THESIS

A STUDY ON THE WATER UTILIZATION IN SOME AREAS UNDER TUBEWELL IRRIGATION

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED BY MD. MIRJAHAN MIAH ENTITLED "A STUDY ON THE WATER UTILIZATION IN SOME AREAS UNDER TUBEWELL IRRIGATION" BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENGINEERING (WATER RESOURCES)

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ABSTRACT

The average performance of the tubewell irrigation units is extremely poor in Bangladesh. It is suggested that a 2-cusec unit should irrigate at least 80 acres of HYV Boro rice but the actual coverage of most of the deep tubewell units is below 40 acres.

Over the last few years, several researchers undertook studies to identify the problems associated with the poor performance. In most of the studies the researchers concentrated on social and institutional aspects and paid little attention to engineering factors. Causes like low operating hours, defective distribution system, lack of extension services, disinterest of the farmers and corrupt officials have been given as the most important problems contributing to the poor performance.

The present study has been planned with a view to quantify the water loss in distribution system and to assess the share of water loss and other factors mostly engineering, to the poor acreage. Water losses were measured in 29-watercourses of 19 deep tubewell units - eight in Savar, four in Joydebpur and three in Rupganj thana of Dacca district and the rest two in Islampur thana of Jamalpur district. The losses were measured by inflow-outflow method except in Islampur where losses

were measured by ponding method. The devices used for inflow-outflow measurement were two 6-inch parshall flumes and a current meter. It was found that the losses in the main distribution canal ranged from about 30% to 87% with an average of about 58%. This means that, on average, over half of the water delivered from the source at the head is lost in the canal before entering into the fields. The causes of such a huge amount of water loss are high seepage rate, inefficient canal section, poor level of maintenance of distribution canals, absence of control structures, lack of proper irrigation schedule, etc.

The study also included collection of other technical as well as socio-economic informations through field measurements, observations, investigations and interviews with local farmers. From the analysis of the data and informations collected it is found that in addition to high water losses the most important causes for poor performance are under utilization of the deep tubewell units, lack of proper distribution schedule, inclusion of some lands having light soils in the scheme, lack of incentive of the group manager, lack of demonstration and extension services, etc.

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M.M.M.

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ABBREVIATIONS

BADC	Bangladesh Agricultural Development Corporation
BBS	Bangladesh Bureau of Statistics
cfs	cubic feet per second
cu.ft.	cubic feet
cusec	cubic feet per second
D-N-D	Dacca-Narayanganj-Demra
DTW	Deep Tubewell
FAO	Food and Agriculture Organization
fps	feet per second
G-K	Ganges-Kabadak
HYV	High Yielding Variety
JCCIP	Joint Caritas - CRS Irrigation Project.
KTCCA	Kotwali Thana Central Co-operative Association
KWH	Kilowatt Hour
LLP	Low Lift Pump
MAF	Million Acre Feet
mds	Maunds
STW	Shallow Tubewell
Tk.	Taka
w.r.t.	with respect to

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CHAPTER - 1

INTRODUCTION

Bangladesh, one of the most densely populated countries of the world, suffers from defficiency in food grains every year. She has a total area of 35.3 million acres of which only 22.5 acres (64%) is cultivable. Moreover, 50% of the cultivable area is not available for intensive cultivation all the year round. This area includes about 2 million acres of low-lying land which are flooded to a depth of 12-15 feet from June to October and can, therefore, only be cultivated when the flood subsides in November. Another 6 million acres of cultivated land are annually flooded to a depth of 3 to 12 feet and are used for low yielding broadcast aman. The remaining 3 million acres in the coastal areas are inundated with saline water and can hardly sustain one crop during the rainy season from June to October. To attain self-sufficiency in food grains in a limited arable land in the country, cereal production must be increased by growing HYV rice, multiple cropping, application of necessary inputs and practicing irrigation efficiently. A general model of rice crops under various stages of input availability is shown below:

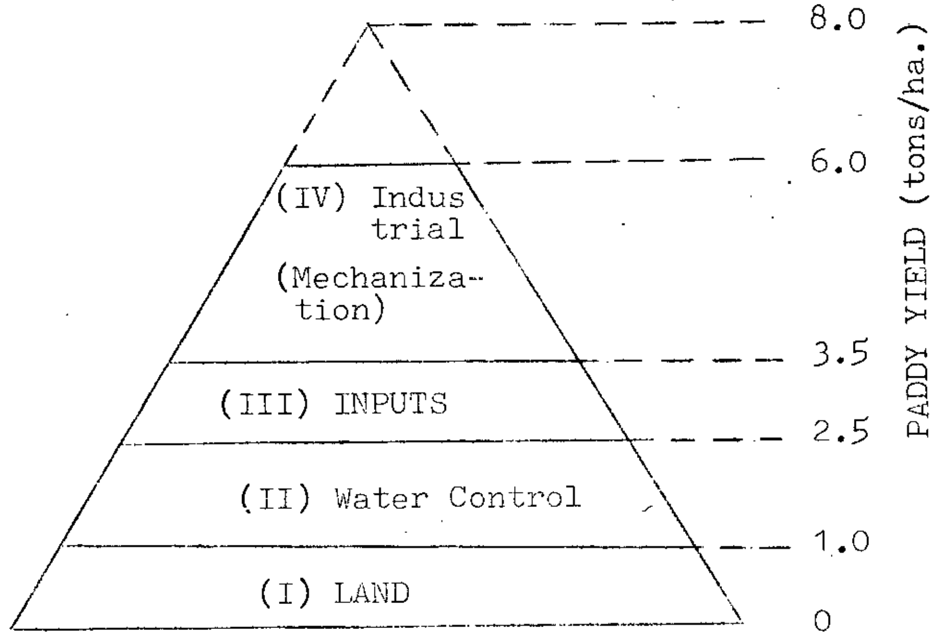

Fig. 1.1 A general model for development stage and paddy yield.

(Source: Asian Development Bank, 1969)

A recent model, prepared hy FAO experts aimed at self-sufficiency in food grain production by 1985 envisaged the development of irrigation facilities, use of high-yielding (HYV) varieties and production targets as under:

Table 1.1 Estimated expansion of irrigated acreage and HYV rice production between 1975-90

Item	1975	1985	1990
Irrigated acreage of rice (% of total land)	10.5	30.6	37.6
HYV rice seeds used (% of total land)	3.6	47.5	63.6
Rice yield per acres (1,000 metric tons)	0.71	1.05	1.28

Source: FAO, November 1974, Rome.

Although irrigation had been introduced in our country since early fifties (Ministry of Agriculture started power pump irrigation in 1951-52) it presently covers only 13% of the cultivated area. Figure 1, Appendix-B shows the area irrigated under different means for the last few years. The figure delineates that surface irrigation i.e., Low-lift pump and Traditional irrigation played an important role in the total irrigated acreage. But further growth of irrigated acreage is greatly constrained by the scarcity of surface water in the lean period.

Bangladesh gets, annually, a net total of 938 million acre feet (MAF) of water (rainfall 203 MAF plus surface inflow 870 MAF less evaporation and deep percolation losses 135 MAF) but the distribution is very skewed. Only 2.5 to 4.5 inches of rainfall occurs during the November-March winter period. The river-flows are significantly low during this winter season ,limiting the potential for surface water use and calls for the utilization of ground water through sophisticated water lifting devices, i.e., deep and shallow tubewell pumping. The nation has an irrigation requirement as shown in table 1.2 where 2.0, million acres will be brought under irrigation by deep or shallow tubewell programmes but the traditional method of irrigation will be kept at 1 million acres.

Table 1.2. Projected National Programme for Irrigation Requirement for the years 1975 through 1996

Type	1975-'76 acres million	1980-'81 acres million	1985-'86 acres million	1995-'96 acres million
Lowlift pump	1.43	1.60	1.80	2.20
Groundwater (Deep, Shallow tubewells and hand pumps)	0.20	0.50	1.45	2.00
Major works	0.07	0.23	0.59	1.00
Traditional method	1.00	1.00	1.00	1.00
Total	2.71	3.33	4.84	7.00

Source: Adapted from Biswas et al., 1978, P5

It is thus a matter of great concern to all planners as well as irrigators to utilize the available water resources carefully and in a planned way which is now utilized carelessly and recklessly. It is needed to apply water to the crops judiciously and efficiently by the right quantity at right time.

Minor irrigation, i.e., Low-lift Pump (LLP), Deep Tubewell (DTW) and Shallow Tubewell (STW) constitutes a large component of present convering but the performances of those irrigation projects have, so far, been very unstaisfactory. Theoretically a 2-cusec deep tubewell should irrigate more than 100 acres of HYV Boro rice but the actual coverage is very low.

Records (KTCCA., 1975) indicate that the deep tubewells installed by Comilla KTCCA irrigated 40 acres per cusec in 1965-66 which came down to 25 acres in 1968-69. Thakurgaon tubewell project consists of 377, 3 to 4 cusec electrically operated tubewells. Reportedly, the project irrigated only 50-60 acres per tubewell in 1970-71 against an average design coverage of 215 acres per tubewells (about 70-75 acres per cusec). The average command area further declined to only 18 acres per tubewell (6 acres per cusec) in 1973-74 (Bangladesh Planning Commission, 1974). The position with regard to BADC tubewells is also not satisfactory. The year wise distribution of the acreage per deep tubewell installed by BADC is shown in figure 2, Appendix - B. The figure indicates that the coverage per deep tubewell varied from 30 to 43 during the period 1967-68 to 1976-77 which had been increased to 45 in 1977-78. But still the acreage per deep tubewell is much less than that a 2-cusec could potentially cover. This poor performance is because of mismanagement and misuse of irrigation water. In order to achieve the goal, i.e., to increase the command area of the existing irrigation schemes, it is essential to identify the problems associated with poor performance and take necessary measures.

Many research works had been conducted to identify the factors responsible for the poor performance of small irrigation units. The following paragraphs give a review of some of the studies undertaken in this field.

In 1976 a study was conducted (Deb, Dewan & Sarker, 1976) to identify the problems associated with the poor performance of deep tubewell irrigation units. In that study the efficiencies of seven deep tubewell units having comparable agro-climatological conditions had been compared and thus the main factors influencing the irrigation efficiency were identified. The researchers observed that, besides some unique problems, the common elements causing the poor acreage are overlooking of ultimate goal, lack of participation of farmers, social clique, low operating hour, etc.

Another study was undertaken covering the year 1975 through 1977 (Biswas, M.R. et al., 1978) for discerning the factors affecting the command area of existing minor irrigation units (DTW, STW and LLP). In that study 64 DTWs, 34 STWs and 88 LLPs were selected from 21 thanas in consultation with BADC personnel and data (both technical and socio-economic) were collected from some randomly selected managers and farmers of each irrigation unit. In that study the researchers observed that besides the other problems, non availability of fuel, spare parts and mechanics in time, corruption of officers or managers and defective water distribution system are the most important problems contributing to the poor performance of all the categories of irrigation projects.

In 1977 a study was conducted (Yunus, M., 1977) to evaluate the operation of deep tubewells in Chittagong division. From the study it was found that about one third of the DTWs were not operating in that year and the acreage of the DTWs in operation was not satisfactory. The researcher pointed out in his report (May, 1977) that the reasons for low acreage are mechanical trouble of the machine, weakness of management committee, high irrigation cost, Kutcha drain, poor soil condition, etc.

In 1977 another research work was carried out (JCCIP, 1978) to see if the expenses of pacca canal is justifiable and also if it is practicable to construct a less expensive type of drain which will effectively reduce seepage losses from irrigation canals. The research workers measured the conveyance losses in some canals of small irrigation units at Bhaberpara (Kustia) and found that the total loss varied from 37% to 75%. They concluded that the loss could be reduced to 30% through better management and that lining is not econimical.

In 1978 the Deep Tubewell Division of BADC (1979) conducted a study on the utilization of deep tubewells in 1977-78. In that study a questionnaire was prepared and the Assistant engineers of BADC were requested to send the filled-in questionnaire to the Implementation Division. On the basis of the data collected from the filled in questionnaire the Implementation Division made a report (BADC, 1979). The report stated that about 19% of the DTWs commissioned upto June 1978 were not in operation during 1977-78 and 47% of DTWs in operation remained under utilized (coverage below 41 acres). The report also stated that disinterest of the group, shortage of inputs and lack of extension services are the main reasons for low coverage.

From the above review it is obvious that many works had been undertaken to identify the problems contributing to the low coverage of the minor irrigation schemes. But almost no work was conducted on water loss in the distribution system. Studies (Biswas, M.R. et al., 1977) revealed that farmers claim pacca drains to increase the command area.

But it was demonstrated (Deb,Dewan and Sarker, 1976) that a high coverage can be achieved with the existing facilities through improvement and maintenance of distribution system and better management.

With this context the present study has been planed with the following objectives:

a) To quantify the water loss in the distribution system of deep tubewell irrigation units.

b) To identify the factors, mostly engineering, responsible for the low water utilization efficiency and to recommend the measures to be taken for judicious and optimum utilization of water resources.

CHAPTER - 2

WATER LOSSES IN THE DISTRIBUTION SYSTEM

2.1 Classification

The water losses from the unlined irrigation canals can be broadly categorized as unavoidable and avoidable losses.

2.1.1 Unavoidable Losses

The unavoidable losses are those losses which can be reduced but can not be totally eliminated. These include seepage and percolation (combinedly seepage) and evaporation losses.

2.1.1.1 Seepage Loss

Seepage loss is that which occurs as a result of direct infiltration of water from the canals into the sub-soils. Seepage loss from the canal depends upon the type of the soil in which the canal prism is located. Loss would be higher in canals excavated in light (sandy) soils than that in canals excavated in heavy (clayee) soils. Seepage loss is influenced by the method of construction of canal, e.g., compaction of sides and bed of the channel greatly reduces the loss and on the other hand loss would be higher if the embankments are made narrow with soils containing dead roots. Seepage loss is also influenced by hydraulic gradient which in turn is effected by the depth of water in the canal and position of ground water table.

Seepage not only causes loss of water but also contributes to a rise of ground water level and leads to water logging and salinity problems. Rising of water table caused by seepage from irrigation canal is demonstrated in Fig. 3b, Appendix - B.

Seepage losses may be effectively controlled through lining of the canal. Lining not only conserves water but also protects lands from water logging and reduces costs of maintenance. But lining should be economically feasible. The quantitative determination of seepage in an existing canal and the locations of probable seepage areas in a proposed canal are thus of major importance to the planner and designer in selecting the reaches of canal to be lined. Future seepage losses of unlined canal may be estimated on the basis of measurements of infiltration rates (Robinson, 1957; Bouwer, 1962) preferably in similar canals, other conditions being comparable. In addition to the direct measurement seepage can be estimated by the following equation proposed by A.N. Kostiakov (1962)

$$S = s \frac{QL}{100} \ m^3/sec \qquad \ldots \qquad \ldots \qquad 2.1$$

where:

s = water losses per Km of canal length (in %)

L = length of the canal (in Km)

Q = water flow (in m^3/sec)

s is calculated by the formula:

$$s = \frac{A}{Q^m} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad 2.2$$

A and m are empirical constants depending on soil permeability. Values of A and m for various ranges of permeability are given in table 2.1.

Table 2.1 Values of the empirical constants A and m in equation 2.2 (After Kostiakov)

Constant	Permeability		
	low	medium	high
A	0.70	1.90	3.40
m	0.30	0.40	0.50

2.1.1.1 Evaporation Loss

Loss due to evaporation is negligible in comparison to seepage loss because evaporation rate is much less than seepage rate. Moreover, the surface area available for evaporation is less compared with that available for seepage. The potential evapotranspiration during the month of May in Dacca is 6.2 in/month(Dan Jenkins, 1979). If we assume that the free surface evaporation is about the same as potential evapotranspiration and the average water surface width in the channels is 3 ft, the average evaporation rate would be 5.76×10^{-4} cusec/1000 ft. This is about 0.2% of the average total loss rate.

Though it is believed by many that evaporation loss can be minimized by irrigating during night, it would increase the operational wastes because the farmers would face difficulty in sealing the holes and undesirable openings in the canals at night. And the overall conveyance losses may be even increased (Tom Trout et al., 1977).

2.1.2 Avoidable losses

The losses which could be eliminated through channel improvement and maintenance and better water management are avoidable losses. These losses include operational wastes, losses due to overtopping and leakage through rodent holes, cracks, poorly closed cuts, weaks and narrow banks.

2.1.2.1 Operational wastes or delivery losses

Operational wastes include water initially infiltrated into dry canal banks, dead storage (if the channel inverts are below the level of the field being irrigated) water left in the bottom of the canal after their use, and losses resulting from short term breaks or leaks in the canals both intentional and accidental. Operational wastes may be minimized through proper water management.

2.1.2.2 Losses due to overtopping or spillage loss

These losses occur when the cross-section of the canal is not sufficient to carry the discharge. Moreover, growth of vegetation and siltation reduce the carrying capacity of the canal causing overtopping of water. The spillage loss can be minimized through proper designing, constructing and regular cleaning of the canals.

2.1.2.3 Leakage through cracks rodent holes and poorly sealed openings

These losses constitute a considerable portion of the total conveyance loss. Rats, ants and insects cut holes through their burrowing activities in the banks. Sometimes the farmers intentionally make some holes to divert water illegally into their fields. A considerable water loss occurs through these holes. It was estimated (Tom Trout, et al., 1977) that the loss through a small ant hole, 1 cm in diameter, might be as high as 0.001 cusec. The farmers usually divert water by cutting openings in the banks which they do not plug properly after irrigation and a small leak through them quickly washes out a larger hole. About half of the total volume of visible leakage occurs through these plugs (Tom Trout, et.al., 1977). These operational losses may be greatly reduced or eliminated by proper attendance of irrigation water,maintenance of watercourses and introducing simple diversion structures made of concrete,wood or bamboo spiles.

2.2 Measurement

There are two methods of measuring the water loss from the irrigation canals. These are Ponding method and Inflow-outflow method.

2.2.1 Ponding method

In this method a canal section of arbitrary length is selected and a bund is built at the lower end. The section is then filled with water, another bund is built at the top end and the rate at which the water level recedes is recorded with time. This rate of fall (ft/sec) when multiplied by the length of the watercourse (ft) and the average width of the water surface (ft) during the time interval, yields the rate of water loss in cubic feet per sec. If the measured loss rate is to be a good estimate of the loss during operation, the elevation of the operational water surface must be measured and the rate of recession must be determined when the water surface is at the operational level.

The method does not require any sophisticated instrument. A measuring tape to measure the length and width of the watercourse, a measuring stick to determine its depth and other measuring sticks to be firmly fixed at the midpoint of each watercourse section to mark the operating level of the water and to monitor the recession of water surface in the section, a watch to measure the elapsed time and a shovel or spade to build the bunds at the ends of the section complete the needed requirements.

The rate of loss is commonly expressed in terms of cusec of waterloss per 1000 ft, though the test sections are generally less than 1000 ft long. In order to make comparisons among the losses in canals of different sizes, it is often desirable to express the water loss in terms of cusec of loss per thousand square feet of wetted surface. This expression of loss requires measurement of the wetted perimeter of the canals. This can be obtained by taking cross-sectional profiles of the canal at some representative locations and can generally be estimated within 10% by knowing the width and depth of the water surface at 6 or more representative locations along the canal.

The recession rate is determined by measuring the slope of the curve relating the water surface level to time, as shown in Fig. 4, Appendix - B at the operating level. Prior to taking measurements, the water should be allowed to flow through the canal for sufficient time required to bring the water content of banks and the bed to near their steady state value.

The main disadvantage of this method is that it prevents delivery of water during the time of measurement.

2.2.2 Inflow-outflow method

This method consist of measuring the rate at which water flows into a watercourse test section and the rate at which water flows out of it. The flow may be measured by the standard devices for measuring stream flow, i.e., flumes, weirs, and current meters. But the parshall flumes of throat width 6 inch are found to be most suitable for measuring flow through canals fed by deep tubewell. Fig. 5, Appendix - B shows a parshall flume. It adapts the ventrui principles to the measurement of flow in open channels. It consists of three principal sections: (i) a converging or contracting section at its upstream end (ii) a constricted section or throat and (iii) a diverging or expanding section downstream. Discharge through parshall flume can occur under either of the two different conditions of flow: (i) free flow and (ii) submerged flow. Flume should be calibrated in the laboratory so that discharge can be obtained from the gauge reading of the flume. When the percentage of submergence is greater than 60, correction should be applied to the measured discharge. An advantage of this flume is that the head loss is minimum.

The difference between inflow and outflow of the watercourse section at any instant indicates the loss at that time. In order to have a good estimate of the loss, measurements should be taken after the canals reach the steady state condition. This steady state condition is generally met after a period of time dependent on the rate of flow and width, depth and slope of the canal.

The accuracy of this method depends upon the rate at which water is lost from the canal per unit of length and the total length of the test section. It is not accurate enough for short sections.

The operational losses, in addition to the steady state loss, can be calculated from the inflow-outflow measurement. This requires to take measurements from the starting of pump up to the complete drainage of water from the canal after stopping the pump. Total inflow into the section before steady state and total outflow from the section before steady state (previous flow) and after stopping the pump (tail flow) are determined. The sum of previous flow and tail flow (Fig.6, Appemdox - B) is then subtracted from the total inflow before steady state to obtain the additional operational losses. This loss is generally expressed as a percentage of total volume pumped in an irrigation period. Assuming this loss to be lineraly proportional to length of watercourses, it can be expressed per 1000 ft (in %).

CHAPTER - 3

METHODOLOGY

3.1 Site selection

Nineteen deep tubewell units —— eight from Savar, four from Joydebpur, two from Gulsan, and three from Rupganj thana of Dacca district and the rest two from Islampur thana of Jamalpur district were selected for this study. The sites were selected in consultation with BADC so that all the three categories, i.e., best, average, and poor and both the types, i.e., electrically operated and mechanically operated deep tubewells had been included in the study. The main criteria for selection were easy accessibility and eagerness of local irrigators' group to participate. The selected deep tubewell irrigation units are listed in table 1, Appendix - A.

3.2 Water loss measurement

Water loss measurements were taken mostly in 2 or 3 canals of each unit. In measuring the loss inflow-outflow method was adopted except the two deep tubewell units of Islampur thana where water losses were measured by ponding method. In the loss measurement by ponding method, the canal was divided into four parts in each of which a comparitively straight section of arbitrary length was selected. A measuring stick was fixed at the midpoint of each section and the operational levels were noted. The bunds were built successively from the downstream . The bund at the bottom end of the fourth section was built first. Each of these sections was then filled to slightly higher than the operational level. The water levels in the section were recorded initially at intervals of 2 minutes which were then increased to 10 to 30 minuites depending upon the rate at which water surface was receeding. Curves were plotted to relate water level with elapsed time and the tangent to that curve at operating level yielded the recession rate (ft/sec.). Widths of the water surface at 5 or more representative locations of the canal were measured during operation from which the average width of the water surface (ft) was obtained. The recession rate was multiplied by the average width and 1000 to obtain cusec loss per 1000 ft. The loss was then expressed as percentage of the actual discharge of DTW. The loss was also expressed as percentage of DTW discharge per 1000 square feet of wetted area. This required to estimate the wetted perimeter of the watercourse. The wetted perimeters were estimated by taking cross-sectional profiles at 3 to 6 representative locations. Total losses of the four parts were calculated and then added to obtain the total water loss in the entire canal. Ponding tests were carried out after the water courses run for at least two hours so that the losses calculated were steady state losses.

In the inflow-outflow measurements mostly two 6-inch parshall flumes were used. The flumes were calibrated in the laboratory. One flume F_1 was placed near the head of the canal i.e., close to the deep tubewell while the other flume F_2 was installed near the tail, i.e., near the field. The flumes were installed carefully such that they were completely horizontal in both the direction of flow and at right angles to the flow. A small carpenter's level was used to assure that those conditions were met. The time at which the pump started or water reached at flume F_1 and time at which water reached at flume F_2 were recorded. Readings were taken at flume F_2 at regular intalvals of 5 min. (initially 2 min.) until the steady state condition reached at flume F_2, i.e., three consecutive readings were same. At that state reading was taken at flume F_1. The difference between the discharges at flume F_1 and flume F_2, when the flow was steady, was the loss termed as steady state loss. The loss was then expressed as percentage of inflow per 1000 feet by measuring the length of the test section. The loss was also expressed in cusec or percentage of inflow per 1000 ft^2. of wetted area by estimating the wetted perimeter of the watercourse in the same way as described earlier. In order to estimate the operational loss, monitoring of discharge at flume F_2 was continued until the flow through that flume was approximately zero. The flow through the flume F_2 before steady state and after stopping the pump were sub tracted from the total inflow in the test section before the steady condition reached. The loss thus obtained was expressed as a percentage of total inflow during one irrigation shift of 6 hours. The visible losses due to leakage and overtopping were estimated from the area and depth of submergence of the lands adjacent to the canals. But such measurement of operational losses could be done only in a few areas because it interfered with the normal operation.

In some cases a 2-inch propeller type calibrated current meter was used to measure the flow. In those cases the current meter was placed at 0.6 depth in three equally spaced verticals of the section. From the readings of the current meter the discharge through that section was calculated. Readings of the current meter were taken after running the canal for a period of time sufficient to bring the flow at steady state.

3.3 Estimation of actual discharge of DTW

Actual discharges of the DTWs were estimated by coordinate method in which both a horizontal and a vertical distance from the top of the inside of the pipe to a point P on the jet, shown in fig. 3.1, were measured. The outlet pipes were checked with a small carpenter's level whether they were perfectely horizontal.

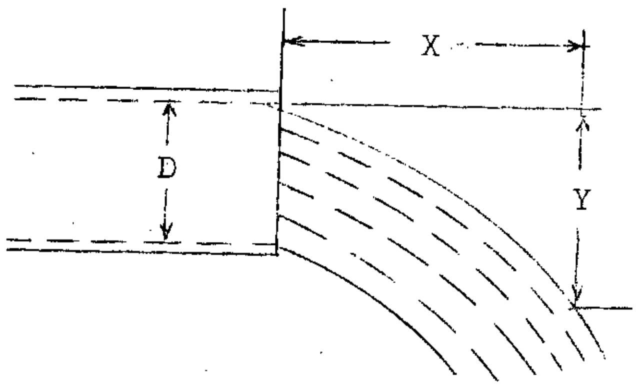

Fig. 3.1 Required measurements to obtain actual discharge from DTWs with horizontal outlet pipes

For pipe discharging horizontally, neglecting the wind friction, the horizontal and vertical distances can be expressed by the following equations:

$$X = vt \quad \ldots \quad \ldots \quad \ldots \quad (3.1)$$

$$Y = \tfrac{1}{2} gt^2 \quad \ldots \quad \ldots \quad \ldots \quad (3.2)$$

where:

X = horizontal distance of the point P from the top of the inside of the pipe

Y = vertical distance of the point P from the top of the inside of the pipe

V = actual velocity of the jet

g = acceleration due to gravity

t = time required by the point to travel a horizontal distance X or vertical distance Y.

From equations (3.1) and (3.2) the actual velocity can be expressed as

$$V = \sqrt{\frac{g}{2}} \frac{X}{\sqrt{Y}} \quad \ldots \quad \ldots \quad (3.3)$$

The cross-sectional area of the pipe is given by

$$a = \frac{\pi}{4} D^2 \quad \ldots \quad \ldots \quad (3.4)$$

From equations (3.3) and (3.4) the discharge through the pipe is expressed as

$$Q = C_d \frac{\pi}{4} D^2 \frac{\sqrt{\frac{g}{2}}\, X}{\sqrt{Y}} \quad \ldots \quad (3.5)$$

Where C_d = coefficient of discharge

Due to nonavailability of any data on C_d, it is assumed to be unity.

