PERFORMANCE OF CONCRETE BURIED PIPE DISTRIBUTION SYSTEMS FOR SURFACE IRRIGATION UNDER FARMERS' MANAGEMENT IN TANGAIL, BANGLADESH

By

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A Master's Thesis

Submitted in partial fulfilment of the requirements
for the award of
Master of Philosophy
of the Loughborough University of Technology.
October 1993

Department of Civil Engineering
Loughborough University of Technology

ABSTRACT

The operation of irrigation systems on eight deep tubewells in Tangail district, Bangladesh, was monitored from 1989 to 1991. These systems used buried non-reinforced concrete pipe to distribute water from deep tubewells and irrigate diversified crops during the dry season.

The potential of buried pipe networks for surface irrigation at low heads is documented, and performance under farmers' management is outlined in this thesis. For example, the utilization rates of all the tubewells were disappointing, averaging 3.5 hrs/day at a discharge of 32.5 l/s compared to the design of 56 l/s. The irrigated area averaging 16.6 ha was typically less than half of the design (40 ha). The reasons for this poor performance were found to be a combination of social, managerial and agro-economic factors.

Leakage through joints and pipe walls averaged 2 leaks per 100 m of pipeline, while 42% of outlet valves were observed to leak. Conveyance losses within the pipelines averaged 0.7 l/s/100 m with earth channel losses averaging 7.7 l/s/100 m.

Measured head losses for different pipe sizes and pump discharges were found compatible with theoretical values when using the Colebrook-White Equation with Ks=0.6 mm. Low pump discharge (58% of design), low periods of pump operation (12% of advised), small areas (42% of intended) and low yields of irrigated crops were commonly observed. Poor farming as well as water management practices contributed to poor levels of irrigation performance.

Farmers' cooperatives were found not efficient and many institutional problems existed. Buried pipe systems and open channel systems were compared in terms of seepage loss and costs. It was found that buried pipe systems were more economical than open channel systems. There is however considerable potential to increase the net returns from buried pipe schemes through more efficient utilization.

Possible improvements are discussed in this thesis. These include moving to systematic irrigation of fields fed by the same branch, instead of the current erratic distribution of water under the farmer's fuel system.

ACKNOWLEDGEMENTS

I would first like to thank my supervisor Mr Ian K Smout, for his valuable assistance, guidance, advice and encouragement during preparation of this thesis, and for the loan of material. My thanks also to Mr R H Neale, Director of Research.

I would like to acknowledge the contribution of the Loughborough University of Technology (LUT) and the Overseas Development Administration (ODA), UK for their funding of the Research Project (R 4575) upon which this thesis is based. Thanks are also due to the British Council for financing me in this study.

The British High Commission, Dhaka, and Mott MacDonald International, consultants on the IDA DTW Project II have provided considerable administrative assistance during the project period. Thanks are also due to Mott MacDonald for valuable technical information. BARI authority, in general, and the Irrigation and Water Management Division in particular facilitated this research work. I would also like to express my thanks to Mr M H Rashid, for his assistance and advice throughout the project period. On-Farm Research Division assisted with site accommodation. Their help is acknowledged.

The Tangail Agricultural Development Project (TADP) provided valuable advice and assistance, especially at the start of the fieldwork, and layouts and background materials on the selected schemes. Thanks are also due to the eight Farmers' Cooperatives (KSS), Taltolapara, East Kutubpur, Shaplapara, Baila, Vailpara, Chulabar, Hazipara and Binnakhaira for their good cooperation in the study and other bodies which provided information and assistance.

In a personal capacity I would like to acknowledge the support given to me by my friends, in particular, Mr Sunil D Gorantiwar.

To my wife, Rashida Karim and son Ishtiaque Karim (Robin), my thanks could never be sufficient. You mean more to me than I can say.

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AC	Asbestos Cement
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCR	Benefit-Cost-Ratio
BIAD	Barind Integrated Area Development
BKB	Bangladesh Krishi (Agricultural) Bank
BP	Buried Pipe
BPDS	Buried Pipe Distribution System
BPDI	Buried Pipe Deep Tubewell Irrigation
BPS	Buried Pipe System
BRDB	Bangladesh Rural Development Board
BRRI	Bangladesh Rice Research Institute
CC	Cement Concrete
cm	Centimetre
cusec	Cubic Foot Per Second
DAE	Depart of Agricultural Extension
dec.	Decimal (247.1 decimal = 1 hectare)
Dia	Diameter
DTW	Deep Tubewell
FAO	Food and Agricultural Organization
FCL	Field Channel Length
ft	Foot
GB	Grameen (Rural) Bank
GTZ	German Agency for Technical Co-operation
hr	Hour
HYV	High Yielding Variety
IDA	International Development Agency
IMP	Irrigation Management Programme
IRRI	International Rice Research Institute
Kg	Kilogram
KSS	Krishak Samabay Samity (Farmers' Cooperative)
l	Litre
LIV	Local Improved Variety
l/s	Litre per second
LUT	Loughborough University of Technology
LV	Local Variety

m	Metre
mins	Minute
mm	Millimetre
MMI	Mott MacDonald International
MMP	Sir M MacDonald and Partners Ltd
obs.	Observation
ODA	Overseas Development Administration
PVC	Polyvinyl chloride
RCC	Reinforced Cement Concrete
RDA	Rural Development Academy
rpm	Revolution per minute
s	Second
STW	Shallow Tubewell
TADP	Tangail Agricultural Development Project
Tk	Taka (Currency, 1 $ US = Tk 38.40, 1991)
UCCA	Upazila Central Cooperative Association
UNDP	United Nation Development Programme
uPVC	Unplasticised Polyvinyl Chloride

Local Terms

Aman	Rice Grown in July-October
Aus	Rice Grown in March-July
Boro	Rice Grown in January-May
Datashak	A kind of leafy vegetables (*Amaranthus gangeticus*)
Kharif	Summer Crop Season
Rabi	Winter Crop Season (October-March)
Upazila	Administrative Boundary (i.e. Sub-district)

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

This thesis is the result of research on buried pipe distribution (BPD) systems in Bangladesh carried out since 1989. At that time little information was known on the performance of these systems. However, a number of BPD systems, using mostly non-reinforced concrete (cement concrete or CC) pipes, have been installed by several organisations using different designs, constructional methods and pipe jointing techniques. Many problems had been observed, but not studied in detail or documented in the literature. For example, the schemes were reputed to have problems of leakages and failure to reach targeted objectives in terms of command area and productivity.

Engineering, agronomic, organisational and management aspects generally control the performance of an irrigation scheme. Nonetheless, the water conveyance and distribution systems are of prime importance in such projects. These systems are mostly of earthen open channels in minor irrigation systems in Bangladesh and suffer from serious problems such as, low conveyance and distribution efficiencies, low command areas and high maintenance costs (Biswas, 1985). Gisselquist (1989) has documented the extra pumping costs required to compensate different losses in the minor irrigation schemes. A survey was conducted by the Master Plan Organisation (MPO) showed that the actual area irrigated by a Deep Tubewell (DTW) is only about 22.0 ha against a potential area of 32.0 ha (BBS, 1990).

Field open channels in surface water distribution systems in Bangladesh, generally originating from DTWs or shallow tubewells (STWs) or even from most canal outlets, run in a random manner with a little consideration of topographical features of the areas (BARI, 1988). Seepage, leakage and evaporation losses are high in such systems. Besides these, Michael (1978) reported that about 2% to 4% of the cultivable land area is taken up by the open channel distribution system.

Plausible economic solutions to some of these problems, for the areas with plain topography and having heavy to medium textured soil, include construction of improved (compacted) earth channels with necessary water control structures and strengthening operation and maintenance capabilities to improve performance of the system. However, the BPD system may be the best solution to these problems provided the users can afford it, especially for uneven topography and light textured soils.

The pipelines are placed underground, cultivation can be done above the pipelines which do not interfere with farming operations, and when properly installed they are very durable and the maintenance cost is low. Their placement below ground surface prevents any damage and eliminates water loss by evaporation. The systems are operated under pressure, so can be laid uphill and downhill, thus permitting the delivery of water to areas not accessible when open channels are used. They do not become clogged by vegetation and wind-blown materials. With an underground pipeline system, the DTW need not be located at the high point of the farm but may be at a location that provides the best water supply. No land needs to be reserved for right-of-way by the BPD system. This is not only an economic advantage but a practical benefit when a large number of field plots belonging to different individuals are not crossed to distribute water from the DTW. It is also not necessary to follow plot boundaries, thus reducing the lengths of field channels.

Despite the clear advantages and benefits by the buried pipe, some problems have been observed in the systems, for instance, unsatisfactory jointing methods and techniques, frequent leaks, faulty outlet valves, poor hydraulic design (using a trial and error method), spillage from air vents and so on. Unfortunately before this record, no dependable studies had been done to evaluate the existing buried pipe systems, identify problems and recommend plausible solutions. Under the circumstances, this study was undertaken to identify the weaknesses and strength in construction, efficient operation, management and utilization of these irrigation schemes.

No evidence has been documented about the performance of the BPD system for surface irrigation in Bangladesh. However, it is commonly believed that the performance of buried pipes is often quoted as an alternative to open channel systems for improved water distribution, but there is no evidence in favour of this statement, consequently many designers lack the confidence to consider buried pipe systems as an option instead of the more conventional surface channel systems.

1.2 OBJECTIVES AND HYPOTHESES

This research has five objectives and tests three hypotheses. The objectives of this thesis are:

Objectives

1. To document and evaluate the overall performance of low pressure non-reinforced concrete buried pipe systems for surface irrigation in Tangail, Bangladesh, including estimation of losses of water from the pipeline system and losses of hydraulic pressure within the system.

2. To investigate the technology of low pressure buried pipe systems, including design, construction and operating methods of the system.

3. To record and analyse the water management practices under buried pipe distribution systems for surface irrigation. (Water management means tubewell operation, irrigation practices and agronomic practice aspects).

4. To analyse the institutions managing the buried pipe distribution systems for surface irrigation and propose suitable performance indicators.

5. To provide useful information for the improvement of buried pipe distribution systems for surface irrigation in Bangladesh, and for extending the use of the system.

The hypotheses of this thesis are:

Hypotheses

1. With a buried pipe distribution system the quantity of water delivered to a field is independent of the position of the outlet which serves that field.

2. Graphical methods based on FAO procedures can be useful for representing and evaluating data on the timing and application depths of field irrigation.

3. Non-engineering factors prevent buried pipe distribution systems in Bangladesh being utilized to their full potential.

To test the first two hypotheses, a simple water balance method of modelling soil moisture extraction under irrigation of farmer-managed buried pipe systems for surface irrigation schemes, where all climatic factors were taken into account, according to Doorenbos & Pruitt (1977) and Doorenbos &

Kassam (1979). However, a correlation study was used to test the hypotheses. The third hypothesis concerned the non-engineering factors relating to operation and maintenance of the buried pipe schemes.

1.3 SCOPE OF THESIS

The first year of fieldwork for this study (1989-90) was carried out on three buried pipe distribution schemes located at Taltolapara, East Kutubpur and Shaplapara in Shakipur Upazila (sub-district) and in the second year (1990-91) five more buried pipe schemes were included. These are located at Baila, Vailpara, Chulabar, Hazipara under Ghatail Upazila and at Binnakhaira in Shakipur Upazila, Tangail. All these schemes are under the Tangail Agricultural Development Project (TADP). While selecting the sites, due consideration was given to good engine condition, road communication, co-operation of the scheme population and crop diversification.

An important function of this thesis is to present technical information in an accessible form for the use of buried pipe systems by a range of different interest groups; particularly those who will be involved in the implementation of forthcoming schemes in the irrigated agriculture.

The buried pipe systems for surface irrigation have been widely used with large numbers of systems operating in the USA, India and China. However, selection of these systems, their design criteria, constructional procedures and methods of operation have been documented in few publications (Bentum, 1992). Buried pipe systems and their components have been described in a wide range of publications, for example by Jensen (1980) and Michael (1978). However, little work has been completed evaluating the performance of the existing systems.

1.4 RESEARCH METHODOLOGIES

This thesis is based on field research work which was carried out on eight non-reinforced concrete buried pipe irrigation schemes over a period of two years in Tangail, Bangladesh. Some of the results of this fieldwork have been published as reports by this author (Rashid and Mridha 1990, and Rashid and Mridha 1992). For this thesis, data have been re-analysed and chapters 6 and 7 in particular are completely new work.

Both published and unpublished materials were examined thoroughly for the review of literature. Any surprise results from the research experience have been documented with illustrations. More emphasis was given to the aspects relating to situations, existing in the farmers' fields.

Methodologies for collecting all sorts of field data regarding research purposes and procedures of analyses have been described in detail in the chapters 4 to 7 of this thesis.

Funding for this study was provided by the Loughborough University of Technology (LUT) from November 1989 to March 1990 and for the remaining period by the Overseas Development Administration (ODA), UK.

1.5 STRUCTURE OF THESIS

Chapter 2 describes an introduction to the project sites where two case studies are included. These are:
a) Case studies of the project areas, and
b) Case studies on buried pipe irrigation schemes.
The membership of the KSS (Krishak Samabay Samity or farmers' cooperative) on each tubewell, their participation in the management and other information on the KSS, DTW and BPD system are discussed.

Although the fieldwork has focused on eight buried pipe schemes in Tangail, the applicability of the finding to other buried pipe schemes in Bangladesh has been broadly checked. Chapter 3 provides the background, the distribution of buried pipe networks along with their present performance. In addition, a number of evaluators' comments on buried pipe systems for surface irrigation have been added to this chapter.

Chapter 4 comprises the hydraulic tests which include flow rates from both the pumps and the outlets, different head losses in the pipelines and conveyance systems from both the pipelines and the earthen field channels. Moreover, constructional procedures of buried pipe irrigation schemes, utilization of irrigation equipment and description of the sample outlets are discussed.

Chapter 5 consists of different command areas, saving of land by buried pipe systems, infield water distribution and agronomic practices. The management and operation procedures are documented with the recommendations of the Irrigation Management Programme (IMP) and possible improvements are discussed.

Water availability in the root zone for upland crops as well as boro-rice has been broadly described in chapter 6. The effect of distances, under-irrigation, excess depletion, depleted days and irrigation losses on crop yields is discussed and possible suggestions are made in this chapter.

Chapter 7 describes many socio-economic constraints of the KSS. This chapter illustrates some of the difficulties of farmer-managed irrigation schemes where farmers resources are unevenly distributed, particularly in the complex technical and management environment of DTW irrigation. Moreover, the KSS institution (farmers' cooperative society) has been thoroughly analysed and its structure and activities for participation in the KSS management discussed. Additionally, present concepts and present methods of its activities are illustrated and examined in detail for selecting appropriate guidelines for future improvement in the KSS management.

CHAPTER 2
PROJECT AREA AND IRRIGATION SCHEMES

2.1 AGRO-ECOLOGY

2.1.1 Location of Project Areas

The three main scheme sites (Taltolapara, East Kutubpur and Shaplapara) are located in Shakipur Upazila (sub-district, Latitude $24^{0}11$`- $24^{0}26$` N, and Longitude $90^{0}04$`- $90^{0}18$` E). Four secondary scheme sites (Baila, Vailpara, Chulabar and Hazipara) are located in Ghatail Upazila (Latitude $24^{0}26$`- $24^{0}35$` N, and Longitude $89^{0}54$`- $90^{0}16$` E) and one secondary scheme (Binnakhaira) is located in Shakipur Upazila. All the schemes are under the Tangail district of Bangladesh (Figure 2.1). Out of the selected eight schemes, the remotest site is Baila and is about 25 Km away from Shakipur Upazila headquarters towards north. The total area of Shakipur Upazila is about 46,381 ha of which 54% is cultivable land, 18% is permanent fallow, 21% is under forest, 3% is under homesteads, and 4% is occupied by water bodies. Of those for Ghatail Upazila the total area is about 45,064 ha of which 58% is cultivable land, 16% is permanent fallow, 19% is under forest, 2% is under homesteads, and 5% is occupied by water bodies (Upazila Agriculture Office, 1990).

2.1.2 Soils

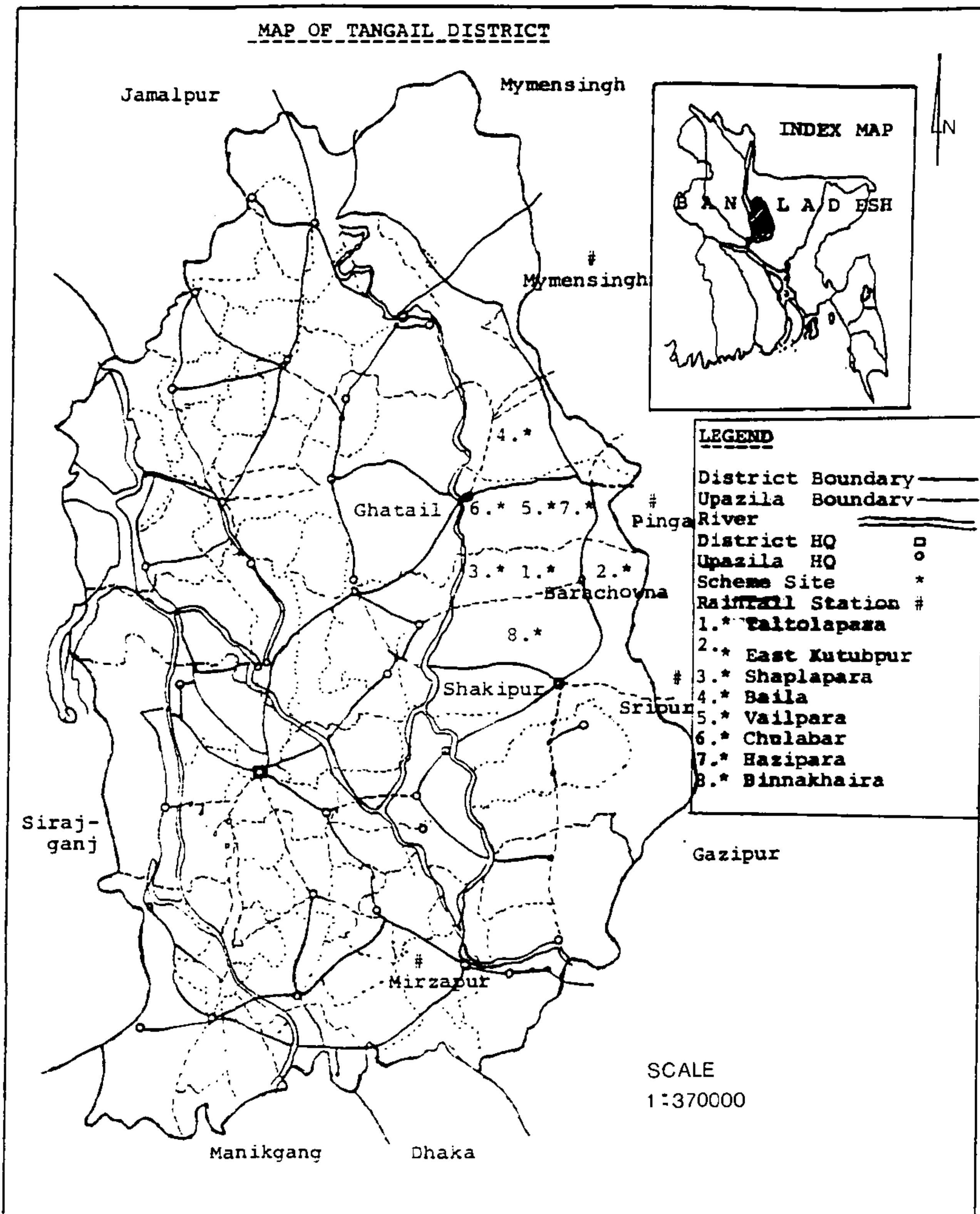
The study area falls under the Madhupur tract which covers about 4,244 sq km in the districts of Dhaka, Narsingdi, Narayangonj, Gazipur, Tangail, Jamalpur, Mymensingh, and Kishoregonj (FAO/UNDP, 1988). The land types distribution of the Madhupur tract are as follows:

Highland	(flood depth 00 cm - 30 cm)	= 56%
Medium highland	(flood depth 30 cm - 90 cm)	= 18%
Medium lowland	(flood depth 90 cm - 180 cm)	= 7%
Lowland	(flood depth 180 cm - 300 cm)	= 9%
Homesteads and water bodies		= 10%

The main soil textural class is clayey and main general soil types are deep red-brown terrace soils, and shallow grey terrace soils. The major limitations existing in the Madhupur tract are low soil fertility, complex relief and soil pattern, and flash floods in the valleys (FAO/UNDP, 1988).

Figure 2.1

Location of the Project Area



As per reconnaissance soil survey, the major soil series occurring in the Barachowna (Kutubpur) area are: i) Tejgaon, ii) Tejkunipara, and iii) Kalma. The important characteristics of the major soil series are given in Table 2.1. This soil survey was conducted by the Soil Resources Development Institute (SRDI).

Table 2.1 Major Soil Series in the Scheme Areas

Characteristics	Soil series		
	Tejgaon	Tejkunipara	Kalma
Flood level type	Highland	Highland	Medium highland
Drainage class	well drained	Moderately well drained	Poorly drained
Top soil colour	Yellow brown to dark brown	Grey to brown	Grey
Top soil texture	Loam	Loam to clay loam	Silty to silty clay loam
Sub soil texture	Clay	Clay	Silty clay loam
Top soil pH	6.1	5.2	5.3
Sub soil pH	5.2	5.2	5.5
Top soil OM(%)*	2.43	2.1	0.3

Note: * = Organic matter in percent.

Source: Agro-ecological Regions of Bangladesh, Report 2, FAO/UNDP, 1988

2.1.3 Land Types

The land under Shakipur and Ghatail Upazilas have been divided into two broad classes (Upazila Agricultural Office, 1990). These are: **a)** highland (flooding depths range from 0.0 cm to 30 cm), and **b)** medium highland (flooding depths range from 30 cm to 90 cm). Chalas (hillock, comparatively higher elevated lands where no rain water stands) are considered as highland and baids (small winding valleys or shallow valleys, mostly shallow flooded by rain water and run-off water during monsoon) are considered as medium highland. The percentage of land distribution patterns for the three schemes is shown in Figure 2.2. Depending on the land elevations, plots were divided into five categories and the percentage of plots under each category and agricultural practices in them are shown in Table 2.2.

Table 2.2 Elevation Ranges of all Plots Under the Three Main Schemes

Schemes	Elevation ranges (metre) 5 - <6	6 - <7	7 - <8	8 - <9	9 - <10.0	Plot no.
Taltolapara						
a) No. of plots	-	-	53	395	244	692
b) % of plots	-	-	7.66	57.08	35.26	100
c) Agril. practice	-	-	DWR	NP	NP	
East Kutubpur						
a) No. of plot	53	192	285	562	43	1135
b) % of plots	4.67	16.92	25.11	49.51	3.79	100
c) Agril. practice	DWR	DWR	DWR	NP	NP	
Shaplapara						
a) No. of plots	1	23	81	287	256	648
b) % of plots	0.15	3.35	12.5	44.29	39.51	100
c) Agril. practice	DWR	DWR	DWR	NP	NP	

Note: DWR = deep water rice, NP = normal agricultural practice. Levels are relative to local scheme datum. Top of pump discharge pipe = 10.00 m

2.1.4 Nutritional Status of Soils

Soil samples from the three main scheme areas have been analysed in the laboratory and nutritional status of soils for those schemes are shown in Table 2.3. Sulphur (S), zinc (Zn), phosphorous (P) and potassium (K) were found at more than the critical levels for all the schemes. Moreover from the results shown in the Table 2.3, it is seen that soils in all the three schemes were acidic in nature (i.e. pH value was less than 7.0) and lacking in organic matter and nitrogen.

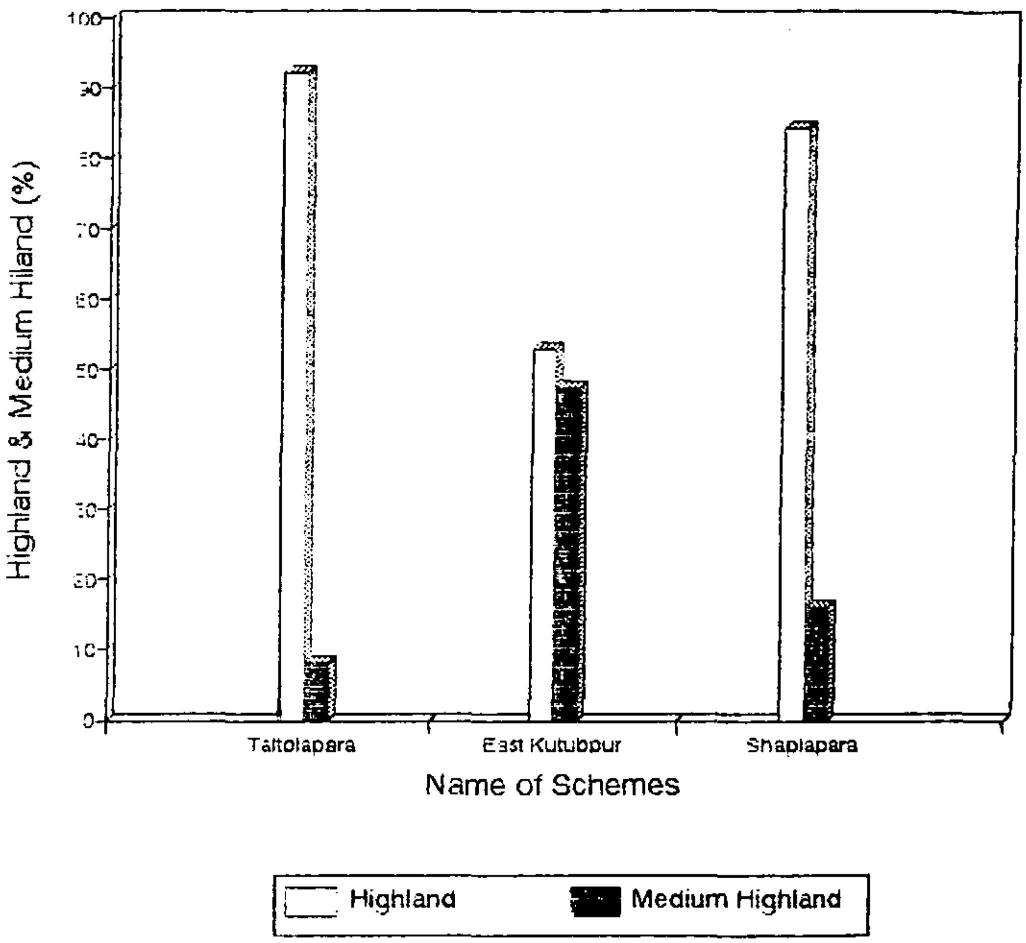
Table 2.3 Nutritional Status of Soils in the Three Maim Schemes

Schemes	Land type	pH	OM (%)	S (mg/l)	Zn	NH4-N	P	K (meq/100ml)
Taltolapara	Highland	6.0	0.97	26	3	15	22	0.42
	Medium highland	5.6	1.27	18	3	16	17	0.36
East Kutubpur	Highland	5.9	0.92	23	3	18	35	0.41
	Medium highland	5.6	1.35	16	4	14	23	0.32
Shaplapara	Highland	6.6	0.84	19	5	13	23	0.42
	Medium highland	5.6	1.60	22	4	14	21	0.38
Critical level		-	-	14	2	75	14	0.20

Source: Summarized from Rashid and Mridha, 1990

Figure 2.2

Land Distribution Patterns



Note: Highland = elevation > 8.0 m; Medium highland = elevation 0.0 to < 8.0 m. Levels are relative to local scheme datum. Top of pump discharge pipe = 10.0 m.

