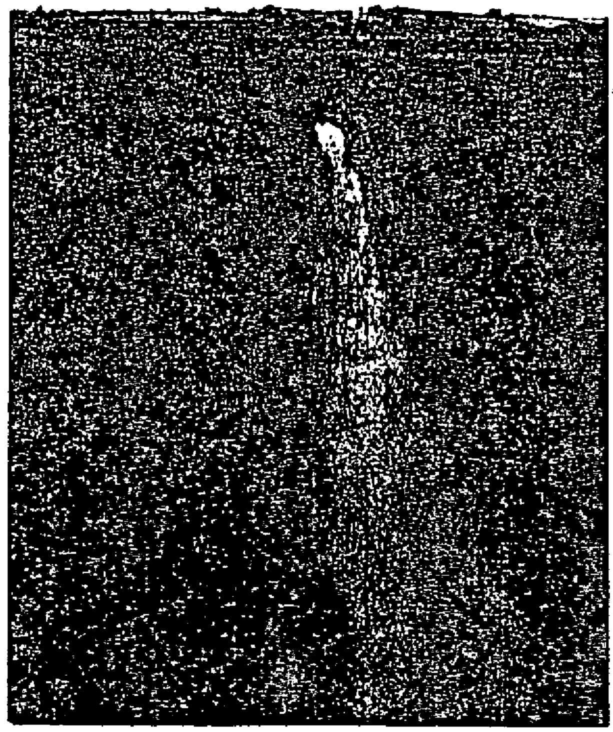
B2, drain 21



B2, drain 25



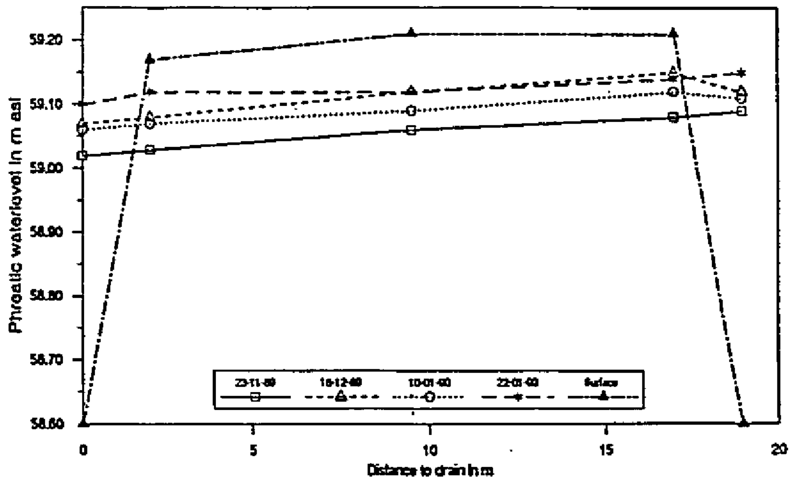
B3, drain 26



B3, drain 30

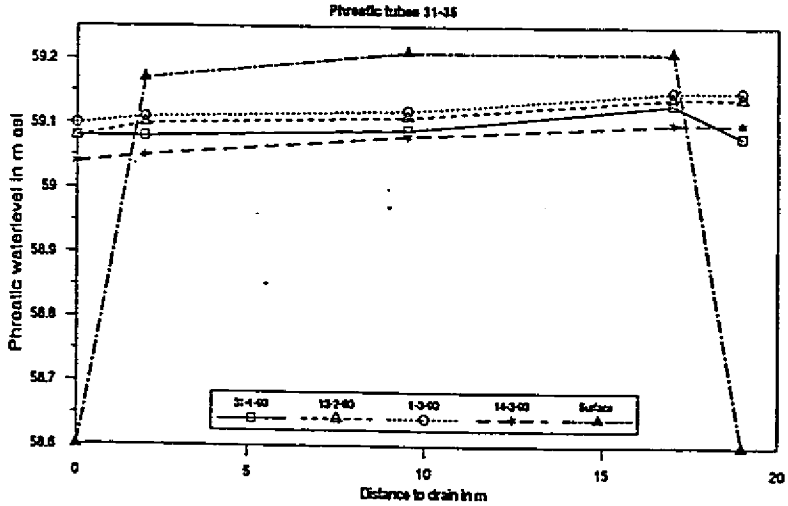
CLARA EAST PLOT C

phreatic tubes 31-35



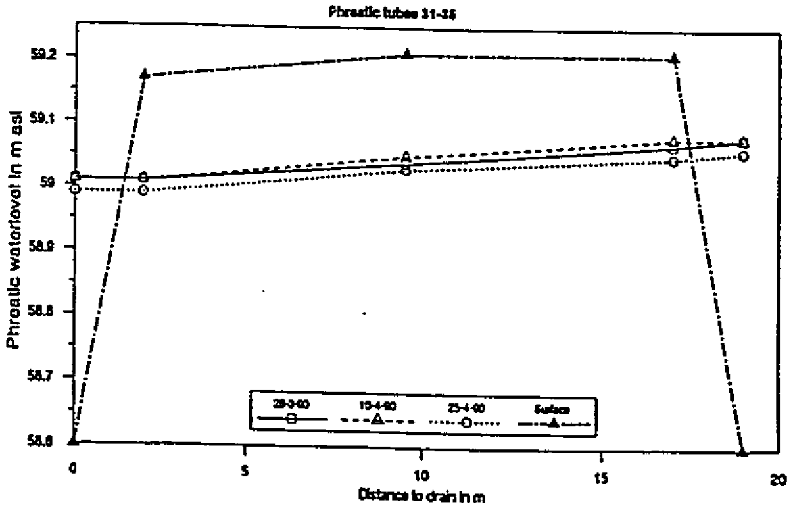
CLARA EAST PLOT C

Phreatic tubes 31-35



CLARA EAST PLOT C

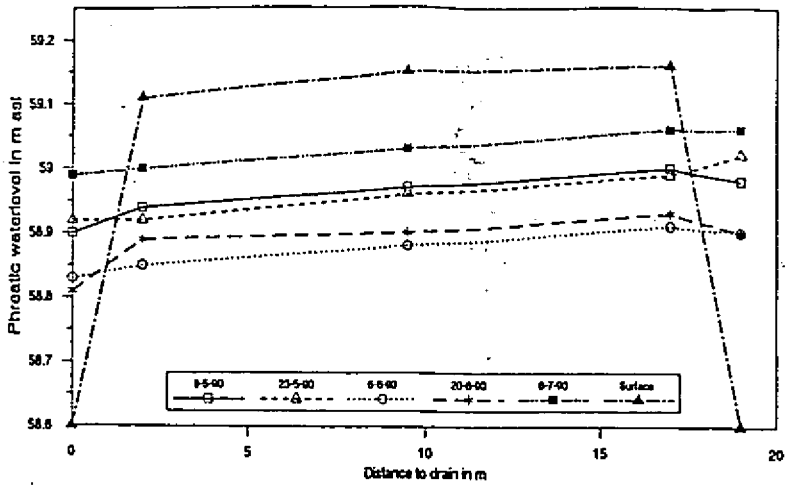
Phreatic tubes 31-35



G24

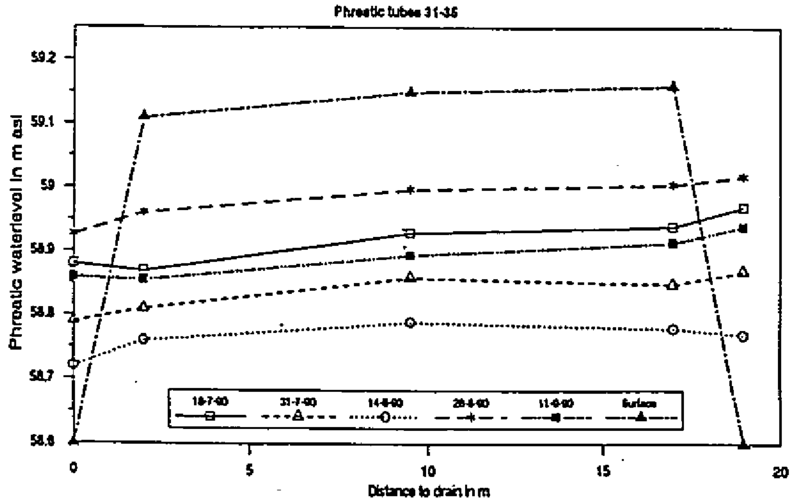
CLARA EAST PLOT C

phreatic tubes 31-35



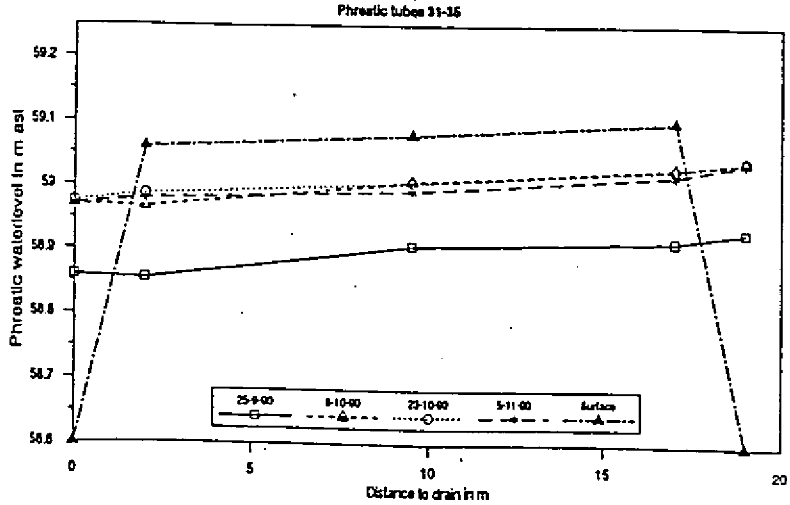