Substituting $C_d = 1$, $D = \frac{1}{2}$ ft (6 in) and the value of g(32.2 ft/sec^2) the discharge is expressed as

$$Q = \frac{0.78\ X}{\sqrt{Y}} \quad \ldots \quad \ldots \quad \ldots \quad (3.6)$$

If Y = 1 ft (12 in) the equation (3.6) becomes

$$Q = 0.78\,X \quad \ldots \quad \ldots \quad \ldots \quad (3.7)$$

Therefore, the measured values of X and Y ordinates were put in equation (3.7) to obtain the actual discharge of the Deep Tubewells.

3.4 Collection of other data and informations

Informations regarding topography, location of DTW with respect to the field, type of land, and general condition of the watercourses were collected through field observations and investigations. Soil samples had been collected from the channel bed which were analysed in the laboratory to obtain the grain size distribution. From the grain size distribution curves the textural class of the soil was determined. The lengths of the main and submain watercourses were measured. Cross sectional measurements were taken at some representative locations along the canals in which the flow measurements were conducted. Regarding other engineering aspects a questionnaire was prepared for interviewing scheme manager, driver and a few farmers of each irrigation scheme. The questionnaire concerned with the command area, operating hours, method of water supply, method of water diversion, presence of any control structure, distribution schedule, mode of application, irrigation frequency, water attendance, and maintenance and cleaning of watercourses. The same questionnaire also secured informations on the type of pump, power, engine, fuel consumption or power consumption, etc. It also soughted the answer for questions relating to mechanical difficulties of pump and or engine, frequency of breakdown and their reasons, and maintenance of pump and or engine.

Another questionnaire was prepared relating to Socio economic aspects for interviewing the manager of the irrigation scheme and individual farmers within each irrigation unit. The questionnaire was designed to ask questions on the formation of irrigation society, initial difficulties in site selection, etc. The questionnaire also outlined questions regarding education, occupation and remuneration of the manager. It was also designed to secure informations regarding availability of fuel, number of farmers in the society and their land holdings and water charge (basis and cost).

Other data like command area, total operating hours and total quantity of fuel consumed during the season, etc., were collected from BADC.

After collecting all the data and informations, they are compiled, arranged in tabular form and analysed. For convenience of analysis, irrigation units were categorized as best, average and poor on the basis of actual irrigated area as shown in table 3.1.

Table 3.1 Classification of deep tubewells on the basis of their actual command area.

Best	above 60 acres
Average	40 to 59 acres
Poor	below 40 acres

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Water loss

The calculations of water loss in the distribution canals have been shown in Table 2, Appendix - A. From the table it is found that the total loss varied from 29.5% to 87.3% with an average of 58.3%. The losses were then expressed in per 1000 feet of canal assuming the variation of loss with length be linear. The per thousand feet loss ranged from 15.7% to 88% with a mean value of 38.25%. In order to compare the losses in the canals of different sizes, they were also expressed as percentage of the inflow into the canal per 1000 ft^2 of wetted area. It should be noted that the losses in the canals of west Bemna and Belgacha had not been included in the comparison because the losses were measured by ponding method. The results obtained were found to be significantly less than those obtained by inflow-outflow method in the watercourses constructed in comparable soil type. This is possibly due to avoiding some locations in the ponding test where most of the leakage losses took place. The table indicates that the loss in the distribution canal was very high, i.e., more that 50 percent of the water delivered at the head was lost in the watercourse before entering into a field at the end. From field observations, the followings are considered to be the major reasons for such a huge amount of water loss.

1) High seepage through the channel body

The laboratory analysis of the soil samples collected from the bed of the channels in which conveyance losses were measured reveals that the textural class of the soil varied from silt loam to silt (Fig. 28 to 31, Appendix - B). These soils are moderately permeable permitting appriciable infiltration through the channel prism. Channel bodies were not compacted. Moreover, the canals run only for a part of the day which dried up after the use and cracks were formed in the channel bed and banks due to shrinkage. These defects of the water-courses aggravated the seepage loss to a considerable figure.

ii) Inefficient canal sections

Deep tubewells are installed at a very high cost but no serious attentions have been paid to the problems to water conveyance to farmers' fields. This aspect is very often left to the farmers themselves. The farmers do not have any experience and training for designing irrigation canal. As a result most of the canals are ill-designed and found to have inefficient cross-section and gradient which can not carry the entire flow. The result is heavy spillage loss Fig. 34 ,Appendix - B.

Cross-sectional areas were estimated from 101 measurements in 29 canals under the study and was found to vary from 1.53 ft^2 to 3.61 ft^2 with an average of 2.21 ft^2. The average velocity of flow in each of the cansls was also estimated from the average discharge and average water area and found to vary from 0.18 fps to 1.08 fps with an overall average of 0.53 fps. Assuming an average total loss of 50% and average velocity of 0.53 fps, a discharge of 2 cusec at the head of the canal requires an average water area of 2.83 ft^2 which is much greater than the existing value. Therefore, in order to carry the full discharge we are to increase the gadient and hence the velocity or the cross-sectional area.

iii) Poor construction

The responsibility of construction of the whole distribution system remained to the farmers themselves. They had to bear the entire cost of construction and constructed the canal banks very narrow with surface soils containing dead roots. The banks thus constructed were more permeable and considerable seepage loss took place.

iv) Poor level of maintenance

The farmers pay very little attention to the maintenance of distribution system, A very little number of deep tubewell units were found in which there was regular maintenance, i.e., cleaning, small repairs, and removal of grass and moss. In most cases weeds grew on the bed and banks of the channel which reduced the channel's carrying capacity causing more spillage loss. Most of the canals remained dry during night and considerable part of the day. Rats and rodents cut holes in the canal banks. Almost all the canals under study were found to have such holes frequently through which considerable amount of water leaked.

v) Absence of control structures

No control structures was observed in the distribution system of all the deep tubewell units under this study. Even the discharge boxes were found to have no structures to control the diversion of water into the canal. Farmers used earth, stone, bricks, tc., to close one water way when they diverted water through the other and considerable leakage occured through that poorly closed waterway. A simple wooden gate could be used to serve the purpose quite satisfactorily. Farmers diverted water into the field by cutting the canal banks. At the end of irrigation cuts were plugged with clay and dirts through which appreciable leakage took place. Because a small leak through that loose soil quickly washed out a larger hole. Simple diversion structures like wooden box turnout, siphon tube and bamboo spiles (Fig.36a and 36b , Appendix - B) can save a lot. Use of some check gates along the canal may facilitate the diversion of water by raising the water surface and thus increasing the working head.

vi) Nonattendance of irrigation water

It was found that almost all deep tubewell units did not have any Line man or Field man to check any visible leakage through holes, cuts, breaks, etc., and overtopping of water and stopped them. As a result quite a huge amount of water loss through visible leakage and spillage was observed. Again, due to absence of water attendant, farmers sometimes stole water by making holes in the canal banks. Attempts had been made to estimate the losses due to visible leakage through holes and poorly closed cuts and overtopping by measuring adjoining area flooded and depth of flooding and was found that about 40% of the total loss occured as leakage and overtopping. These losses could be very easily eliminated through proper maintenance of the canal and water attendance during irrigation.

The textural class of the soils were determined by grain size analysis (Fig. 28 to 31, Appendix - B) of the samples collected from the canal bed and attempt had been made to relate the water loss per 1000 ft^2 of wetted area with soil type as in Table 5, Appendix - A. It is evident from the table that there was a large variation of the water loss with comparable and even with the same type of soil. Although soil type, more specifically permeability, plays an important role in the seepage loss it was found to have little influence on the total loss. Because a considerable portion of the total loss occured as leakage and spillage which were not influenced by the soil type but by the level of maintenance of the canals. Moreover, other factors like location of ground water table, hydraulic gradient, degree of compaction of the soil forming the canal body etc., had some influences on the loss rate. The losses shown in Table 2, Appendix - A are steady state losses which occured when the system was in steady state, or flowing at a constant rate. In addition to them some losses like water initially infiltrated into the dry canal banks, dead storage water left in the bottom of the canal after their use etc., were also appreciable. Initially the canal banks were dry and the infiltration rate was very high which then gradually reduced to an equilibrium. The volume of water which laid in the bottom of the canal section after all drainable water had entered into the field was considered as a loss of irrigation water in the conveyance system. This loss was caused by canal inverts being below the level of the field being irrigated and by deep sections followed by sections with higher beds. Attempts were made to evaluate these additional operational losses. Calculations of these losses are shown in Table 4, Appendix - A, which indicates that operational losses resulted in an about 9% total additional loss over steady state measurement. The above figure, however, was obtained from a very few measurements and have only suggestive value. It should be noted that the operational losses were calculated on the basis of 6 hours irrigation period.

4.2 Analysis of other technical data and informations

4.2.1 Location of DTW with respect to the field

Location of DTW has an influence upon the water utilization efficiency in terms of command area as it affects the total length of the distribution watercourses and in turn the water losses. The following table (Table 4.1) reveals the importance of DTW's location.

Table 4.1 Relation between location of DTW's and their command area

Category	Near the centre	Eccentric
Best	71%	29%
Average	50%	50%
Poor	33%	67%

The above table indicates that the percentage of eccentric DTWs were lower for the best category than that for the poor category. It means that the average performance of Schemes having DTW at the centre of the command area was better in comparison with those having eccentric DTW.

4.2.2 Topography

Topography has a control upon the lay out of the distribution system. Level lands with uniform gentle slope enables a simple lay out of the canals and it permits the water to flow evenly over the land from the watercourses. The lands with local undulations make the layout complicated and increase the length of the watercourses per unit area and hence increase the total water losses. The following table (Table 4.2) shows that most of the units of the best category were level indicating that the average performances of the DTWs in a level area were comparatively good. Therefore, topography of the area should be considered before installing a DTW. Some correction of the topography can be made by land levelling.

Table 4.2 Relation between topography of the DTW area and command area

Category	Almost level	Undulated
Best	71%	29%
Average	67%	33%
Poor	50%	50%

4.2.3 Soil type

The soils of the irrigation units under the present study were found mostly silt loam and silt. But the soil of the same unit was not always found uniform throughout the whole area. In some irrigation units, mostly in Rupganj, some of the lands were found to consist of very light soil which required very frequent irrigation. Such lands are not suitable for flooded rice cultivation. Wheat may be found to be more suitable crop for those lands. Therefore, for the success of an irrigation units thorough investigation of soil conditions is required before installing a DTW.

4.2.4 Utilization status of DTW and Pump

Field measurements shows that the actual discharge of the DTWs varied from 0.816 cusec to 1.86 cusec with an average of 1.46 cusec (Table 7, Appendix - A) against the design discharge of 2 cusec. The probable reasons for these low discharges are summarised as follows:

i) There may be some difficulties with the DTWs like partial clogging of the strainer or improper development or may be due to improper selection of pump.

ii) In most cases the individual farmer bought his own fuel and gave it to the driver to get water into his field only. Therefore, for most of the time only one canal was fed which was not sufficient to carry the full supply. And hence the farmers operated the pump at lower rate.

iii) The farmer or driver tried to optimize the fuel consumption by the engine as it was not adequately available in the market. As a result engines were operated, in most cases, at speed lower than optimum value because the farmer thought that the rate of fuel consumption would be low at that speed. But actually the rate of fuel consumption per unit weight of water lifted increases if the engine is operated at speed below the optimum value as indicated in (Fig. 4.3). Moreover, lower speed of the pump results in less discharge causing underutilization of the facilities.

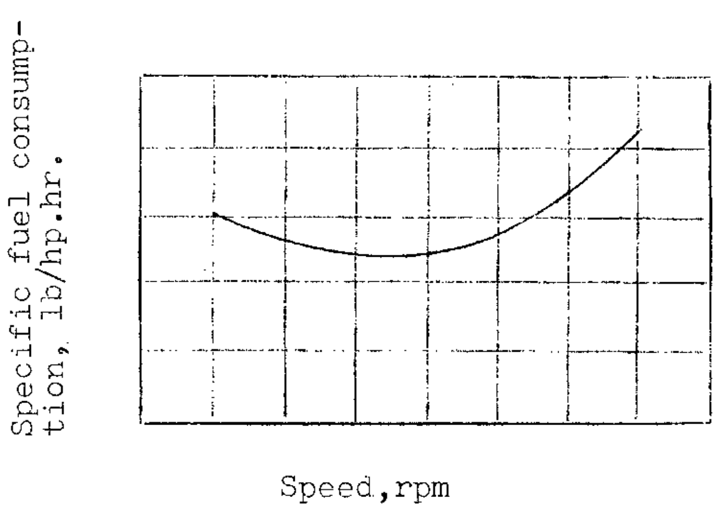

Fig. 4.3 Relation between engine speed and specific fuel consumption of Internal Combustion engine.

It was found that the farmers operated the pumps in two shifts with a break because they thought that the engine required a rest for its normal operation. But actually the engine does not require such a rest and this type of operation not only increases the loss due to filling of canal but also detrimental to the engine. Because starting and stopping cause more tear and wear of the engine.

Attempts had also been made to collect informations regarding the operating hours of the pumps but the farmers did not have any records on pumping hour. Therefore, total pumping hours for the season was computed from the data on total fuel consumption for the season and the rate of fuel consumption and it was found that the average figure for that was 900 hours (Table 9, Appendix - A). This is equivalent to an operation of 7.5 hours per day, assuming an irrigation period of 120 days. This is undoubtedly a very low value. The most important reason for the low running hours was the non-availability of fuel.

From the above findings it is evident that the DTWs were underutilized both in terms of flow rate and operating hours per day. The efficiency of the irrigation units in terms of command area can be greatly increased by running the pump at its full capacity and for a longer period of time per day. This necessitates adequate supply of fuel, better irrigation schedule and efficient distribution system.

4.2.5 General conditions of the watercourses

Most of the watercourses were found inefficient to carry the discharge of the deep tubewell and considerable overtopping of water took place. Moreover, lack of proper maintenance made the conditions of the watercourses worse. Weeds grew on the canal body, rats and insects made holes in the banks, and the farmers cut the banks to divert water which they did not seal properly. Fig. 33 to 35 , Appendix - B show some of the common problems with most of the canals. These all caused considerable additional operational losses over the unavoidable seepage and evaporation losses.

4.2.6 Performance of the engine

The performances of most of the engines were found good. They did not suffer any major mechanical difficulty except the replacement of some minor spare parts like piston ring, fuel fitter, etc. The average fuel consumption per hour of the engines was found about 1 gallon.

Although the cost of operation of pump can be reduced to about one-third by replacing the engine by an electric motor it may create more critical problem. Power failure occurs frequently and the shortage of water during critical stages of growth because of power failure may cause serious damage to crops.

4.2.7 Water distribution schedule

In almost all irrigation units there was no definite distribution schedule. Water was distributed either on serial or on first come first service basis which resulted in considerable misuse of irrigation water. Loss of water can be minimized to greater extent by following a proper irrigation schedule in which the entire scheme is to be divided into few blocks and water is to be distributed by rotation. A considerable portion of the water loss from the watercourses can be potentially used by starting irrigation from the tail end of a canal and gradually approaching towards the head.

4.3 Analysis of Socio-economic informations

4.3.1 Formation of irrigation society

The entire responsibility of operation and maintenance of the schemes, invariably, remains to the farmers. To perform this responsibility the farmers need to form an organization which may be called as irrigation society. The irrigation society performs the following activities:

i) collect fees

ii) design, construct and maintain the distribution systems

iii) maintain DTW, pump and engine

iv) pay rent to BADC

v) distribute inputs like fertilizer, pesticides, etc. supplied by BADC among the farmers.

vi) fix the water distribution schedule

vii) settle any conflict among the farmers

The success of an irrigation scheme largely depends on the strength of the society. Therefore, it is important to investigate into the formation of society. It was observed that irrigation society used to be formed:

i) through the initiative of the local people

ii) through institutional initiative which refers to thana level government institutions and officers and

iii) through individual initiative.

In the second case it was reported that government officers visited the field area and talked to a few social leaders and got the committee formed without consulting all the participating members. Such organizations were thought to have been imposed from above and very often did not succeed. Findings are shown in the following table (Table 4.3).

Table 4.3 Relation between initiative behind the formation of society and command area.

Category	Local people	Institution or individual
Best	86%	14%
Average	100%	0
Poor	50%	50%

From the above table it is found that the highest percentage of institutional or individual initiative occured under poor category meaning that the performance of the society formed through institutional initiative or individual initiative was comparatively poor. It is evident from this finding that for the success of irrigation scheme the society should be formed from grass root level i.e., through initiative of local people.

4.3.2 Manager

The leader of irrigators group is called the manager. The success of the irrigation project largely depends upon the sincerity, intelligence, level of education, working capacity, etc., of the manager. He has to perform a good number of important functions such as supervision of distribution work, collection of fund from the members, purchase of fuel and spareparts, distribution of loan, maintenance of accounts, etc. Therefore, manager's occupation, level of education, remuneration, land under the scheme, etc., have some influence upon the performance of the scheme. Informations on these had been collected, analysed and findings are listed below:

i) Education

It is found from Table 10, Appendix - A, that the educational level of most of the managers (73%) was below secondary. It is obvious from this that he might find it difficult to perform his duties satisfactorily and this may be one of the reasons for the poor performance of most of the irrigation schemes.

ii) Occupation

It was observed that agriculture was the main occupation of the manager. About 63% of the managers absolutely depended upon agriculture. However, some managers were engaged inbusiness and service keeping agriculture as their main occupation. The following table (Table 4.4) shows the distribution of various occupations of managers.

Table 4.4 Occupation of managers

Agriculture	Business	Service	Combined
63%	-	-	37%

Above table shows that over one third on the managers had another source of income which might make him less interested in doing his duties sincerely with a result of poor management of the irrigation society.

iii) Remuneration

Table 10, Appendix - A reveals that 84% of the manager did not take any remuneration and only 16% took remuneration either in cash (salary) or kind (get water without fee). This lack of incentive might contribute to the poor performance of most of the DTWs.

4.3.3 Selection of DTWs site

Selection of the DTWs site has an important bearing upon its performance. The site should be selected from technical considerations but sometimes the power structures influence plays a lot of roles in the selection of site. But in case of almost all the DTWs under this study, sites were selected through consensus opinion (Table 10, Appendix - A).

4.3.4 Availability of fuel

It was found that more that 59% of engine operated DTW units had to purchase fuel from the open market at higher cost because the supply of fuel by BADC was not sufficient. Due to the high cost of the fuel the farmers could not operate the DTW for longer durations. This results in underutilization of the existing facilities. By providing adequate fuel supply at control price the coverage per deep tubewell can be greatly improved.

4.3.5 Number of farmers in the society and their land holdings

It is found from Table 11, Appendix - A that a large number of farmers (more than 64 farmer on average) were involved in each irrigation society and most of them (75% on average) hold less than one acre of lands. This means that each of the DTW unit consists of a large number of plots of different owner. This made the distribution difficult and considerable amount of water was misused.

4.3.6 Water charge

Two methods were observed (Table 12, Appendix - A) for fixing the irrigation fee. These were: i) on the basis of area irrigated and ii) mixed in which costs of maintenance of DTW , pump. and engine., BADC rent, remunerations of Driver, etc., were realized on the basis of the area irrigated but the individual farmer had to buy his own fuel. Both of the methods had some advantages and disadvantages but still the first method was better. In the second method it was very difficult to plan distribution shedule because many farmers could not afford to purchase fuel when their turn came and the driver had to supply water to the fields of other farmers who could give the fuel. This resulted random distribution causing considerable misuse of water resources. The farmers having their lands adjacent to the distribution canals or in the lower elevations always got advantages. They needed a little fuel to irrigate their lands because the lands were partially irrigated by the water lost from the canals or higher lands due to seepage. This inequity problems made the farmers having their lands near the tail of the canals or at higher elevations less interested in irrigation. These difficulties could be overcome by adopting the first method of water charging. Again in the first method the influencial farmers supplied excessive water into their fields while the supply into the fields of small or poor farmers were insufficient causing unequal distribution. But the unequal distribution problem could be solved by strictly following a proper irrigation schedule.

Regarding the total cost of irrigation water for the season, the figure was found to vary from Tk.300 per acre to Tk. 860 per acre with an average of about Tk. 500 per acre (Table 12, Appendix - A). The cost of irrigation can be reduced to about one third by replacing the engine by an electric motor. But this may create some more critical problems. Electric power failure occurs very frequently and failure of power during the critical stages of growth may cause serious damage to crops.

CHAPTER - 5

CONCLUSIONS AND RECOMMENDATIONS

The important conclusions and recommendations which can be made from the study are:

1. About 30% to 87% of the water delivered from the DTWs is lost in the distribution canals before entering into the fields. And more than one-third of this loss occurs as leakage through rodent holes, cracks and cuts and overtopping of water. The causes and recommended measures are:

   a) Although deep tubewells are installed by investing a huge amount of money the entire responsibility of construction of distribution system is left to the farmers. Farmers construct the distribution canals with least or no experiences. As a result canals are very often found inefficient in cross-section and or gradient causing considerable spillage loss. A supervisory help in the construction of canals from an organization like BADC can save a lot. Embankments of the canals are found very weak and narrow enhancing seepage. A scheme may be undertaken to improve all the existing canals in which the government organization may provide technical advice and the local farmers may provide labour.

b) Farmers do not maintain the distribution system regularly. As a result weeds grow on the channel body which reduces the carrying capacity and cause spillage of water. Rats and rodents make holes in the canal banks through which considerable leakage occurs. These losses can be greatly reduced through regular maintenance of the canals. Field demonstrations and incentives like prizes for the best maintenance may increase farmers interest in maintence.

c) Due to the absence of control structures, i.e., diversion structures, the fields are supplied with irrigation water by cutting the canal banks. After irrigation the cuts are not properly sealed and a considerable leakage takes place. Simple diversion structures like wooden box turnont, bamboo spiles, etc., can save a lot. The operational wastes can be greatly reduced through water attendance. A water attendant can be employed in each DTW unit to check and stop any visible leakage and overtopping of water in the canal during irrigation. No doubt that construction of pucca canals near the head of water sources would reduce the water loss but this would involve a huge investment and may not be economically viable. Other alternatives like manual compaction of earthen channel and lining with low cost materials may found to be more justified. Study should be conducted to find out the most economical way of reducing water losses.

2. In most of the deep tubewell units the pump is run at lower rate and for a low operating period due to inadequate supply of fuel. This results in under-utilization of the existing facilities. The pumping hour should be increased to at least 12 to 16 hours per day by assuring adequate supply of fuel. The pump and engine should be operated optimally so that rate of fuel consumption per unit weight of water lifted is minimum. Engine should be operated continuously without any break because this will not only reduce the loss of filling of canal but also ensure longer life of engine due to less tear and wear.

3. Location of the DTW should be determined on the basis of topography so that water can be distributed over the entire area by gravity.

4. Thorough investigation of soil type should be conducted before installing a DTW in an area.

5. At present a few deep tubewell units have definite distribution schedule and as a result maldistribution exists in most DTW units. But each DTW unit should have a definite distribution schedule fixed through the consensus opinion of the farmers. In order to reduce the misuse of water the whole area should be divided into some blocks and water should be distributed by rotation among the blocks. And in each block irrigation should be started from the tail end.

6. Before going to install a DTW in an area a detailed socio-economic study of the area regarding the potentialities of irrigated agricultural development, farmers' problems and needs, farmers' interest and eagerness to participate in operation and maintenance of DTW, etc., should be conducted.

7. Managing committee should be formed from grass root level, i.e., through the initiative of local people.

8. Since the role of manager is very important he should be sincere, honest, dutiful and intelligent. Some kind of remuneration should be given to him so that he is induced to work hard. If the remuneration is on the basis of acreage per deep tubewell and yield per acre, there is a possibility of increasing the existing acreage of irrigation units.

9. The most important reason for the low operating hour of the pumps is nonavailability of fuel. Therefore, uncertainty regarding the availability of fuel should be eliminated in order to improve the efficiency of DTW irrigation units.

10. Water charge should be realized on the basis of actual area irrigated because this method enables to maintain a definite distribution schedule. In this method fuel should be bought by the co-operatives so that the poor farmers can get water in time although he pays irrigation fee after the harvest.

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APPENDIX - A

TABLES

TABLE - 1

LIST OF THE DEEP TUBEWELLS SELECTED FOR THE STUDY

Location	JL No	Plot No
1. Chapain, Savar, Dacca	653	5
2. South Dariapur, Savar, Dacca	665	143
3. Rajasan 3, Savar, Dacca	670	154
4. Rajasan 4, Savar, Dacca	670	298
5. Baralia, Savar, Dacca	104	1634
6. Sonalia 3, Savar, Dacca	582	250
7. Badda, Savar, Dacca	647	147
8. Aukhpara, Savar, Dacca	596	18
9. West Bamna, Islampur, Jamalpur		148
10. Belgacha, Islampur, Jamalpur	70	1183
11. Gazipura, Joydebpur, Dacca	107	129
12. Itahata, Joydebpur, Dacca	35	2345
13. Technagar Para, Joydebpur, Dacca	37	29
14. Salna Maidda Para, Joydebpur, Dacca	30	57
15. Dakhsin Khan 10, Gulsan, Dacca	193	2912
16. Dakhsin Khan 8, Gulsan, Dacca	193	3729
17. Amlabo 1, Rupganj, Dacca	116	1224
18. Amlabo 2, Rupganj, Dacca	166	767
19. Paraguon 2, Rupganj, Dacca	139	329

TABLE - 2

WATER LOSS CALCULATIONS

Location of Deep Tubewell	Total length of water-course(ft).	Length of test section(ft)	Inflow (cfs)	Outflow (cfs)	Loss (cfs)
Chapain, Savar	1125	1025	0.738	0.486	0.252
Chapain, Savar	1046	746	0.607	0.479	0.128
Chapain, Savar	1500	1200	0.645	0.380	0.265
South Dariapur, Savar	800	800	1.800	0.515	1.285
South Dariapur, Savar	868	862	1.800	0.700	1.100
Rajasan 3, Savar, Dacca	2722	2712	1.730	0.850	0.905
Rajasan 4, Savar	2480	2100	1.770	1.090	0.680
Baralia, Savar	2600	2572	1.810	1.080	0.730
Sonalia 3, Savar	1740	700	1.840	1.510	0.330
Badda, Savar	1915	365	1.790	1.640	0.150
Badda, Savar	1705	740	0.584	0.392	0.192
Aukhpara, Savar	1120	375	0.855	0.745	0.110
Aukhpara, Savar	1015	378	0.650	0.570	0.080
West Bamna, Islampur	1482	1482	1.830	-	0.553
Belgacha, Islampur	2915	2915	2.130	-	0.374
Gazipura, Joydebpur	1970	1180	0.900	0.427	0.473
Gazipura, Joydebpur	3076	795	0.920	0.750	0.170
Itahata, Joydebpur	2000	2000	0.410	0.090	0.320
Itahata, Joydebpur	1992	1760	0.350	0.080	0.270
Technagar Para, Joydebpur	1884	1525	0.660	0.242	0.418
Salna Maidda Para Joydebpur	1379	1150	1.010	0.472	0.538
Dakhsin Khan 10, Gulsan	2250	1580	0.900	0.438	0.462
Dakhsin Khan 8, Gulsan	1280+1223	1280+1150	0.910	0.526	0.384
Amlabo 1, Rupganj	1075	1000	0.703	0.242	0.461
Amlabo 2, Rupganj	1674	1100	0.820	0.380	0.440
Amlabo 2, Rupganj	1205	870	0.410	0.200	0.210
Parageon 2, Rupganj	1000+1450	1000+1450	1.300	0.361	0.939

TABLE - 2 (Contd.)