2.1.5 Climate

The project area has a tropical monsoon climate with much of the rain falling between May and October (Figure 2.3). Climatic information recorded in four surrounding meteorological stations (Figure 2.1) is shown in Table 2.4. The long-term annual rainfall at Mirzapur (12 years), Sripur (66 years), Pinga (69 years), and Mymensingh (36 years) were 1892.30 mm, 2478.40 mm, 1770.90 mm, and 2231.50 mm, respectively and with an average of 2093.30 mm. The number of months with a mean annual rainfall of 200 mm or above is five, from May to September at all four stations. The period between November and April is defined as a dry season because of little rainfall. The dry season is very important for the farmers to determine irrigation water applications.

The long-term mean monthly temperature at Mymensingh was found to be the highest (33.8^{0}C) in the month of April and lowest (11.6^{0}C) in January (Figure 2.3). The relative humidity fluctuated between 49% and 88%. From the point of view of water balance, May to October are the surplus period and the monthly mean ranged from 86.50 mm to 383.80 mm. On the other hand, the months November to April were the stress period, which ranged from 39.70 mm to 108.80 mm. November to April is the arid period on the basis of the aridity index. From Table 2.4, it is found that the months from November to April is the deficit period. The relationships between rainfall, evapotranspiration and temperature are shown in Figure 2.3.

Table 2.4 Climatic Information

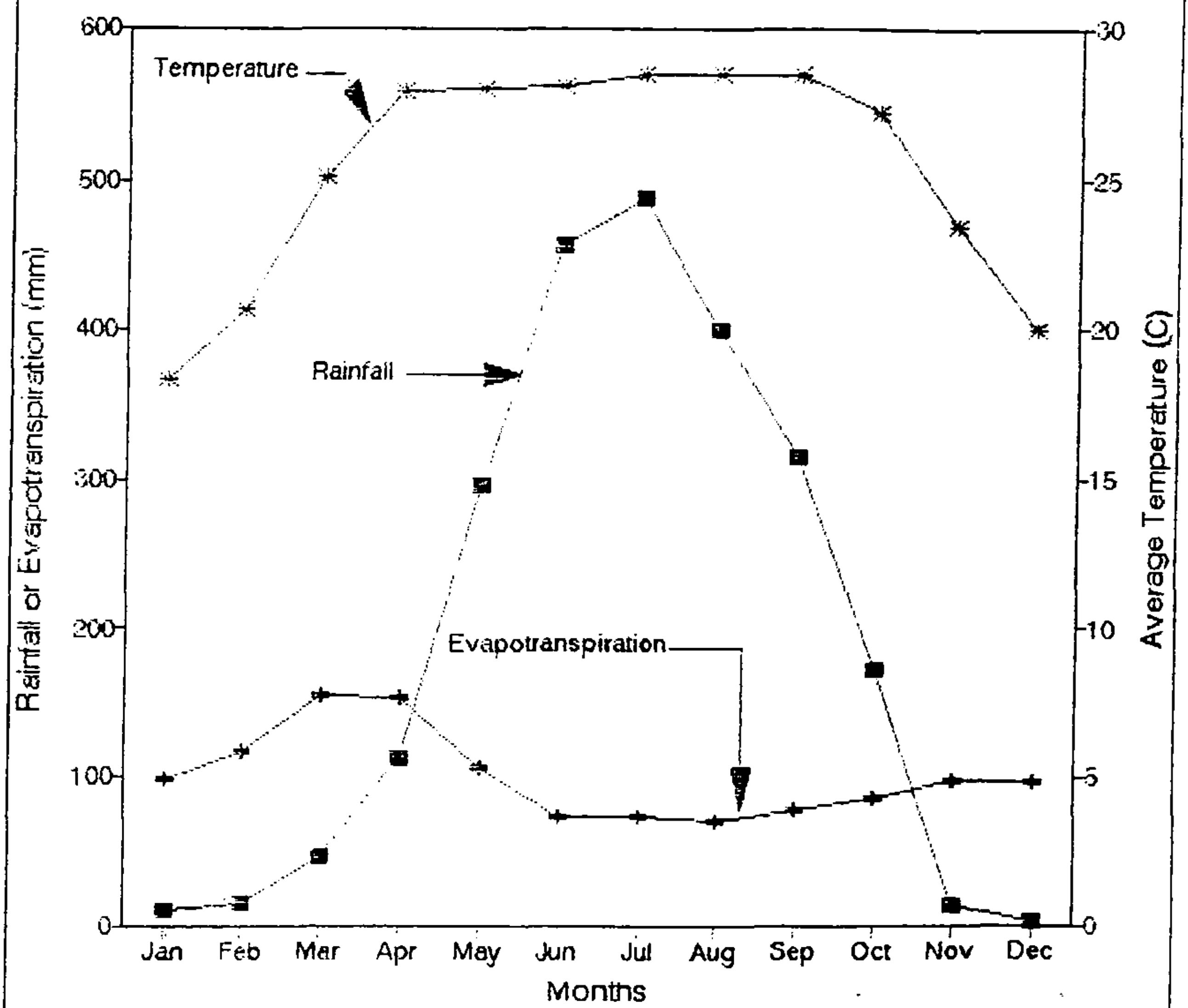
Parameters	Name of Station	J	F	M	A	M	J	J	A	S	O	N	D	Total
Rainfall (mm)	Mirzapur	10.8	18.7	34.9	95.1	201.1	363.1	306.1	434.6	238.8	164.4	16.7	8.0	1892.3
	Sripur	13.0	21.0	51.0	133.2	293.3	452.0	460.9	525.7	283.5	168.2	67.4	8.6	2478.4
	Pinga	15.6	22.2	42.1	97.7	214.8	329.5	309.5	307.2	250.8	146.9	28.5	6.4	1770.9
	Mymensingh	11.7	16.3	46.5	113.3	296.7	456.4	388.4	399.8	314.7	172.0	13.7	2.0	2231.5
	Average	12.8	19.6	43.6	109.8	251.5	400.3	366.2	416.8	272.0	162.9	31.6	6.3	2093.3
Temperature (° C)	Mymensingh													
	Maximum	25.2	27.6	32.0	33.8	32.4	31.2	31.3	31.3	31.5	30.7	28.7	26.4	
	Minimum	11.6	13.8	18.2	22.0	23.5	24.9	25.7	25.6	25.4	23.8	18.2	13.6	
Relative humidity (%)	Mymensingh													
	0900 hrs	62	77	75	76	82	87	87	88	85	85	81	84	
	1800 hrs	62	58	49	56	74	82	81	81	82	79	73	67	
Evapotranspiration(mm)	Mymensingh	98.4	118.1	155.3	153.0	106.3	72.6	72.6	71.4	77.6	85.5	96.8	96.8	1204.4*
Water balance (mm)	Mymensingh													
	Surplus	-	-	-	-	190.4	383.8	315.8	328.4	237.1	86.5			
	Stress	86.7	101.8	108.8	39.7							83.1	94.8	
Aridity index	Mymensingh	0.12	0.14	0.30	0.74	2.79	6.29	5.35	5.60	4.06	2.01	0.14	0.02	

Note: Aridity index refers to the rainfall divided by potential evapotranspiration. * = This reported crop evapotranspiration (ETc) data is 11% lower than the ETc calculated by CROPWAT.

Source: Manalo (undated)

Figure 2.3

Average Climate at Mymensingh



2.1.6 Hydro-geology

Surface deposits consist of older alluvium known as the Madhupur Clay, mostly red brown and silty clay deposits and generally not subject to flooding (UNDP, 1982). Monsor (1990) concluded that the Madhupur Clay was formed between 730,000 and 900,000 years ago. In most areas, the presence of a thick sequence of surface clay inhibits recharge (Rashid and Mridha, 1990). Nonetheless, potential recharge is greater than 200 mm per year. Deep tubewell development is feasible with optimal discharges of 28 l/s to 56 l/s. A shallow tubewell in this area is not feasible owing to the thick sequence of upper clay and silt and the deep water levels. The lithology of the project area is based on the bore-log information shown in Table 2.5. This reveals that the depth to the top of the main aquifer is around 45 m to 50 m. The transmissibility of main aquifer ranges between 1000 to 1500 sq m per day (UNDP, 1982).

Table 2.5 Lithology of the Project Area

Depth below ground surface (m)	Types of formation
00.0 - 09.0	Clay
09.0 - 15.0	Clay with fine sand
15.0 - 30.0	Fine to medium sand and medium sand
30.0 - 32.0	Medium to course sand
32.0 - 40.0	Course sand
40.0 - 45.0	Medium to fine sand with reddish clay
45.0 - 76.0	Course sand with gravel

Source: BADC, 1986

2.2 CASE STUDIES OF THE PROJECT AREAS

2.2.1 Introduction

The study area is a rice based area in the rainy season (June to August) with a range of crops grown in the dry season (November to April, see section 5.2.2.1). As on irrigated land elsewhere in Bangladesh, farmers grow Transplanted Aman rice (T Aman) as a main crop followed by Boro-rice and then Aus-rice. However diversified cropping is more common in this area, and other crops grown in the dry season are wheat, gram, sweetpotato, mustard, onion, chilli, potato and vegetables such as brinjal, various gourds, radish, soybean and so on. Banana and watermelon are widely adopted in the areas.

2.2.2 Methodology

A case study was carried out in the project areas. A sample was selected of 37 farmers (out of 362). Six (out of 39) were taken from the landless, ten (out of 91) from marginal, nine (out of 81) from small, six (out of 96) from medium, and six (out of 55) from large farm groups. The farmers were randomly selected from the different categories of farmers in six buried pipe schemes of which four were under the study in Shakipur Upazila.

2.2.3 Classification of Farmers

Table 2.6 shows the highest (16) number of farmers are from the landless group at Taltolapara scheme. This is because, as observed by interviewing the landless farmers, many do not want to live far away from the main road, which has been constructed over the Taltolapara scheme. Therefore, the landless farmers living far away from the main road, are trying to shift their houses near to the main road. As a result, the number of landless farmers in this scheme is higher. An average farmers' status in the Taltolapara scheme is in the small category, so has been discussed above.

Table 2.6 Farmers' Categories in the Three Main Schemes

Farmers category	Land holding(ha)	Schemes		
		Taltolapara	East Kutubpur	Shaplapara
landless	0.01 to 0.20	16	03	05
Marginal	0.21 to 0.50	07	12	13
Small	0.51 to 1.01	14	19	06
Medium	1.01 to 2.00	13	11	28
Large	>2.00	11	18	10
Total farmer		61	63	62
Landholding (ha/farmer)		0.93	1.13	1.16
Farmers' status		Small	Medium	Medium

2.2.4 Crops and Cropping Patterns

Before the installation of deep tubewells in this area the crops practised were broadcast aus (B Aus), jute, transplanted aman (T Aman), blackgram, sesame and mustard as major crops. The major cropping patterns followed previously in highland and medium highland are shown in Table 2.7. These patterns are still being practised by the farmers where irrigation water is not available. After deep tubewells are installed cropping patterns change (Table 2.8). Farmers usually irrigate crops from November to April with a little reference to other months and with the availability of water farmers have turned to grow boro-rice and transplanted aus (T Aus), and more areas have been brought under T Aman. Some new crops were introduced by the Tangail Agricultural Development Project (TADP) Unit in the areas. These are mainly vegetables. Farmers are trying to accept these new crops enthusiastically but the areas sown with the new crops are very small. Farmers are still in a trial and error stage to accommodate these crops into some stable cropping patterns.

Table 2.7 Cropping Patterns Before Deep Tubewells (6 Schemes)

Land Types	Cropping Patterns (Fully rainfed farming)					
1. Highland	i) B Aus	-	Mashkalai	-	Fallow
	ii) B Aus	-	Mustard	-	Fallow
	iii) B Aus	-	Sesame	-	Fallow
	iv) B Aus	-	Fallow	-	Fallow
	v) B Aus	-	T Aus	-	Fallow
	vi) Jute	-	Chilli	-	Fallow
	vii) Jute	-	Mashkalai	-	Fallow
	viii) Jute	-	Fallow	-	Mustard
	ix) Ginger/Turmeric/Aroids			-	Fallow
2. Medium highland	i) B Aus	-	T Aman	-	Fallow
	ii) T Aus	-	T Aman	-	Fallow
	iii) Fallow	-	T Aman	-	Fallow
	iv) Deep water rice			-	Fallow

Table 2.8 Cropping Patterns After Deep Tubewells (6 Schemes)

Land Types	Cropping patterns		
	April - August (Rainfed)	August - November (Rainfed & irrigated)*	November - April (Irrigated)
a) Highland	i) B Aus	- T Aman	- Boro
	ii) B Aus	- T Aman	- Wheat
	iii) B Aus/T Aus	- T Aman	- Watermelon
	iv) B Aus/T Aus	- T Aman	- Soybean
	v) B Aus/T Aus	- Rabi Chilli	
	vi) T Aus	- T Aman	- Boro
	vii) B Aus	- Cotton	- Fallow
	viii) Banana		
	ix) Jute	- T Aman	- Winter vegetables
	x) Aroids	- T Aman	
	xi) Turmeric		
	xii) Brinjal		
b) Medium Highland	i) B Aus	- T Aman	- Boro
	ii) B Aus	- T Aman	- Fallow
	iii) T Aus	- T Aman	- Fallow
	iv) Fallow	- T Aman	- Boro
	v) Deep water rice	- Fallow	- Fallow

Note: * = About 95% rainfed farming

The cropping intensity of the Shakipur Upazila was estimated by the Upazila office (Department of Agricultural Extension or DAE) to be 174% in 1989. The Bangladesh Bureau of Statistics (BBS, 1989) put the Upazila cropping intensity figure at 207%. For the six schemes in Shakipur, the average cropping intensity of the irrigated area was 233% (Table 2.9). The cropping intensity estimation was higher because of considering the irrigated area only. Details of the crops grown on the selected schemes during the irrigation seasons are given in section 5.2.

Table 2.9 Cropping Intensity According to Farm Category (6 Schemes)

Farm Category	Average cropped area (ha) per farm					Cropping intensity(%)
	Net	Single	Double	Triple	Total	
Landless	0.13 (100)	0.00 (0.0)	0.08 (61.3)	0.05 (38.7)	0.31 -	238.5 -
Marginal	0.36 (100)	0.01 (3.3)	0.17 (46.7)	0.18 (50.0)	0.89 -	247.2 -
Small	0.67 (100)	0.05 (7.8)	0.34 (51.2)	0.28 (41.0)	1.57 -	234.3 -
Medium	1.13 (100)	0.05 (4.3)	0.63 (55.7)	0.45 (40.0)	2.66 -	235.4 -
Large	2.60 (100)	0.57 (21.8)	1.50 (57.7)	0.53 (20.5)	5.16 -	198.5 -
Average	0.89 (100)	0.12 (14)	0.49 (55)	0.28 (31)	1.94 -	232.8 -
DAE	24,435	9029	12775	2632	42576	174.24
BBS	20,240	3007	12738	4495	41968	207.36

Note: Figure in parentheses indicate percentage. DAE refers to the Department of Agricultural Extension and BBS stands for the Bangladesh Bureau of Statistics

2.2.5 Socio-economic Conditions

Before the implementation of TADP, Shakipur and Ghatail Upazilas were very backward areas in terms of agricultural practices and production, trade and communication, education and culture. With the effort of the TADP, the situation has much improved there, for example, the change in cropping pattern described above.

2.2.6 Land Ownership and Distribution

Table 2.10 shows that the average farm size of landless, marginal, small, medium and large farmers is a total land area of 0.09, 0.35, 0.72, 1.52 and 3.97 ha, respectively. The average farm size of all categories is 1.17 ha, of which 84% is under crops, 6% under homesteads, 3% under forest, 0.3% under ponds, 6% fallow land and 2% under orchard. It appears that marginal farmers are the most efficient in terms of land utilization.

Table 2.10 Distribution of Land According to Utilization (6 Schemes)

Farm category	Area (ha) under Crop	Homestead	Forest	Pond	Fallow	Orchard	Total land
Landless	0.06 (67.0)	0.03 (33.0)	-	-	-	-	0.09 (100)
Marginal	0.31 (89.0)	0.03 (8.6)	0.003 (0.9)	-	0.002 (0.6)	0.0004 (0.1)	0.35 (100)
Small	0.61 (84.7)	0.05 (6.9)	0.01 (1.39)	- -	0.05 (6.9)	0.001 (0.14)	0.72 (100)
Medium	1.28 (84.2)	0.09 (5.9)	0.06 (3.9)	-	0.09 (5.9)	-	1.52 (100)
Large	3.26 (82.0)	0.16 (4.0)	0.1 (2.5)	0.02 (0.5)	0.28 (7.1)	0.15 (3.78)	3.97 (100)
Average	0.98 (84.0)	0.07 (6.0)	0.03 (3.0)	0.003 (0.3)	0.07 (6.0)	0.025 (2.0)	1.17 (100)

Note: Figure in parentheses indicate percentage

2.2.7 Tenancy Systems

The average cultivated land of all categories of farms is 0.90 ha of which 19% is rented in and 4.60% mortgaged in. At the same time the average own cultivated land of all farm categories is 0.98 ha of which 5% is rented out and 6.50% mortgaged out (Tables 2.11 & 2.12).

Two types of mortgaged system are found in the study areas. These are:

a) a landowner mortgages out his land by taking some amount of money from the cultivator. When this money is repaid by the owner, the land is free from lease. The cultivator will manage the land upto repayment time. This system is called the "daishudi".

b) the land is mortgaged for a fixed period of time for a fixed rent. After the time the land will free from lease. This system is called the "khaikhalashi".

Table 2.11 Land Rented-in and Rented-out (6 Schemes)

Farm category	Average area (ha) per farm					
	Cultivated land			Cultivated land/family	Percent of land Rented	
	Own	Rented in	Rented out		in	out
Landless	0.06	0.07	-	0.123	56.91	0.0
Marginal	0.31	0.07	-	0.40	17.5	0.0
Small	0.61	0.08	-	0.68	11.76	0.0
Medium	1.28	0.07	0.07	1.13	6.19	6.19
Large	3.26	0.17	0.64	2.60	6.53	24.62
Average	0.98	0.09	0.12	0.90	19.0	5.0

Source: Summarized and rearranged from Rashid and Mridha, 1990

Table 2.12 Land Mortgaged-in and Mortgaged-out (6 Schemes)

Farm category	Average area (ha) per farm					
	Cultivated land			Cultivated land/family	Percent of land Mortgaged	
	Own	Mortgaged in	Mortgaged out		in	out
Landless	0.06	0.012	0.009	0.123	9.76	7.32
Marginal	0.31	0.02	-	0.40	5.0	0.0
Small	0.61	0.01	0.02	0.68	1.47	2.94
Medium	1.28	0.06	0.21	1.13	5.31	18.58
Large	3.26	0.07	0.26	2.60	2.69	10.0
Average	0.98	0.03	0.08	0.90	4.60	6.50

Source: Summarized and rearranged from Rashid and Mridha, 1990

Six different tenancy systems were observed in the scheme areas (Table 2.13). The most prevalent system is 50:50 sharing between the landowner and the share-cropper. Recently, the Grameen Bank (GB) has introduced a new system in which the GB supplies only the irrigation water and in return, it collects 25% grain yield from the farmers. The rest of the grain is shared equally by the cultivator and the landowner.

Table 2.13 Tenancy Systems in the Scheme Areas (6 Schemes)

Sharer	Sharing of inputs(%)					Sharing systems(%)	
	Seed	Ferti-lizer	Pesti-cide	Irri-gation	Labour	Grain	By-product
1. Sharecropper	0	100	100	100	100	50	100
Landowner	100	0	0	0	0	50	0
2. Sharecropper	0	100	100	100	100	50	50
Landowner	100	0	0	0	0	50	50
3. Sharecropper	100	100	100	100	100	50	100
Landowner	0	0	0	0	0	50	0
4. Sharecropper	50	50	100	100	100	50	100
Landowner	50	50	0	0	0	50	0
5. Sharecropper	50	50	100	100	100	50	50
Landowner	50	50	0	0	0	50	50
6. Sharecropper	0	100	100	0	100	37.5	100
Landowner	100	0	0	0	0	37.5	0
Grameen Bank	0	0	0	100	0	25.0	0

Source: BARI, 1990

2.2.8 Credit Systems

The Bangladesh Krishi Bank (BKB) and the GB are the two main credit supplying agencies in the areas. Farmers are not interested in getting institutional credit because it takes a long time and has procedural complications. In avoiding the formal procedure, farmers sometimes borrow money from local lenders at a high rate (8%-10% per month).

2.2.9 Water Charge Systems

The KSS members have to pay a bank instalment half yearly Tk 20,520.00 (Tk 38.40 = 1 $ US, 1991) for a DTW. This amount is divided among the farmers, who register their land under the DTW for irrigation before an irrigation season. The water charge is fixed on the irrigated land area. Maintenance costs, for example, driver salary, repair works, and cost of oil are supposed to be collected from farmers before starting the season, but in practice, this was not found to be implemented. A thorough discussion of this can be found in section 7.1. A few terms are used frequently in this thesis. These are described below:

Own Fuel System

This own fuel system is often called farmers' fuel system. In this system, fuel (diesel) used for running the pump is purchased by the individual farmer instead of using project fuel or KSS fuel. According to the Irrigation and Management Programme (IMP) constitution, each farmer would have paid money to the KSS for buying project fuel, but in practice, this was not seen to be implemented except for one out of eight schemes. Fuel bought by the individual farmer is called the "own fuel system".

Oil Charge

Oil charge means collecting money against lubricating oil which is essential to follow schedule maintenance of the engine. Although based on crops a fixed rate of oil charge is payable by all the members according to their presumed cultivated land areas and the oil charge is supposed to be collected before starting the irrigation season, a number of defaulters were seen in the study schemes.

First Come First Served

This is a new system observed in the scheme areas. Under this system, farmers arrive at the pump house with a fuel container in hand. The pump operator provides irrigation water to the farmers in the order of who reaches the pump house first. This system is called the "first come first served". A long queue of farmers near the pump house was often observed during the peak demand time.

2.2.10 Irrigation Practice

Areas under irrigation by different farm categories are shown in Table 2.14. This table shows that participation of large farmers in irrigated agriculture is smaller than the other farm categories. The reason attributed for low participation is that large farmers are not interested in agriculture as they find other businesses (brokery, shop keeping, teaching, servicing abroad, local medicine etc) more profitable than agriculture. What is more, about 40% of agricultural land is left fallow because of getting unsatisfactory returns as is discussed in detail in sections 5.1 and 7.1.

Table 2.14 Irrigated Areas by Different Farm Categories (6 Schemes)

Farm Category	Cultivated land area (ha) per farm				Total land (ha)
	Irrigated land		Non-irrigated land		
	High	Medium high	High	Medium high	
Landless	0.05 (83)	0.01 (17)	-	-	0.06 (100)
Marginal	0.20 (63)	0.07 (22)	0.02 (6)	0.03 (9)	0.32 (100)
Small	0.25 (42)	0.12 (20)	0.18 (30)	0.05 (8)	0.60 (100)
Medium	0.76 (59)	0.17 (13)	0.11 (9)	0.24 (19)	1.28 (100)
Large	1.12 (34)	0.15 (5)	0.58 (18)	1.42 (43)	3.27 (100)
Average	0.42 (40)	0.10 (10)	0.19 (18)	0.34 (32)	1.05 (100)

Note: Figures in parentheses indicate percentage

2.3 CASE STUDIES ON BURIED PIPE IRRIGATION SCHEMES

2.3.1 Introduction

This case-study is based on collecting all information regarding buried pipe schemes, including farmers' cooperative, irrigation equipment and buried pipe systems. All the components in buried pipe schemes are interrelated with one another. When any of these components are poorly managed agricultural productivity necessarily declines.

Tangail Agricultural Development Project (TADP) with financial assistance from the German Agency for Technical Cooperation (GTZ) started the project in the eastern part of the Tangail district at the beginning of the 1980`s. Later the project introduced DTWs and buried pipe distribution systems (BPDSs) to ensure efficient utilization of water, as well as to demonstrate high inputs, with HYV crops, for maximizing the yield.

2.3.2 Methodology

Information on farmers' cooperative or the Krishak Samabay Samity (KSS) was collected from the manager of the respective schemes. The same was also collected from the Bangladesh Rural Development Board (BRDB) office and also from TADP record. Data regarding deep tubewells were collected from the Bangladesh Agricultural Development Corporation (BADC) both from Shakipur and Ghatail Upazilas.

All data on the BPDS were measured in the field with the help of the manager and TADP staff. The same was also collected from the implementing agency, TADP, who installed these systems. The basic information of the schemes is shown in Table 2.15.

2.3.3 Farmers' Cooperative

The KSS (Krishak Samabay Samity or Farmers' cooperative) is primarily formed by the BRDB following application from a farmers' cooperative after downpayment, which was made out of cash or loan to buy the irrigation equipment. TADP organised the farmers' cooperative society for better use of production technologies, and for providing loans to the needy farmers through BRDB. The KSS is responsible for the operation of the tubewell, and uses the "farmers fuel" system to finance the operation. Under this system the farmer pays a fixed charge per unit area to cover the use of the pump, and provides the fuel for operation.

2.3.4 Deep Tubewells

Each deep tubewell (DTW) was installed by the Government agency (BADC) following application from a cooperative of villagers or KSS, who took out a loan from the Government agency (BRDB) through a bank to buy the tubewell. In principle the KSS owned and managed the tubewell.

2.3.5 Buried Pipelines

Buried Pipe Systems (BPSs) were installed by the TADP, who handed this to the KSS institution at a subsidized cost to be paid in instalments. The KSS owned and managed the BPS. Three buried pipe systems showing their outlets' location, together with different pipe lengths and diameters in the field are shown on the schematic layout of the schemes (Figures 2.4, 2.5 and 2.6). The five other buried pipe figures are given in Appendix A (Figures A.1, A.2, A.3, A.4 and A.5).

