NAME OF THE PROJECT

# ALL INDIA CO-ORDINATED RESEARCH PROJECT ON AGRICULTURAL DRAINAGE UNDER ACTUAL FARMING CONDITIONS ON WATERSHED BASIS, KARUMADY

(I.C.A.R.)

1986-87



CENTRE

AICRP ON AGRICULTURAL DRAINAGE

KARUMADY-688 564

KERALA AGRICULTURAL UNIVERSITY

C O N T E N T S

## ANNUAL REPORT FOR THE YEAR 1986-87

### SECTION - A

| | | |
|---|---|---|
| 1. | Title of the Scheme | : All India Co-ordinated Research Project on Agricultural Drainage under actual farming conditions on watershed basis, (ICAR), Regional Centre, (KAU), Karumady P.O., Alleppey District, Kerala State. |
| 2. | ICAR sanction No. and Date. | Original sanction No.F.4-5/77/AE dated 20.3.1981 of I.C.A.R. Revised sanction No.4-14/80/AE dated 22.10.1982 of ICAR. Further Order No.4-2/85/AE dated 1.8.1986. |
| 3. | Date of commencement of the project. | 01-12-1981. |
| 4. | Date of completion | : 31.3.1990. |
| 5. | Sanctioned grant for the complete duration of the project. | 29.7 lakhs. |
| 6. | Sanctioned grant for the year for which the report is prepared. | 3.5 lakhs vide Order No.4-2/85/AE dated 1.8.1986 of I.C.A.R. |

7. <u>Staff Position during 1986-87.</u>

| Sl. No. | Name of Post | No.of sanc-tioned post. | No.of post filled | No.of posts vacant | Name of incumbent | Scale of pay | Date of joining |
|---|---|---|---|---|---|---|---|
| 1. | Assoc.Professor (Agrl.Engg.) | 1 | 1 | .. | Sri.E.K.Mathew | 1950-2950 | 1.10.84 to till date |
| 2. | Asst.Professor (Agronomy). | 1 | 1 | .. | Sri.Madhusudan Nair | 1500-2685 | 27.9.86 to ,, |
| 3. | Asst.Professor (Agrl.Engg) | 1 | 1 | .. | Sri.T.D.Raju | 1500-2685 | 1.10.84 to ,, |
| 4. | Farm Asst.(Sr.Gr.) | 1 | 1 | .. | Sri.R.Madhavan Pillai | 975-1726 | 10.6.85 to ,, |
| 5. | Draughtsman (Civil Gr.II) | 1 | - | 1 | | 700-1140 | Vacant - since inception. |
| 6. | Farm Asst.Gr.II. | 2 | 2 | .. | 1) T.J.Mathew | 675-1125 | 17.6.85 to 1.9.86 |
| | | | | | 2) Sri.K.O.Shahul Hameed. | ,, | 12.9.86 to till date. |
| | | | | | 3) I.Krishnakumari | ,, | 11.7.86 to ,, |
| 7. | TechnicianGr.III. | 2 | 2 | .. | 1) K.Vasudevan | ,, | 9.12.82 - 19.5.86 |
| | | | | | 2) K.Aravindan | ,, | 10.12.82- 19.5.86 |
| | | | | | 3) K.P.Sreedharan Nair | ,, | 30.5.86 to till date. |
| | | | | | 4) Thomas Scaria | ,, | 5.6.86 to ,, |
| 8. | Typist Grade-I. | 1 | 1 | .. | Smt.K.K.Mary | 780-1320 | 15.7.85 to 3.6.87 |

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|
| 9. | Assistant Grade-I | 1 | 1 | .. | Sri.K.Govindan | 780-1320 | 15.7.85 to 3.6.1987. |
| 10. | Lab.Asst.Gr.II. | 1 | 1 | .. | K.Kunju Pillai | 675-1125 | 1.1.86 to till date |
| 11. | Driver (LDV Gr.III) | 1 | 1 | .. | K.V.Kumaran | 640-1000 | 8.1.86 to 15.6.1987 |
| 12. | Peon | 1 | 1 | .. | M.Mohammed Haneef | 550-800 | 7.12.85 to till date |
| 13. | Watcham | 2 | 2 | .. | 1) N.Raveendran | ,, | 16.11.85 to till date |
|  |  |  |  |  | 2) C.A.Chacko | ,, | 7.12.85 to till date |
| 14. | Overseer(Civil Gr.I.) | 1 | - | 1 | .. | 825-1430 | Vacant - since inception. |

8. Financial information:-

i) Expenditure statement from the year of commencement to 1986-87:

| Sl. No. | Year | Sanctioned grant for the year. | University sanction | Expenditure | Expenditure as % of the sanctioned grant. |
|---|---|---|---|---|---|
| 1. | 1981-82 | 1,28,100/- | 36,000/- | 7,242.85 | 5.65 |
| 2. | 1982-83 | 4,78,200/- | 4,37,000/- | 1,26,509.50 | 26.45 |
| 3. | 1983-84 | 3,83,800/- | 3,83,800/- | 2,44,951.89 | 63.82 |
| 4. | 1984-85 | 3,80,200/- | 3,80,200/- | 3,38,[illegible].35 | 88.90 |
| 5. | 1985-86 | 2,86,000/- | 2,86,800/- | 2,61,094.23 | 91.04 |
| 6. | 1986-87 | 3,50,000/- | 3,50,000/- | 3,23,997.91 | 95.57 |

ii) Expenditure statement of the year 1986-87 from 1.4.86 to 31.3.1987.

| Sl. No. | Budget head | Sanctioned grant for the year | ICAR sanction. | University sanction | Total expenditure. | Expenditure as % of the sanctioned grant. |
|---|---|---|---|---|---|---|
| 1) | Salary | 1,72,000/- | .. | 1,72,000/- | 2,23,969.53 | 130.21% |
| 2) | T.A. | 10,000/- | .. | 10,000/- | 8,124.65 | 81.24% |
| 3) | Recurring Contingencies | 60,000/- | .. | 60,000/- | 47,149.53 | 78.58% |
| 4) | Non recurring Cont: | 1,08,000/- | .. | 1,08,000/- | 44,753.80 | 41.44% |
| Grand Total : | | 3,50,000/- | .. | 3,50,000/- | 3,23,997.91 | 95.57% |

The Excess payment in pay and allowances was incurred vide Order No.3/16/87/AE dated 25.3.1987 of Assistant Director General (Engg.), I.C.A.R.

# SECTION - B.

## PROJECT AREA - A BRIEF DESCRIPTION.

3. i) Kuttanad:-

Kuttanad tract is a deltaic alluvium formation of four river systems viz. 'Meenachil', 'Pampa', 'Manimala', and 'Achen Coil' and the low lying area in and around 'Vembanadu Lake'. The total area of Kuttanad tract is about 870 sq.km. out of which 290 sq.km. is under garden lands, scattering all over the tract and is lying 1 to 2m above the sea level, used mainly for coconut cultivation and habitation. The remaining portion which was under submergence was progressively reclaimed as polders by constructing ring bunds. These polders lie about 0.5 to 2m below mean sea level and the impounded water is drained out by using locally manufactured axial-flow pumps. The area of each polder unit ranges from 75 to 500 ha. and the total area under polder cultivation is estimated as about 520.39 Sq.Km. The whole area is criss-crossed by rivers, channels, canals and other waterways. The general topography of the area is flat and level.

The total watershed area of the above four rivers is nearly 5,000 Sq.Km. and discharge their water into Kuttanad region. After flowing through a net work of canals and channels, they join the Vembanad Lake. The catchment area has an annual rainfall varying between 200 cm to 300 cm. A good part of the rains, 60% are received during South West monsoon resulting in floods and most often submerging the low lands. The Kuttand region experiences fairly uniform temperature throughout the year ranging between 21°C and 36°C. The mean relative humidity is high and is about 70%.

The Vembanad Lake which is the non-reclaimed part of the Kuttanad extends between Alleppey and Cochin with an area of 80 Sq.Km. This lake is connected to Arabian Sea at Cochin. The water in the lake is saline except during the monsoon season when the surface water is sweetened by flood water. When the flow in the rivers dwindles from the month of December, the saline water from the sea intrudes the entire area due to tidal action. The salinity in the northern parts of Kuttanad goes beyond limits of tolerance for rice cultivation from January onwards and it spreads rapidly to the southern parts. The surface water remains saline till the first flood washes it during the succeeding South West Monsoon.

The soil is acid sulphate in nature and is having high acidity. Three major problems encountered during cultivation in this area are:

1) high acidity
2) damage caused by floods and
3) intrusion of saline water during the fag end of crop period.

B.ii) <u>Kari Lands</u>:-

The whole Kuttanad tract is differentiated into three types of lands, namely Karappadam, Kayal lands and Kari lands. The Kari land occupies an area of nearly 7,000 ha. They are located in the Taluks of Shertallai, Ambalapuzha and Kuttanad of Alleppey District and Vaikom and Kottayam of Kottayam District.

The Kari lands are a unique agricultural tract with Kari soils - black charcol coloured organic soil. These lands are quite similar to that of Kuttanad region with respect of topography, formation, climate and vegetation, but the organic matter content of the soil is very high.

It is believed that this soil was formed and developed in the distant geologic past when the area was covered by dense forest vegetation. In the succeeding geological ages, the sea advanced and engulfed many places. After thousands of years, the sea receded exposing the coastal region and part of the present midlands. During this geological upheavals, the entire forest area was submerged far below the ground and thereafter silted upto varying levels.

The profile of Kuttanad alluvium consists essentially of alternating layers of clay and sand, admixed with varying proportions of organic matter. The clay is usually a grey, dark or bluish black in colour. This alluvial formations exist in layers varying upto 30 metres in depth underlain by sand stone and mottled clay of tertiary formation. Still distinct, the Kari soils can be readily be discerned by the deep black charcoal colour, due to high organic matter content. The top soil is admixed with well decomposed organic matter to the tune of 10-30%. But, underneath, the top layer is the partially decomposed, fibrous plant residues containing less than 50% mineral matter. Hence, these soils are both mucky and peaty in nature. In some places, large logs of wood locally known as 'Kandamaram' occur embedded in the sub soil. Beneath this layer, the soil is an admixture of sand, organic matter and clay and still deeper it becomes river sand.

Kari soils are extremely acidic in reaction with pH ranging 3-4.5 and the pH reduces further when the soil gets dried up. It is found that the extremely low pH on drying is due to the production of free sulphuric acid by oxidation of sulphur compounds in the soil. The fertility status of the soil is poor. Besides, the soil contains toxic concentrations of Fe, Al and toxic organic products.

B. iii) <u>The Project Area</u>:- Kavil Thekkumpuram Padasekharam.

B.iii(a) Location and Area:-

The project area is a typical representative tract of Kari land with an area of 69.99 ha. The project area comes under Ambalapuzha village and Taluk of Alleppey District. It lies 4 Kms. east of Ambalapuzha Junction on National Highway 47. The padasekharam is encircled by Ambalapuzha-Thakazhy road at north, Kalathil thodu at east, Kari thodu at south and Karumady thodu at west.

(b) Physiography and Hydrology:-

The project field is located 1 to 1.5m below mean sea level. The water collected in the project area is drained out by pumping to nearby canals using axial flow pumps (petty and parah). There are two pumping outlets, one with a 3 HP and the other with 20HP axial flow pump. The former is installed on the ring bund of Karumady thodu and the latter on the ring bund of Kari thodu. Two drainage channels, with an average width of 2.5m and a depth of 0.7m, are inter connected and lead water to the pumping bays. There is a net work ofsmall drainage channels which opens out into the main drainage channel.

The land has got almost an even topography.

The water level in the surrounding water ways will be higher by 1 to 1.5m than that in the paddy fields during the season of cultivation. The havoc of flood, over topping and breaching of bunds and flooding of paddy fields are anticipated during the period of SW monsoon. Inundation of salt water and damage of crops are experienced during the period January to March.

2.iii(c) Climate:-

The project area experiences a typical tropical climate. The monthly mean of the weather parameters for the period from 1976 to 1985 and that for the period from 1986 January to March 1987 is given in table-A. The monthly changes in climatic parameters have also been illustrated through fig.A and B.

2.iii(d) Land Holding and Utilization:-

From the survey conducted at this station and from the records available with Revenue Department, it is found that altogether 125 cultivators are there in the project Area, farming 75.238 ha of paddy fields. When the tenureship of the land is classified based on the extent of holding, it was seen that a substantial number of holdings fall below 1 acre. Out of 125 Nos.of holdings, 75 holdings were with an average extent of 1 acre or below that and 35 holdings were with an average extent between 1 acre and 2.5 acre. Only 15 holdings were with mean acreage above 2.5 acre. The average size of holding is 0.601 ha (1.49 acres).

The total area of the project field is 88.919 ha. and actual paddy field is 75.238 ha. The rest of the land is occupied by roads, trenches and reclaimed dry lands. The dry lands are used for human habitation and for the cultivation of perennial crops, mainly coconut.

B.iii(e) Cropping:-

The one and the only crop raised in the wet land is paddy and there is 100% coverage under HYVs.

Table - A.

MONTHLY VARIATIONS OF WEATHER PARAMETERS IN THE PROJECT AREA

(a) Total Rainfall cm.

| | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. | 1.70 | 4.39 | 4.57 | 12.08 | 28.46 | 66.26 | 53.86 | 39.73 | 28.51 | 29.59 | 2[illegible].87 | 6.66 | 292.62 |
| B. | 0.16 | 0.36 | 3.[illegible]6 | 8.08 | 9.84 | 35.96 | 24.48 | 24.5[illegible] | 33.64 | 15.12 | 19.0[illegible] | [illegible] | 175.92 |
| C. | .. | 1.18 | .. | | | | | | | | | | |

(b) Monthly mean maximum Temp. °C.

| | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. | 33.82 | 33.4[illegible] | 34.47 | 34.76 | 33.70 | 30.61 | 3[illegible].19 | 3[illegible].47 | 31.62 | 32.22 | 31.76 | 33.61 | 32.55 |
| B. | 31.16 | 32.89 | 33.03 | 32.0 | 32.03 | 29.8[illegible] | 29.2 | 28.35 | 29.33 | 30.4[illegible] | 30.90 | 32.5 | 31.12 |
| C. | 32.30 | 32.0 | 33.14 | | | | | | | | | | |

Contd.....

(c) Monthly Mean Minimum Temp. °C.

| | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total Mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. | 22.05 | 23.29 | 25.07 | 25.42 | 25.60 | 24.48 | 23.89 | 24.33 | 24.73 | 25.40 | 24.38 | 23.32 | 24.27 |
| B. | 21.65 | 22.64 | 24.45 | 22.40 | 25.42 | 23.90 | 24.0[illegible] | 24.09 | 24.16 | 24.50 | 23.10 | 23.20 | 23.63 |
| C. | 22.10 | 22.60 | 24.55 | | | | | | | | | | |

(d) Monthly mean evaporation (mm).

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. | 3.77 | 4.23 | 4.76 | 5.01 | 4.94 | 4.23 | 4.39 | 4.13 | 4.37 | 4.28 | 3.94 | 3.20 | 4.28 |
| B. | 3.43 | 4.28 | 4.94 | 5.08 | 4.57 | 4.31 | 4.03 | 3.96 | 4.58 | 3.57 | 3.43 | 3.11 | 4.11 |
| C. | 3.41 | 3.79 | 4.05 | | | | | | | | | | |

A = Monthly mean for the year 1976 to 1985.

B = Monthly mean for the year 1986.

C = Monthly mean for the year 1987.

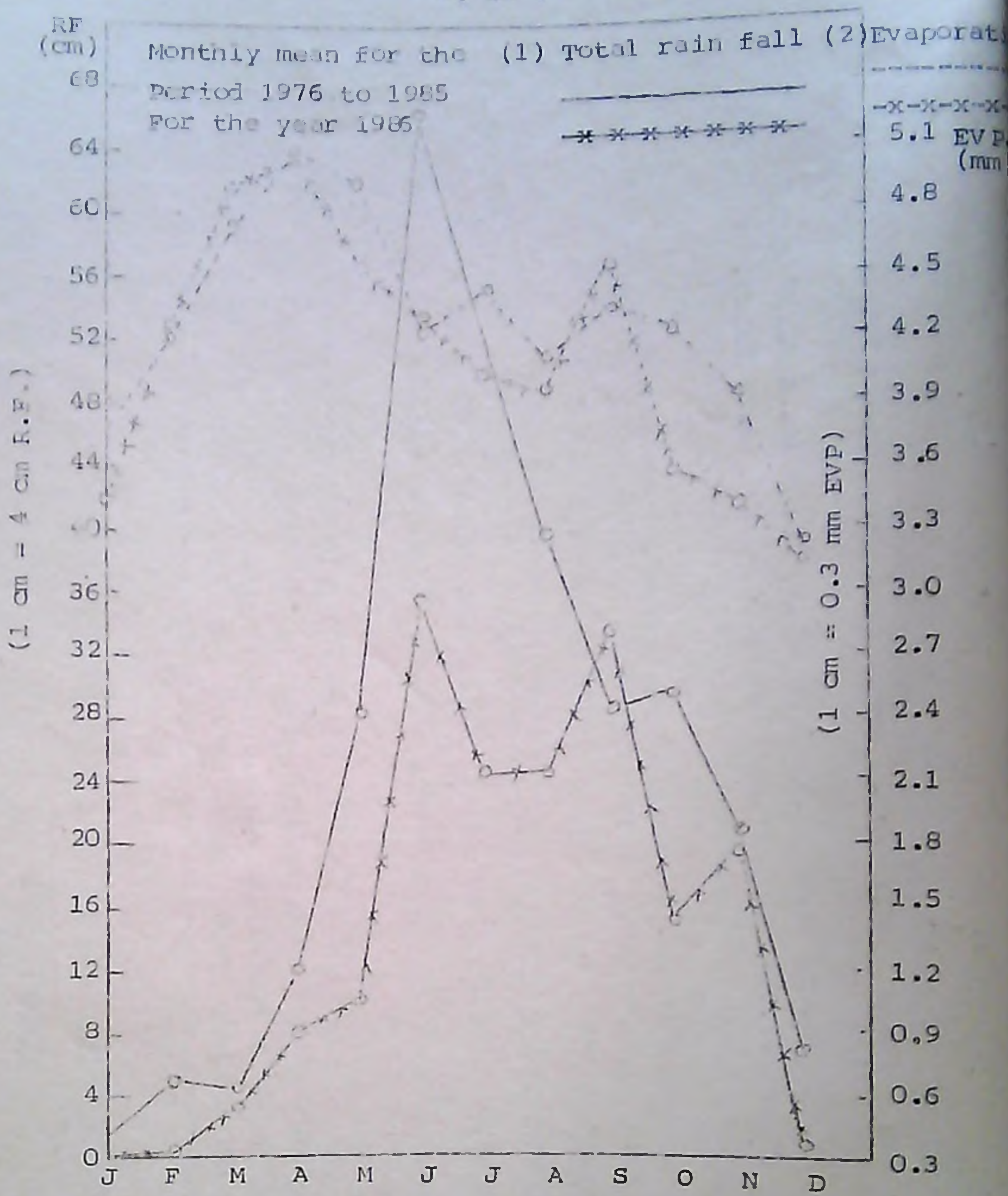


Figure - (A)

Mean monthly variation in total rainfall
and evaporation in the project area

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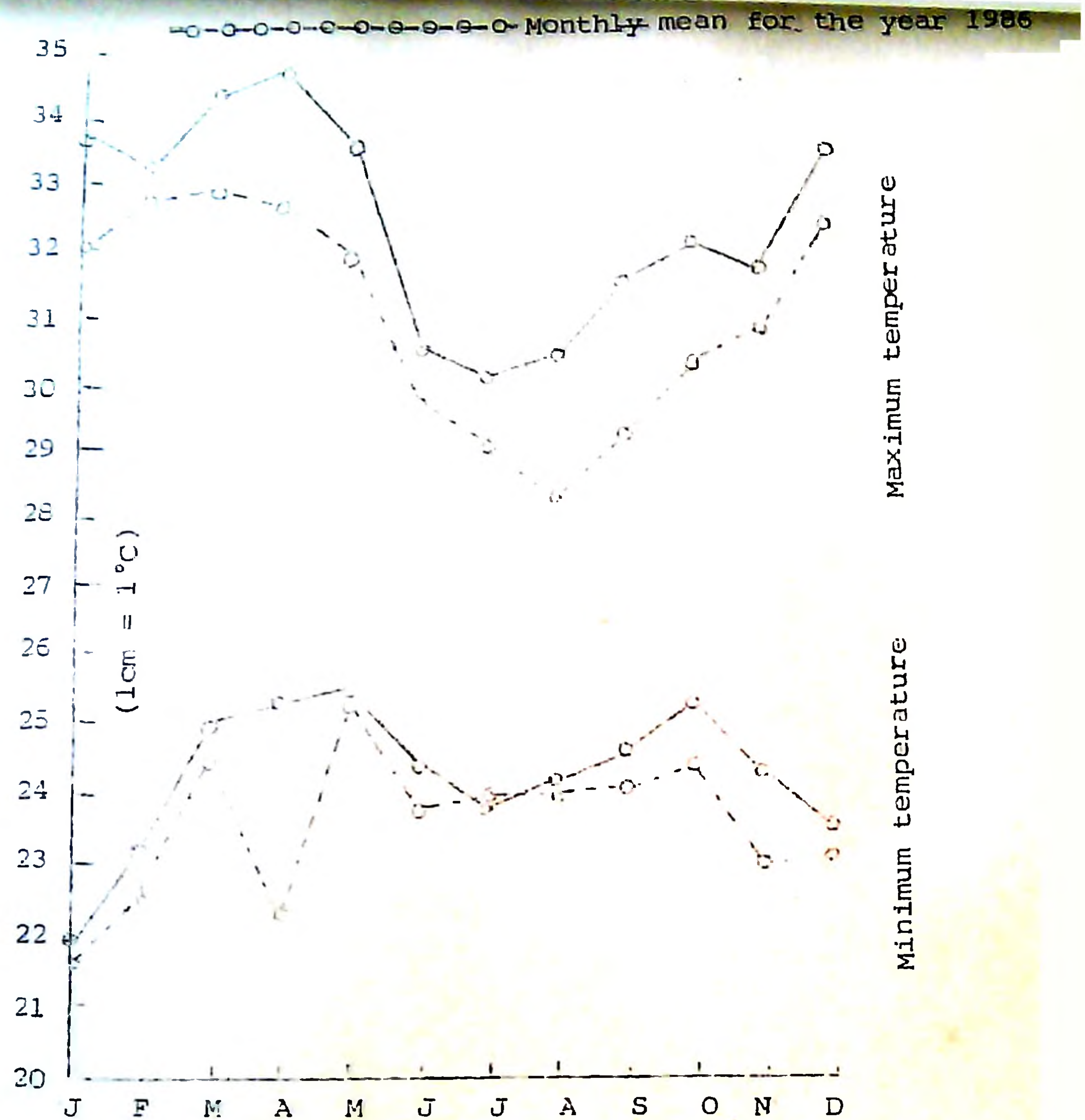



Figure - (B)

Mean monthly variation in maximum and minimum temperature in the project area

B.iii(f) Soil Characteristics:-

The soil of the project area is typical Kari soil. A soil monolith from 0-2m depth has been drawn from the project area and has been displayed in a glass box. From the visual observation it is seen that from 0-60 depth, the soil is clayey and black in colour due to high organic matter content. The clay type is the ex panding one and large cracks are formed on drying. From 60-90m depth, lot of wooden debris, undecomposed organic material, are seen embedded. Below that, the soil is an admixture of clay, sand and organic matter. From the depth of 1.5m onwards, the soil is almost of the river sand type.

SECTION - C.

Objectives of the project:

1. To comprehend the effect of a surface and subsurface drainage system on the movement of soil liquids:

   i) To study the effect of surface and subsurface drains in preventing the rise of toxic products from sub-surface soil into root zone.

   ii) To study the effect of surface drains in removing the toxic products already present in the root zone.

   iii) To study the influence of sub-surface drains on lowering water table and its effect on growth and development of roots.

2. To study the pattern of hydrological cycle occuring in the watershed area and its importance and influence on the drainage.

3. <u>To develop a feasible technology for the layout of sub-surface drainage system suitable to peat and muck soils:</u>

   i) To develop the criteria for the design of sub-surface drains in peat and muck soils.

   ii) To evaluate the types of drains (such as tile drains, PVC pipes etc.) and size and spacing of slots on drains suitable for the lay out of subsurface drains.

   iii) To evaluate the filter materials to be used for the layout of subsurface drains.

   iv) To decide upon the depth and spacing of the layout of sub-surface drains.

   v) To develop the criteria for the design of auxiliary structures of subsurface drains.

4. <u>To develop criteria for design parameters of surface Drainage:</u>

5. <u>To develop the drainage pattern required for different crops:</u>

   i) To determine the drainage requirement of rice crop under static and fluctuating conditions of water levels.

   ii) To study the feasibility of changing monocropping pattern to diversified cropping and to develop agro techniques required for the diversified cropping.

   iii) To fix up the drainage requirements of the competent crops of diversified cropping.

6. To evaluate the feasibility of using the return flow from drainage for irrigation in relation to water quality ratings.

7. To evaluate the socio-economic benefits accrued from the drainage projects.

## S E C T I O N - D.

### TECHNICAL PROGRAMME FOR THE YEAR 1986-87.

I. Technical Programme for the year 1986-87 as approved in the previous annual workshop:

1. Performance evaluation of the executed sub-surface drainage system in the farmers field will be carried out on the following aspects.

   a) Periodical changes in water quality as influenced by the drainage system.

   b) Fluctuations in ground water table.

   c) Assessment of hydraulic properties of the tile drainage system.

   d) Theoretical prediction of drain performance in terms of water entry quality of the drain.

   e) Effectiveness of the drainage system in the performance of paddy crops in "vari lands".

2. Evaluation of the suitability of different filter materials for sub-surface drainage including the criteria for their design and economics of various filters.

II. Brief technical programme of the projects taken up at the centre during 1986-87.

| Sl No. | Title of the project | Title of the problem. | Duration. | Page No. |
|---|---|---|---|---|
| 1. | Survey and characterisation of quality of water in the project area. | Periodical changes in the quality of surface water in the project area. | Dec.1982 to till end of the scheme. | 18 |
| 2. | Preparation of water contour map and hydraulic map in the project area. | Seasonal fluctuation of ground water table with reference to surface and subsurface water level in the project area. | Jan.1982 to till the end of the scheme | 28 |
| 3. | Development of a suitable technology for the subsurface drainage system in the Kari lands of Kuttanad. | a) Assessment of hydraulic properties of the tile drainage system. | Dec.1984 to continuing. | 38 |
| | | b) Effectiveness of tile drainage system in the performance of paddy crop in the Kari lands. | Dec.1984 to continuing. | 50 |
| | | c) Evaluation of different filter materials to find its economic suitability including its design criteria for the subsurface drainage system. | | 70 |

RESEARCH PROJECT NO.1.

1. Title of the project : Survey and characterisation of quality of water in the project area.

2. Title of the problem : Periodical changes in quality of surface and subsurface water in the project area.

3. Objectives:-

1) To assess the periodic changes in the quality of flooding water, drainage water and ground water.

2) To identify the fluctuation in the quality of water during the periods of fallowing and cultivation.

4. Practical utility:-

The study will give useful information on the quality of water moving in the project area and enable to study the impact of quality of water on the ecology of the area. The information thus acquired can serve effectively in the planning of cultivation in the project area.

5. Technical programme:-

Water samples will be drawn at weekly intervals from the observation wells, piezometers, drainage channels and water ways and its quality such as pH and EC will be assessed.

6. Observations taken:-

pH and EC of the water sample to be estimated at weekly intervals.

7. Date of starting : December 1982

8. Date of completion : Throughout.

9. Progress of work:-

Water samples were collected at weekly intervals from pre-determined places for studying the periodic variations in pH and EC. In all cases the pH values were slightly acidic and ranged between 5 to 6.5. The surface drained water also has shown the same values of pH as that of the outside waterbodies. The time based fluctuation of pH is graphically represented in fig.1(1) and 1(2). The EC values have ranged between 0.5 to 2.5 mmhos/cm (Fig. 1(3) and 1(4)). In this case also the values representing the surface drained water followed the same pattern of fluctuations of the outside waterbody suggesting that the contribution of surface drainage in removing salt from the soil is negligible.

pH of water samples at weekly intervals

| Date | Karumady thodu. | Kari thodu | Kalathil thodu | Drainage channel. |
|---|---|---|---|---|
| 3.4.86 | 6.23 | 5.03 | 6.16 | 5.37 |
| 10.4.86 | 5.33 | 5.30 | 6.02 | 4.85 |
| 17.4.86 | 5.88 | 3.41 | 6.30 | 3.78 |
| 24.4.86 | 5.93 | 5.60 | 6.30 | 4.78 |
| 30.4.86 | 6.35 | 6.46 | 6.73 | 5.44 |
| 8.5.86 | 6.35 | 6.04 | 6.14 | 4.95 |
| 15.5.86 | 6.92 | 6.78 | 6.31 | 6.69 |
| 22.5.86 | 6.61 | 6.58 | 5.68 | 5.33 |
| 29.5.86 | 4.33 | 5.42 | 3.67 | 6.78 |
| 5.6.86 | 3.54 | 3.66 | 3.60 | 3.56 |

Contd.....

| Date | Karumady thodu | Kari thodu | Kalathil thodu | Drainage channel. |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| 12.6.86 | 4.94 | 3.55 | 3.48 | 4.70 |
| 19.6.86 | 6.67 | 5.05 | 4.61 | 5.92 |
| 26.6.86 | 5.77 | 5.81 | 3.57 | 5.88 |
| 3.7.86 | 5.81 | 4.60 | 4.80 | 5.33 |
| 10.7.86 | 6.27 | 4.85 | 4.40 | 5.85 |
| 17.7.86 | 6.80 | 6.26 | 6.37 | 6.71 |
| 24.7.86 | 6.6 | 6.75 | 5.34 | 6.86 |
| 31.7.86 | 5.98 | 6.00 | 6.65 | 6.78 |
| 7.8.86 | 6.93 | 6.30 | 4.15 | 5.28 |
| 14.8.86 | Flood | Flood | Flood | Flood |
| 21.8.86 | 6.48 | 6.00 | 6.20 | 6.38 |
| 28.8.86 | 6.72 | 5.95 | 6.35 | 6.30 |
| 4.9.86 | 6.88 | 6.20 | 7.00 | 6.93 |
| 11.9.86 | 6.49 | 6.53 | 6.00 | 6.71 |
| 18.9.86 | 5.83 | 6.10 | 5.65 | 4.78 |
| 25.9.86 | 6.37 | 6.85 | 6.60 | 6.75 |
| 3.10.86 | 6.47 | 5.85 | 6.00 | 6.03 |
| 9.10.86 | 7.10 | 5.95 | 6.85 | 5.90 |
| 16.10.86 | 6.57 | 5.30 | 6.85 | 5.88 |
| 23.10.86 | 6.80 | 6.75 | 6.55 | 6.05 |
| 30.10.86 | 6.83 | 5.50 | 6.15 | 5.98 |
| 6.11.86 | 6.97 | 6.25 | 6.60 | 5.95 |
| 13.11.86 | 6.75 | 6.50 | 6.60 | 5.95 |
| 20.11.86 | 4.63 | 6.20 | 3.60 | 6.65 |
| 27.11.86 | 6.43 | 6.10 | 5.55 | 6.08 |

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| 4.12.86 | 6.83 | 7.00 | 6.25 | 6.25 |
| 11.12.86 | 6.33 | 6.00 | 6.35 | 5.80 |
| 18.12.86 | 6.97 | 6.05 | 6.50 | 6.42 |
| 25.12.86 | .. | .. | .. | .. |
| 1.1.1987 | 6.85 | 6.90 | 6.45 | 6.55 |
| 8.1.87 | 6.80 | 6.85 | 6.90 | 6.88 |
| 15.1.87 | 6.93 | 6.65 | 6.50 | 6.75 |
| 22.1.87 | 7.65 | 6.65 | 7.60 | 7.58 |
| 30.1.87 | 7.27 | 7.05 | 6.60 | 6.60 |
| 5.2.87 | 7.63 | 8.15 | 6.45 | 7.68 |
| 19.2.87 | 7.70 | 6.65 | 6.40 | 6.68 |
| 27.2.87 | 7.13 | 7.20 | 6.40 | 6.95 |
| 5.3.87 | .. | .. | .. | .. |
| 12.3.87 | .. | .. | .. | .. |
| 19.3.87 | 7.25 | 6.55 | 7.65 | 8.02 |
| 26.3.87 | 5.50 | 4.90 | 6.30 | 6.60 |

EC of water samples at weekly intervals

| Date | Karumady thodu | Kari thodu | Kalathil thodu | Drainage channel. |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| 3.4.86 | 5.33 | 4.80 | 0.32 | 2.40 |
| 10.4.86 | 7.20 | 6.60 | 0.54 | 2.30 |
| 17.4.86 | 4.70 | 5.70 | 1.12 | 2.85 |
| 24.4.86 | 3.00 | 6.20 | 1.10 | 2.70 |
| 30.4086 | 7.07 | 3.20 | 1.20 | 1.26 |
| 8.5.86 | 6.30 | 6.60 | 0.[illegible]1 | 4.68 |
| 15.5.86 | 1.77 | 1.50 | 2.20 | 2.32 |
| 22.5.86 | 2.71 | 0.[illegible]5 | 1.02 | 2.08 |
| 29.5.86 | 1.23 | 2.01 | 1.30 | 2.20 |
| 5.6.86 | 5.10 | 2.80 | 2.20 | 3.90 |
| 12.6.86 | 0.77 | 3.70 | 3.35 | 2.14 |
| 19.6.86 | 1.67 | 2.60 | 2.30 | 2.20 |
| 26.6.37 | 3.35 | 3.90 | 3.55 | 3.45 |
| 3.7.86 | 0.77 | 1.76 | 1.50 | 2.02 |
| 10.7.86 | 0.95 | 2.25 | [illegible].43 | 2.21 |
| 17.7.86 | 0.25 | 0.60 | 0.32 | 0.43 |
| 24.7.86 | 0.71 | 1.92 | 1.56 | 0.99 |
| 31.7.86 | 0.72 | .. | 0.78 | 1.29 |
| 7.8.86 | 0.50 | 0.75 | 1.35 | 0.72 |
| 14.8.86 | Flooded | Flooded | Flooded | Flooded |
| 21.8.86 | 0.15 | 0.12 | 0.23 | 0.24 |
| 28.8.86 | 0.37 | 0.27 | 0.24 | 0.27 |
| 4.9.86 | 0.34 | 0.33 | 0.35 | 0.58 |
| 11.9.86 | 1.80 | 0.63 | 1.65 | 0.79 |
| 18.9.86 | 3.33 | 0.90 | 0.83 | 1.49 |

Contd....