Location of Deep Tubewell	Loss per 1000 ft (cfs)	Loss per 1000 ft (% of inflow)	Total loss (%)	Loss per 100 ft^2 wetted area (% of inflow)
Chapain, Savar	0.246	33.3	40.4	9.68
Chapain, Savar	0.171	28.3	29.5	8.27
Chapain, Savar	0.220	34.1	51.0	9.58
South Dariapur, Savar	1.600	88.0	71.3	20.27
South Dariapur, Savar	1.276	70.8	61.4	12.96
Rajasan 3, Savar, Dacca	0.330	19.3	52.5	6.00
Rajasan 4, Savar	0.324	18.3	45.4	5.38
Baralia, Savar	0.284	15.7	40.8	4.35
Sonalia 3, Savar	0.471	25.6	44.5	6.88
Badda, Savar	0.410	22.9	43.8	5.95
Badda, Savar	0.260	44.4	75.9	12.30
Aukhpara, Savar	0.290	33.9	38.0	9.20
Aukhpara, Savar	0.210	32.3	32.7	8.20
West Bamna, Islampur	0.373	20.4	30.2	5.78
Belgacha, Islampur	0.128	6.0	17.6	1.78
Gazipura, Joydebpur	0.400	44.0	86.7	12.20
Gazipura, Joydebpur	0.213	23.0	70.7	7.01
Itahata, Joydebpur	0.160	39.0	78.0	14.26
Itahata, Joydebpur	0.153	43.8	87.3	16.02
Technagarpara, Joydebpur	0.274	41.5	78.2	12.65
Salna Maidda Para, Joydebpur	0.468	46.3	63.9	13.66
Dakhsin Khan 10, Gulsan	0.292	32.4	72.9	11.30
Dakhsin Khan 8, Gulsan	0.158	17.3	43.3	6.61
Amlabo 1, Rupganj	0.461	65.5	70.4	16.64
Amlabo 2, Rupganj	0.400	68.8	81.7	14.87
Amlabo 2, Rupganj	0.240	58.5	70.5	21.40
Parageon 2, Rupganj	0.383	29.5	72.7	9.82

TABLE - 3

CALCULATION OF WATER LOSS BY PONDING METHOD

Name of the Deep Tubewell site	Canal		Length of section (ft)	Test Section (ft)	Average width (ft)	Rate of Recession (ft/sec.)	Loss(cfs)	Total loss (cfs)
West Bamna, Islampur	Main 1	Sec 1	386	60	3.94	1.85×10^{-5}	0.028	
		Sec 2	219	46	3.52	3.08×10^{-5}	0.024	0.553
		Sec 3	383	50	3.33	1.388×10^{-5}	0.177	
		Sec 4	494	42	3.77	1.74×10^{-4}	0.324	
Belgacha, Islampur	Main 1	Sec 1	395	91	4.33	1.073×10^{-5}	0.0183	
		Sec 2	423	52	3.88	5.787×10^{-6}	0.0095	0.192
		Sec 3	393	70	3.77	6.9×10^{-5}	0.1022	
		Sec 4	312	57	3.61	5.51×10^{-5}	0.0620	
	Main 3	Sec 1	266	62	3.30	1.917×10^{-5}	0.017	
		Sec 2	361	54	2.9	3.98×10^{-5}	0.042	
		Sec 3	367	60	2.73	1.27×10^{-5}	0.013	0.182
		Sec 4	398	60	1.416	1.96×10^{-4}	0.110	

TABLE - 4

CALCULATION OF OPERATIONAL LOSS

Flow from the pump before steady state at Flume F_2, cu.ft.	Flow through Flume F_2		Operational loss		
	Before Steady State (Previous flow) cu.ft.	After pump stopped (Tail flow) cu.ft.	cu.ft.	% on 6 hours operation basis	
				Total	Per 1000 ft.
3,456	560	438	2,458	6.32	7.9
3,024	625	412	1,987	5.11	5.9
1,820	371	326	1,123	12.7	14.6
1,599	122	63	1,414	16.0	8.0

TABLE - 5

RELATION BETWEEN SOIL TYPE AND WATER LOSS

Location of Deep Tubewell	Textural class of the soil			
	Type	Composition		
		Sand(%)	Silt(%)	Clay(%)
Chapain, Savar	Silt loam	15.0	77.5	7.5
South Dariapur, Savar	Silt loam	22.0	74.0	4.0
Rajasan 3, Savar	Silt loam	26.0	65.0	9.0
Rajasan 4, Savar	Silt	11.0	80.0	9.0
Baralia, Savar	Silt loam	13.5	74.0	12.5
Sonalia 3, Savar	Silt loam	18.5	67.5	14.0
Badda, Savar	Silt loam	32.5	61.0	6.5
Aukhpara, Savar	Silt loam	19.5	72.0	8.5
West Bamna, Islampur	Silt loam	22.0	72.0	6.0
Belgacha, Islampur	Silt loam	20.5	74.5	5.0
Gazipura, Joydebpur	Silt	15.0	80.0	5.0
Itahata, Joydebpur	Silt loam	18.0	77.5	4.5
Technagar Para, Joydebpur	Silt loam	23.0	72.0	5.0
Salna Maidda Para Joydebpur	Silt loam	23.5	67.5	9.0
Dakhsin Khan 10, Gulsan	Silt loam	17.0	77.0	6.0
Dakhsin Khan 8, Gulsan	Silt	11.5	83.5	5.0
Amlabo 1, Rupganj	Silt	12.5	82.5	5.0
Amlabo 2, Rupganj	Silt	15.5	80.5	4.0
Paragaon 2, Rupganj	Silt	12.5	81.5	6.0

TABLE - 5 (Contd.)

Location of Deep Tubewell	Effective grain size, D_{10}, mm.	Average Water loss per 1000 ft^2 of wetted area, % of inflow
Chapain, Savar	0.0029	9.17
South Dariapur, Savar	0.0044	16.61
Rajasan 3, Savar	0.0018	6.00
Rajasan 4, Savar	0.0028	5.38
Baralia, Savar	0.0013	4.35
Sonalia 3, Savar	0.0010	6.88
Badda, Savar	0.0035	9.12
Aukhpara, Savar	0.0026	8.70
West Bamna, Islampur	0.0020	5.78
Belgacha, Islampur	0.0034	1.78
Gazipura, Joydebpur	0.0042	9.60
Itahata, Joydebpur	0.0041	15.14
Technagarpara, Joydebpur	0.0042	12.65
Salna Maidda Para, Joydebpur	0.0022	13.66
Dakhsin Khan 10, Gulsan	0.0048	11.30
Dakhsin Khan 8, Gulsan	0.0056	6.61
Amlabo 1, Rupganj	0.0039	16.64
Amlabo 2, Rupganj	0.0047	15.75
Paragaon 2, Rupganj	0.0045	9.82

TABLE - 6

SOIL TYPES, CROPS IRRIGATED AND TOPOGRAPHY OF THE AREA

Name of the Deep Tubewell site	Soil type	Crop(s) irrigated
Chapain, Savar	Silt loam	Mainly Boro HYV. Some vegetable lands are also irrigated
South Dariapur, Savar	Silt loam	Boro HYV
Rajasan 3, Savar	Silt loam	Maily Vegetable and Fruits. Some Boro lands are also irrigated
Rajasan 4, Savar	Silt loam	Maily Vegetable and Fruits. Some Boro lands are also irrigated
Baraliā, Savar	Silt loam	Boro HYV
Sonalia, Savar	Silt loam	Boro HYV
Badda, Savar	Silt loam	Boro HYV
Aukhpara, Savar	Silt loam	Boro HYV
West Bamna, Islampur	Silt loam	Boro HYV
Belgacha, Islampur	Silt loam	Boro HYV
Gazipura, Jpydebpur	Silt	Boro HYV
Technagarpara, Joydebpur	Silt loam	Boro HYV
Itahata, Joydebpur	Silt loam	Boro HYV
Salna Maiddapara, Joydebpur	Silt loam	Mostly Boro HYV
Dakhsin Khan 10, Gulsan	Silt loam	Mostly Boro HYV
Dakhsin Khan 8, Gulsan	Silt	Mostly BOro HYV
Amlabo 1, Rupganj	Silt	Mostly Boro HYV
Amlabo 2, Rupganj	Silt	Mostly Boro HYV
Paragaon 2, Rupganj	Silt	Mostly Boro HYV

Source: Field observations and investigations.

TABLE - 6 (Contd.)

Name of the Deep Tubewell site	Topography
Chapain, Savar	Deep Tubewell is located on a ridge and Boro lands are around the ridge 10 to 15 ft. below. Lands are level and slightly slopping
South Dariapur, Savar	Lands are level and gently slopping.
Rajasan 3, Savar	Deep Tubewell is on a ridge and Boro fields are on the western and Northern side 8 to 12 ft. below and are slighty undulated.
Rajasan 4, Savar	Deep Tubewell is located on a ridge and the Boro fields are on the east and south and are level
Baralia, Savar	Area is undulated but the lands are terraced and levelled.
Sonalia, Savar	Area is undulated but the lands are terraced and levelled.
Badda, Savar	Partly undulated and partly level with getle slope.
Aukhpara, Savar	Lands are fairly level and gently slopping
West Bamna, Islampur	Lands are level and mildly slopping
Belgacha, Islampur	Lands are level and slopping
Gazipura, Joydebpur	Lands are level and gently slopping
Technagarpara, Joydebpur	Area is undulated but lands are terraced and made level
Itahata, Joydebpur	Lands are fairly level with gentle slope
Salna Maiddapara, Joydebpur	Undulated
Dakhsin Khan 10, Gulsan	Undulated
Dakhsin Khan 8, Gulsan	Area is undulated and the lands are terraced and levelled.
Amlabo 1, Rupganj	Lands are fairly level with gentle slope
Amlabo 2, Rupganj	Lands are fairly level with gentle slope
Paragaon 2, Rupganj	Lands are fairly level with gentle slope

Source: Field observations and investigations.

TABLE - 7

DATA ON DEEP TUBEWELLS AND PUMPS

Name of the Deep Tubewell site	Location with respect to the field	Capacity (cfs)	Actual discharge at which the farmers operate the pump (cfs)	Command area (acres)
Chapain, Savar	At the centre on an elevated place(ridge)	2	1.02	60.0
South Dariapur, Savar	Eccentric towards North-est on an elevated place	2	1.80	13.0
Rajasan 3, Savar	At the centre on an elevated place	2	1.73	14.3
Rajasan 4, Savar	At the centre on an elevated place	2	1.77	13.8
Baralia, Savar	Slightly eccentrice on an elevated place	2	1.81	100.0
Sonalia, Savar	Appx. at the centre on an elevated place	2	1.84	70.0
Badda, Savar	At the centre on an elevated place	2	1.86	67.0
Aukhpara, Savar	At the centre on an elevated place	2	1.79	40.0
West Bamna, Islampur	On one side on an elevated place	2	1.83	42.0
Belgacha, Islampur	Appx. at the centre on an elevated place	2.25	2.13	57.0
Gazipura, Joydebpur	Slightly eccentric towards south west	2	1.82	85.0
Itahata, Joydebpur	Near the centre on an elevated land	2	1.12	60.0

Source: Field measurements, observations and investigations.

TABLE - 7 (Contd.)

Name of the Deep Tubewell site	Location with respect to the field	Capacity (cfs)	Actual discharge at which the farmers operate the pump(cfs)	Command area (acres)
Technagarpara, Joydebpur	At the centre on an elevated land	2.00	0.816	55.0
Salna Maiddapara, Joydebpur	At the centre on an elevated land	2.00	1.01	30.0
Dakhsinkhan 10,Gulsan	Eastern side on an elevated place	2.00	0.91	47.0
Dakhsinkhan 8,Gulsan	Near the centre on an elevated land	2.00	0.91	87.0
Amlabo 1,Rupganj	On the eastern side on an elevated place	2.25	2.03	52.5
Amlabo 2,Rupganj	On the south eastern side on an elevated land	2.25	1.88	39.0
Paragaon 2,Rupganj	Near the centre on an elevated place	2.00	1.30	39.0

Source: Field measurements,observations and investigations.

TABLE - 7 (Contd.)

Name of the Deep Tubewell site	Command area per cusec capacity (acres)	Energy	Energy consumption per hour(gallon/ hr.or units (K.W.H)) /hr.
Chapain, Savar	30.00	Diesel	0.8
South Dariapur, Savar	6.50	Electricity	16 units
Rajasan 3, Savar	7.15	Diesel	1.0
Rajasan 4, Savar	6.9	Diesel	1.0
Baralia, Savar	50.0	Electricity	13 units
Sonalia, Savar	35.0	Diesel	1.0
Badda, Savar	33.5	Diesel	0.8 to 1.0
Aukhpara, Savar	20.0	Diesel	0.8 to 1.0
West Bamna, Islampur	21.0	Diesel	1.0
Belgacha, Islampur	25.33	Diesel	1.0
Gazipura, Joydebpur	42.5	Diesel	1.00
Itahata, Joydebpur	30.0	Electricity	15 units

Source: Field Measurements, observations and investigations

TABLE - 7 (Contd.)

Name of the Deep Tubewell site	Command area per cusec capacity (acres)	Energy	Energy consumption per hour(gallon/hr.or units (K.W.H.)/hr.
Technagarpara,Joydebpur	27.5	Diesel	1.00
Salna Maiddapara, Joydebpur	15.0	Diesel	0.9
Dakhsinkhan 10,Gulsan	23.5	Diesel	0.8
Dakhsinkhan 8,Gulsan	43.5	Diesel	0.8
Amlabo 1, Rupganj	23.33	Electricity	13 units
Amlabo 2, Rupganj	17.33	Diesel	1.0
Paragaon 2,Rupganj	19.5	Diesel	1.0

Source: Field measurements,observations and investigations.

TABLE - 7 (Contd.)

Name of the Deep Tubewell site	Peak running hours/day		Pump	
	Total	No. of shift	Type	Brand
Chapain, Savar	18	3	Centrifugal	K.S.B.
South Dariapur, Savar	4	1	Turbine	Johnston
Rajasan 3, Savar	8	2	Turbine	Johnston
Rajasan 4, Savar	9	2	Turbine	Johnston
Baralia, Savar	18	3	Turbine	Johnston
Sonalia, Savar	10	2	Turbine	Johnston
Badda, Savar	12	2	Turbine	Johnston
Aukhpara, Savar	12	2	Turbine	Johnston
West Bamna, Islampur	12	2	Turbine	Johnston
Belgacha, Islampur	16	2	Turbine	Johnston
Gazipura, Joydebpur	18	2	Turbine	Johnston
Itahata, Joydebpur	18	3	Turbine	Johnston

Source: Field Measurements, observations and investigations

TABLE - 7 (Contd.)

Name of the Deep Tubewell site	Peak running hours/days		Pump	
	Total	No.of shift	Type	Brand
[illegible],Joydebpur				
Technagarpara, Joydebpur	18	3	Turbine	Johnston
Salna Maiddapara, Joydebpur	12	2	Turbine	Johnston
Dakhsinkhan 10,Gulsan	12	2 or 3	Turbine	Johnston
Dakhsinkhan 8,Gulsan	16	3	Turbine	Johnston
Amlabo 1,Rupganj	18	3	Turbine	Johnston
Amlabo 2,Rupganj	8	2	Turbine	Johnston
Paragaon 2,Rupganj	8	2 or 3	Turbine	Johnston

Source: Field measurements,observations and investigations

TABLE - 7 (Contd.)

Name of the Deep Tubewell site	Engine	Mechanical Difficulties
Chapain, Savar	Russian	Mechanical difficulties and engine is replaced this year.
South Dariapur, Savar	-	Electrification in the last season
Rajasan 3, Savar	Ruston	No difficulties
Rajasan 4, Savar	Ruston	No difficulties
Baralia, Savar	-	No difficulties
Sonalia, Savar	Ruston	No major difficulties
Badda, Savar	Ruston	Some difficulties this year.
Aukhpara, Savar	Ruston	No major difficulties
West Bamna, Islampur	Ruston	No major difficulties
Belgacha, Islampur	Ruston	No major difficulties
Gazipura, Joydebpur	Ruston	No major difficulties
Itahata, Joydebpur	-	No difficulties

Source: Field Measurements, observations and investigations.

TABLE - 7 (Contd.)

Name of the Deep Tubewell site	Engine	Mechanical Difficulties
Technagarpara, Joydebpur	Ruston	No major difficulties
Salna Maiddapara, Joydebpur	Ruston	No difficulties
Dakhsinkhan 10, Gulsan	Ruston	No difficulties
Dakhsinkhan 8, Gulsan	Ruston	No difficulties
Amlabo 1, Rupganj	-	No difficulties
Amlabo 2, Rupganj	Ruston	No difficulties
Paragaon 2, Rupganj	Ruston	No difficulties

Source: Field measurements, observations and investigations

TABLE - 8

GENERAL CONDITION OF THE WATERCOURSES

Name of the Deep Tubewell site	Alignment	Weeds/grass on bed	Rodent holes and cracks	Breaks and cuts
Chapain, Savar	More or less straight	None	Less	Moderate
South Dariapur, Savar	More or less straight	Light grass cover	Frequent	Frequent
Rajasan 3, Savar	More or less tortous	Moderate	None	None
Rajasan 4, Savar	More or less tortous	Moderate	None	None
Baralia, Savar	More or less straight	Less	None	None
Sonalia, Savar	More or less straight	Less	Less	Moderate
Badda, Savar	More or less straight	Light grass cover	Moderate	Moderate
Aukhpara, Savar	Slightly tortous	Moderate	None	Moderate
West Bamna, Islampur	Tortous	Less	Frequent	Less
Belgacha, Islampur	Slightly tortous	Light grass cover	Less	Less
Gazipura, Joydebpur	Almost straight	Moderate	Frequent	Less
Technagarpara, Joydebpur	Tortous	Less	Less	Less
Itahata, Joydebpur	Straight	Less	Less	Moderate
Salna Maiddapara, Joydebpur	Straight	Moderate	Moderate	Moderate
Dakhsin Khan 10, Gulsan	More or less straight	Less	Frequent	Frequent
Dakhsin Khan 8, Gulsan	Tortous	Less	Moderate	Moderate
Amlabo 1, Rupganj	More or less straight	Thick grass cover	Less	Moderate
Amlabo 2, Rupganj	More or less straight	Moderate	Less	Less
Paragaon 2, Rupganj	Slightly Tortous	Moderate	Frequent	Frequent

Source: Field observations and investigations

TABLE - 8 (Contd.)

Name of the Deep Tubewell site	Overtopping	El.of canal bed w.r.t. the field	Maintenance
Chapain, Savar	Frequent	Mostly above	No maintence
South Dariapur, Savar	Frequent	Mostly above	No maintence
Rajasan 3, Savar	Less	Above	Not regular
Rajasan 4, Savar	Less	Above	Not regular
Baralia, Savar	None	Mostly above	Regular maintence
Sonalia, Savar	None	Mostly above	Not regular
Badda, Savar	None	Partly above & Partly below	Not regular
Aukhpara, Savar	Less	Mostly below	Not regular
West Bamna, Islampur	Moderate	Mostly below	Not regular
Belgacha, Islampur	Moderate	Partly above & Partly below	Not regular
Gazipura, Joydebpur	Less	Mostly below	Regular maintence
Technagarpara, Joydebpur	Less	Mostly below	Regular maintence
Itahata, Joydebpur	Frequent	Mostly above	Not regular
Salna Maiddapara, Joydebpur	Frequent	Mostly above	Not regular
Dakhsinkhan 10, Gulsan	Less	Mostly above	Not regular
Dakhsinkhan 8, Gulsan	Less	Partly above & Partly below	Not regular
Amlabo 1, Rupganj	Frequent	Mostly below	Not regular
Amlabo 2, Rupganj	Frequent	Mostly below	Not regular
Paragaon 2, Rupganj	Less	Mostly above	Not regular

Source: Field observations and investigations

TABLE - 9

INFORMATIONS REGARDING SUPPLY, DISTRIBUTION AND APPLICATION OF WATER

Name of the Deep Tubewell site	No. of main canal	Total length	Water supply to the canals	No. of canals fed at a time
Chapain, Savar	3	2140;2030;2248	Alternatively	1
South Dariapur, Savar	3	800; 868; 450	Alternatively & simulteneously	-
Rajasan 3, Savar	2	2722;2790	Alternatively & simulteneously	-
Rajasan 4, Savar	3	2480;1650; 410	Alternatively & simulteneously	-
Baralia, Savar	3	3247; 812; 525	Alternatively	1
Sonalia, Savar	2	2800;1740	Alternatively	1
Badda, Savar	3	1915;1705;1695	Alternatively	1
Aukhpara, Savar	3	1015;1120;2775	Alternatively	1
West Bamna, Islampur	2	2612;1492	Alternatively	1
Belgacha, Islampur	3	1523;4231;1392	Alternatively	2
Gazipura, Joydebpur	3	1970;3076;2210	Alternatively	2
Technagarpara, Joydebpur	4	1884;4200;1025; 2820	Alternatively & simulteneously	1 to 2
Itahata, Joydebpur	4	2000;1992;1180; 1025	Alternatively	2
Salna Maiddapara, Joydebpur	3	1379;2115;1923	Alternatively	1
Dakhsin Khan 10, Gulsan	2	2250;1660	Alternatively	1
Dakhsin Khan 8, Gulsan	4	1280;1223;2500; 2180	Alternatively	1
Amlabo 1, Rupganj	3	1075;1223;1100	Alternatively	2
Amlabo 2, Rupganj	4	1674;1205; 782; 1152	Alternatively	2
Paragaon 2, Rupganj	3	1000;1450;1215	Alternatively & simulteneously	-

TABLE - 9 (Contd.)

Name of the Deep Tubewell site	Method of canals of fed at water a time diversion	Measuring/ control structures	Distri-bution basis
Chapain, Savar	Cutting the side & making an opening	None	Serial
South Dariapur, Savar	Cutting the side & making an opening	None	No defin-ite system
Rajasan 3, Savar	Cutting the side & making an opening	None	No defin-ite system
Rajasan 4, Savar	Cutting the side & making an opening	None	No defin-ite system
Baralia, Savar	Cutting the side & making an opening	None	Rotation
Sonalia, Savar	Cutting the side & making an opening	None	Serial
Badda, Savar	Cutting the side & making an opening	None	Serial
Aukhpara, Savar	Cutting the side & making an opening	None	Serial
West Bamna, Islampur	Cutting the side & making an opening	None	Serial
Belgacha, Islampur	Cutting the side & making an opening	None	Serial
Gazipura, Joydebpur	Cutting the side & making an opening	None	Mixed
Technagarpara, Joydebpur	Cutting the side & making an opening	None	No defin-ite system
Itahata, Joydebpur	Cutting the side & making an opening	None	No defin -ite system
Salna Maiddapara, Joydebpur	Cutting the side & making an opening	None	No defin-ite system
Dakhsin Khan 10, Joydebpur	Cutting the side & making an opening	None	Rotation
Dakhsin Khan 8, Joydebpur	Cutting the side & making an opening	None	No defin-ite system
Amlabo 1, Rupganj	Cutting the side & making an opening	None	No defin-ite system
Amlabo 2, Rupganj	Cutting the side & making an opening	None	Rotation
Paragaon 2, Rupganj	Cutting the side & making an opening	None	Serial

TABLE - 9 (Contd.)

Name of the Deep Tubewell site	Mode of Application	Average frequency of irrigation(days)	Total hours of pumping during the irrigation season.
Chapain, Savar	Intermittent	5 to 7	1447
South Dariapur, Savar	Continuous	-	610
Rajasan 3, Savar	Intermittent	2 to 3	397
Rajasan 4, Savar	Intermittent	2 to 3	220
Baralia, Savar	Intermittent	7 to 10	2144
Sonalia, Savar	Intermittent	5 to 6	500
Badda, Savar	Intermittent	4 to 5	745
Aukhpara, Savar	Intermittent	4 to 5	1200
West Bamna, Islampur	Intermittent	3 to 5	862
Belgacha, Islampur	Intermittent	3 to 5	Not available
Gazipura, Joydebpur	Intermittent	5 to 7	1372
Technagarpara, Joydebpur	Intermittent	7 to 10	1790
Itahata, Joydebpur	Intermittent	5 to 7	1139
Salna Maiddapara, Joydebpur	Intermittent	3 to 5	1400
Dakhsin Khan 10, Gulsan	Intermittent	5 to 10	378
Dakhsin Khan 8 Gulsan	Intermittent	7 to 15	372
Amlabo 1, Rupganj	Intermittent	2 to 4	Not available
Amlabo 2, Rupganj	Intermittent	2 to 4	Not available
Paragaon 2, Rupganj	Intermittent	3 to 5	Not available

TABLE - 10

SOCIO-ECONOMIC INFORMATIONS

Name of the Deep Tubewell site	Formation of irrigation society	Manager		
		Education	Occupation	Remuneration
Chapain, Savar	Through initiative of local people	Below secondary	Agriculture	Voluntary
South Dariapur, Savar	Through initiative of local people	Above secondary	Business and Agriculture	Voluntary
Rajasan 3, Savar	Through Institutional initiative	Below secondary	Agriculture	Voluntary
Rajasan 4, Savar	Through Institutional initiative	Below secondary	Agriculture	Voluntary
Baralia, Savar	Initiative of local people	Below secondary	Agriculture	Voluntary
Sonalia, Savar	Initiative of local people	Above secondary	Agriculture & Service	Voluntary
Budda, Savar	Initiative of local people	Below secondary	Agriculture	Voluntary
Aukhpara, Savar	Initiative of local people	Below secondary	Agriculture	Voluntary
West Bamna, Islampur	Initiative of local people	Secondary	Agriculture & Buisness	Voluntary
Belgacha, Islampur	Initiative of local people	Below secondary	Agriculture & Buisness	Takes remuneration
Gazipura, Joydebpur	Initiative of local people	Secondary	Agriculture & Buisness	Voluntary
Technagarpara, Joydebpur	Initiative of local people	Below secondary	Agriculture	Voluntary
Itahata, Joydebpur	Initiative of local people	Below secondary	Agriculture	Voluntary

Source: Interviews with Group Manager and local farmers.

TABLE - 10 (Contd.)

Name of the Deep Tubewell site	Formation of irrigation society	Manager		
		Education	Occupation	Remuneration
Salna Maddiapara, Joydebpur	Initiative of local people	Below secondary	Agriculture	Voluntary
Dakhsin Khan 10, Gulsan	Initiative of local people	Below secondary	Agriculture	Voluntary
Dakhsin Khan 8, Gulsan	Initiative of local people	Secondary	Agriculture	Voluntary
Amlabo 1, Rupganj	Initiative of local people	Below secondary	Agriculture & Buisness	Takes remuneration
Amlabo 2, Rupganj	Initiative of local people	Below secondary	Agriculture & Buisness	Takes remuneration
Paragaon 2, Rupganj	Through individual initiative	Below secondary	Agriculture	Takes remuneration

Source: Interviews with Group Manager and local farmers.

TABLE - 10 (Contd.)

Name of the Deep Tubewell site	Site selection	Availability of fuel	
		At control price(%)	At open market price (%)
Chapain,Savar	Consensus opinion	50	50
South Dariapur,Savar	Power structure influence	-	-
Rajasan 3,Savar	Consensus opinion	35	65
Rajasan 4,Savar	Consensus opinion	30	70
Baralia,Savar	Consensus opinion	-	-
Sonalia,Savar	Consensus opinion	0	100
Budda,Savar	Consensus opinion	-	-
Aukhpara,Savar	Consensus opinion	15	85
West Bamna,Islampur	Consensus opinion	75	25
Belgacha,Islampur	Consensus opinion	25	75
Gazipura,Joydebpur	Consensus opinion	67	33
Technagarpara,Joydebpur	Consensus opinion	67	33
Itahata,Joydebpur	Consensus opinion	-	-
Salna Maddiapara, Joydebpur	Consensus opinion	57	43
Dakhsinkhan 10,Gulsan	Consensus opinion	0	100
Dakhsinkhan 8,Gulsan	Consensus opinion	0	100
Amlabo 1,Rupganj	Consensus opinion	-	-
Amlabo 2,Rupganj	Consensus opinion	0	100
Paragaon 2,Rupganj	Consensus opinion	0	100

Source: Interviews with Group Manager and local farmers.