Figure 2.4

Buried Pipe Layout (Taltolapara)

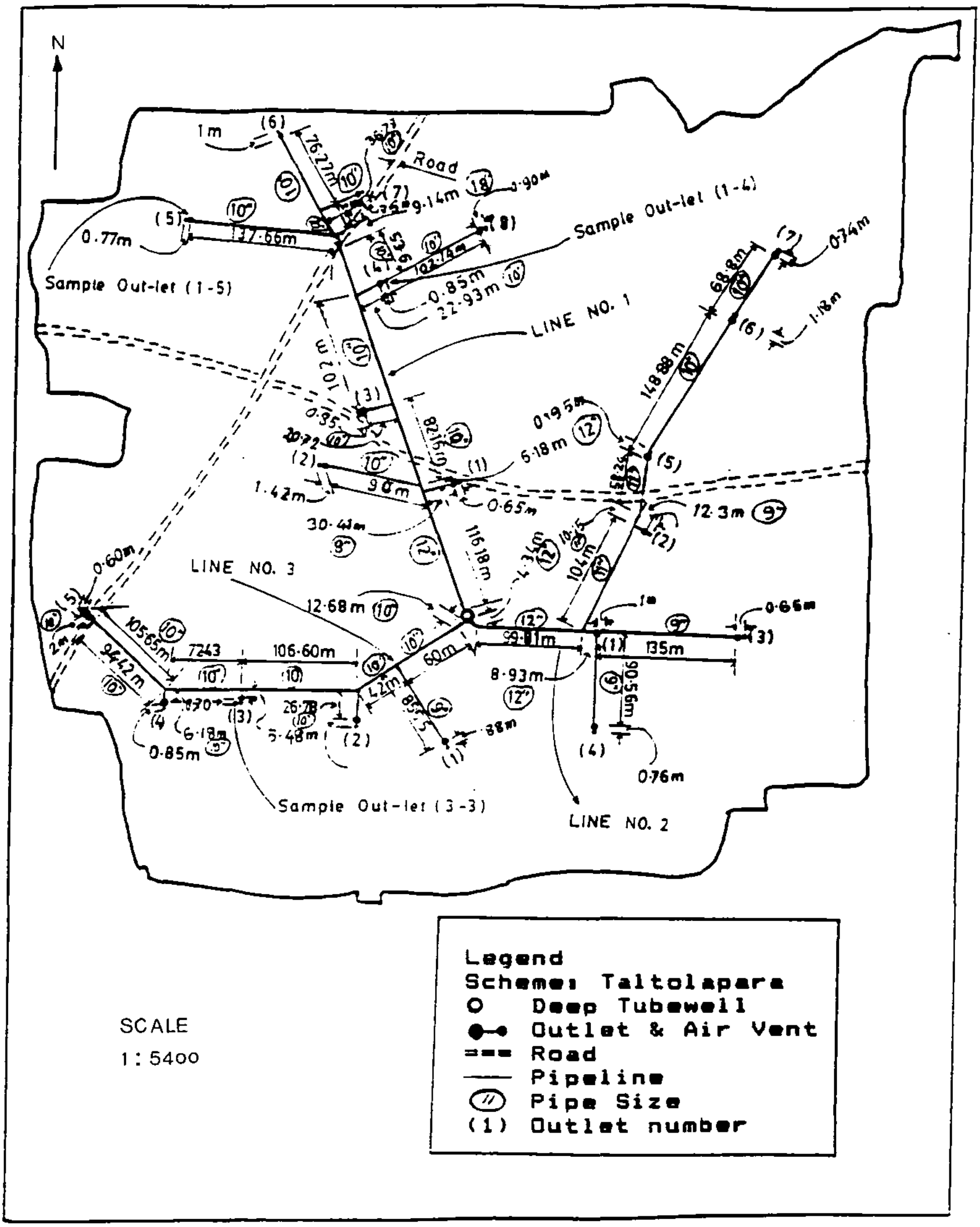


Figure 2.5

Buried Pipe Layout (East Kutubpur)

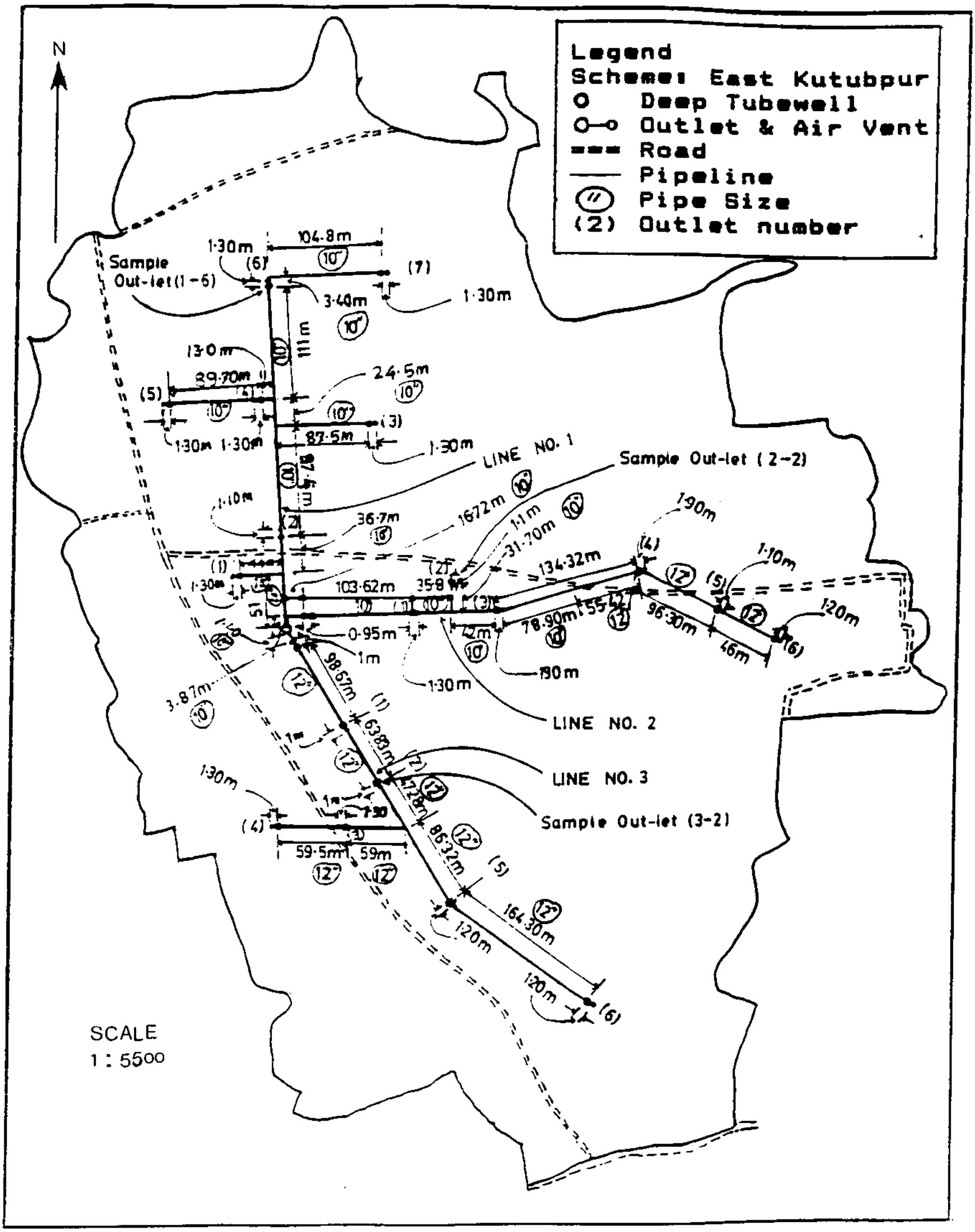
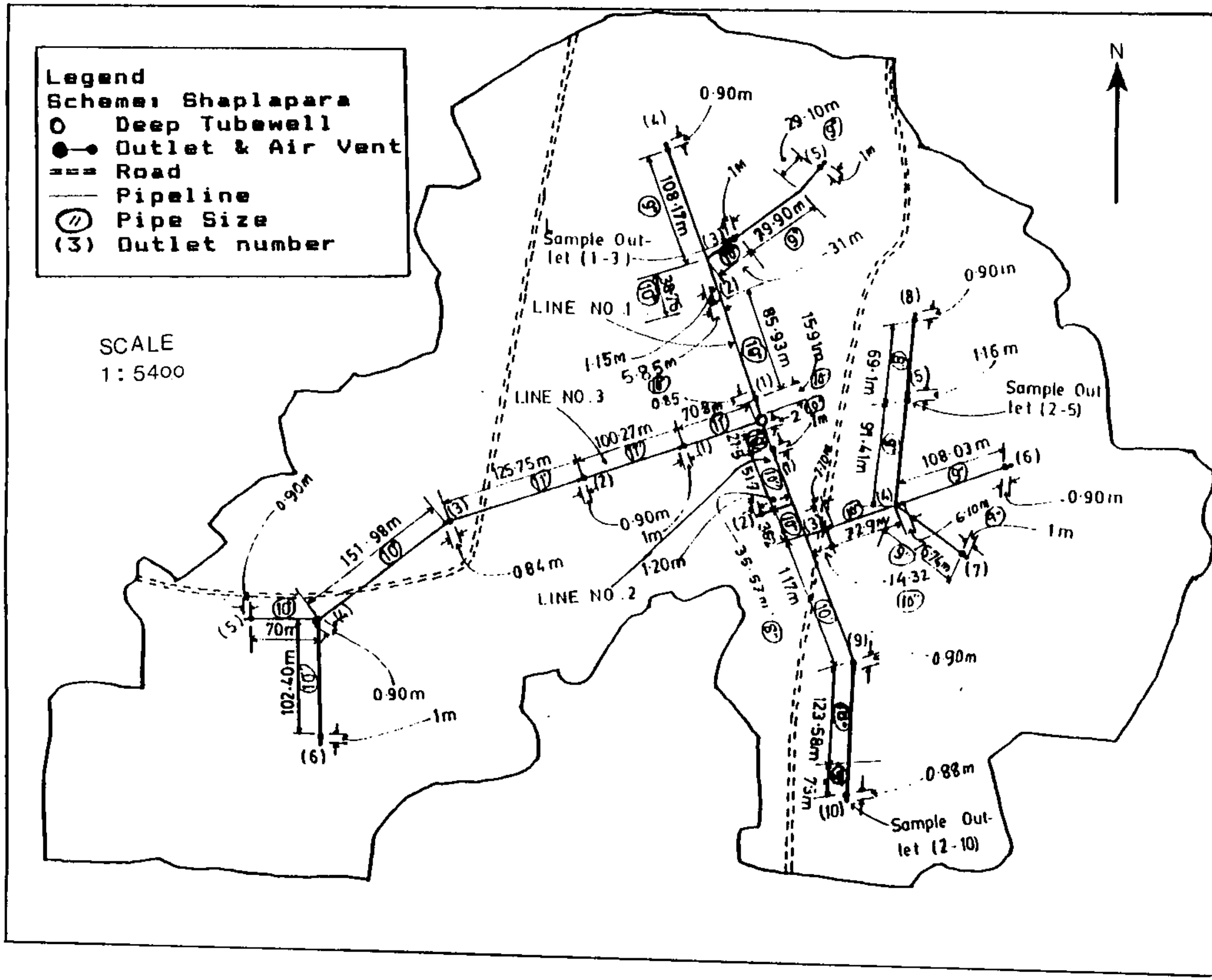


Figure 2-6

Buried Pipe Layout (Shaplapara)



The TADP is one of the few organisations who have been constructing BP systems for the KSS. TADP with the assistance from the German Agency for Technical Cooperation (GTZ) has been working in Tangail for promoting irrigated agriculture using a DTW/STW with BPDS.

Early buried pipe systems constructed by the TADP was different in that they used the same pipe size throughout the scheme and installed a head tank for a pipeline. For example, the number of header tanks at Binnakhaira was four for the four pipelines and later it was modified to one. The new one has the inlet valves set on raised concrete pipes about 2.67 m off the bottom of the header tank. According to TADP design two main pipelines have to be operated simultaneously at Binnakhaira and Baila schemes. However, the farmers do not exactly follow the rules. Two schemes are provided with check structures. At East Kutubpur these are "H" shaped concrete pipes used to prevent back flow of water into the header tank. At Binnakhaira the check structures are used to control the flow into the branch pipelines, but these are of no use, because the threads of the alfalfa valves (inside check structures) are damaged.

Table 2.15 Information on Eight Buried Pipe Schemes

Parameters	Schemes							
	Taltolapara	East Kutubpur	Shaplapara	Baila	Vailpara	Chulabar	Hazipara	Binnakhaira
KSS/Scheme history								
KSS/scheme name	Taltolapara	East Kutubpur	Shaplapara	Baila	Vailpara	Chulabar	Hazipara	Binnakhaira
Upazila	Shakipur	Shakipur	Shakipur	Ghatail	Ghatail	Ghatail	Ghatail	Shakipur
TADP code no.	1.17	1.06	1.16	3.20	3.13	3.10	3.22	1.03
DTW no.	TADP- 5	TADP-3	TADP-4	248	240	237	246	TADP-8
KSS regist. no.	52/88	51/87	58/88	1/89	5/87	14/87	5/90	53/86
Members at regist.	17	23	32	31	26	32	35	27
Members at present	42	44	42	39	35	50	44	58
Members making downpayment	26	31	32	31	22	32	35	27
KSS regist. date	13-05-1986	13-05-1986	13-05-1986	30-06-1989	03-10-1987	08-10-1987	09-05-1990	13-05-1986
Downpayment date	21-10-1985	24-08-1985	06-05-1986	03-02-1988	28-05-1986	09-04-1986	03-02-1988	09-04-1985
JL no.	290	290	290	303	306	305	306	288
Plot no.	849	129	147	55	173	145	173	614
Non KSS members	19	19	20	-	-	6	2	19
DTW history								
Down payment(Tk)	13000.00	13000.00	13000.00	13000.00	13000.00	13000.00	13000.00	13000.00
Subsidized DTW cost (Tk)	175000.00	175000.00	175000.00	175000.00	175000.00	175000.00	175000.00	130000.00
Total payment(Tk)	92512.00	89819.00	68210.00	82467.00	64835.00	30400.00	33220.00	108885.00
Contractor	S Hassan	The drillers Engineers	M/S Snctti Enterprise	The drillers Engineers	M/S Delower Hossain & Brothers	M/S Delower Hossain & Brothers	The drillers Engineers	M/S Soil Tech.
Drilling date	24-04-1986	09-03-1986	05-08-1986	18-03-1988	12-11-1986	22-09-1986	09-03-1988	14-05-1985
Installation date	28-04-1986	13-03-1986	10-08-1986	23-03-1988	15-11-1986	26-09-1986	14-03-1988	18-05-1985
MS housing (ft)	96	96	96	96	96	96	96	104
MS reducer (ft)	2	2	3	3	2.5	2.5	2	2
GI blind pipe(ft)	30	50	72	65	96	90	82	30
Strainer (ft)	80	100	100	100	100	100	100	100
GI bail plug	5	5	5	5	5	5	5	5
Well depth (ft)	213	253	276	269	299.5	293.5	285	241
Pump set depth(ft)	73	75	70	80	80	80	80	80
Gravel (ft^3)	526	650	600	600	625	575	625	665
Engine type (Horizontal)	Deutz F2L 912	Deutz F3L 912	Deutz F2L 912	Deutz F21 912	Deutz F2L 912	Deutz F2L 912	Deutz F2L 912	Deutz F3L 912
HP of prime mover	27	32	27	32	27	27	27	36
RPM of prime mover	2250	2250	2250	2250	2250	2250	2250	2250
Operated by	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Pump type	KSB B12 B/2	KSB B12 B/2	KSB B12 B/2	KSB B12 B/2	KSB B12 B/2	KSB B12 B/2	KSB B12 B/2	KSB B12 B/2
BHP of pump	20.5	26	20.5	20.5	20.5	20.5	20.5	26
RPM of pump	1500	1500	1500	1500	1500	1500	1500	1500
Gear ratio (Engine:pump)	3:2	3:2	3:2	3:2	3:2	3:2	3:2	3:2
No. of stage	2	2	2	3	2	2	2	2
Design disch.(Cusec)	2	2	2	2	2	2	2	2

Table 2.15 continued

	Schemes							
	Taltolapara	East Kutubpur	Shaplapara	Baila	Vailpara	Chulabar	Hazipara	Binnakhaira
At Development								
a) Development date	25-06-1986	14-03-1986	18-10-1986	01-04-1988	03-01-1987	26-10-1986	14-04-1988	-
b) SWL(ft)	32.33	31.92	13.00	31.33	12.42	12.83	34.33	-
c) Discharge(Cusec)	3.0	2.25	3.0	3.00	3.0	2.25	3.0	-
House making date	27-07-1986	03-06-1986	13-12-1986	09-06-1988	02-03-1987	18-12-1986	04-06-1988	-
Commissioning date	23-02-1987	06-08-1986	06-02-1987	05-07-1988	28-06-1987	17-12-1986	05-07-1988	30-12-85
Handing over date	25-03-1987	08-09-1986	18-02-1987	05-07-1988	28-06-1987	17-12-1986	03-08-1988	30-12-85
Buried Pipe history								
Installation date	November 1988	November 1987	November 1988	November 1989	November 1989	November 1989	November 1990	November 1987
BP length (m)								
size(inch) 18	18.28	-	-	-	-	-	-	-
12	236.67	782.57	-	-	-	-	-	-
11	172.39	-	297.27	294.14	578.81	437.64	91.44	-
10	1314.34	985.02	820.25	966.14	741.67	836.16	505.97	-
9	417.22	-	626.73	571.70	435.78	586.69	60.96	-
8	31.06	-	114.95	-	-	-	-	3991.54
Total length (m)	2189.96	1767.59	1859.20	1831.98	1756.26	1860.49	658.37	3991.54
Actual cost (Tk)								
a) Total	2,70,788.00	2,47,020.00	2,05,081.00	-	-	-	-	-
b) Per meter length	123.65	139.75	110.31	-	-	-	-	-
Downpayment(Tk)	8000.00	4000.00	8000.00	8000.00	8000.00	8000.00	3800.00	4000.00
Subsidized cost (Tk)								
a) Total	94750.00	40,000.00	80,000.00	80,000.00	80,000.00	80,000.00	30,000.00	40,000.00
b) Per metre length	43.27	22.63	43.03	43.67	45.55	43.00	45.57	10.02
Main pipeline	3	3	3	2	3	3	1	4
Branch pipeline	13	5	7	3	3	4	3	7
Outlet	21	20	21	20	20	20	7	50
Outlet dia (mm)	200	250	200	200	200	200	230	180
Air vent	20	19	21	20	20	19	7	47
Air vent dia(mm)	150	250 & 300	152	200	200	200	200	200
Header tank (HT)	1	1	1	1	1	1	1	1
Header tank dia(cm)	91	92	92	92	92	91	92	*
Height of HT (top to bottom, m)	4.15	3.37	3.56	3.66	3.61	3.62	3.63	3.78
Check structure	-	2	-	-	-	-	-	8
Inlet dia of BP(mm)	250	250	250	250	250	250	250	180
Control structure at outlet	0	0	0	0	0	0	0	50

* Inside of header tank is modified, 4 pipes of 10 inch diameter each and height 2.67 m from bottom of header tank (92 cm dia) and at top of each pipe carried inlet valve inside of header tank

CHAPTER 3
BURIED PIPE NETWORKS IN BANGLADESH

3.1 INTRODUCTION

A comparative review of Buried Pipe Distribution Systems (BPDSs) worldwide has been presented by Bentum (1992). This literature review is confined to BPDS in Bangladesh. The most common form of the BPDS found in Bangladesh is a closed low pressure system with a branching pipe layout. Most systems use non-reinforced concrete (CC) pipes and few uPVC pipes. This pipe system usually receives water from a deep tubewell (DTW) and distributes this over a command area of 40 ha via around 20 outlets and supplies water to individual field plots via earthen field channels. The pipeline is buried, the only above ground structures are inlet structures at the head of the pipe system, outlets and air vents for the control of pressure fluctuations along the pipeline.

As mentioned earlier the buried pipe (BP) as distribution systems in DTW irrigation in Bangladesh began about a decade ago. Since then, a number of BP systems, mostly CC pipelines have been installed by several organisations. At present about 10,000 ha area has been used under BP systems for surface irrigation. However, the growing demand for irrigation water and the increasing trends of rising irrigation costs have created an awareness of the wastefulness of present methods of irrigation and have made the farmers concerned about crop water requirements and losses in the conveyance system. Nevertheless, in areas with undulating land topography and light textured soils earthen open channel systems are found to be inconvenient both technically and economically (Rashid and Mridha, 1992).

3.2 THE EXTENT AND HISTORY OF BURIED PIPES

Matin (1990) reported that the first BP system was introduced in 1982 by the Rural Development Academy (RDA), Bogra, under the technical assistance of the Food and Agricultural Organisation (FAO) of the United Nations. The project was implemented in Narhatta under Kahalu Upazila, where asbestos cement (AC) pipes were used in the system having two loops to irrigate 67 ha of land. The total pipe length was about 3000 m. The RDA implemented the second BP scheme, made of PVC pipes, having a diameter of 150 mm and a length of 1000 m to irrigate 60 ha of land in the same Upazila in the same year. In 1984, the third BP scheme was installed at Rajshahi by the RDA under the technical and financial support from FAO. For this scheme, low cost CC pipes were used for a total pipe length of 990 m to irrigate an area of 12 ha.

A buried pipe water distribution system has been working satisfactorily at the Bangladesh Agricultural Research Institute (BARI) Central Farm at Joydebpur since 1979 (Rashid and Mridha, 1992). This system has a command area of about 100 ha (Michael, 1987). Three DTWs were interconnected by 200 mm diameter PVC pipes. A tank located at the upper reach was also connected to the BP system to deliver water from the tank to the experimental plots. The tank was used to store water from rainfall or to receive pumping water from the DTWs at the idle time.

In 1985, a cement concrete BP system was built for the Development Service Centre, where an eight-hectare of agricultural land was used in the Savar area. The scheme is run by a foreign mission group (Gisselquist, 1989).

Barind Integrated Area Development (BIAD) Project of BADC at Rajshahi constructed 3 BP systems in 1987-88. These are: a) Uttar Andharkota DTW, b) Paramanandapur DTW and c) Ramnagar DTW. A total of 13 schemes have so far been completed but 11 of these have been stopped due to various problems and the other two are working but showing very poor performance. The reason for the poor performance is probably due to a fault in hydraulic design. It provided 15 to 18 outlets per scheme and portable division structures at outlets of some of the schemes (Rashid and Mridha, 1992).

In 1989, the Overseas Development Administration (ODA) started funding BP systems on 24 tubewells, as a pilot development under the DTW-II Project. This is being implemented by Mott MacDonald International (MMI). They have constructed BP systems for the KSS in different parts of Dhaka, Mymensingh and Manikgonj districts. These are located at Dhamrai in Dhaka district, Bhaluka, Trisal and Mymensingh in Mymensingh district and Shaturia in Manikgonj district. Two buried pipe schemes of which one is a branching system using CC pipe, and the second is a loop system using uPVC pipe and 3 or 4 other partial systems using CC pipes have been completed to date. Loop networks require a higher standard of water tightness than branch systems (Rashid and Mridha, 1992), because the whole loop is filled by water during operation. However, they use smaller diameter pipe and can therefore be cheaper. MacDonald provided diversion boxes around outlet valves.

Rahman (1987) reported an agreement concerning technical and economic cooperation which was made between the Government of the people's Republic of Bangladesh and the Government of the Federal Republic of Germany in July 1972. Later, two subsequent agreements (one in 1982 and the other in 1985) were signed to start an agriculturally based area development project with the name

"Tangail Agricultural Development Project or TADP". The project started in April 1985 with the objectives to increase food production with emphasis on irrigated crops and to reduce unemployment in rural areas by public works for the improvement of rural infrastructure (Rahman, 1987). Under the programme, irrigation equipment and lined irrigation channels were set, rural roads were improved and high yielding varieties (HYV) of wheat, banana and other crops were demonstrated in Tangail district.

In 1986, the project was jointly evaluated by a team of Bangladesh and German consultants. After the evaluation, some changes were recommended in project design including a focus on the Command Area Development (CAD), in which the irrigation duty (irrigation area per unit of flow rate) were to be increased through better management of irrigation water, improving services of the Krishak Samabay Samity (KSS) and strengthening extension services. For better water management, TADP considered two things:

a) Water Users Organisation, and
b) Water Conveyance Structures.

Therefore, TADP put emphasis on the improvement of these two things to achieve their objectives. Thus, they decided to install BP systems to irrigate 40 ha by a DTW (56 l/s capacity) and 14 ha by a STW (14 l/s capacity). They set a target of converting earthen channels into BP systems for 8 DTWs within 1987 (Rahman, 1987).

To date TADP has constructed 45 CC pipeline systems (with 11 partial) which are all branching systems. All these systems have pressure in the range of 2 m to 4 m head of water. TADP provided about 20 outlets on each system and no division box/structure at the outlet. Reports are available setting out the designs on the TADP (Georgi, 1989), BIAD (Matin, 1990), and the ODA Projects (MMP, 1989a, 1989b, 1989c, 1989d and 1989e).

3.2.1 Type of Buried Pipes

Buried pipelines for surface irrigation are usually constructed with:

a) Non-reinforced cement concrete (CC) pipes
b) Reinforced cement concrete (RCC) pipes
c) Plastic pipes (uPVC/PVC)
d) Asbestos cement (AC) pipes

a) **Non-reinforced Cement Concrete Pipes**

Sand, cement, course aggregates (usually brick-chips) and water are usually used to make non-reinforced concrete (CC) pipes. These CC pipes are the most common in Bangladesh and widely used in the buried pipe schemes for surface irrigation. In small farms, where high pressures are not involved, this pipe may be used. The CC pipes are generally used under low pressure upto a head of 6 metre or 0.6 Kg/sq cm of water (Michael, 1978). Generally the CC pipes are cheaper than reinforced concrete pipes. Under most field conditions, they are the most economical. They may be either hand made or machine made. However, much skill and supervision are required to ensure good quality pipes.

The TADP, BIAD and MacDonald have been manufacturing CC pipes under the direct supervision of project staff, as pipes available in the market typically have low quality and relatively high costs. The quality of pipes depends on the quality of the concrete used and the proper curing of pipes after making. Georgi (1989) documented poor quality of khoa (brick-chips); the poor ratio of cement, sand and khoa; and inadequate curing as the main reasons for low pipe quality in Bangladesh. The local sands, peagravel are in most of the cases contaminated with clay, silt, and organic matter, they originate from river beds or hilly areas.

The CC pipes used in Bangladesh are either hand made using inside-outside shuttering or machine made using a spinning machine, which is designed to produce pipes in circular shape.

b) **Reinforced Cement Concrete Pipes**

Higher operating heads demand stronger pipes, like reinforced cement concrete (RCC) pipes. In making RCC pipes, course aggregates sized in the range of 7 to 12 mm are used. Steel and concrete are bonded together very tightly so as to make pipes stronger.

c) **Plastic Pipes (uPVC/PVC)**

Unplasticised poly vinyl chloride (uPVC) and polyvinyl chloride (PVC) pipes are currently being manufactured in Bangladesh in the range of diameters from 75 mm to 200 mm for buried pipe distribution systems. The uPVC is stronger and more rigid than polyethylene and cheaper than glass reinforced plastic (GRP) pipes which are generally used for high head applications (Rashid and Mridha, 1992).

d) Asbestos Cement Pipes

Asbestos cement pipes are usually more costly than CC and RCC pipes but can be easily installed, have a long service life and are adapted to a wide range of water pressures. Two types of AC pipes are used for buried pipelines. One has been made for high pressure and the other is for low pressure.

3.2.2 Selection of Pipe Materials

With the advent of pipelines to transport irrigation water, there has evolved a wide range of pipe materials with each particular type having its own special characteristics which make it either more or less suitable for a particular application. However, the selection of material mainly depends on the relative costs (Rashid and Mridha, 1990). The conditions under which the pipe is to be operated is given the second priority.

The concrete used for making pipes should be made of good quality cement, sand and course aggregate so proportioned and mixed as will produce a homogeneous concrete mixture of the required strength. Generally, a mixture made of 1 part cement, 2 parts sand and 3 parts course aggregate, with a minimum of water to make it workable and suitable to make pipes of adequate strength (Michael, 1978).

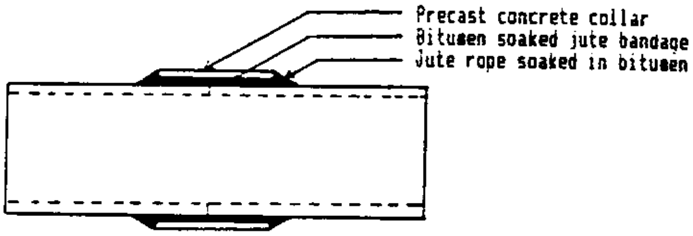
3.2.3 Pipe Jointing

In Bangladesh, different organisations are using different jointing techniques in the low pressure buried pipe systems for surface irrigation. The most common joints are:

a) Tongue and groove joints (refer to Table 4.11)
b) Bellmouth-socket and spigot joints
c) Plane-end pipe joints
d) Collar joints

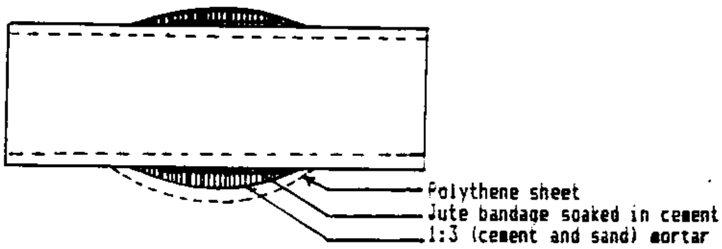
The BIAD system of jointing plane-end CC pipes uses a precast concrete collar to cover a bitumen soaked jute bandage (Figure 3.1). Earlier TADP used the first 3 joints. At present, the TADP joint uses in-situ cement-sand mortar banding to cover a jute bandage soaked in cement slurry (Figure 3.2). MacDonald uses joints similar to the TADP.