CLARA EAST PLOT C

Phreatic tubes 31-35

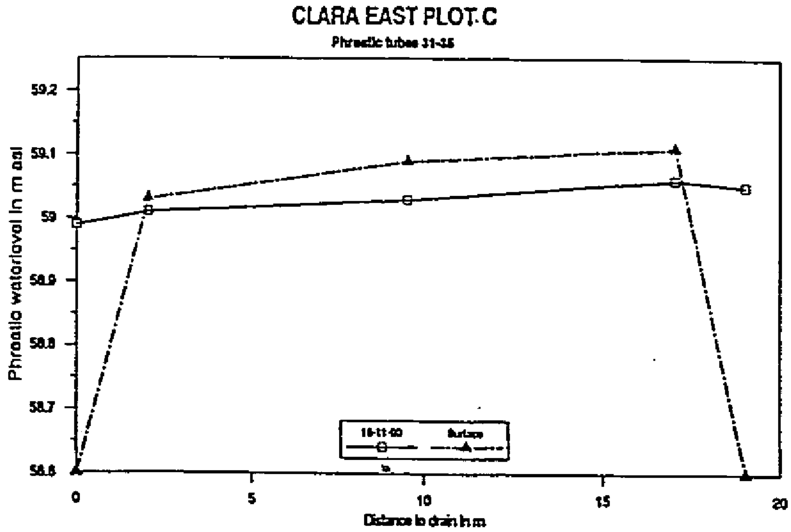


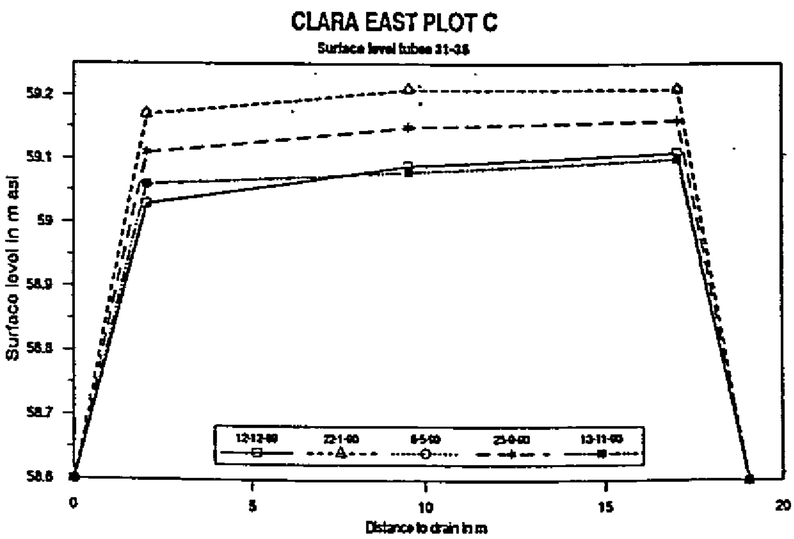
CLARA EAST PLOT C

Phreatic tubes 31-35



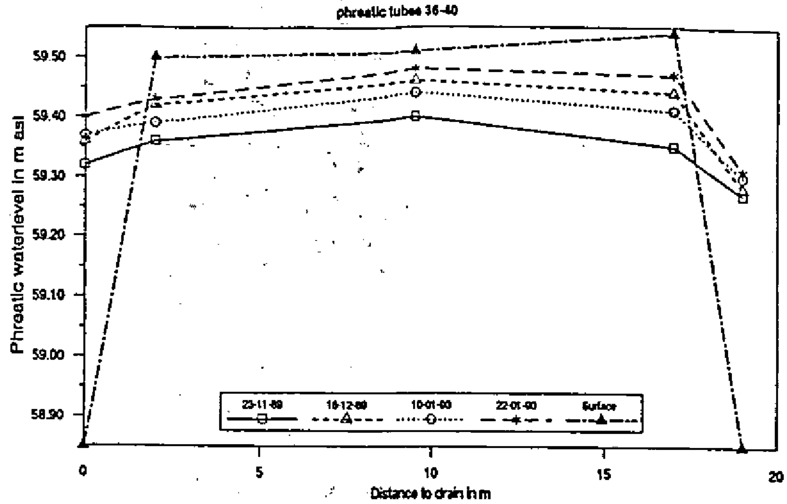
G25


CLARA EAST PLOT C
Phreatic tubes 31-35
Phreatic waterlevel in m asl
59.2
59.1
59
58.9
58.8
58.7
58.6
0
5
10
15
20
Distance to drain in m
Surface


CLARA EAST PLOT C
Surface level tubes 31-35
Surface level in m asl
59.2
59.1
59
58.9
58.8
58.7
58.6
0
5
10
15
20
Distance to drain in m