TABLE - 11

LAND HOLDING OF THE FARMERS

Name of the Deep Tubewell site	Total No.of farmers in the scheme	Less than 1 acre (% of total)	1 to 2 acres (% of total)	More than 2 acres (% of total)
Chapain, Savar	35	74	20	6
South Dariapur, Savar	17	100	0	0
Rajasan 3, Savar	16	68	31.4	0.6
Rajasan 4, Savar	15	73	26.34	0.66
Baralia, Savar	128	87	10.0	3.0
Sonalia, Savar	110	90	10.0	0
Badda, Savar	42	33	48	19.0
Aukhpara, Savar	35	51	35	14.0
West Bamna, Islampur				
Belgacha, Islampur				
Gazipura, Joydebpur	124	76	18.5	5.5
Technagarpara, Joydebpur	45	44	40.0	16.0
Itahata, Joydebpur	63	78	16.0	6.0
Salna Maiddapara, Joydebpur	72	90.7	8.0	1.3
Dakhsin Khan 10, Gulsan	65	87	9.0	4.0
Dakhsin Khan 8, Gulsan	95	80	13.0	7.0
Almabo 1, Rupganj	80	70	25.0	5.0
Amlabo 2, Rupganj	75	83	13.0	4.0
Paragaon 2, Rupganj	79	92	7.0	1.0

Source: Field investigations.

TABLE - 12

WATER CHARGE AND YIELD

Name of the Deep Tubewell site	Water charge		Average yield (mds/acre)
	Basis	Total for the season (Tk.per acre)	
Chapain, Savar	Mixed	500	60
South Dariapur, Savar	Area	460	58
Rajasan 3, Savar	Mixed	570	45 to 57
Rajasan 4, Savar	Mixed	570	45 to 57
Baralia, Savar	Area	200	50
Sonalia, Savar	Mixed	300	54
Badda, Savar	Mixed	860	46
Aukhpara, Savar	Mixed	730	50
West Bamna, Islampur	Area	500	60 to 70
Belgacha, Islampur	Area	425	50 to 70
Gazipura, Joydebpur	Area	350	70
Technagarpara, Joydebpur	Mixed	375	60
Itahata, Joydebpur	Area	328	52
Salna Maiddapara, Joydebpur	Area	400	43
Dakhsin Khan 10, Gulsan	Area	515	54
Dakhsin Khan 8, Gulsan	Area	485	40
Amlabo 1, Rupganj	Area	330	70
Amlabo 2, Rupganj	Area	500	50
Paragaon 2, Rupganj	Area	566	50

Source: Interviews with local farmers.

APPENDIX - B

FIGURES

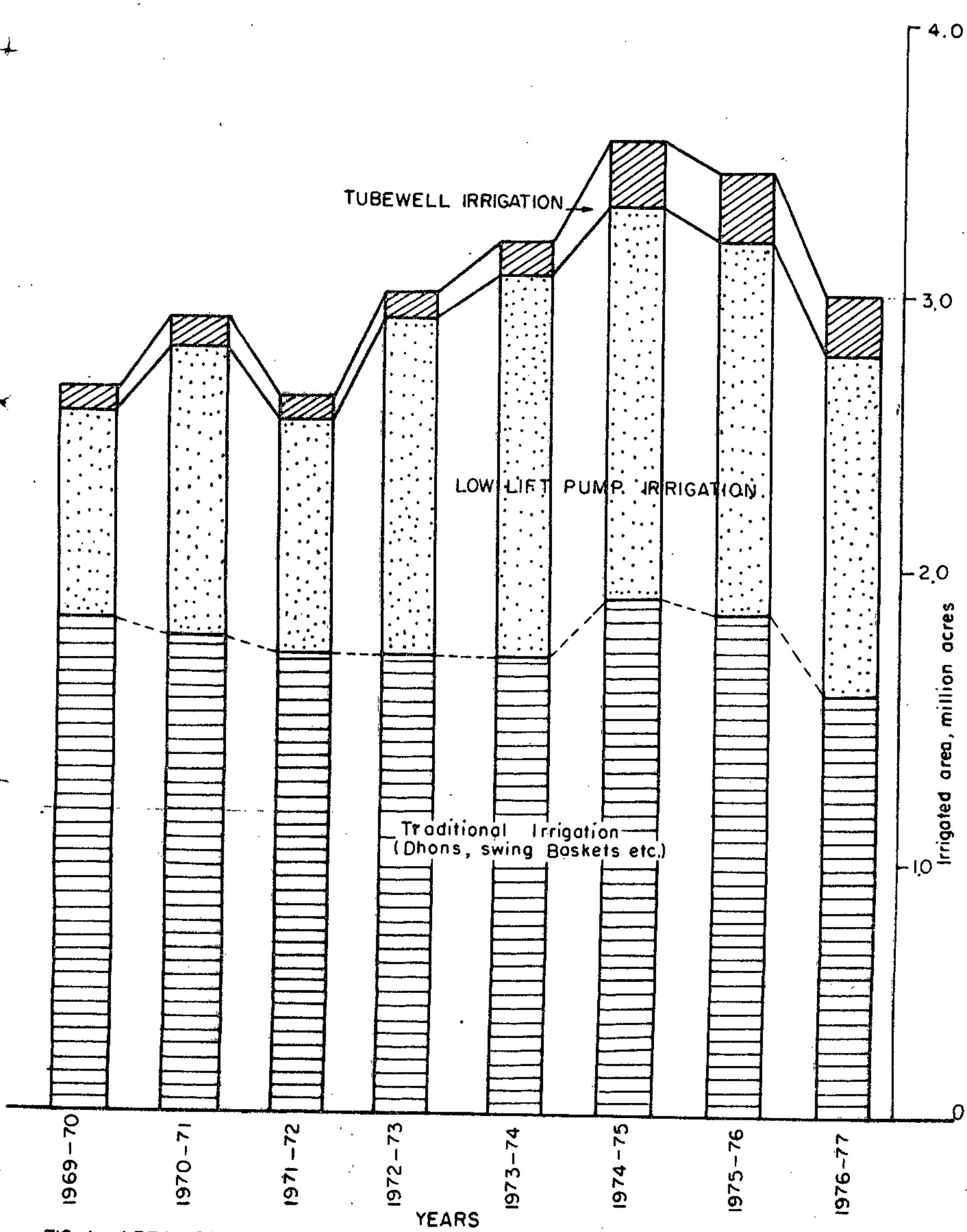


FIG. 1 AREA IRRIGATED UNDER DIFFERENT MEANS IN BANGLADESH
(SOURCE OF DATA: BBS)

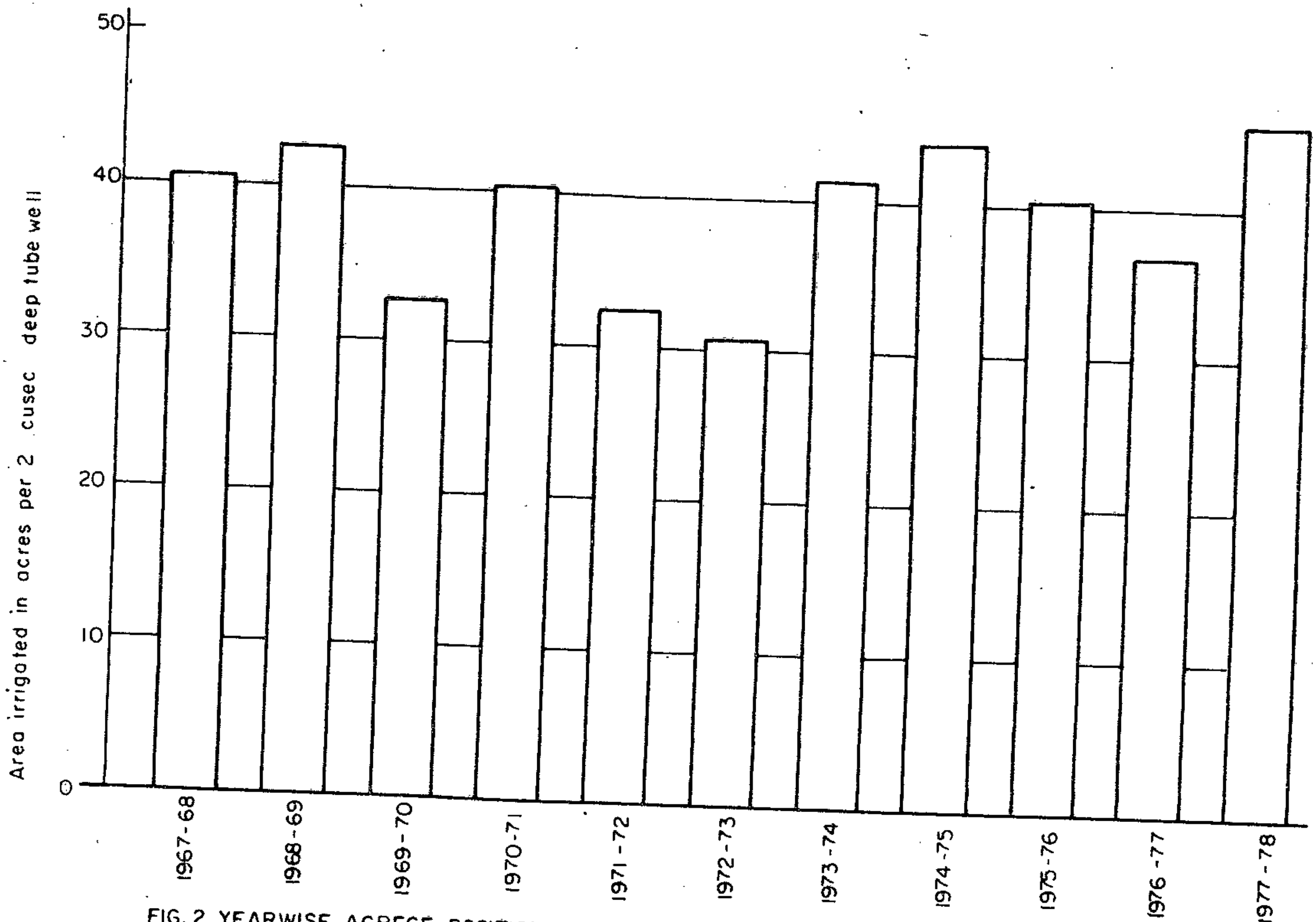


FIG. 2 YEARWISE ACREGE POSITION OF DEEP TUBEWELL
(SOURCE OF DATA: BADC)

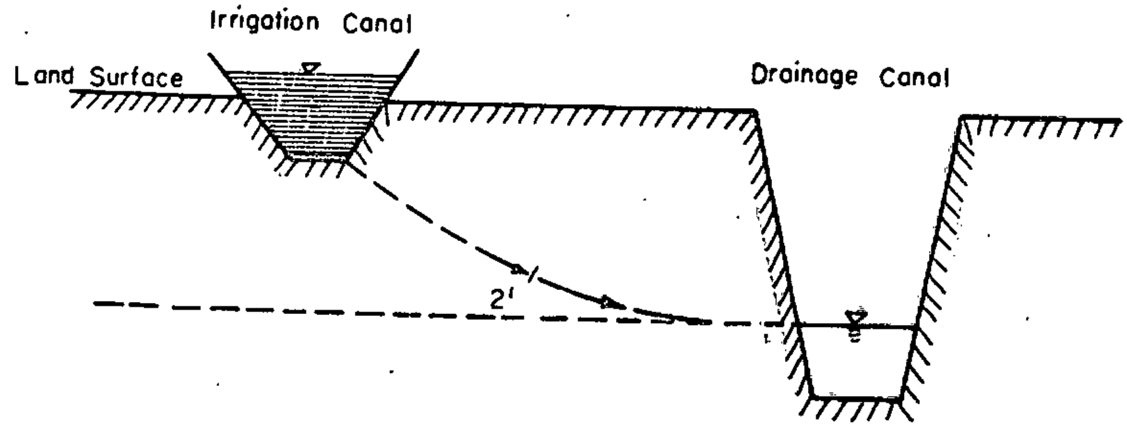


FIG. 3b IRRIGATED FIELD GROUNWATER TABLE WITHOUT (1) AND WITH (2) CANAL SEEPAGE.