Figure 3.1
BIAD Concrete Pipe Joint



1. Wet pipe ends
2. Coat surfaces to be jointed with cement slurry
3. Wrap jute bandage soaked in bitumen around pipe joint
4. Slip collar into place and fit wedges to maintain uniform clearance between pipe and collar
5. Fill gap between pipe & collar with cement & sand mortar
6. Drive bitumen soaked rope into gap between pipe & collar
7. Finish ends of collar with mortar banding bevelled to angle of 45θ

Figure 3.2
TADP Concrete Pipe Joint



1. Form hollow in trench base at site of joint
2. Lay polythene sheet in hollow to prevent moisture migration
3. Wet pipe ends
4. Apply neat cement slurry to surface to be jointed
5. Wrap jute bandage soaked in 1:1 cement & sand mortar twice around joint
6. After 15 minutes apply 1:3 cement & sand mortar banding over jute bandage and finish off
7. Cover finished joint prevent moisture loss by evaporation from fresh concrete

3.2.4 System Performance

Buried pipe systems made of PVC and AC have been performing satisfactorily. However, most of the CC systems have encountered considerable leakage problems in the pipelines. Inadequate jointing technology and lack of proper supervision while constructing the systems might be the reasons for this. Leakage through pipe body was also observed which is mainly due to the weak constructional procedures and the faulty materials. Michael (1987) mentioned that one of the possible reasons for not obtaining leak-proof joints in the CC/RCC pipes is that the pipes with collar joints, available in Bangladesh, are usually not provided with a recession (groove) at the ends.

A limited number of outlets (about 20) in many systems have resulted in longer earthen field channels. This has greatly increased the systems' water conveyance losses or in other words has greatly reduced the systems conveyance efficiency. Farmers noticed that 2 cusec (56 l/s) outlets were inconvenient for the prevailing field situations (refer to section 4.2.2.4), because they preferred own fuel system. Some outlet valves were found completely damaged in many of the schemes. These were due to mishandling or faulty operation (for example, refer to section 4.2.2.5). Outlets were either without any division box or with masonry division boxes many of which were damaged due to the differential settlement of freshly formed earth works under the structures. In many places air vents were constructed unnecessarily high (for example, Taltolapara, Chulabar and Hazipara schemes, see Table 4.2) and outlet valves too low, even below field levels.

It is felt that there is considerable scope for improving the pipes, design, and construction of BP systems. A field block of 1 ha provided with a separate outlet of 1 cusec (28 l/s) capacity, with the valve located about 15 cm above the field level with a division box (protection against scouring) would be convenient.

3.2.5 System Costs

The capital cost of RCC, PVC, uPVC and AC pipe water distribution systems installed in Bangladesh have been higher than for earth channel systems but less than for a lined channel system. Michael (1987) reported that the asbestos cement pipe water distribution system at Narhatta (Bogra) has not been found to be cost-effective. The cost incurred (1983 prices) was estimated Tk 15,018.00 per ha which is exorbitant. The CC pipes are found to be the most economic provided the system is properly designed and care is taken to make them leak-proof.

TADP`s construction costs were Tk 7,000.00 per ha in 1987-88 (Gisselquist, 1989). Some 15% to 20% of this is contributed by the farmers, partly in labour for trench excavation, and partly in cash. In this study, based on three schemes the costs incurred were Tk 6,000.00 per ha (refer to Table 2.15).

A comparative costing of the different distributing systems were made by this study. Costs outlined (Table 3.1) show that non-reinforced concrete (CC) buried pipe systems to be lower (47%) in cost than other improved systems (for instance, uPVC pipe systems).

Table 3.1 Comparative Costs of Different Distribution Systems

System	Right of way(m)	PV of costs as of 1989-90 price (Tk/m)			Percent of lined channel
		Land	Construction	Total	
Brick lining (lined)	3.0	75	584	659	100
Unimproved earth channel	2.4	58	39	98	15
Improved (compacted) earth channel with control structures	3.0	75	105	180	27
Pre-cast semicircular	1.5	38	374	412	63
In-situ semicircular CC pipes	1.5	38	558	596	90
CC buried pipe (10")	-	-	308	308	47
uPVC pipe (8")	-	-	770	770	116

Note: Tk 38.40 = 1 $ US, 1991. Land value = Tk 2,47,100.00 per ha

MacDonald`s (MMP, 1989a) construction costs, are on average Tk 11,115.00 per ha for CC pipe systems and Tk 33,345.00 per ha for uPVC pipe systems (price as of May, 1990). The cost of uPVC pipes was three times more than the cost of CC pipes. The cost of CC pipes by MacDonald was higher than TADP's cost, because MacDonald used brick-chips instead of Kauchi (which refers to minerals in crystalline form available in hilly areas in the forest and these were used by TADP) in the construction of CC pipes and also provided water division structures for each outlet. BIAD`s construction cost for CC pipe systems came to be about Tk 12,000.00 per ha, which was very close to MacDonald's cost.

3.3 EVALUATION OF BURIED PIPE SYSTEMS

No systematic study has so far been made to evaluate the existing BP systems in Bangladesh. However, Some assessments made by different evaluators are:

Ahmed (1984) reports that new buried pipe systems give high conveyance and distribution efficiencies besides yielding other economic and non-economic advantages. However, a conversion from earthen channel to buried pipe requires a large additional investment.

Gisselquist (1989) pointed out additional benefits: the BP system can be used with badly sited deep tubewells (for example those not located at the highest point in the command area) and with shallow tubewells or low lift pumps located in low areas or wherever water is available.

MacDonald (1992) reviewed BPDSs installed in Bangladesh and concluded that the main benefits of the system are: **a)** more efficient wateruse, **b)** fewer right-of-way issues, **c)** higher level of agricultural development, and **d)** reduced maintenance costs.

Georgi (1989) documents that from two years field experience, a growing demand for this system of irrigation is found at farmers' level. He adds that in future, small entrepreneurs will be able to build BPSs for farmers' cooperatives on demand. Further promotion can be done through the Government of Bangladesh (GOB), Non-Government Organisations (NGOs) or the private sector and the systems need not be subsidized. The economic return will be such that they might induce farms to take up a scheme and pay the full amount of investment. He also adds, implementation of the BPS could be done in phases subject to the availability of funds, with an overall plan and decisions prepared in advance for the whole scheme covering the desired command area.

Brod (1990) argues from his practical experience that farmers did not operate the BPS at Agollapara KSS, Bhaluka, Mymensingh. The pump was designed for 2 cusec (56 l/s) capacity and the outlets were designed for 1 cusec (28 l/s) capacity each. Farmers were advised to operate two outlets at a time, but farmers did not like to do so, consequently the full 56 l/s DTW discharge was directed down a 28 l/s outlet, resulting in the overflow of the header tank. This problem can be solved replacing the pump by a 1 cusec one.

Rahman (1990) documented that pipe production makes some income generating activities among the landless farmers. He added promotion of BPS was taken by some NGOs or the private sectors as a special programme. This indicates the future scope of the BPS is very bright. So, more attention should be given for planning, designing, constructing, production training and developing entrepreneurship to extend the system throughout Bangladesh.

Palmer-Jones and Mandal (1988) reported that buried concrete pipe is an alternative to reduce water losses although it needs high initial investment and construction skills.

Jenkins (1983) documented many advantages of buried pipe systems which were not consuming valuable agricultural land, regulated water flow even against undulation and broken topography, promises to irrigate more area at minimum water loss.

Bentum and Smout (1993) reported that buried pipe systems are to be preferred over open channel alternatives in the following situations:
a) where poorly cohesive soils would result in high seepage losses,
b) where variations in ground level mean that irrigable land cannot be reached by an open canal system, and
c) where water is valuable in terms of crops and limitation of water resources (e.g. groundwater sources).

Pluje (1981) reported that pipe systems built in Bogra, had a lot of difficulties. For instance, the use of asbestos cement pipe was difficult to construct, seepage problems from ill fitting joints and high installation costs.

3.4 BURIED PIPE SYSTEMS IN ASIA

India has been using low pressure buried pipe systems for more than 20 years. Hannan and Haque (1984) reported that the World Bank funded a series of major projects on buried pipes e.g. the Uttar Pradesh Public Tubewell Project, the Bihar Public Tubewell Project, the West Bengal Minor Irrigation Project etc. In Uttar Pradesh, there were 6000 CC and 560 plastic pipe systems installed by 1984 (Rashid and Mridha, 1992). In Gujarat farmers themselves have installed pipe systems on private tubewells.

Merriam (1985) conducted a study on a 145 ha buried pipe distribution system in Sri Lanka with the pipelines taking off the level top canal and supplying water to individual 1 ha farms on demand. He concluded the installation cost of the BPS was about US $ 810.00 per ha against a cost of US $ 335.00 per ha for conventional unlined tertiary canal systems. He also reported that non-reinforced tongue and groove mortar jointed pipe proved much more satisfactory than collar jointing pipe. However, by this study it was observed that plane-end pipe jointing was superior to other joints (see section 4.2.2.10). The World Bank has also funded BPS in Sri Lanka through the concrete pipeline pilot project "Mahaweli Project". In Thailand buried PVC pipe systems have been installed on the "Sukhothai Groundwater Development Project" (Bentum, 1992).

3.5 BURIED PIPE SYSTEMS WORLDWIDE

Literature on pipe systems shows that buried pipe systems have been installed in many countries and substantial investment is continuing in Nepal, China, Taiwan, Indonesia, France, Spain, USA and Australia.

From a number of FAO reports and World Bank publications, Field (1990) documented the total area of world irrigation at around 254 million hectares, with 94% of this being surface irrigation. Estimated areas of the different types of irrigation for both developed and developing countries of the world are summarised in Table 3.2.

Table 3.3 shows estimated areas of buried pipe systems for surface irrigation in the world. Low pressure buried pipe systems used in USA cover the largest (7.3 million hectares) area (Baudequin et al, 1990) followed by China at 2.5 million hectares (DST China, 1990) and then India (1 million hectare). Baudequin et al (1990) also reported low pressure buried pipe systems occupy around 43% of all surface irrigation in USA. This indicates the widespread use of low pressure buried pipe system in the USA. Bentum (1992) documented less than 5% of the total world irrigation area as being irrigated by low pressure buried pipe systems.

Non-reinforced concrete pipe materials have been successfully used for buried pipe distribution systems since the early 1920's (Coles, 1991) and have been widely used for pipe systems in the USA (Pimley and Fischer, 1990). While non-reinforced concrete pipe is strong in comparison, it has weaknesses when subjected to tensile forces. Koluvek (1970) while acknowledging that reinforced concrete pipe superior pipe material, concludes that such pipe too expensive for irrigation distribution systems in the USA.

Table 3.2 Summary of World Irrigation Areas ('000 ha)

System	Developing Countries	Developed Countries	Total
Surface(ex BPDS)	180,255(97%)	46,628(68.6%)	226,883(89.5%)
Sprinkler	1,500(0.85%)	12,592(18.5%)	14,092(5.5%)
Micro-irrigation	200(0.15%)	1,000(1.5%)	1,200(0.5%)
Low pressure Pipes(est)	3,685(2%)	7,740(11.4%)	11,425(4.5%)

Source: Field W P, 1990

Table 3.3 Country Areas (ha) Estimated on Buried Pipe Systems

Developing Countries	('000)	Developed Countries	('000)
China	2,500(68%)	USA	7,310(94%)
India	1,000(27%)	France	200(2.6%)
Bangladesh	10(0.3%)	Japan(est)	60(0.8%)
Africa	100(2.7%)	Australia	40(0.5%)
Nepal	15(0.4%)	Spain, Port	130(1.7%)
South-east Asia	20(0.5%)		
South America	50(1.4%)		
Totals	3,685		7,740

Source: Bentum et al, 1991

CHAPTER 4
HYDRAULIC TESTS AND BURIED PIPE TECHNOLOGY

This chapter is particularly concerned with objectives 1 and 2.

4.1 HYDRAULIC TESTS

4.1.1 Methodology

4.1.1.1 Pump Discharge

Pump discharge measurement was carried out on a monthly basis. A calibration curve of the pump discharge against engine speed for each measurement was prepared once steady conditions had been reached after about 35 minutes of pumping. The pump discharge was measured by volumetric method in the header tank for all the schemes except Binnakhaira, where it was done by a Kent meter installed on the discharge pipe between the pump and the header tank. Times required to fill the header tank up to different levels as marked were recorded at three engine speeds after closing the inlet valves. For each engine speed, three sets of data were obtained. The engine speed was measured using an electronic digital tachometer. The discharge of the pump was calculated by dividing the volume pumped by the corresponding time. The average of the three discharges was then calculated for each engine speed. The pump discharge was calculated by the following equation:

$$Q_P = V_P/T_E \quad \text{...... ....} \quad (4.1)$$

Where, Q_P = pump discharge, (l/s); V_P = volume of water pumped, (l) and T_E = elapsed time, (s).

4.1.1.2 Outlet Discharge

Discharges at end outlets were measured on a monthly basis using a cutthroat flume which was locally fabricated as per standard specifications (Skogerboe, 1973). The flume was set in the open earthen channel at a distance 5.0 m to 20.0 m away from the outlet to avoid turbulence. Flow depths in the flume were taken at steady condition for each pipeline after pumping for about 35 minutes. Special care was given in setting, levelling and measuring the flow depths in the flume. Three readings were taken at 5 minute intervals for a specific engine speed and it was repeated thrice by changing the engine speed. Then the discharge was calculated for the individual flume reading using a pre calibration chart.

4.1.1.3 Head Loss

Head loss measurements were done on a monthly basis. Head losses were measured at three pump discharges (at three engine speeds) by taking water surface elevations (WSEs) at different air vents located on the pipeline. After stabilizing the discharge for a specific engine speed, WSEs were recorded at 5 minute intervals on a specified data sheet for different air vents to obtain accurate head losses. Measurements were taken by inserting tape from the top of the air vent. Small weights (brick-chips and/or small stones) were tied to the end of the measuring tapes to keep them straight. A permanent marking had been made on the top of each air vent from which the depth to water level in the air vent was measured.

The elevation difference of two water levels indicated the head loss for the section between two air vents. The same procedures were followed for three engine speeds. These were done to establish a series of actual head losses for a range of flow.

Head loss per 100 m length of pipe of different sizes and the corresponding discharges were plotted with the theoretical curve for pipe friction. These were derived from simultaneous measurements of the water levels in two air vents at steady conditions and averaged over three replications. In a buried pipe distribution system, generally the head loss resulting from the friction is more significant than the other losses. These include mainly: i) friction loss, ii) losses due to joints and bends, and iii) head loss due to leakage (if any).

The discharge data were grouped at an interval of 5 l/s (e.g., 21.00 l/s to <26.00 l/s, 26.00 l/s to <31.00 l/s, etc). Then the average value of discharges and the average value of the corresponding head losses under each group were used to plot the curves.

4.1.1.4 Static and Pumping Water Levels

Static water levels in the well were measured at 15 days interval or as convenient using a depth gauge. Pumping water levels were taken during the head loss measurements. However, water levels in the deep tubewells at East Kutubpur and Binnakhaira could not be taken due to absence of dipping holes at the pump base. At East Kutubpur, it was only possible to measure static water levels through a column pipe, but at Binnakhaira, it was not possible to measure static water levels through a column pipe due to the modification of the header tank structure as well as the setting of the Kent meter.

4.1.1.5 Water Loss from Header Tanks by Ponding Method

A flap valve shown in Figure 4.1 was fitted at the end of the pump discharge pipe at each scheme by concreting bolts into the wall of the header tank (HT). All outlet valves in the HT were tightly closed. The HT was then filled with pumped water and the changes in water levels within the HT were recorded against time. This was repeated thrice for getting accurate water losses. Then graphs were plotted with the cumulative time along the abscissa and the cumulative loss of water along the ordinate. Then a tangent was drawn at any point on the curve and from that tangent the water loss was calculated with respect to hydrostatic head. This test was conducted on a monthly basis. Equation for water loss from the header tank was as follows:

$$W_{LHTP} = V_L/T_E \quad \ldots\ldots \ldots\ldots \ldots\ldots \ldots\ldots \quad (4.2)$$

Where, W_{LHTP} = water loss from the header tank, (l/s); V_L = change in volume of water, (l) and T_E = elapsed time, (s).

4.1.1.6 Water Loss from Pipeline by Ponding Method

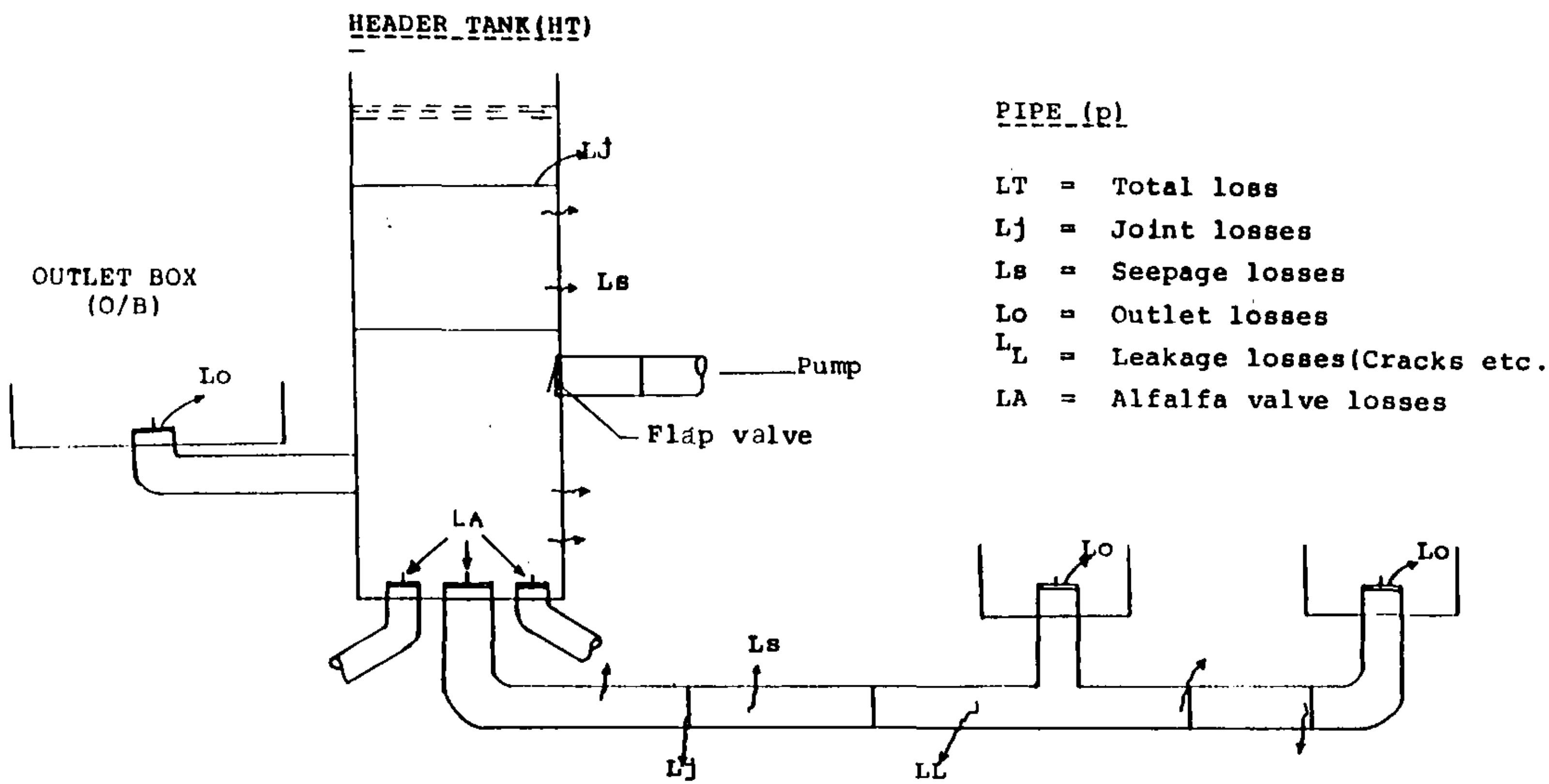
The test was carried out on a monthly basis for each main pipeline separately with the flap valve fitted on the discharge pipe. All outlet valves on the pipeline under test were closed completely to stop leakages. The header tank and the pipeline were filled with pumped water until overflow occurred through the air vent(s), when the pump was stopped and the flap valve was closed automatically by back water pressure. After 5 to 10 minutes when the water level in the header tank stabilized, the fall of water level was recorded against time. These were repeated three times. Similarly, the test was conducted for other pipelines. Then graphs were plotted following the procedures in the preceding section 4.1.1.6. Components of water losses from the whole system are shown in Figure 4.1. Water loss was calculated by the following equation:

$$W_{LPLP} = \{(V_{WL}/T_E)/(P_{Lgth})\} \times 100 \quad \ldots\ldots \ldots\ldots \quad (4.3)$$

Where, W_{LPLP} = water loss from pipeline by ponding method, (l/s/100 m); V_{WL} = change in volume of water, (l); T_E = elapsed time, (s) and P_{Lgth} = total length of pipeline, (m).

Figure 4.1

Components of Water Losses



Total Losses

$$L_T = L_{HT} + Lp \quad (l/s)$$

$$L_T = [Lj + Ls + Lo + LA]\,HT + [Ls + Lj + Lo + L_L]\,p$$

4.1.1.7 Water Loss from Pipeline by Inflow-outflow Method

Pump discharges for different engine speeds were measured (section 4.1.1.1) on a monthly basis. After that all the outlet valves on the pipeline under test were closed completely to stop any leakage except the end outlet valve. This was kept open and a cutthroat flume was set to measure the flow. Then the pump was started and engine speed was fixed. After running the pump for about 35 minutes, the flow depths at steady condition in the flume were taken simultaneously three times at 5 minute intervals. Then the engine speed was changed and fixed again. After 30 minutes, the flow depths in the flume were taken in the same way and then repeated for the third time. The average value was used in the discharge calculation for each engine speed. Similarly, the test was conducted for other pipelines. The difference between the pump discharge and the outlet discharge for a specific engine speed gave the water loss from the pipeline. For a single engine speed water loss from the pipeline can be calculated by the following equation:

$$W_{LPLI} = \{(Q_P - Q_O)/(P_{Lgth})\} \times 100 \quad \text{...... .....} \quad (4.4)$$

Where, W_{LPLI} = water loss from pipeline by inflow-outflow method, (l/s/100 m); Q_P = pump discharge, (l/s); Q_O = outlet discharge, (l/s) and P_{Lgth} = total pipe length, (m).

4.1.1.8 Conveyance Loss in Field Channels

This measurement was done on a monthly basis. Conveyance losses in the field channels were measured by inflow-outflow method using cutthroat flumes. Two flumes were set at the two ends of a channel section. The flumes were set carefully, level was checked by a spirit level. When the flow was steady, the flow depths in the flumes were taken simultaneously three times at 5 minute intervals for a specific outlet discharge. The average value was used in the discharge calculation. It was repeated thrice with changes in the discharge. By measuring the section length conveyance loss was calculated using the following formula:

$$C_{LF} = \{(Q_1 - Q_2)/L_S\} \times 100 \quad \text{...... ....} \quad (4.5)$$

Where, C_{LF} = conveyance loss from field channels, (l/s/100 m); Q_1 = discharge at section 1, (l/s); Q_2 = discharge at section 2, (l/s) and L_S = length of channel section, (m).

4.1.2 Results and Discussion

4.1.2.1 Pump Discharges

Pump discharges for the eight deep tubewell schemes at normal operating conditions are shown in Table 4.1. Results revealed that at none of the schemes could the design engine speed (2250 revolution per minute or rpm) be attained. Reasons attributed for the low engine speed were:

a) At Taltolapara, maximum engine speed possible was 1800 rpm instead of 2250 rpm. This low speed was mainly due to the lack of proper engine servicing, which resulted from using own fuel system (refer to section 2.2.9), by which farmers individually bought fuel from local traders using plastic containers of specified sizes (for example, containers vary from 2 to 4 litre capacity). This fuel was used once to run the pump. As observed from the field situation the fuel was of different grades and impure. After using this fuel the nozzle of the engine became weak, resulting in the engine speed going down over a period. This poor engine performance also made the farmers lose confidence in cultivating more land under irrigation.

b) The engine at East Kutubpur was operated at a speed ranging from 1450 to 1550 rpm for pipeline 1 (without check structure on the pipeline) because of some shorter air vents (Table 4.2), at greater speeds spillage occurred through air vents as well as the header tank. For the other two pipelines (with check structures) engine speed was in between 1750 and 1850 rpm. Spillage through air vents occurred for engine speeds greater than 1850 rpm. This was due to the fault in hydraulic design.

Table 4.1 Pump and Outlet Discharges at Operating Conditions

Schemes	Operating speed(rpm)	Discharge (l/s)			
		Pump	Average	Outlet	Average
Taltolapara	1750-1650	34.45-27.28	30.47	30.19-23.78	26.20
East-Kutubpur	1800-1500	43.32-33.98	38.31	34.47-26.28	30.98
Shaplapara	1900-1700	33.85-25.81	29.39	33.21-24.32	26.74
Baila*	1400-1300	26.00-17.21	22.37	22.37-14.01	18.92
Vailpara	1700-1600	37.12-29.25	33.06	33.94-25.96	30.92
Chulabar	1900-1800	41.72-37.57	39.49	36.62-32.35	34.60
Hazipara	1800-1600	50.54-38.59	42.48	39.08-25.50	30.26
Binnakhaira	1700-1600	29.41-23.72	26.32	20.68-16.33	19.84

Note: * = As per design, 2 pipelines are to be operated at a time, but for this study only one pipeline was operated at a time, that is why the speed shown here is low

Table 4.2 **Elevation (m) of Air Vents at Different Schemes**

Schemes	Pipeline		
	1	2	3
Taltolapara	1.11-2.09	1.14-2.44	1.92-2.24
East Kutubpur	0.79-1.95	0.38-1.31	0.61-1.39
Shaplapara	1.41-1.69	1.06-1.90	0.64-1.17
Baila	0.56-1.46	1.02-1.71	
Vailpara	1.06-1.47	0.12-1.65	0.50-1.67
Chulabar	1.30-2.04	1.55-1.83	1.47-2.00
Hazipara	1.89-2.89		
Binnakhaira	0.32-1.37	0.48-1.49	0.73-1.90

Note: Top of pump discharge pipe was assumed as a local datum of 0.0 metre. Baila has two pipelines and Hazipara has one pipeline

c) Binnakhaira and Baila schemes were designed for operating two pipelines at a time. But due to the own fuel system at Binnakhaira, farmers were compelled to operate one pipeline at a time, so to check spillage through air vents, engine speed was kept low. At Baila as fuel-oil was supplied by the KSS, the engine was operated at variable speeds depending on whether one pipeline was in operation or two.

d) The capacity of field channels was very low everywhere as observed and measured (refer to section 5.1.2.7) and due to own fuel system water flow was confined to one channel at a time. This also led to running the engine at a lower speed than in the design.