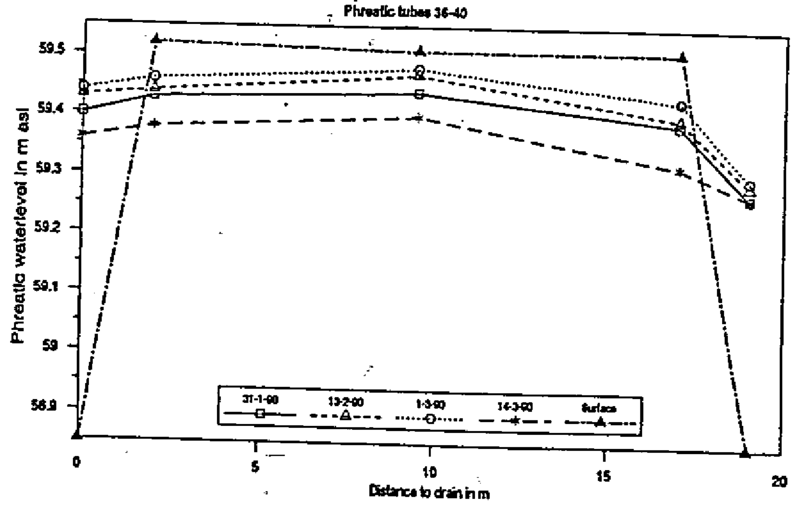
CLARA EAST PLOT C

phreatic tubes 36-40



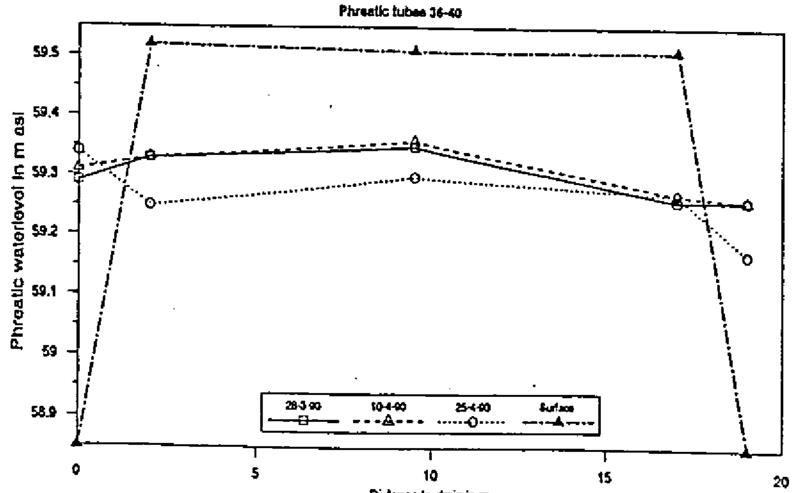
CLARA EAST PLOT C

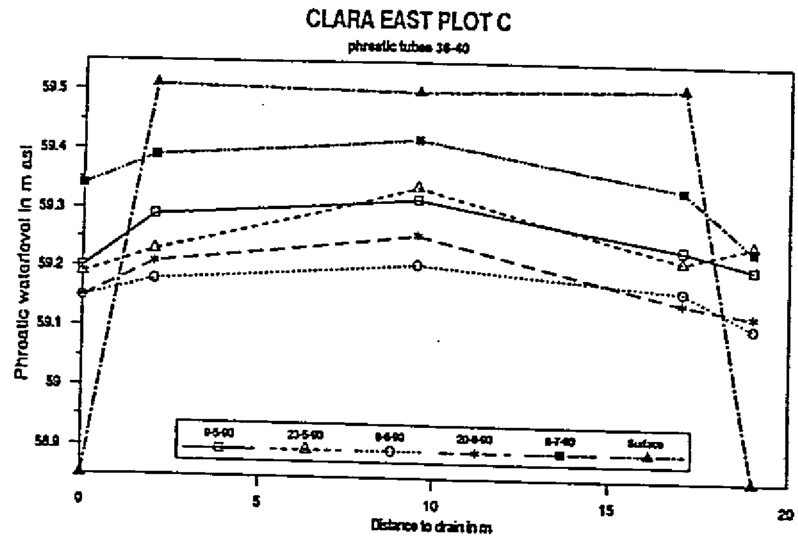
Phreatic tubes 36-40

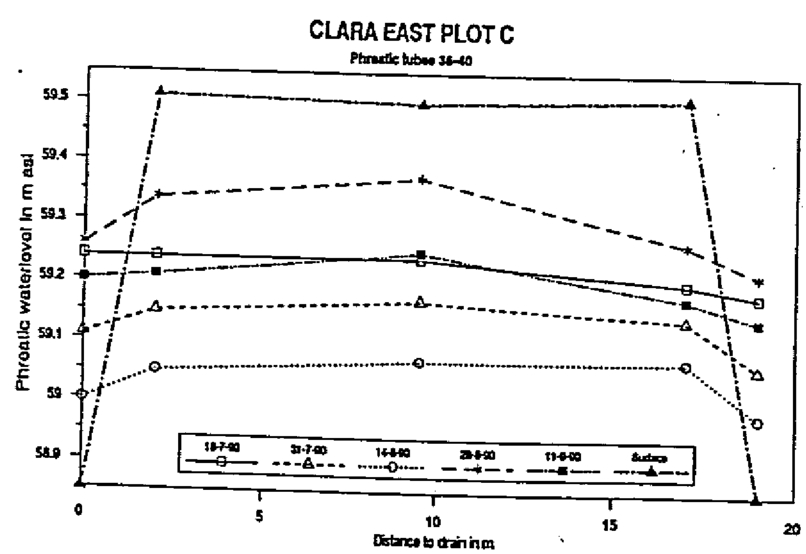


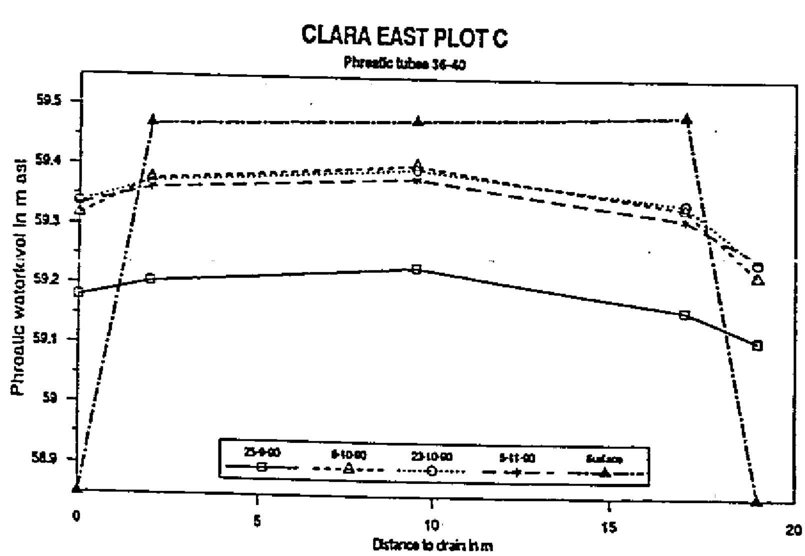
CLARA EAST PLOT C

Phreatic tubes 36-40




CLARA EAST PLOT C
phreatic tubes 36-40
Phreatic waterlevel in m asl
Distance to drain in m
9-5-90
23-5-90
6-6-90
20-6-90
6-7-90
Surface

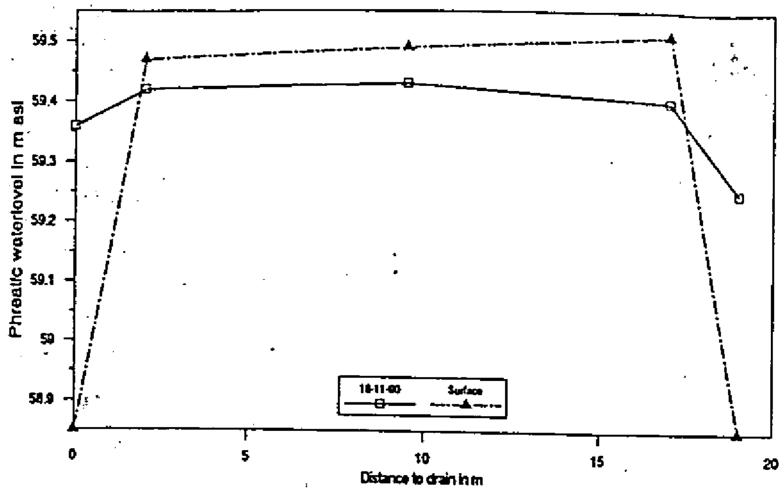