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| 25.9.86 | 0.68 | 0.45 | 0.59 | 0.63 |
| 3.10.86 | 0.26 | 0.45 | 0.28 | 0.39 |
| 9.10.86 | 0.37 | 0.75 | 0.63 | 0.82 |
| 16.10.86 | 0.44 | 0.69 | 0.63 | 0.78 |
| 23.10.86 | 1.01 | 1.01 | 0.87 | 1.10 |
| 9.10.86 | 1.51 | 1.44 | 0.87 | 1.00 |
| 6.11.86 | 0.44 | 0.45 | 0.18 | 0.15 |
| 13.11.86 | 0.40 | 0.18 | 0.24 | 0.45 |
| 20.11.86 | 0.72 | 0.31 | 1.25 | 0.21 |
| 27.11.86 | 2.30 | 2.25 | 1.75 | 1.80 |
| 4.12.86 | 0.50 | 2.70 | 1.01 | 1.63 |
| 11.12.86 | 0.65 | 1.35 | 1.00 | 1.93 |
| 18.12.86 | 0.18 | 1.20 | 0.59 | 0.74 |
| 25.12.86 | .. | .. | .. | .. |
| 1.1.87 | 0.28 | 0.29 | 0.22 | 0.77 |
| 3.1.87 | 0.18 | 0.53 | 0.22 | 0.64 |
| 5.1.87 | 0.16 | 0.22 | 0.27 | 0.28 |
| 22.1.87 | 0.15 | 0.22 | 1.14 | 0.37 |
| 30.1.87 | 0.14 | 0.52 | 1.14 | 0.51 |
| 5.2.87 | 0.60 | 0.36 | 1.11 | 1.20 |
| 9.2.87 | 0.15 | 0.72 | 1.02 | 2.43 |
| 27.2.87 | 0.13 | 0.17 | 1.32 | 1.65 |
| 5.3.87 | .. | .. | .. | .. |
| 2.3.87 | .. | .. | .. | .. |
| 9.3.87 | 0.35 | 0.85 | 1.30 | 2.25 |
| 6.3.87 | 3.20 | 1.90 | 1.75 | 2.30 |

Figure - 1(1)

Periodic changes in pH of water in different water bodies wrt time Karumady thodu and Karithodu

Scale : Horizontal - 1cm 2 week
Vertical - 2cm 1 pH

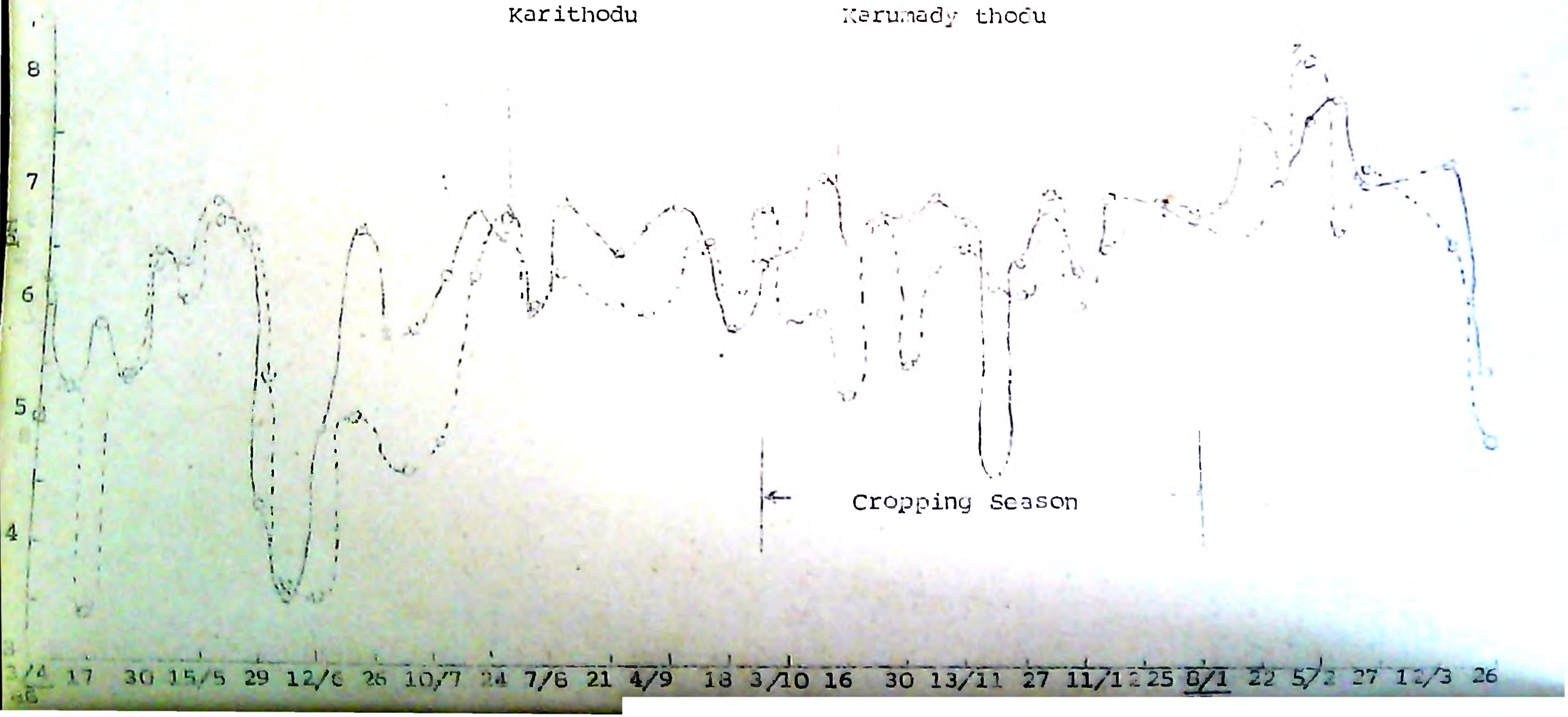


Figure - 1(2)

Periodic changes of pH of water in different waterbodies wrt time
(Kalathil thodu and Drainage channel)

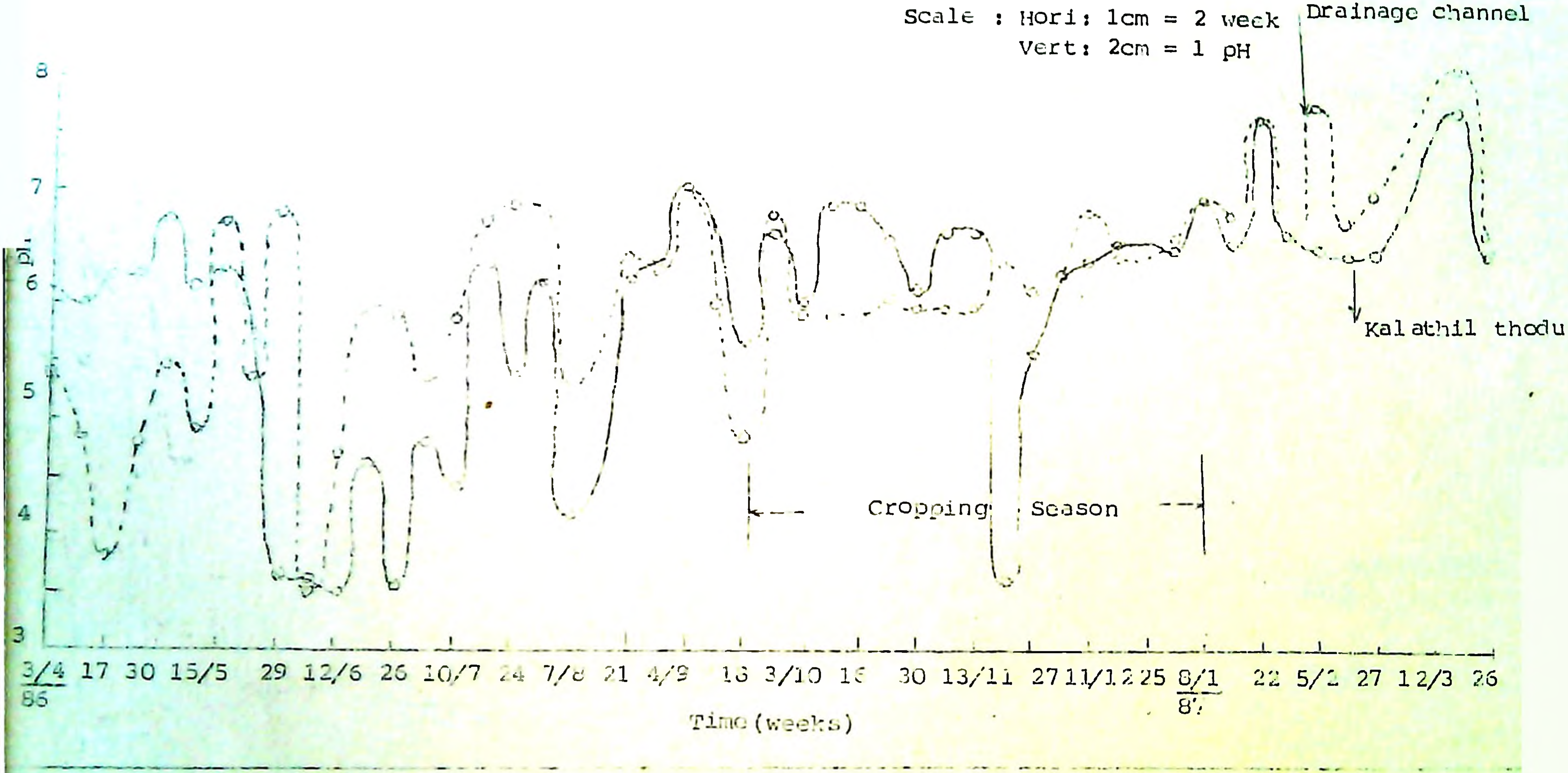


Figure - 1(3)

Periodic changes in EC of water in different water bodies wrt time

(Karumady thodu and Kari thodu)

Scale : Horizontal 1cm - 2 weeks
Vertical 1cm - 0.5 EC(mmhos cm)

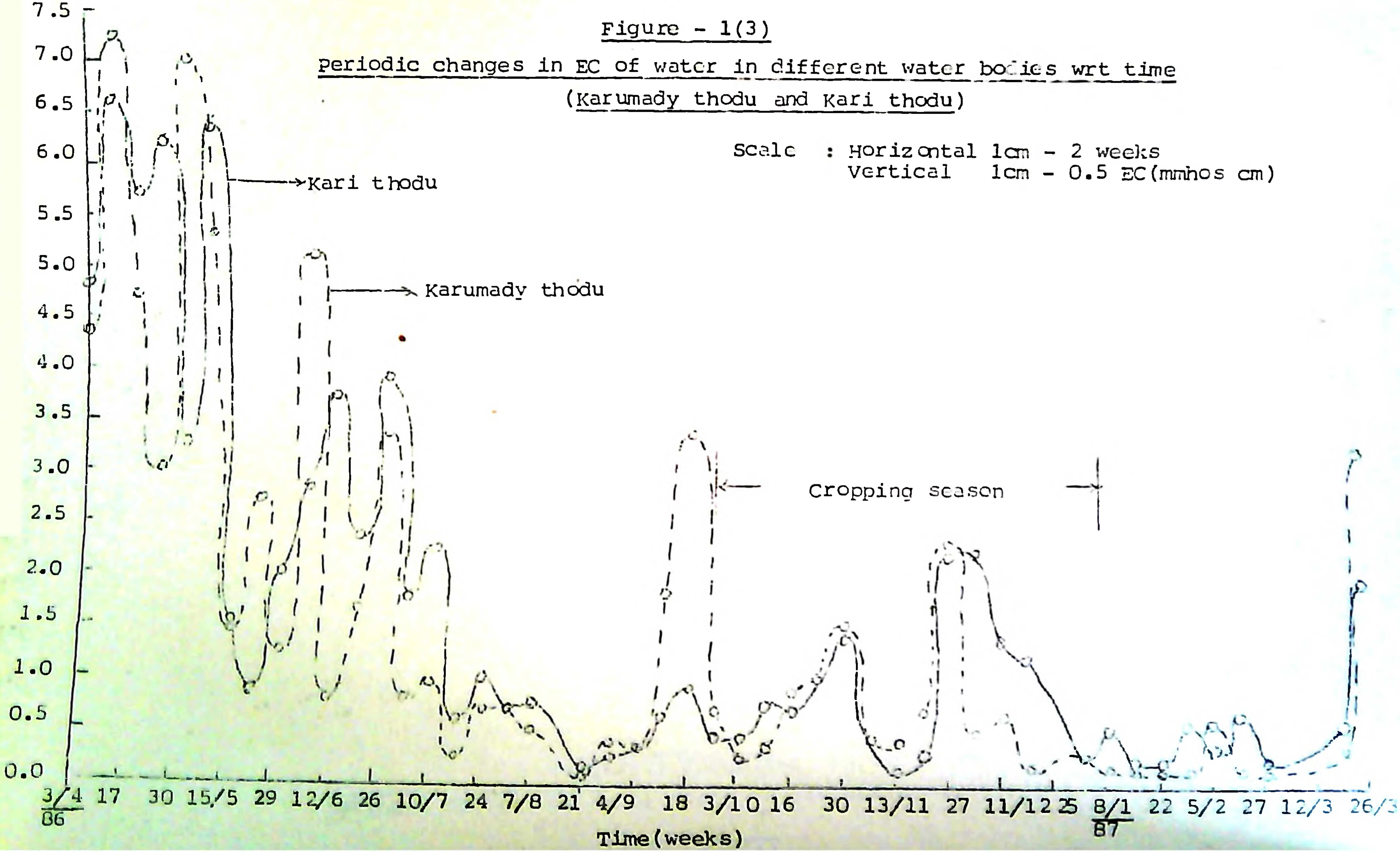
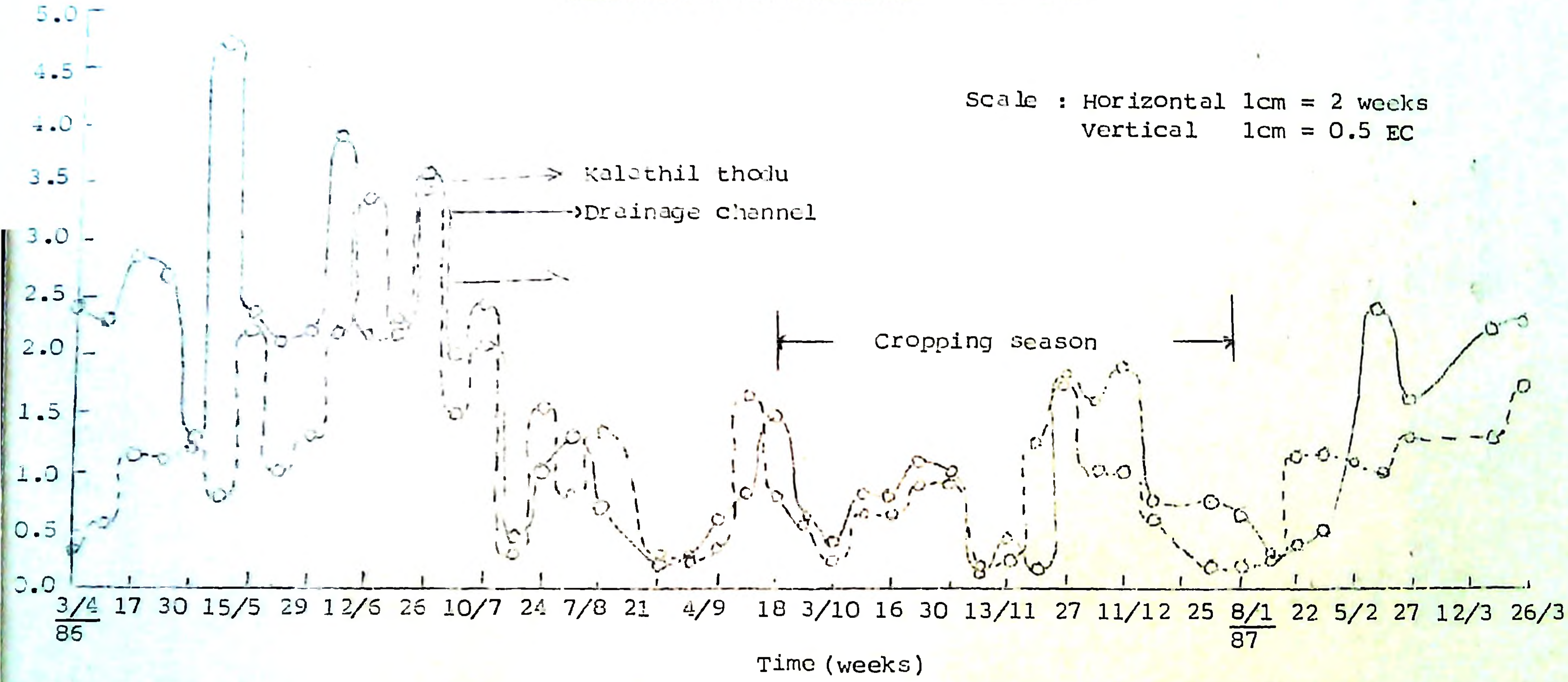


Figure - 1(4)

Periodic changes in EC of water in different waterbodies wrt time
(Kalathil thodu and Drainage channel)



## RESEARCH PROJECT No.2.

1. Title of the project : Preparation of water table contour map, and hydraulic map of the project area.

2. Title of the problem : Seasonal fluctuation of ground water table with reference to surface water level and characterisation of aquifer in the project area "Kavil thekkumpuram padasekharam".

3. Objectives:-

   a) Study on the seasonal changes in ground water with reference to surface water movement in water ways outside.

   b) Seasonal changes on the level and movement of water in waterways.

   c) Identification and characterisation of aquifer, if any, existing in the project area.

4. Practical utility:-

This study will enable to understand the changes that take place in ground water after the layout of surface and subsurface drainage system.

5. Technical programme:-

In order to record ground water table fluctuation, observation wells will be installed at a depth of 1m. using 40mm or 50mm of PVC pipes at 100m apart. The pipes will be perforated with 6mm holes at 10 x 5cm spacing and will be wound with nylon ropes/coir to prevent clogging. Water level in these wells will be recorded at weekly intervals.

6. Observations to be taken : Water levels in observation wells, waterways and piezometers will be recorded at weekly intervals.

7. Date of starting : June 1982

8. Date of completion : Till the scheme work is completed.

9. Progressof work:-

The field is installed with 24 observation wells in 3 bands at 100m apart to record the water table fluctuations. the observation in these wells had started since its installation. A definite pattern of groundwater movement with respect to the outside waterbody could not be traced since water movement was affected by the drainage pumping. The movement of ground water with reference to the water level of the surrounding waterbody is graphically shown through figure 2(2) and 2(3) for the cropping period. The monthly average values of water table elevation are given in table 2(i) to 2(iii).

Figure - 2(1)

Location of observation wells in the project area

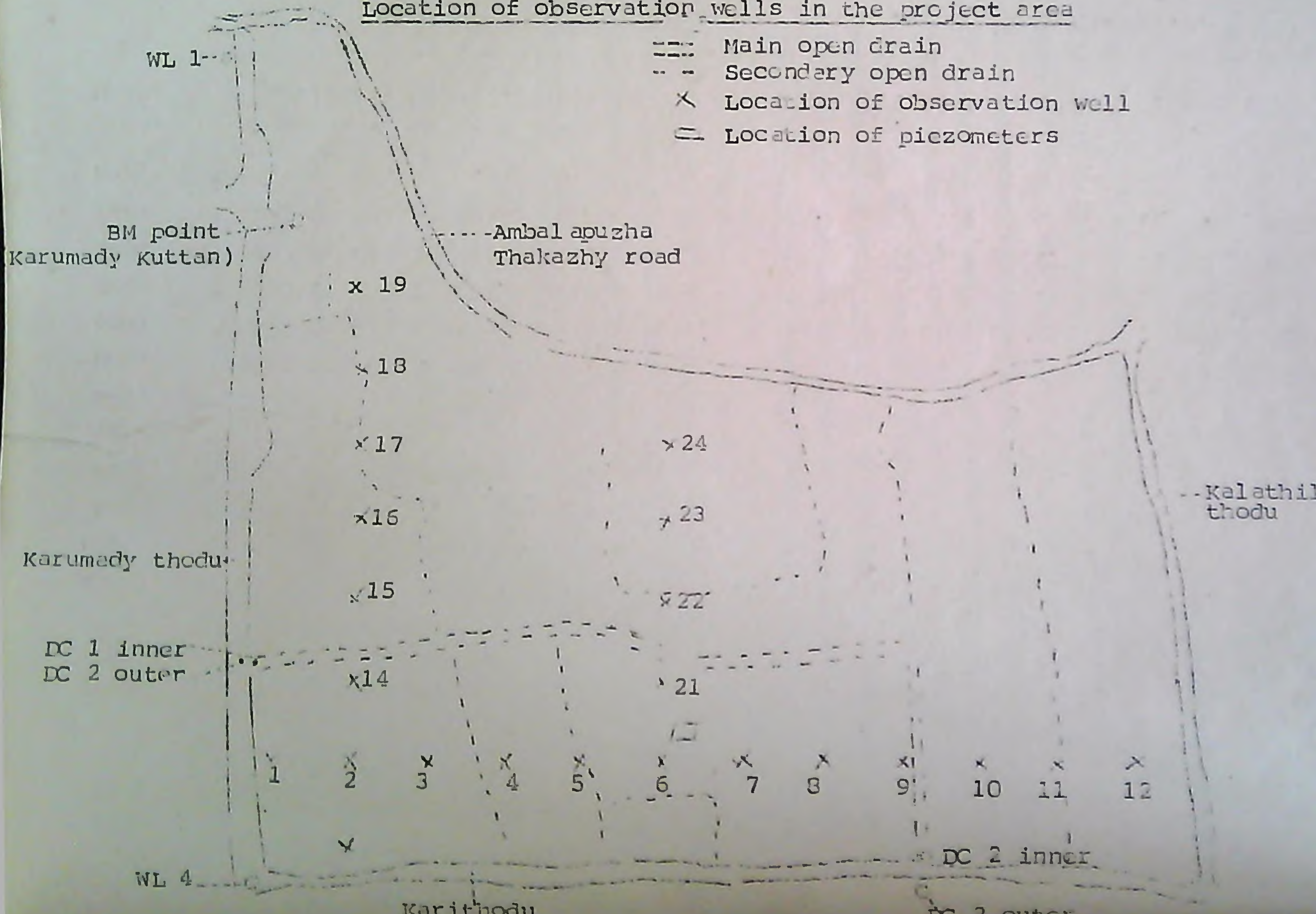


Table - 2(i).

Ground water table level in the project area (as read from surface bench mark elevation = 1000 cm.)

| Month | OBW1 | OBW2 | OBW3 | OBW4 | OBW5 | OBW6 | OBW7 | OBW8 | OBW9 | 10 | 11 | OBW12 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
| April '86 | ....... Flood fallowing ........ | | | | | | | | | | | | |
| May " | ,, | | | | | | | | | | | | |
| June " | ,, | | | | | | | | | | | | |
| July " | ,, | | | | | | | | | | | | |
| Aug. " | ,, | | | | | | | | | | | | |
| Sep. " | ,, | | | | | | | | | | | | |
| Oct. " | 826.9 | 829.3 | 807.8 | 821.0 | 808.5 | 809.5 | .. | 823.5 | 819.3 | .. | .. | 860.8 | 822.96 |
| Nov. " | 829.6 | 835.8 | 814.4 | 818.8 | 812.1 | 815.6 | .. | 827.4 | 822.9 | .. | .. | 869.1 | 828.41 |
| Dec. " | 830.5 | 834.7 | 823.8 | 829.0 | 820.7 | 818.3 | .. | 826.8 | 823.5 | .. | .. | 875.8 | 831.46 |
| Jan. 1987 | 827.6 | 832.7 | 815.6 | 823.[illegible] | 817.4 | 810.3 | .. | 8[illegible]2.1 | 821.5 | .. | .. | 871.4 | 826.84 |
| Feb. " | 831.0 | 831.5 | 826.0 | 828.0 | 830.0 | 818.0 | .. | 827.5 | 829.5 | .. | .. | .. | 827.69 |
| March " | .. | .. | .. | .. | .. | . | .. | .. | .. | .. | .. | .. | .. |
| Mean | 829.12 | 832.80 | 817.52 | 825.96 | 817.74 | 814.34 | | .825.46 | 823.34 | | | 869.28 | |

Contd....

| Month | OBW13 | OBW2 | OBW14 | OBW16 | OBW17 | OBW18 | OBW19 | Mean |
|---|---|---|---|---|---|---|---|---|
| April 86 | | | | | ...... Flood fallowing ...... | | | |
| May " | | | | | ,, | ,, | | |
| June " | | | | | ,, | ,, | | |
| July " | | | | | ,, | ,, | | |
| Aug. " | | | | | ,, | ,, | | |
| Spet. " | | | | | ,, | ,, | | |
| Oct. " | 800.8 | 829.3 | 811.0 | 825.8 | 816.5 | 825.0 | 831.5 | 819.99 |
| Nov. " | 809.0 | 835.8 | 819.1 | 827.8 | 823.8 | 826.3 | 837.8 | 825.66 |
| Dec. " | 811.7 | 834.7 | 828.0 | 827.8 | 828.1 | 829.8 | 836.3 | 828.06 |
| Jan. '87 | 807.5 | 832.7 | 819.2 | 823.2 | 824.0 | 826.0 | 831.6 | 823.46 |
| Feb. " | .. | 831.5 | 831.0 | 832.0 | 828.0 | 830.0 | 826.5 | 829.83 |
| March " | .. | .. | .. | .. | .. | .. | .. | .. |
| Mean | 807.25 | 832.8 | 821.66 | 827.32 | 824.08 | 827.42 | 832.74 | |

| Month | | OBW20 | OBW6 | OBW21 | OBW22 | OBW23 | OBW24 | Mean |
|---|---|---|---|---|---|---|---|---|
| April | 1986 | | | | ...... Flood fallowing ...... | | | |
| May | " | | | | ,, | ,, | | |
| June | " | | | | ,, | ,, | | |
| July | " | | | | ,, | ,, | | |
| August | " | | | | ,, | ,, | | |
| Sept. | " | | | | ,, | ,, | | |
| Oct. | " | 801.3 | 809.5 | 783.8 | .. | 825.8 | .. | 805.1 |
| Nov. | " | 806.3 | 815.6 | 793.1 | .. | 836.9 | .. | 812.98 |
| Dec. | " | 810.7 | 818.3 | 799.0 | .. | 835.8 | .. | 815.95 |
| Jan. | 1987 | 803.0 | 810.3 | 791.2 | .. | 832.6 | .. | 809.28 |
| Feb. | " | 807.0 | 818.0 | 800.0 | .. | 832.0 | .. | 814.25 |
| March | " | .. | .. | .. | .. | .. | .. | .. |
| Mean | | 805.66 | 814.34 | 793.42 | .. | 832.62 | | |

Contd.....

**Table - 2(ii)**

Surface water level in waterways, which surrounds the project area (as read from surface bench mark elevation - 1000 cm).

**Table - 2(iii)**

Surface water level in the Drainage Channel (as read from Bench Mark Elevation - 1000 cm.)

| Month | WL-1* | WL-4 | DC-1 | DC-2 |
|---|---|---|---|---|
| April 1986 | 839.5 | 836.1 | 833.9 | 844.9 |
| May " | 858-3 | 854-5 | 849.6 | 862.4 |
| June " | 876.0 | 872.0 | 878.0 | 883.0 |
| July " | 874.1 | 870.7 | 877.9 | 853.9 |
| August " | 863.5 | 864.3 | 867.0 | 872.0 |
| Sept. " | 861.3 | 857.6 | 848.0 | 853.0 |
| Oct. " | 869.5 | 865.3 | 783.3 | 795.7 |
| Nov. " | 882.5 | 876.5 | 796.5 | 813.8 |
| Dec. " | 886.5 | 883.5 | 810.0 | 816.3 |
| January 87 | 872.6 | 864.0 | 804.8 | 808.3 |
| February " | 845.2 | 840.5 | 783.3 | 789.7 |
| March " | 827.5 | 824.0 | 757.5 | 703.0 |
| Mean | 863.04 | 859.08 | 824.57 | 824.71 |

* Reference points are given in Fig.2(1).