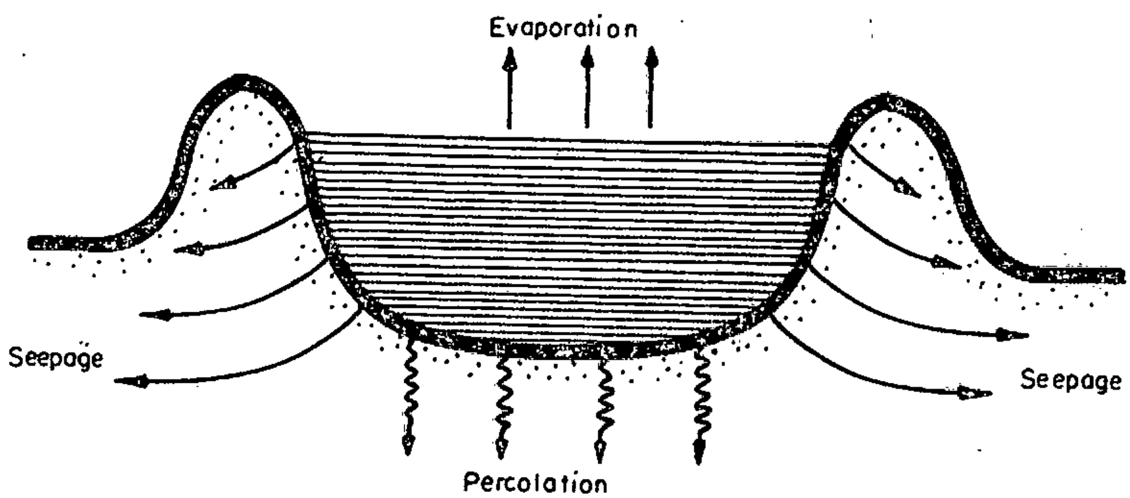


FIG. 3a LOSSES FROM IRRIGATION CANAL

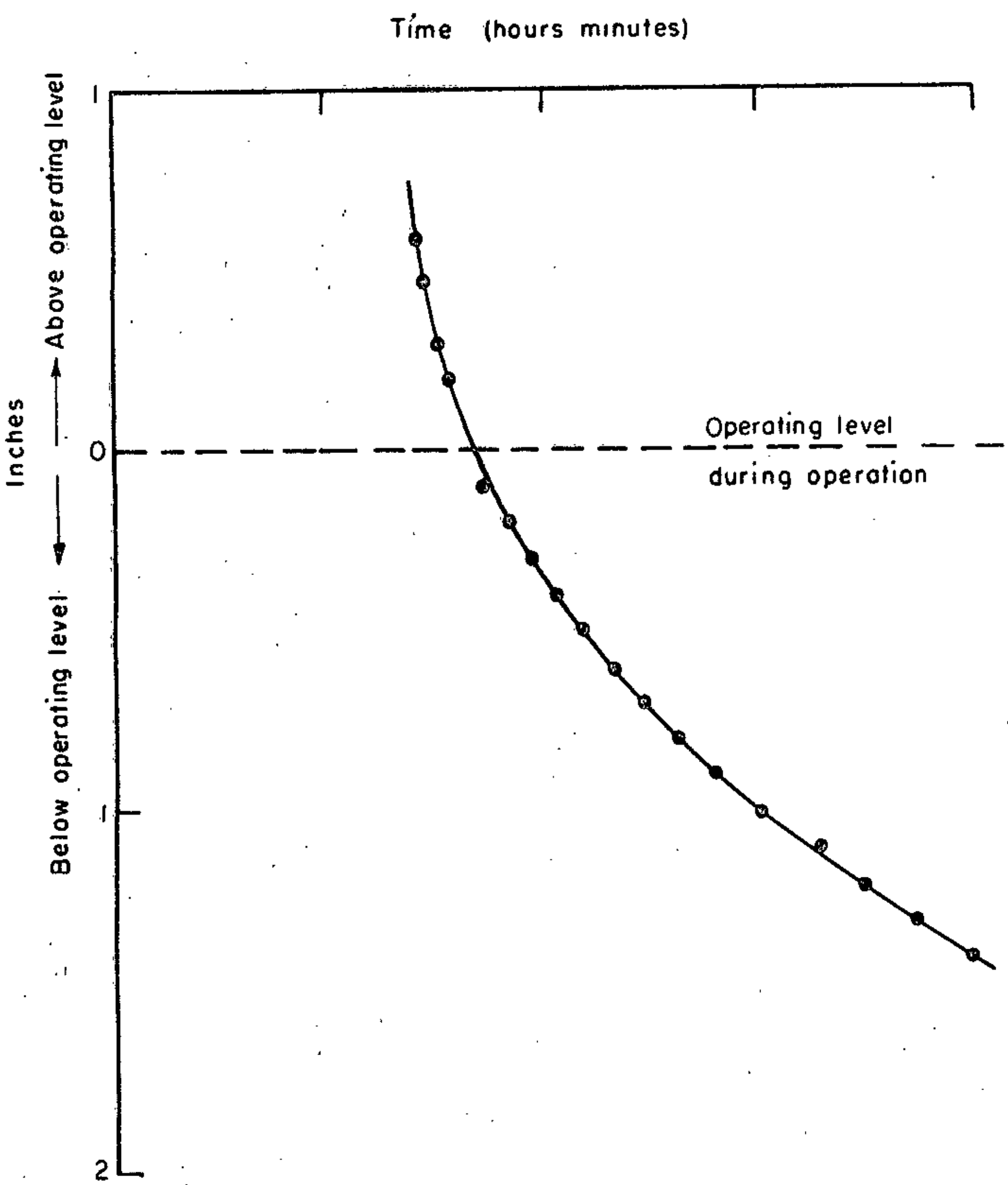


FIG. 4 RECESSION RATE OF THE WATER SURFACE IN THE PONDING TEST SECTION

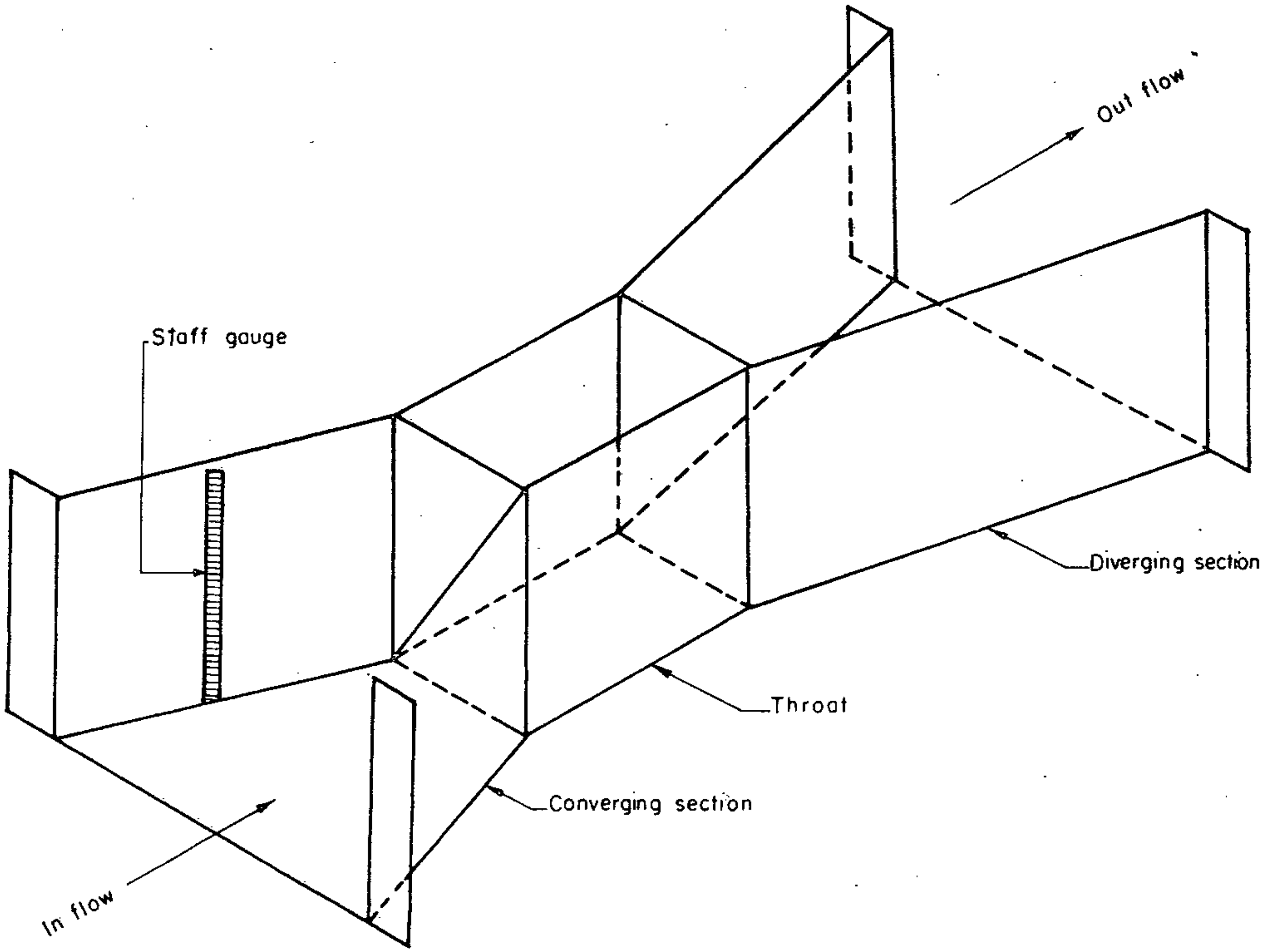


FIG. 5 PARSHALL FLUME

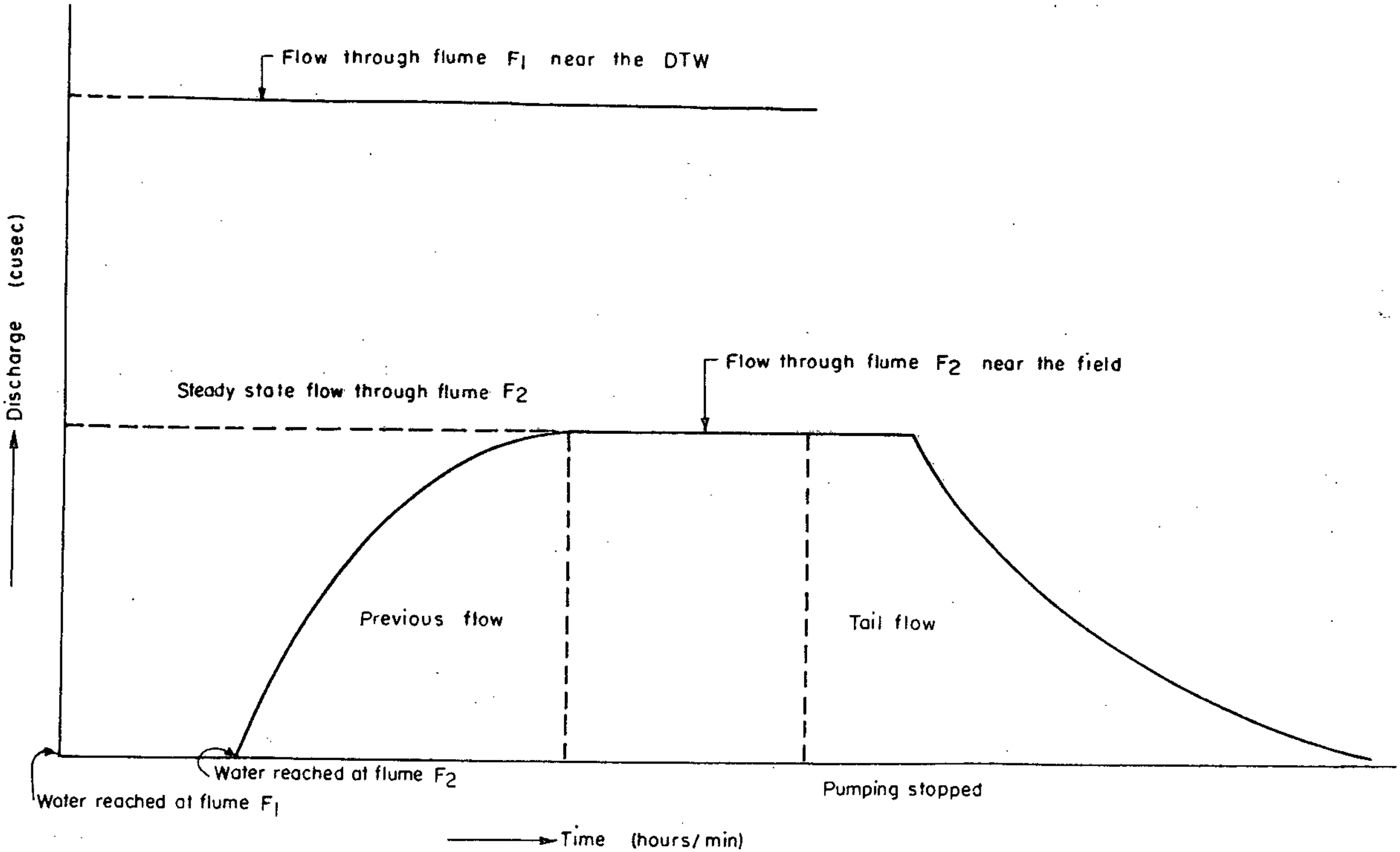


FIG. 6 FLOW THROUGH FLUMES F_1 AND F_2 PLACED NEAR THE TUBEWELL AND FIELD RESPECTIVELY

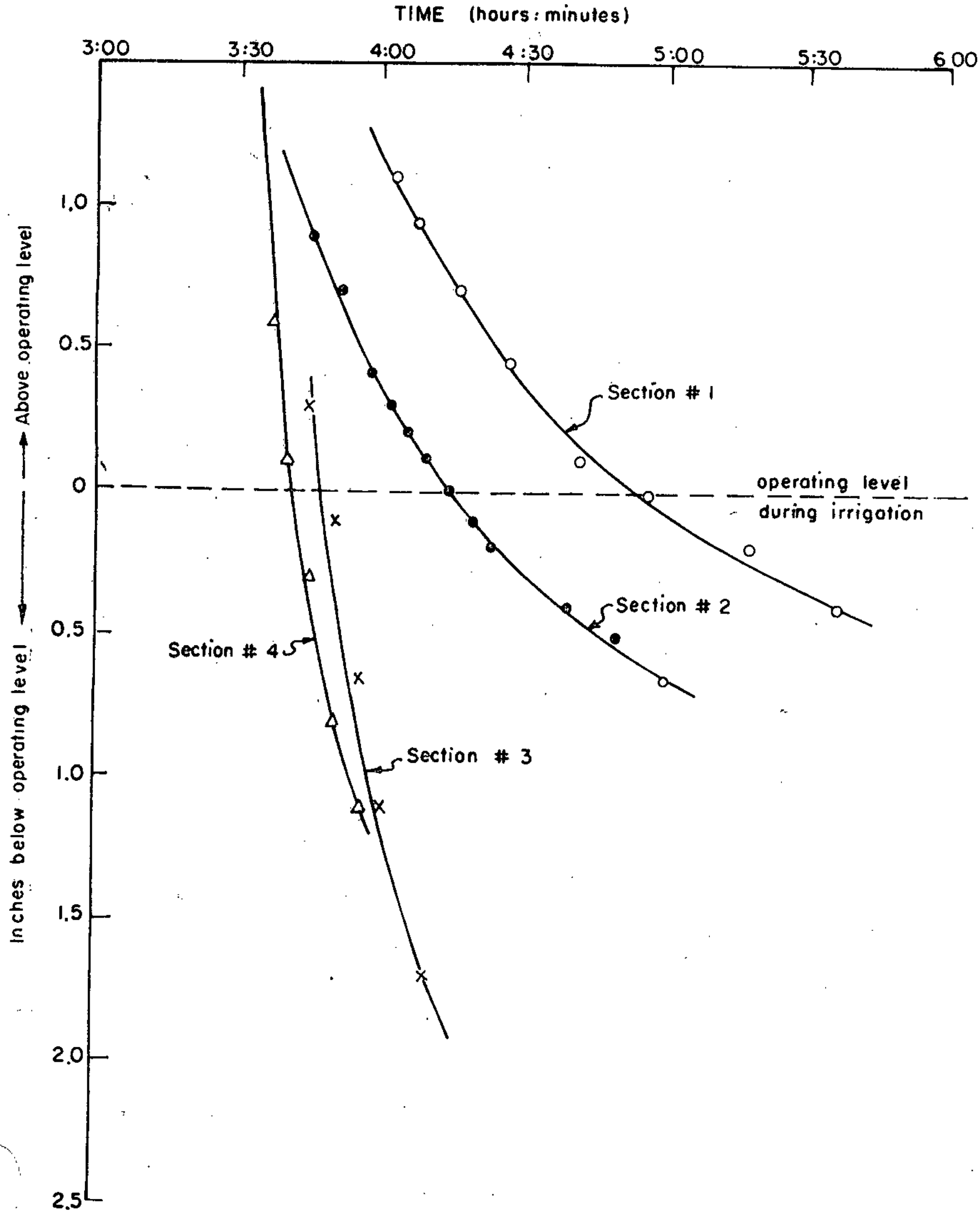


FIG. 7 RECESSION RATE OF WATER SURFACE IN THE FOUR TEST SECTIONS OF CANAL 2, WEST BAMNA, ISLAMPUR

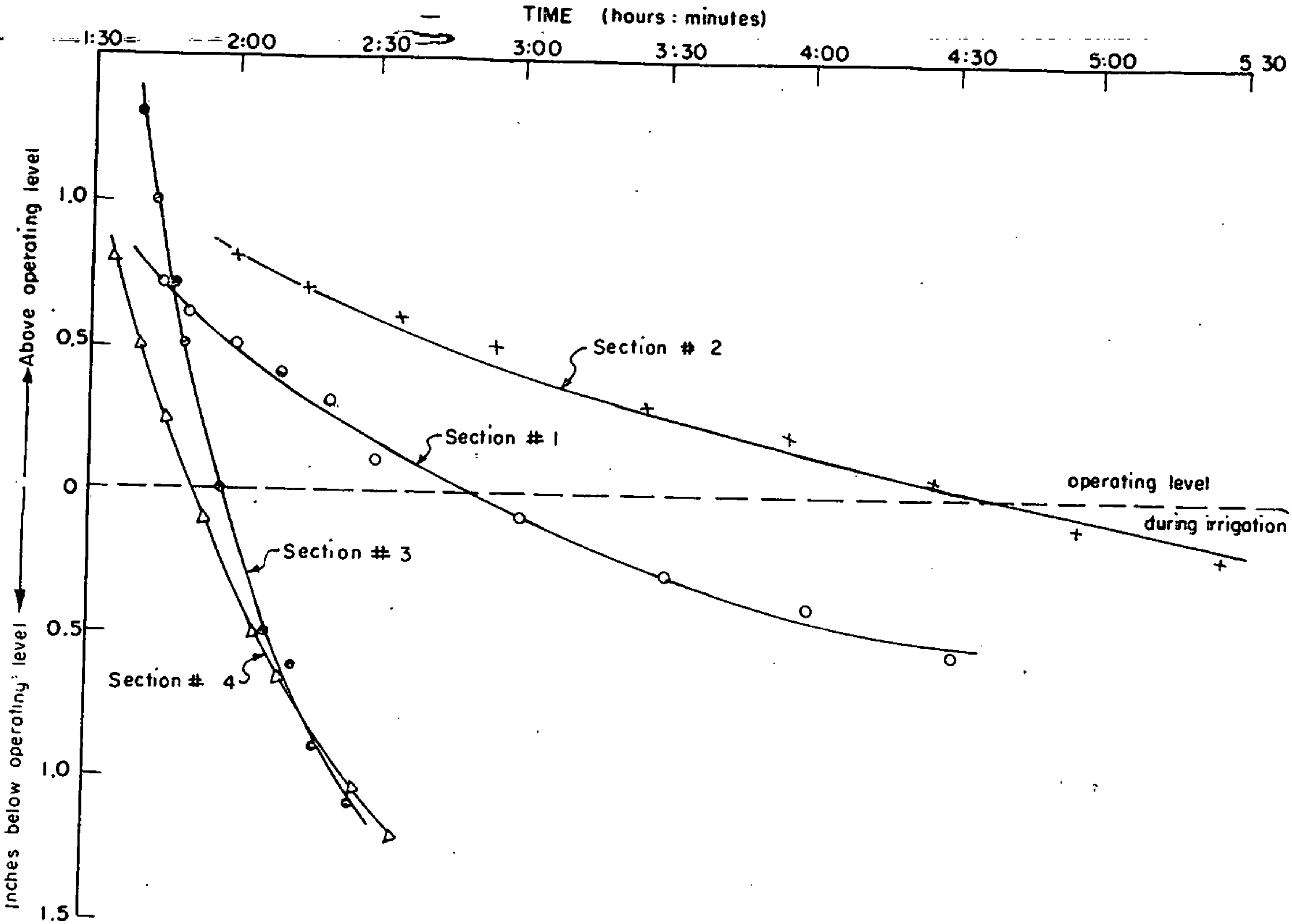


FIG. 8 RECESSION RATE OF WATER SURFACE IN THE FOUR TEST SECTIONS OF CANAL I, BELGACHA, ISLAMPUR

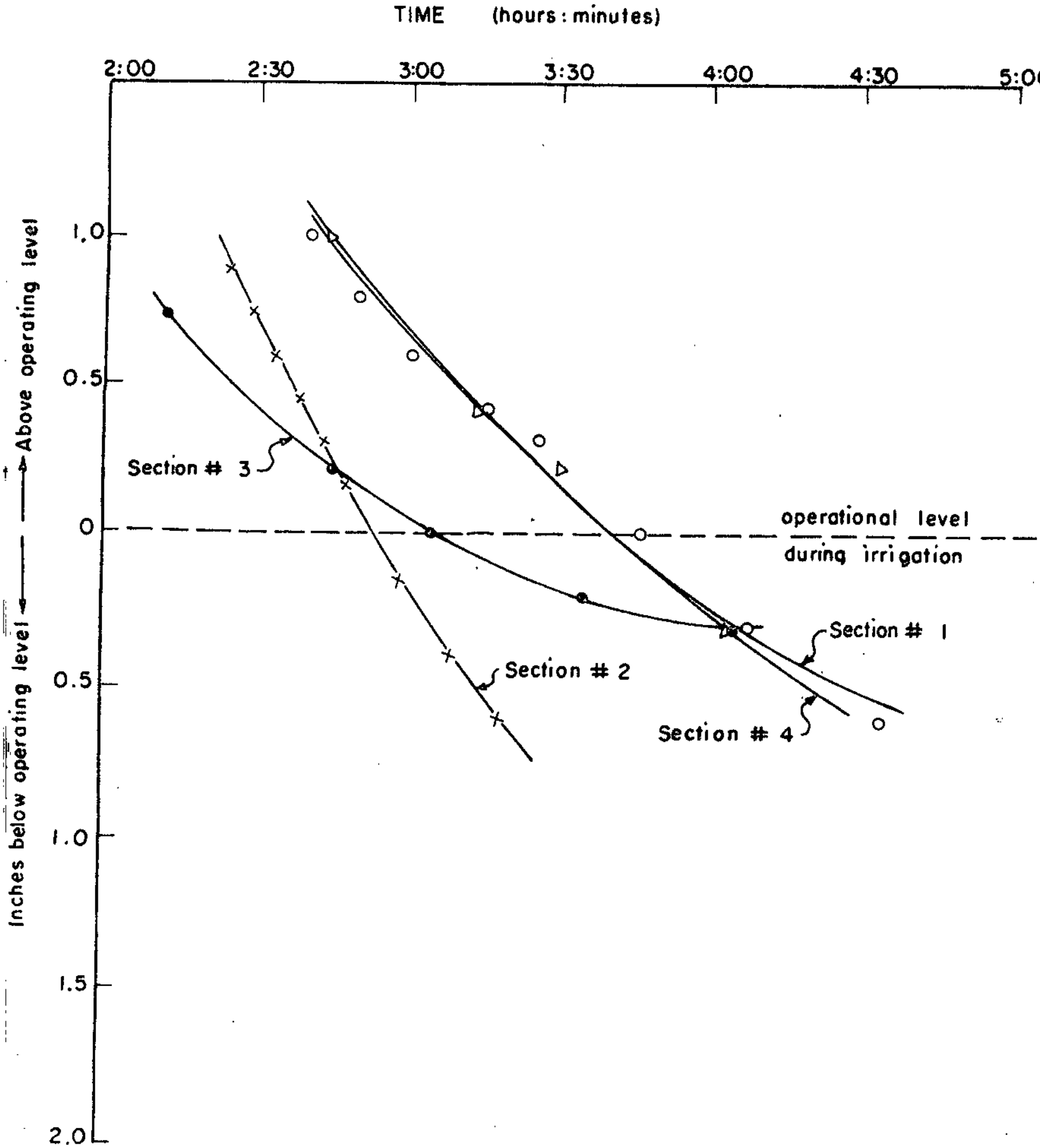


FIG. 9 RECESSION RATE OF WATER SURFACE IN THE FOUR TEST SECTIONS OF CANAL 3, BELGACHA, ISLAMPUR

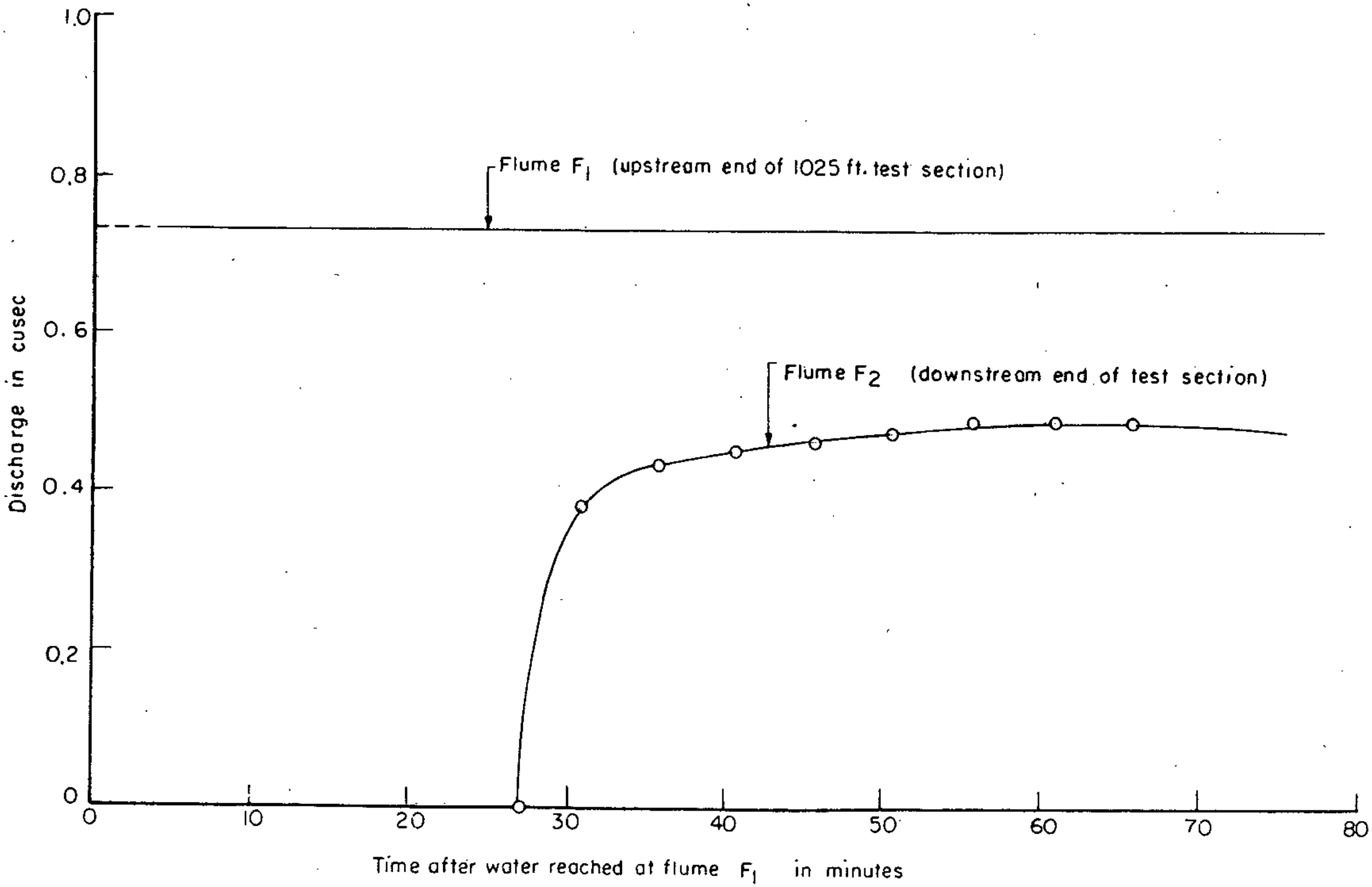


FIG. 10 FLOW MEASURED AT FLUMES ON CANAL I, CHAPAIN, SAVAR

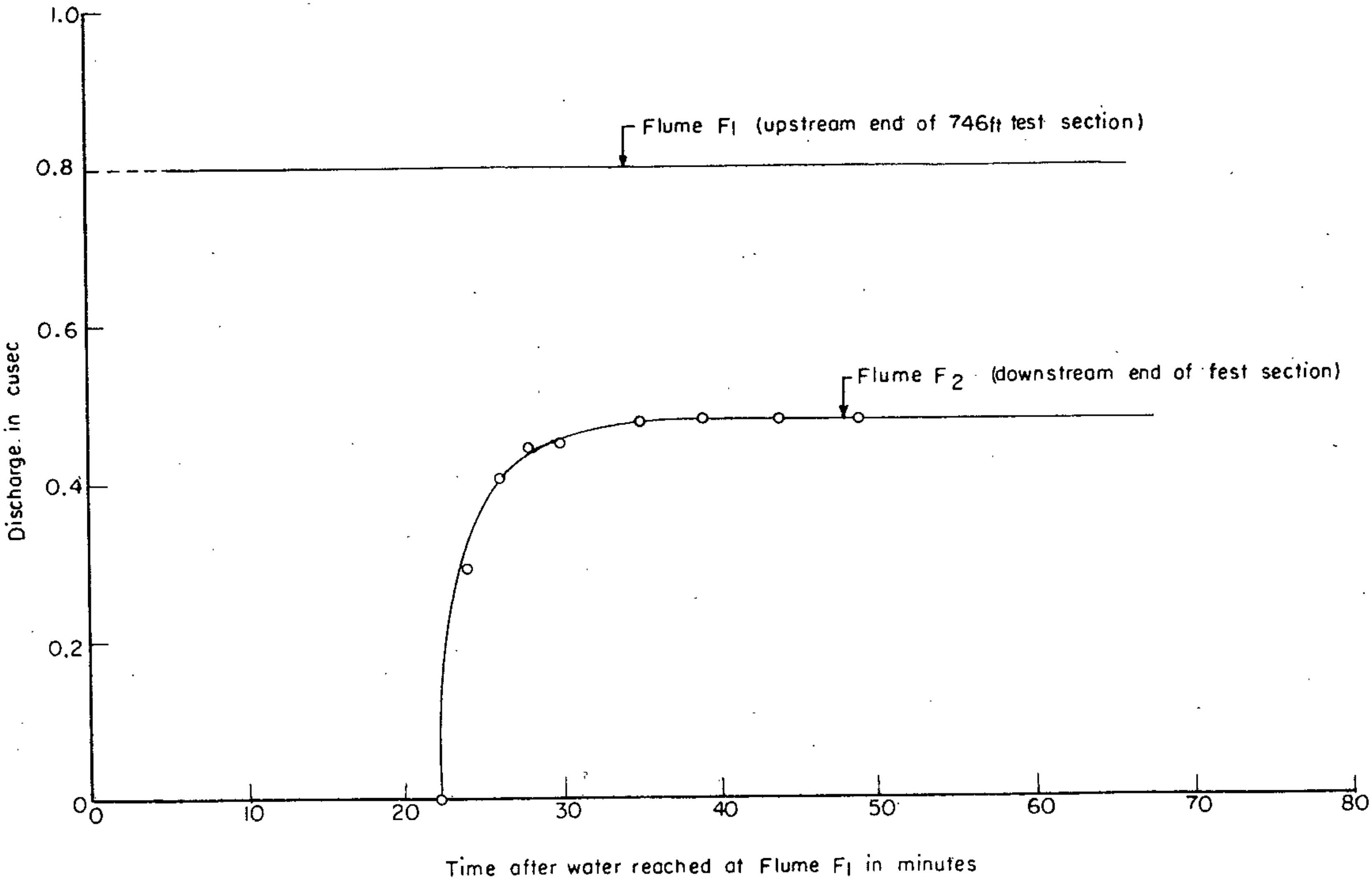


FIG. 11 FLOW MEASURED AT FLUMES ON CANAL 2, CHAPAIN, SAVAR

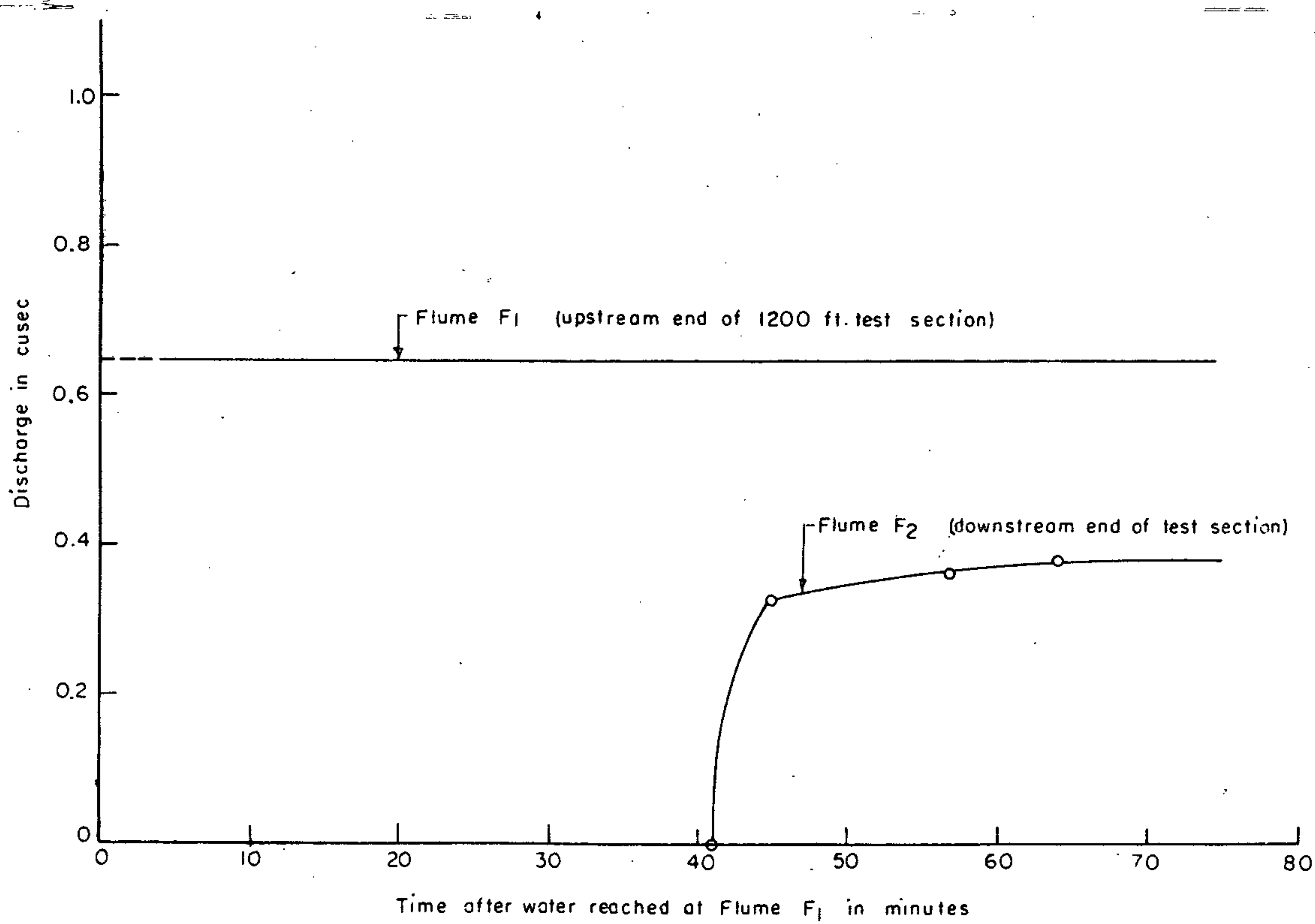


FIG. 12 FLOW MEASURED AT FLUMES ON CANAL 3, CHAPAIN, SAVAR

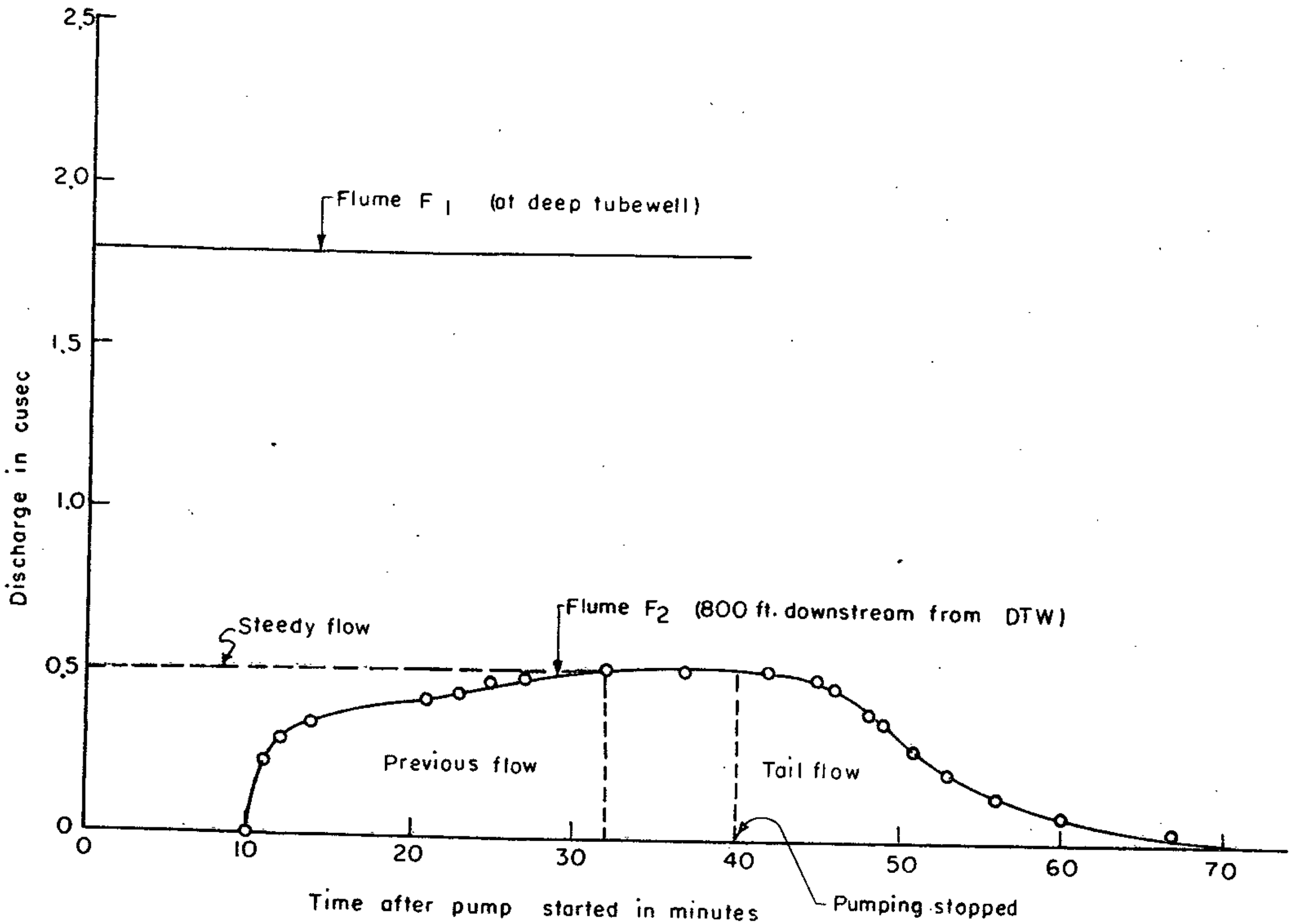


FIG.13 FLOW MEASURED AT FLUMES ON CANAL I, SOUTH DARIAPUR, SAVAR

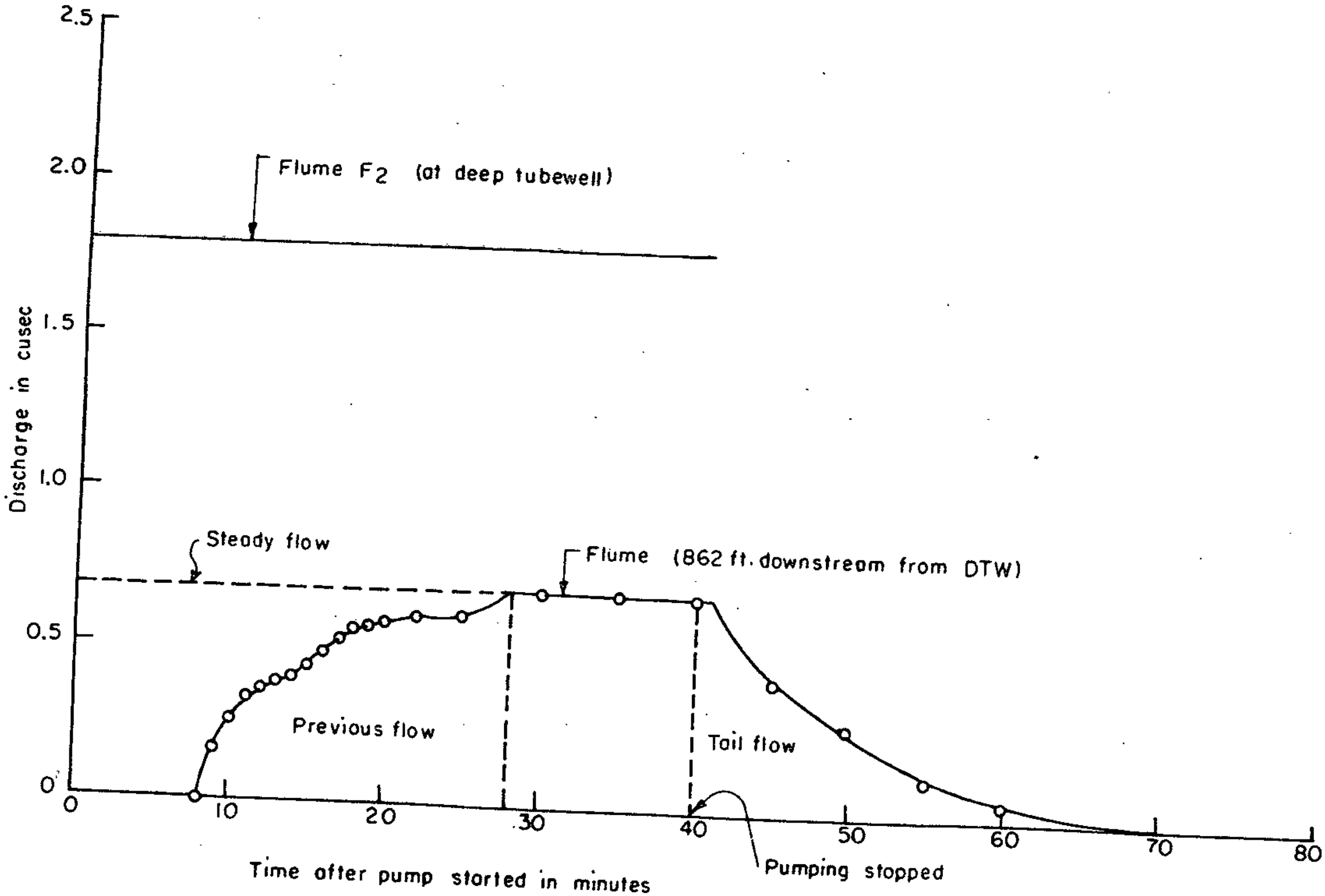


FIG. 14 FLOW MEASURED AT FLUMES ON CANAL 2 SOUTH DARIAPUR, SAVAR