CLARA EAST PLOT C
Phreatic tubes 36-40
Phreatic waterlevel in m asl
Distance to drain in m
18-7-90
31-7-90
14-8-90
28-8-90
11-9-90
Surface


CLARA EAST PLOT C
Phreatic tubes 36-40
Phreatic waterlevel in m asl
Distance to drain in m
25-9-90
8-10-90
23-10-90
5-11-90
Surface

G28

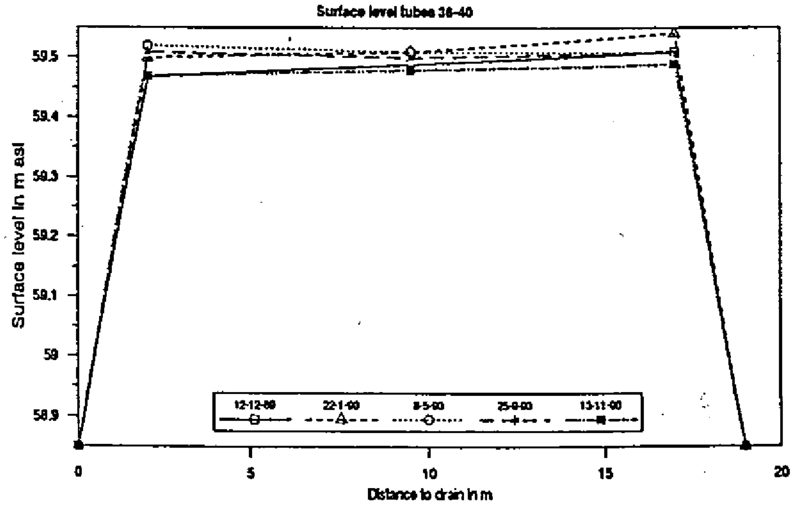
CLARA EAST PLOT C

Phreatic tubes 36-40



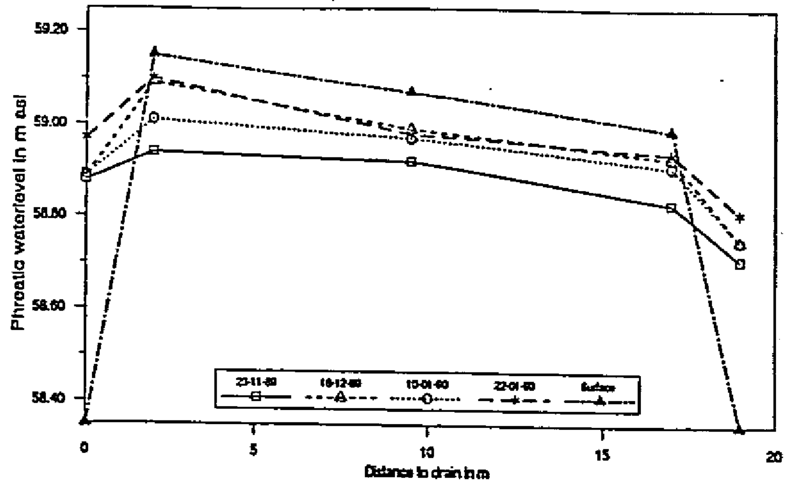
CLARA EAST PLOT C

Surface level tubes 36-40



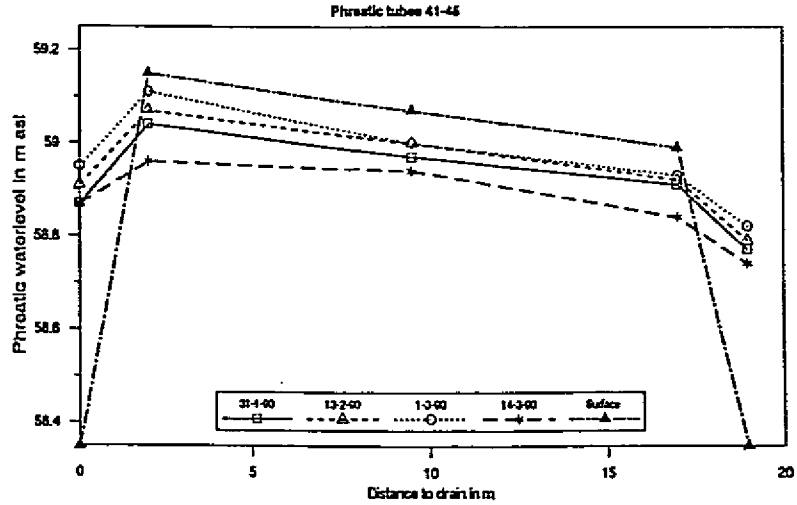
CLARA EAST PLOT C .