Figure - 2(2)

Movement of ground water table in the project area wrt time and surrounding waterbody level (Karumady thodu)

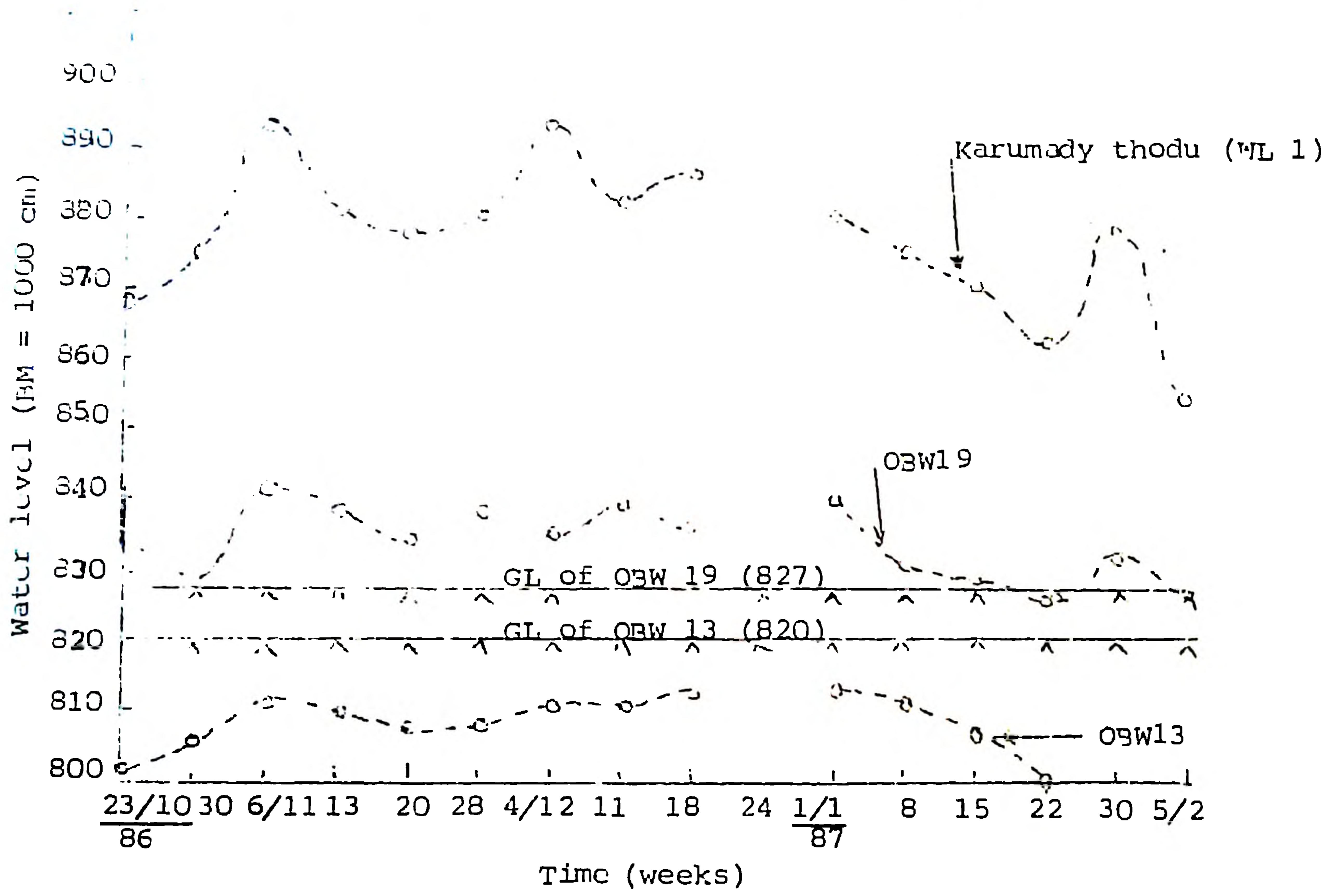
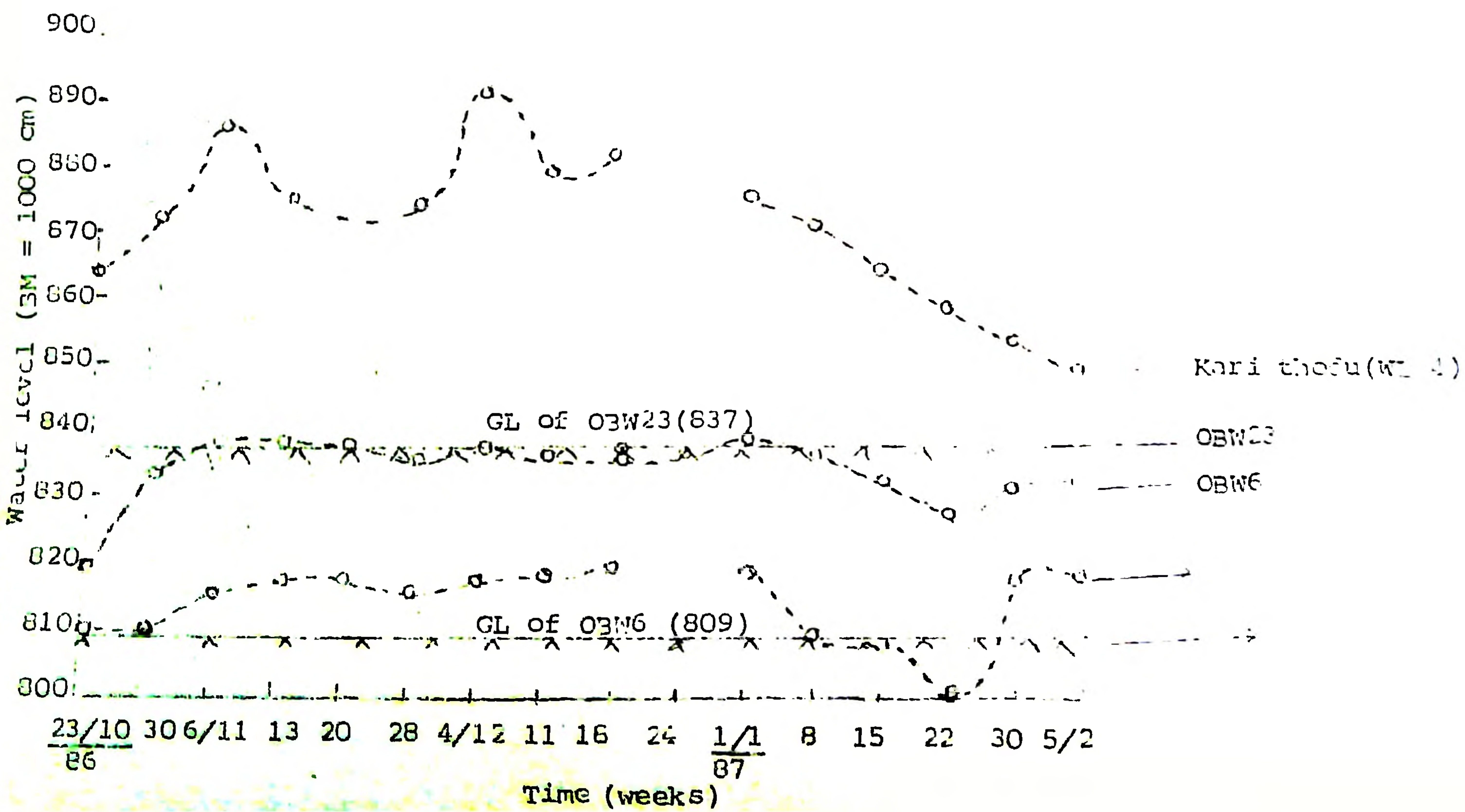


Figure - 2(3)

Movement of ground water table in the project area wrt time and surrounding waterbody level(Kari thodu)



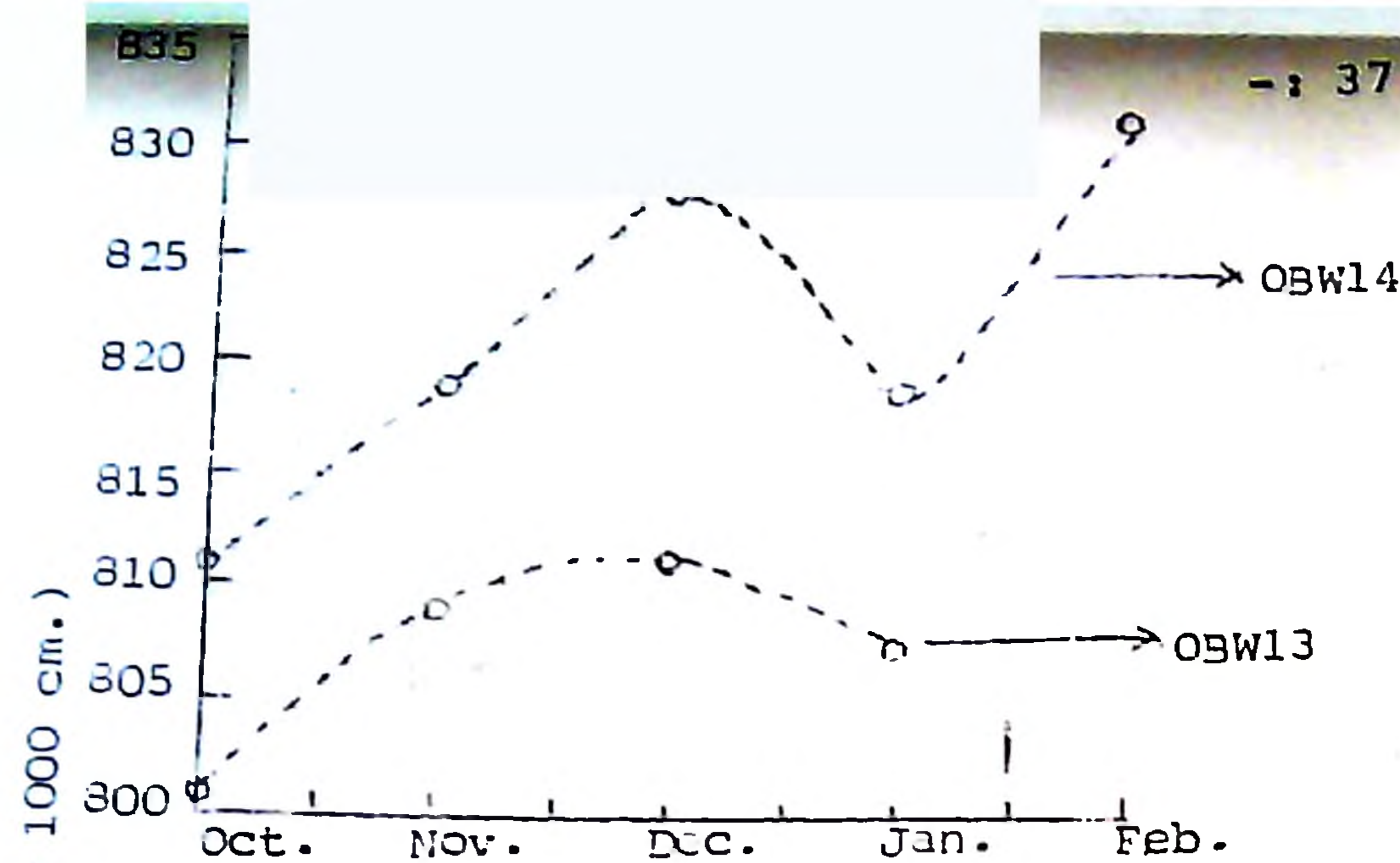
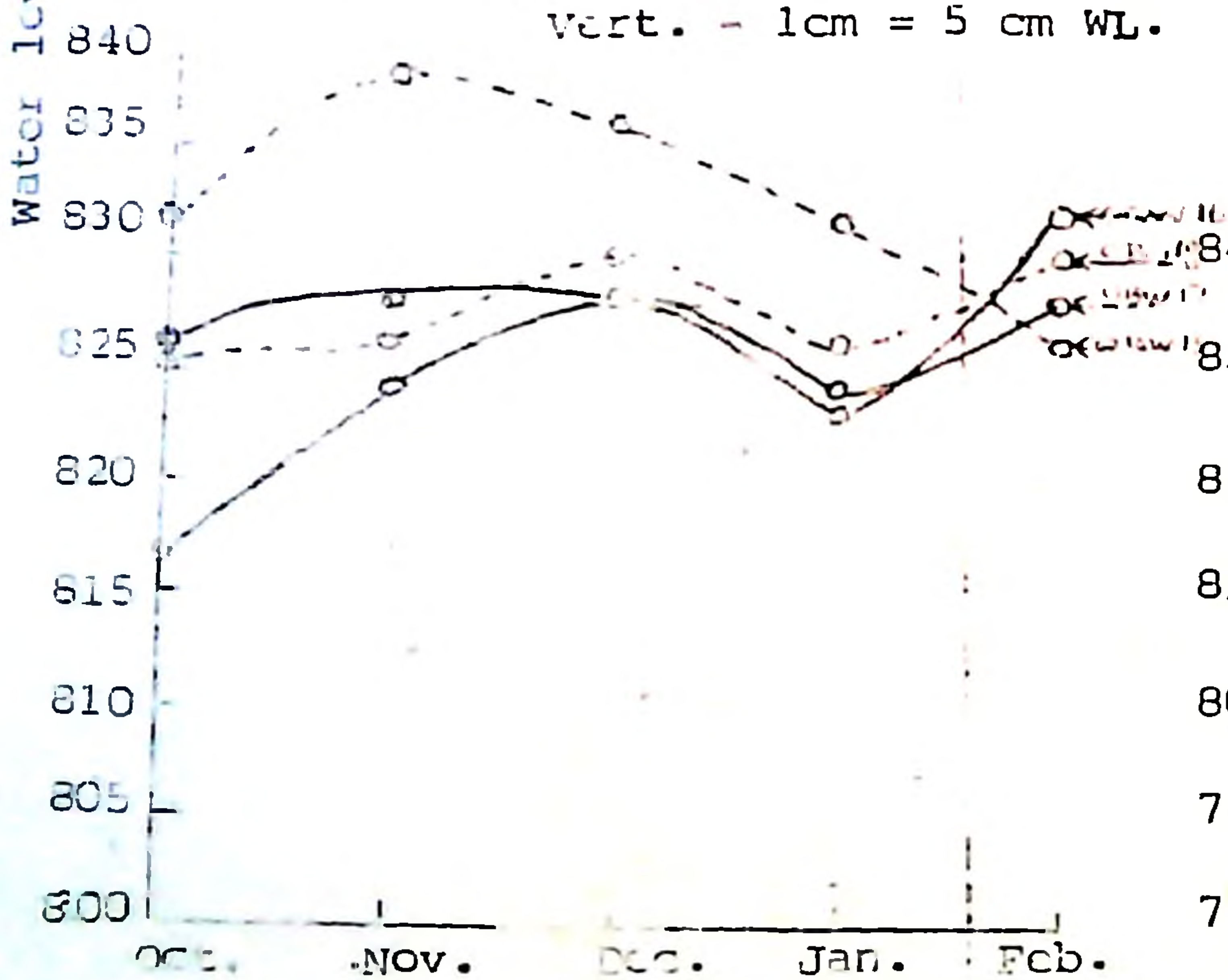


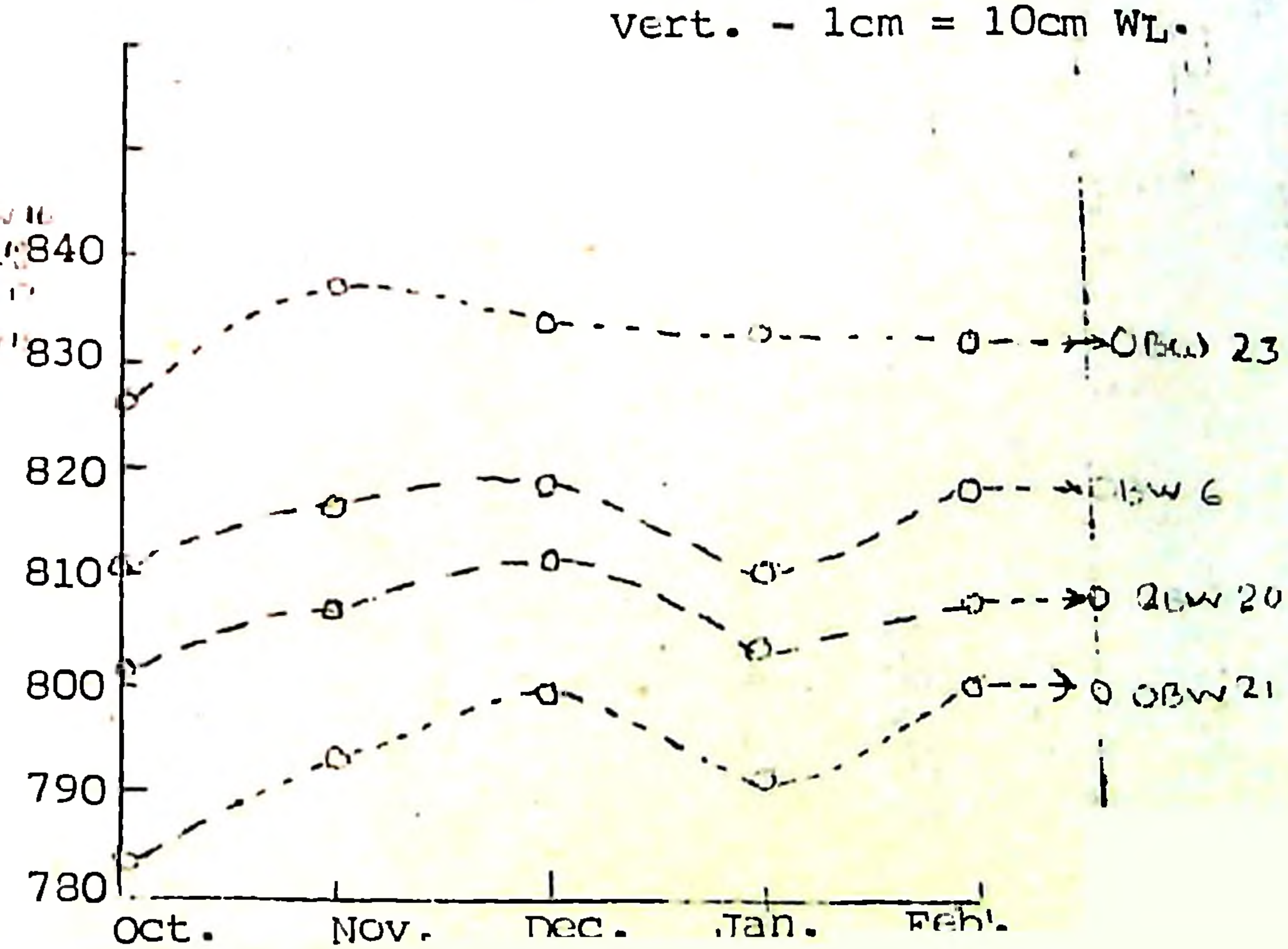

Figure - 2(4)

Relative water table depth in the project area

Scale : Hori. - 2cm = 1 month
Vert. - 1cm = 5 cm WL.




Scale : Hori. - 2cm = 1 month
Vert. - 1cm = 10cm WL.



# RESEARCH PROJECT NO.3a.

1. Title of the project : Development of a suitable technology for the sub-surface drainage system in the Kari lands of Kuttanad.

2. Title of the problem : Assessment of hydraulic properties of the tile drainage system.

3. Objectives:

   a) To estimate different parameters of hydraulics of the tile drainage system in Kari lands.

   b) To evaluate the performance of tile drainage system in the project area.

   c) To collect information to develop a viable technology for the sub-surface drainage system in the project area.

4. Practical utility:

This is a basic study aimed at gathering valuable parameters of the hydraulics of the tile drainage system. The information collected and compiled can be used for deriving a suitable technology for the design of a sub-surface tile drainage system for the Kari lands of Kuttanad.

5. Technical programme:

Planning was made to lay 9 lines of parallel tile drains. The first six lines were to be spaced at 15m and to have 75m length and the remaining were to be spaced at 30m and to have 100m length. The initial line designated as 1B15, the sixth line designated as 6B15/30 and the last line, 9B30, were laid to function as buffer lines to minimize the boundary effects. The lines designated as 2E15, 3E15, 4E15 and 5E15 are experimental lines of 15m spacing and the lines 7E30 and 8E30 are experimental lines of 30m spacing.

Further replication of parallel drains of 30m spacing or some other else could not be planned because of the geometry of the location.

All the above drains were to run at a slope of 0.2% and at an average depth of 0.875m. The drains were to be provided with a sand filter of an average thickness of 10-15 cms. all around the drain. All the parallel drains were to open into separate collection sumps where the discharge measurements were to be made. The collection sumps were inter connected by PVC pipes of 110/160mm dia. laid at 0.4% slope which drain into a main drainage sump from where the drained water is pumped into the outside waterbody.

The tile drains are of baked clay, 60m long, with bell mouth at one end (125 mm outer dia. and 100mm inner dia). These drains are provided with 15 Nos.of 6mm holes in three bands of 5 holes each, on the 1/3rd periphery area.

A series of observation wells were also to be installed in the experimental field to record the subsidence of ground water.

6. <u>Observations to be recorded:</u>

   a) Rate of discharge at each collection sump.
   b) Water table readings at each observation well.
   c) Computation of transmissivity, hydraulic conductivity, drainage intensity factor and effective porosity.

7. Date of start : December 1984

8. Date of completion : Till the end of the scheme.

9. <u>Progress of work:</u>

The installation of the drainage system was completed during 1985-86 and the complete laying procedures are mentioned in the Annual Report 1985-86. The layout of the system is given in figure 3a(1).

## Data Processing:

Just after the completion of harvest of the paddy crop in the experimental area, continuous drainage pumping started on 11.2.1987 which was continued upto 2.3.1987. Observations like drainage flow through the tile drains and water table recession in the 12 observation wells were recorded at different time intervals. The readings interpolated from this data at 20hr. interval are given in appendix-1. The general pattern of the graph drawn for discharge versus time and water table recession at midpoint between drains versus time (fig 3a(1) to 3a(5)) indicated that there is a continuous recharge towards the drains from the outside waterbody when the drains are located nearer to the outside waterbody. The intensity of this recharge reduces as the distance of the drains increases and ceases or becomes negligible at a certain distance away from the waterbody. This is attributed to the fact that the outside waterbody is clearly about 1M above the average water table elevation in the field. The above fact can be inferred when a comparison is made for the q versus t and h versus t graphs drawn for 2E15 and 7E30. In the case of 2E15, a drain close to the outside waterbody, the discharge and the water table height tends to become constant towards the later stages while in the case of 7F30 which is far way from the main waterbody, the discharge and the water table height above the drain at mid-spacing tends to become zero. The drainage flow through the drain 7E30 is a case of nonsteady state. The theoretical approach to the analysis of non-steady state is given in appendix-2. The q versus h graph for 7E30 is shown in figure 3a(6). [illegible] [illegible]. The ln q vs t and ln h vs t graph for 7E30 is shown in fig.3a(7). The graphical and mathematical analysis of the problem is also given in appendix-2. From the analysis of the following parameters were found.

## Table 3a(i)

**Values of Discharge at different hydraulic heads.**

| Head (cm) | 2E15* | | 3E15* | | 4E15* | | 5E15* | | 7E30@ | | 8E30@ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm/ day | lit/ minute | mm/ day | lit/ minute | mm/ day | lit/ minute | mm/ day | lit/ minute | mm/ day | lit/ minute | mm/ day | lit/ minute |
| 65 | 11.50 | 8.98 | 12.00 | 9.38 | .. | .. | 9.20 | 7.19 | 3.75 | 7.81 | .. | .. |
| 60 | 10.00 | 7.81 | 9.30 | 7.27 | 7.30 | 5.70 | 6.00 | 4.69 | 2.15 | 4.48 | 3.30 | 6.88 |
| 55 | 9.35 | 7.30 | 8.40 | 6.56 | 5.80 | 4.53 | 4.90 | 3.83 | 1.70 | 3.54 | 2.45 | 5.10 |
| 50 | 9.00 | 7.03 | 7.80 | 6.09 | 5.10 | 3.98 | 4.30 | 3.36 | 1.40 | 2.92 | 1.95 | 4.06 |
| 45 | 8.50 | 6.64 | 7.10 | 5.55 | 4.55 | 3.55 | 4.00 | 3.13 | 1.20 | 2.50 | 1.65 | 3.44 |
| 40 | 7.80 | 6.09 | 6.60 | 5.16 | 4.10 | 3.20 | 3.70 | 2.89 | 1.00 | 2.08 | 1.40 | 2.92 |
| 35 | 7.00 | 5.47 | 6.20 | 4.84 | 3.80 | 2.97 | 3.40 | 2.66 | 0.80 | 1.67 | 1.35 | 2.81 |
| 30 | 5.75 | 4.49 | 5.60 | 4.38 | 3.50 | 2.73 | 3.00 | 2.34 | 0.65 | 1.35 | 1.00 | 2.08 |
| 25 | .. | .. | 4.70 | 3.67 | 2.90 | 2.27 | 2.60 | 2.03 | 0.50 | 1.04 | 0.80 | 1.67 |
| 20 | .. | .. | .. | .. | 2.20 | 1.72 | 2.00 | 1.56 | 0.40 | 0.83 | 0.65 | 1.35 |
| 15 | .. | .. | .. | .. | .. | .. | .. | .. | 0.30 | 0.63 | 0.55 | 1.15 |
| 10 | .. | .. | .. | .. | .. | .. | .. | .. | 0.20 | 0.42 | 0.40 | 0.83 |

* 15 m spacing

@ 30 m spacing

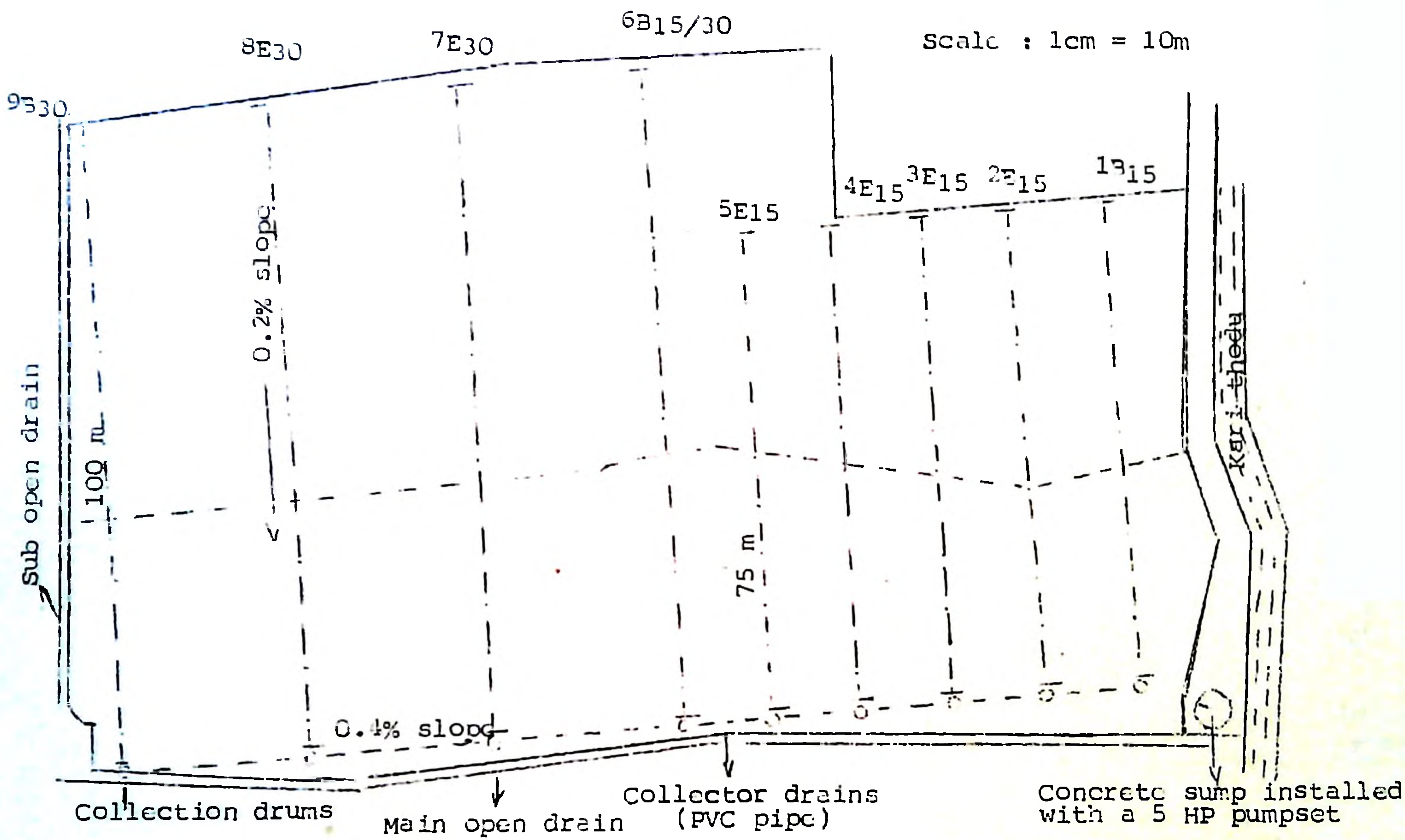
Table - 3a(2)

Values of discharge and average hydraulic head at identical values of elapsed time

| | 2E15 | | 3E15 | | 4E15 | | 5E15 | | 7E30 | | 8E30 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | q (mm/day) | h (m) | q (mm/day) | h (m) | q (mm/day) | h (m) | q (mm/day) | h (m) | q (mm/day) | h (m) | q (mm/day) | h (m) |
| 0 | .. | 0.69 | .. | 0.67 | .. | 0.65 | .. | 0.67 | .. | 0.66 | .. | 0.65 |
| 20 | 9.70 | 0.59 | 8.60 | 0.56 | 6.10 | 0.56 | 6.50 | 0.62 | 2.30 | 0.62 | 3.30 | 0.60 |
| 40 | 9.10 | 0.51 | 7.40 | 0.48 | 5.10 | 0.50 | 5.20 | 0.57 | 1.75 | 0.56 | 2.35 | 0.54 |
| 60 | 8.70 | 0.48 | 6.90 | 0.43 | 4.60 | 0.45 | 4.50 | 0.52 | 1.50 | 0.52 | 1.95 | 0.50 |
| 80 | 8.50 | 0.45 | 6.60 | 0.40 | 4.20 | 0.42 | 4.10 | 0.47 | 1.30 | 0.48 | 1.70 | 0.46 |
| 100 | 8.30 | 0.43 | 6.40 | 0.37 | 4.00 | 0.39 | 3.90 | 0.44 | 1.15 | 0.44 | 1.50 | 0.42 |
| 120 | 8.10 | 0.42 | 6.30 | 0.36 | 3.90 | 0.37 | 3.70 | 0.40 | 1.05 | 0.41 | 1.35 | 0.38 |
| 140 | 7.90 | 0.41 | 6.10 | 0.34 | 3.80 | 0.35 | 3.50 | 0.37 | 0.90 | 0.38 | 1.20 | 0.35 |
| 160 | 7.80 | 0.40 | 6.00 | 0.33 | 3.70 | 0.33 | 3.40 | 0.35 | 0.80 | 0.35 | 1.05 | 0.32 |
| 180 | 7.70 | 0.39 | 5.80 | 0.32 | 3.60 | 0.32 | 3.20 | 0.33 | 0.70 | 0.32 | 0.95 | 0.29 |
| 200 | 7.50 | 0.38 | 5.70 | 0.31 | 3.50 | 0.30 | 3.10 | 0.31 | 0.65 | 0.29 | 0.80 | 0.26 |
| 220 | 7.40 | 0.37 | 5.60 | 0.30 | 3.40 | 0.29 | 2.90 | 0.29 | 0.55 | 0.27 | 0.75 | 0.24 |
| 240 | 7.30 | 0.37 | 5.50 | 0.29 | 3.30 | 0.28 | 2.80 | 0.28 | 0.50 | 0.24 | 0.70 | 0.21 |
| 260 | 7.10 | 0.36 | 5.30 | 0.28 | 3.20 | 0.27 | 2.70 | 0.26 | 0.45 | 0.22 | 0.60 | 0.19 |
| 280 | 7.00 | 0.35 | 5.10 | 0.27 | 3.10 | 0.26 | 2.50 | 0.25 | 0.40 | 0.19 | 0.55 | 0.16 |
| 300 | 6.80 | 0.34 | 5.00 | 0.26 | 2.90 | 0.25 | 2.30 | 0.23 | 0.35 | 0.17 | 0.50 | 0.14 |
| 320 | 6.60 | 0.34 | 4.80 | 0.26 | 2.80 | 0.24 | 2.20 | 0.22 | 0.30 | 0.15 | 0.40 | 0.11 |
| 340 | 6.40 | 0.33 | 4.70 | 0.25 | 2.60 | 0.23 | 2.00 | 0.20 | 0.25 | 0.12 | 0.35 | 0.09 |
| 360 | 6.20 | 0.32 | 4.50 | 0.24 | 2.50 | 0.22 | 1.90 | 0.19 | 0.20 | 0.10 | 0.25 | 0.07 |
| 380 | 6.10 | 0.31 | 4.30 | 0.23 | 2.30 | 0.21 | 1.80 | 0.18 | 0.20 | 0.08 | 0.20 | .. |
| 400 | 5.90 | 0.31 | 4.10 | 0.22 | 2.20 | 0.20 | 1.60 | 0.17 | 0.15 | .. | 0.15 | .. |
| 420 | 5.70 | 0.30 | 3.90 | 0.21 | 2.10 | .. | 1.40 | 0.16 | 0.10 | .. | 0.10 | .. |
| 440 | 5.60 | 0.29 | 3.80 | 0.21 | 2.00 | .. | 1.30 | .. | 0.05 | .. | 0.05 | .. |

Figure - 3a(1)

Layout of tile drains




Note : PVC, 110mm size from 9B30 to 7E30 (60m)
PVC, 160mm size from 7E30 to sump(113m)

Figure - 3a(2)

Discharge versus time (2E15)

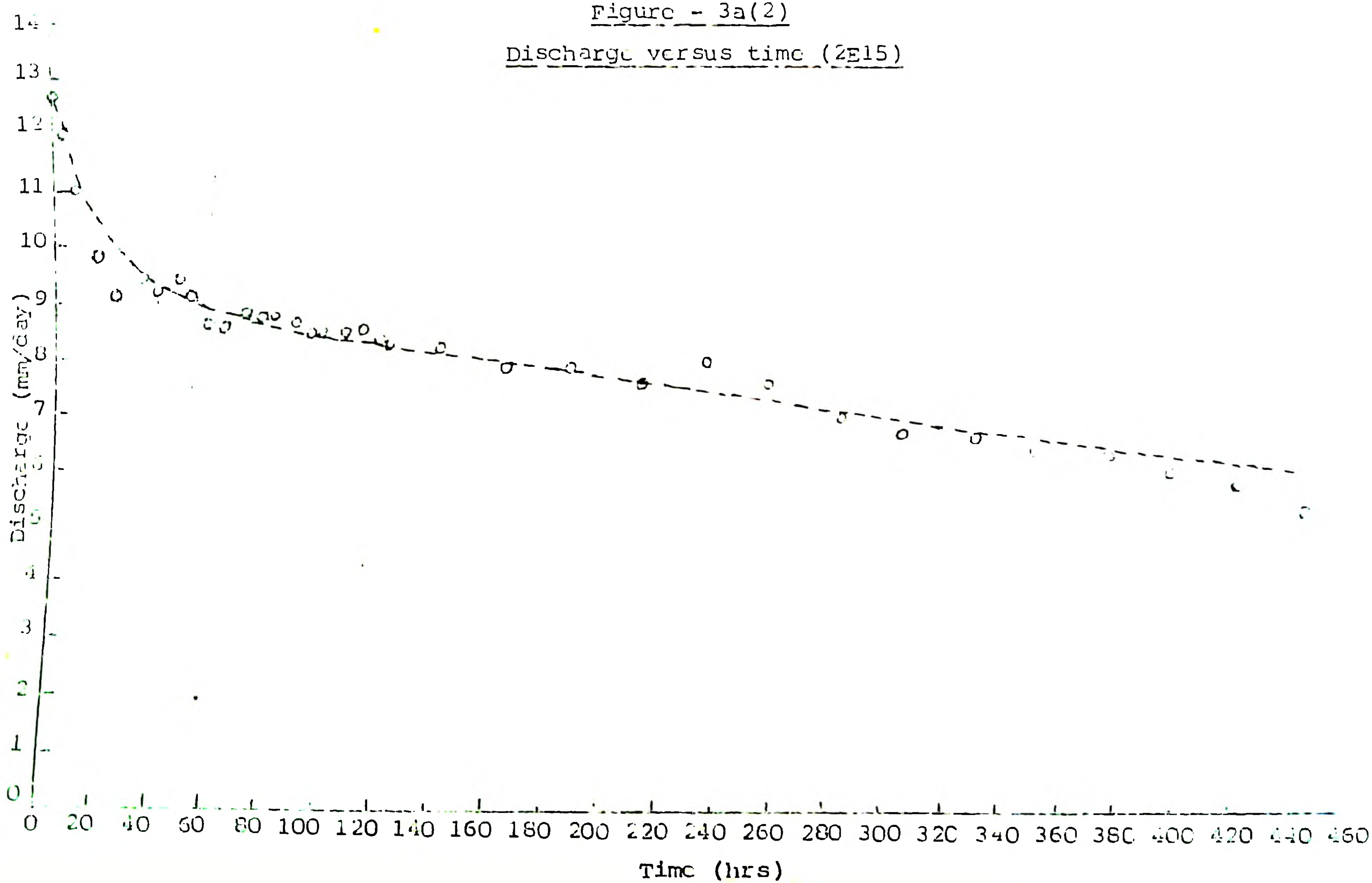


Figure - 3a(2)