For low engine speed, pump discharges were found to be less at every scheme, ranging from 50.54 l/s to 23.72 l/s (Table 4.1) with an average of 32.48 l/s which was only 58% of design (Table 4.3). These showed a wide variation. High fluctuation of engine speeds throughout the season and own fuel system as well as static water levels were responsible for that variation.

4.1.2.2 Outlet Discharges

Discharges of the end outlet of each pipeline at every scheme are shown in Table 4.1. As can be seen from the Table, the pump discharges decreased with time. This was due to the increasing depth to static water levels (Figure 4.5) during the dry season. Outlet discharges varied between 39.08 l/s and 16.33 l/s over the season with an average of 27.28 l/s. This shows that the outlet acted actually as a 1 cusec (28 l/s), although it was designed for 2 cusec (56 l/s). As earlier stated due to the poor performance of engines, pump discharges were found to be going down, as a result, outlet discharges were also found to be decreasing. Again, with own fuel system, rotational water distribution could not be followed, frequent switching of the operation from pipeline to pipeline could not be stopped and flow to more than one channel from an outlet could not be allowed.

4.1.2.3 CC Buried Pipes in Distributing Water

The pump is designed for 56 l/s capacity and each outlet has the same capacity as the pump; therefore, theoretically there is no difference between the pump discharge and the outlet discharge. However, transit loss in the pipeline resulted in lower outlet discharges. Distributions of irrigation water through CC buried pipes were found to be more economical in terms of reducing conveyance systems (Table 4.3). The table also shows that 84% of pumped water can be delivered more efficiently to any outlet throughout the command area. However, when conveyance of field channels is considered in the system it comes to a figure of 69%, which has been discussed in detail in section 4.1.2.9.

Table 4.3 Performance of CC Buried Pipes

Schemes	Discharge in % of design		Transit efficiency of CC pipeline (%)
	Pump	Outlet	
Taltolapara	54	47	87
East Kutubpur	68	55	81
Shaplapara	52	48	92
Baila	40	34	85
Vailpara	59	55	93
Chulabar	71	62	87
Hazipara	76	54	71
Binnakhaira	47	35	74
Average	58	49	84

Note: Design discharge = 56 l/s (for both pump and outlet). Transit efficiency of CC buried pipes refers to the ratio of actual outlet discharge to the actual pump discharge

4.1.2.4 Head Loss

The curves of head losses (hydraulic gradient, m/100 m) versus discharges (l/s) were constructed for different sizes of non-reinforced cement concrete (CC) pipes on a monthly basis. The measured head loss values agreed with the theoretical values where the Colebrooke-White Equation was used, with Ks (roughness height) equal to 0.6 mm. These are shown in Figures 4.2, 4.3, and 4.4 for the pipe sizes 230 mm, 250 mm and 280 mm, respectively. The figures show that in most cases measured head losses were found to be quite close to the theoretical values. However, the values at East Kutubpur (250 mm pipe size) and Baila (280 mm pipe size) were found to deviate on the higher side to a large extent from the theoretical curves. This was probably due to the excessive leakage of water through pipes (Table 4.10) and outlet valves (Table 4.9). Figure 4.2 shows that, for 230 mm pipe size, the head loss was found to be lowest at the Baila scheme. Shaplapara, Hazipara and Chulabar schemes had losses lower than the theoretical values for pipe sizes 230 mm, 250 mm and 280 mm, respectively. Head losses lower than the theoretical values were obtained probably due to smaller values of roughness co-efficient as well as the short pipe sections considered. It was also observed that head losses between the header tank and the first outlet were always higher than the head losses in the normal pipe section because of entrance loss at the inlet.

4.1.2.5 Static Water Levels

Static water levels for the study areas from January 1990 to June 1991 are shown in Figure 4.5. Maximum depth to the static water level was found to be highest (10.30 m) at the Taltolapara scheme during early May 1991 and minimum depth to the static water level was found in August, 1990 which was the lowest (4.50 m) at the East Kutubpur scheme.

During April, the majority of the dugwells in the villages were either dried up or about to dry and water scarcity was observed. From Figure 4.5, it was observed that the depletion period started from mid August and continued to early May when the recharge period started and continued up to mid August.

Static and pumping water levels for a particular period of pumping resulted in drawdown for six buried pipe schemes as shown in Table 4.4.

Table 4.4 Static and Pumping Water Levels

Schemes	Water levels (m)		Drawdown (m)	Pumping time(mins)	Engine speed(rpm)
	Static	Pumping			
Taltolapara	10.30	13.77	3.47	40	1750
Shaplapara	9.65	13.48	3.83	48	1800
Baila	9.60	13.49	3.89	55	1500
Vailpara	10.10	13.90	3.80	45	1700
Chulabar	9.75	14.86	5.11	65	1900
Hazipara	9.83	12.39	2.56	40	1800

Figure 4.2

Head Loss in 230 mm (9") Concrete Pipe

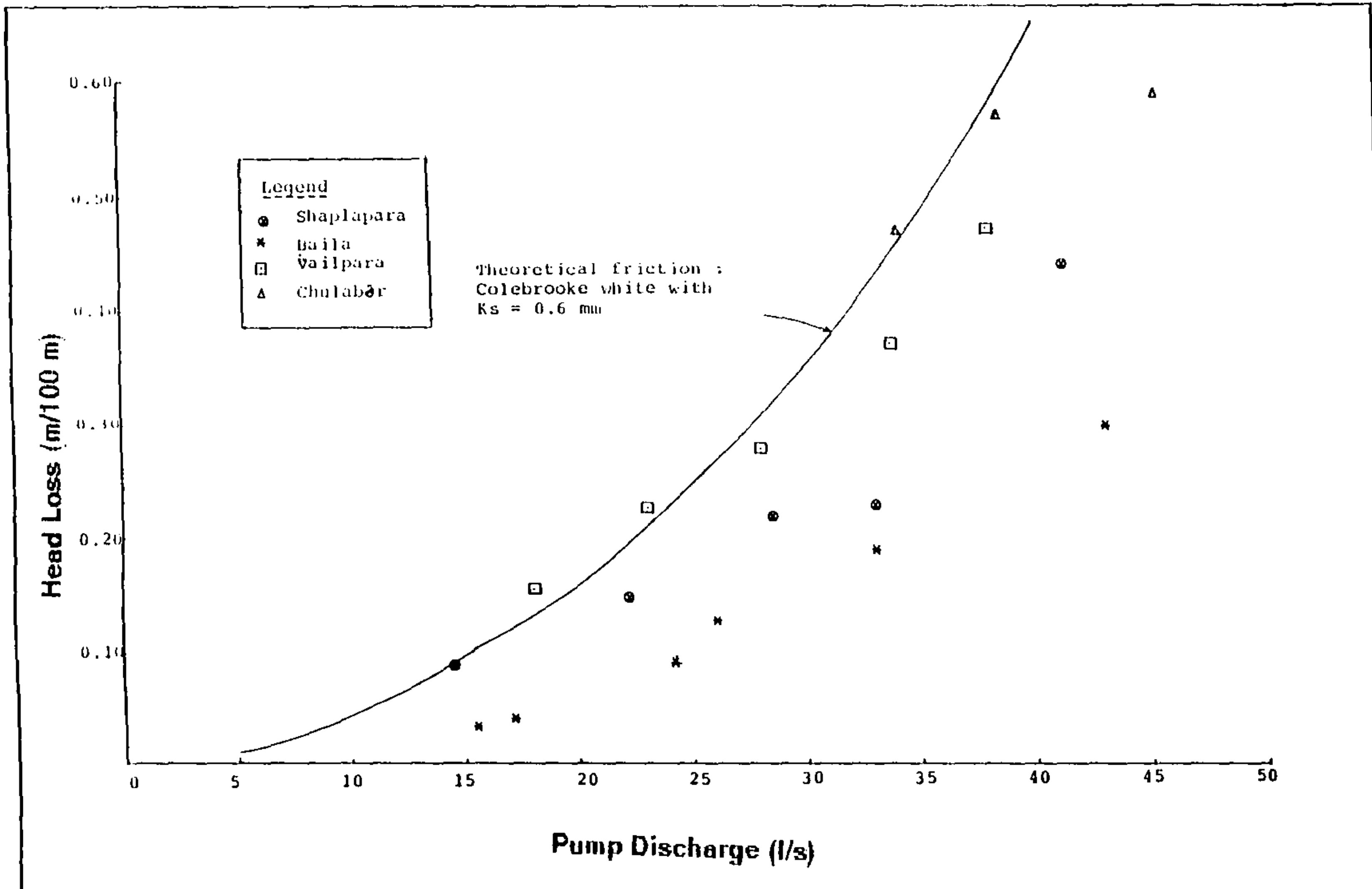


Figure 4.3
Head Loss in 250 mm (10") Concrete Pipe

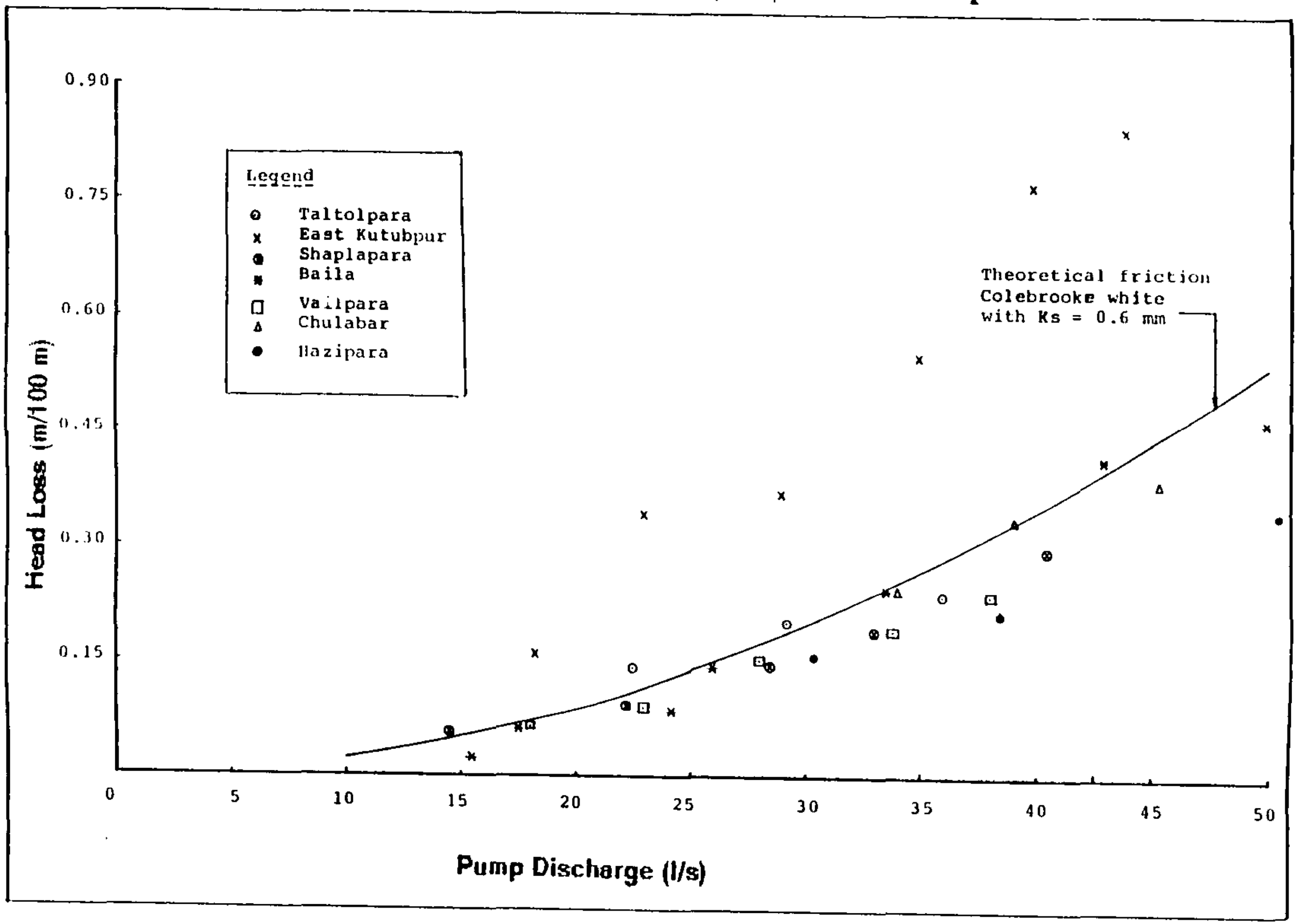


Figure 4.4
Head Loss in 280 mm (11") Concrete Pipe

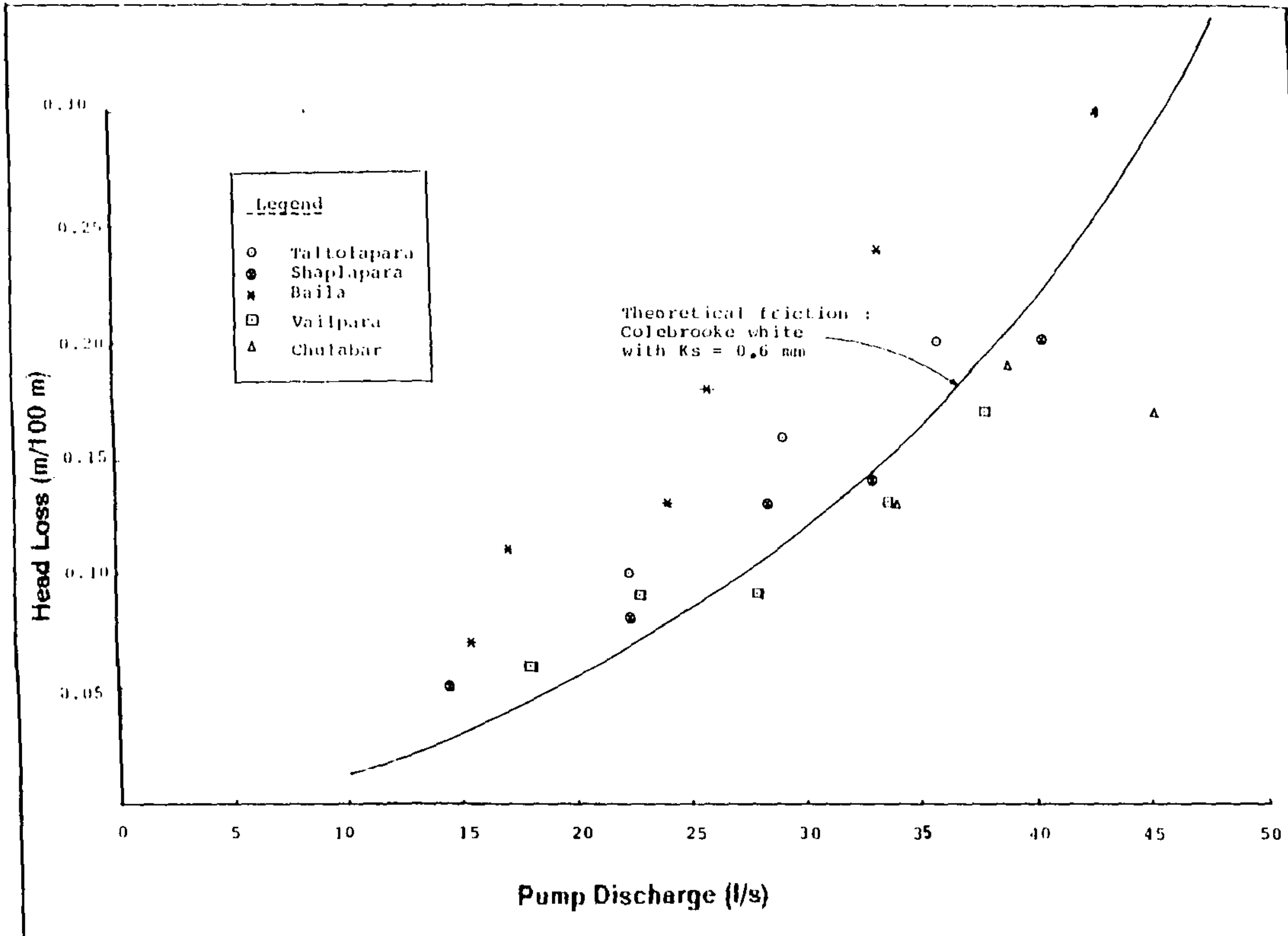
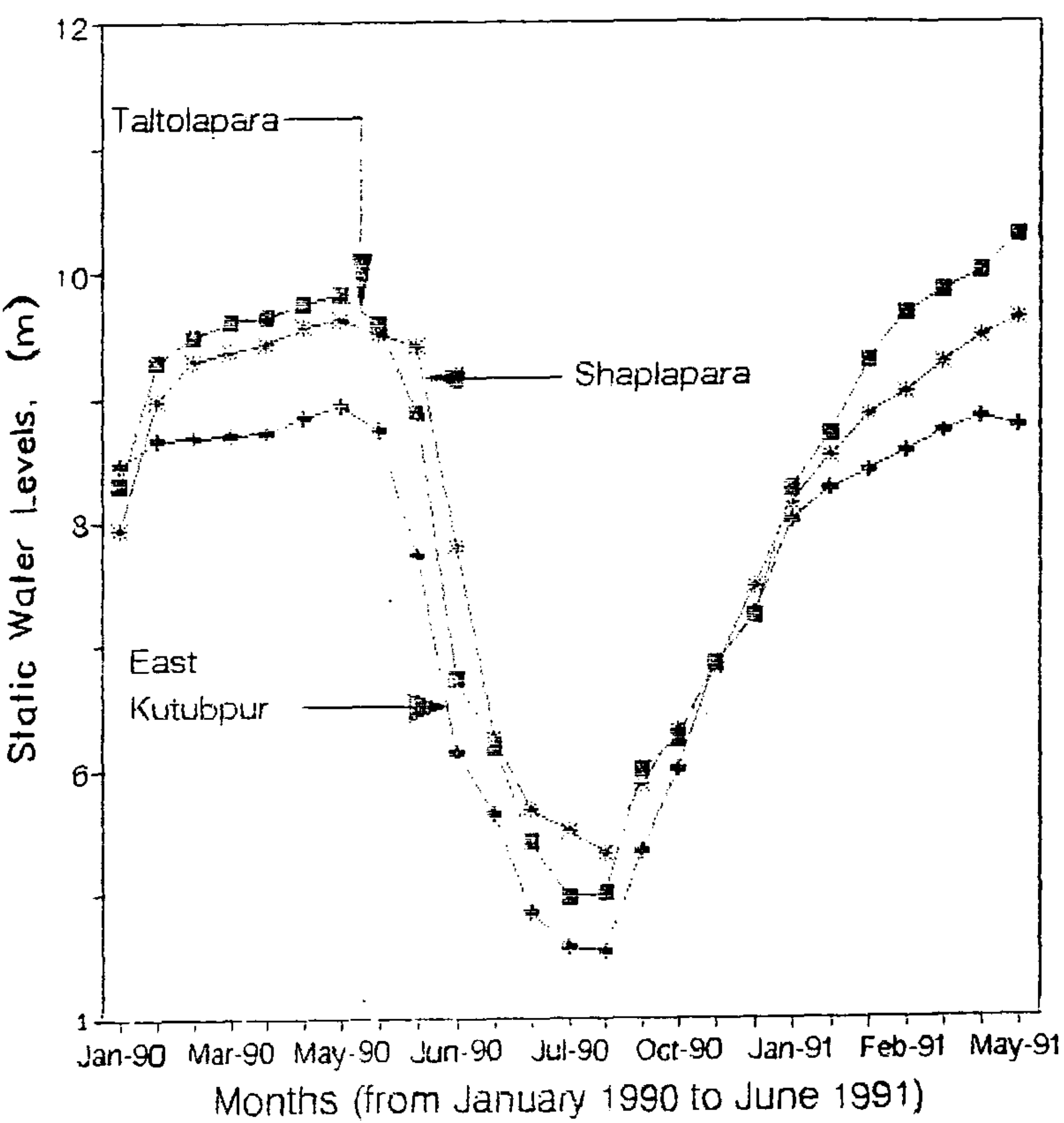


Figure 4.5

Static Water Levels



4.1.2.6 Water Loss from Header Tank

The ponding method was applied at all the schemes to detect and determine water losses from the header tank (with a flap valve fitted). A flap valve fitted with a rubber gasket on its periphery was tested and it was seen that it was almost 100% leak proof. The results of water losses are shown in Table 4.5. Water loss from the Header Tank (HT) was found to be negligible at the East Kutubpur, Baila and Vailpara schemes. The negligible water loss from the HT may be due to water soaking into the wall of the HT and the inlet valves of these schemes might be leak-proof. For the other schemes, water loss from the HT was found to be a little bit high (0.22 l/s to 0.50 l/s). The high loss was mainly due to the leakage through the inlet valves in the base of the HT. The reasons for this non-leak-proof functioning of the inlet valves were:

a) Damaged threads and securing pins on the spindle were responsible for water loss from the HT at Taltolapara, Chulabar and Shaplapara. Frequent switching and over tightening of the inlet valves by top control lever (handle) were the main reasons for the damaged threads and securing pins.

Table 4.5 Water Loss from Header Tank by Ponding Method

Schemes	Measured		Operating	Height between
	Hydrost. head(m)	Water loss(l/s)	hydrost. head(m)	bottom & discharge pipe(m)
Taltolapara	1.97-2.09 (2.05)	0.14-0.63 (0.38)	0.84-1.84 (1.34)	1.08
East Kutubpur	2.88-3.30 (3.00)	0.03-0.07 (0.05)	1.19-2.41 (2.16)	1.27
Shaplapara	1.95-3.25 (2.38)	0.10-0.56 (0.22)	1.75-2.25 (2.00)	0.94
Baila	2.04-3.55 (2.80)	0.05-0.07 (0.06)	1.68-2.18 (1.93)	1.07
Vailpara	2.10-2.57 (2.34)	0.05-0.07 (0.06)	1.41-1.91 (1.66)	0.99
Chulabar	2.83-3.01 (2.92)	0.18-0.52 (0.35)	1.23-1.73 (1.48)	0.77
Hazipara	1.45-3.25 (2.35)	0.41-0.59 (0.50)	0.98-1.48 (1.23)	0.84
Average	2.54	0.23	1.67	

Note: Figure in parentheses indicate average value. Benchmark was taken from bottom of the header tank

b) At Hazipara, fitting of the inlet valve in the HT was not proper or water tight. This might be either a setting problem or a design fault.

c) Sometimes coarser particles, e.g., sand, granular brick-chips, stone-chips were dropped in the HT by children playing. These were deposited on face of the inlet valves which did not allow proper setting of the inlet valves.

No visible leakages were found through the header tank's wall. However, during the first test, when the HT was filled with water, water soaking into the wall of the HT was observed. While the water was soaking some sort of buzzing sound was heard and air bubbles were observed.

From study of the water loss from the HT, it is concluded that water leaking through inlet valves goes into the pipelines, therefore, may not be considered as actual water losses.

4.1.2.7 Water Loss from CC Pipelines by Ponding Method

Water loss from CC pipelines was determined by both the "ponding method" and the "inflow-outflow" methods. The results of the ponding method are summarized in Table 4.6. By this method, an operating head was not possible to maintain, because, in most cases, after stopping the pump, spillage through air vents continued for about 10 to 30 seconds. By the time spillage through air vents stopped, water levels in the header tank went down below the operating level which might be due to the excessive leakages. From the field experience, it was seen that after stopping the engine to and fro water motion continued for about 5 to 10 minutes. This was probably due to the influence of inertia forces.

At Taltolapara, pipeline 1 and pipeline 3 showed higher water loss (0.36 l/s/100 m to 0.65 l/s/100 m) because these two pipelines passed through beneath the main road, where more leakages were detected (pipe size under the road was 460 mm). Pipeline 1, 2, and 3 had 2, 7, and 5 visible leakages, respectively during the last test. Faulty materials and weak jointing were the main causes of such leakages and traffic load might be another reason.

The ponding method at East Kutubpur scheme was done only on pipeline 1. This method was not possible on the other two pipelines due to the presence of check structures. Performance of this scheme was poor because of severe leakage problems. For example, TADP repaired 360 leaks in January '91 and many leakages existed in the schemes as reported by the KSS farmers (Table 4.10).

At Shaplapara, water loss was 0.55 l/s/100 m in pipeline 1. This was due to continuous leaking through 3 (out of 5) outlet valves during the test (Table 4.9). Mishandling of outlet valves was probably the reason for such leakages.

Table 4.6 Water Loss from CC Pipeline by Ponding Method

Schemes	Hydrostatic head (m) at		Water loss	Obs.
	Measurement	Operating	(l/s/100m)	
Taltolapara	0.82-1.08 (0.94)	1.00-2.00 (1.50)	0.36-0.65 (0.50)	9
East Kutubpur	2.13-2.46 (2.20)	2.50-3.00 (2.75)	0.22-0.36 (0.29)	5
Shaplapara	1.44-2.06 (1.67)	2.00-2.50 (2.25)	0.17-0.55 (0.33)	14
Baila	2.16-2.58 (2.37)	2.50-3.00 (2.75)	0.02-0.18 (0.10)	6
Vailpara	1.46-2.22 (1.88)	2.00-2.50 (2.25)	0.11-0.46 (0.23)	9
Chulabar	1.00-2.19 (1.62)	2.00-2.50 (2.25)	0.09-0.19 (0.15)	3
Hazipara	1.25	1.50-2.00 (1.75)	1.17-1.19 (1.18)	2
Average	1.70	2.20	0.33	

Note: Figure in parentheses indicate average value

The Baila scheme consisted of two pipelines. Pipeline 1 contained three visible leaks, and pipeline 2 had no visible leak. Therefore, water loss from the pipeline 2 was less (0.02 l/s/100 m to 0.07 l/s/100 m) in comparison to the other pipeline (0.14 l/s/100 m to 0.18 l/s/100 m). From the study, it was observed that pipeline 2 of this scheme had the best performance among all the schemes. The Vailpara scheme had three pipelines. Pipeline 3 had three visible leakages and experienced higher water leakages than the other two pipelines.

At Chulabar scheme, under existing conditions pipeline 3 was found to be better than the other two pipelines because of fewer leakages. It was quite an interesting phenomenon that pipeline 1 had one very large leakage from where the house-wives collected water using pitchers for animal-use. Pipeline

2 had two leakages of which one was very large and that damaged the wheat crop (by stagnant water).

The Hazipara scheme was found to be in the worst condition (Table 4.6), even though it was a partially buried pipe scheme. From one large leakage (beside the road) water loss at the rate of about 2 l/s (by eye estimation) was observed. Probably one of the pipes on the pipeline was broken under the road. Special care should be taken while constructing pipelines beneath a road.

Average water loss rate by ponding method was found to be 0.33 l/s/100 m, which is about 50% of the reported water loss value (0.70 l/s/100 m) by Ray (1990) from non-reinforced concrete pipelines installed under the IDA-DTW II Project. Moreover, water loss in the pipeline was only 4.3% of those measured in the earthen open channel systems (7.69 l/s/100 m, Table 4.7). However, a very high loss 1.18 l/s/100 m was observed at the Hazipara scheme. The reason for this has been described in the preceding paragraph.

In conveyance loss calculation, water loss from the header tank was not deducted from the total water loss as occurred from the pipelines. Because, in the HT test water leaked through inlet valves went directly into the pipelines and in the pipeline test this leakage did not occur. Therefore, water loss from the HT was not the actual loss, as the own fuel operating system caused frequent switching between the pipelines. In fact, the results of the ponding method were not used because they were lower than the results from the inflow-outflow method.