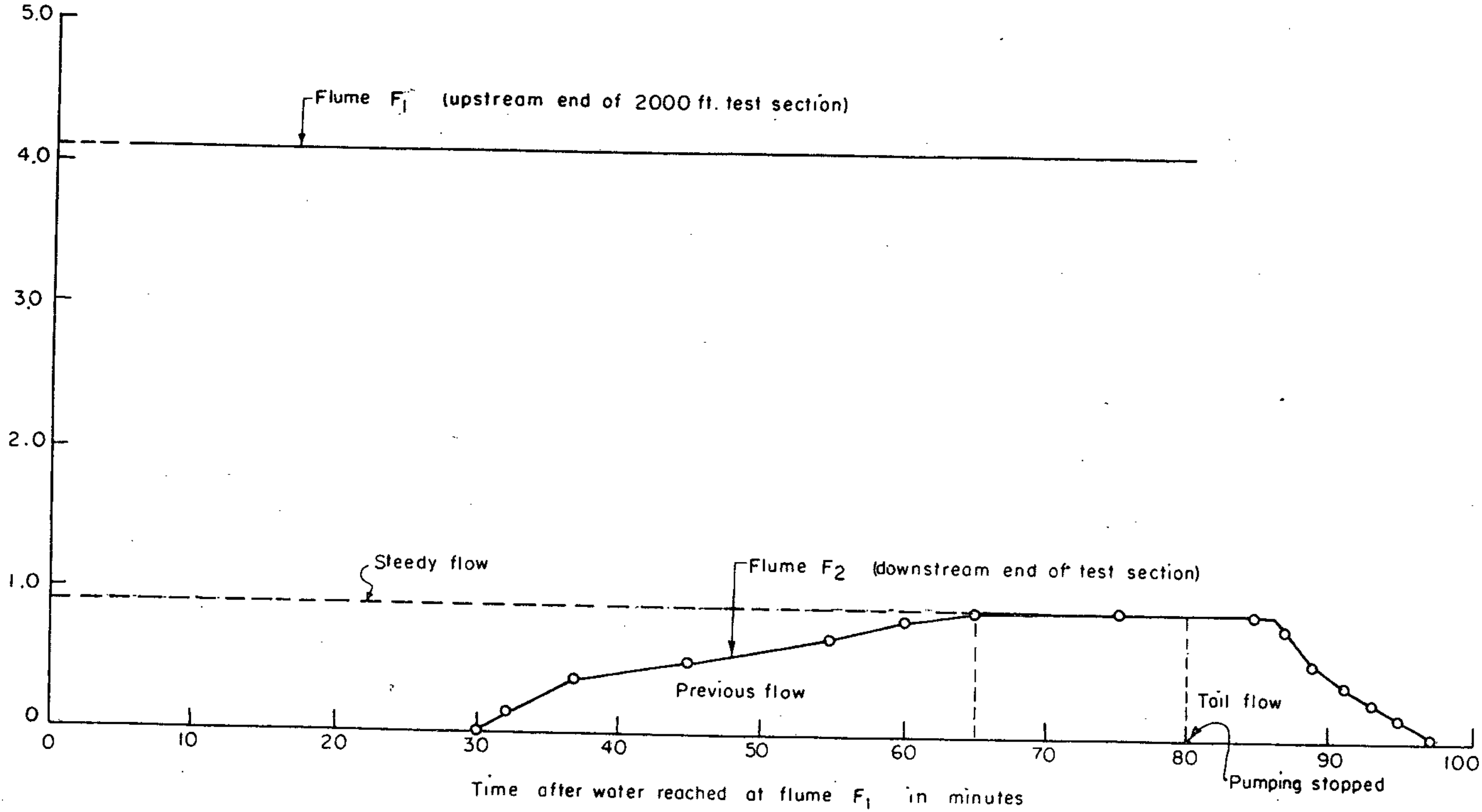


FIG. 15.5 FLOW MEASURED AT FLUMES ON CANAL I, ITAHATA, JOYDEBPUR

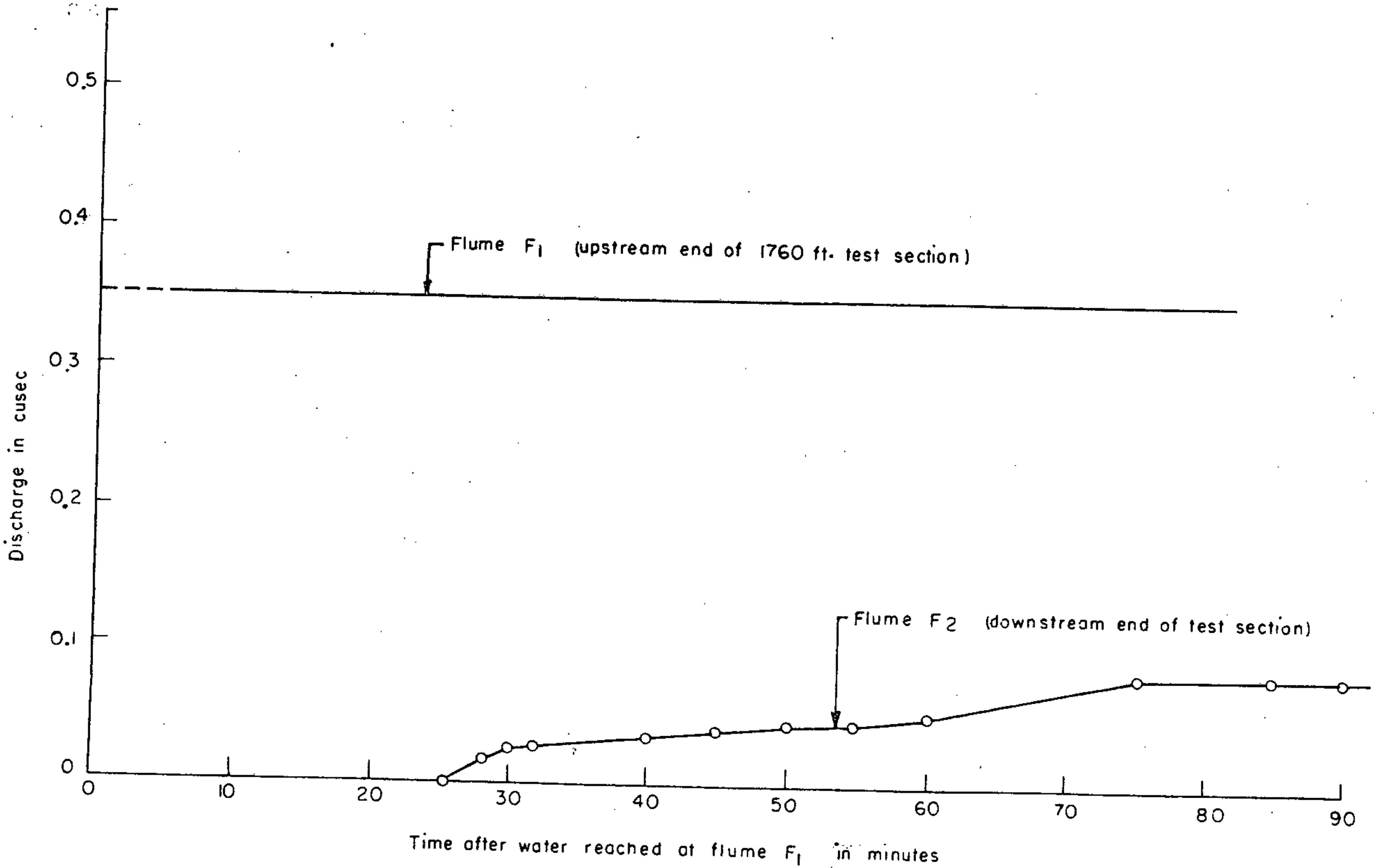


FIG. 16b FLOW MEASURED AT FLUMES ON CANAL 2, ITAHATA, JOYDEBPUR

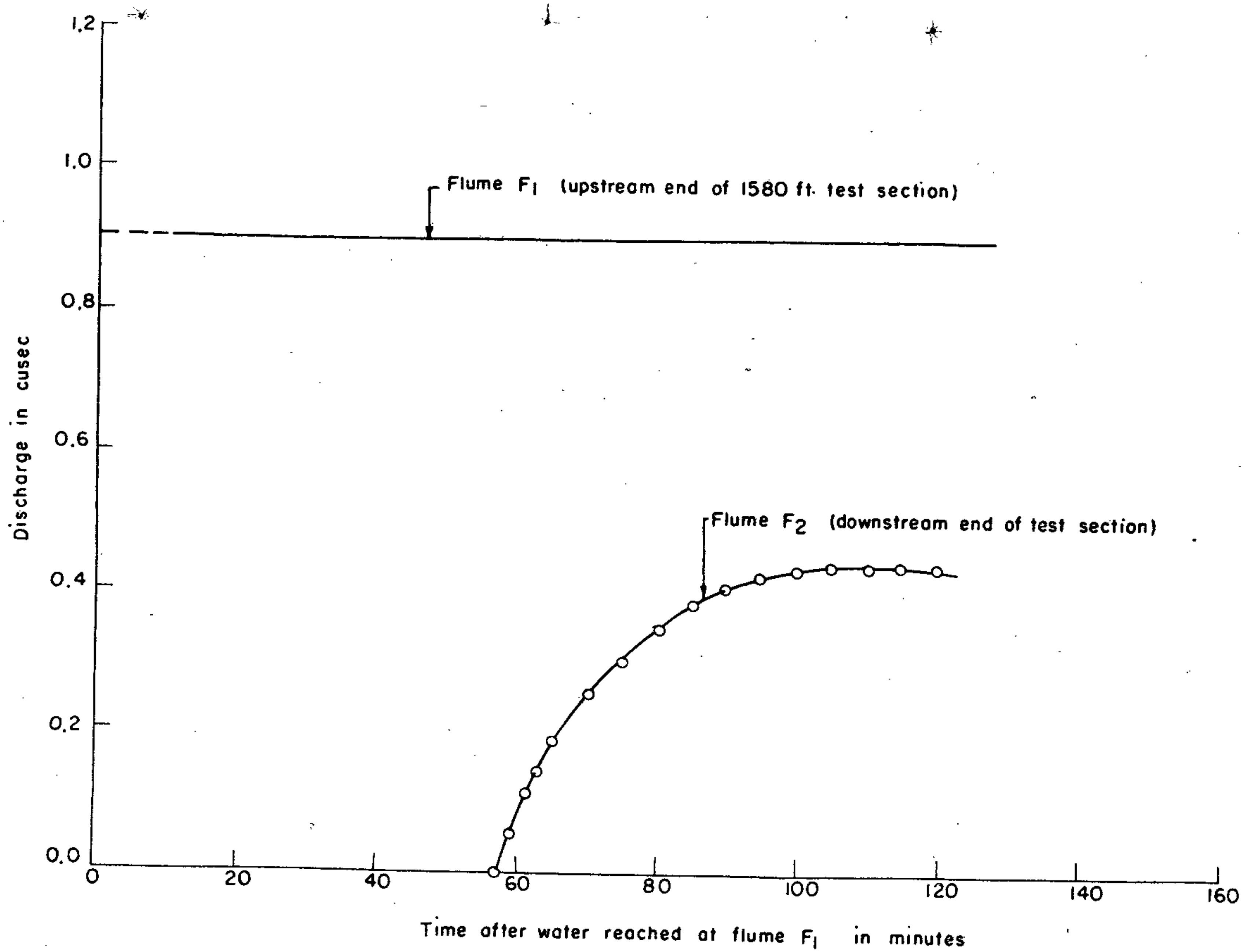


FIG. 17 FLOW MEASURED AT FLUMES ON CANAL I DAKHSIN KHAN 10, GULSHAN

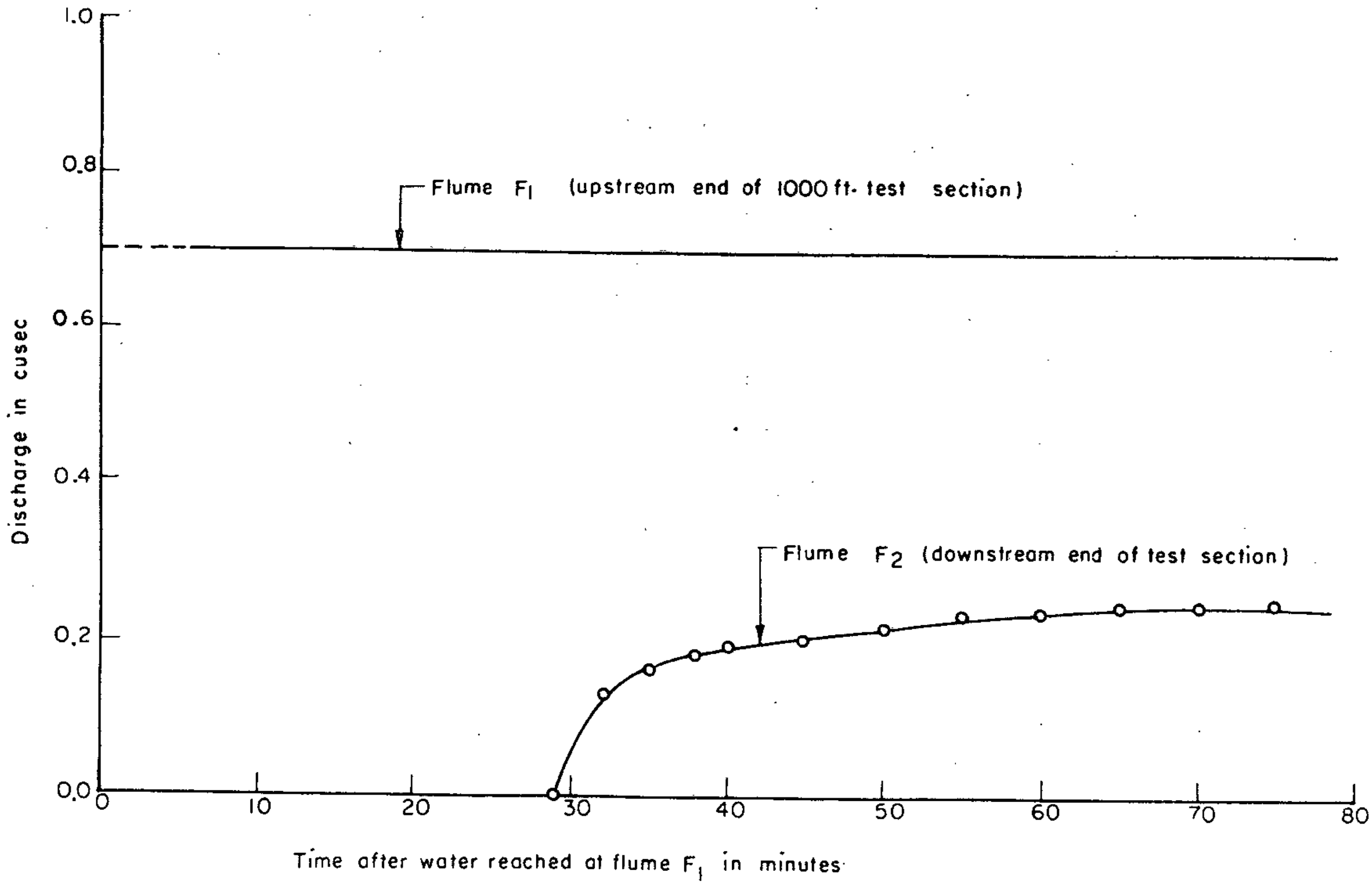


FIG. 18 FLOW MEASURED AT FLUMES ON CANAL 1, AMLABO 1, RUPGANJ

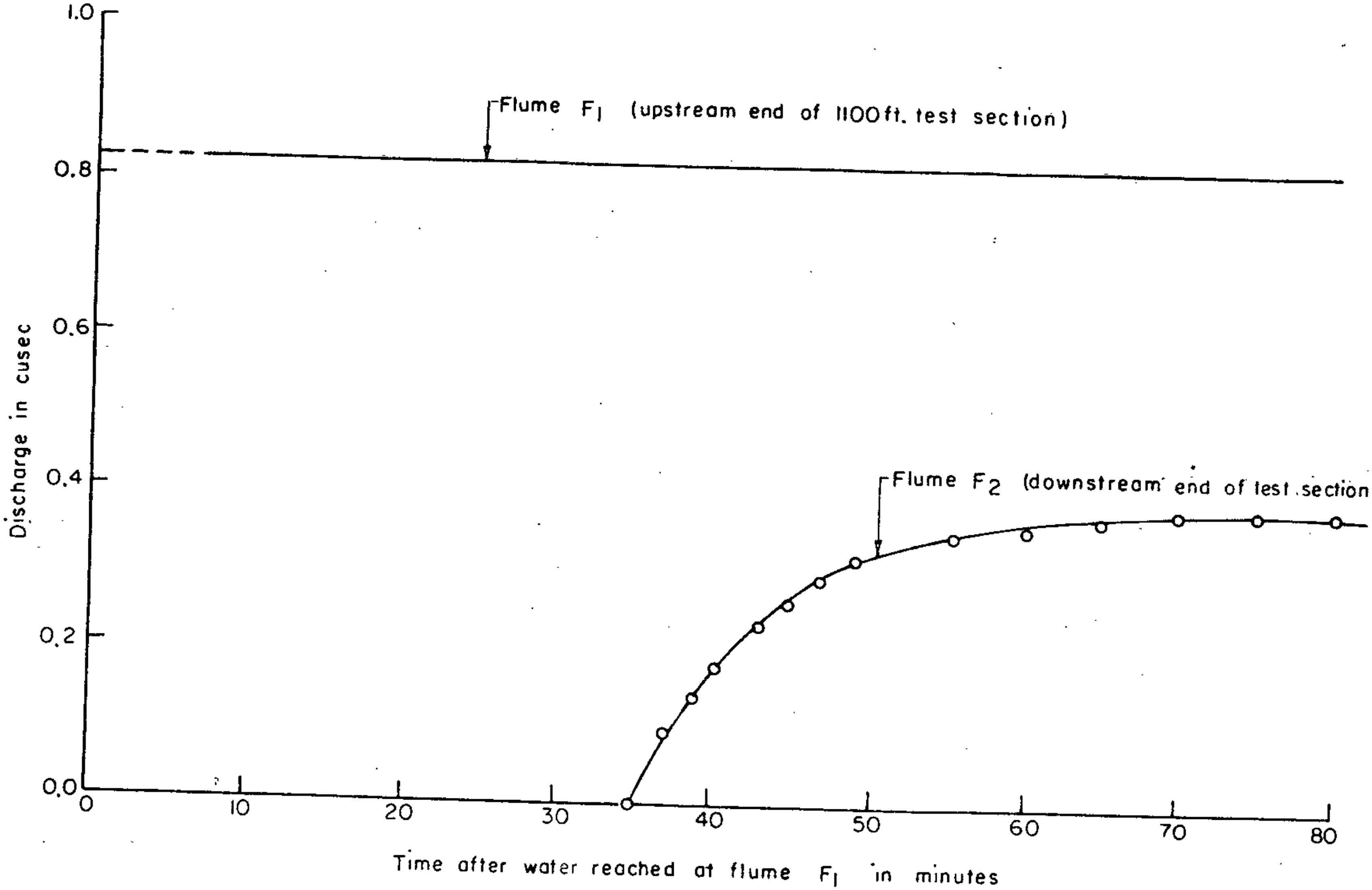


FIG. 19 FLOW MEASURED AT FLUMES ON CANAL 1, AMLABO 2, RUPGANJ

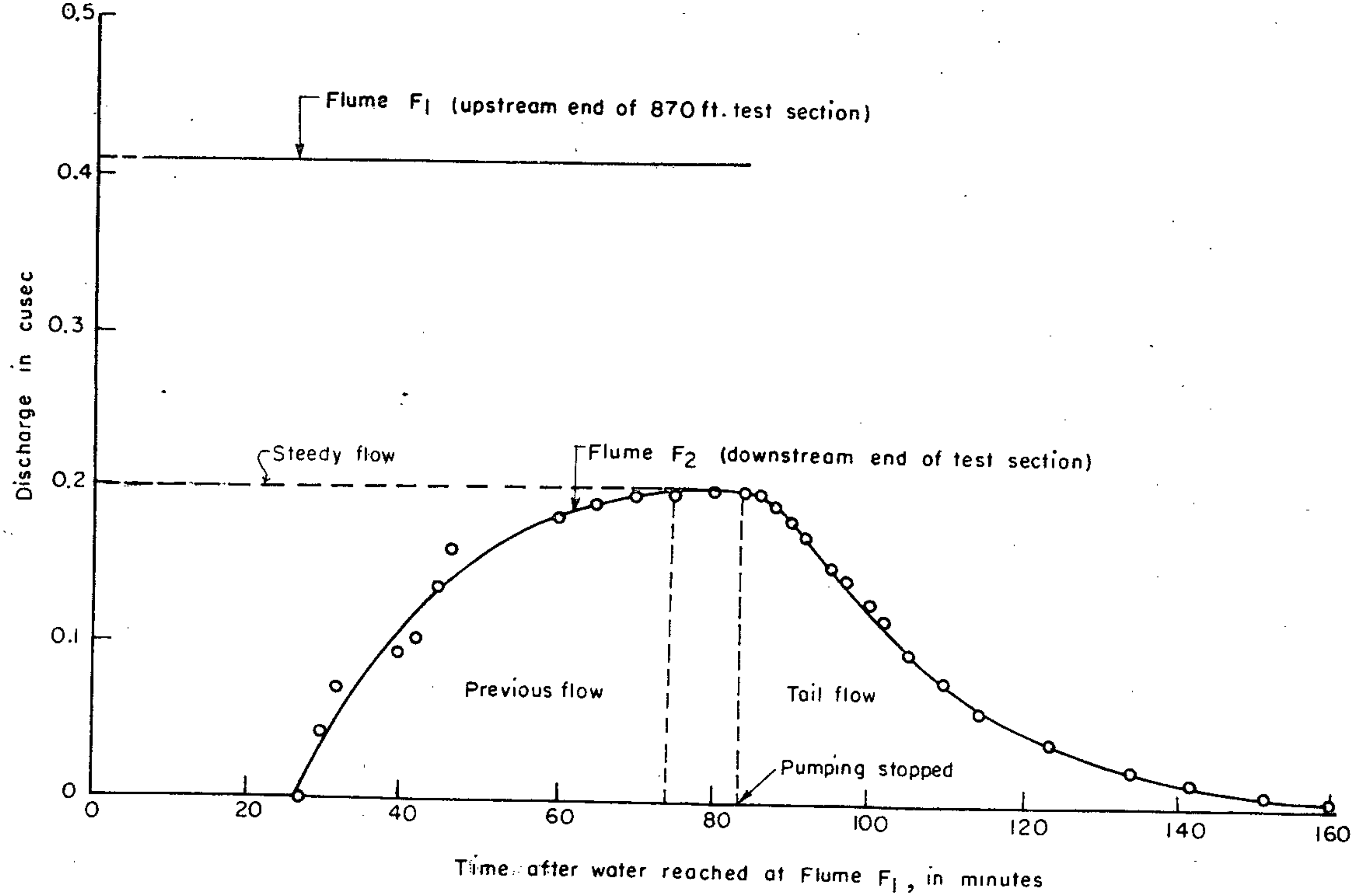
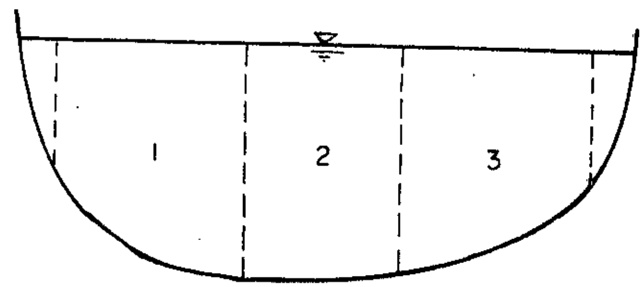


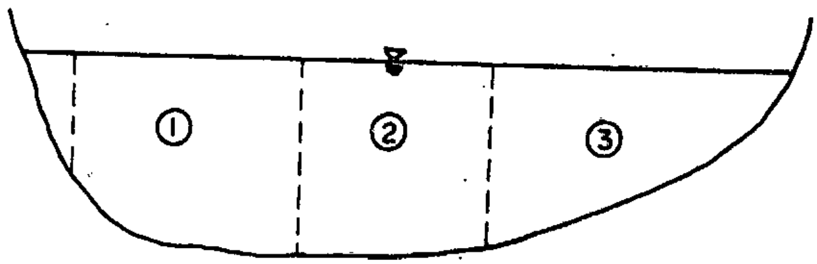
FIG. 20 FLOW MEASURED AT FLUMES ON CANAL 2, AMLABO 2, RUPGANJ



SECTION AT 2722 FT. DOWNSTREAM THE DTW. IN CANAL 1,
RAJASAN 3, SAVAR
Scale: 1"=5"

Area, ft^2	Velocity, ft/sec	Discharge, cfs
0.1875	1.86	0.348
0.166	1.98	0.330
0.118	1.52	0.147
	TOTAL	0.825

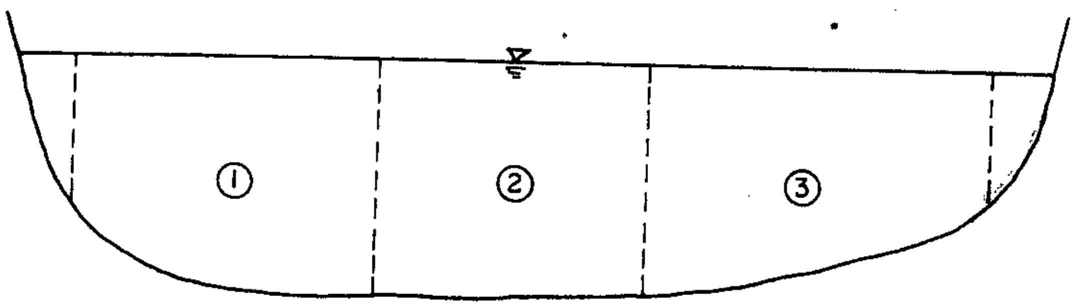
FIG. 21 CALCULATION OF DISCHARGE FROM CURRENT METER READINGS



SECTION 2 AT 2480 FT DOWNSTREAM THE DTW IN CANAL I, RAJASAN 4, SAVA
Scale: 1"=5"

Area, ft^2	Velocity, fps	Discharge, cfs
0.198	1.773	0.351
0.174	2.4	0.417
0.153	2.19	0.335
	Total	1.093

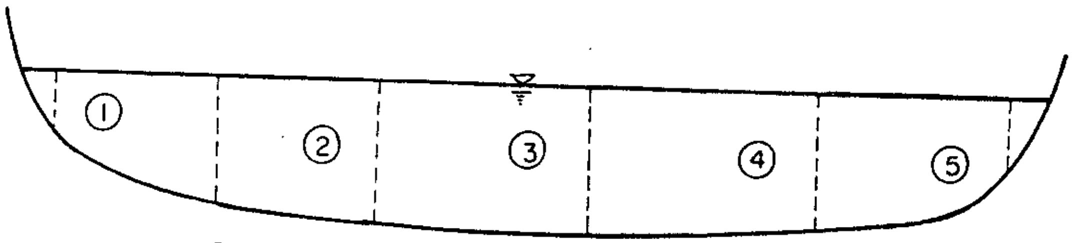
FIG. 22 CALCULATION OF DISCHARGE FROM CURRENT METER READINGS.