Discharge versus time (7E30)

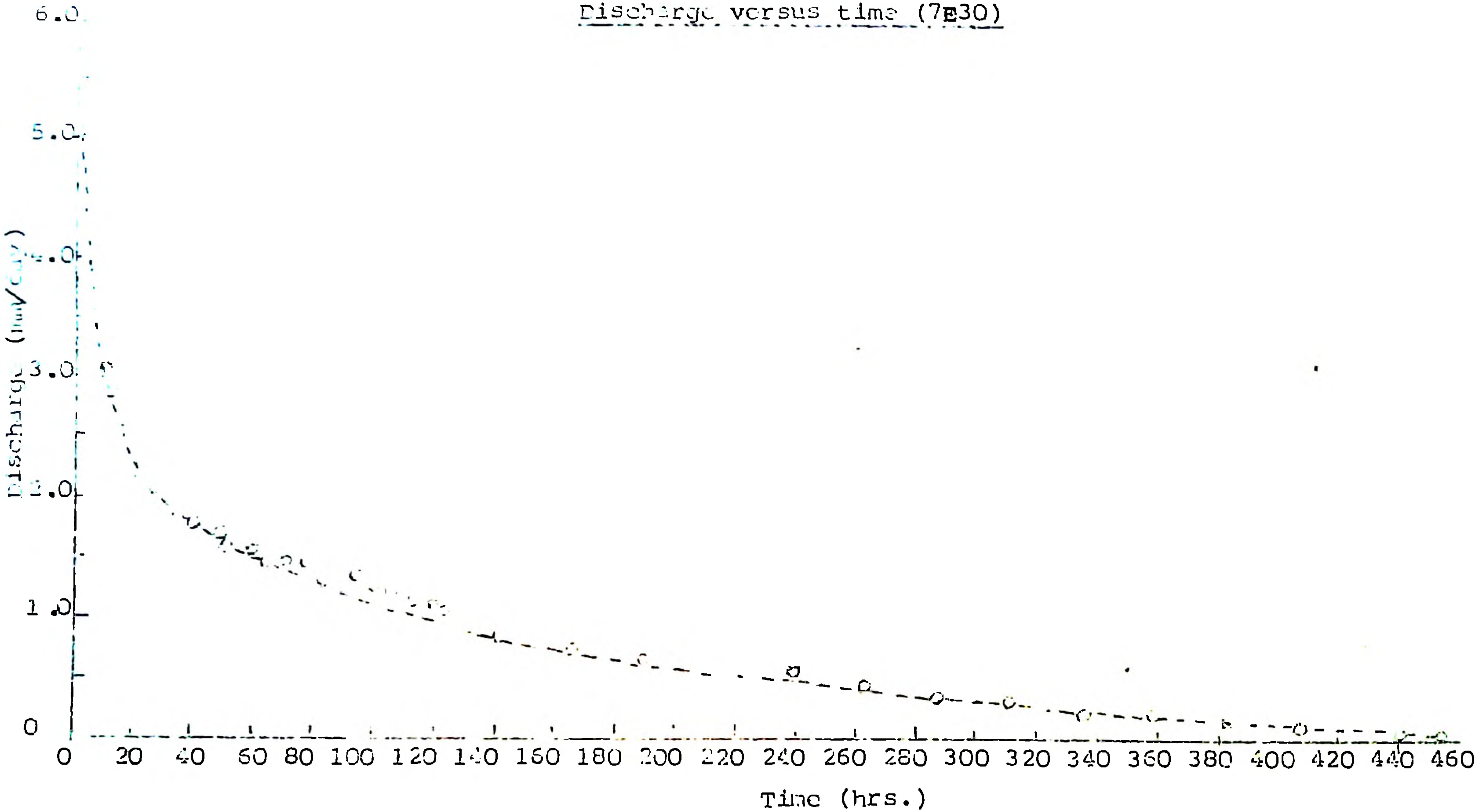


Figure - 3a(4)

Hydraulic head versus time (2E15)

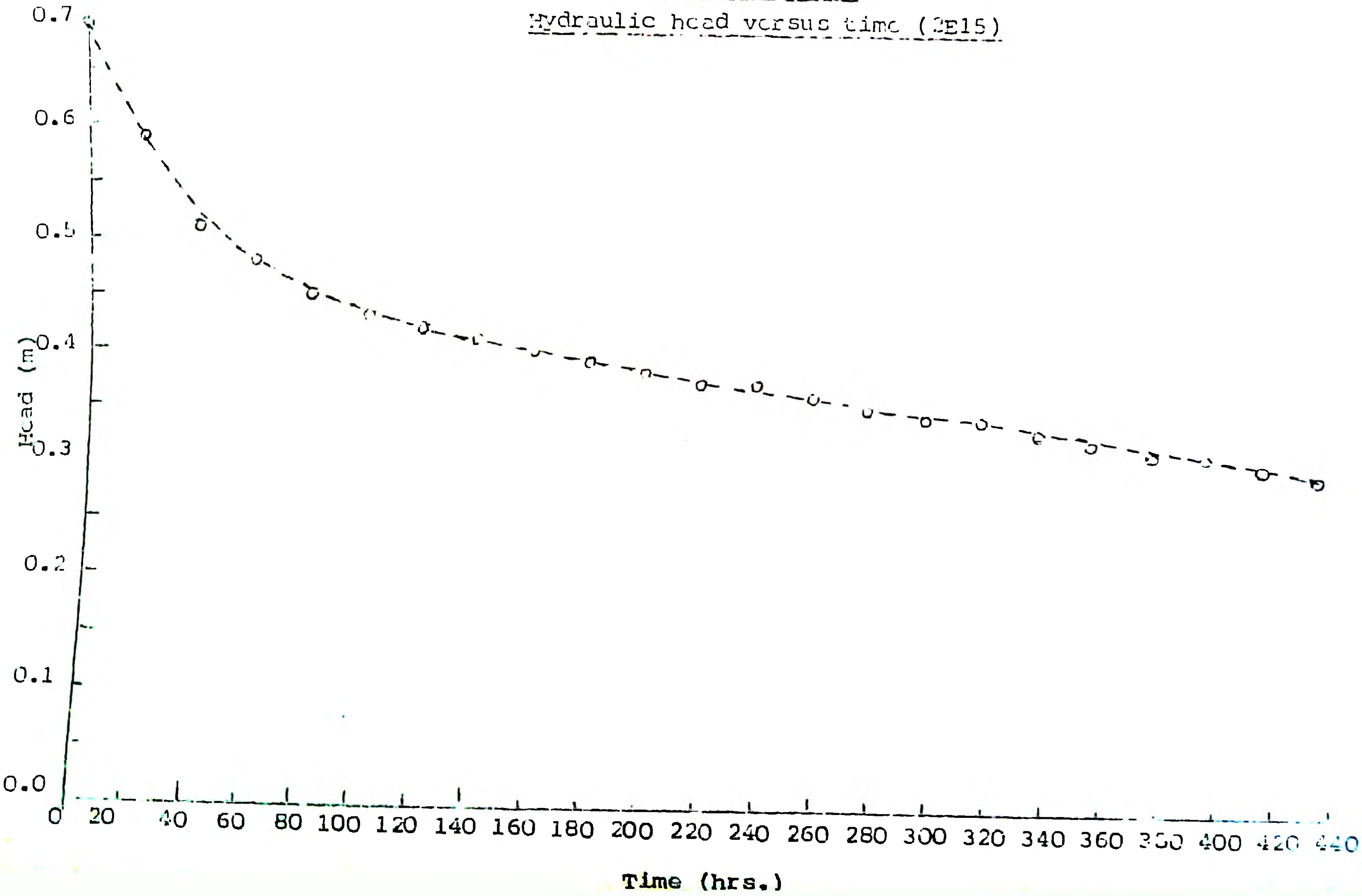


Figure - 3a(5)

Hydraulic head versus time (7E30)

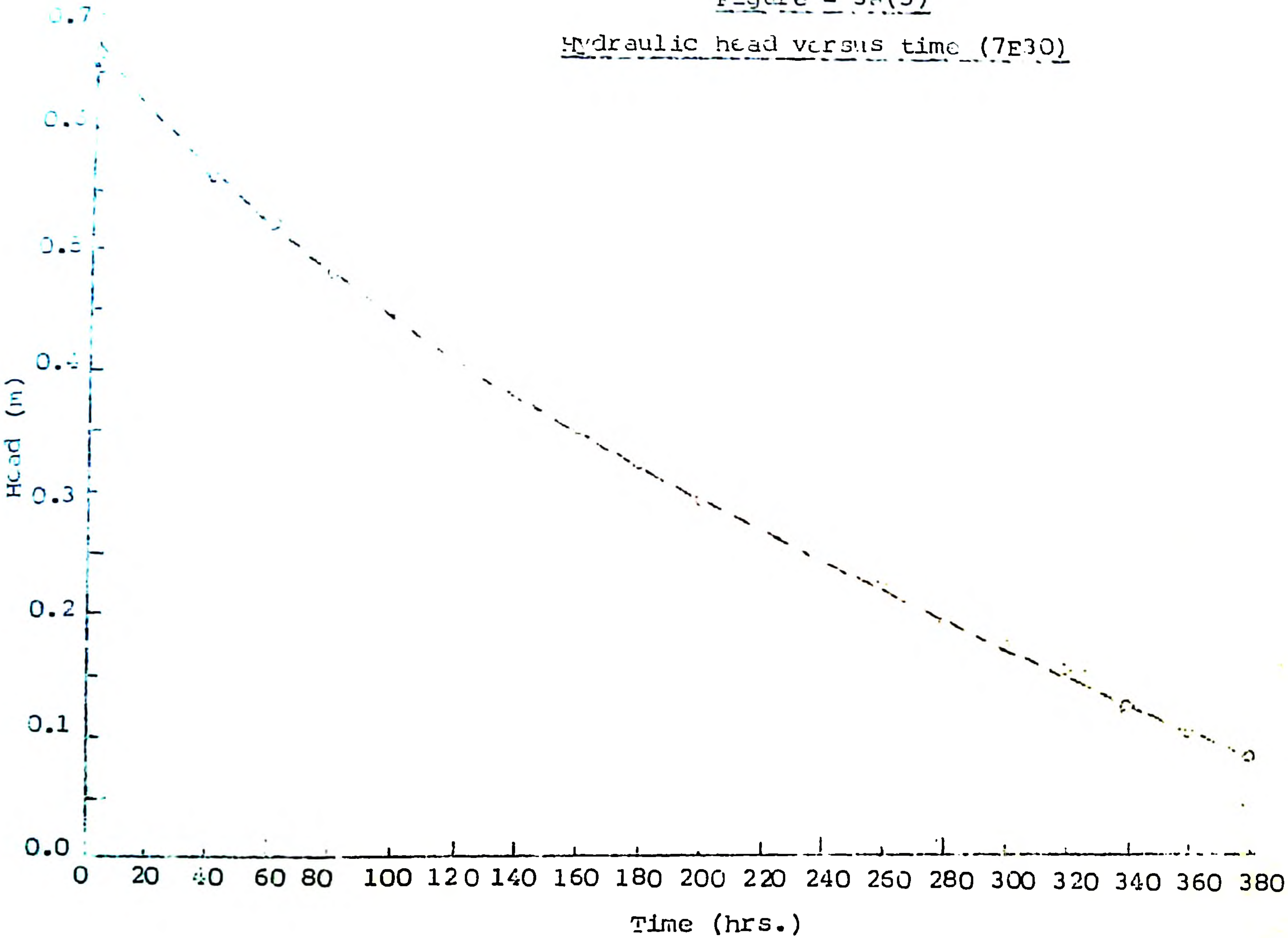


Figure - 3a(6)

Discharge versus hydraulic head (7E30)

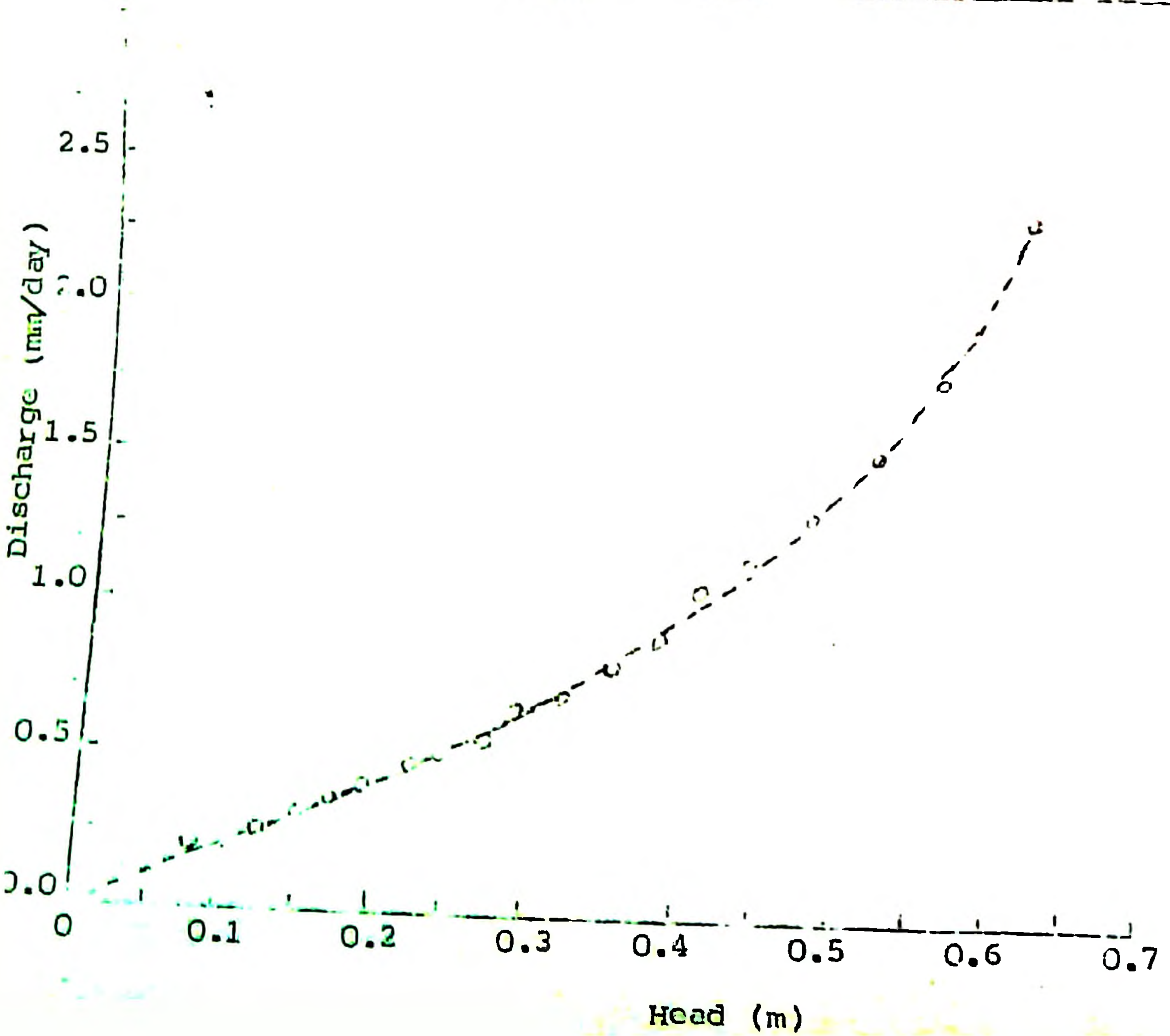
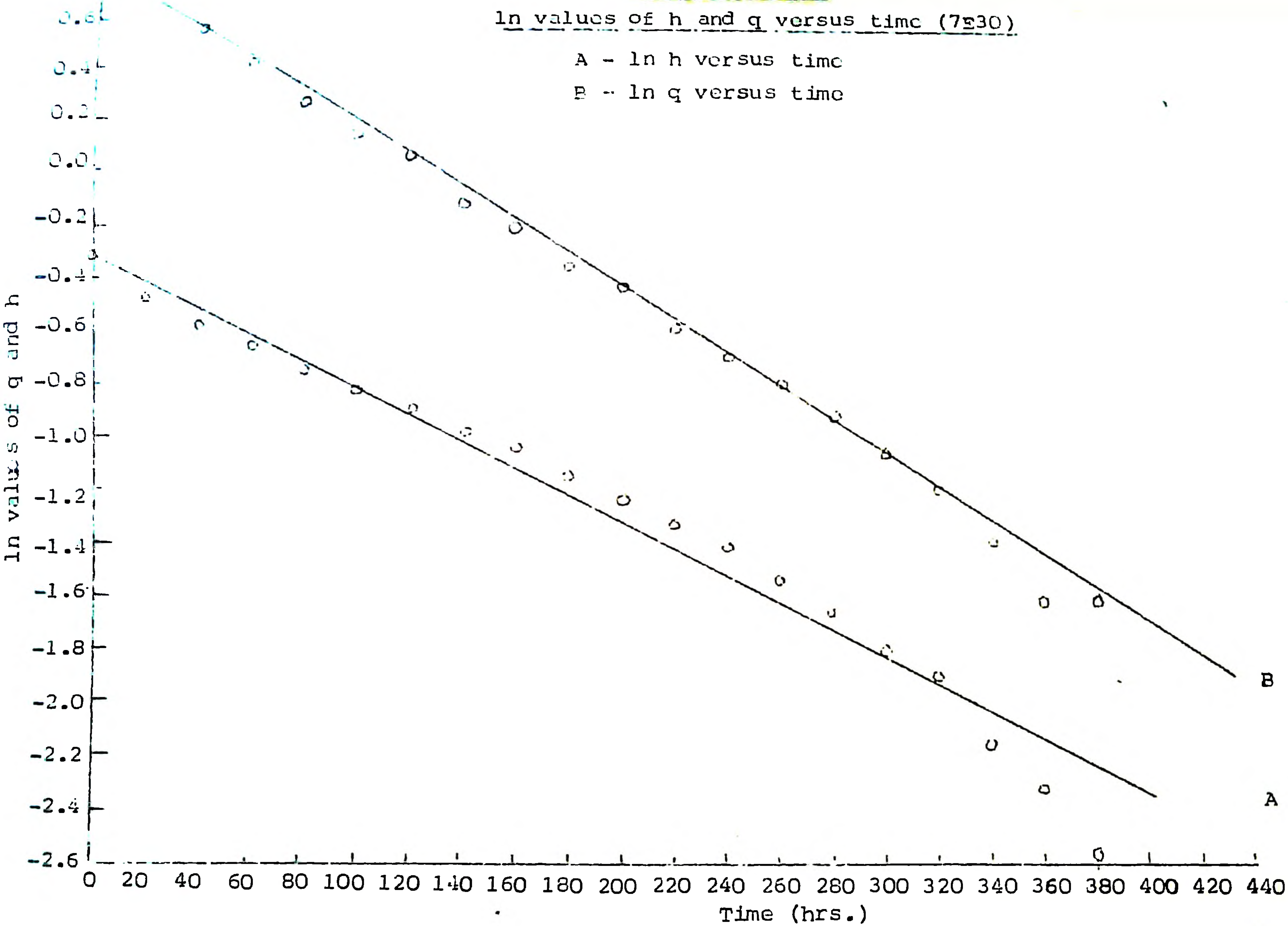


**Figure - 3a(7)**

ln values of h and q versus time (7=30)



1) Drainage intensity factor = 0.14 $days^{-1}$
2) Kd = 0.40 $m^2$/day.
3) (effective porosity) = 2.96%
4) d (equivalent depth) = 2.1 m.
5) k (hydraulic conductivity)= 0.19 m/day.

The generalized equation $q = \frac{2\ Kdh}{L^2}$ holds good for the drains which are away from the effect of recharge phenomenon which has been observed to happen upto a distance of 45m away from the main waterbody. Since the design has to accomodate for the worst conditions, the hydraulic parameters computed can be successfully used for finding the discharge for any hydraulic head. This can be verified for values of the drain lines 4E15, 5E15, 7E30 and 8E30 (table 3a(i)).

RESEARCH PROJECT NO.3b.

1. Title of the project : Development of a suitable technology for the sub-surface drainage system in the Kari lands of Kuttanad.

2. Title of the problem : Effectiveness of tile drainage system in the performance of paddy crop in the Kari land.

3. Objectives:

a) To assess the incremental yield of paddy due to tile drainage system.

b) To study the growth pattern of paddy crop under tile drainage system.

c) To study the effect of tile drainage in the improvement of root zone profile of Kari lands.

4. Practical utility:

Earlier studies in this line revealed a remarkable improvement on the growth and yield of paddy crop and also on the fertility of root zone. Hence, this detailed experiment will bring out the magnitude of incremental productivity of Kari lands with laying of a suitable drainage system. The study will also help in arriving at an optimum spacing of tile drains.

5. Technical programme:

Paddy crop is to be raised in the field laid out with the lateral drains, giving uniform package of practices in the whole experimental area. The standing crop will be divided into different strips of 5m width along the drain line. The first strip (treatment T1) will fall 2.5m on either side of the centre of the drain line. The second, T2, will fall between 2.5m and 5m from the drain line on either side and T3 will fall between 5m and 7.5m from the drain line on either side. Hence, lateral drains of 15m spacing will have four treatments T1,T2,T3 and a control and 4 replications (4 experimental lines). The drain lines with 30m spacing will have 7 treatments (T1 to T7) with 2 replications. The different growth parameters will be recorded for each strip and analysed. The changes in the soil qualities will be estimated to assess the improvement of soil fertility.

6. Observations to be recorded:

a) Growth and yield parameters of paddy.
b) Physico-chemical analysis of soil.
c) Monitoring of quality of drainage and irrigation water.

7. Date of start : December 1984.

8. Date of completion : Till the scheme ends.

9. Progress of work:

The experimental field was subjected to continuous pumping throughout the cultivation season. Observations like No.of plants/m$^2$, No.of panicles/m$^2$, height at maturity, length of panicle, grains per panicle, grain yield, straw weight and 100 grain weight were recorded and subjected to statistical analysis. The analysis was done separately for 15m and 30m spacing. The results of the analysis are represented in Appendix-3. The paddy crop raised in the experimental plot was visually very healthy when compared with the crop raised outside the experimental area during the growing season. However, the crop was severely attacked by the BPH towards the later stages for the want of timely prophylatic measures. The BPH attack in the control plot was not as seve as that of the experimental plot. This unexpected factor is reflected in the statistical analysis. However, the trend shows that there is an average increase of 560 kg of addition grain yield/ha due to the introduction of sub-surface drainag The 100 grain weight analysed from the experiment was found significantly superior over to the 100 grain weight of the control plot.

With a view avoid all the controllable setbacks the station is planning to provide the farmers with inputs like seeds, fertilizers and plant protection materials for the nex cropping season. These inputs will be made available to the farmers in the experimental area and will be applied under proper supervision from the station scientists so that a uniform package of practice can be given to the experimental are and the control plot.

Water samples from each tile drain were collected at fortnightly intervals and they were analysed for its EC and p Figure No.3b(1) is a graph of EC of drained water from differ ent drains versus time for the year 1985-86 and 1986-87. It could be seen that the soils which were closer to the outside natural body of water drained less salts that the one which is farther. This could be because of the higher water level outside the farming area creating a natural internal drainage and to some extent washing the soil. The same observation was noted in the last reporting year also. This observation substantiates comparatively higher yields at places where there is a nearby waterway or drainage channel, as reported by this station in the earlier reports. The graph mentioned above also gives an idea on the reduction of salt content of the area controlled by the drain 7E30. The graph of pH of drained water from different drains versus time for the year 1985-86 and 1986-87 (figure No.3b(2)), gave almost identical values of pH for each drain (5.75 to 7 for this season). A comparison has shown a remarkable improvement in the acidity level of the soil controlled by the drain 7E30. The higher pH levels are because of the submerged condition of the soil during cropping season which prevent entry of air into the soil system prohibiting oxidation and formation of acidity.

Weekly monitoring of EC of irrigation water, drained water (sub-surface drainage) and surface drainage water was also done during the cropping season. The EC of irrigation water was then compared with that of the sub-surface drainage water. The comparison shown in figure 3b(3) has indicated that a substantial amount of salts can be leached through the sub-surface drainage system. The same values for the year 1985-86 is also incorporated in the graph for easy comparison of reduction in salt after one drainage season. The EC values of irrigation water remained same with respect to time while the EC values of sub-surface drainage water has come down the level which proves a reduction in the salt level of the soil after one drainage season. On an average, the difference between the EC of drained water and irrigation water was 2.25 mmhos/cm which quantitatively amounts to 1440 ppm or 1440 mg/litre. This is equivalent to 144 kg of salt/ha/cm of drained water.

The EC values of irrigation water ranged between 0.2 to 2.4 mmhos/cm for the season and that of the drained water ranged between 2.4 to 4.8 mmhos/cm.

The graph 3b(5) gives a study on the amount of salt that can be leached if surface drainage system is incorporated in the project area. It could be seen that the surface drainage system does not contribute anything to the removal of salt from the soil. The EC values of surface drainage water and irrigation water remained same throughout the season. The surface drains get its volume of water from the flooding water normally used for irrigation purpose and washing the top soil. The top 5-10cm of the soil is already in the washed condition due to the regular practice of the farmers of flooding and dewatering the fields. Moreover, the flooding water does not get any opportunity time to percolate down and hence to pick up the salts. The high water table condition also contribute for not allowing the flooding water to move down. The above mentioned reasons disqualify the effective use of surface drains as an alternative solution to the sub-surface drains. However, the surface drains can be economically and effectively used as collector drains for the sub-surface drains, provided they are deepened and widened.

A close study of the weekly values of pH of irrigation water, subsurface drainage water and the surface drainage water leads to the following inferences. The pH values of sub-surface drainage water and irrigation water remained identical and the values ranged between 6 to 7.5. The surface drained water remained slightly acidic and the values ranged between 5.75 to 6.5. The soil on drying during the intermittent flooding and drying practiced by the farmers gets acidified on aeration and this acidity is washed and drained into the surface drains and hence it is slightly acidic. Thus the surface drains contribute to the removal of acidity alone.

The EC and pH values of daily water samples collected from the drainage sump which gets its water from the sub-surface drainage system is shown in figure 3b(7) and 3b(8). It could be seen that the main problem is controlling the salt than the acidity. The acidity problem gets automatically controlled with rice cultivation during which there is always submerged water.

Soil samples from the experimental site and a control plot taken after drying the soil through drainage was also analysed and a statistical study was conducted with regard to the leaching of different salts on drainage. The tables showing the results are given in Appendix 4. A mean table representing the above data is given as table 3b(vi). It has been found that there is a significant reduction in chlorides from the experimental plot when compared to that of the control plot and that the leaching effect was more on the soils just above the drains. The $SO_4$, Mg and Ca was found more for the soils in treatment-I viz. on the line of 15m spacing. This may be attributed to the fact that on intensive drainage in this treatment there was more oxidation resulting in higher toxic ion formation which has to be leached out by further irrigation and drainage.

The water sample data collected during the cropping season from different drains was analysed for finding the different elements leached out and the result is shown in table 3b(vii).

Table 3b(i).

Water sample data taken at fortnightly Intervals (Collected from tiles) 1986-87.

pH values

| Location | 23.10.86 | 6.11.86 | 20.11.86 | 4.12.86 | 18.12.86 |
|---|---|---|---|---|---|
| 2E15 | 6.10 | 6.35 | 6.20 | 7.00 | 6.30 |
| 3E15 | 6.10 | 6.30 | 6.20 | 6.55 | 6.30 |
| 4E15 | 6.25 | 6.20 | 6.15 | 6.60 | 6.80 |
| 5E15 | 6.20 | 6.25 | 6.10 | 6.90 | 6.40 |
| 7E30 | 6.50 | 6.15 | 6.05 | 5.85 | 6.75 |
| 8E30 | 6.30 | 6.25 | 6.20 | 6.45 | 7.00 |

EC Values (mmhos/cm.)

| Location | 23.10.86 | 6.11.86 | 20.11.86 | 4.12.86 | 18.12.86 |
|---|---|---|---|---|---|
| 2E15 | 1.90 | 2.10 | 2.60 | 2.50 | 2.80 |
| 3E15 | 1.80 | 2.80 | 3.30 | 3.20 | 3.30 |
| 4E15 | 1.80 | 2.80 | 3.80 | 4.00 | 3.90 |
| 5E15 | 2.10 | 3.45 | 4.80 | 4.50 | 4.80 |
| 7E30 | 2.10 | 3.40 | 5.30 | 4.70 | 5.25 |
| 8E30 | 2.25 | 3.90 | 5.00 | 4.70 | 5.44 |

## Table - 3b(ii).

### Weekly averages of pH and EC of irrigation water and drained water (1986-87).

### pH Values

| Date | Irrigation water | Drained water | Difference |
|---|---|---|---|
| 9.10.86 | 7.59 | 7.45 | 0.14 |
| 16.10.86 | 7.36 | 7.52 | 0.16 |
| 23.10.86 | 6.80 | 7.12 | 0.32 |
| 30.10.86 | 6.53 | 7.01 | 0.48 |
| 6.11.86 | 6.51 | 6.95 | 0.44 |
| 13.11.86 | 6.05 | 6.02 | 0.03 |
| 20.11.86 | 6.97 | 6.92 | 0.05 |
| 27.11.86 | 6.66 | 6.94 | 0.28 |
| 4.12.86 | 6.34 | 6.74 | 0.10 |
| 11.12.86 | 6.42 | 6.71 | 0.29 |
| 18.12.86 | 6.81 | 7.30 | 0.49 |
| 25.12.86 | 7.45 | 7.23 | 0.22 |
| 1.1.1987 | 7.53 | 7.84 | 0.31 |

### EC (mmhos/cm)

| Date | Irrigation water | Drained water | Difference |
|---|---|---|---|
| 9.10.86 | 0.74 | 3.48 | 2.74 |
| 16.10.86 | 0.67 | 3.32 | 2.65 |
| 23.10.86 | 1.17 | 2.80 | 1.63 |
| 30.10.86 | 1.08 | 2.94 | 1.86 |
| 6.11.86 | 0.68 | 2.77 | 2.09 |
| 13.12.86 | 0.31 | 2.55 | 2.24 |
| 20.11.86 | 0.55 | 3.32 | 2.77 |
| 27.11.86 | 1.73 | 3.53 | 1.80 |
| 4.12.86 | 2.08 | 3.53 | 1.45 |
| 11.12.86 | 2.31 | 3.61 | 1.30 |
| 18.12.86 | 1.02 | 3.62 | 2.60 |
| 25.12.86 | 0.64 | 3.49 | 2.85 |
| 1.1.1987 | 0.59 | 3.88 | 3.29 |
| | | Total | :29.27 |
| | | Average | :2.25mmhos/cm |

## Table - 3b(iii)

**Weekly averages pH and EC of Irrigation water, Surface Drainage Water and Sub-surface Drainage water.**

### pH values

| Date | Irrigation water | Surface drainage water (from drainage channel) | Subsurface drainage water (from collection sump). |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| 9.10.86 | 7.59 | 5.90 | 7.45 |
| 16.10.86 | 7.36 | 5.88 | 7.52 |
| 23.10.86 | 6.80 | 6.05 | 7.12 |
| 30.10.86 | 6.53 | 5.98 | 7.01 |
| 6.11.86 | 6.51 | 5.95 | 6.95 |
| 13.11.86 | 6.05 | 5.95 | 6.02 |
| 20.11.86 | 6.97 | 6.65 | 6.92 |
| 27.11.86 | 6.66 | 6.08 | 6.94 |
| 4.12.86 | 6.84 | 6.25 | 6.74 |
| 11.12.86 | 6.42 | 5.80 | 6.71 |
| 18.12.86 | 6.81 | 6.42 | 7.30 |
| 25.12.86 | 7.45 | .. | 7.23 |
| 1.1.1987 | 7.53 | 6.55 | 7.84 |

### EC (mmhos/cm.)

| (1) | (2) | (3) | (4) |
|---|---|---|---|
| 9.10.86 | 0.74 | 0.82 | 3.48 |
| 16.10.86 | 0.67 | 0.78 | 3.32 |
| 23.10.86 | 1.17 | 1.10 | 2.80 |
| 30.10.86 | 1.08 | 1.00 | 2.94 |
| 6.11.86 | 0.68 | 0.15 | 2.77 |
| 13.11.86 | 0.31 | 0.45 | 2.55 |
| 20.11.86 | 0.55 | 0.21 | 3.32 |
| 27.11.86 | 1.73 | 1.80 | 3.53 |
| 4.12.86 | 2.08 | 1.63 | 3.53 |
| 11.12.86 | 2.31 | 1.93 | 3.61 |
| 18.12.86 | 1.02 | 0.74 | 3.62 |
| 25.12.86 | 0.64 | .. | 3.49 |
| 1.1.87 | 0.59 | 0.77 | 3.88 |

Table - 3b(iv)

Water sample data taken daily from the drainage Sump. EC (mmhos/cm.)