phreatic tubes 41-45



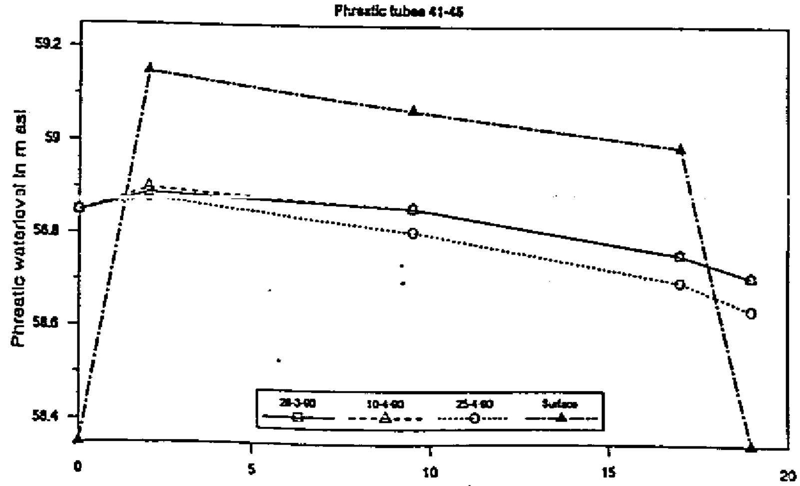
CLARA EAST PLOT C

Phreatic tubes 41-45



CLARA EAST PLOT C

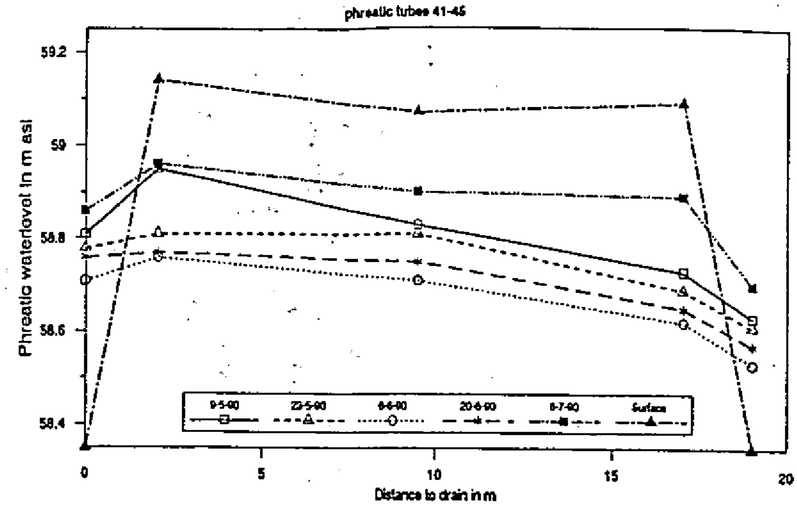
Phreatic tubes 41-45



G30

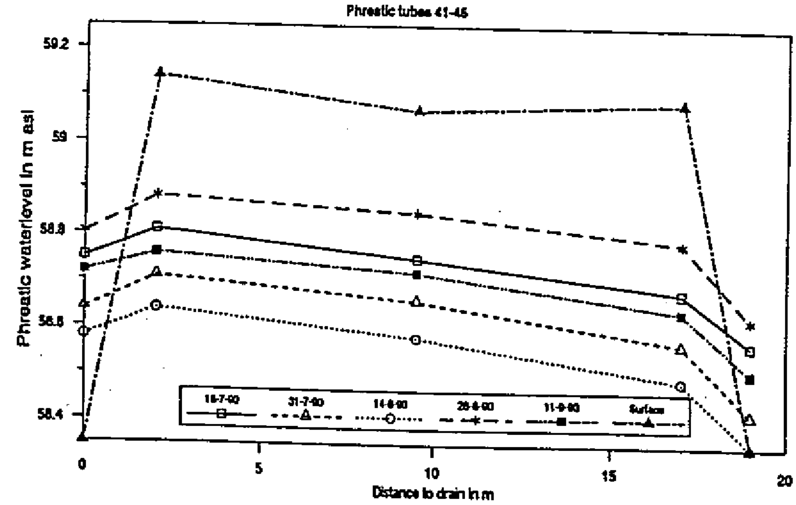
CLARA EAST PLOT C

phreatic tubes 41-45



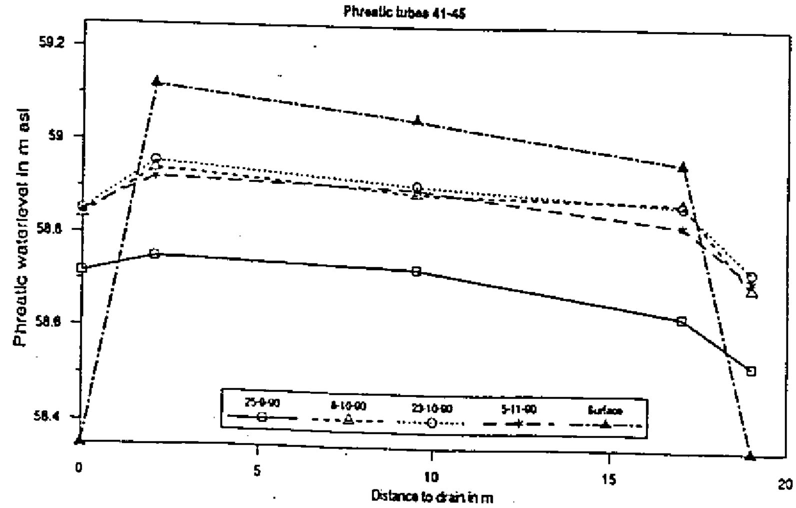
CLARA EAST PLOT C

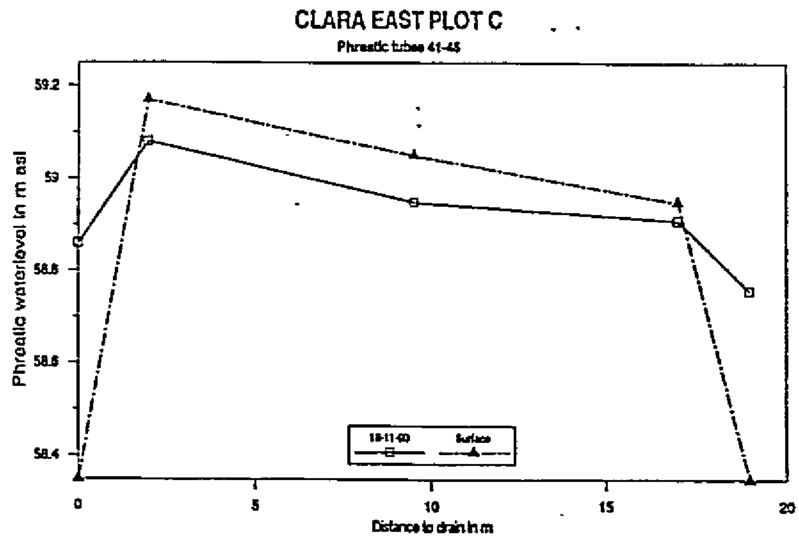
Phreatic tubes 41-45

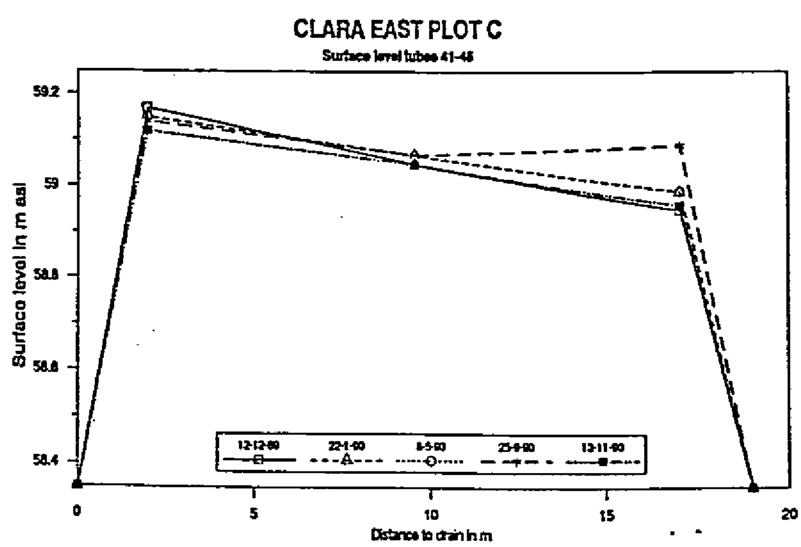


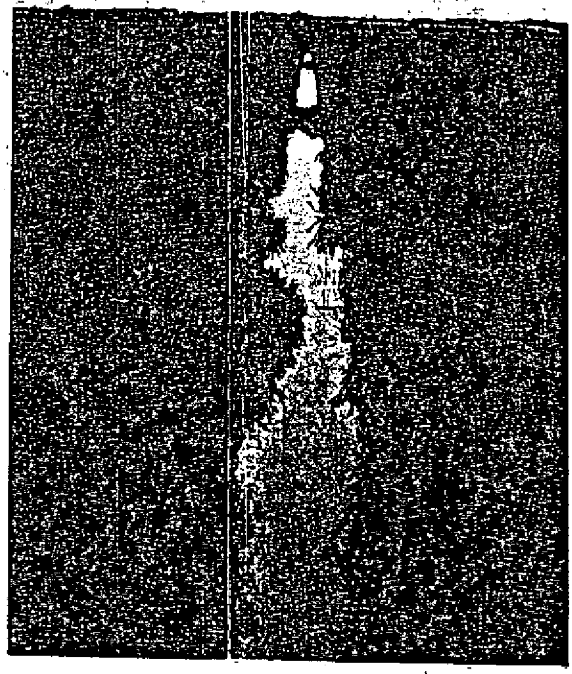
CLARA EAST PLOT C

Phreatic tubes 41-45

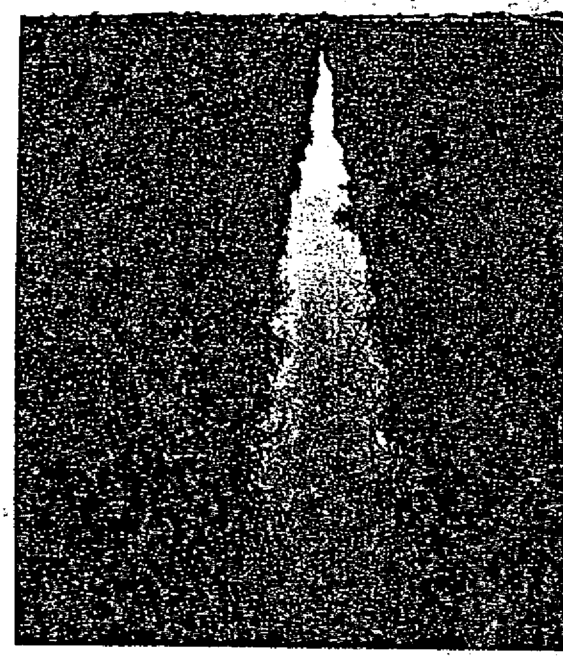



CLARA EAST PLOT C
Phreatic tubes 41-45
Phreatic waterlevel in m asl
59.2
59
58.8
58.6
58.4
0
5
10
15
20
Distance to drain in m
Surface

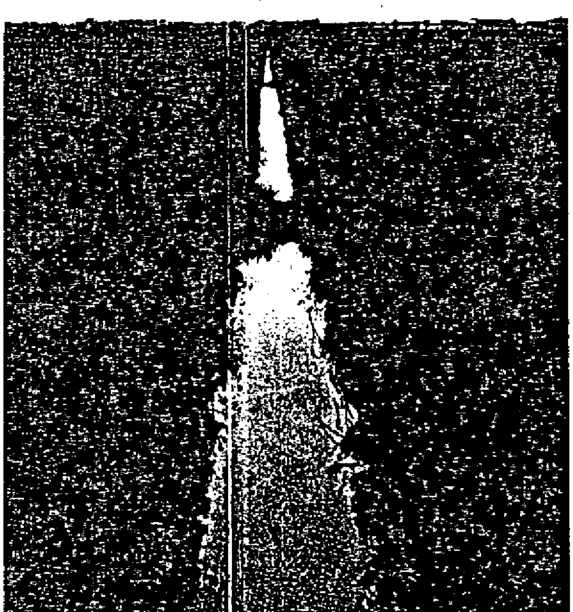

CLARA EAST PLOT C
Surface level tubes 41-45
Surface level in m asl
59.2
59
58.8
58.4
0
5
10
15
20
Distance to drain in m