SECTION : 3247 FT. DOWNSTREAM THE DTW IN CANAL I, BARAWALIA, SAVAR
Scale: 1" = 5"

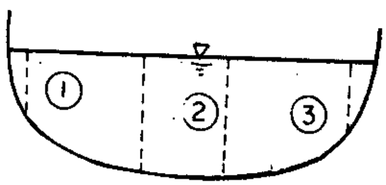
Area ft^2	Velocity fps	Discharge cfs
0.312	1.02	0.319
0.291	1.06	0.309
0.312	1.56	0.455
	Total	1.083

FIG. 23 CALCULATION OF DISCHARGE FROM CURRENT METER READINGS



SECTION I 10 FT. DOWNSTREAM THE DTW.
Scale: 1" = 10"

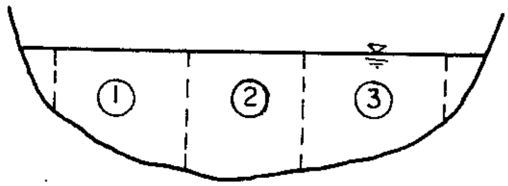
Area, ft.^{2}	Velocity, fps	Discharge cfs
0.323	0.625	0.2
0.424	0.751	0.318
0.597	0.835	0.4986
0.638	0.835	0.533
0.444	0.653	0.29
	TOTAL	1.84



SECTION 700 FT. DOWNSTREAM THE SECTION I IN CANAL I, SONALIA, SAVAR
Scale: 1" = 10"

Area ft.^{2}	Velocity fps	Discharge cfs
0.215	2.1	0.45
0.18	3.1	0.56
0.215	2.36	0.50
	TOTAL	1.51

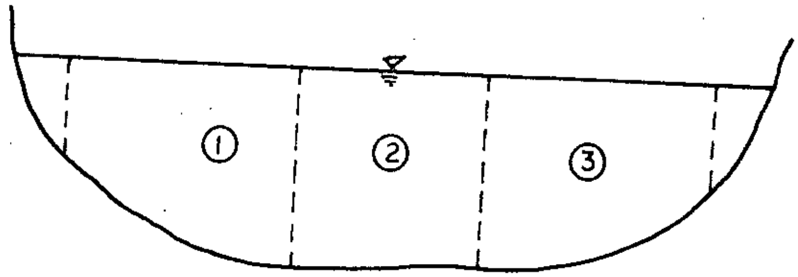
FIG. 24 CALCULATION OF DISCHARGE FROM CURRENT METER READINGS



SECTION 1180 FT. DOWNSTREAM THE DTW IN CANAL 2, GAZIPURA, JOYDEBPUR
Scale: 1" = 10"

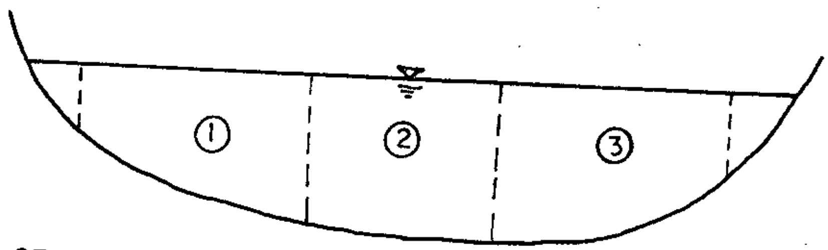
Area, ft.	Velocity, fps	Discharge, cfs
0.257	·4167	·107
0.271	·786	.213
0.243	·423	·107
	Total	0.427

FIG. 25 CALCULATION OF DISCHARGE FROM CURREN METER READINGS



SECTION AT 1280 FT DOWNSTREAM THE DTW IN CANAL 1, DAKHSIN KHAN 8,GULSA
Scale: 1" = 5"

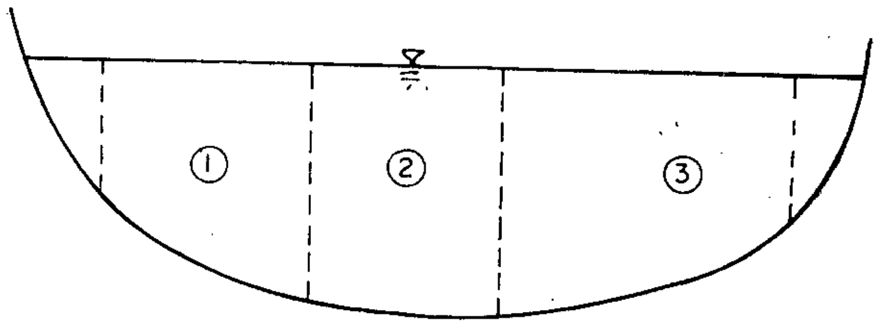
Area ft^2	Velocity fps	Discharge cfs
0.18	0.398	0.071
0.173	0.765	0.132
0.177	0.398	0.070
	Total	0.273



SECTION AT 1150 FT DOWNSTREAM THE DTW IN CANAL 2 DAKHSIN KHAN 8,GULSAN
Scale: 1" = 5"

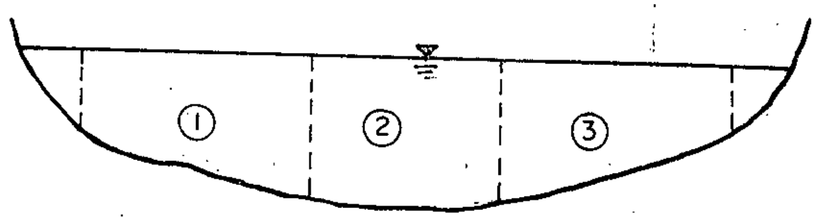
Area ft^2	Velocity fps	Discharge cfs
0.127	0.597	·076
0.141	0.807	·14
0.158	0.398	·063
	Total	0.253

FIG. 26 CALCULATION OF DISCHARGE FROM CURRENT METER READINGS



SECTION 1000 FT. DOWNSTREAM THE DTW IN CANAL I, PARAGAON, RUPGANJ.
Scale: 1"=5"

Area, ft	Velocity, fps	Discharge, cfs
0.191	0.322	0.0615
0.22	0.36	0.0792
0.288	0.398	0.0902
	Total	0.2314



SECTION 1450 FT. DOWNSTREAM THE DTW IN CANAL 2, PARAGAON, RUPGANJ
Scale: 1"=5"

Area, ft.^{2}	Velocity, fps	Discharge, cfs
0.125	0.474	0.059
0.132	0.36	0.047
0.118	0.208	0.024
	Total	0.130

FIG. 27 CALCULATION OF DISCHARGE FROM CURRENT METER READINGS

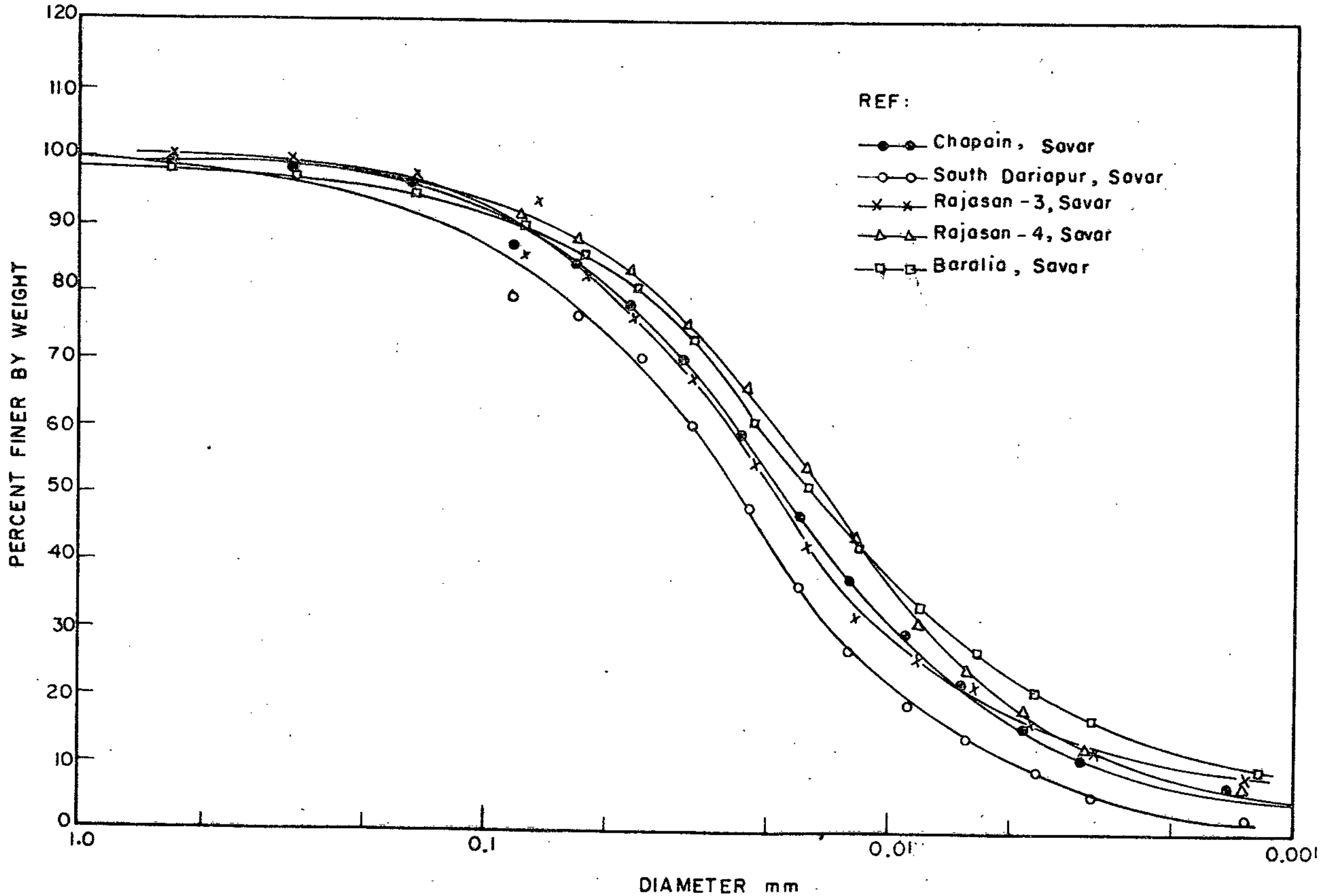


FIG. 28 GRAIN SIZE DISTRIBUTION

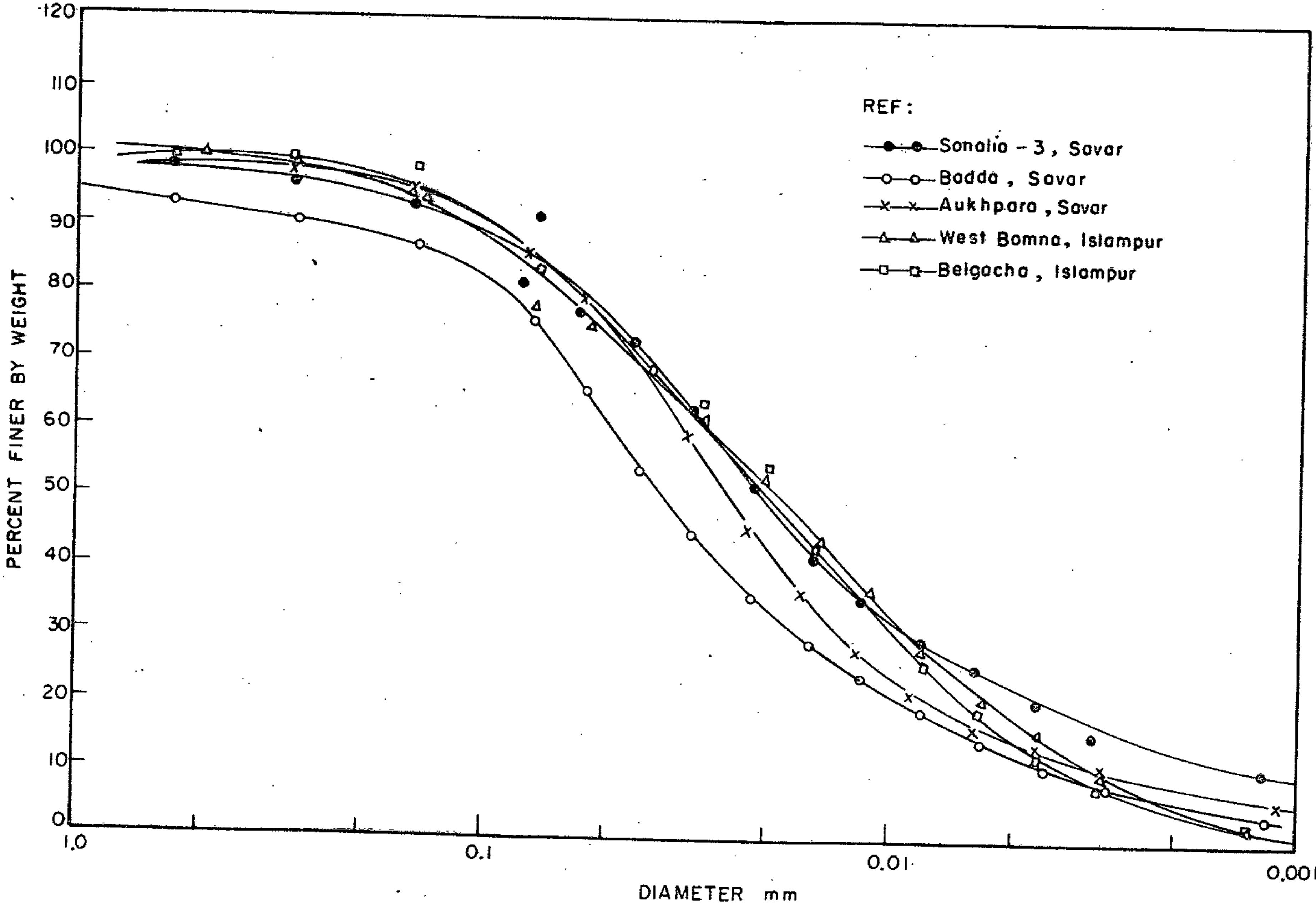


FIG. 29 GRAIN SIZE DISTRIBUTION

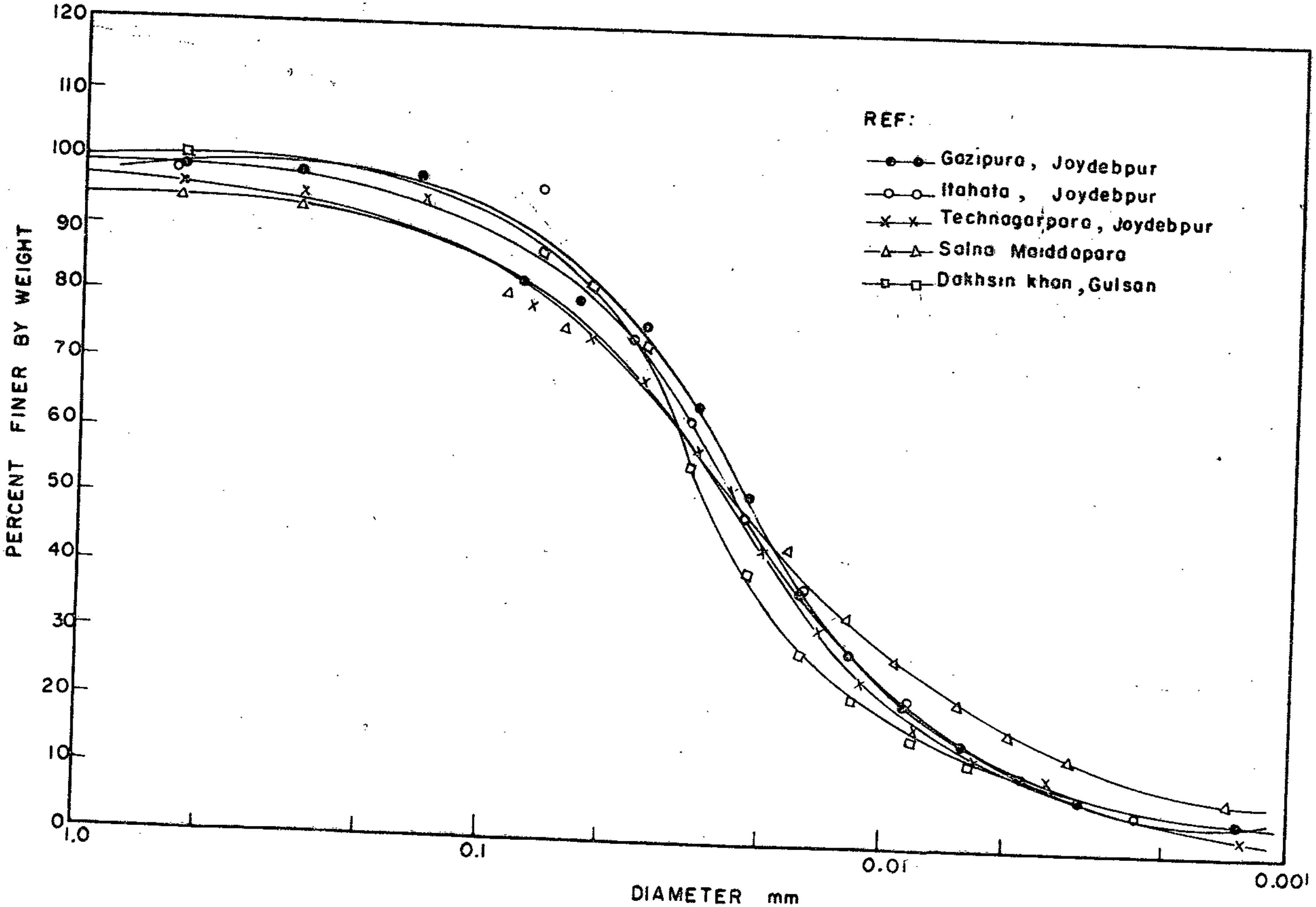


FIG. 30 GRAIN SIZE DISTRIBUTION

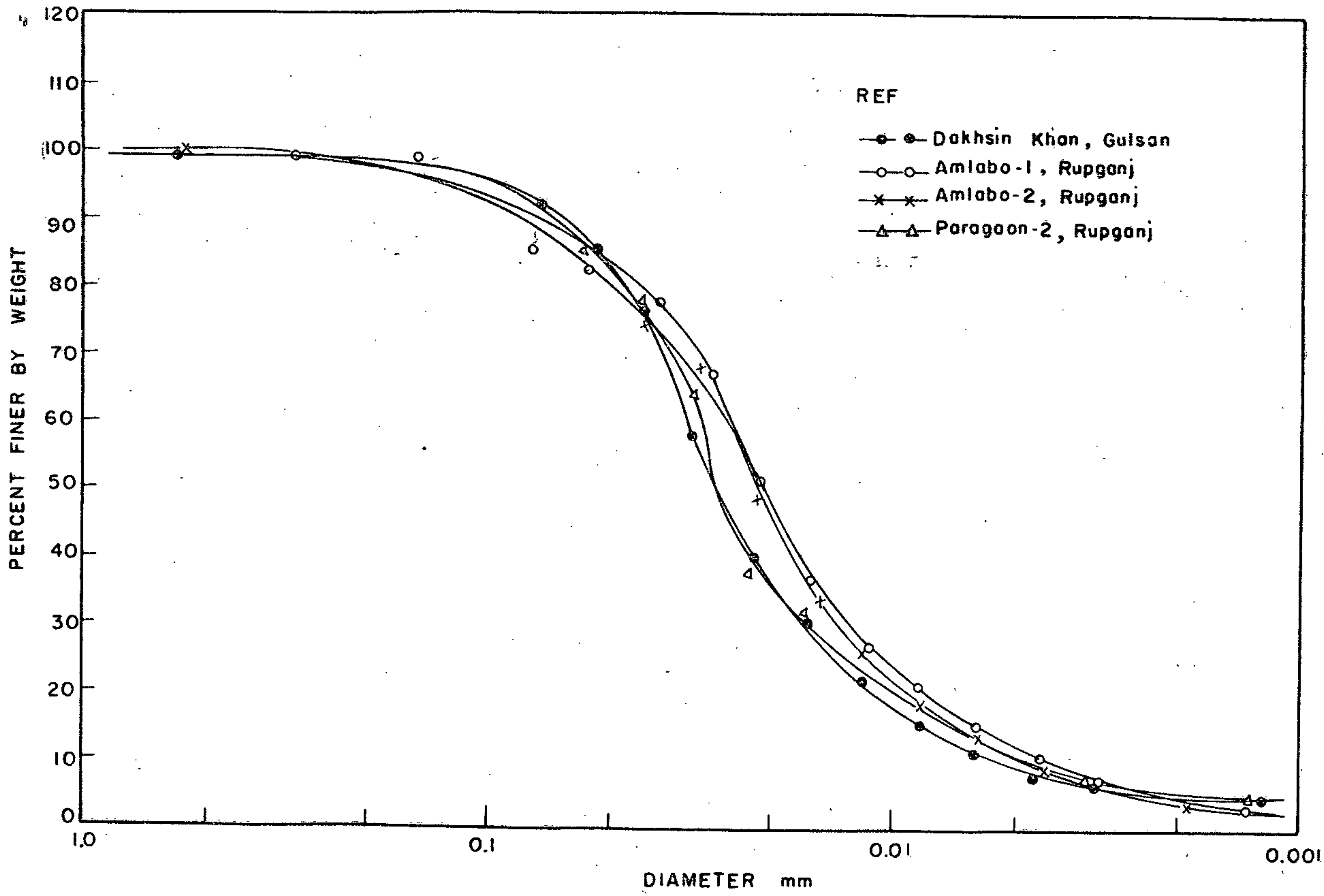


FIG. 31 GRAIN SIZE DISTRIBUTION

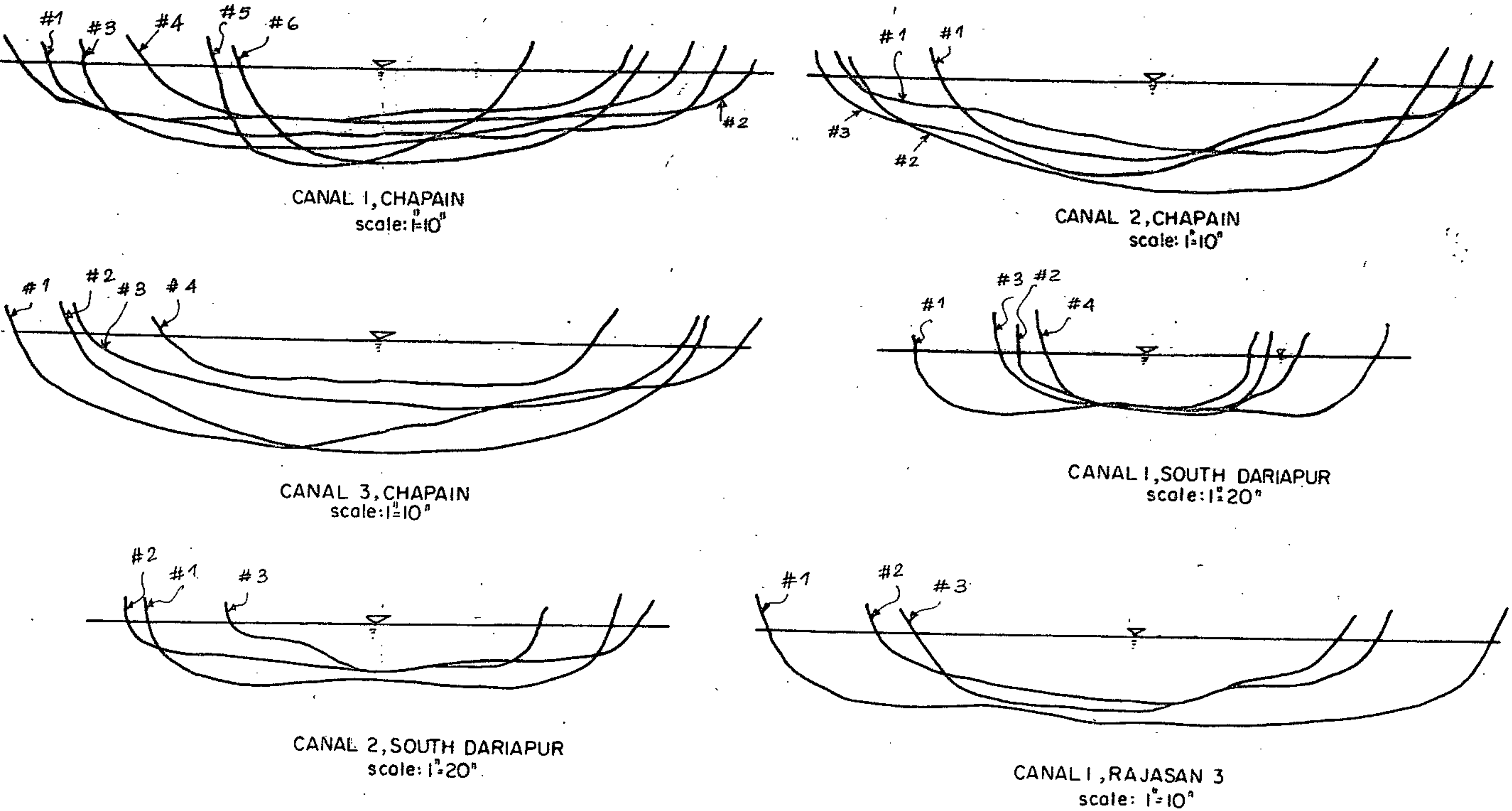
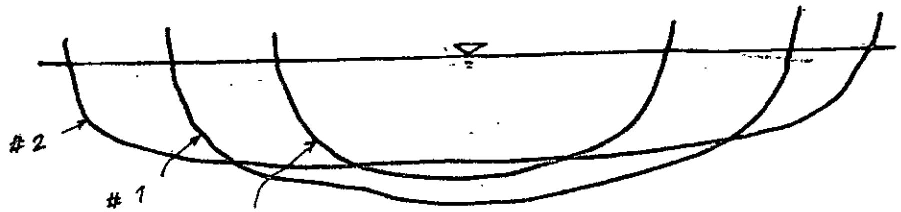
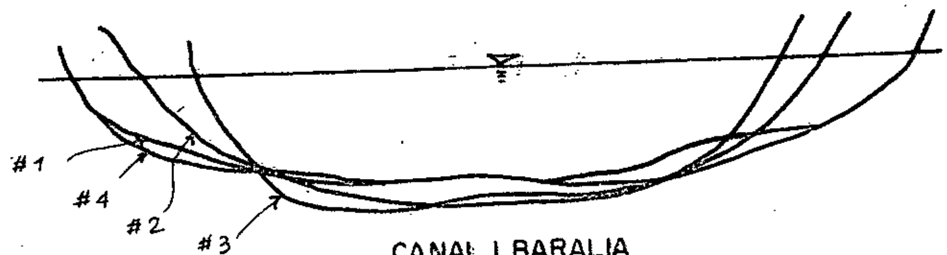