| Date | E.C. | Date | E.C. | Date | E.C. |
|---|---|---|---|---|---|
| 8.10.86 | 3.30 | 8.11.86 | 3.13 | 9.12.86 | 3.95 |
| 9.10.86 | 3.65 | 9.11.86 | 3.03 | 19.12.86 | 4.70 |
| 10.10.86 | 3.57 | 10.11.86 | .. | 11.12.86 | 3.90 |
| 11.10.86 | 3.25 | 11.11.86 | .. | 12.12.86 | 3.36 |
| 12.10.86 | 3.60 | 12.11.86 | .. | 13.12.86 | 3.80 |
| 13.10.86 | 3.55 | 13.11.86 | .. | 14.12.86 | 3.88 |
| 14.10.86 | 3.65 | 14.11.86 | .. | 15.12.86 | 3.85 |
| 15.10.86 | 3.10 | 15.11.86 | 3.30 | 16.12.86 | 3.36 |
| 16.10.86 | 2.55 | 16.11.86 | 3.30 | 17.12.86 | 2.69 |
| 17.10.86 | 3.07 | 17.11.86 | 3.35 | 18.12.86 | 3.85 |
| 18.10.86 | 2.55 | 18.11.86 | 3.55 | 19.12.86 | 3.95 |
| 19.10.86 | 2.82 | 19.11.86 | 3.28 | 20.12.86 | 3.55 |
| 20.10.86 | 3.13 | 20.11.86 | 3.43 | 21.12.86 | 3.83 |
| 21.10.86 | 4.00 | 21.11.86 | 3.28 | 22.12.86 | 3.75 |
| 22.10.86 | .. | 22.11.86 | 3.28 | 23.12.86 | 3.78 |
| 23.10.86 | 1.17 | 23.11.86 | 3.60 | 24.12.86 | 3.13 |
| 24.10.86 | [illegible] | 24.11.86 | 3.38 | 25.12.86 | 2.63 |
| 25.10.86 | 3.00 | 25.11.86 | 3.75 | 26.12.86 | 3.13 |
| 26.10.86 | 3.50 | 26.11.86 | 3.63 | 27.12.86 | 3.80 |
| 27.10.86 | 2.90 | 27.11.86 | 3.60 | 28.12.86 | 3.95 |
| 28.10.86 | [illegible] | 28.11.86 | 3.53 | 29.12.86 | 3.70 |
| 29.10.86 | .. | 29.11.86 | 3.02 | 330.12.86 | 4.50 |
| 30.10.86 | 1.60 | 30.11.86 | 3.20 | 31.12.86 | 3.95 |
| 31.10.86 | 2.65 | 1.12.86 | 3.75 | 1.1.87 | 4.10 |
| 1.11.86 | [illegible] | 2.12.86 | 3.20 | 2.1.87 | 4.10 |
| 2.11.86 | 2.37 | 3.12.86 | 4.18 | 3.1.87 | 3.95 |
| 3.11.86 | 2.90 | 4.12.86 | 3.80 | 4.1.87 | 4.20 |
| 4.11.86 | 3.30 | 5.12.86 | 3.15 | 5.1.87 | 4.28 |
| 5.11.86 | 2.95 | 6.12.86 | 3.00 | 6.1.87 | 4.10 |
| 6.11.86 | [illegible] | 7.12.86 | 2.70 | 7.1.87 | 4.30 |
| 7.11.86 | 2.50 | 8.12.86 | 3.85 | | |

## Table - 3b.(v)

**Water sample data taken daily from the drainage sump**

**pH values**

| Date | pH | Date | pH | Date | pH |
|---|---|---|---|---|---|
| 8.10.86 | 7.30 | 7.11.86 | 6.10 | 7.12.86 | 6.10 |
| 9.10.86 | 7.60 | 8.11.86 | 6.35 | 8.12,86 | 6.70 |
| 10.10.86 | 7.55 | 9.11.86 | 5.53 | 9.12.86 | 6.18 |
| 11.10.86 | 7.50 | 10.11.86 | .. | 10.12.86 | 6.45 |
| 12.10.86 | 7.63 | 11.11.86 | .. | 11.12.86 | 8.15 |
| 13.10.86 | 7.05 | 12.11.86 | .. | 12.12.86 | 7.68 |
| 14.10.86 | 7.60 | 13.11.86 | .. | 13.12.86 | 6.73 |
| 15.10.86 | 7.50 | 14.11.86 | .. | 14.12.86 | 7.28 |
| 16.10.86 | 7.78 | 15.11.86 | 6.85 | 15.12.86 | 7.05 |
| 17.10.86 | 7.65 | 16.11.86 | 7.15 | 16.12.86 | 7.93 |
| 18.10.86 | 7.03 | 17.11.86 | 6.35 | 17.12.86 | 7.30 |
| 19.10.86 | 6.95 | 18.11.86 | 7.78 | 18.12,86 | 7.13 |
| 20.10.86 | 7.15 | 19.11.86 | 6.83 | 19.12.86 | 6.30 |
| 21.10.86 | 6.40 | 20.11.86 | 7.03 | 20.12.86 | 8.05 |
| 22.10.86 | .. | 21.11.86 | 6.78 | 21.12.86 | 7.98 |
| 23.10.86 | 7.50 | 22.12.86 | 6.95 | 22.12.86 | 7.15 |
| 24.10.86 | 6.50 | 23.11.86 | 7.05 | 23.12.86 | 7.60 |
| 25.10.86 | 7.1[illegible] | 24.11.86 | 6.68 | 24.12.86 | 6.98 |
| 26.10.86 | 7.73 | 25.11.86 | 7.35 | 25.12.86 | 6.65 |
| 27.10.86 | 7.20 | 26.11.86 | 7.05 | 26.12.86 | 6.58 |
| 28.10.86 | 7.15 | 27.11.86 | 6.73 | 27.12.86 | 7.95 |
| 29.10.86 | .. | 28.11.86 | 6.53 | 28.12.86 | 7.88 |
| 30.10.86 | 6.20 | 29.11.86 | 6.78 | 29.12.86 | 8.13 |
| 31.10.86 | 7.65 | 30.11.86 | 6.98 | 30.12.86 | 8.30 |
| 1.11.86 | 7.63 | 1.12.86 | 7.38 | 31.12.86 | 8.03 |
| 2.11.86 | 7.25 | 2.12.86 | 6.95 | 1.1.87 | 8.00 |
| 3.11.86 | 7.90 | 3.12.86 | 6.83 | 2.1.87 | 8.15 |
| 4.11.86 | 6.53 | 4.12.86 | 5.73 | 3.1.87 | 7.68 |
| 5.11.86 | 6.30 | 5.12.86 | 6.98 | 4.1.87 | 7.48 |
| 6.11.86 | 6.40 | 6.12.86 | 6.43 | 5.1.87 | 7.63 |
| | | | | 6.1.87 | 6.95 |
| | | | | 7.1.87 | 7.03 |

Table 3b(vi)

Mean table of soil analysis data

| Treat. No. | Treatment | Cl | SO4 | Ca | Mg. |
|---|---|---|---|---|---|
| 1. | On the line 15m spacing | 2.13 | 794.50 | 3.05 | 10.00 |
| 2. | Mid-spacing of 15m. | 2.50 | 643.00 | 1.28 | 2.78 |
| 3. | On the line 30m spacing | 2.31 | 583.00 | 1.07 | 2.64 |
| 4. | Mid spacing of 30m. | 3.79 | 563.75 | 1.67 | 3.89 |
| 5. | Control | 4.16 | 665.25 | 1.75 | 4.85 |
| | C.D. | 0.76 | 99.02 | 1.27 | 3.89 |

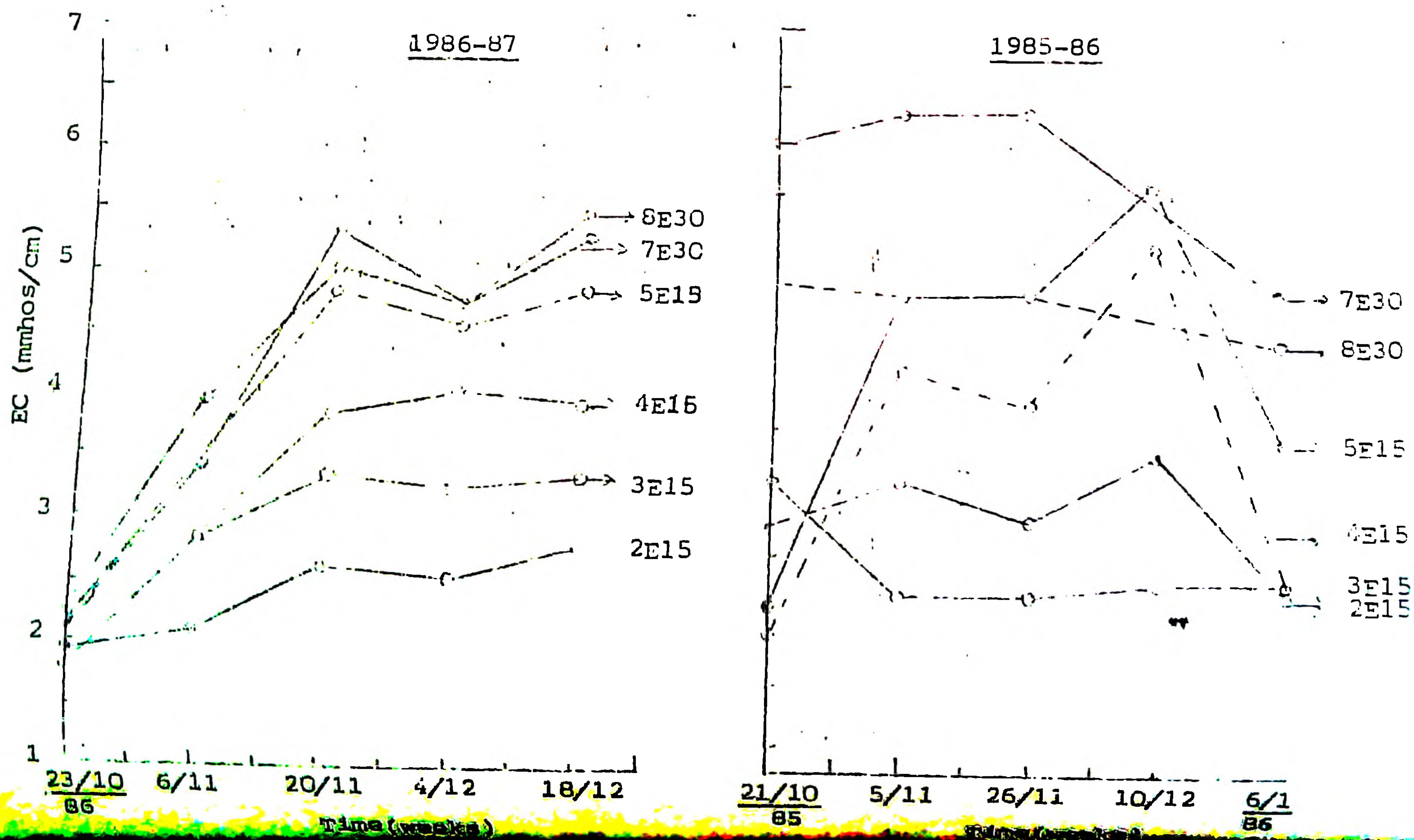
Table 3b(vii)

Drained Water sample - Samples taken from the tile drains.

| | pH | EC (mmhos/cm) | CO3 (me/lit) | HCO3 (m.e/lit) | Cl. (me/lit) | SO4 (ppm) | Fe (ppm) | Ca (me/lt) |
|---|---|---|---|---|---|---|---|---|
| 2E15 | 6.40 | 3.10 | T | 3.44 | 19.98 | 526 | 100 | 1.12 |
| 3E15 | 6.20 | 3.00 | 3.44 | T | 24.79 | 522 | 28 | 1.56 |
| 4E15 | 6.15 | 3.00 | T | 5.16 | 67.34 | 465 | 79 | 2.04 |
| 5E15 | 6.15 | 4.50 | T | 3.44 | 42.18 | 541 | 53.24 | 3.36 |
| 7E30 | 8.15 | 5.70 | T | 13.76 | 52.54 | 503 | T | T |
| [illegible]E30 | [illegible] | [illegible] | [illegible].88 | 1.72 | 41.44 | 556 | 203 | T |

Figure - 3b(1)

EC of water samples from tile drains at fortnightly intervals



pH of water samples from tile drains at fortnightly intervals

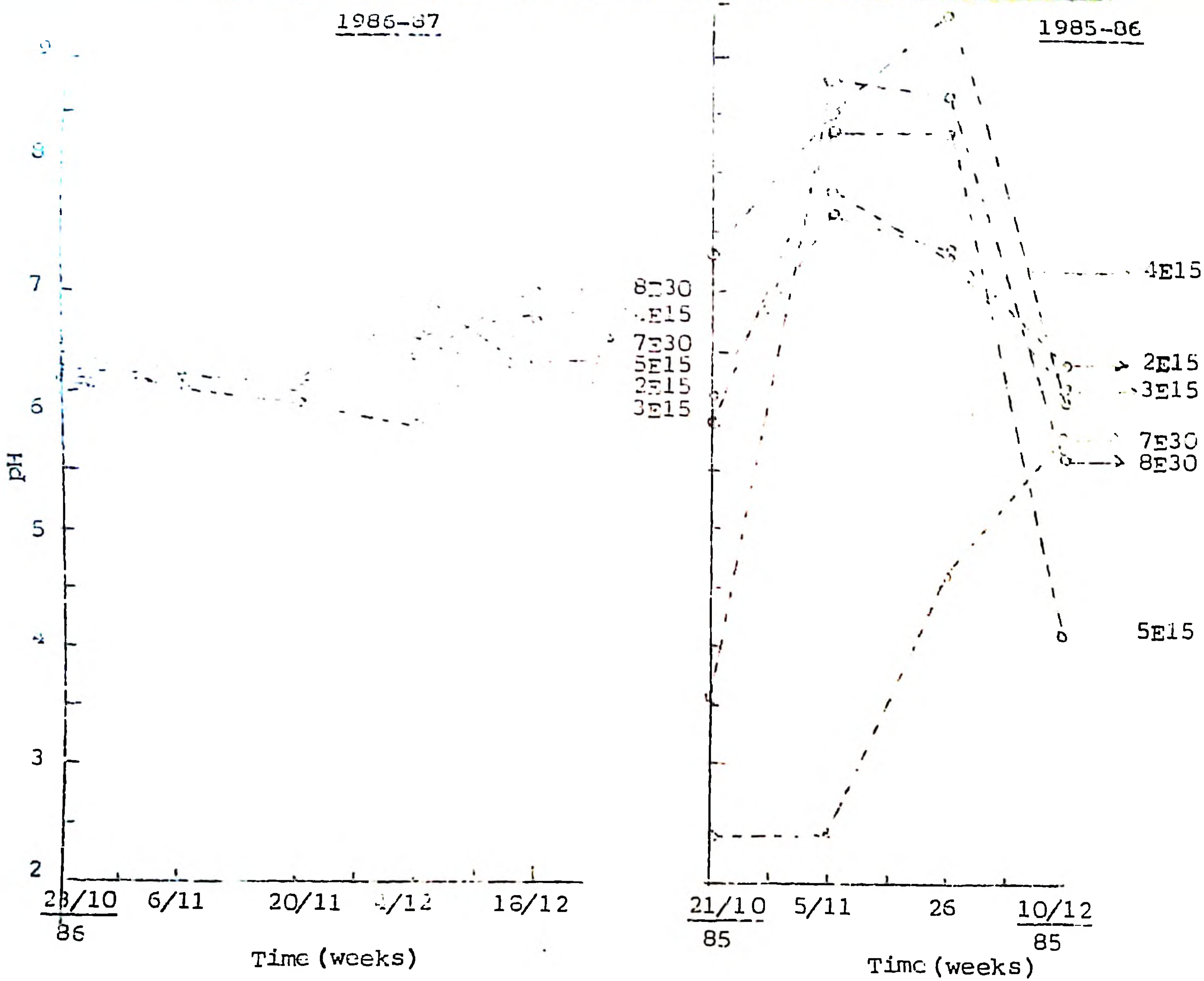


Figure - 3b(3)

Weekly comparison of EC between Irrigation and Drained water

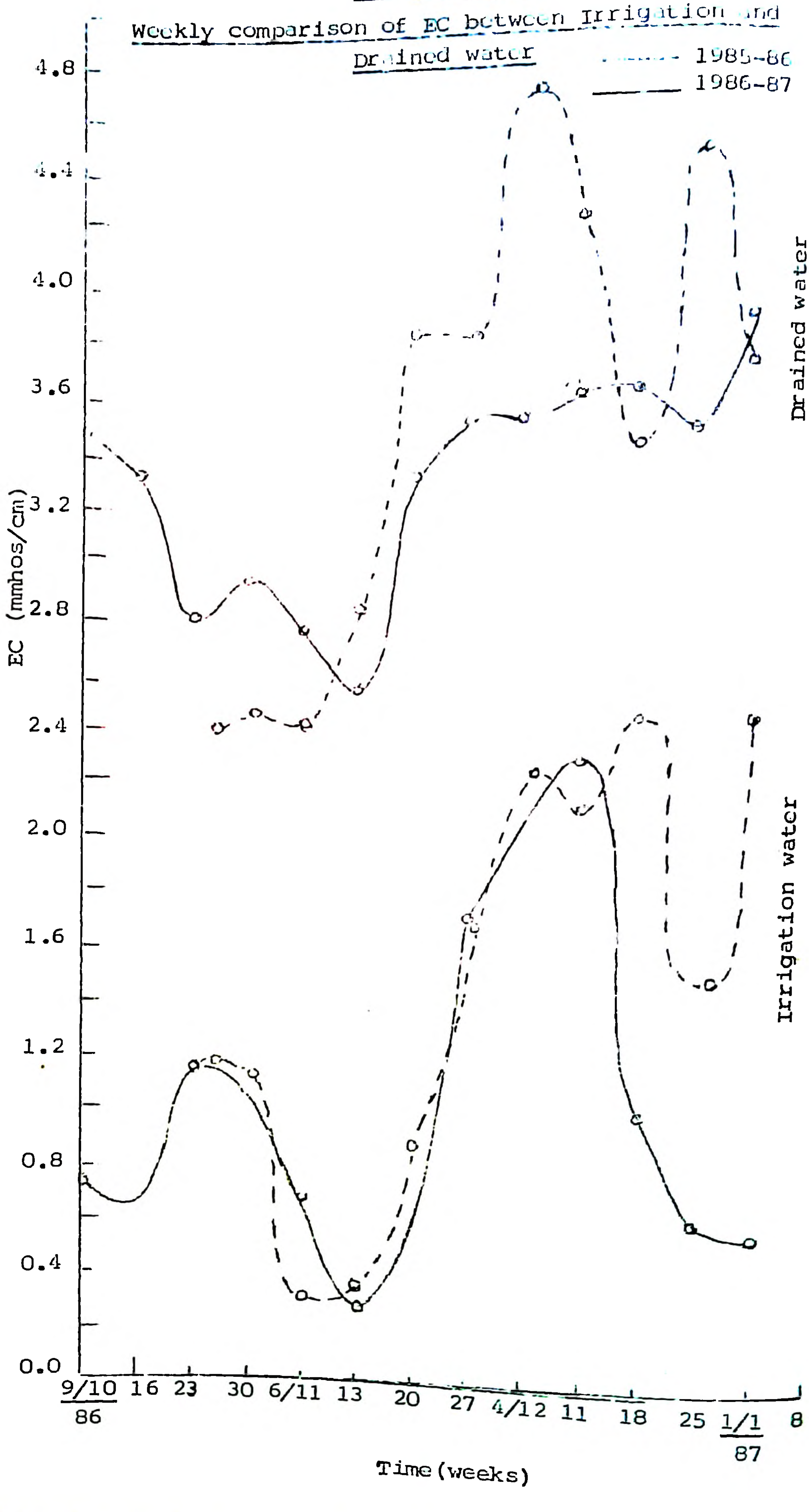


**Figure - 3b(4)**

Weekly comparison of pH between Irrigation and drained water

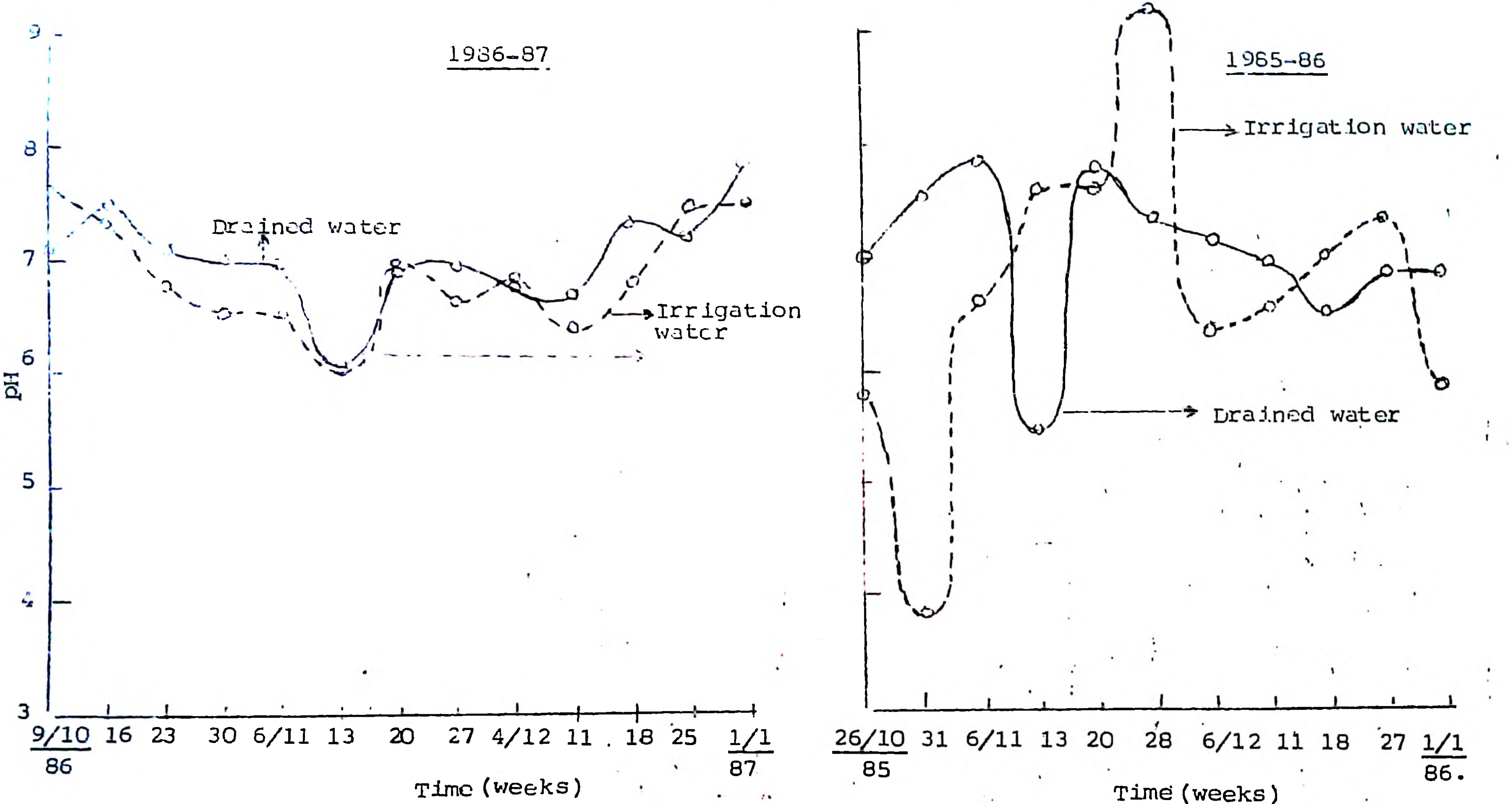


Figure - 3b(5)

Weekly comparison of EC between Irrigation, Surface drained and Sub-surface drained water

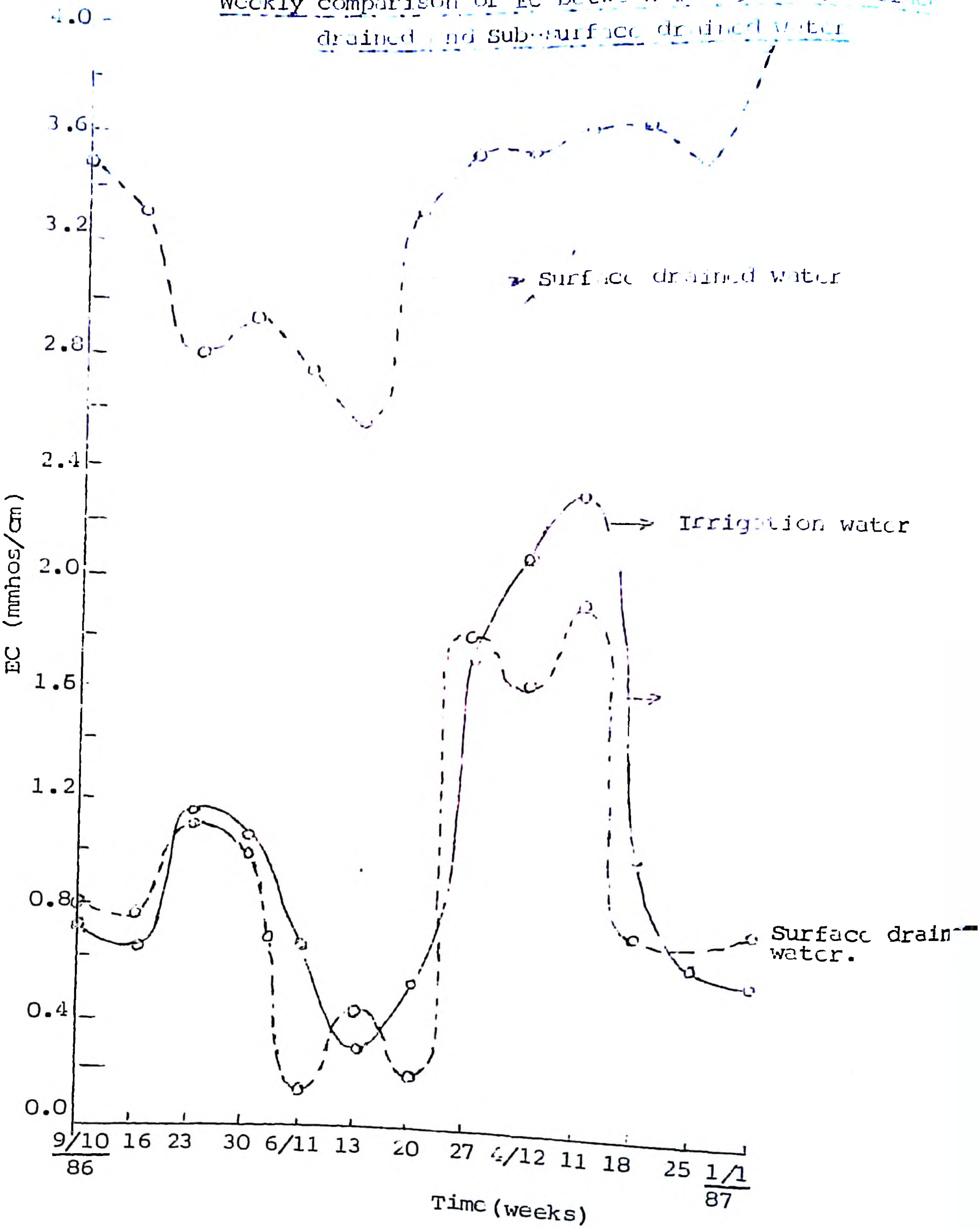


Figure - 3b(6)

Weekly comparison of pH between Irrigation, Surface drained and Sub-surface drained water

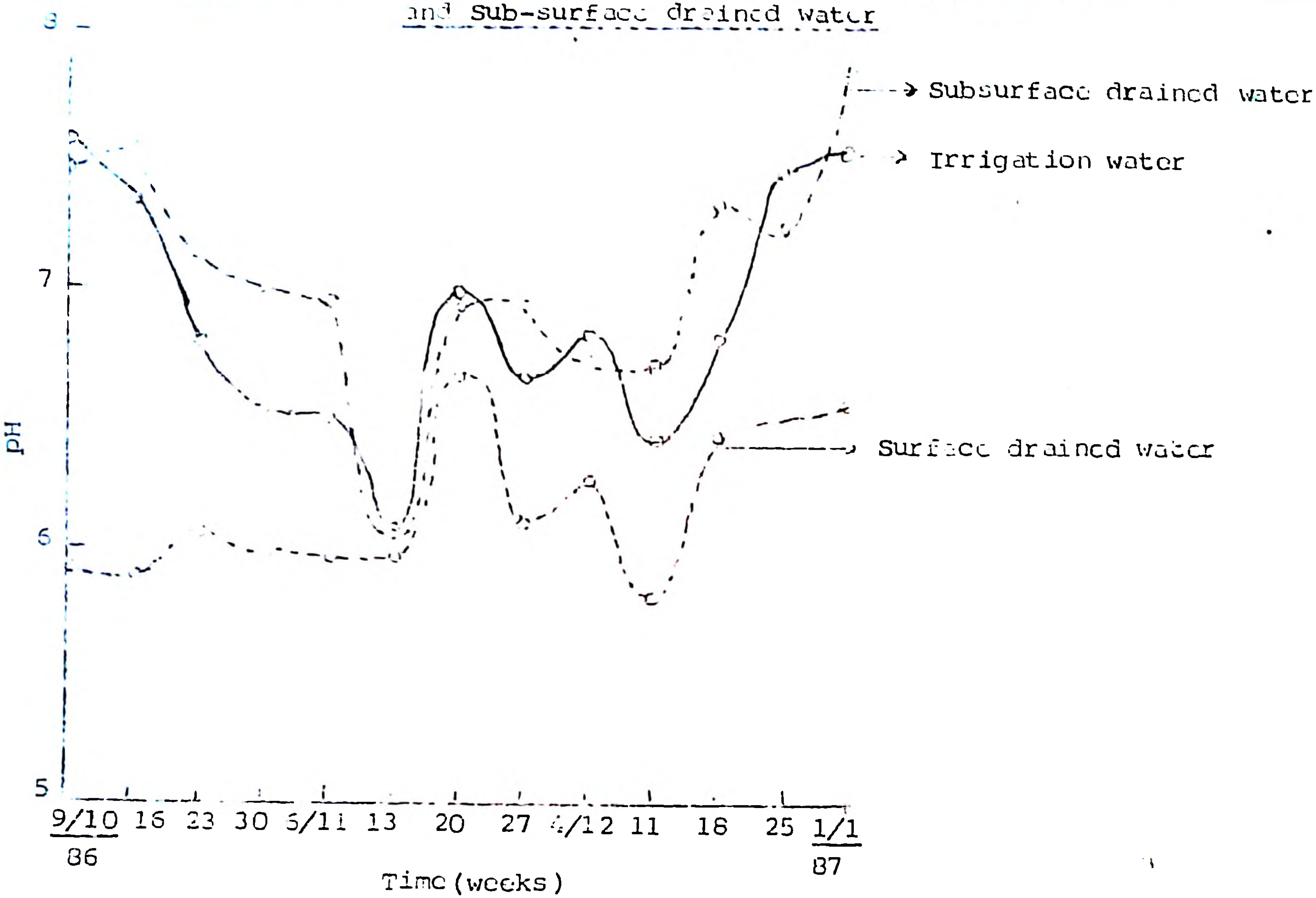


Figure - 3b(7)

EC of daily water samples collected from drainage sump during cultivation

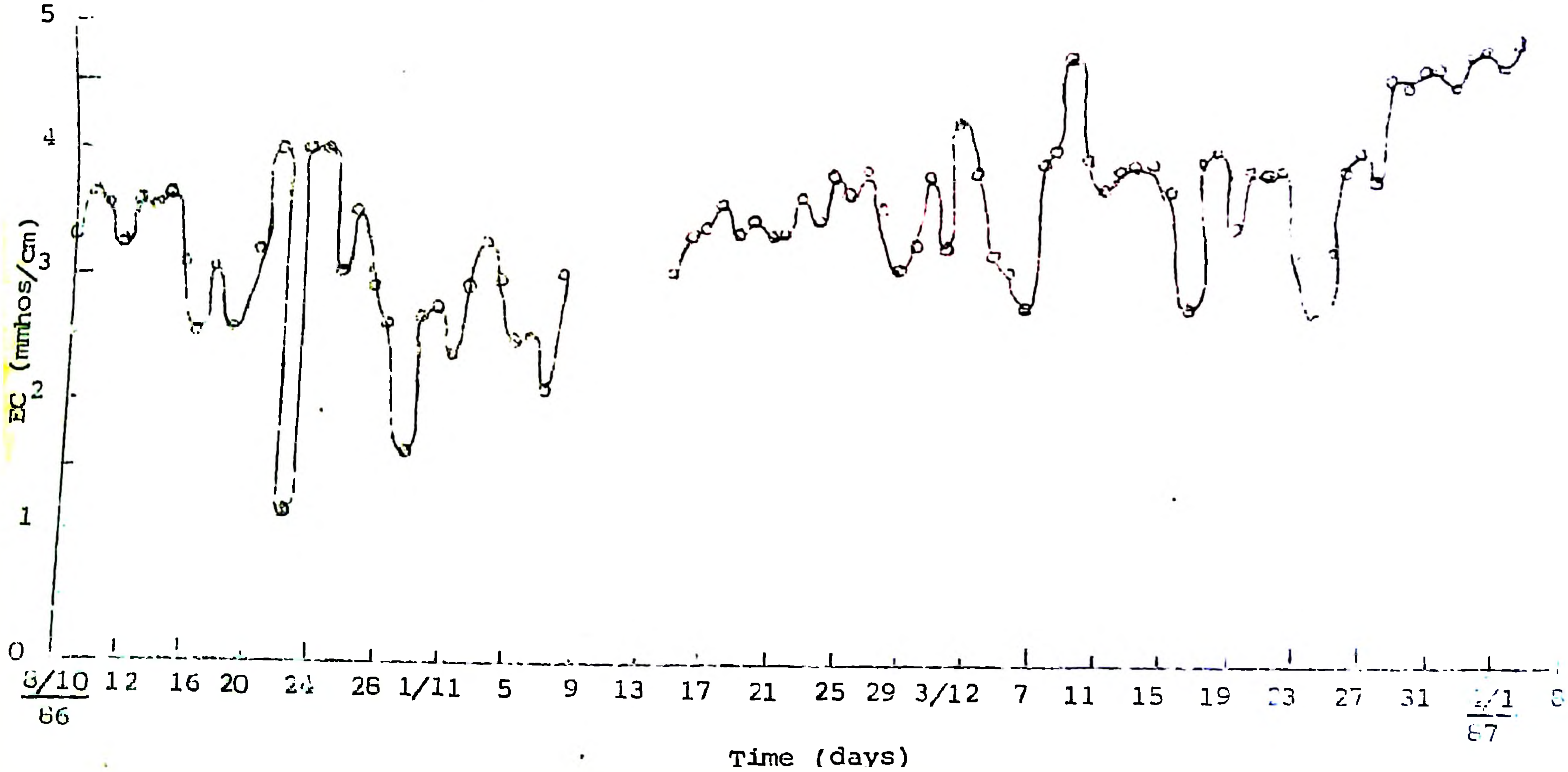
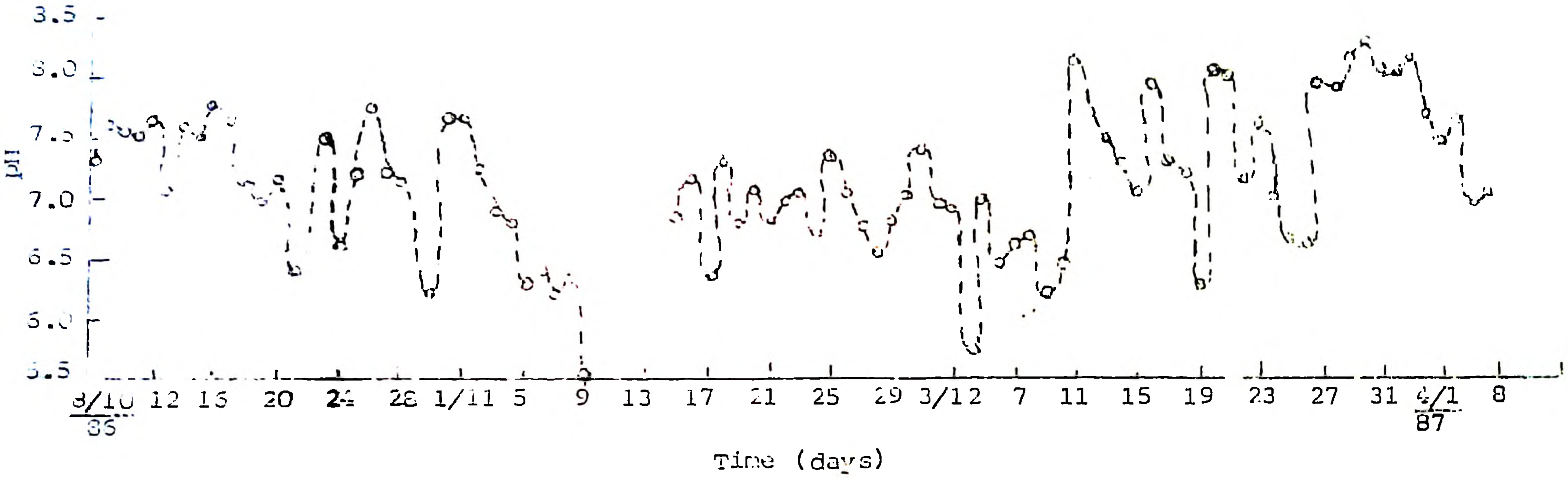


Figure - 3b(8)

pH of daily water samples collected from drainage sump during cultivation



RESEARCH PROJECT 3c.