The following factors influencing the leakage loss rate are:

a) number of leakages present in the pipeline,
b) size of the leakages, and
c) tightness and fitting of the outlet valves.

4.1.2.8 Water Loss from CC Pipelines and Earthen Channels by Inflow -Outflow Method

Calculated results of water loss from pipeline and earthen field channel at operating conditions are presented in Table 4.7. As can be seen from this Table the highest (1.44 l/s/100 m) water loss from the pipeline was found at the Hazipara scheme, which showed a deplorable condition as described in the preceding section 4.1.2.7. Average water loss in the pipeline by inflow-outflow method was 0.69 l/s/100 m, which was only 9% of those measured by earthen channel (7.69 l/s/100 m). However, water losses by the inflow-outflow method were always greater than those obtained by the ponding method. This was probably due to the higher hydrostatic head in the case of the inflow-outflow method and therefore these figures are thought to be a more accurate estimate of actual losses during operation.

Table 4.7 Water Loss at Operating Conditions

Schemes	Water loss (l/s/100 m)		Water saved
	Pipeline	Earth channel	by pipeline (%)
Taltolapara	0.58	8.56	93
East Kutubpur	0.68	6.82	90
Shaplapara	0.45	7.30	94
Baila	0.35	5.88	94
Vailpara	0.50	9.37	95
Chulabar	0.86	9.19	91
Hazipara	1.44	7.08	80
Binnakhaira	0.67	7.32	91
Average	0.69	7.69	91

Water loss from an earthen open channel includes seepage, leakage, percolation and evaporation. Sometimes flow over the channel banks (spillage) occurs, this is also included in the water loss. The highest (9.37 l/s/100 m) water loss was found at the Vailpara scheme followed by Chulabar (9.19 l/s/100 m) and then the Taltolapara scheme (8.56 l/s/100 m). At the Vailpara scheme, soil was lighter than at the other schemes.

The lowest water loss (5.88 l/s/100 m) was found at the Baila scheme where the soil was comparatively heavy. The average conveyance loss at operating conditions was found to be 7.69 l/s/100 m, which was 24% of the average pump discharge (section 4.1.2.1). For open channel systems in the Manikgonj district , BARI has reported water losses whose typical value was 9 l/s/100 m in the farmers` built open channels and 7 l/s/100 m in the improved (compacted) earth channels (Rashid et al, 1990). It is assumed that without a buried pipe distribution system an earthen channel distribution system would be used with losses as measured in the earthen field channels. Table 4.7 shows an estimated water saving of 91% by CC buried pipe systems over earthen open channel systems. This saved water can be used to extend the command area.

4.1.2.9 Performance of Irrigation Equipment

Table 4.8 shows the sum of water losses in the CC pipelines and the field channels, giving the overall conveyance efficiencies. On average 69% pumped water can reach any field plots within the command area of about 40 ha using buried pipe systems, whereas it is not possible by an open channel system, for example, Biswas et al (1984) reported about 50% of pumped water may be lost using earthen channel systems. However, the total conveyance loss was the highest (42%) at the Binnakhaira scheme followed by Hazipara (35%) and then the Chulabar scheme (34%). A long pipe section (refer to Table 5.6) used per irrigation was the main reason for high conveyance loss at the Binnakhaira scheme, though water loss from the pipeline was 0.67 l/s/100 m. At the Hazipara scheme, high water loss from the pipeline (Table 4.7) was the cause of high conveyance loss. Longer field channels (see Table 5.6) as well as high water loss from the pipeline were responsible for high conveyance loss at the Chulabar scheme.

Table 4.8 Performance Indicator of Irrigation Equipment

Schemes	Total conveyance losses (pipeline + channel),(%)	DTW Effic.* (%)	Duty (ha/l/s)	Duty in % of design duty
Taltolapara	28	72	0.50	70
East Kutubpur	28	72	0.36	51
Shaplapara	29	71	0.71	100
Baila	26	74	0.86	121
Vailpara	29	71	0.51	72
Chulabar	34	66	0.34	48
Hazipara	35	65	0.35	49
Binnakhaira	42	58	0.74	104
Average	31	69	0.55	77

Note: * = DTW (deep tubewell) efficiency refers to the total conveyance efficiency resulting from pipelines as well as earthen field channels of the system. Dêsign duty is the design command area (40 ha) divided by the design pump discharge (56 l/s) and is equal to 0.71

In buried pipe schemes, average DTW efficiency is 69%, which is 121% of the reported DTW efficiency (57%) for earthen open channel systems in Bangladesh reported by Dutta (1991). This indicates that the water distribution pattern through buried pipe systems is superior to those of conventional irrigation systems. However, a very similar result 58% DTW efficiency is seen at the Binnakhaira scheme (Table 4.8). The reason for this has been discussed in the preceding paragraph.

Table 4.8 also includes the "duty" expressing the actual area irrigated (Table 5.3) by a unit of pump discharge (Table 4.1). The duty is found to be variable in the buried pipe schemes. The Baila scheme shows the over duty (121%). One possible reason for over duty might be the better management system (refer to section 7.2). Only the Shaplapara scheme achieves the design duty of 0.71 ha/l/s.

4.2 BURIED PIPE TECHNOLOGY

4.2.1 Methodology

Information on constructional aspects of Buried Pipe Systems (BPS) was collected from the Tangail Agricultural Development Project (TADP) office, Tangail. The procedures of pipeline installation along with other technical aspects were observed at fields, where new BP systems installation were being carried out.

Information regarding pipe manufacturing process, and leakage problems on the BPS were collected through field visits, observations, discussion with the different project personnel and also from the project documents. A review of literature concerning BPSs helped to collect all sorts of information from the other buried pipe schemes, which have been working at different locations in Bangladesh.

4.2.2 Results and Discussion

4.2.2.1 Non-reinforced Concrete (CC) Pipes

Bentum et al (1991) reported that these systems are widely built throughout the world with a large numbers of systems in India, Bangladesh and China. The systems are widely documented including descriptions by World Bank (1983); Gisselquist (1986 and 1989) and DST China (1990).

Two types of Cement Concrete (CC) pipe were manufactured by the Tangail Agricultural Development Project (TADP). These are: **a)** Hand made or vertical moulded CC pipe, and **b)** Machine spun CC pipe.

a) Hand Made Non-reinforced Concrete (CC) Pipes

The sizes of hand made CC pipe usually vary from 150 mm to 300 mm in diameter and from 1.00 m to 1.10 m in length. The wall thickness of pipes varies from 25 mm to 35 mm, depending on the diameter of the pipe. Forms consisted of two shutters, inside and outside shutters. The outer parts of the shutters were quite trouble free and easy to produce. The inner shutter was made in three sections for easy removal from inside a ready cast pipe. Shutters were circular in shape. Each shutter had two baseplates, to enable the production of at least two pipes per day. The baseplates were made of wood or cast iron. Before casting, the shutters were well brushed with burnt lubricant, which helped when removing the shutters from the pipes. The concrete mixture ratios by volume used were reported by Georgi (1989):

i) 1 Cement : 2 sand : 4 Khoa (brick-chips)
  100 cft concrete = 18 bags cement + 40 cft sand + 90 cft khoa
ii) 1 Cement : 2 sand : 3 Khoa
  100 cft concrete = 21 bags cement + 53 cft sand + 79 cft khoa
    1 cft = 0.0283 m^3
    1 bag cement = 1.2 cft by volume

Various types of concrete aggregates are available in Bangladesh. These are: **i)** khoa (brick chips) made of ceramic bricks, **ii)** peagravel, **iii)** stone chips, **iv)** kauchi (minerals in crystalline form available in hilly areas in the forest), **v)** Sylhet sands (very good quality) and **vi)** local sand (medium to good quality).

TADP always used kauchi (to lower the cost) as coarse aggregates and its size ranged from 6 mm to 13 mm for pipe diameters ranging from 150 mm to 300 mm and those for header tank aggregates ranged from 10 mm to 19 mm (Georgi, 1989).

Aggregates were screened and washed before use. As per the above specification concrete mixtures (slurry) were filled into the shutter gradually and each layer was compacted carefully with long iron rods. After about 6 hours the inner part of the shutter was removed first then 3 hours later the outer part of the shutter was removed and started curing.

b) Machine Spun Concrete (CC) Pipes

The spinning gear is a device which is designed to produce CC pipes in circular forms (outer forms only). Usual length of pipes were 1.83 metres. The hand driven spinning gear was rotating the form at a rate of about 300 rpm, when a 230 mm or 250 mm form was used.

The forms were oiled with used lubricating oil and then the concrete mixture paste was shovelled into the form during rotation. The inner surface of the pipe was formed and shaped with the help of a T-profiled steel bar, held on both ends by the pipe making masons, with one working on each side of the gear. The inner diameter of the pipes was given by a circular hole in the cast iron wheels which hold the forms.

The compaction of the concrete was done by centrifugal force due to rotation. The inner side of the pipes was coated with 1 mm to 2 mm thick 1:1 cement-sand mixture with the help of long brushes. About 6 to 8 hours after casting, the forms were removed from the pipe and then started curing. About 10 to 15 minutes was required to produce one pipe and 50 to 60 pipes could be produced per day (Rashid and Mridha, 1990).

4.2.2.2 Pipe Quality

In this study, it was found that machine made pipes were superior to those manufactured by hand or vertically moulded pipes. On average 86% leakage occurred in the hand made pipe. Reasons for such a leakage were: hand made or vertically moulded pipes had irregular wall thickness, higher pore-space (poorer compaction), a higher incidence of leakage, and generally lower strength (for example, more leakages at the East Kutubpur scheme in Table 4.11). Many pipe manufacturers do not give adequate attention to curing.

4.2.2.3 Pipe Installation

Pipes are usually laid on undisturbed soil at a depth of 60 cm to 100 cm and in a reasonably straight trench. Extra compaction and sand filling is usually avoided to keep installation cost low (Georgi, 1989). Pipes are usually laid at the natural land grade.

As has been mentioned in chapter 3, TADP constructed a number of buried pipe systems for the farmers. However, they did not give adequate attention to the compaction of bed soils in the excavating trench which allowed differential settlement, as a result some pipes were observed to crack circumferentially. This was because of the uneven compaction of bed soils during the installation of the BPS. Longitudinal cracks on pipe body usually at both top and bottom were observed in the fields. This was for the expansion and contraction by wetting and drying and variation of soil temperature. Other probable reasons might be the variation of different stresses, changes of moisture gradient all the time in the wall, air circulation causes stress in the pipeline. Moreover, more leakages were observed at joints (Table 4.10). The reason was either weak jointing or no support beneath joints.

For trouble free operation, pipeline installation should include the following steps according to hydraulic design. These are:

a) selection of depth and grade of laying,

b) digging a trench to proper depth and grade with sufficient working space,

c) the bottom of the trench should be compacted and smooth with uniform foundation,

d) the bed beneath each joint should be scraped to a small pit so that sand filling and jointing work can be done conveniently,

e) lowering the pipe using rope and touching end to end,

f) sealing the joints,

g) moist soil can be used for the back-fill after 12 hours of sealing the joints.

4.2.2.4 Outlet (Riser) Valves

This structure has an alfalfa valve and is used to control the flow of water in the pipeline as well as in the fields. When these are set at the inlets of the main pipelines in the header tank, they control the flow into the main pipelines. On the other hand, if these are set at the ends of main and branch pipelines, they only control the flow into the earthen field channels or directly into the fields.

The outlet valves at the bottom of the header tank are usually operated from top of the tank by top control lever or handle. However, the field valves are operated by a small key.

All the buried pipe schemes have 20 or 21 outlets of 2 cusec (56 l/s) capacity each, except Binnakhaira where 50 outlets of 1 cusec (28 l/s) capacity have been installed (Table 4.9). Two cusec (56 l/s) outlets were found to be inconvenient under the own fuel management and irrigation method practices. One cusec (28 l/s) outlets, provided for 1 ha, and operating one at a time connecting with 1 cusec (28 l/s) pump may be suitable.

4.2.2.5 Leakages of Outlet Valves

Table 4.9 shows conditions of outlet (riser) valves in the eight schemes. On average 42% outlets were found to be leaking water. Generally, pipe system with 5 to 10 outlets was pressurised at one time. A deplorable condition was found at the Binnakhaira scheme followed by East Kutubpur and then the Chulabar scheme. An average of 11 number outlet valves were non-leak proof per scheme (Table 4.9). However, pump operators were appointed on some conditions. The conditions were: a) full time pump operation with full cooperation of the farmers, b) to keep up to date log-book records and c) handling outlet valves. It was observed from the field situation that in most of the schemes (7 out of 8) pump operators started and stopped the pump only, but individual farmers opened alfalfa valves, resulting in mishandling. Faulty design was another reason for non-leak proof outlet valves. For example, two outlet valves at the East Kutubpur scheme had no hole (on top of them) for using the operating key, farmers and/or pump operators opened these alfalfa valves using hammers, axes and whatever they had near at hand, resulting in mishandling by the farmers. After three years, TADP replaced them by other faulty valves having slanting edged lids. So, all outlet valves had top lids of slanting edges, which were found to be not convenient for controlling water leaking.

Table 4.9 Water Leakages Through Outlet Valves

Schemes	No. of valves	Observed leakages	Percent of valve leaking	Visual estimates(l/s)
Taltolapara	21	4	19	0.3
East Kutubpur	20	14	70	0.8
Shaplapara	21	7	33	0.4
Baila	21	3	14	0.2
Vailpara	21	7	33	0.4
Chulabar	21	13	62	0.6
Hazipara	8	3	38	0.6
Binnakhaira	50	36	72	0.5
Average		11	42	0.5

Measurements and visual estimates of outlet seepage losses were in the range of 0.2-0.8 l/s per leaking outlet valve. Brod (1990) reported outlet valve leaking in Bangladesh ranges from 0.4-0.6 l/s.

It was observed that pump operators lost outlet operating keys most frequently. When they lost keys, they used to open the valves by coupling a stick with a valve using rope and trying to twist, resulting in opening the valve. Sometimes farmers were seen to do this work, leading to damage to outlet valves.

Faulty design and interference by village people were mainly responsible for leaking outlet valves. Restriction on touching the outlets by the villagers might help to reduce water loss through outlet valves, and was practised on one scheme out of eight.

4.2.2.6 Air Vents

Air vents are vertical structures of cement concrete pipes connected with the pipeline and used mainly to release entrapped air (if any) in the pipelines. Big air pockets in the pipeline are a danger for the system. Flow of water in the pipeline is always disrupted by air. Interaction between air and water in the pipeline makes a hydraulic hammer which can crack the pipes. TADP installed one air vent for one outlet and the distance between the air vent and the outlet was around 1 metre (refer to Figures 2.4, 2.5 and 2.6).

The height of air vents in the study areas has been selected by a trial and error method, because after completing a new buried pipe scheme, TADP always test the system. During the first test, some air vents were observed overflowing, they added 1 or 2 more pipes on top of existing air vents. This phenomenon indicates that little or no consideration was given to hydraulic design when they installed new buried pipe schemes. Although elevations of different air vents were within a limit (Table 4.2), their distributions were not in sequence, for example, short air vents were installed near the pump and long air vents far away. Moreover, high frequency of failure (1 in 5) was observed. In most of the schemes, air vents were hand made pipes and on average 17.50% air vents were observed leaking water through their bodies at a rate of 0.2 l/s per leaking air vent. Air vents should be installed near the header tank, at all high points in the pipeline and at the end of any pipeline.

4.2.2.7 Selection of Pipe Sizes

At an early stage of the project, TADP used the same pipe size throughout the scheme, for example, the Binnakhaira scheme has the same pipe size of 200 mm (refer to Table 2.15). Generally, after determining the head loss of a pipe network, the loss of a section gives the vertical drop of the hydraulic gradient, which helps to find out the loss of energy at each junction point of the pipe network. Calculating the loss of energy by rearranging the pipe network of different combination of pipes gives the appropriate selection of pipe sizes.

A large-sized pipe carries more water than a small-sized pipe for very little increase in capital cost on the same right-of-way and for essentially the same operation and maintenance cost. For example, a 300 mm pipe will carry 3 times and a 250 mm will carry 2 times as much water as will a 200 mm pipe (Merriam, 1987).

4.2.2.8 Curing of Pipes

Curing is an important phenomenon to make pipes attain sufficient strengths. Besides the correct cement, sand, courser aggregate and water ratios used for pipe making, quality pipes can not be obtained without proper curing. The best method of curing is to submerge the pipes in water for at least 21 days (Georgi, 1989). Other curing methods proposed by TADP are to cover the pipes with: a) moist gunny bags, b) rice straw and c) water hyacinths.

4.2.2.9 Leakages Through Pipe Bodies and Joints

All the eight schemes were constructed on CC pipe systems and encountered the problem of leakage in joints and pipe bodies (Table 4.10). Leakage numbers at East Kutubpur were found to be extremely high (20.37 leakages/100 m). The probable reasons were:

a) the use of hand made vertical moulded pipes, which contained more voids in the pipe wall that reduced pipe strength as well as durability of the pipe;
b) faulty materials, as observed 15-20 pipes cracked spontaneously when exposed to sun while a leakage was being repaired;
c) short or broken pipes as shown by 70-80 joints existing in 125 m of pipeline;
d) inadequate curing and
e) poor jointing.

These reasons for more leakages were also confirmed by Georgi (1989) when describing the problems encountered with vertically moulded pipes. Leakage problems were observed at all the schemes, averaging 2.1 leaks/100 m of pipelines (Tables 4.10 and 5.6). Table 4.10 shows that for the eight schemes 42% leakage occurred through pipe bodies and 58% leakage at joints. This reflected the weak jointing technique. Probable reasons for weak jointing were inexperienced masons, inadequate curing, and poor compaction of bed soils under the trench which allows differential settlement of soils resulting in misalignment. This may be overcome in many cases using improved technology, good compaction of bed soils under the trench, quality materials and proper supervision. However, Merriam (1985 and 1990) reported very low rates of joint leakage from CC pipelines built in Sri Lanka and India, using tongue and groove jointed pipe, but no evidence from field tests.

Table 4.10 Number of Leakages Repaired

Schemes	Leakages on				
	Pipe body	Joint	Total leaks	Leaks/100m per season	Date of repairing
Taltolapara	3	7	10	0.46	Dec."90
East Kutubpur	155	205	360	20.37	Jan."91
Shaplapara	1	1	2	0.11	Dec."90
Baila	3	3	6	0.33	Jan."91
Vailpara	8	15	23	1.31	Jan."91
Chulabar	6	14	20	1.07	Feb."91
Hazipara	2	3	5	0.76	Feb."91
Binnakhaira	17	26	43	1.08	Dec."90
Average	24.4 (42%)	34.3 (58%)	58.6	3.19	
Average*	5.7 (37%)	9.9 (63%)	15.57	0.73	

Note: * = Average value except the East Kutubpur scheme

Table 4.10 also shows that after East Kutubpur, Binnakhaira had the highest number of leakages (43) followed by Vailpara (23) and then the Chulabar scheme (20). For those schemes, pipes were used from two manufacturers: i) Barachowna and ii) Shagordighi. The quality of pipe at Barachowna was inferior to that of Shagordighi as observed by breakage, cracks and irregular wall thickness. Moreover, at the Barachowna site, all the pipes were made by hand. The rest of the schemes showed few leakages which might be due to use of machine made pipes which were taken from the Shagordighi manufacturing site.

4.2.2.10 Existing Conditions of Buried Pipes

Pipe types, jointing methods and number of leakages repaired to date for the three main schemes are shown in Table 4.11. Total leakages repaired since installation of buried pipe was the highest (725) at East Kutubpur and the lowest (44) at Shaplapara scheme. East Kutubpur scheme experienced more leakages due to the bad quality pipes as well as bell-mouth socket and spigot joints. Two pipelines at this scheme did not hold water even for a few minutes in spite of providing "H" shaped check structures which indicated there were many invisible leakages in the pipelines. This was confirmed by interviewing the farmers. It was observed that the plane-end pipe jointing has proved less expensive, simpler to construct, though prone to some leakage and it is now the most commonly used method. MMP (1989a) reported that the plane ended pipe are chosen for its low cost and ease of installation. The more commonly used joint systems include mortar jointed plane ended pipe (MMP, 1989b), tongue and groove pipe with mortar joint (Merriam, 1990) and spigot and socket pipe with a mortar seal or rubber gasket (Koluvek, 1990). Indian, American and British standards provide general specifications, even though for irrigation use the ASAE (American Society of Agricultural Engineers) provides the most relevant recommendations (ASAE S261.7, 1989)

Another keen observation was made that maximum leakages (72%) were found in the section between the pump and the first outlet. This was perhaps due to the high operating pressure at this section. Nevertheless, broken outlets and air vents as shown in Table 4.11 were completely damaged and these were clogged by straw and soils.

Table 4.11 Conditions of Buried Pipe Since Installation

Parameters	Schemes		
	Taltolapara	East Kutubpur	Shaplapara
Installation year	November" 88	November" 87	November"88
Type of pipes	Hand made and machine spun (CC pipe)	Hand made (vertical mould) (CC pipe)	Hand made and machine spun (CC pipe)
Jointing	a) Tongue & groove b) Plane-end pipe	a) Bellmouth-socket and spigot	a) Tongue & groove b) Plane-end pipe
Leakages repaired*			
a) pipe body	28	184	10
b) at joint	145	541	34
c) total	173	725	44
d) per 100 m	7.9	41.02	2.37
Broken valves	1	7	1
Broken air vents	2	1	1

Note: * = Number of leakages repaired since installation of buried pipe

4.2.2.11 Benefits of Buried Pipe Systems

Bentum (1992) documented many benefits which have been reported by a number of authors, for example, Campbell (1984), Gisselquist (1986), and Cunningham (1986). Campbell (1984) showed that the efficiency of water delivery to a field by open channel systems is at least 35% less than with the buried pipe systems. He also concluded that the major benefit of the BPDS is a "higher level of agricultural development (including a move to higher value crops) which results from the greater reliability of irrigation supply".

A buried pipe system ensures sufficient supply of water to the remote point of field plots under the command area. In other words, this system is used to upgrade irrigation delivery facilities. A great advantage which includes an improvement in water conservation, for instance, the ability to extend water deliveries to different plots that could not otherwise be irrigated. Moreover, the larger flow can be divided into smaller sizes without any distribution problems.

Pipelines do not have to follow contour grades so can be laid on straight lines and up and down hills. No land is used for right-of-way which is essential in open channel systems (refer to Table 3.1). Evaporation loss is eliminated. Saving of water on the selected systems was estimated at 91% over earthen channels (Table 4.7). The maintenance cost is almost negligible (refer to Table 7.4) if proper installation is done.

Distances between the plots and the water source have no influence on yield by this system and there were no significant differences between top landers and tail landers and position in the scheme did not influence yield (see chapter 6). The direction of flow can be shifted more rapidly from one part of the command to another part during low demand time. Measured water can be delivered by this system.

This study has clearly identified the benefits of non-reinforced buried pipe systems over earthen open channel systems. These include the reduction in seepage losses, lower costs of construction and installation compared to lined channels.

4.3 PUMP OPERATION

4.3.1 Methodology

4.3.1.1 Pump Operation

Pump operation time was recorded in a pump log-book. A pump log-book was provided to each pump operator for keeping daily records. The log-book was checked by the field staff daily. Daily average operating hours was calculated as:

$$Hr/day = \{(Hr/season)/(Days/season)\} \;...... \;(4.6)$$

Where, Hr = hours. Generally, a pump can be operated at its rated load for 20 hours a day or even more without causing any harm to the machine provided proper maintenance is done and care is taken (Rashid and Mridha, 1990). It is normally advised that a pump is operated 6 days a week (or 26 days a month) keeping one day per week for maintenance, servicing and/or minor repairs. Pump operation (PO) can be calculated by the following equation:

$$PO = [\{(hrs/day)/20\} \times \{(days/month)/26\}] \times 100 \;... \;(4.7)$$

Where, PO = pump operation, (% of advised), hrs = hours.

4.3.1.2 Outlet Opening and Closing Times

For each outlet, opening and closing times for the three main schemes were recorded daily. The field staff used to collect the information regularly with full cooperation from the pump operator.

4.3.1.3 Breakdown Records

The breakdown of prime movers and pumps with the causes were recorded in the log-book. These were checked weekly. Repairing costs were collected by collecting receipts.

4.3.1.4 Fuel and Oil Consumption

From log-books, fuel and oil consumptions were calculated throughout the season.

4.3.2 Results and Discussion

4.3.2.1 Pump Operation

Pump operation per day and per month for the two dry seasons are shown in Tables 4.12 and 4.13. Tables showed that pump operation per day varied from 1.87 hours at East Kutubpur to 6.23 hours at the Baila scheme. The average pump operation per day was 4.39 hours only which was low. Weak organisation and inefficient management systems were mainly responsible for this. From these two tables, pump operation per season was found to be in the range of 224 hours to 725 hours with an average of 457 hours. The lowest (224 hours/season) pump operation at East Kutubpur was due to the breakdown of the engine. In 1989-91, only 12% of advised pump operation was observed. Other probable causes for this low pump operation were:

a) own fuel and first come first served systems (refer to section 2.2.9),
b) low area under boro-rice (only 15%, see Table 5.8),
c) low water requirements for diversified cropping pattern,
d) high fuel costs doubling in one year (refer to chapter 7),
e) farmers prefer to wait for rainfall rather than buy fuel and get water,
f) first user always had to fill up the pipeline by water and pay extra for this so no farmer preferred to start the pump first,
g) disturbance of engine,
h) conflicts among the farmers and
i) shortage of credit/financial resources.

Moreover, low pump operation causes a low command area. A thorough discussion has been made in chapter 7.

Table 4.12 Pump Operation (1989-90)

Schemes	Pump operation				Percent of advised pump operation
	Hours	Days	hrs/day	days/month	
Taltolapara	648	126	5.14	21	21
East Kutubpur	224	120	1.87	17	6
Shaplapara	486	122	3.98	20	15
Average	453	123	3.66	19	14

Table 4.13 Pump Operation (1990-91)

Schemes	Pump operation Hours	Days	hrs/day	days/month	Percent of advised pump operation
Taltolapara	488	127	3.84	18	13
East Kutubpur	310	121	2.56	17	8
Shaplapara	725	124	5.85	18	20
Baila	629	101	6.23	14	17
Vailpara	584	100	5.84	14	16
Chulabar	284	79	3.59	11	8
Hazipara	300	77	3.90	11	8
Binnakhaira	350	64	5.47	9	9
Average	459	99	4.66	14	12

Note: Maximum advised pumping = 26 days/month, 20 hrs/day. Percent of advised pump operation was calculated by equation 4.7

4.3.2.2 Outlet Opening and Closing Times

A few outlets were never used during the study period, for example, an outlet (2-5) at East Kutubpur and an outlet (3-1) at Shaplapara (see Figures 2.5 and 2.6) were never used. At East Kutubpur, the landowner under (2-5) outlet lived abroad with his family and the land had been given to his younger brother for use. The younger brother being a large farmer could hardly manage his own land, so excess land obtained from the elder brother was kept fallow. As per the instruction of the elder brother, the younger could neither lease the land nor give them to a share cropper. At the Shaplapara scheme, the landowner under (3-1) outlet lived at a distant place about 15 Km away from the scheme where he was a large farmer, so he did not bother about this land. As a result, this land remained fallow all the time.

Frequencies of outlet used per scheme are shown in Table 4.14. It was observed that the use of many outlets was very low and 9% of outlets were found never to be used throughout the season even though every outlet had been given an equal importance during construction (Mayer, personal communication, 1991). To make the buried pipelines economically justified the use of these low use outlets will have to be increased significantly.