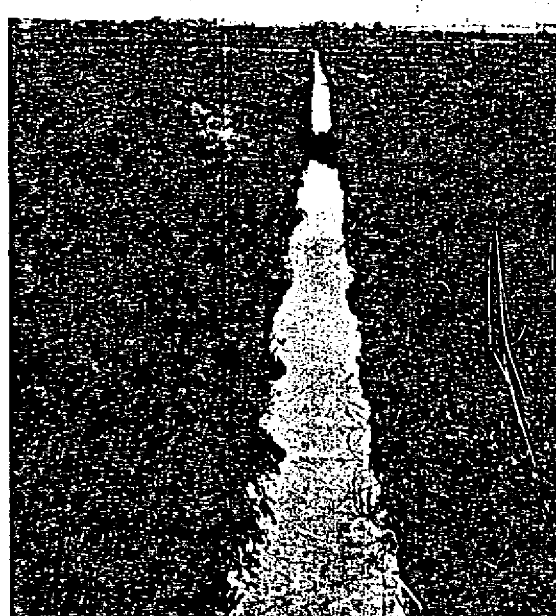
C1, drain 31



C1, drain 35

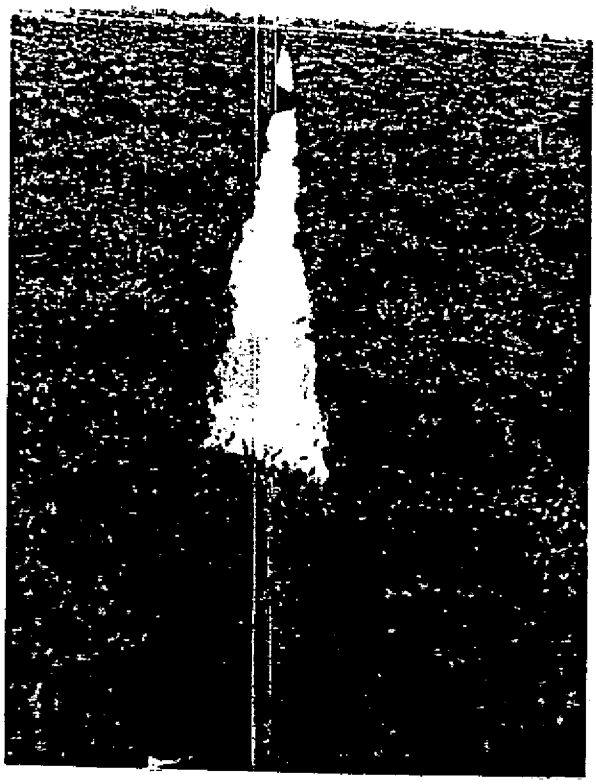


C2, drain 36

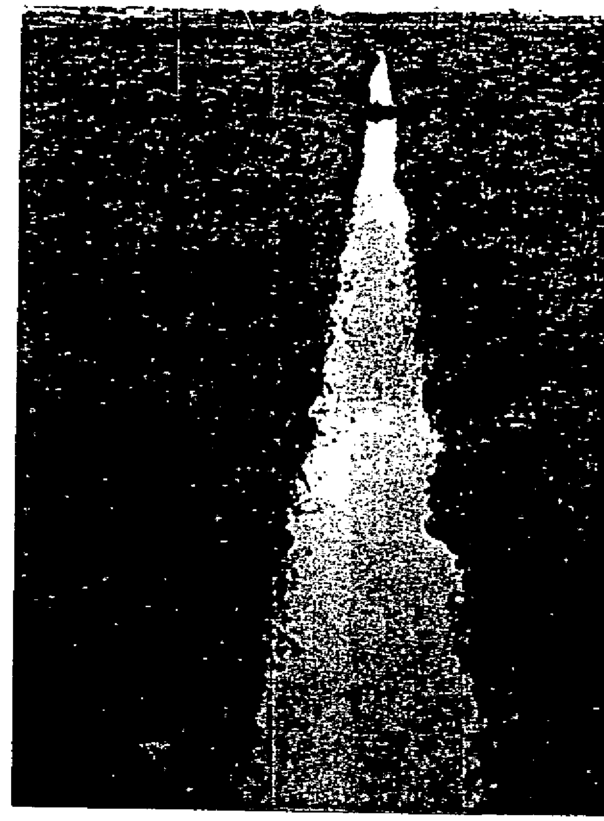


C2, drain 40

G33



C3, drain 41



C3, drain 45

APPENDIX H

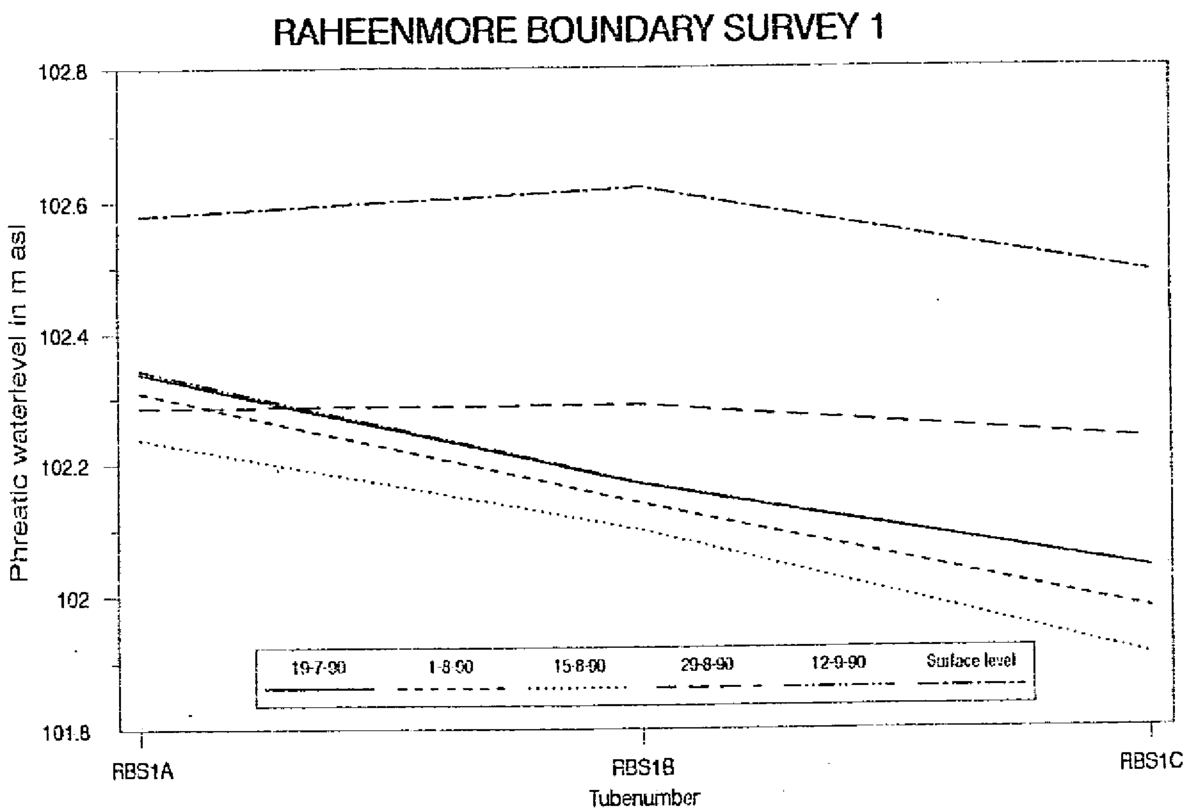
Raheenmore Boundary Survey

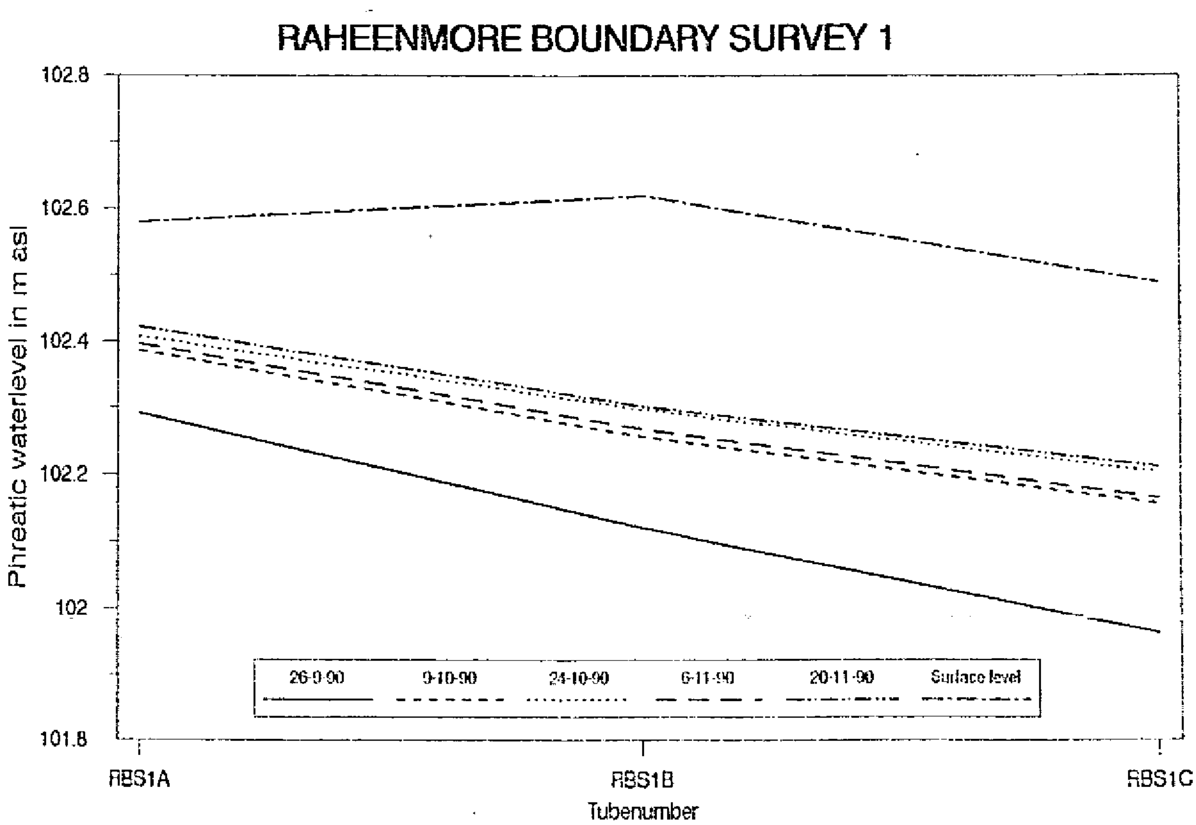
H2 RBS 1

H3 RBS 2

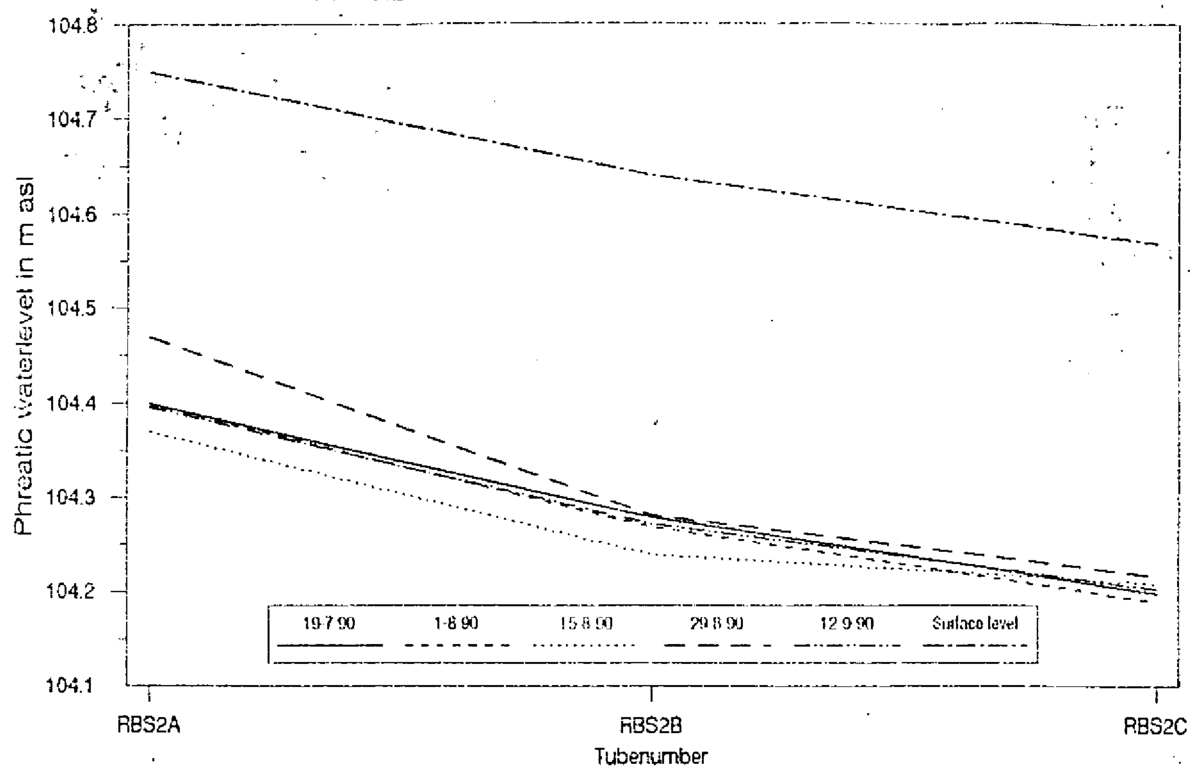
H4 RBS 3

H5 RBS 4