1. Title of the project : Development of a suitable technology for the sub-surface drainage system in the [illegible] lands of Kuttanad.

2. Title of the project : Evaluation of different filter materials to find its economic suitability including its design criteria for the sub-surface drainage system

3. Objectives : To study the effectiveness and economic [illegible] of different envelope materials used and its design criteria.

4. Practical utility:

One of the main factors which increases the cost per hectare of the sub-surface tile drainage system is the envelope material used. The study can throw light into the effectiveness of the envelope materials used and can suggest an economically viable envelope material.

5 Technical programme:

The filter material will be statistically tested by the Randomized Block Design technique. Each block consists of treatments and there will be three replications. The treatments are:

i) Sea sand all around the drain
ii) Sea sand around the joints only
iii) River sand all around the drain
iv) River sand around the joints only.
v) Paddy straw around the joints only
vi) Coir fibre around the joints only
vii) No filter materials.

The filter materials were selected according to the local availability. Each treatment is a tile line of 40 M length and is spaced at 15M. The drainage flow and the subsidence of water table will be studied from each treatment. The yield data also will be collected from each treatment.

6. Observations to be recorded:

1. Water table elevations.
2. Drainage flow
3. Crop yield data

7. Date of start : January 1987

8. Date of completion : December 1990.

9. Progress of work:

The layout of the experiment is shown in figure 3c(1). The experimental area is in the 'Kavil Thekkumpuram Padasekharam' which is a true representation of 'Kari soils', and is of about 1.2 ha. There are altogether 22 lines and each line is of 40M length and is spaced at 15M. The tile drains are baked clay pipes, 60cm long with bell mouth at one end (125 mm outer dia and 100 mm inner dia) provided with 15 Nos.of 6mm holes in three bands of 5 holes each, on the 1/3rd periphery area. There were laid with the tail of one into the bell mouth of the other, with the bell mouth pointing towards the down stream end. The tile lines are given a 0.2% slope towards the down steam end and discharge into collection sumps made of concrete rings of 60 cm inner diameter. The filter materials used in each case was allotted in radom.

Laying of filter materials:

a) River sand:-

There are two treatments with river sand. In one case the river sand is spread all around the drain. In this mode of application the river sand is first spread in the trench to a 10cm thickness and then the tiles are laid to the correct grade. Over this a 10cm thickness of river sand is again spread and the trench is then backfilled. In the other case, the river sand is applied at the joints only with a 10cm thickness above and below the bell mouth of the drain. About $0.075/m^3/m$ of river sand is required when spread all around and $0.015m^3$ when spread around the joints only.

b) Sea sand:-

In this case also there are two treatments and the mode of application is essentially the same as above except for the material used.

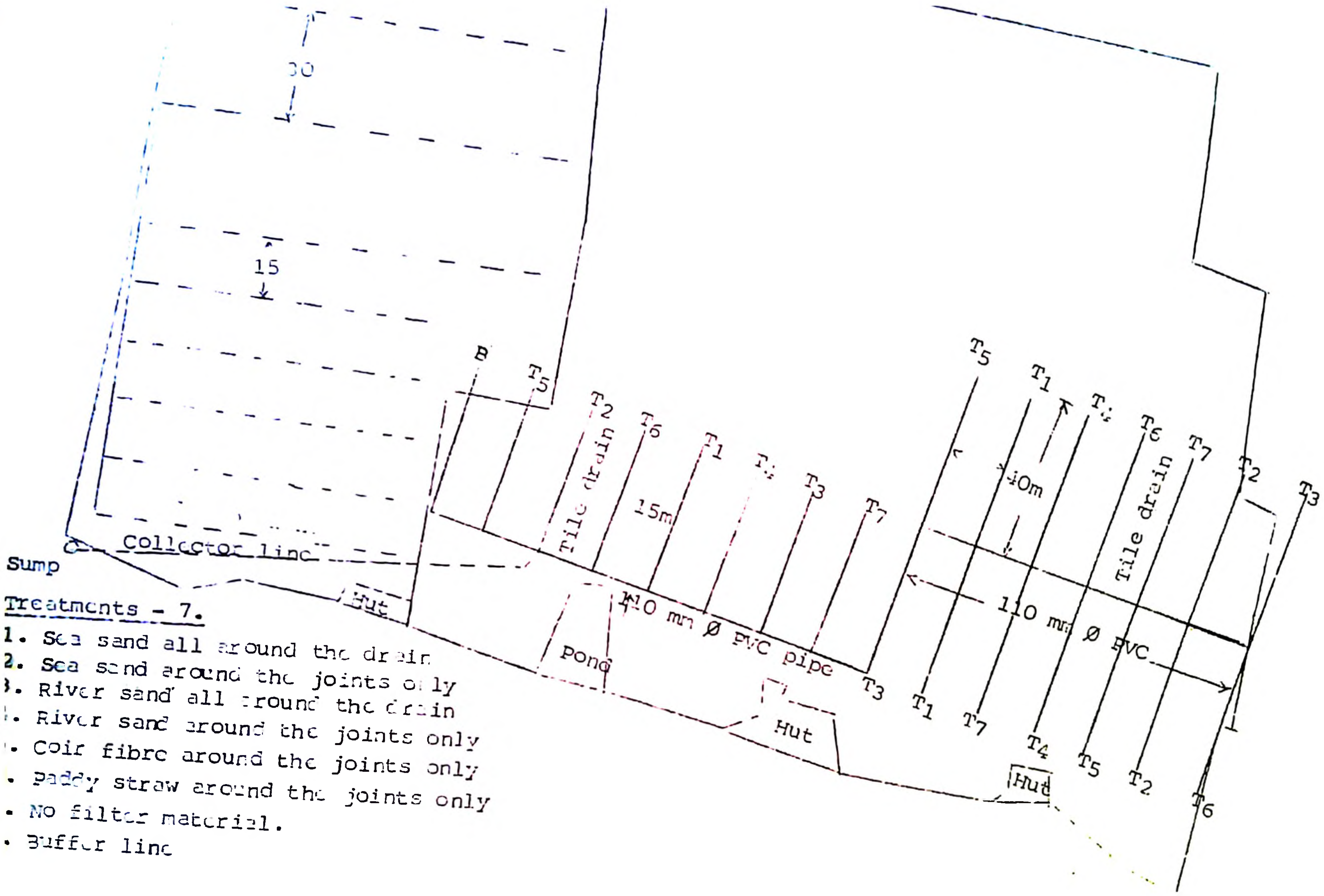
c) Coir fibre:-

This is a material locally available and is made after beating the coconut husk and is a raw material for making coir. The fibre is wound around the joints of the tile drains. About 380 gms.of coir fibre is required to completely wound one bell mouth joint.

d) Paddy straw:-

Paddy straw is also tried since it is cheaply and easily available locally. The wrapping method is essentially the same as that of the coir fibre except that the material required per joint is only 300 gms.

The execution of the above work was only just completed and the observations can be done from the next season onwards.




**Treatments - 7.**

1. Sea sand all around the drain
2. Sea sand around the joints only
3. River sand all around the drain
4. River sand around the joints only
5. Coir fibre around the joints only
6. Paddy straw around the joints only
7. No filter material.

- Buffer line

## SECTION - E.

## SUMMARY.

The monitoring of quality of irrigation and drainage water were continued. The assessment was mainly focussed on the acidity and salinity of the irrigation and drainage water. The EC values ranged between 0.5 to 2.5 mmhos/cm for the irrigation water. The surface drained water also followed the same pattern of fluctuations of the irrigation water suggesting that the contribution of surface drainage in removing the salt from the soil is negligible. The pH values of irrigation and surface drained water were slightly acidic and ranged between 5 to 6.5.

As far as the ground water movement in the project area was concerned with respect to the outside water bodies, a definite pattern could not be traced. The ground water movement was greatly affected by the drainage pumping.

The experiment on the 'Development of a suitable technology for the sub-surface drainage system in the Kari lands of Kuttanad' has revealed that there is a continuous recharge from the outside waterbody towards the cropping area and that the intensity of this recharge reduces as the distance increases. The drains located nearer to these waterbodies also get a certain amount of recharge. The recharge becomes negligible beyond a distance of approximately 45m. Thus drains nearer to the waterbody experience more or less a steady state condition and those away experience a non-steady condition.

The mathematical analysis of the data collected from drainage pumping has given the following hydraulic parameters

1) Drainage intensity factor = 0.14 $days^{-1}$
2) Kd = 0.40$m^2$/day
3) $\gamma$ (effective porosity) = 2.96%
4) d (equivalent depth) = 2.1m.
5) K (hydraulic conductivity) = 0.19 m/day.

The generalized equation $q = 2\pi Kdh/L^2$ holds good for the drains which are away from the effect of recharge phenomenon. Since the design has to accomodate for the worst conditions, the hydraulic parameters computed can be successfully used for finding the discharge for any hydraulic head. The paddy crop raised in the experimental plot was visually very healthy when compared with the crop raised outside the experimental area during the growing season. However, the crop was severely attacked by the BPH towards the later stages for the want of timely prophylactic measures. The BPH attack in the control plot was not as severe as that of the experimental plot. However, the trend shows that there is an average increase of 560 kg of additional grain yield/ha due to the introduction of subsurface drainage. The 100 grain weight analysed from the experiment was found significantly superior ~~over~~ to the 100 grain weight of the control plot.

With a view avoid all the controllable setbacks the station is planning to provide the farmers with inputs like seeds, fertilizers and plant protection materials for the next cropping season. These inputs will be made available to the farmers in the experimental area and will be applied under proper supervision from the station scientists so that a uniform package of practice can be given to the experimental area and the control plot.

The analysis of sub-surface drained water showed that the soils which were closer to the outside natural body of water drained less salts than the ones which were farther. This could be because of the higher water level outside the farming area creating a natural internal drainage and to some extent washing the soil. The same observation was noted in the last reporting year also. This observation substantiates comparatively higher yields at places where there is a nearby waterway or drainage channel as reported by this station in the earlier reports. The relative difference which was observed in the case of EC of the drained water from different drains was not seen in the case of pH values and they remained identical and slightly acidic. The higher pH levels are because of the submerged condition of the soil during cropping season which prevent entry of air into the soil system prohibiting oxidation and formation of acidity.

The comparison of EC values of irrigation water and the sub-surface drained water indicated that a substantial amount of salts can be leached through the sub-surface drainage system. On an average, the difference between the EC of sub-surface drained water and irrigation water was 2.25mmhos/cm which was quantitatively equivalent to 144 kg of salt/ha/cm of drained water. The EC values of surface drainage water and irrigation water remained same throughout the season indicating that the surface drainage does not contribute anything to the removal of salt from the soil. The surface drains get its volume of water from the flooding water normally used for irrigation purpose and washing the top soil. The top 5-10cm of soil is already in the washed condition due to the regular practice of the farmers of flooding and dewatering the fields. Moreover, the flooding water does not get any opportunity time to percolate down and hence to pick up the salts. The high water table condition also contribute for not allowing the flooding water to move down. The above mentioned reasons disqualify the effective use of surface drains as an alternative solution to the sub-surface drains. However, the surface drains can be economically used as collector drains for the sub-surface drains, provided they are deepened and widened.

A close study of the weekly values of pH of irrigation water, sub-surface drainage water and the surface drainage water leads to the following inferences. The pH values of sub-surface drainage water and irrigation water remained identical and the values ranged between 6 to 7.5. The surface drained water remained slightly acidic and the values ranged between 5.75 to 6.5. The soil on drying during the intermittent flooding and drying practiced by the farmers gets acidified on aeration and this acidity is washed and dumped into the surface drains and hence it is slightly acidic. The main problem is thus found to be controlling the salt than acidity. The acidity problem gets automatically controlled with rice cultivation during which there is always submerged water.

From the data so far collected by the station, it is found that the sub-surface drainage system can be effectively and successfully used in the Kari lands of Kuttanad provided that the cost factors are reasonable. Studies for minimizing the cost have already been taken up in this direction. One of the main factors which increases the cost of the system is the use of filter materials around the drains. An experiment has already been laid out for finding the economically viable and locally available filter material.

## SECTION - F

### Technical Programme 1987-88.

1. Monitoring of periodical changes in the quality of surface and sub-surface water in the project area.

2. Monitoring of seasonal fluctuations of ground water table with reference to surface water level.

3. Assessment of hydraulic properties of the tile drainage system.

4. Effectiveness of tile drainage system in the performance of paddy crop in the Kari land.

5. Evaluation of different filter materials to find its economic suitability including its design criteria for the sub-surface drainage system.

6. Studies on the changes of soil chemical properties with respect to time on sub-surface drainage.

## SECTION-G.

## A P P E N D I X - 1.

**Discharge at 20 hour interval in mm/day for different tile drains**

| Time | 2E15* | 3E15* | 4E15* | 5E15* | 7E30@ | 8E30@ |
|---|---|---|---|---|---|---|
| 20 | 9.70 | 8.60 | 6.10 | 6.50 | 2.30 | 3.30 |
| 40 | 9.10 | 7.40 | 5.10 | 5.20 | 1.75 | 2.35 |
| 60 | 8.70 | 6.90 | 4.60 | 4.50 | 1.50 | 1.95 |
| 80 | 8.50 | 6.60 | 4.20 | 4.10 | 1.30 | 1.70 |
| 100 | 8.30 | 6.40 | 4.00 | 3.90 | 1.15 | 1.50 |
| 120 | 8.10 | 6.30 | 3.90 | 3.70 | 1.05 | 1.35 |
| 140 | 7.90 | 6.10 | 3.80 | 3.50 | 0.90 | 1.20 |
| 160 | 7.80 | 6.00 | 3.70 | 3.40 | 0.80 | 1.05 |
| 180 | 7.70 | 5.80 | 3.60 | 3.20 | 0.70 | 0.95 |
| 200 | 7.50 | 5.70 | 3.50 | 3.10 | 0.65 | 0.80 |
| 220 | 7.40 | 5.60 | 3.40 | 2.90 | 0.55 | 0.75 |
| 240 | 7.30 | 5.50 | 3.30 | 2.80 | 0.50 | 0.70 |
| 260 | 7.10 | 5.30 | 3.20 | 2.70 | 0.45 | 0.60 |
| 280 | 7.00 | 5.10 | 3.10 | 2.50 | 0.40 | 0.55 |
| 300 | 6.80 | 5.00 | 2.90 | 2.30 | 0.35 | 0.50 |
| 320 | 6.60 | 4.80 | 2.80 | 2.20 | 0.30 | 0.40 |
| 340 | 6.40 | 4.70 | 2.60 | 2.00 | 0.25 | 0.35 |
| 360 | 6.20 | 4.50 | 2.50 | 1.90 | 0.20 | 0.25 |
| 380 | 6.10 | 4.30 | 2.30 | 1.80 | 0.20 | 0.20 |
| 400 | 5.90 | 4.10 | 2.20 | 1.60 | 0.15 | 0.15 |
| 420 | 5.70 | 3.90 | 2.10 | 1.40 | 0.10 | 0.10 |
| 440 | 5.60 | 3.80 | 2.00 | 1.30 | 0.05 | 0.05 |

* 15m spacing.

@ 30m spacing.

**Average head at 20 hour interval in M for different tile drains**

| Time | 2E15* | 3E15* | 4E15* | 5E15* | 7E30@ | 8E30@ |
|---|---|---|---|---|---|---|
| 0 | 0.69 | 0.67 | 0.65 | 0.67 | 0.66 | 0.65 |
| 20 | 0.59 | 0.56 | 0.56 | 0.62 | 0.62 | 0.60 |
| 40 | 0.51 | 0.48 | 0.50 | 0.57 | 0.56 | 0.54 |
| 60 | 0.48 | 0.43 | 0.45 | 0.52 | 0.52 | 0.50 |
| 80 | 0.45 | 0.40 | 0.42 | 0.47 | 0.48 | 0.46 |
| 100 | 0.43 | 0.37 | 0.39 | 0.44 | 0.44 | 0.42 |
| 120 | 0.42 | 0.36 | 0.37 | 0.40 | 0.41 | 0.38 |
| 140 | 0.41 | 0.34 | 0.35 | 0.37 | 0.38 | 0.35 |
| 160 | 0.40 | 0.33 | 0.33 | 0.35 | 0.35 | 0.32 |
| 180 | 0.39 | 0.32 | 0.32 | 0.33 | 0.32 | 0.29 |
| 200 | 0.38 | 0.31 | 0.30 | 0.31 | 0.29 | 0.26 |
| 220 | 0.37 | 0.30 | 0.29 | 0.29 | 0.27 | 0.24 |
| 240 | 0.37 | 0.29 | 0.28 | 0.28 | 0.24 | 0.21 |
| 260 | 0.36 | 0.28 | 0.27 | 0.26 | 0.22 | 0.19 |
| 280 | 0.35 | 0.27 | 0.26 | 0.25 | 0.19 | 0.16 |
| 300 | 0.34 | 0.26 | 0.25 | 0.23 | 0.17 | 0.14 |
| 320 | 0.34 | 0.26 | 0.24 | 0.22 | 0.15 | 0.11 |
| 340 | 0.33 | 0.25 | 0.23 | 0.20 | 0.12 | 0.09 |
| 360 | 0.32 | 0.24 | 0.22 | 0.19 | 0.10 | 0.07 |
| 380 | 0.31 | 0.23 | 0.21 | 0.17 | 0.07 | - |
| 400 | 0.31 | 0.22 | 0.20 | 0.16 | - | - |
| 420 | 0.30 | 0.21 | - | -- | - | - |
| 440 | 0.29 | 0.21 | - | - | - | - |

* 15m spacing.

@ 30m spacing.

## Hydraulic head at 20 hour interval in meters for different observation wells

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 111 | OBW 112 | OBW 113 | OBW 114 | OBW 115 |
| 0 | 0.65 | 0.64 | 0.62 | 0.67 | 0.68 |
| 20 | 0.34 | 0.54 | 0.44 | 0.35 | 0.35 |
| 40 | 0.26 | 0.47 | 0.39 | 0.31 | 0.26 |
| 60 | 0.23 | 0.43 | 0.38 | 0.28 | 0.20 |
| 80 | 0.21 | 0.40 | 0.37 | 0.27 | 0.16 |
| 100 | 0.20 | 0.38 | 0.36 | 0.27 | 0.14 |
| 120 | 0.20 | 0.37 | 0.36 | 0.26 | 0.13 |
| 140 | 0.20 | 0.36 | 0.35 | 0.25 | 0.12 |
| 160 | 0.19 | 0.36 | 0.35 | 0.25 | 0.12 |
| 180 | 0.19 | 0.35 | 0.35 | 0.25 | 0.11 |
| 200 | 0.19 | 0.35 | 0.34 | 0.24 | 0.11 |
| 220 | 0.19 | 0.35 | 0.34 | 0.24 | 0.11 |
| 240 | 0.18 | 0.34 | 0.33 | 0.24 | 0.11 |
| 260 | 0.18 | 0.34 | 0.33 | 0.23 | 0.10 |
| 280 | 0.18 | 0.33 | 0.33 | 0.23 | 0.10 |
| 300 | 0.17 | 0.32 | 0.32 | 0.23 | 0.10 |
| 320 | 0.17 | 0.31 | 0.32 | 0.22 | 0.10 |
| 340 | 0.17 | 0.31 | 0.31 | 0.21 | 0.09 |
| 360 | 0.17 | 0.30 | 0.30 | 0.21 | 0.09 |
| 380 | 0.17 | 0.29 | 0.30 | 0.20 | 0.09 |
| 400 | 0.16 | 0.29 | 0.29 | 0.20 | 0.09 |
| 420 | 0.16 | 0.28 | 0.29 | 0.20 | 0.08 |
| 440 | 0.16 | 0.28 | 0.28 | 0.19 | 0.08 |
| 460 | 0.16 | 0.27 | 0.27 | .. | 0.08 |

The subscripts of observation wells denote the following:

1. First digit indicates the observation well line number
2. Second digit indicate the drain line number
3. Third digit indicate the position of the observation well number from the drain line towards the north.