Table 4.14 Frequencies of Outlet Use

Frequency of outlet use/season	Schemes: Taltolapara 1989-90	Taltolapara 1990-91	East Kutubpur 1989-90	East Kutubpur 1990-91	Shaplapara 1989-90	Shaplapara 1990-91	Average use(%)
00-05	0(0)	4(19)	4(20)	3(15)	1(5)	4(19)	13
06-10	5(24)	2(10)	7(35)	7(35)	3(14)	1(5)	21
11-15	5(24)	2(10)	4(20)	3(15)	3(14)	4(19)	17
16-20	1(5)	1(5)	3(15)	2(10)	5(24)	2(10)	12
21-25	2(10)	3(14)	0(0)	1(5)	1(5)	0(0)	6
26-30	5(24)	3(14)	1(5)	0(0)	3(14)	2(10)	11
31-35	0(0)	4(19)	0(0)	0(0)	1(5)	3(14)	6
36-40	0(0)	0(0)	0(0)	3(15)	1(5)	0(0)	3
>40	3(14)	2(10)	1(5)	1(5)	3(14)	5(24)	12
Outlets	21	21	20	20	21	21	

Note: Figure in parentheses indicate percentage of outlet used per scheme

Total irrigation time, time taken in filling pipelines, numbers of outlet openings, average time per opening per day of pump operation are shown in Table 4.15. Pipe filling time was calculated from the total pumping hours (Tables 4.12 and 4.13) minus the total irrigation time (Table 4.15). It is evident that time taken for pipe filling (lost time) was the highest (18.62%) at East Kutubpur and the lowest (3.26%) at Shaplapara with an average of 8.52% which was probably due to use of own fuel system. This lost time could be recovered only using project fuel or KSS fuel system. At East Kutubpur, the lost time was high because the pipe sizes were larger (e.g., 10" and 12"), so more filling time was needed. The total time lost in filling the pipeline also depended on the number of changes of pipelines during each day of operation. Only one outlet was opened at a time, receiving the full tubewell discharge through that outlet.

From Table 4.15, on average outlet valves were used 428 times per season per scheme. Average time per outlet used was 59 minutes. However, a quite surprising result was that on average only 3.47 outlets were used per day of pump operation. Reasons for low utilizations of outlets have been described in the subsequent sections.

Table 4.15 **Distribution of Pumping Times**

Parameters	Schemes					
	Taltolapara		East Kutubpur		Shaplapara	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
Pumping time (hr)	648	488	224	310	486	725
Irriga. time (hr)	618.75	453.79	199.43	252.29	453.08	701.34
Pipe filling time						
a) hours	29.25	34.21	24.57	57.71	32.92	23.66
b) % of pumping	4.51	7.01	10.97	18.62	6.77	3.26
Outlet openings	466	467	300	322	483	531
Avg. time per opening (mins)	78	62	40	46	52	78
Outlet opening/day of pump operation	3.7	3.68	2.5	2.66	4.0	4.28

4.3.2.3 Fuel and Oil Consumption

Fuel and oil consumption for eight schemes are shown in Table 4.16. This table reveals that seasonally fuel consumption at East Kutubpur was the highest (4.88 l/hr), which was mainly due to the engine problem. In 1989-90 irrigation season farmers at this scheme paid Tk 22,473.00 for engine repairs at the beginning of the season (refer to Table 7.4). But, due to the shortage of financial resources all old parts could not be changed, so even after a big repair high fuel consumption occurred. Table 4.16 shows that oil consumption was greater than 1% of fuel consumption in 5 out of 8 schemes. For the first three schemes, three seasons data show that fuel as well as oil consumption increased as the equipment became older. This indicated poor maintenance and servicing of the engine. Reasons for this poor servicing were: a) weak KSS management and lack of leadership, b) lack of unity among the farmers even relatives, c) no fixed budget for servicing and maintenance, and d) farmers did not bother for the pump life and its condition.

It was observed that sometimes the engine was unused for several days (5 to 10 days) for want of lubricating oil. It was also noticed that sometimes burnt oil was used. This was due to the fact that the oil charge was not (or could not be) collected in time from the farmers (refer to section 7.2.3.1). The high rise (double) in prices of spare-parts within a year was another reason for the poor maintenance of the engine.

Table 4.16 Fuel and Oil Consumption

Schemes	Season time	Consumed(l/hr) Fuel	Oil	Oil consumed as % of fuel
Taltolapara	Dec."89 to May "90	3.80	0.01	0.26
	Jun."90 to Nov."90	4.04	0.02	0.50
	Dec."90 to Jun."91	4.08	0.03	0.74
East Kutubpur	Dec."89 to May "90	4.25	0.10	2.35
	Jun."90 to Nov."90	4.78	0.12	2.51
	Dec."90 to Jun."91	4.88	0.14	2.87
Shaplapara	Dec."89 to May."90	3.36	0.03	0.89
	Jun."90 to Nov."90	3.43	0.04	1.17
	Dec."90 to Jun."91	3.48	6.06	1.72
Baila	Dec."90 to Jun."91	4.12	0.04	0.97
Vailpara	Dec."90 to Jun."91	3.97	0.03	0.76
Chulabar	Dec."90 to Jun."91	3.98	0.06	1.51
Hazipara	Dec."90 to Jun."91	4.05	0.06	1.48
Binnakhaira	Dec."90 to Jun."91	3.10	0.12	3.87
Average		3.95	0.06	1.54

4.4 SAMPLE OUTLETS

4.4.1 Methodology

Three sample outlets from each of the schemes of Taltolapara, East Kutubpur and Shaplapara were selected for water management study. The selected sample outlet areas along with plots are shown on schematic layout of the schemes (Figures 4.6, 4.7 and 4.8 for the Taltolapara scheme; Figures 4.9, 4.10 and 4.11 for the East Kutubpur scheme and Figures 4.12, 4.13 and 4.14 for the Shaplapara scheme).

Figure 4.6

Sample Outlet at Taltolapara (1-4)

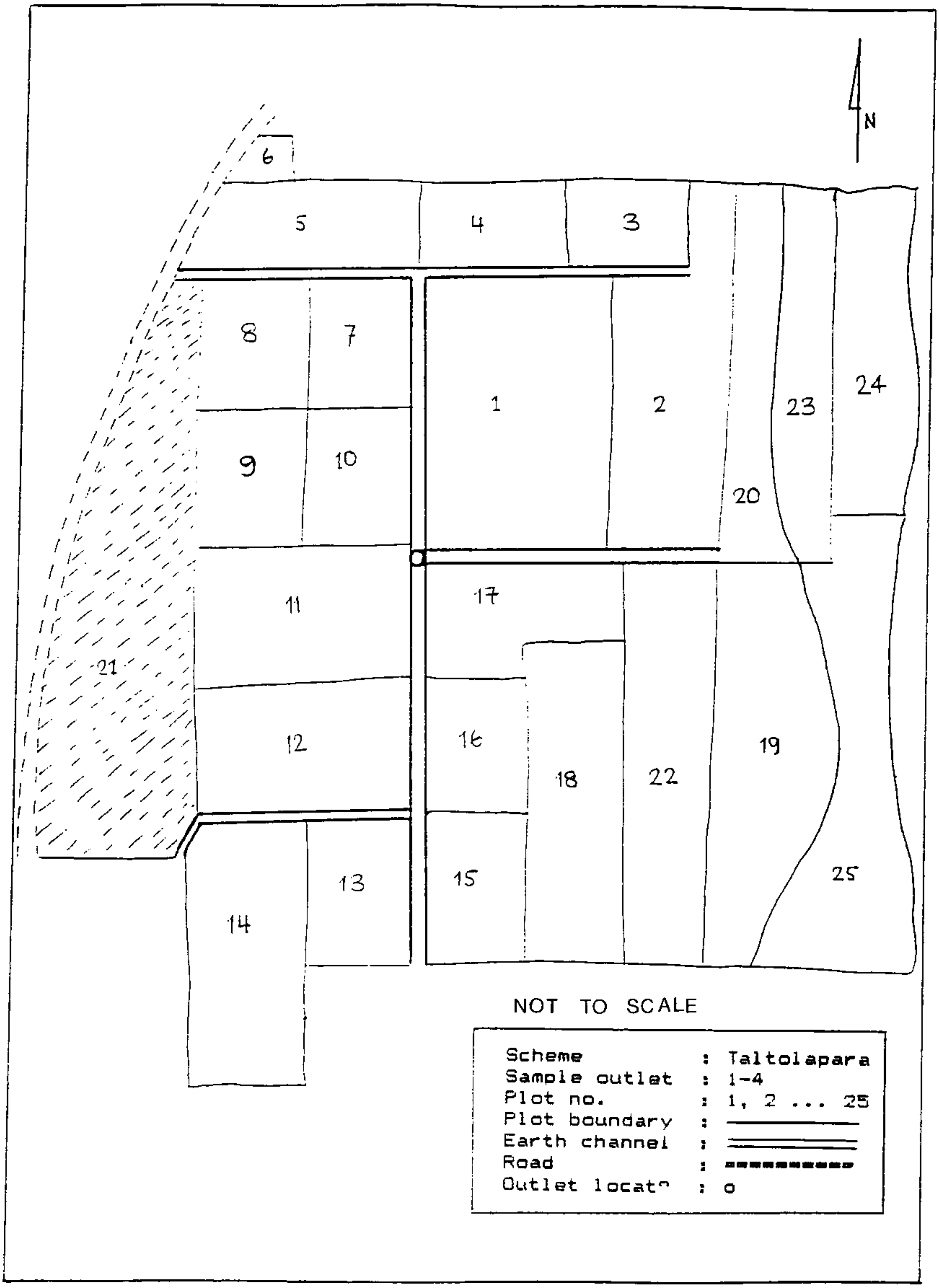


Figure 4.7

Sample Outlet at Taltolapara (1-5)

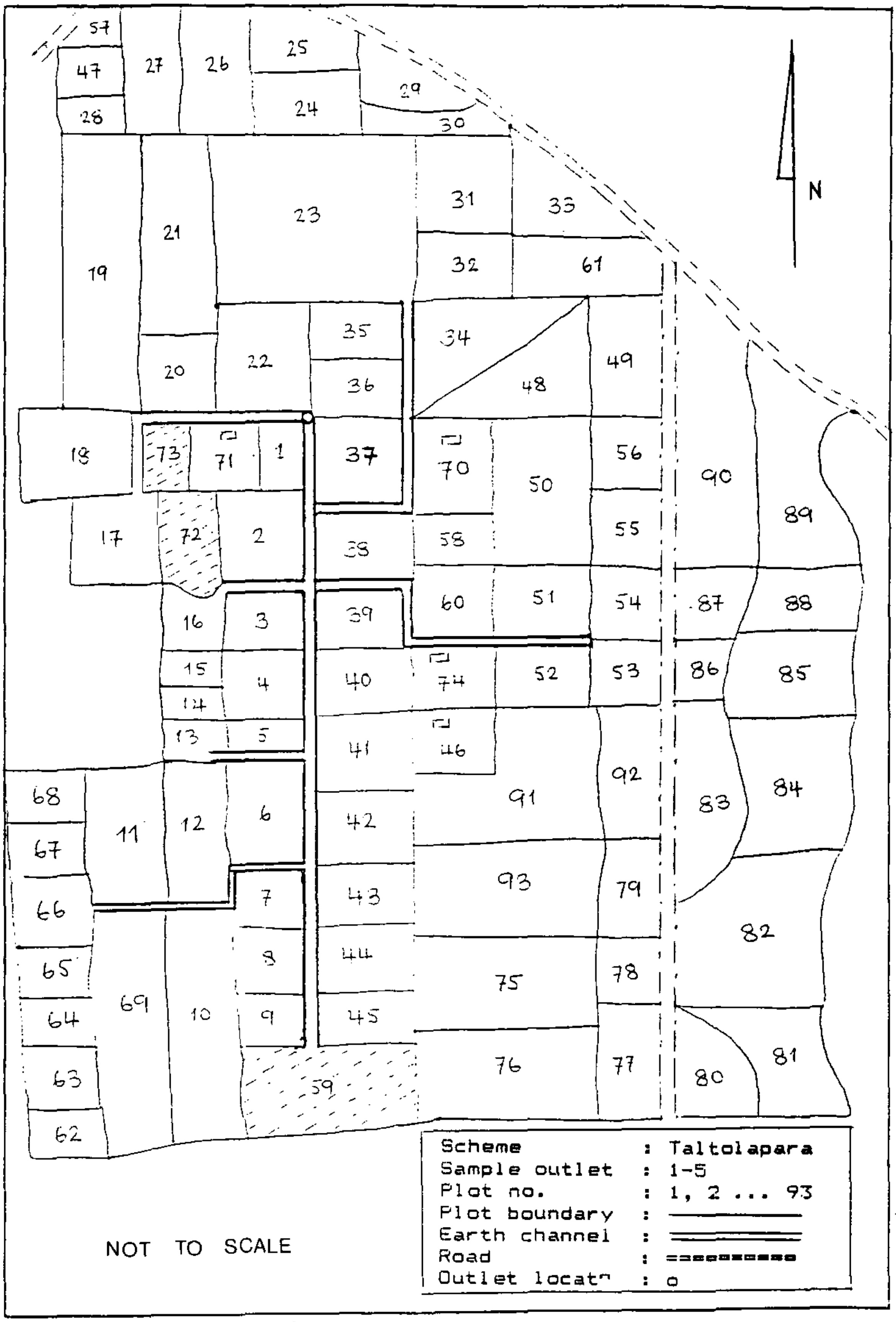


Figure 4.8

Sample Outlet at Taltolapara (3-3)

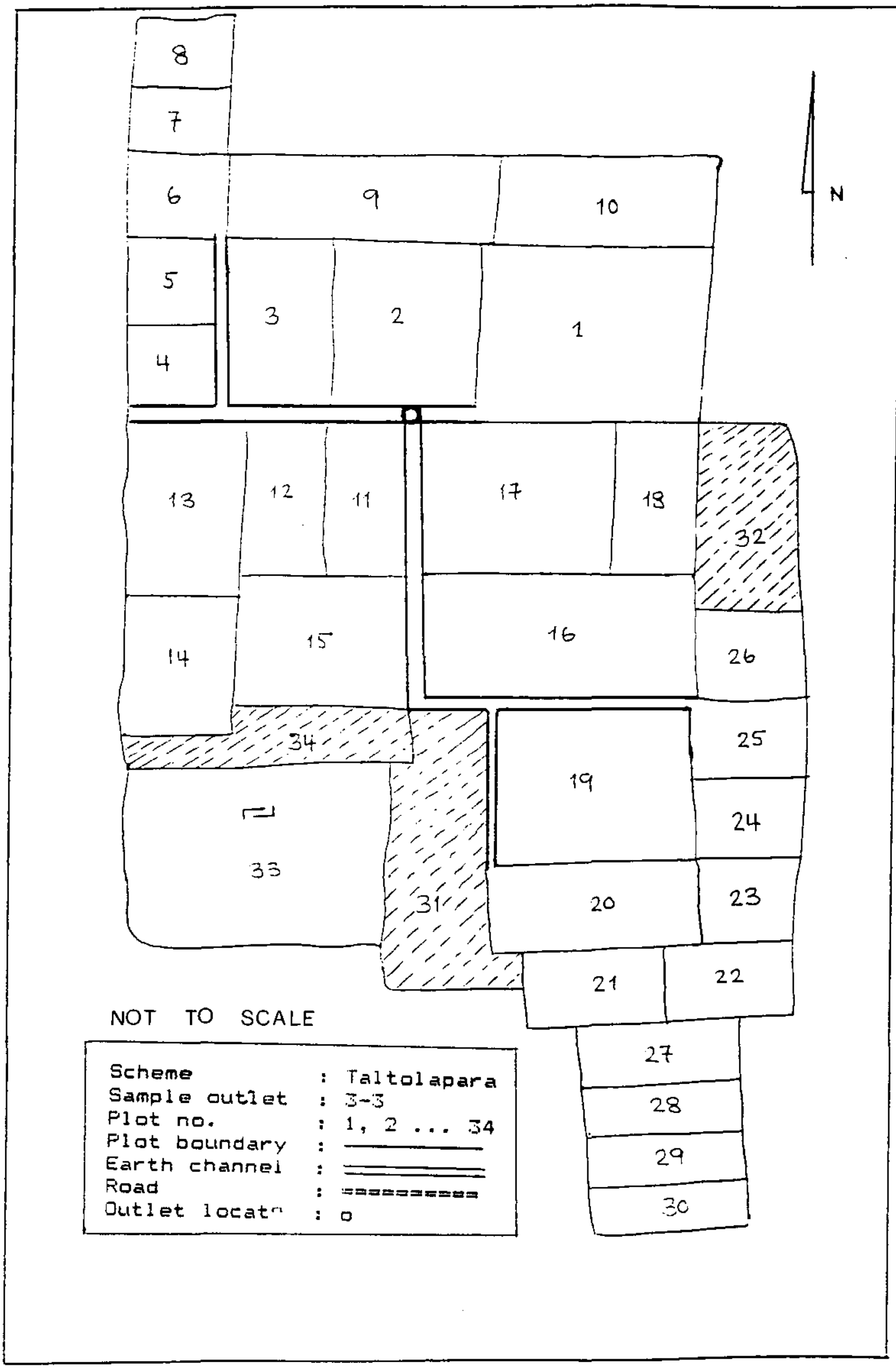


Figure 4.9

Sample Outlet at East Kutubpur (1-6)

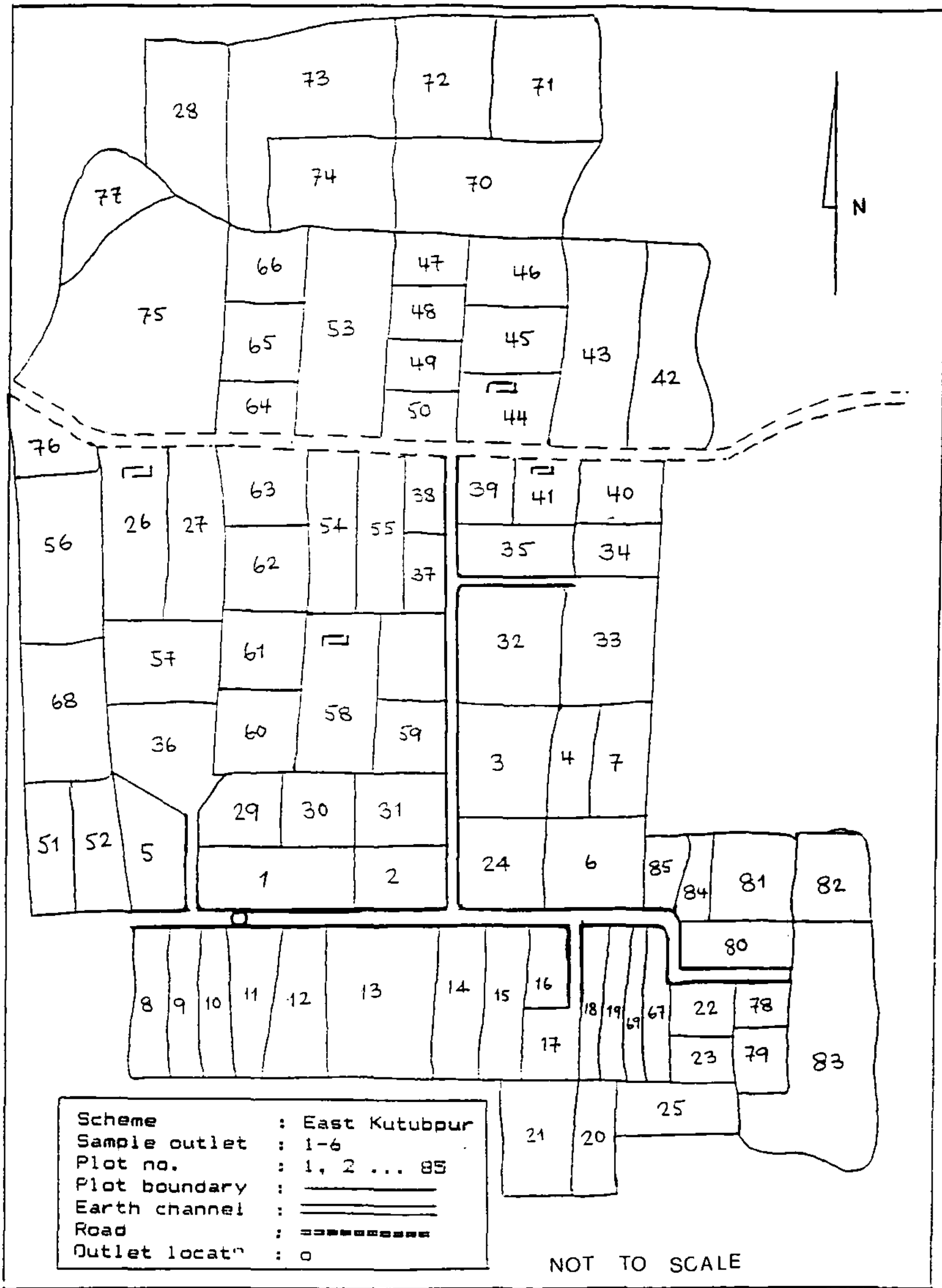


Figure 4.10

Sample Outlet at East Kutubpur (2-2)

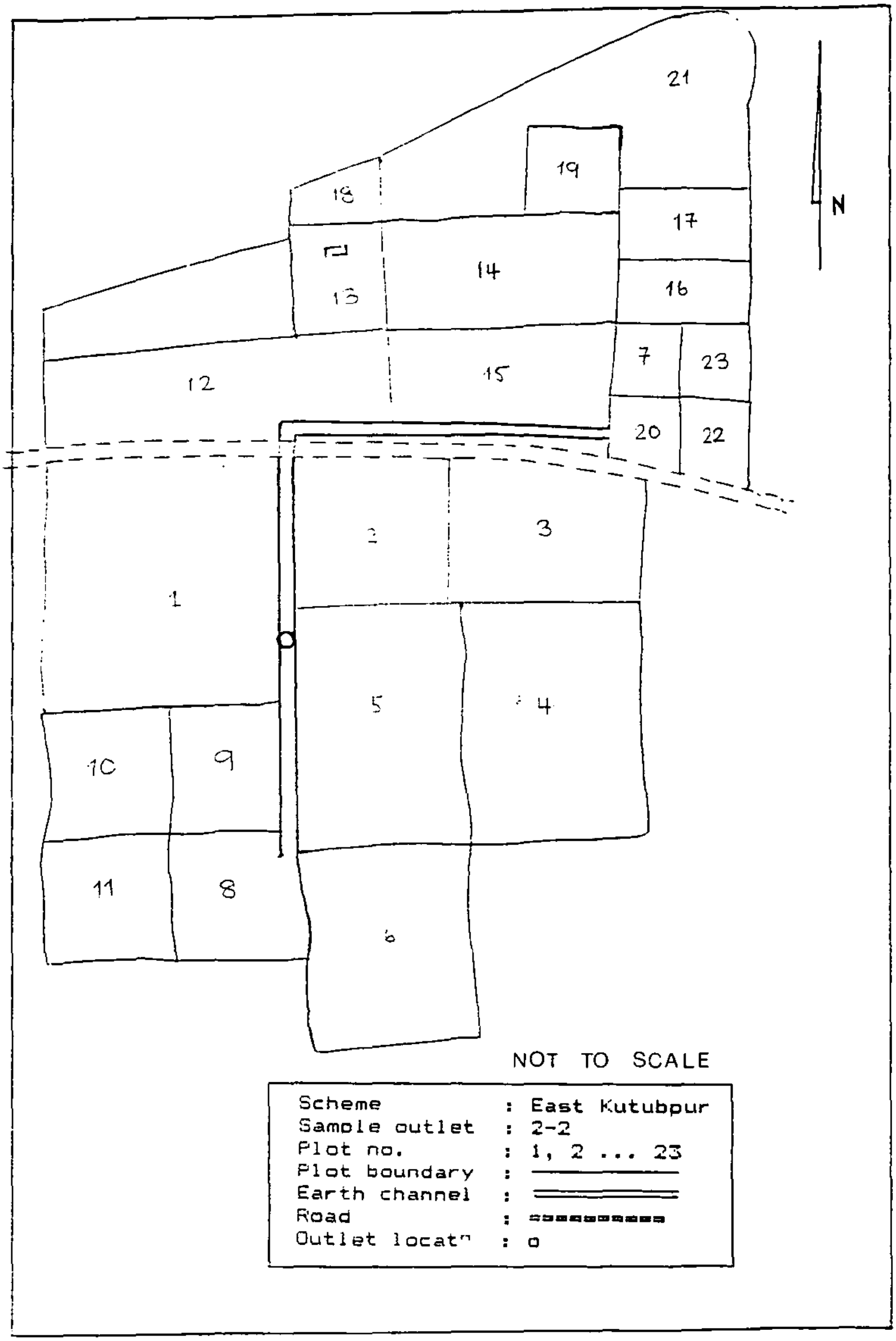


Figure 4.11

Sample Outlet at East Kutubpur (3-2)

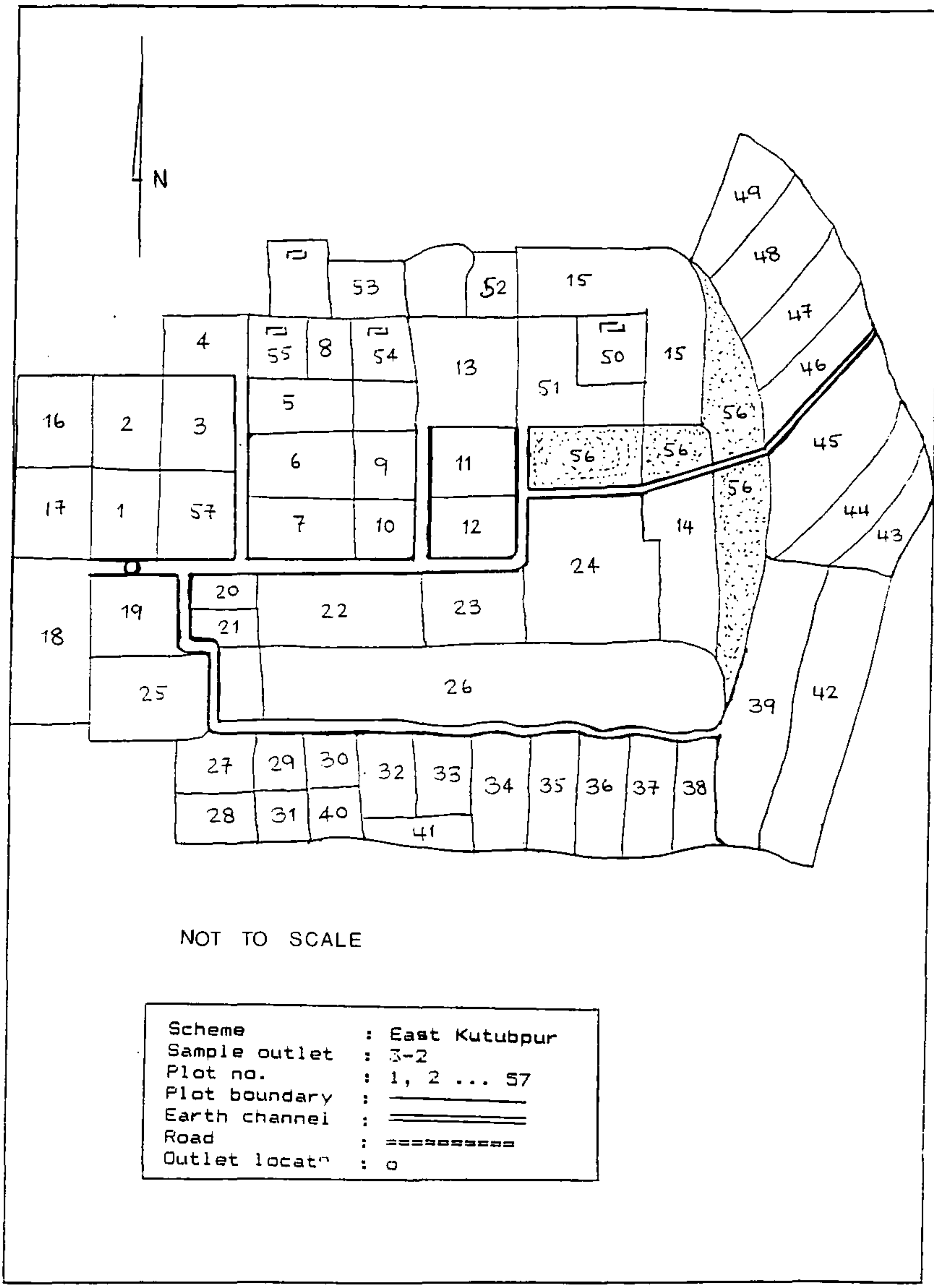


Figure 4.12

Sample Outlet at Shaplapara (1-3)