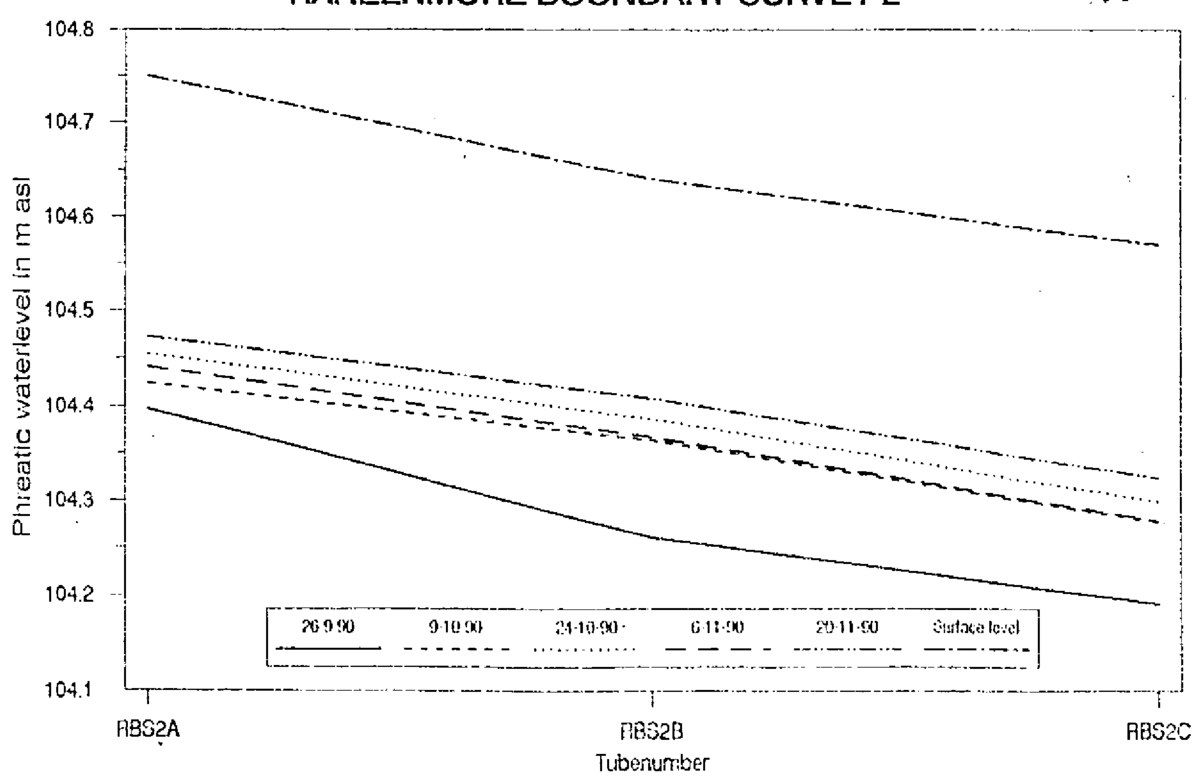

RAHEENMORE BOUNDARY SURVEY 1
102.8
102.6
102.4
102.2
102
101.8
Phreatic waterlevel in m asl
19-7-90
1-8-90
15-8-90
29-8-90
12-9-90
Surface level
RBS1A
RBS1B
RBS1C
Tubenumber

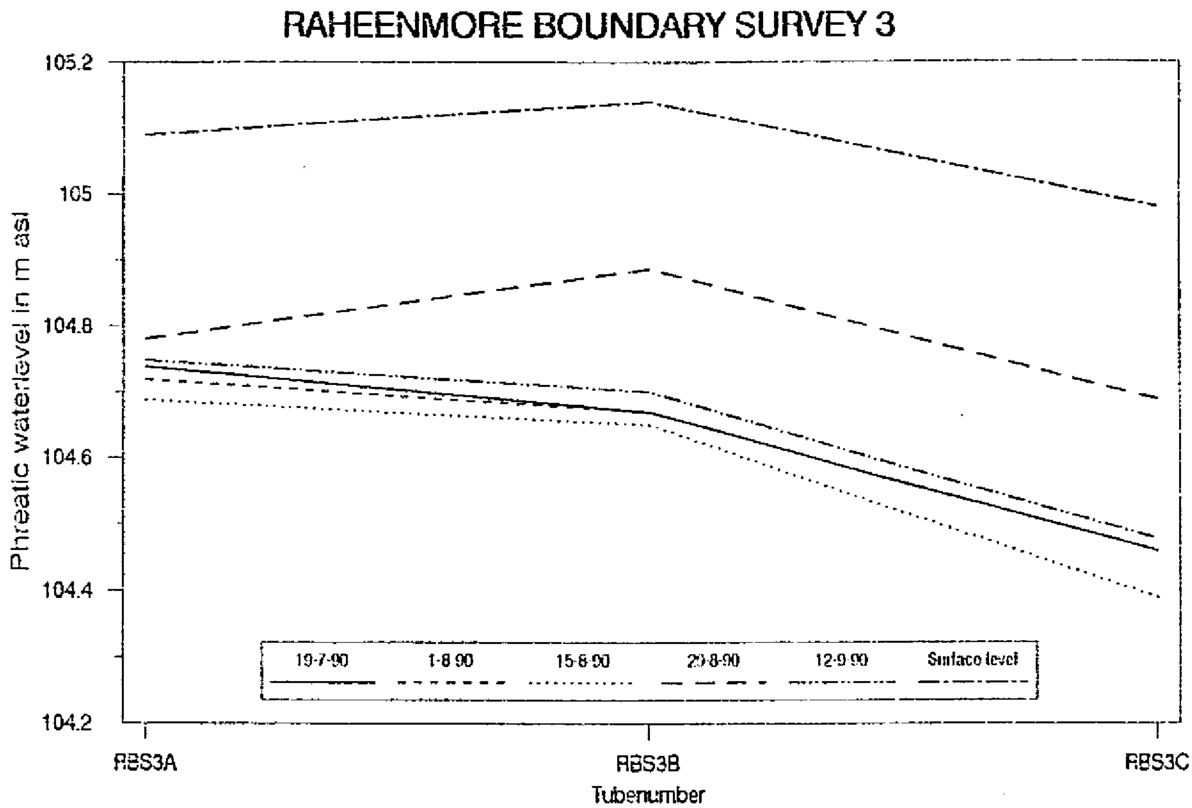

RAHEENMORE BOUNDARY SURVEY 1
102.8
102.6
102.4
102.2
102
101.8
Phreatic waterlevel in m asl
26-9-90
9-10-90
24-10-90
6-11-90
20-11-90
Surface level
RBS1A
RBS1B
RBS1C
Tubenumber