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 121 | OBW 122 | OBW 123 | OBW 124 | OBW 125 |
| 0 | 0.60 | 0.61 | 0.62 | 0.61 | 0.54 |
| 20 | 0.25 | 0.38 | 0.50 | 0.40 | 0.31 |
| 40 | 0.18 | 0.31 | 0.42 | 0.28 | 0.21 |
| 60 | 0.13 | 0.27 | 0.39 | 0.24 | 0.16 |
| 80 | 0.11 | 0.25 | 0.36 | 0.21 | 0.13 |
| 100 | 0.10 | 0.23 | 0.33 | 0.19 | 0.11 |
| 120 | 0.10 | 0.23 | 0.32 | 0.18 | 0.10 |
| 140 | 0.10 | 0.22 | 0.31 | 0.18 | 0.10 |
| 160 | 0.10 | 0.21 | 0.30 | 0.17 | 0.09 |
| 180 | 0.09 | 0.21 | 0.30 | 0.17 | 0.09 |
| 200 | 0.09 | 0.20 | 0.30 | 0.16 | 0.09 |
| 220 | 0.09 | 0.20 | 0.29 | 0.16 | 0.08 |
| 240 | 0.09 | 0.19 | 0.28 | 0.16 | 0.08 |
| 260 | 0.09 | 0.19 | 0.27 | 0.16 | 0.08 |
| 280 | 0.09 | 0.19 | 0.27 | 0.15 | 0.08 |
| 300 | 0.09 | 0.19 | 0.26 | 0.15 | 0.07 |
| 320 | 0.08 | 0.18 | 0.25 | 0.15 | 0.07 |
| 340 | 0.08 | 0.18 | 0.25 | 0.14 | 0.07 |
| 360 | 0.08 | 0.18 | 0.24 | 0.14 | 0.07 |
| 380 | 0.08 | 0.17 | 0.23 | 0.14 | 0.07 |
| 400 | 0.07 | 0.17 | 0.23 | 0.13 | 0.06 |
| 420 | 0.07 | 0.16 | 0.23 | 0.13 | 0.06 |
| 440 | 0.07 | 0.16 | 0.22 | 0.13 | 0.06 |
| 460 | 0.07 | 0.15 | 0.22 | 0.12 | 0.06 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 131 | OBW 132 | OBW 133 | OBW 134 | OBW 135 |
| 0 | 0.60 | 0.60 | 0.58 | 0.56 | 0.61 |
| 20 | 0.11 | 0.32 | 0.47 | 0.40 | 0.23 |
| 40 | 0.06 | 0.24 | 0.39 | 0.32 | 0.19 |
| 60 | 0.05 | 0.21 | 0.34 | 0.27 | 0.18 |
| 80 | 0.04 | 0.20 | 0.31 | 0.24 | 0.17 |
| 100 | 0.04 | 0.19 | 0.29 | 0.22 | 0.17 |
| 120 | 0.04 | 0.19 | 0.28 | 0.21 | 0.17 |
| 140 | 0.04 | 0.18 | 0.27 | 0.20 | 0.16 |
| 160 | 0.04 | 0.18 | 0.26 | 0.19 | 0.16 |
| 180 | 0.04 | 0.17 | 0.25 | 0.19 | 0.16 |
| 200 | 0.04 | 0.17 | 0.25 | 0.18 | 0.16 |
| 220 | 0.04 | 0.16 | 0.24 | 0.18 | 0.15 |
| 240 | 0.03 | 0.16 | 0.24 | 0.18 | 0.15 |
| 260 | 0.03 | 0.15 | 0.23 | 0.18 | 0.15 |
| 280 | 0.03 | 0.15 | 0.23 | 0.17 | 0.14 |
| 300 | 0.03 | 0.14 | 0.22 | 0.17 | 0.14 |
| 320 | 0.03 | 0.14 | 0.22 | 0.17 | 0.14 |
| 340 | 0.03 | 0.13 | 0.21 | 0.17 | 0.13 |
| 360 | 0.02 | 0.13 | 0.21 | 0.16 | 0.13 |
| 380 | 0.02 | 0.13 | 0.20 | 0.16 | 0.12 |
| 400 | 0.02 | 0.12 | 0.19 | 0.15 | 0.12 |
| 420 | 0.02 | 0.12 | 0.19 | 0.15 | 0.11 |
| 440 | 0.02 | 0.12 | 0.18 | 0.15 | 0.11 |
| 460 | 0.02 | 0.11 | .. | 0.14 | 0.10 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 141 | OBW 142 | OBW 143 | OBW 144 | OBW 145 |
| 0 | 0.60 | 0.64 | 0.55 | 0.55 | 0.65 |
| 20 | 0.16 | 0.48 | 0.45 | 0.31 | 0.25 |
| 40 | 0.11 | 0.40 | 0.38 | 0.25 | 0.18 |
| 60 | 0.09 | 0.39 | 0.35 | 0.22 | 0.15 |
| 80 | 0.09 | 0.30 | 0.34 | 0.22 | 0.13 |
| 100 | 0.08 | 0.28 | 0.33 | 0.20 | 0.13 |
| 120 | 0.08 | 0.26 | 0.32 | 0.20 | 0.13 |
| 140 | 0.08 | 0.25 | 0.32 | 0.20 | 0.13 |
| 160 | 0.08 | 0.24 | 0.30 | 0.19 | 0.12 |
| 180 | 0.07 | 0.23 | 0.30 | 0.19 | 0.12 |
| 200 | 0.07 | 0.23 | 0.29 | 0.19 | 0.12 |
| 220 | 0.07 | 0.22 | 0.28 | 0.18 | 0.12 |
| 240 | 0.07 | 0.21 | 0.27 | 0.18 | 0.11 |
| 260 | 0.07 | 0.21 | 0.27 | 0.18 | 0.11 |
| 280 | 0.07 | 0.20 | 0.26 | 0.17 | 0.11 |
| 300 | 0.06 | 0.20 | 0.25 | 0.17 | 0.11 |
| 320 | 0.06 | 0.19 | 0.24 | 0.16 | 0.10 |
| 340 | 0.06 | 0.18 | 0.23 | 0.15 | 0.10 |
| 360 | 0.06 | 0.18 | 0.22 | 0.15 | 0.10 |
| 380 | 0.06 | 0.18 | 0.21 | 0.14 | 0.10 |
| 400 | 0.06 | 0.17 | 0.20 | 0.14 | 0.09 |
| 420 | 0.05 | 0.17 | 0.20 | 0.13 | 0.09 |
| 440 | 0.05 | 0.16 | 0.19 | 0.13 | 0.09 |
| 460 | 0.05 | 0.16 | .. | 0.13 | 0.09 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 151 | OBW 152 | OBW 153 | OBW 154 | OBW 155 |
| 0 | 0.65 | 0.65 | 0.68 | 0.58 | 0.59 |
| 20 | 0.06 | 0.38 | 0.63 | 0.51 | 0.43 |
| 40 | 0.05 | 0.28 | 0.56 | 0.44 | 0.34 |
| 60 | 0.05 | 0.23 | 0.50 | 0.39 | 0.30 |
| 80 | 0.05 | 0.20 | 0.46 | 0.35 | 0.27 |
| 100 | 0.05 | 0.20 | 0.43 | 0.33 | 0.25 |
| 120 | 0.55 | 0.19 | 0.40 | 0.30 | 0.24 |
| 140 | 0.05 | 0.18 | 0.38 | 0.28 | 0.22 |
| 160 | 0.05 | 0.18 | 0.37 | 0.28 | 0.21 |
| 180 | 0.05 | 0.17 | 0.35 | 0.27 | 0.21 |
| 200 | 0.05 | 0.17 | 0.34 | 0.25 | 0.20 |
| 220 | 0.05 | 0.17 | 0.33 | 0.25 | 0.19 |
| 240 | .05 | 0.17 | 0.32 | 0.24 | 0.18 |
| 260 | 0.05 | 0.16 | 0.31 | 0.23 | 0.18 |
| 280 | 0.05 | 0.16 | .30 | 0.22 | 0.17 |
| 300 | .05 | 0.15 | 0.28 | .21 | 0.16 |
| 320 | 0.05 | 0.15 | .27 | 0.20 | 0.15 |
| 340 | [illegible] | 0.15 | 0.26 | 0.20 | 0.15 |
| 360 | 0.04 | 0.14 | 0.25 | .19 | 0.14 |
| 380 | .04 | 0.13 | 0.24 | 0.18 | 0.13 |
| 400 | [illegible] | 0.13 | 0.23 | 0.17 | 0.12 |
| 420 | 0.04 | .12 | 0.21 | 0.15 | 0.11 |
| 440 | 0.04 | .11 | .20 | .15 | 0.11 |
| 460 | .03 | .11 | .. | 0.14 | 0.10 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 161 | OBW 162 | OBW 163 | OBW 164 | OBW 165 |
| 0 | 0.60 | 0.53 | 0.61 | 0.60 | 0.60 |
| 20 | 0.44 | 0.48 | 0.59 | 0.46 | 0.36 |
| 40 | 0.35 | 0.43 | 0.54 | 0.37 | 0.26 |
| 60 | 0.30 | 0.40 | 0.50 | 0.32 | 0.20 |
| 80 | 0.28 | 0.37 | 0.47 | 0.27 | 0.16 |
| 100 | 0.25 | 0.35 | 0.43 | 0.25 | 0.14 |
| 120 | 0.23 | 0.33 | 0.40 | 0.22 | 0.12 |
| 140 | 0.22 | 0.32 | 0.36 | 0.20 | 0.11 |
| 160 | 0.21 | 0.30 | 0.35 | 0.19 | 0.10 |
| 180 | 0.20 | 0.29 | 0.31 | 0.17 | 0.10 |
| 200 | 0.20 | 0.28 | 0.28 | 0.16 | 0.10 |
| 220 | 0.19 | 0.27 | 0.26 | 0.15 | 0.09 |
| 240 | 0.19 | 0.27 | 0.24 | 0.13 | 0.09 |
| 260 | 0.18 | 0.25 | 0.21 | 0.12 | 0.09 |
| 280 | 0.18 | 0.25 | 0.19 | 0.11 | 0.09 |
| 300 | 0.17 | 0.24 | 0.17 | 0.10 | 0.08 |
| 320 | 0.16 | 0.23 | 0.17 | 0.09 | 0.08 |
| 340 | 0.16 | 0.22 | 0.17 | 0.07 | 0.07 |
| 360 | 0.15 | 0.21 | 0.13 | 0.06 | 0.06 |
| 380 | 0.15 | 0.20 | 0.11 | 0.04 | 0.05 |
| 400 | 0.14 | 0.18 | 0.09 | 0.03 | 0.05 |
| 420 | 0.13 | 0.17 | 0.07 | 0.02 | 0.04 |
| 440 | 0.12 | 0.16 | 0.06 | .. | 0.04 |
| 460 | 0.11 | 0.15 | 0.04 | .. | 0.03 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 171 | OBW 172 | OBW 173 | OBW 174 | OBW 175 |
| 0 | 0.33 | 0.60 | 0.60 | 0.55 | 0.53 |
| 20 | 0.28 | 0.39 | 0.53 | 0.41 | 0.14 |
| 40 | 0.17 | 0.31 | 0.43 | 0.33 | 0.09 |
| 60 | 0.15 | 0.27 | 0.37 | 0.28 | 0.07 |
| 80 | 0.14 | 0.24 | 0.33 | 0.23 | 0.06 |
| 100 | 0.12 | 0.22 | 0.30 | 0.21 | 0.06 |
| 120 | 0.12 | 0.21 | 0.27 | 0.19 | 0.05 |
| 140 | 0.11 | 0.19 | 0.24 | 0.17 | 0.05 |
| 160 | 0.11 | 0.18 | 0.22 | 0.15 | 0.04 |
| 180 | 0.11 | 0.17 | 0.20 | 0.13 | 0.04 |
| 200 | 0.10 | 0.17 | 0.18 | 0.11 | 0.03 |
| 220 | 0.10 | 0.16 | 0.16 | 0.09 | 0.02 |
| 240 | 0.09 | 0.15 | 0.14 | 0.07 | 0.02 |
| 260 | 0.09 | 0.14 | 0.12 | 0.05 | .. |
| 280 | 0.09 | 0.13 | 0.10 | 0.04 | .. |
| 300 | 0.08 | 0.12 | 0.08 | 0.03 | .. |
| 320 | 0.08 | 0.11 | 0.06 | .. | .. |
| 340 | 0.07 | 0.09 | 0.04 | .. | .. |
| 360 | 0.07 | 0.08 | 0.03 | .. | .. |
| 380 | 0.06 | 0.07 | 0.005 | .. | .. |
| 400 | 0.05 | 0.05 | .. | .. | .. |
| 420 | 0.04 | 0.04 | .. | .. | .. |
| 440 | 0.04 | 0.03 | .. | .. | .. |
| 460 | .. | 0.02 | .. | .. | .. |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 181 | OBW 182 | OBW 183 | OBW 184 | OBW 185 |
| 0 | 0.54 | 0.55 | 0.53 | 0.50 | 0.51 |
| 20 | 0.[illegible] | 0.3[illegible] | 0.49 | 0.46 | 0.41 |
| 40 | 0.15 | 0.26 | 0.45 | 0.42 | 0.43 |
| 60 | 0.11 | 0.23 | 0.41 | 0.38 | 0.27 |
| 80 | 0.08 | 0.21 | 0.38 | 0.34 | 0.23 |
| 100 | 0.06 | 0.20 | 0.35 | 0.32 | 0.19 |
| 120 | 0.05 | 0.18 | 0.32 | 0.29 | 0.16 |
| 140 | 0.03 | 0.17 | 0.30 | 0.28 | 0.13 |
| 160 | 0.02 | 0.16 | 0.27 | 0.25 | 0.12 |
| 180 | 0.02 | 0.14 | 0.25 | 0.23 | 0.10 |
| 200 | 0.02 | 0.12 | 0.22 | 0.21 | 0.08 |
| 220 | .. | 0.10 | 0.20 | 0.19 | 0.07 |
| 240 | .. | 0.09 | 0.18 | 0.17 | 0.0 |
| 260 | .. | 0.07 | 0.16 | 0.15 | 0.0 |
| 280 | .. | 0.06 | 0.13 | 0.13 | 0.0 |
| 300 | .. | 0.05 | 0.11 | 0.11 | 0.0 |
| 320 | .. | 0.03 | 0.09 | 0.09 | .. |
| 340 | .. | 0.02 | 0.07 | 0.07 | .. |
| 360 | .. | .. | 0.05 | 0.06 | .. |
| 380 | .. | .. | 0.03 | 0.03 | .. |
| 400 | .. | .. | 0.01 | .. | .. |
| 420 | .. | .. | .. | .. | .. |
| 440 | .. | .. | .. | .. | .. |
| 460 | .. | .. | .. | .. | .. |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 211 | OBW 212 | OBW 213 | OBW 214 | OBW 215 |
| 0 | 0.70 | 0.68 | 0.70 | .. | 1.06 |
| 20 | 0.23 | 0.52 | 0.60 | 0.73 | 0.70 |
| 40 | 0.20 | 0.49 | 0.48 | 0.66 | 0.60 |
| 60 | 0.19 | 0.40 | 0.46 | 0.63 | 0.57 |
| 80 | 0.18 | 0.39 | 0.44 | 0.62 | 0.56 |
| 100 | 0.18 | 0.38 | 0.44 | 0.61 | 0.56 |
| 120 | 0.18 | 0.37 | 0.43 | 0.60 | 0.55 |
| 140 | 0.18 | 0.36 | 0.42 | 0.60 | 0.55 |
| 160 | 0.18 | 0.36 | 0.42 | 0.60 | 0.55 |
| 180 | 0.18 | 0.35 | 0.41 | 0.60 | 0.55 |
| 200 | 0.17 | 0.35 | 0.41 | 0.59 | 0.55 |
| 220 | 0.17 | 0.35 | 0.40 | 0.59 | 0.55 |
| 240 | 0.17 | 0.34 | 0.40 | 0.59 | 0.54 |
| 260 | 0.17 | 0.34 | 0.39 | 0.58 | 0.54 |
| 280 | 0.16 | 0.34 | 0.38 | 0.58 | 0.54 |
| 300 | 0.16 | 0.33 | 0.38 | 0.57 | 0.54 |
| 320 | 0.15 | 0.33 | 0.37 | 0.56 | 0.54 |
| 340 | 0.15 | 0.32 | 0.36 | 0.56 | 0.53 |
| 360 | 0.15 | 0.32 | 0.35 | 0.55 | 0.53 |
| 380 | 0.15 | 0.31 | 0.35 | 0.55 | 0.53 |
| 400 | 0.14 | 0.31 | 0.34 | 0.54 | 0.53 |
| 420 | 0.14 | 0.30 | 0.34 | 0.54 | 0.53 |
| 440 | 0.14 | 0.30 | 0.33 | 0.53 | 0.52 |
| 460 | .. | 0.30 | .. | .. | |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 221 | OBW 222 | OBW 223 | OBW 224 | OBW 225 |
| 0 | 0.82 | 0.83 | 0.67 | 0.81 | 0.74 |
| 20 | 0.21 | 0.61 | 0.54 | 0.62 | 0.35 |
| 40 | 0.19 | 0.44 | 0.[illegible]4 | 0.52 | 0.30 |
| 60 | 0.18 | 0.41 | 0.39 | 0.[illegible]8 | 0.28 |
| 80 | 0.18 | 0.[illegible]0 | 0.36 | 0.46 | 0.27 |
| 100 | 0.18 | 0.40 | 0.35 | 0.[illegible] | 0.26 |
| 120 | 0.18 | 0.39 | 0.35 | 0.43 | 0.25 |
| 140 | 0.18 | 0.39 | 0.34 | 0.43 | 0.25 |
| 160 | 0.19 | 0.39 | 0.34 | 0.42 | 0.25 |
| 180 | 0.19 | 0.39 | 0.33 | 0.42 | 0.24 |
| 200 | 0.19 | 0.38 | 0.33 | 0.41 | 0.24 |
| 220 | 0.19 | 0.38 | 0.32 | 0.41 | 0.24 |
| 240 | 0.19 | 0.38 | 0.31 | 0.40 | 0.24 |
| 280 | 0.19 | 0.37 | 0.31 | 0.40 | 0.23 |
| 300 | 0.19 | 0.37 | 0.30 | 0.40 | 0.23 |
| 320 | 0.19 | 0.36 | 0.30 | 0.39 | 0.23 |
| 340 | 0.19 | 0.36 | 0.29 | 0.39 | 0.23 |
| 360 | 0.18 | 0.36 | 0.28 | 0.38 | 0.22 |
| 380 | 0.18 | 0.35 | 0.28 | 0.38 | 0.22 |
| 400 | 0.18 | 0.35 | 0.27 | 0.38 | 0.22 |
| 420 | 0.18 | 0.35 | 0.27 | 0.37 | 0.21 |
| 440 | 0.18 | 0.34 | 0.26 | 0.37 | 0.21 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 231 | OBW 232 | OBW 233 | OBW 234 | OBW 235 |
| 0 | 0.65 | 0.65 | 0.69 | 0.62 | 0.63 |
| 20 | 0.06 | 0.47 | 0.49 | 0.38 | 0.22 |
| 40 | 0.06 | 0.34 | 0.42 | 0.28 | 0.17 |
| 60 | 0.06 | 0.28 | 0.40 | 0.24 | 0.15 |
| 80 | 0.06 | 0.24 | 0.38 | 0.22 | 0.14 |
| 100 | 0.06 | 0.21 | 0.37 | 0.21 | 0.14 |
| 120 | 0.06 | 0.19 | 0.36 | 0.20 | 0.13 |
| 140 | 0.06 | 0.18 | 0.36 | 0.20 | 0.13 |
| 160 | 0.06 | 0.17 | 0.35 | 0.19 | 0.13 |
| 180 | 0.06 | 0.16 | 0.35 | 0.19 | 0.13 |
| 200 | 0.06 | 0.15 | 0.34 | 0.19 | 0.13 |
| 220 | 0.06 | 0.15 | 0.34 | 0.19 | 0.13 |
| 240 | 0.06 | 0.15 | 0.33 | 0.18 | 0.13 |
| 260 | 0.06 | 0.14 | 0.32 | 0.18 | 0.12 |
| 280 | 0.06 | 0.14 | 0.32 | 0.18 | 0.12 |
| 300 | 0.06 | 0.14 | 0.31 | 0.18 | 0.11 |
| 320 | 0.06 | 0.13 | 0.31 | 0.18 | 0.11 |
| 340 | 0.06 | 0.13 | 0.30 | 0.17 | 0.11 |
| 360 | 0.06 | 0.12 | 0.30 | 0.17 | 0.10 |
| 380 | 0.06 | 0.12 | 0.29 | 0.16 | 0.10 |
| 400 | 0.06 | 0.12 | 0.29 | 0.16 | 0.10 |
| 420 | 0.06 | 0.12 | 0.29 | 0.15 | 0.09 |
| 440 | 0.06 | 0.11 | 0.28 | 0.15 | 0.09 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 241 | OBW 242 | OBW 243 | OBW 244 | OBW 245 |
| 0 | 0.68 | 0.65 | 0.66 | .. | 0.69 |
| 20 | 0.48 | 0.45 | 0.64 | .. | 0.29 |
| 40 | 0.36 | 0.38 | 0.62 | .. | 0.19 |
| 60 | 0.28 | 0.33 | 0.59 | .. | 0.15 |
| 80 | 0.23 | 0.29 | 0.58 | .. | 0.13 |
| 100 | 0.19 | 0.25 | 0.56 | .. | 0.13 |
| 120 | 0.17 | 0.23 | 0.54 | .. | 0.13 |
| 140 | 0.15 | 0.22 | 0.53 | .. | 0.13 |
| 160 | 0.13 | 0.22 | 0.51 | .. | 0.12 |
| 180 | 0.12 | 0.20 | 0.50 | .. | 0.12 |
| 200 | 0.12 | 0.20 | 0.49 | .. | 0.12 |
| 220 | 0.12 | 0.19 | 0.48 | .. | 0.12 |
| 240 | 0.11 | 0.18 | 0.46 | .. | 0.12 |
| 260 | 0.11 | 0.17 | 0.45 | .. | 0.12 |
| 280 | 0.11 | 0.17 | 0.45 | .. | 0.11 |
| 300 | 0.10 | 0.16 | 0.44 | .. | 0.11 |
| 320 | 0.10 | 0.15 | 0.43 | .. | 0.11 |
| 340 | 0.10 | 0.14 | 0.42 | .. | 0.11 |
| 360 | 0.10 | 0.14 | 0.41 | .. | 0.11 |
| 380 | 0.09 | 0.13 | 0.40 | .. | 0.11 |
| 400 | 0.09 | 0.12 | 0.39 | .. | 0.10 |
| 420 | 0.08 | 0.12 | 0.38 | .. | 0.10 |
| 440 | 0.08 | 0.11 | 0.37 | .. | 0.10 |
| 460 | .. | .. | .. | .. | 0.40 |

| Time | Head (m) | | | | |
| --- | --- | --- | --- | --- | --- |
| | OBW 251 | OBW 252 | OBW 253 | OBW 254 | OBW 255 |
| 0 | 0.67 | 0.68 | 0.67 | 0.66 | 0.66 |
| 20 | 0.06 | 0.59 | 0.63 | 0.59 | 0.55 |
| 40 | 0.06 | 0.35 | 0.57 | 0.52 | 0.28 |
| 60 | 0.06 | 0.28 | 0.51 | 0.45 | 0.25 |
| 80 | 0.06 | 0.23 | 0.46 | 0.40 | 0.23 |
| 100 | 0.06 | 0.20 | 0.40 | 0.36 | 0.22 |
| 120 | 0.06 | 0.19 | 0.36 | 0.33 | 0.21 |
| 140 | 0.06 | 0.17 | 0.31 | 0.31 | 0.21 |
| 160 | 0.06 | 0.16 | 0.28 | 0.30 | 0.20 |
| 180 | 0.06 | 0.16 | 0.25 | 0.28 | 0.20 |
| 200 | 0.06 | 0.15 | 0.23 | 0.27 | 0.19 |
| 220 | 0.06 | 0.15 | 0.21 | 0.26 | 0.19 |
| 240 | 0.06 | 0.14 | 0.19 | 0.25 | 0.18 |
| 260 | 0.06 | 0.14 | 0.17 | 0.24 | 0.18 |
| 280 | 0.06 | 0.13 | 0.15 | 0.24 | 0.18 |
| 300 | 0.06 | 0.12 | 0.14 | 0.23 | 0.17 |
| 320 | 0.06 | 0.12 | 0.12 | 0.22 | 0.17 |
| 340 | 0.06 | 0.11 | 0.10 | 0.21 | 0.16 |
| 360 | 0.05 | 0.11 | 0.09 | 0.20 | 0.16 |
| 380 | 0.05 | 0.10 | 0.07 | 0.19 | 0.15 |
| 400 | 0.05 | 0.10 | 0.06 | 0.18 | 0.15 |
| 420 | 0.05 | 0.09 | 0.05 | 0.17 | 0.14 |
| 440 | 0.05 | .. | .. | 0.17 | 0.13 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 261 | OBW 262 | OBW 263 | OBW 264 | OBW 265 |
| 0 | 0.66 | 0.50 | 0.65 | 0.70 | 0.68 |
| 20 | 0.45 | 0.43 | 0.64 | 0.65 | 0.45 |
| 40 | 0.37 | 0.36 | 0.62 | 0.57 | 0.33 |
| 60 | 0.32 | 0.31 | 0.60 | 0.50 | 0.26 |
| 80 | 0.28 | 0.28 | 0.58 | 0.45 | 0.22 |
| 100 | 0.25 | 0.26 | 0.55 | 0.40 | 0.19 |
| 120 | 0.23 | 0.24 | 0.52 | 0.36 | 0.17 |
| 140 | 0.22 | 0.23 | 0.49 | 0.34 | 0.16 |
| 160 | 0.21 | 0.23 | 0.47 | 0.32 | 0.14 |
| 180 | 0.20 | 0.22 | 0.44 | 0.30 | 0.13 |
| 200 | 0.20 | 0.21 | 0.41 | 0.28 | 0.13 |
| 220 | 0.19 | 0.20 | 0.38 | 0.25 | 0.12 |
| 240 | 0.19 | 0.19 | 0.35 | 0.23 | 0.12 |
| 260 | 0.18 | 0.18 | 0.32 | 0.21 | 0.11 |
| 280 | 0.18 | 0.17 | 0.29 | 0.19 | 0.10 |
| 300 | 0.17 | 0.16 | 0.26 | 0.17 | 0.09 |
| 320 | 0.17 | 0.16 | 0.24 | 0.15 | 0.09 |
| 340 | 0.16 | 0.15 | 0.21 | 0.13 | 0.08 |
| 360 | 0.16 | 0.15 | 0.18 | 0.11 | 0.07 |
| 380 | 0.15 | 0.14 | 0.15 | 0.09 | 0.07 |
| 400 | 0.15 | 0.13 | 0.13 | 0.07 | 0.06 |
| 420 | 0.14 | 0.12 | 0.10 | 0.05 | 0.05 |
| 440 | 0.13 | 0.12 | 0.08 | 0.06 | 0.04 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 271 | OBW 272 | OBW 273 | OBW 274 | OBW 275 |
| 0 | .. | 0.69 | 0.64 | 0.65 | 0.63 |
| 20 | .. | 0.65 | 0.56 | 0.50 | 0.41 |
| 40 | .. | 0.58 | 0.48 | 0.41 | 0.31 |
| 60 | 0.24 | 0.52 | 0.42 | 0.35 | 0.25 |
| 80 | .22 | 0.52 | 0.39 | 0.30 | 0.21 |
| 100 | 0.21 | 0.42 | 0.35 | 0.28 | 0.20 |
| 120 | 0.21 | 0.33 | 0.32 | 0.26 | 0.18 |
| 140 | 0.20 | 0.35 | 0.30 | 0.23 | 0.16 |
| 160 | 0.19 | 0.32 | 0.27 | 0.22 | 0.15 |
| 180 | 0.18 | ,0.30 | 0.25 | 0.20 | 0.13 |
| 200 | 0.17 | 0,27 | 0.22 | 0.18 | 0.11 |
| 220 | 0.16 | 0.24 | 0.20 | 0.16 | 0.10 |
| 240 | 0.16 | 0.2[illegible] | 0.17 | 0.14 | 0.08 |
| 260 | 0.15 | 0.20 | 0.15 | 0.12 | 0.07 |
| 280 | 0.15 | 0.18 | 0.12 | 0.10 | 0.06 |
| 300 | 0.14 | 0.16 | 0.10 | 0.09 | 0.05 |
| 320 | 0.13 | 0.14 | 0.07 | 0.07 | 0.03 |
| 340 | 0.12 | 0.12 | 0.05 | 0.05 | 0.02 |
| 360 | 0.11 | 0.10 | 0.04 | 0.03 | 0.02 |
| 380 | 0.10 | 0.08 | .. | 0.02 | .. |
| 400 | 0.10 | 0.06 | .. | .. | .. |
| 420 | 0.09 | 0.04 | .. | .. | .. |
| 440 | 0.08 | 0.02 | .. | .. | .. |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 281 | OBW 282 | OBW 283 | OBW 284 | OBW 285 |
| 0 | 0.63 | 0.65 | 0.72 | 0.63 | 0.64 |
| 20 | 0.41 | 0.52 | 0.70 | 0.60 | 0.49 |
| 40 | 0.30 | 0.42 | 0.68 | 0.54 | 0.39 |
| 60 | 0.25 | 0.36 | 0.65 | 0.49 | 0.28 |
| 80 | 0.20 | 0.33 | 0.61 | 0.44 | 0.25 |
| 100 | 0.18 | 0.30 | 0.57 | 0.40 | 0.23 |
| 120 | 0.16 | 0.28 | 0.53 | 0.36 | 0.20 |
| 140 | 0.15 | 0.25 | 0.49 | 0.33 | 0.18 |
| 160 | 0.14 | 0.24 | 0.44 | 0.31 | 0.16 |
| 180 | 0.12 | 0.22 | 0.40 | 0.28 | 0.15 |
| 200 | 0.12 | 0.20 | 0.35 | 0.26 | 0.13 |
| 220 | 0.11 | 0.19 | 0.32 | 0.25 | 0.11 |
| 240 | 0.10 | 0.17 | 0.28 | 0.23 | 0.10 |
| 260 | 0.08 | 0.16 | 0.24 | 0.20 | 0.08 |
| 280 | 0.08 | 0.14 | 0.21 | 0.19 | 0.07 |
| 300 | 0.06 | 0.13 | 0.18 | 0.17 | 0.05 |
| 320 | 0.05 | 0.11 | 0.14 | 0.15 | 0.03 |
| 340 | 0.04 | 0.10 | 0.12 | 0.14 | 0.02 |
| 360 | 0.03 | 0.08 | 0.10 | 0.13 | .. |
| 380 | 0.02 | 0.06 | 0.07 | 0.11 | .. |
| 400 | .. | 0.05 | 0.05 | 0.10 | .. |
| 420 | .. | 0.06 | 0.03 | 0.08 | .. |
| 440 | .. | .. | 0.01 | 0.07 | .. |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 311 | OBW 312 | OBW 313 | OBW 314 | OBW 315 |
| 0 | 0.75 | 0.76 | 0.77 | 0.76 | 0.76 |
| 20 | 0.48 | 0.67 | 0.74 | 0.60 | 0.52 |
| 40 | 0.38 | 0.61 | 0.69 | 0.48 | 0.42 |
| 60 | 0.32 | 0.56 | 0.65 | 0.40 | 0.33 |
| 80 | 0.30 | 0.52 | 0.61 | 0.36 | 0.26 |
| 100 | 0.27 | 0.50 | 0.58 | 0.33 | 0.23 |
| 120 | 0.26 | 0.48 | 0.56 | 0.32 | 0.19 |
| 140 | 0.25 | 0.46 | 0.54 | 0.30 | 0.16 |
| 160 | 0.24 | 0.46 | 0.53 | 0.30 | 0.15 |
| 180 | 0.23 | 0.45 | 0.51 | 0.29 | 0.15 |
| 200 | 0.22 | 0.44 | 0.50 | 0.29 | 0.14 |
| 220 | 0.22 | 0.44 | 0.49 | 0.28 | 0.13 |
| 240 | 0.22 | 0.43 | 0.49 | 0.28 | 0.13 |
| 260 | 0.21 | 0.42 | 0.48 | 0.27 | 0.12 |
| 280 | 0.21 | 0.41 | 0.47 | 0.27 | 0.12 |
| 300 | 0.21 | 0.40 | 0.46 | 0.26 | 0.11 |
| 320 | 0.20 | 0.40 | 0.46 | 0.25 | 0.11 |
| 340 | 0.19 | 0.39 | 0.45 | 0.25 | 0.10 |
| 360 | 0.19 | 0.38 | 0.44 | 0.25 | 0.10 |
| 380 | 0.18 | 0.37 | 0.44 | 0.24 | 0.10 |
| 400 | 0.18 | 0.36 | 0.43 | 0.23 | 0.10 |
| 420 | 0.17 | 0.35 | 0.42 | 0.22 | 0.09 |
| 440 | 0.16 | 0.34 | 0.41 | 0.22 | 0.09 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 321 | OBW 322 | OBW 323 | OBW 324 | OBW 325 |
| 0 | 0.75 | 0.74 | 0.74 | 0.74 | 0.72 |
| 20 | 0.53 | 0.69 | .72 | 0.62 | 0.50 |
| 40 | 0.39 | 0.61 | 0.67 | 0.48 | 0.33 |
| 60 | 0.30 | 0.55 | 0.62 | 0.38 | 0.23 |
| 80 | 0.24 | 0.51 | 0.58 | 0.33 | 0.17 |
| 100 | 0.19 | 0.47 | 0.54 | 0.28 | 0.13 |
| 120 | 0.15 | 0.43 | 0.51 | 0.25 | 0.10 |
| 140 | 0.12 | 0.39 | 0.48 | .22 | 0.08 |
| 160 | 0.10 | .37 | 0.47 | 0.20 | 0.07 |
| 180 | 0.09 | 0.35 | 0.45 | 0.18 | 0.06 |
| 200 | 0.08 | 0.33 | 0.43 | 0.17 | 0.06 |
| 220 | 0.07 | 0.32 | 0.42 | 0.16 | 0.05 |
| 240 | 0.06 | 0.31 | 0.40 | 0.15 | 0.05 |
| 260 | 0.06 | .30 | 0.39 | 0.15 | 0.05 |
| 280 | 0.05 | 0.28 | 0.37 | 0.14 | 0.04 |
| 300 | 0.04 | 0.27 | 0.36 | 0.13 | 0.04 |
| 320 | 0.04 | 0.26 | 0.34 | 0.13 | 0.04 |
| 340 | 0.03 | 0.25 | 0.33 | 0.12 | 0.03 |
| 360 | 0.03 | 0.24 | 0.32 | 0.11 | 0.03 |
| 380 | 0.03 | 0.23 | 0.30 | 0.10 | 0.02 |
| 400 | 0.02 | 0.22 | 0.29 | 0.10 | 0.02 |
| 420 | 0.02 | 0.22 | 0.28 | 0.09 | 0.02 |
| 440 | 0.02 | 0.21 | 0.26 | 0.09 | 0.01 |
| 460 | 0.02 | 0.21 | .. | 0.08 | 0.01 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 331 | OBW 332 | OBW 333 | OBW 334 | OBW 335 |
| 0 | 0.72 | 0.73 | 0.71 | 0.73 | 0.72 |
| 20 | 0.41 | 0.58 | 0.65 | 0.66 | 0.41 |
| 40 | 0.25 | 0.43 | 0.57 | 0.55 | 0.26 |
| 60 | 0.16 | 0.33 | 0.49 | 0.46 | 0.17 |
| 80 | 0.10 | 0.26 | 0.42 | 0.38 | 0.15 |
| 100 | 0.07 | 0.22 | 0.37 | 0.36 | 0.09 |
| 120 | 0.05 | 0.18 | 0.33 | 0.28 | 0.07 |
| 140 | 0.04 | 0.16 | 0.30 | 0.22 | 0.06 |
| 160 | 0.03 | 0.14 | 0.28 | 0.21 | 0.05 |
| 180 | 0.03 | 0.12 | 0.26 | 0.19 | 0.05 |
| 200 | 0.02 | 0.11 | 0.24 | 0.16 | 0.04 |
| 220 | 0.02 | 0.10 | 0.22 | 0.15 | 0.04 |
| 240 | 0.02 | 0.09 | 0.20 | 0.13 | 0.03 |
| 260 | 0.02 | 0.08 | 0.19 | 0.12 | 0.03 |
| 280 | 0.02 | 0.08 | 0.17 | 0.11 | 0.03 |
| 300 | 0.01 | 0.07 | 0.15 | 0.10 | 0.02 |
| 320 | 0.01 | 0.06 | 0.14 | 0.09 | 0.02 |
| 340 | 0.01 | 0.05 | 0.12 | 0.07 | 0.02 |
| 360 | 0.01 | 0.05 | 0.10 | 0.06 | 0.02 |
| 380 | .. | 0.04 | 0.08 | 0.05 | 0.01 |
| 400 | .. | 0.03 | 0.07 | 0.04 | 0.01 |
| 420 | .. | 0.02 | 0.05 | 0.03 | 0.01 |
| 440 | .. | 0.02 | 0.04 | 0.02 | 0.01 |
| 460 | .. | 0.01 | .. | .. | .. |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 341 | OBW 342 | OBW 343 | OBW 344 | OBW 345 |
| 0 | 0.78 | 0.74 | 0.72 | 0.75 | 0.72 |
| 20 | 0.26 | 0.60 | 0.69 | 0.63 | 0.57 |
| 40 | 0.11 | 0.45 | 0.62 | 0.51 | 0.46 |
| 60 | 0.06 | 0.36 | 0.55 | 0.42 | 0.36 |
| 80 | 0.04 | 0.29 | 0.48 | 0.35 | 0.29 |
| 100 | 0.03 | 0.24 | 0.42 | 0.29 | 0.24 |
| 120 | 0.03 | 0.22 | 0.37 | 0.26 | 0.20 |
| 140 | 0.03 | 0.19 | 0.32 | 0.22 | 0.17 |
| 160 | 0.03 | 0.17 | 0.29 | 0.20 | 0.15 |
| 180 | 0.03 | 0.15 | 0.26 | 0.18 | 0.14 |
| 200 | 0.02 | 0.13 | 0.23 | 0.17 | 0.13 |
| 220 | 0.02 | 0.12 | 0.21 | 0.15 | 0.11 |
| 240 | 0.02 | 0.11 | 0.19 | 0.14 | 0.10 |
| 260 | 0.02 | 0.10 | 0.17 | 0.13 | 0.09 |
| 280 | 0.02 | 0.09 | 0.15 | 0.11 | 0.08 |
| 300 | 0.02 | 0.08 | 0.13 | 0.10 | 0.07 |
| 320 | 0.02 | 0.07 | 0.12 | 0.09 | 0.07 |
| 340 | 0.02 | 0.06 | 0.10 | 0.08 | 0.06 |
| 360 | 0.02 | 0.05 | 0.10 | 0.07 | 0.05 |
| 380 | 0.01 | 0.05 | 0.08 | 0.06 | 0.05 |
| 400 | 0.01 | 0.03 | 0.06 | 0.05 | 0.04 |
| 420 | 0.01 | 0.03 | 0.05 | 0.04 | 0.04 |
| 440 | .. | 0.02 | .. | 0.03 | 0.03 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 351 | OBW 352 | OBW 353 | OBW 354 | OBW 355 |
| 0 | 0.73 | 0.74 | 0.75 | 0.08 | 0.77 |
| 20 | 0.58 | 0.67 | 0.72 | 0.21 | 0.65 |
| 40 | 0.44 | 0.58 | 0.67 | 0.28 | 0.56 |
| 60 | 0.35 | 0.50 | 0.61 | 0.29 | 0.47 |
| 80 | 0.28 | 0.42 | 0.55 | 0.29 | 0.40 |
| 100 | 0.23 | 0.36 | 0.49 | 0.29 | 0.35 |
| 120 | 0.19 | 0.31 | 0.44 | 0.28 | 0.30 |
| 140 | 0.15 | 0.27 | 0.40 | 0.26 | 0.26 |
| 160 | 0.13 | 0.24 | 0.36 | 0.25 | 0.23 |
| 180 | 0.11 | 0.21 | 0.32 | 0.23 | 0.20 |
| 200 | 0.10 | 0.19 | 0.29 | 0.22 | 0.19 |
| 220 | 0.10 | 0.17 | 0.27 | 0.21 | 0.17 |
| 240 | 0.09 | 0.15 | 0.24 | 0.20 | 0.16 |
| 260 | 0.08 | 0.13 | 0.21 | 0.18 | 0.14 |
| 280 | 0.07 | 0.12 | 0.18 | 0.17 | 0.13 |
| 300 | 0.07 | 0.10 | 0.16 | 0.15 | 0.12 |
| 320 | 0.06 | 0.09 | 0.13 | 0.13 | 0.11 |
| 340 | 0.06 | 0.07 | 0.11 | 0.11 | 0.09 |
| 360 | 0.05 | 0.06 | 0.08 | 0.09 | 0.03 |
| 380 | 0.05 | 0.04 | 0.06 | 0.08 | 0.07 |
| 400 | 0.04 | 0.03 | 0.04 | 0.06 | 0.06 |
| 420 | 0.03 | 0.02 | 0.02 | 0.05 | 0.05 |
| 440 | 0.03 | 0.01 | .. | 0.03 | 0.04 |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 361 | OBW 362 | OBW 363 | OBW 364 | OBW 365 |
| 0 | .. | 0.77 | 0.76 | 0.73 | 0.71 |
| 20 | .. | 0.72 | 0.75 | 0.63 | 0.35 |
| 40 | .. | 0.66 | 0.72 | 0.52 | 0.23 |
| 60 | .. | 0.60 | 0.68 | [illegible] | 0.18 |
| 80 | .. | 0.54 | 0.64 | 0.38 | 0.14 |
| 100 | .. | 0.49 | 0.60 | 0.33 | 0.13 |
| 120 | .. | 0.45 | 0.57 | 0.30 | 0.12 |
| 140 | .. | 0.41 | 0.53 | 0.28 | 0.11 |
| 160 | .. | 0.37 | 0.50 | 0.25 | 0.10 |
| 180 | 0.17 | 0.34 | 0.47 | 0.23 | 0.09 |
| 200 | 0.15 | 0.31 | 0.43 | 0.20 | 0.09 |
| 220 | 0.14 | 0.28 | 0.40 | 0.19 | 0.08 |
| 240 | 0.13 | [illegible] | 0.37 | 0.17 | 0.07 |
| 260 | 0.13 | 0.26 | 0.33 | 0.15 | 0.07 |
| 280 | 0.12 | 0.20 | 0.30 | 0.14 | 0.07 |
| 300 | 0.11 | 0.18 | 0.27 | 0.12 | 0.06 |
| 320 | 0.10 | 0.15 | 0.24 | 0.10 | 0.05 |
| 340 | 0.10 | 0.13 | 0.20 | 0.09 | 0.04 |
| 360 | 0.09 | 0.10 | 0.17 | 0.07 | 0.04 |
| 380 | 0.08 | 0.08 | 0.15 | 0.06 | 0.03 |
| 400 | 0.07 | 0.06 | 0.11 | 0.04 | .. |
| 420 | 0.06 | 0.05 | 0.08 | 0.02 | .. |
| 440 | 0.06 | .. | 0.05 | 0.02 | .. |
| 460 | .. | .. | 0.02 | .. | .. |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 371 | OBW 372 | OBW 373 | OBW 374 | OBW 375 |
| 0 | 0.46 | 0.72 | 0.69 | 0.70 | 0.43 |
| 20 | 0.06 | 0.53 | 0.66 | 0.27 | 0.08 |
| 40 | 0.05 | 0.40 | 0.60 | 0.23 | 0.05 |
| 60 | 0.05 | 0.33 | 0.54 | 0.22 | 0.03 |
| 80 | 0.05 | 0.27 | 0.48 | 0.20 | 0.02 |
| 100 | 0.05 | 0.23 | 0.43 | 0.18 | 0.01 |
| 120 | 0.05 | 0.20 | 0.38 | 0.16 | .. |
| 140 | 0.05 | .18 | .35 | 0.15 | .. |
| 160 | 0.04 | 0.17 | 0.32 | 0.14 | .. |
| 180 | 0.04 | 0.15 | 0.28 | 0.12 | .. |
| 200 | 0.04 | 0.14 | 0.26 | .11 | .. |
| 220 | 0.04 | 0.12 | 0.23 | .10 | .. |
| 240 | 0.04 | 0.11 | 0.21 | 0.09 | .. |
| 260 | 0.03 | 0.10 | .18 | 0.08 | .. |
| 280 | .03 | 0.09 | 0.16 | 0.07 | .. |
| 300 | 0.03 | 0.07 | 0.13 | 0.06 | .. |
| 320 | 0.03 | 0.06 | 0.11 | 0.05 | .. |
| 340 | 0.03 | 0.05 | 0.09 | 0.04 | .. |
| 360 | 0.02 | 0.03 | 0.07 | 0.03 | .. |
| 380 | 0.02 | 0.02 | 0.05 | 0.02 | .. |
| 400 | .. | .. | .. | 0.02 | .. |
| 420 | .. | .. | .. | 0.01 | .. |

| Time | Head (m) | | | | |
|---|---|---|---|---|---|
| | OBW 381 | OBW 382 | OBW 383 | OBW 384 | OBW 385 |
| 0 | 0.65 | 0.68 | 0.70 | 0.67 | 0.67 |
| 20 | 0.04 | 0.26 | 0.67 | 0.46 | 0.50 |
| 40 | 0.03 | 0.22 | 0.63 | 0.41 | 0.38 |
| 60 | 0.02 | 0.20 | 0.60 | 0.38 | 0.30 |
| 80 | 0.02 | 0.18 | 0.56 | 0.35 | 0.24 |
| 100 | 0.02 | 0.17 | 0.53 | 0.33 | 0.19 |
| 120 | 0.02 | 0.15 | 0.49 | 0.33 | 0.15 |
| 140 | 0.02 | 0.15 | 0.46 | 0.31 | 0.12 |
| 160 | 0.02 | 0.13 | 0.43 | 0.28 | 0.10 |
| 180 | 0.01 | 0.12 | 0.40 | 0.26 | 0.08 |
| 200 | 0.01 | 0.11 | 0.37 | 0.24 | 0.06 |
| 220 | 0.01 | 0.10 | 0.34 | 0.23 | 0.05 |
| 240 | .. | 0.10 | 0.31 | 0.20 | 0.04 |
| 260 | .. | 0.08 | 0.28 | 0.18 | 0.03 |
| 280 | .. | 0.07 | 0.25 | 0.16 | 0.03 |
| 300 | .. | 0.06 | 0.23 | 0.14 | 0.02 |
| 320 | .. | 0.05 | 0.20 | 0.12 | 0.. |
| 340 | .. | 0.04 | 0.18 | 0.10 | .. |
| 360 | .. | 0.03 | 0.15 | 0.08 | .. |
| 380 | .. | 0.03 | 0.13 | 0.07 | .. |
| 400 | .. | 0.02 | 0.11 | 0.05 | .. |
| 420 | .. | 0.02 | 0.09 | 0.03 | .. |
| 440 | .. | 0.01 | 0.07 | 0.01 | .. |
| 460 | .. | .. | .. | 0.01 | .. |