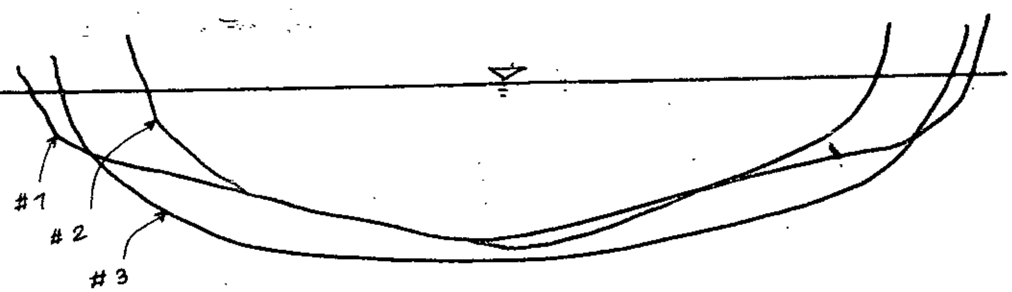
FIG 32 CROSS-SECTIONAL PROFILES OF THE CANALS



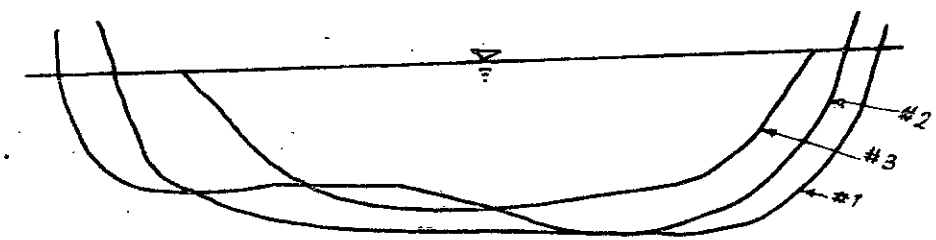
CANAL I, RAJASAN 4
scale: 1"=10"



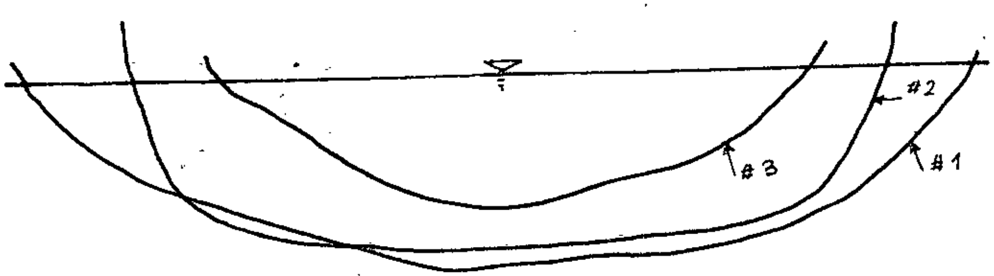
CANAL I, BARALIA
scale: 1"=10"



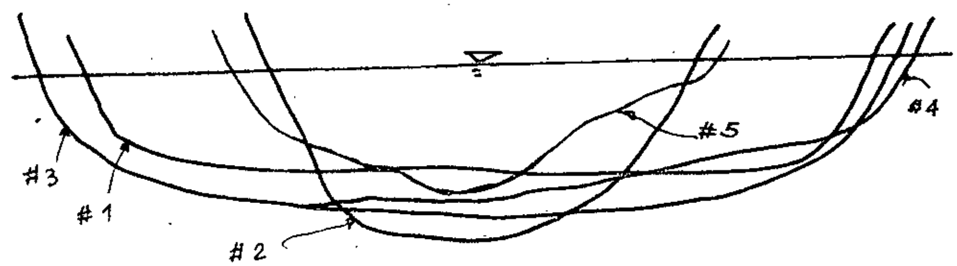
CANAL I, SONALIA
scale: 1"=10"



CANAL I, AUKHPARA
scale: 1"=10"

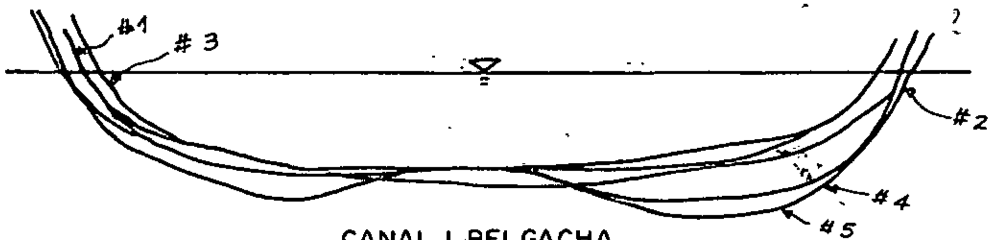


CANAL I, BADDA
scale: 1"=10"

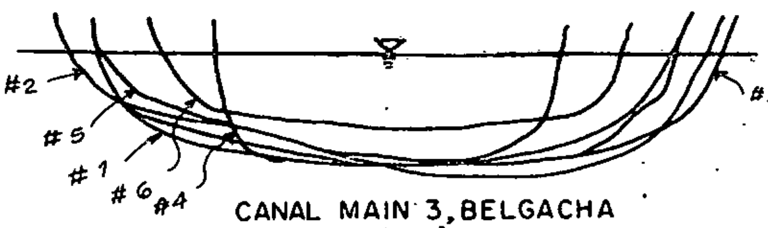


CANAL 2, WEST BAMNA
scale: 1"=10"

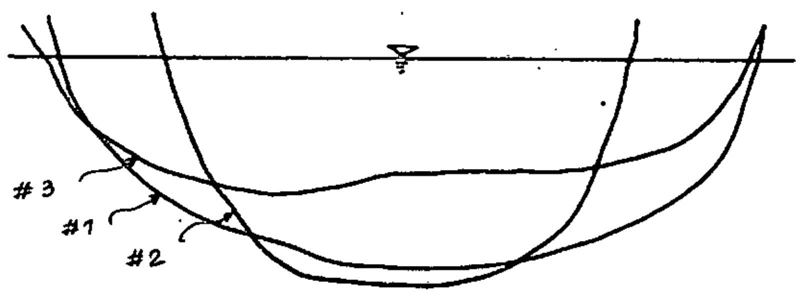
FIG 32 (contd) CROSS-SECTIONAL PROFILES OF THE CANALS



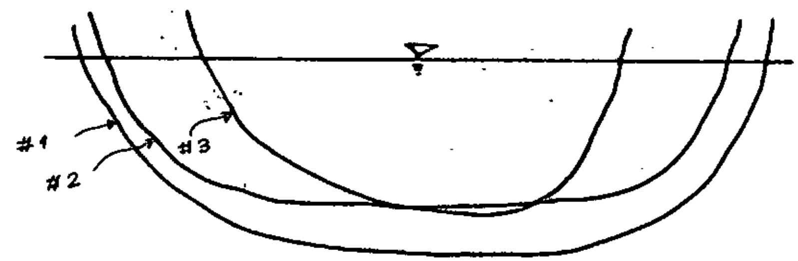
CANAL 1, BELGACHA
scale: 1"=10"



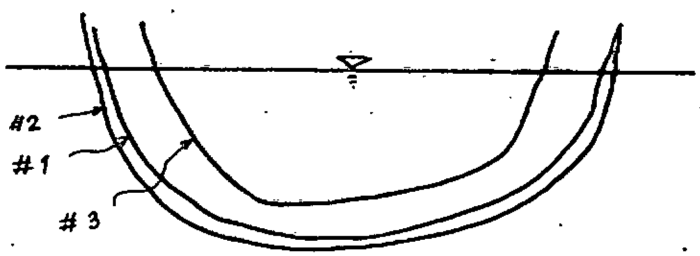
CANAL MAIN 3, BELGACHA
scale: 1"=10"



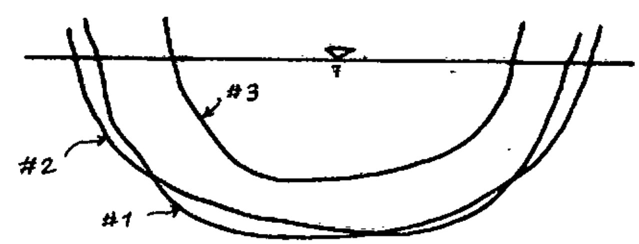
CANAL 1, GAZIPURA
scale: 1"=10"



CANAL 2, GAZIPURA
scale: 1"=10"

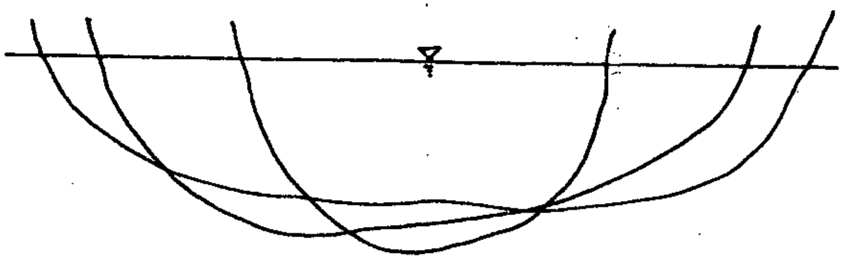


CANAL 1, ITAHATA
scale: 1"=10"

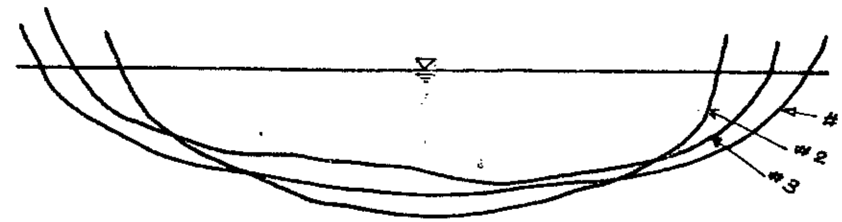


CANAL 2, ITAHATA
scale: 1"=10"

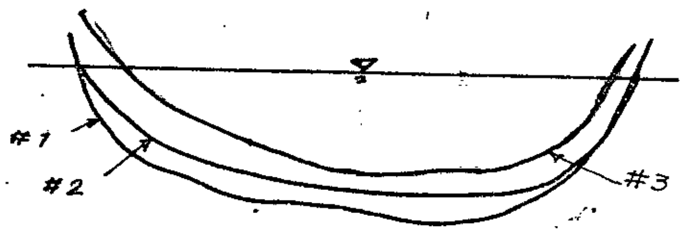
FIG 32 (contd) CROSS-SECTIONAL PROFILES OF THE CANALS



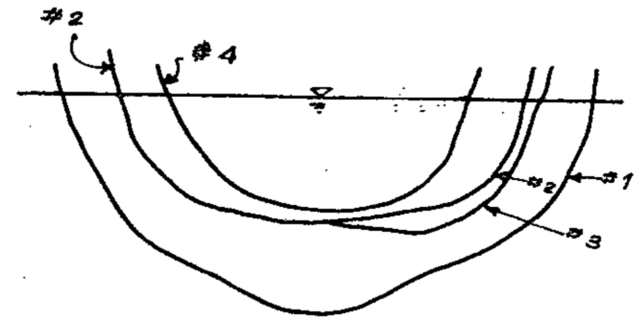
CANAL I, TECHNAGARPARA
scale: 1" = 10"



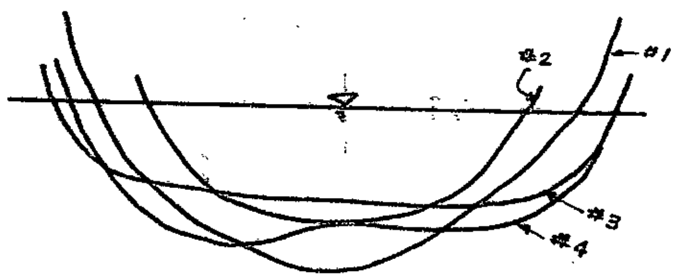
CANAL I, SALNA MAIDDAPARA
scale: 1" = 10"



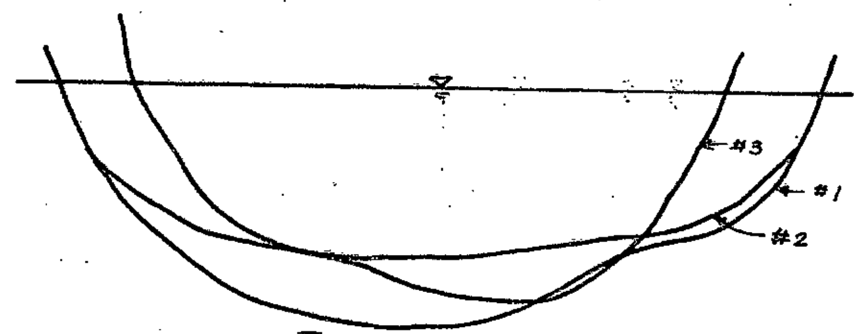
CANAL I, DAKHSIN KHAN 10
scale: 1" = 10"



CANAL I, DAKHSIN KHAN 8
scale: 1" = 10"

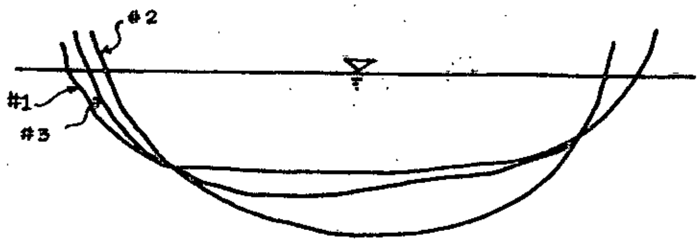


CANAL 2, DAKHSIN KHAN 8
scale: 1" = 10"

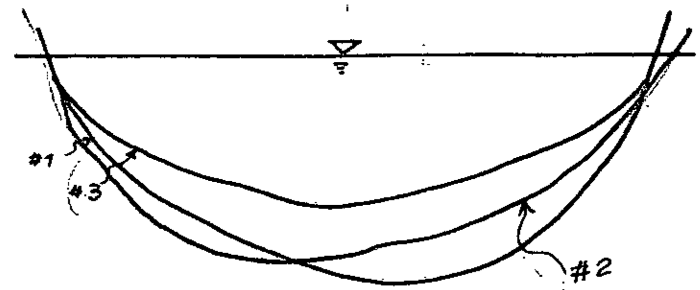


CANAL I, AMLABO I
scale: 1" = 10"

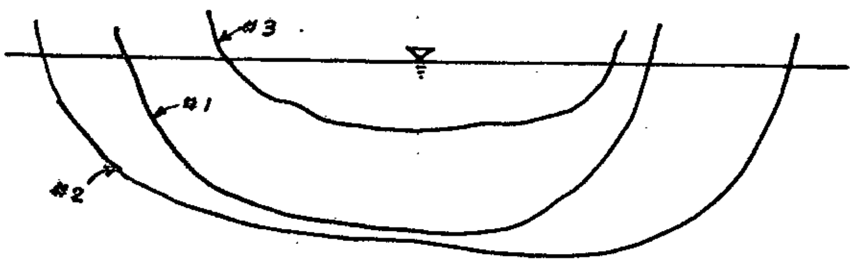
FIG. 32 (contd.) CROSS-SECTIONAL PROFILES OF THE CANALS



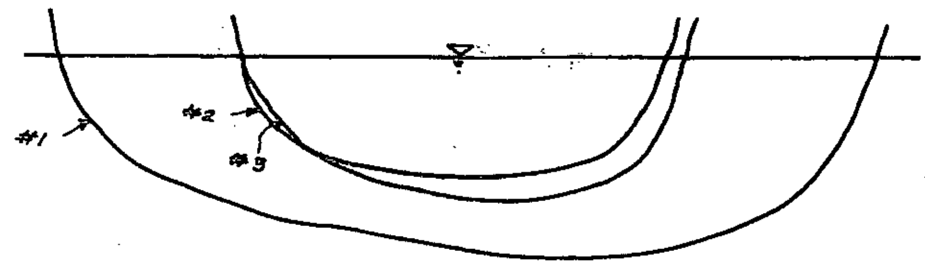
CANAL 1, AMLABO 2
scale: 1" = 10"



CANAL 2, AMLABO 2
scale: 1" = 10"



CANAL 1, PARAGAON 2
scale: 1" = 10"



CANAL 2, PARAGAON 2
scale: 1" = 10"

FIG. 32 (contd.) CROSS-SECTIONAL PROFILES OF THE CANALS

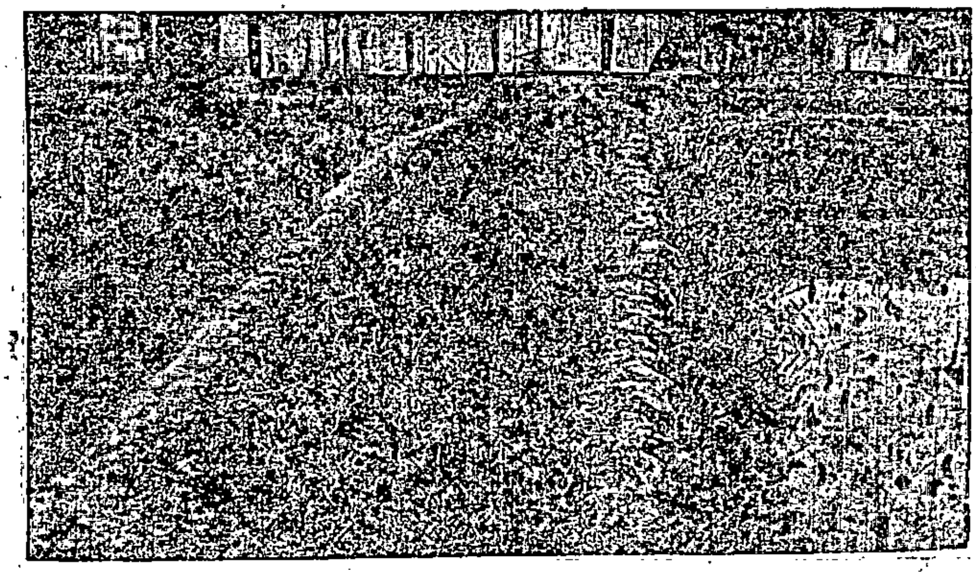


Fig. 33. Thick weeds on the channel body

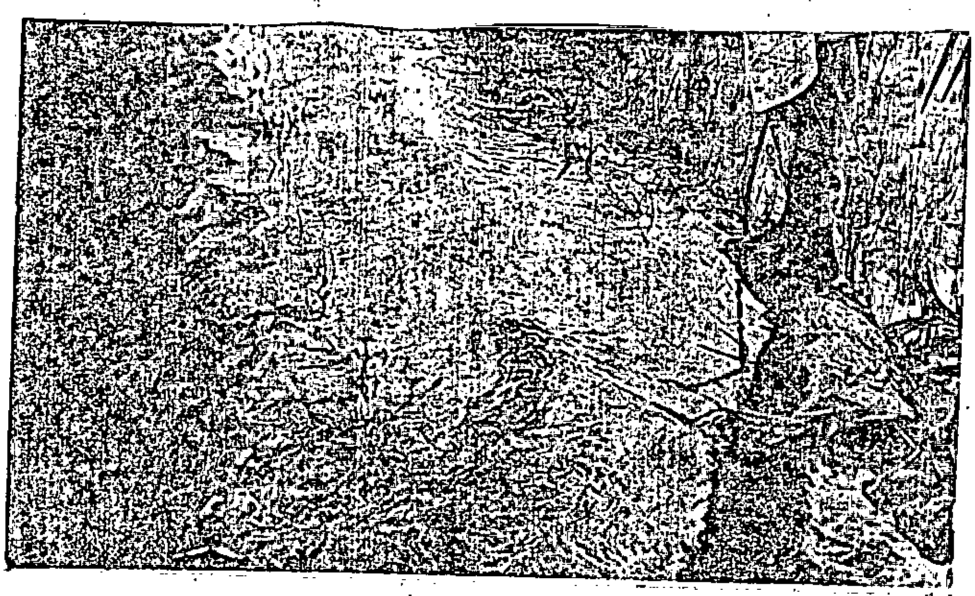


Fig. 34. Spillage due to inefficient canal section

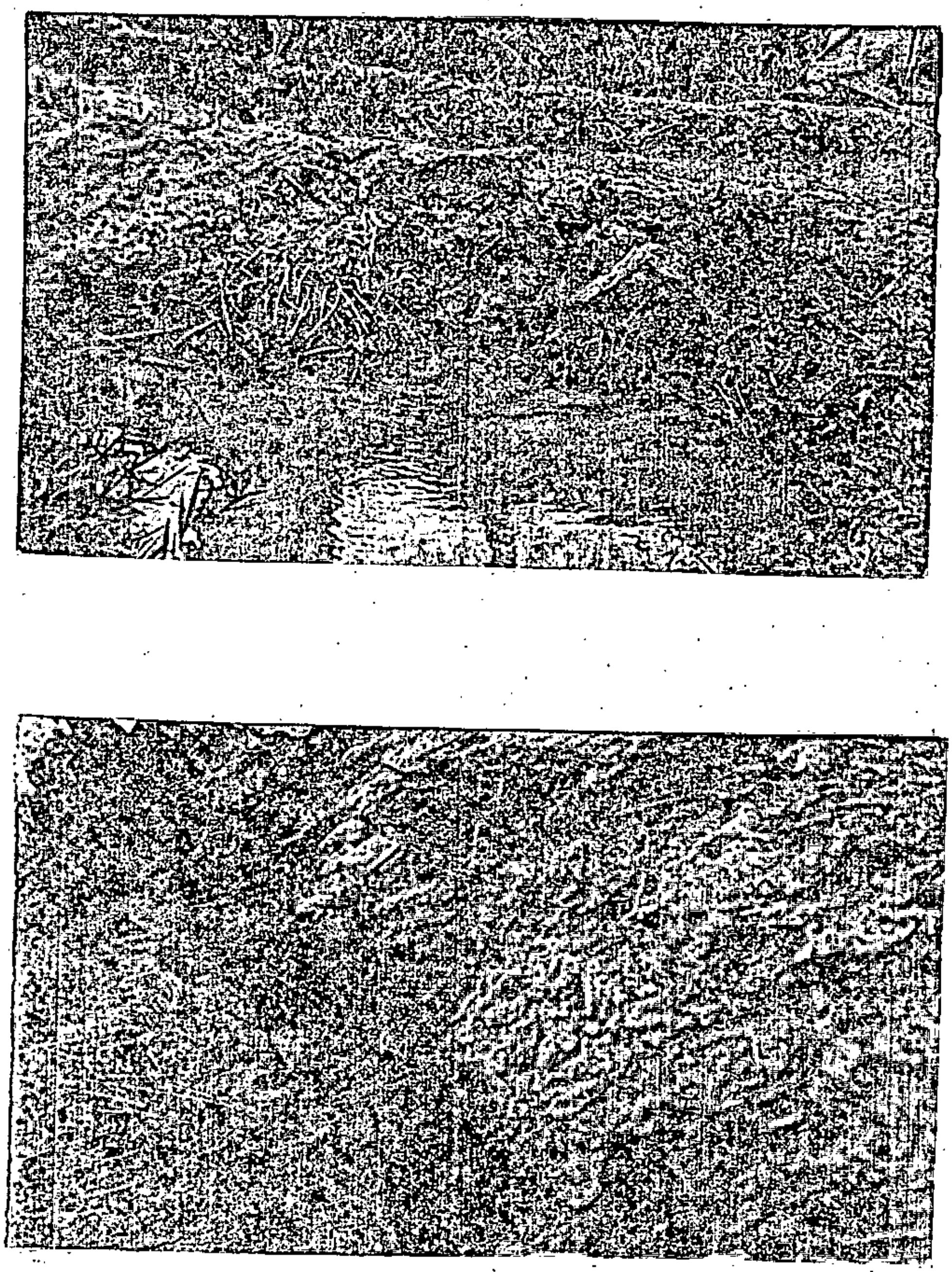


Fig. 35. Leakage through poorly sealed opening

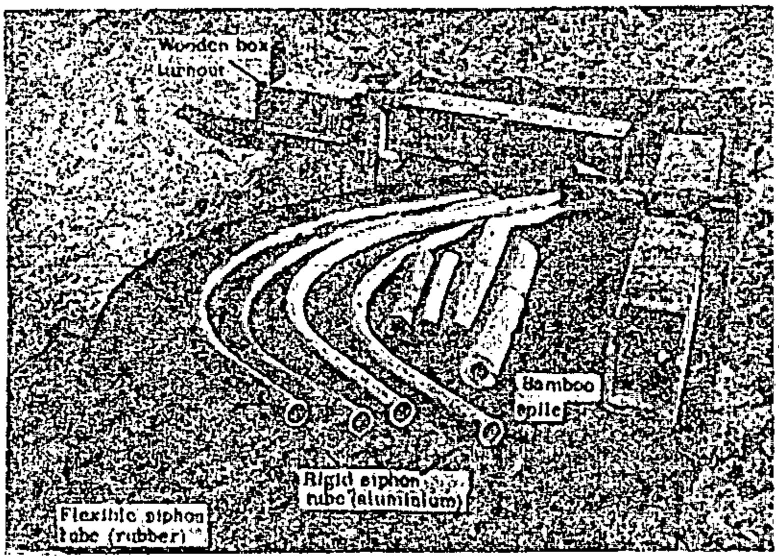


Fig. 36a. Different kinds of diversion structures used in farm irrigation practice

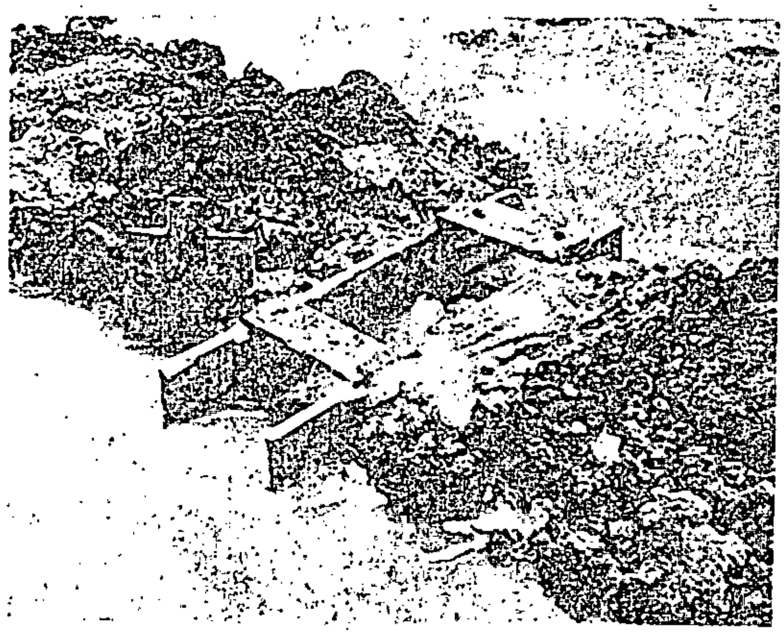


Fig. 36b. Wooden turn out installed to divert water from a supply channel to a field