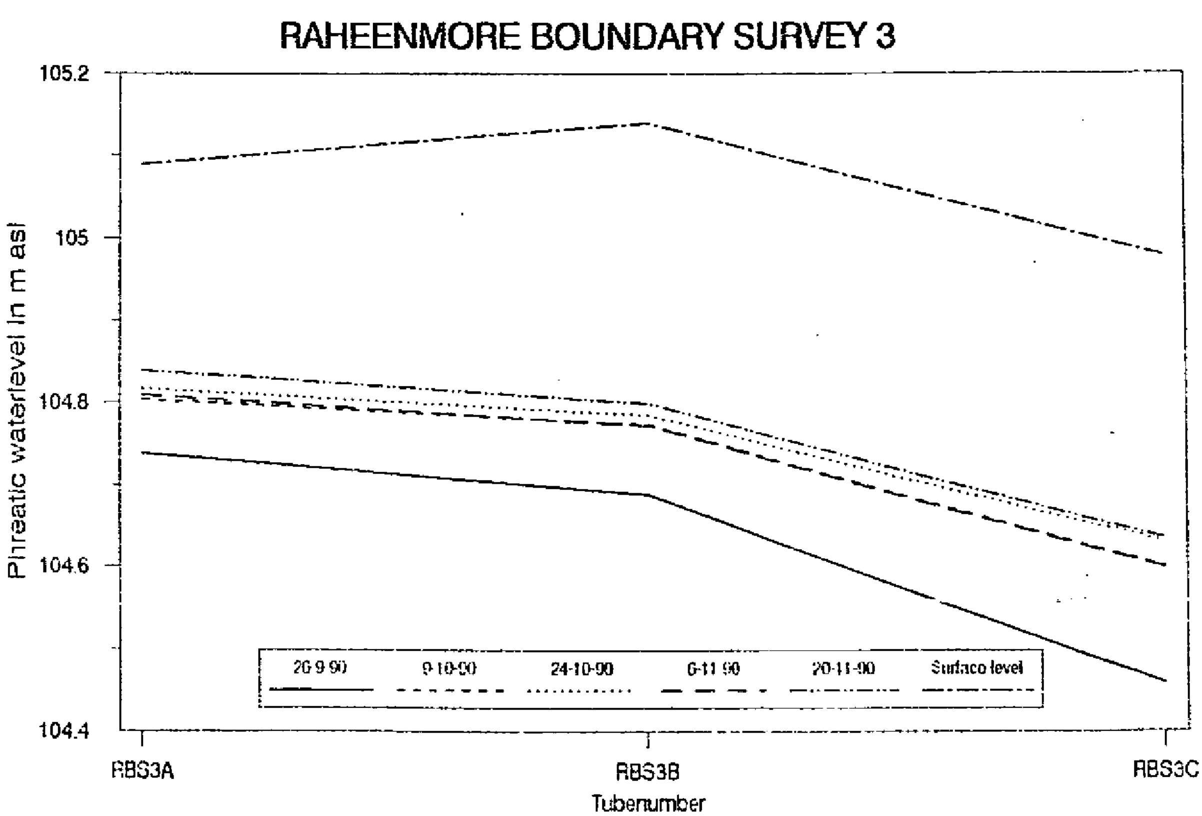
RAHEENMORE BOUNDARY SURVEY 2

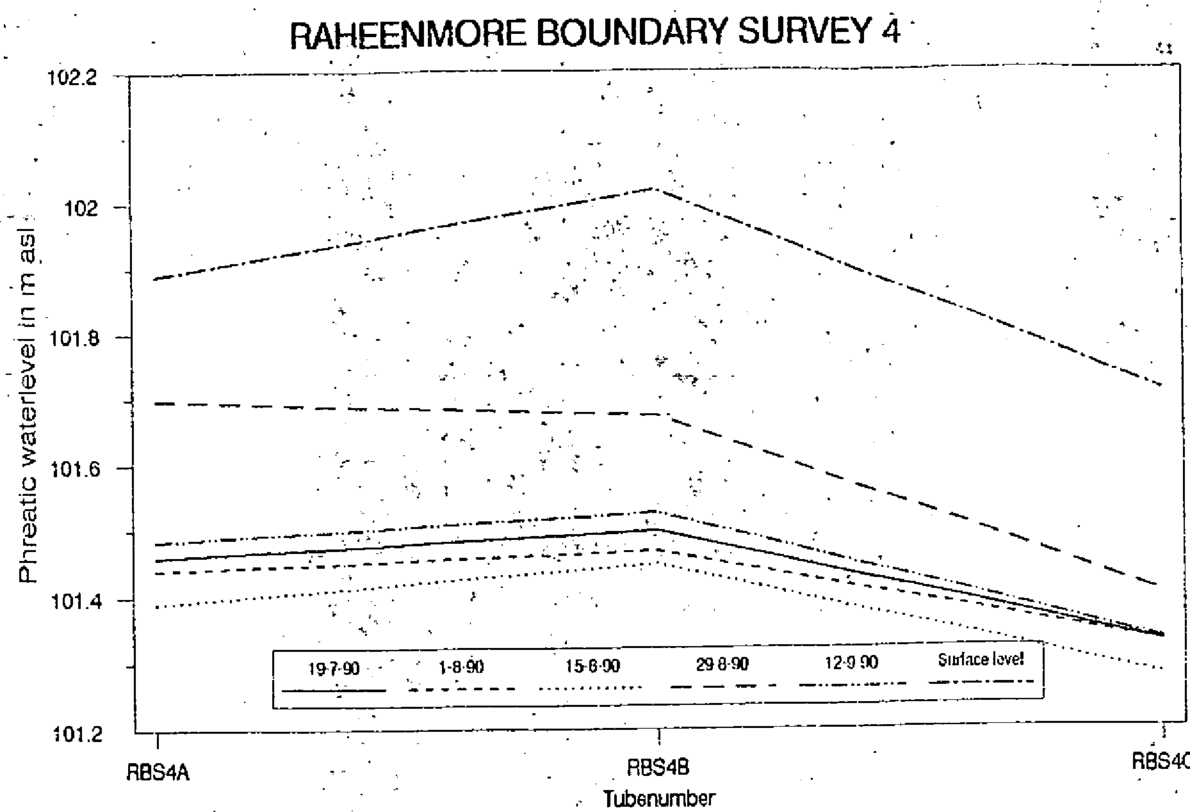


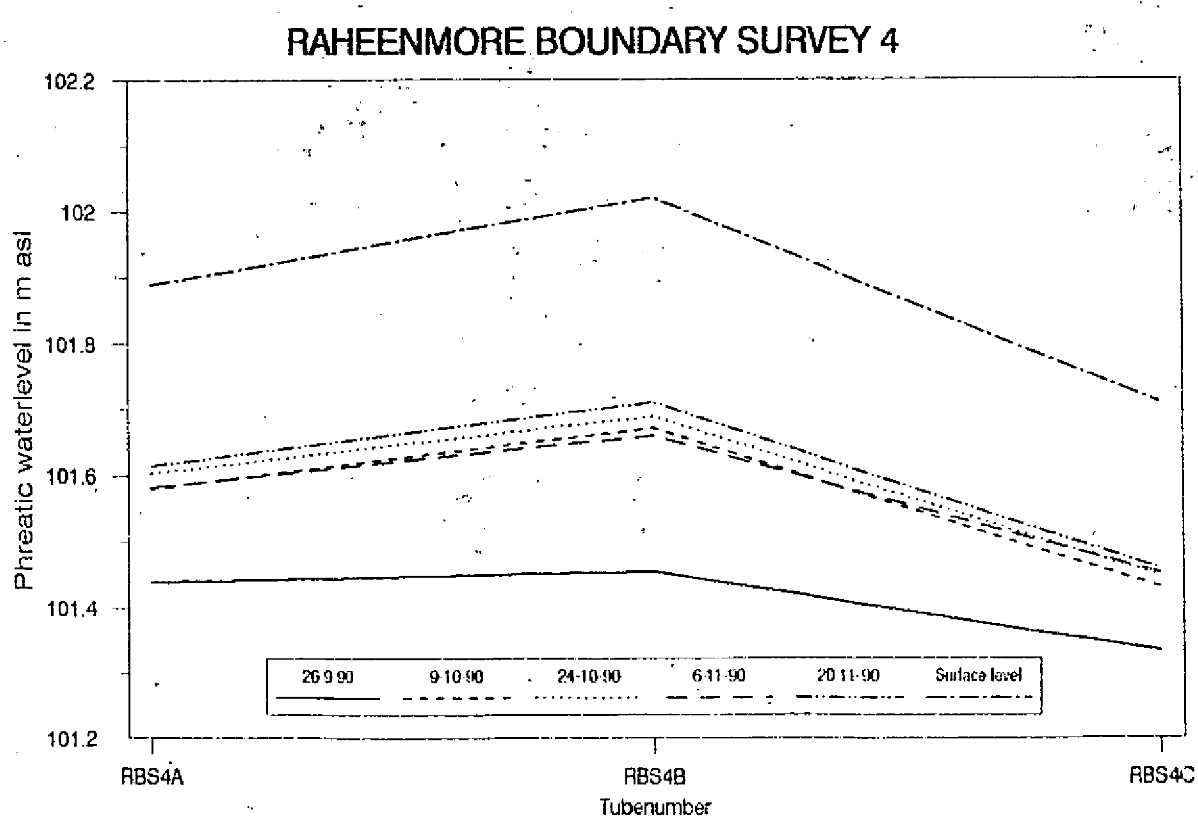
RAHEENMORE BOUNDARY SURVEY 2




RAHEENMORE BOUNDARY SURVEY 3
105.2
105
104.8
104.6
104.4
104.2
Phreatic waterlevel in m asl
19-7-90
1-8-90
15-8-90
29-8-90
12-9-90
Surface level
RBS3A
RBS3B
RBS3C
Tubenumber


RAHEENMORE BOUNDARY SURVEY 3
105.2
105
104.8
104.6
104.4
Phreatic waterlevel in m asl
20-9-90
9-10-90
24-10-90
6-11-90
20-11-90
Surface level
RBS3A
RBS3B
RBS3C
Tubenumber


RAHEENMORE BOUNDARY SURVEY 4
102.2
102
101.8
101.6
101.4
101.2
Phreatic waterlevel in m asl
19-7-90
1-8-90
15-6-90
29-8-90
12-9-90
Surface level
RBS4A
RBS4B
RBS4C
Tubenumber


RAHEENMORE BOUNDARY SURVEY 4
102.2
102
101.8
101.6
101.4
101.2
Phreatic waterlevel in m asl
26-9-90
9-10-90
24-10-90
6-11-90
20-11-90
Surface level
RBS4A
RBS4B
RBS4C
Tubenumber