## APPENDIX - 2.

### Theoretical approach to non-steady state condition

The differential equation for non-steady state flow, as derived on the basis of the Dupuit - Forchheimer assumption is

$$KD \frac{\partial^2 h}{\partial x^2} = \mu \frac{\partial h}{\partial t} - R \quad \text{or} \qquad (a)$$

when the recharge rate R equals zero

$$KD \frac{\partial^2 h}{\partial x^2} = \mu \frac{\partial h}{\partial t} \quad \text{where} \qquad (b)$$

KD = transmissivity of the aquifer ($m^2$/day)

R = recharge rate per unit surface area (m/day)

h = hydraulic head as a function of x and t (m)

x = horizontal distance from the centre of drain

t = time (days)

$\mu$ = drainable pore space (dimension less)

The solution to equation (b) is found by Glover which is given below:

$$h(x,t) = \frac{4}{\pi} h_0 \sum_{n=1,3,5} \frac{1}{n} e^{-n^2 \alpha t} \sin \frac{n \pi x}{L} \quad \ldots (c)$$

Where $\alpha = \frac{\pi^2 KD}{\mu L^2}$ (reaction factor, $days^{-1}$) where

L = the drain spacing

For the water table height midway between the drains at any time t, $x = \frac{L}{2}$ and hence

$$h_t = \frac{4}{\pi} h_0 \sum_{n = 1,3,5} \frac{1}{n} e^{-n^2 \alpha t} \quad -(d)$$

Apparently the value of each term of equation (d) decreases with increasing n. If $\alpha t > 0.2$ the second and next term will be comparatively small and may be neglected. Thus equation (d) reduces to

$$h_t = \frac{4}{\pi} h_0 e^{-\alpha t} \quad \longrightarrow \quad (e)$$

Since at time $t = t1$ and $t = t2$

$$ht_1 = \frac{4}{\pi} h_0 \; e^{-\alpha t_1}$$

$$ht_2 = \frac{4}{\pi} h_0 \; e^{-\alpha t_2}$$

Therefore, $\frac{ht_1}{ht_2} = \frac{e^{-\alpha t_1}}{e^{-\alpha t_2}}$ ——————— (f)

From Darcy's law, we can also prove that

$$\frac{qt_1}{qt_2} = \frac{e^{-\alpha t_1}}{e^{-\alpha t_2}} \qquad \text{——————— (g)}$$

Hence a plot of qt or ht on a log scale and time (t) on a linear scale will result in a straight line and the slope of the line will give the factor $\alpha$ Where

$$\alpha = \frac{\pi^2 K d}{\mu L^2} \qquad \text{——————— (h)}$$

To calculate the hydraulic conductivity K, plot qt vs ht. The relationship yields a straight line when most of the water passes to the drains through the soil below the drain level.

Therefore, $Kd = \frac{q}{h} \frac{L^2}{2\pi}$ ——————— (i)

Once the Kd value is known, the $\mu$, the effective porosity can be found out from equation (h).

The equivalent depth $d$ can be found out from the expression $d = \frac{D}{\frac{8D}{\pi L} \ln\left(\frac{D}{U}\right) + 1}$ ——(j) where

$U = \pi r$, $r$ being the radius of the drain.

If $D > L/2$ Then $D$ is taken as $L/2$.

The hydraulic conductivity K is then found out by dividing the Kd value by d.

From the graph of q versus h, the straight portion is because when most of the water flows to the drains through the soil below the drain level.

Therefore $Kd = \frac{q}{h} \frac{L^2}{2\pi}$ where $\frac{q}{h}$ = 0.002125 (from graph)

$$= \frac{0.002125 \times 30^2}{2 \times \pi} = 0.3044 \ m^2/day$$

From the graph ln h versus t and ln q versus t, the $\alpha$ values (slope of the line) are obtained as 0.00519 $hour^{-1}$ and 0.00625 which are numerically equal to 0.12456 $days^{-1}$ and 0.15 $days^{-1}$.

But $\alpha = \frac{\pi^2 Kd}{\mu L^2}$

Therefore $\mu = \frac{\pi^2 Kd}{\alpha L^2}$ = 0.0268 and 0.0223 respectively. The average effective porosity is thus calculated as 0.025.

The equivalent depth d is calculated from the expression (j) which yields.

d = 2.10 m.

Therefore K = 0.3044/2.1 = 0.145 m/day.

Similarly, the values of 8E30 are as given below

q/h = 0.003375

Kd = 0.4834$m^2$/day

$\mu$ = 0.037

d = 2.10m.

k = 0.230 m/day.

Thus the following average values of different hydraulic parameters are arrived at for the experimental area.

1. Drainage intensity factor = 0.14 $days^{-1}$
2. Kd value = 0.40$m^2$/day
3. $\psi$ (effective porosity) = 2.96%
4. d (equivalent depth) = 2.1m
5 K (hydraulic conductivity) = 0.19m/day.

## APPENDIX - 3.

**Mean table of Plant Growth and Yield Attributing Characters (15m).**

| Treat. No. | Treatment | No.of plants/ $m^2$. | Ht. at maturity cm. | No.of panicles/$m^2$ | Grain yield MT/ha | Straw yield MT/ha | Panicle length (cm) | No.of Grains/ panicle | 100 grain weight (gms) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 2.5m from drain line to either side. | 126.67 | 90.00 | 321.67 | 3.94 | 5.12 | 22.58 | 98.47 | 2.76 |
| 2. | 2.5m to 5m on either side. | 136.67 | 90.23 | 228.33 | 3.99 | 4.47 | 21.40 | 84.76 | 2.81 |
| 3. | 5m to 7.5m on either side. | 125.00 | 89.35 | 315.00 | 3.77 | 4.48 | 22.78 | 98.00 | 2.89 |
| 4. | Control (No drainage) | 108.33 | 86.58 | 350.00 | 3.60 | 4.56 | 20.55 | 82.72 | 2.60 |
| | C.D. (0.05) | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | 13.32 | 0.13 |

Item : No.of plants/m$^2$ - 15m spacing.

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 100 | 90 | 120 | 140 | 150 | 160 | 126.67 |
| $T_2$ | 120 | 120 | 160 | 100 | 160 | 160 | 136.67 |
| $T_3$ | 150 | 90 | 100 | 90 | 160 | 160 | 125.00 |
| $T_4$ (Control) | 60 | 110 | 90 | 130 | 110 | 150 | 108.33 |
| Total : | 430 | 410 | 470 | 460 | 580 | 630 | |

Gross : 2980.00

Variance Table

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 9683.33 | 1936.67 | 3.29 | 2.90 | Significant. |
| Treat | 3 | 2483.33 | 827.78 | 1.41 | 3.29 | Non-significant |
| Error | 15 | 8816.67 | 587.78 | | | |
| Total | 23 | 20983.33 | | | | |

Item : Height at maturity (in cm) - 15m spacing.

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 92.0 | 95.4 | 90.8 | 85.0 | 90.3 | 86.5 | 90.00 |
| $T_2$ | 93.2 | 95.4 | 94.2 | 84.7 | 81.6 | 87.3 | 90.23 |
| $T_3$ | 95.8 | 98.2 | 94.1 | 77.2 | 83.4 | 87.4 | 89.35 |
| $T_4$ (Control) | 89.4 | 88.6 | 94.2 | 91.0 | 69.7 | 86.6 | 86.58 |
| Total : | 375.40 | 377.60 | 373.30 | 337.90 | 325.00 | 347.80 | |

Gross : 2137.00

Variance Table

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 624.[illegible]7 | 124.39 | 5.06 | 2.90 | Significant. |
| Treat | 3 | 50.86 | 16.95 | 0.69 | 3.29 | Non-significant. |
| Error | 15 | 370.30 | 24.58 | | | |
| Total | 23 | 1045.54 | | | | |

Item : No.of panicles/$m^2$ - 15m spacing.

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 240 | 260 | 310 | 370 | 340 | 410 | 321.67 |
| $T_2$ | 330 | 290 | 390 | 340 | 320 | 400 | 328.33 |
| $T_3$ | 200 | 300 | 360 | 270 | 350 | 410 | 315.00 |
| $T_4$ (Control) | 360 | 390 | 310 | 390 | 300 | 350 | 350.00 |
| Total | 1130 | 1240 | 1370 | 1270 | 1310 | 1570 | |

Gross : 7890.00

Variance table

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 27487.50 | 5497.50 | 1.75 | 2.90 | Non-significant |
| Treat | 3 | 4145.83 | 1381.9 | 0.44 | 3.29 | Non-significant |
| Error | 15 | 47029.17 | 3135.28 | | | |
| Total | 23 | 78662.50 | | | | |

Item : Length of the Panicle (in cm.) - 15m spacing

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 22.97 | 24.85 | 22.88 | 21.50 | 20.10 | 23.18 | 22.58 |
| $T_2$ | 23.12 | 21.65 | 19.66 | 20.03 | 21.35 | 22.56 | 21.40 |
| $T_3$ | 23.20 | 22.89 | 21.72 | 22.70 | 22.40 | 23.78 | 22.78 |
| $T_4$ (Control) | 17.23 | 22.00 | 19.83 | 22.30 | 20.70 | 21.25 | 20.55 |
| Total : | 86.52 | 91.39 | 84.09 | 86.53 | 84.55 | 90.77 | |

Gross = 523.85

Variance table

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 11.96 | 2.39 | 1.19 | 2.90 | Non-significant |
| Treat | 3 | 19.75 | 6.58 | 3.28 | 3.29 | Non-significant |
| Error | 15 | 30.07 | 2.00 | | | |
| Total | 23 | 61.78 | | | | |

Item : No.of grains/panicle - 15m spacing.

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 103.60 | 126.40 | 101.11 | 88.10 | 76.90 | 94.7 | 98.47 |
| $T_2$ | 97.33 | 85.10 | 83.22 | 69.10 | 79.60 | 94.2 | 84.76 |
| $T_3$ | 100.60 | 98.80 | 95.30 | 94.70 | 92.10 | 106.5 | 98.00 |
| $T_4$ (Control) | 67.70 | 90.00 | 75.88 | 91.22 | 87.50 | 84.0 | 82.72 |
| Total : | 369.23 | 400.30 | 355.51 | 343.12 | 336.10 | 379.40 | |

Gross : 2183.66

Variance table

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 717.16 | 143.43 | 1.22 | 2.90 | Non-significant |
| Treat | 3 | 1274.08 | 424.69 | 3.62 | 3.29 | significant |
| Error | 15 | 1759.45 | 117.30 | | | |
| Total | 23 | 3750.70 | | | | |

CD = 13.32 grains/panicle

## Grain yield MT/ha - 15m spacing.

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 4.624 | 3.815 | 3.115 | 3.399 | 4.367 | 4.340 | 3.94 |
| $T_2$ | 4.865 | 3.749 | 3.486 | 3.618 | 3.815 | 4.427 | 3.99 |
| $T_3$ | 4.231 | 3.399 | 3.224 | 3.421 | 4.077 | 4.252 | 3.77 |
| $T_4$ (Control) | 4.712 | 3.093 | 3.421 | 3.137 | 3.399 | 3.837 | 3.60 |
| Total | 18.43 | 14.06 | 13.25 | 13.58 | 15.66 | 16.86 | |

Gross = 91.82

### Variance Table

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 5.23 | 1.06 | 17.69 | 2.90 | Significant |
| Treat | 3 | 0.58 | 0.19 | 3.23 | 3.29 | Non-significant |
| Error | 15 | 0.89 | 0.06 | | | |
| Total | 23 | 6.75 | | | | |

Straw yield MT/ha - 15m spacing.

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 3.5 | 3.6 | 3.9 | 4.8 | 6.3 | 8.6 | 5.12 |
| $T_2$ | 5.7 | 3.5 | 3.6 | 2.9 | 5.9 | 5.2 | 4.47 |
| $T_3$ | 4.0 | 3.6 | 5.2 | 3.2 | 4.7 | 6.2 | 4.48 |
| $T_4$ (Control) | 4.45 | 3.5 | 3.15 | 4.5 | 6.15 | 5.6 | 4.56 |
| Total | 17.65 | 14.20 | 15.85 | 15.40 | 23.05 | 25.60 | |

Gross = 111.75

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 26.72 | 5.34 | 5.54 | 2.90 | Significant. |
| Treat | 3 | 1.72 | 0.57 | 0.60 | 3.29 | Non-significant |
| Errors | 15 | 14.47 | 0.96 | | | |
| Total | 23 | 42.91 | | | | |

## 100 grain weight (gms) - 15m spacing

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| 1. | 2.672 | 2.761 | 2.792 | 2.595 | 2.843 | 2.919 | 2.760 |
| 2. | 2.765 | 2.788 | 2.825 | 2.749 | 2.905 | 2.830 | 2.810 |
| 3. | 2.835 | 2.989 | 3.035 | 2.658 | 2.925 | 2.914 | 2.890 |
| 4.Control | 2.646 | 2.498 | 2.566 | 2.733 | 2.471 | 2.677 | 2.600 |
| Total | 2.730 | 2.759 | 2.805 | 2.684 | 2.786 | 2.835 | |

Gross = 66.39

### Variance table

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 0.06 | 0.01 | 1.06 | 2.90 | Non-significant |
| Treat | 3 | 0.28 | 0.09 | 8.22 | 3.29 | Significant. |
| Error | 15 | 0.17 | 0.01 | | | |
| Total | 23 | 0.50 | | | | |

CD = 0.13 gms/100 grain.

Mean table of plant growth and yield attributing characters (30m).

| Treat. No. | Treatment | No.of plants/$m^2$ | Ht.at maturity cm. | No.of panicle/$m^2$ | Grain yield MT/ha | Straw yield MT/ha | Panicle length (cm) | No.of grains/ panicle | 100grain weight (gms) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 2.5m from drain line to either side. | 138.33 | 93.18 | 391.67 | 4.44 | 6.83 | 21.74 | 88.08 | 2.78 |
| 2. | 2.5m to 5m on either side. | 160.00 | 86.70 | 370.00 | 4.35 | 5.90 | 22.72 | 104.33 | 2.86 |
| 3. | 5 to 7.5m on either side. | 133.33 | 89.48 | 373.33 | 4.52 | 6.53 | 22.59 | 95.74 | 2.80 |
| 4. | 7.5 to 10m on either side | 133.33 | 92.32 | 325.00 | 4.52 | 5.62 | 21.77 | 83.16 | 2.86 |
| 5. | 10 to 12.5m on either side. | 148.33 | 86.42 | 343.33 | 4.36 | 5.54 | 22.12 | 89.80 | 2.86 |
| 6. | 12.5 to 15m on either side. | 125.00 | 89.87 | 363.33 | 4.34 | 6.15 | 22.99 | 100.45 | 2.79 |
| 7. | Control (No drainage). | 108.33 | 86.58 | 350.00 | 3.60 | 4.56 | 20.55 | 82.72 | 2.60 |
| | C.D. | N.S. | N.S. | N.S | 0.38 | N.S. | 1.41 | N.S. | 0.16 |

Item : No.of Plants/m$^2$ - 30m spacing

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 150 | 100 | 140 | 160 | 140 | 140 | 138.33 |
| $T_2$ | 160 | 170 | 180 | 160 | 150 | 140 | 160.00 |
| $T_3$ | 160 | 150 | 110 | 160 | 90 | 130 | 133.33 |
| $T_4$ | 120 | 180 | 110 | 150 | 120 | 120 | 133.33 |
| $T_5$ | 170 | 160 | 220 | 120 | 130 | 90 | 148.33 |
| $T_6$ | 200 | 150 | 100 | 120 | 80 | 100 | 125.00 |
| $T_7$ (Control) | 60 | 110 | 90 | 130 | 110 | 150 | 108.33 |
| Total | 1020 | 1020 | 950 | 1000 | 820 | 870 | |

G.T. : 5680

Variance table

| | df | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 5076.19 | 1015.24 | 1.00 | 2.534 | Non-significant |
| Treat | 6 | 9780.95 | 1630.16 | 1.61 | 2.421 | Non-significant |
| Error | 30 | 30390.48 | 1013.02 | .. | .. | |
| Total | 41 | 45247.62 | | | | |

Item : Height at Maturity (in cm.) – 30 M sapcing

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 90.3 | 99.2 | 90.0 | 86.5 | 92.3 | 100.8 | 93.18 |
| $T_2$ | 81.6 | 89.6 | 91.4 | 87.3 | 91.4 | 78.9 | 86.70 |
| $T_3$ | 93.4 | 89.8 | 88.6 | 87.4 | 90.4 | 97.3 | 89.48 |
| $T_4$ | 86.0 | 92.5 | 93.6 | 92.2 | 95.2 | 94.4 | 92.32 |
| $T_5$ | 88.8 | 80.1 | 85.0 | 87.8 | 85.0 | 91.8 | 86.42 |
| $T_6$ | 87.9 | 87.0 | 93.9 | 87.7 | 90.6 | 92.1 | 89.87 |
| $T_7$ (Control) | 89.4 | 88.6 | 94.2 | 91.0 | 69.7 | 86.6 | 86.58 |
| Total | 607.4 | 626.8 | 636.7 | 619.9 | 614.6 | 641.9 | |

Gross : 3747.3

Variance table

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 124.07 | 24.81 | 0.90 | 2.534 | Non-significant |
| Treat | 6 | 281.68 | 46.95 | 1.71 | 2. 21 | Non-significant |
| Error | 30 | 821.89 | 27.53 | | | |
| Total | 41 | 1231.63 | | | | |

Table - 2.

No.of panicles/$m^2$ - 30 m spacing

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 340 | 510 | 350 | 410 | 380 | 360 | 391.67 |
| $T_2$ | 320 | 400 | 380 | 400 | 310 | 410 | 370.00 |
| $T_3$ | 350 | 380 | 360 | 410 | 340 | 400 | 373.33 |
| $T_4$ | 320 | 320 | 360 | 320 | 290 | 340 | 325.00 |
| $T_5$ | 330 | 260 | 450 | 310 | 390 | 320 | 343.33 |
| $T_6$ | 470 | 390 | 230 | 300 | 420 | 370 | 363.33 |
| $T_7$ (Control) | 360 | 390 | 310 | 390 | 300 | 350 | 350.00 |
| Total : | 2490 | 2650 | 2440 | 2540 | 2430 | 2550 | |

Gross : 15100

Variance table

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 4790.48 | 958.10 | 0.29 | 2.534 | Non-significant |
| Treat | 6 | 17357.14 | 2892.86 | 0.88 | 2.421 | Non-significant |
| Error | 30 | 98242.86 | 3274.76 | | | |
| Total | 41 | 120390.48 | | | | |

Item : Length of the panicle (in cm.) – 30M spacing

| Tr. | RI | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 20.10 | 21.45 | 21.15 | 23.18 | 21.75 | 22.79 | 21.74 |
| $T_2$ | 21.35 | 23.66 | 23.22 | 22.56 | 22.18 | 23.35 | 22.72 |
| $T_3$ | 22.40 | 23.00 | 20.17 | 23.78 | 23.75 | 22.41 | 22.59 |
| $T_4$ | 21.40 | 21.21 | 19.27 | 23.68 | 23.63 | 21.41 | 21.77 |
| $T_5$ | 20.71 | 19.01 | 23.67 | 23.79 | 23.34 | 22.19 | 22.12 |
| $T_6$ | 21.85 | 23.65 | 22.[illegible]0 | 23.5[illegible] | 2[illegible].30 | 22.30 | [illegible] |
| $T_7$ (Control) | 17.23 | 22.00 | 19.[illegible] | 22.30 | 20.70 | 21.23 | 20.55 |
| Total | 145.04 | 153.98 | [illegible] | 162.83 | 159.65 | 155.6[illegible] | |

Gross : 926.79

Variance table

| DF | | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 30.14 | 6.03 | 4.21 | 2.534 | Significant |
| Treat | 6 | 24.33 | 4.05 | 2.83 | 2.421 | Significant |
| Error | 30 | 42.92 | 1.43 | | | |
| Total | 41 | 97.39 | | | | |

CD = 1.41

Item : No.of Grains/Panicle - [illegible] spacing

| Tr. | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 76.90 | 89.50 | 88.20 | 94.70 | 82.80 | 96.40 | 88.08 |
| $T_2$ | 79.60 | 123.88 | 114.77 | 94.20 | 91.30 | 122.20 | 104.33 |
| $T_3$ | 91.10 | 100.44 | 71.50 | 106.50 | 112.60 | 91.30 | 95.74 |
| $T_4$ | 75.90 | [illegible] | [illegible] | 102.50 | 113.80 | 77.10 | 83.16 |
| $T_5$ | 73.90 | [illegible] | 107.50 | 99.20 | 100.50 | 97.10 | 89.80 |
| $T_6$ | 85.60 | 101.10 | [illegible] | 110.20 | 117.80 | 96.10 | 100.45 |
| $T_7$ (Control) | 67.70 | 90.00 | [illegible] | 91.22 | 87.50 | 84.00 | 82.72 |
| Total : | 551.70 | 632.39 | [illegible] | 698.52 | 706.30 | 664.20 | |

Gross : [illegible]

Variance table

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 2415.20 | 483.04 | 2.64 | 2.534 | Significant. |
| Treat | 6 | 2531.10 | 421.85 | 2.31 | 2.421 | Non-significant |
| Error | 30 | 5479.37 | 182.65 | | | |
| Total | 41 | 10425.67 | | | | |

Grain yield MT/ha - 30m spacing

| Treatment | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 4.428 | 4.493 | 4.296 | 4.275 | 4.559 | 4.559 | 4.44 |
| $T_2$ | 3.968 | 4.297 | 4.625 | 4.275 | 4.406 | 4.537 | 4.35 |
| $T_3$ | 4.012 | 4.581 | 4.734 | 4.319 | 4.647 | 4.844 | 4.52 |
| $T_4$ | 4.078 | 4.122 | 4.734 | 4.725 | 4.997 | 4.909 | 4.52 |
| $T_5$ | 4.099 | 4.034 | 4.493 | 3.958 | 4.624 | 4.953 | 4.36 |
| $T_6$ | 4.471 | 3.749 | 4.712 | 4.165 | 4.362 | 4.603 | 4.34 |
| T7 (Control) | 4.712 | 3.093 | 3.422 | 3.137 | 3.399 | 3.837 | 3.60 |
| Total : | 29.77 | 28.37 | 31.02 | 28.41 | 30.99 | 32.24 | |

Gross : 180.80

Variance table

| DF | | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 1.74 | 0.35 | 3.34 | 2.534 | Significant |
| Treat | 6 | 3.68 | 0.61 | 5.90 | 2.421 | Significant |
| Error | 30 | 3.12 | 0.10 | | | |
| Total | 41 | 8.55 | | | | |

C.D. : 0.38

Straw yield - 30m spacing (MT/ha.

| Treatment | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 6.30 | 7.20 | 7.00 | 8.60 | 4.20 | 7.70 | 6.83 |
| $T_2$ | 5.90 | 5.70 | 4.60 | 5.20 | 6.70 | 7.30 | 5.90 |
| $T_3$ | 4.70 | 7.15 | 5.40 | 6.20 | 6.30 | 8.40 | 6.53 |
| $T_4$ | 4.60 | 5.00 | 5.90 | 4.90 | 7.00 | 6.30 | 5.62 |
| $T_5$ | 3.90 | 4.00 | 8.30 | 3.45 | 6.80 | 6.80 | 5.54 |
| $T_6$ | 5.70 | 5.40 | 3.50 | 4.70 | 10.00 | 7.60 | 6.15 |
| $T_7$ (Control) | 4.45 | 3.50 | 3.15 | 4.50 | 6.15 | 5.60 | 4.56 |
| Total : | 35.55 | 37.95 | 38.85 | 37.55 | 47.15 | 49.70 | |

Variance table

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 24.14 | 4.83 | 2.50 | 2.534 | Non-significant |
| Treat | 6 | 19.97 | 3.33 | 1.74 | 2.421 | Non-significant |
| Error | 30 | 57.51 | 1.92 | | | |
| Total | 41 | 101.62 | | | | |

100 gram weight - 30m spacing

| Treatment | I | II | III | IV | V | VI | Mean |
|---|---|---|---|---|---|---|---|
| $T_1$ | 2.843 | 2.534 | 2.678 | 2.919 | 2.763 | 2.914 | 2.78 |
| $T_2$ | 2.642 | 2.876 | 2.974 | 2.830 | 3.037 | 2.789 | 2.86 |
| $T_3$ | 2.925 | 2.846 | 2.746 | 2.865 | 2.674 | 2.772 | 2.80 |
| $T_4$ | 2.892 | 2.844 | 2.803 | 2.995 | 2.963 | 2.648 | 2.86 |
| $T_5$ | 2.952 | 3.080 | 2.617 | 2.799 | 2.831 | 2.895 | 2.86 |
| $T_6$ | 2.789 | 2.733 | 2.989 | 2.834 | 2.717 | 2.694 | 2.79 |
| $T_7$ (Control) | 2.648 | 2.498 | 2.566 | 2.733 | 2.471 | 2.677 | 2.60 |
| Total : | 19.69 | 19.41 | 19.37 | 19.97 | 19.46 | 19.39 | |

Gross : 117.28

Variance table

| DF | | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 5 | 0.04 | 0.01 | 0.45 | 2.534 | Non-significant |
| Treat | 6 | 0.31 | 0.05 | 2.95 | 2.421 | significant |
| Error | 30 | 0.52 | 0.02 | | | |
| Total | 41 | 0.87 | | | | |

CD = 0.16

# APPENDIX - 4.

## SOIL ANALYSIS DATA.

Item : Chlorides (m.e/lit)

.....

| Tr. | I | II | III | IV | Total | Mean |
|---|---|---|---|---|---|---|
| $T_1$ | 2.59 | 2.22 | 2.59 | 1.11 | 8.51 | 2.13 |
| $T_2$ | 2.96 | 2.59 | 2.22 | 2.22 | 9.99 | 2.50 |
| $T_3$ | 2.59 | 2.22 | 2.22 | 2.22 | 9.25 | 2.31 |
| $T_4$ | 4.07 | 3.33 | 4.44 | 3.33 | 15.17 | 3.79 |
| $T_5$ (Control) | 4.81 | 2.96 | 5.18 | 3.70 | 16.65 | 4.16 |
| Total | 17.02 | 13.32 | 16.65 | 12.58 | | |

Gross = 59.57

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 3 | 3.09 | 1.03 | 4.25 | 3.49 | Significant |
| Treat | 4 | 13.85 | 3.46 | 14.32 | 3.26 | Significant |
| Error | 12 | 2.90 | 0.24 | | | |
| Total | 19 | 19.84 | | | | |

CD = 0.76

$T_1$ = On the line of 15m spacing.

$T_2$ = Mid-spacing of 15m.

$T_3$ = On the line of 30m spacing.

$T_4$ = Mid-spacing of 30m.

$T_5$ = Control.

Sulphate (SO4) (ppm)

| Tr. | I | II | III | IV | Total | Mean |
|---|---|---|---|---|---|---|
| 1. | 770 | 770 | 792 | 846 | 3178 | 794.50 |
| 2. | 625 | 659 | 667 | 621 | 2572 | 643.00 |
| 3. | 537 | 579 | 610 | 606 | 2332 | 583.00 |
| 4. | 404 | 537 | 777 | 537 | 2255 | 563.75 |
| 5 | 613 | 632 | 716 | 700 | 2661 | 665.25 |
| Total | 2949 | 3177 | 3562 | 3310 | | |

Gross = 12998.

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 3 | 39374.6 | 13124.87 | 3.18 | 3.49 | Non-significant. |
| Treat | 4 | 132359.3 | 33089.83 | 8.01 | 3.26 | Significant. |
| Error | 12 | 49559.9 | 4129.99 | | | |
| Total | 19 | 221293.8 | | | | |

CD = 99.02

## Calcium m.e/lit.

| Tr. | I | II | III | IV | Total | Mean |
|---|---|---|---|---|---|---|
| 1. | 2.28 | 2.56 | 4.12 | 3.24 | 12.2 | 3.05 |
| 2. | 1.12 | 1.48 | 1.32 | 1.20 | 5.12 | 1.28 |
| 3. | 1.08 | 0.88 | 1.16 | 1.16 | 4.28 | 1.07 |
| 4. | 0.64 | 1.04 | 4.32 | 0.68 | 6.68 | 1.67 |
| 5. | 0.92 | 1.40 | 1.96 | 2.72 | 7.00 | 1.75 |
| Total | 6.04 | 7.36 | 12.88 | 9.00 | | |

Gross = 35.28

| DF | | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 3 | 5.28 | 1.76 | 2.6 | 3.49 | Non-significant. |
| Treat | 4 | 9.51 | 2.38 | 3.51 | 3.26 | Significant. |
| Error | 12 | 8.12 | 0.68 | | | |
| Total | 19 | 22.91 | | | | |

C.D. = 1.27

Magnesium m.e/lit.

| Tr. | I | II | III | IV | Total | Mean |
|---|---|---|---|---|---|---|
| 1. | 6.08 | 10.60 | 9.04 | 14.28 | 40.00 | 10.00 |
| 2. | 3.12 | 1.04 | 4.00 | 2.96 | 11.12 | 2.78 |
| 3. | 2.32 | 2.72 | 2.64 | 2.88 | 10.56 | 2.64 |
| 4. | 1.24 | 2.16 | 10.48 | 1.68 | 15.56 | 3.89 |
| 5. | 2.24 | 3.72 | 6.00 | 7.44 | 19.40 | 4.85 |
| Total | 15.00 | 20.24 | 32.16 | 29.24 | | |

Gross = 96.64

| | DF | SS | MS | F ratio | F table | Remarks |
|---|---|---|---|---|---|---|
| Block | 3 | 37.82 | 12.61 | 1.98 | 3.49 | Non-significant. |
| Treat | 4 | 146.45 | 36.61 | 5.75 | 3.26 | Significant. |
| Error | 12 | 76.43 | 6.37 | | | |
| Total | 19 | 260.69 | | | | |

CD = 3.89