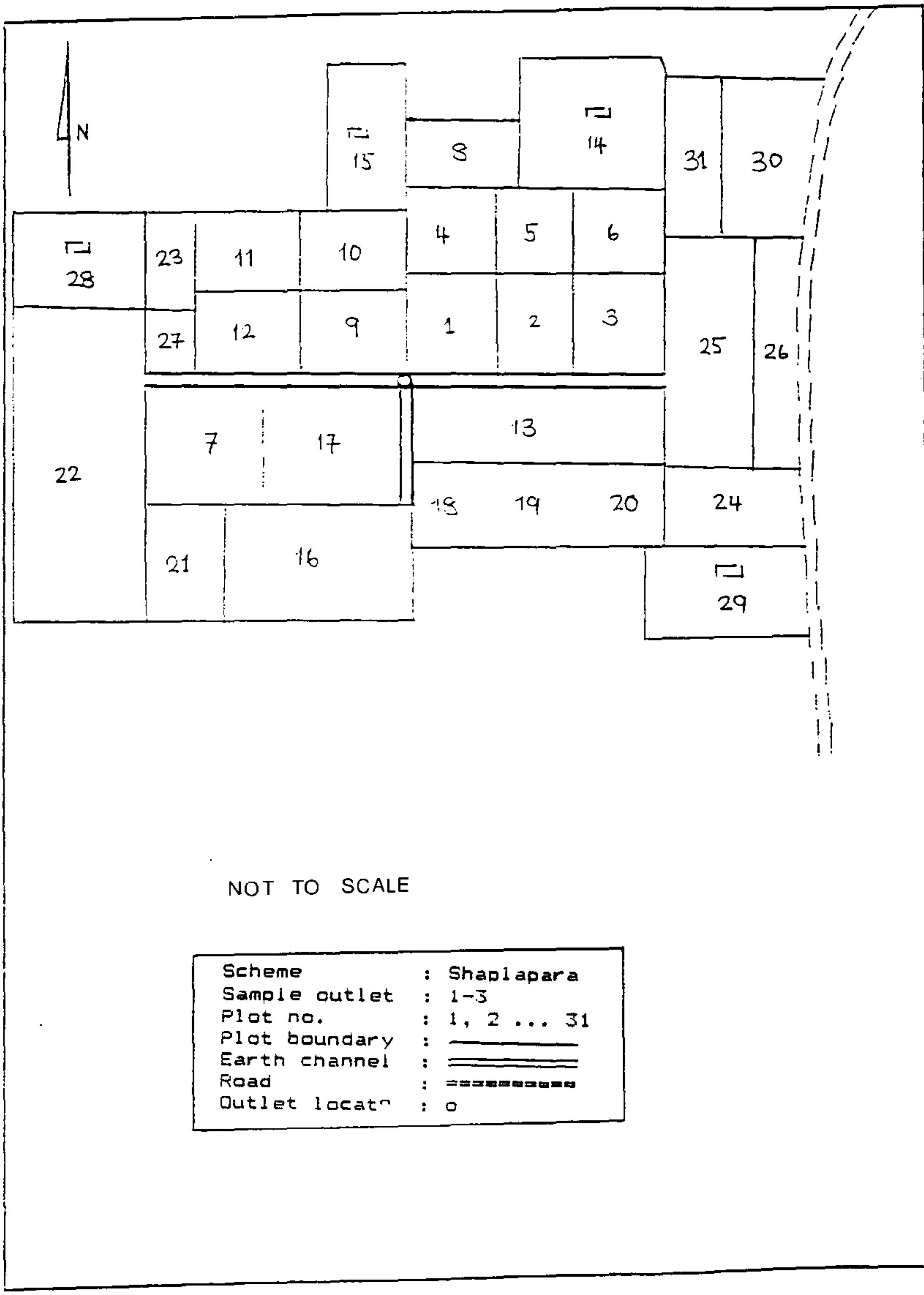


Figure 4.13

Sample Outlet at Shaplapara (2-5)

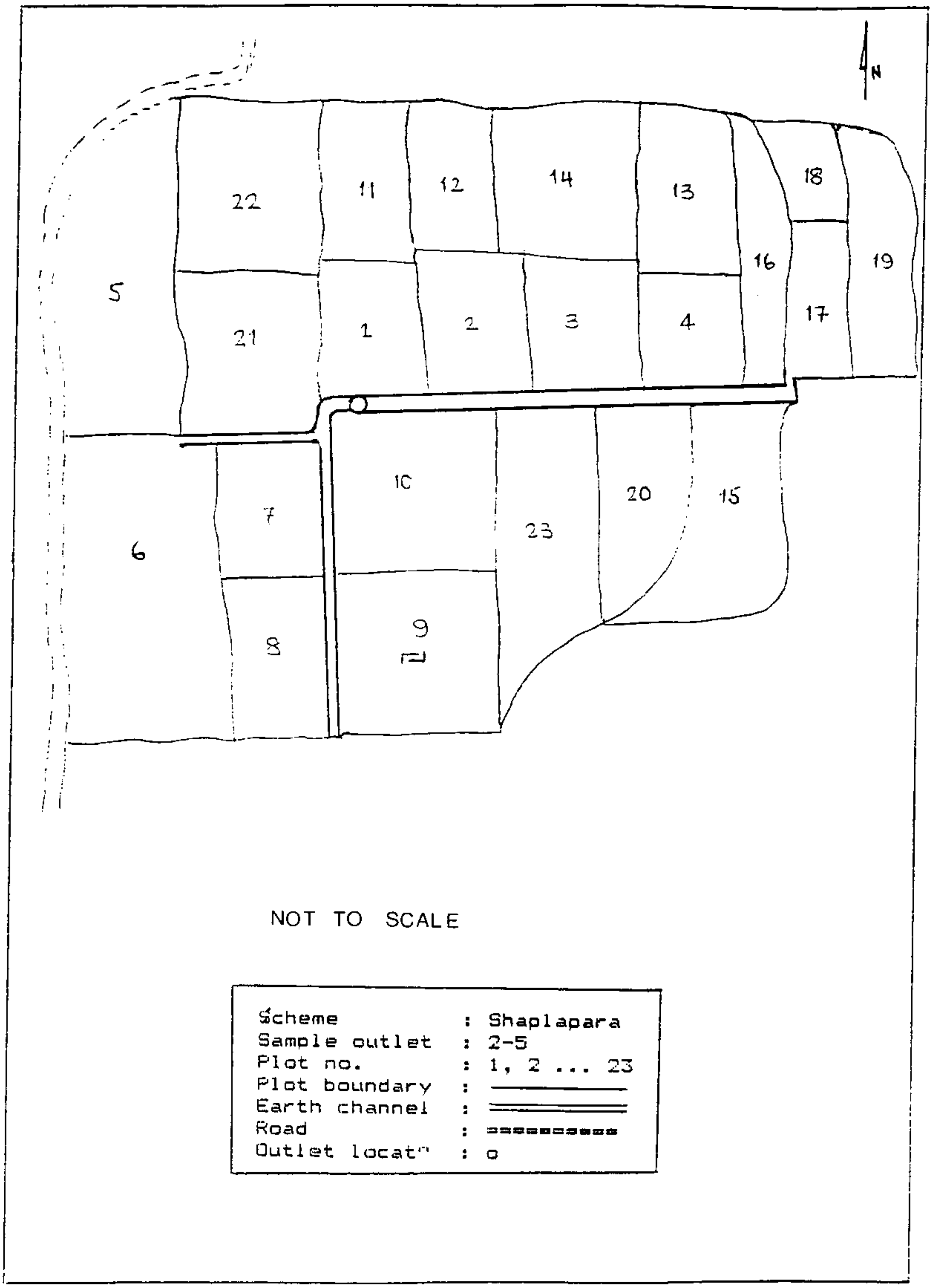
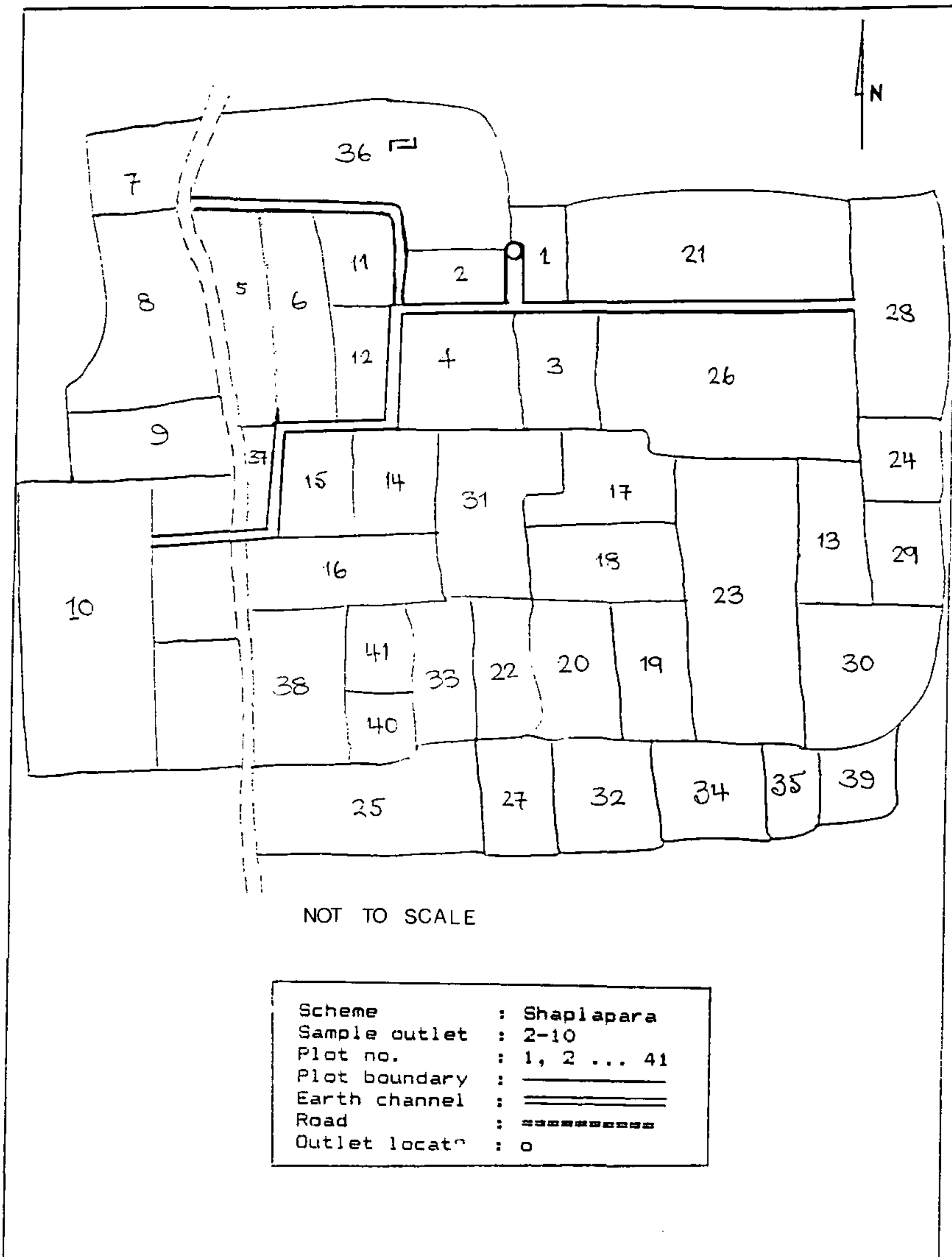


Figure 4.14

Sample Outlet at Shaplapara (2-10)



4.4.1.1 Selection of Sample Outlets

In order to study the farmers' practices deeply and also to see the effects of irrigation and management factors and their interactions on agricultural production investigation was based on the following criteria:

a) one outlet which serves land owned by the scheme manager,

b) one near the middle of a branch, and

c) one outlet which serves land owned by non-KSS members or near the tail of a branch.

4.4.1.2 Sample Outlet Information

For each irrigation at the sample outlet, engine speed, sample outlet number, plot number, irrigation time (t) and channel length (C_{Lgth}) were recorded on a field register regularly.

4.4.1.3 Sample Outlet Discharge

The discharge from the sample outlet was estimated by the following formula:

$$Q_{SO} = [Q_P - \{(W_{LP}/100) \times P_{Lgth}\}] \quad \text{...... ......} \quad (4.8)$$

Where, Q_{SO} = sample outlet discharge, (l/s); Q_P = pump discharge, (l/s); W_{LP} = water loss from the pipeline under test, (l/s/100 m) and P_{Lgth} = total pipe length, (m).

4.4.1.4 Field Discharge

Measuring engine speed showed the pump discharge on the curve. The discharge from the sample outlet was estimated by equation 4.8 for that particular time. Conveyance loss from the field channel (C_{LF}) was deducted from the sample outlet discharge (Q_{SO}), resulting in field discharge. The equation is as follows:

$$Q_F = [Q_{SO} - \{(C_{LF}/100) \times C_{Lgth}\}] \quad \text{...... ......} \quad (4.9)$$

Where, Q_F = field discharge, (l/s); Q_{SO} = sample outlet discharge, l/s; C_{LF} = conveyance loss from field channels, (l/s/100 m) and C_{Lgth} = channel length between plot and outlet, (m).

4.4.1.5 Plot Area Measurements

More emphasis was given to the area under the sample outlets where a map with different plots was drawn directly, along with identification numbers, with the help of respective landowners (Figures 4.6 to 4.14). After measuring plot dimensions, the plot area was calculated. Moreover, knowing other plot areas with the help of the respective landowner and/or cultivator, the total command area was estimated.

4.4.2 Data From Sample Outlets

Descriptions of these sample outlets are given in Table 4.17. Cultivated plot sizes were found to vary from 81 sq m to 2266 sq m with an average plot size of 495 sq m. Land holding per family by the cultivators varied from 0.08 ha to 1.6 ha. It appeared from the Table that farmers under sample outlets were classified from landless to medium group in terms of land holding status.

Table 4.17 Information on Sample Outlets

Parameters	Schemes								
	Taltolapara			East Kutubpur			Shaplapara		
Sample position	* 1-4	1-5	3-3	1-6	2-2	3-2	1-3	2-5	2-10
Command area (ha)									
a) Gross	1.82	3.89	1.72	2.90	0.82	2.25	1.52	1.07	2.63
b) Actual	0.66	1.39	1.10	1.10	0.43	0.73	1.25	0.77	1.66
Unavailable of cultivation (ha)	0.13	0.21	0.12	0.13	0.04	0.07	0.20	0.08	0.28
Fallow land (ha)	1.04	2.30	0.50	1.68	0.36	1.45	0.07	0.23	0.69
Total plots	25	93	34	84	24	61	31	23	40
Plot sizes(m^2)	283-821	81-688	121-1052	81-1214	121-809	121-809	162-1376	121-1214	162-2266
Cultivated plots	14	30	18	22	11	15	27	22	29
Landowner	4	10	5	13	3	15	8	7	6
Cultivator	2	6	4	9	2	5	7	6	5
Land (ha/family)	0.81-1.0	0.08-0.6	0.40-1.0	0.10-1.0	0.5-1.0	0.10-1.6	0.16-1.2	0.13-1.0	0.20-1.2
KSS farmer	2	3	3	4	2	1	5	4	2
Non KSS farmer	0	3	1	5	0	4	2	2	3

* First digit indicates pipeline number and the second digit indicates outlet number

CHAPTER 5
IRRIGATION AND AGRONOMIC PRACTICES

This chapter is particularly concerned with objective 3.

5.1 IRRIGATION PRACTICES

5.1.1 Methodology

5.1.1.1 Irrigated Area

Details of irrigated areas for each dry season since installation of deep tubewells were collected from the Tangail Agricultural Development Project (TADP) office, Tangail. Irrigated areas after buried pipe (BP) except sample outlets were estimated through interviewing the manager as well as the respective landowners. Irrigated area under the sample outlets were measured in the fields.

5.1.1.2 Gross Command Area

Gross command area was determined by walking through the whole scheme as well as marking on the site map, the area which was irrigated and also could be irrigated from the tubewell. Utilization of lands under the gross command were also demarcated on the site map. Knowing the plot area with the help of the manager and the respective landowner, the gross command area was calculated.

5.1.1.3 Actual and Intended Command Area

The actual command area was obtained in consultation with the pump operator, scheme manager, and/or prominent villagers. This was checked by field visits on the basis of a) reconnaissance survey through the scheme area, b) mouza (cadastral) map and block registers, c) plots under each outlet and d) crops grown in each plot.

The intended command areas of each Deep Tubewell (DTW) were taken from the TADP office, Tangail. The intended area was based on 56 l/s pump discharge. The same was also calculated based on actual available discharge.

5.1.1.4 Land Occupied by Channels

Length and width of feeder earth channels and field channels (before buried pipe) were identified and measured consulting with the scheme manager, pump operator, KSS president, KSS and non-KSS farmers. The same parameters for the field channels under BP systems were also measured in the fields by field staff.

5.1.1.5 Land Saved by Buried Pipe Systems

Cultivable area saved by a buried pipe system was also calculated by the following equation:

$$LS_{BP} = \{(A_{BBP} - A_{ABP})/10{,}000\} \times 100 \quad \ldots\ldots\ \ldots \quad (5.1)$$

Where, LS_{BP} = land saved by buried pipe, (%); A_{BBP} = unit area under earthen channel before buried pipe, (m^2/ha); A_{ABP} = unit area under earthen channel after buried pipe,(m^2/ha).

5.1.1.6 Length of Buried Pipelines

Length of pipelines consisted of different sizes of pipe on the line (refer to Figures 2.4, 2.5 and 2.6 in the text and Figures A.1, A.2, A.3, A.4 and A.5 in Appendix A). Lengths of the pipeline were measured directly in the field with the help of the manager and TADP record. The same were also obtained from the TADP office. Difference between these two measurements was less than 1% for each of the schemes. Moreover, pipe layout for each of the schemes was drawn showing different lengths and diameters.

5.1.1.7 Field Topography and Configuration

The Reduced Level (RL) of every plot under the gross command, top of outlets, top of air-vents and top of header tank were measured by field survey using a levelling instrument. The RL of the benchmark point (the top of the pump discharge pipe) was taken as 10.00 m.

5.1.1.8 Water Distribution Systems

The present method of water distribution systems was observed in the fields and recorded in a note book. Farmers' practising water distribution systems were surveyed and analysed.

5.1.2 Results and Discussion

5.1.2.1 Irrigated Area

Actual irrigated area for two irrigation seasons and the intended command area are shown in Table 5.1. In the first year the use of buried pipe distribution systems (Tables 2.15 and 5.1) command area was comparatively higher at all the schemes probably due to the use of project fuel organized by the Krishak Samabay Samity (KSS or farmers' cooperative). Another reason for this high command area was that farmers thought that they were going to get more irrigation water everywhere within the scheme by paying a small amount of irrigation charge. This assumption was correct, but conflicts as well as mismanagement among the farmers altered the situation in the following years (refer to chapter 7).

Table 5.1 Actual and Intended Command Areas

Parameters	Schemes		
	Taltolapara	East Kutubpur	Shaplapara
Actual command area(ha)			
a) 1987-88	13.27	19.02	29.22
b) 1988-89	27.68	17.20	18.37
Intended command area(ha)			
a) TADP design	40	40	40
b) Pump discharge	30-35	30-35	30-35

5.1.2.2 Unirrigated Area

Command areas for the dry seasons on eight schemes (Tables 5.2 and 5.3) varied from 9.25 to 21.55 ha, with an average of 16.64 ha, which was less than 50% of the intended command area (Table 5.1). Inefficient pump operations (refer to section 4.3.2.1) and ineffective management systems were mainly responsible for the low utilization of the irrigation equipment. Causes for this low command area have been described in the subsequent sections. It was also found that unirrigated area varied from 5.34% to 21.54% of the total command area with an average of 13.73% (Tables 5.2 and 5.3), indicating low and under-utilization of pumps (refer to section 4.3.2).

Table 5.2 Command Area (1989-90)

Schemes	Command area (ha)		Total command area (ha)	Percent of unirrigated land
	Irrigated land	Unirrigated land		
Taltolapara	18.87	1.97	20.84	9.45
East Kutubpur	9.25	2.54	11.79	21.54
Shaplapara	20.66	2.12	22.78	9.31
Average	16.26	2.21	18.47	13.43

Table 5.3 Command Area (1990-91)

Schemes	Command area (ha)		Total command area (ha)	Percent of unirrigated land
	Irrigated land	Unirrigated land		
Taltolapara	15.15	2.31	17.46	13.23
East Kutubpur	13.85	3.62	17.47	20.72
Shaplapara	21.55	1.23	22.78	5.34
Baila	19.28	1.97	21.25	9.27
Vailpara	16.74	1.62	18.36	8.82
Chulabar	13.36	2.88	16.24	17.73
Hazipara	14.81	3.40	18.21	18.67
Binnakhaira	19.56	3.98	23.54	16.91
Average	16.79	2.63	19.41	13.84

5.1.2.3 Usages of Gross Command Area

Gross command area (GCA) refers to the total area under a scheme boundary. Utilization of the GCA for the three main schemes is shown in Table 5.4. This table shows that there was a considerable variation in land utilization from year to year and irrigated area was only 40% of the GCA. From the Table 5.4, on average about 40% land was left fallow which indicated the poor utilization of the command area. The reasons for excess fallow land, as observed and got from the survey results were as follows:

a) for own fuel system, farmers were not compelled to cultivate all the land under the scheme;

b) a few farmers were involved in other businesses and a few farmers lived abroad;

c) fear of pump breakdown in the dry season;

d) fodder crisis, land was kept fallow for animal grazing (see Figure 7.1);

Table 5.4 **Usages of Gross Command Area**

Parameters	Schemes					
	Taltolapara		East Kutubpur		Shaplapara	
	1889-90	1990-91	1989-90	1990-91	1989-90	1990-91
Irrigated cultivation						
a) Total(ha)	18.87	15.15	9.25	13.85	20.66	21.55
b) Percent	43.43	34.86	22.25	33.33	49.70	51.85
Non-irrigated cultivation						
a) Total(ha)	1.97	2.31	2.54	3.62	2.12	1.23
b) Percent	4.54	5.32	6.10	8.71	5.12	2.96
Unavailable of cultivation						
a) Total(ha)	5.33	5.53	3.90	3.90	4.39	4.39
b) Percent	12.25	12.72	9.39	9.39	10.58	10.58
Orchard						
a) Total(ha)	0.25	0.25	0.08	0.08	0.25	0.25
b) Percent	0.57	0.57	0.20	0.20	0.60	0.60
Forest						
a) Total(ha)	0.70	0.70	1.89	1.89	1.99	1.99
b) Percent	1.61	1.61	4.55	4.55	4.78	4.78
Pond						
a) Total(ha)	0.18	0.18	-	-	0.14	0.14
b) Percent	0.42	0.42	-	-	0.33	0.33
Fallow land						
a) Total(ha)	16.16	19.34	23.90	18.22	12.01	12.01
b) Percent	37.18	44.50	57.51	43.84	28.89	28.89
Total land under scheme						
a) Total(ha)	43.46	43.46	41.56	41.56	41.56	41.56
b) Percent	100	100	100	100	100	100

Note: Unavailable of cultivation includes mosque, bazar, school etc.

e) farmers were generally accustomed to grow only two crops a year on the same land;

f) shortage of financial resources;

g) high prices of agricultural inputs, for example, fuel price was doubled in one irrigation season;

h) shortage of draft power (refer to section 7.1.2.3);

i) sloping land (uneconomic considering investment), land development was costly;

j) improper cropping pattern, three crops can not be accumulated;

k) high leakages (e.g., East Kutubpur) and irrigation cost was high, so farmers were discouraged;

l) inability of small and marginal farmers to manage inputs;
m) less or no confidence in the KSS leadership;
n) management problem of more land,
o) tenancy systems were not in favour of share cropper;
p) yield of crops did not satisfy the farmer;
q) crops damaged by natural hazards;
r) conflicts among the brothers/relatives and
s) availability of agricultural inputs.

Moreover, many social and institutional problems existed in the schemes (refer to Figure 7.1).

5.1.2.4 Water Distribution Under Farmers' Practices

All the eight schemes were under the Irrigation Management Programme (IMP) where a rotational block irrigation system was supposed to be followed. Unfortunately, at none of the schemes was a rotational block system practised. No irrigation plan and definite system was followed for allocating and distributing pump water. Any one, either KSS or non-KSS farmers, at any time could use the pump by providing only the fuel. This resulted in frequent switching of water flow in the pipelines.

From outlets water was distributed locally through earthen field channels. Plots that were not connected by field channels were irrigated by plot to plot distribution. Water was applied to the field mostly by flooding method. However, some farmers used a furrow method on vegetables. For boro-rice three types of irrigation systems observed were:

a) continuous flooding,
b) water applied at saturated condition and
c) alternate drying and wetting.

5.1.2.5 Infield Water Distribution

For each scheme, three outlets of which one near the pump, one at middle and one at the end of each pipeline were selected for this infield water distribution (see the location of each outlet in Figures 2.4, 2.5 and 2.6). Volume of water delivered per season was calculated considering the average pump discharge and the total irrigating time per outlet. Table 5.5 shows the water distribution patterns in the farmers' field using buried pipe systems. Although flow rates for each outlet on the same pipeline were the same, it is

Table 5.5 Water Distribution Pattern in the Three Main Schemes

Outlet no.	Position of the outlet	Distance from DTW (m)	Volume delivered per season (ha-m)	Irrigated area (ha)	Applied depth (m)
Taltolapara					
1-1*	Head	116	0.05	0.52	0.10
1-4	Middle	329	0.20	0.95	0.21
1-5	Tail	498	0.29	1.09	0.27
2-1	Head	113	0.05	0.53	0.09
2-5	Middle	277	0.27	0.79	0.34
2-7	Tail	494	0.33	0.61	0.54
3-1	Head	158	0.29	0.70	0.41
3-3	Middle	227	0.34	0.96	0.35
3-5	Tail	390	0.09	0.46	0.20
East Kutubpur					
1-1	Head	95	0.07	0.54	0.13
1-3	Middle	273	0.12	0.89	0.13
1-6	Tail	321	0.15	1.02	0.15
2-2	Head	192	0.05	0.48	0.10
2-4	Middle	336	0.07	0.19	0.37
2-6	Tail	479	0.31	0.54	0.57
3-2	Head	165	0.13	0.62	0.21
3-4	Middle	331	0.19	0.70	0.27
3-6	Tail	463	0.13	0.72	0.18
Shaplapara					
1-1	Head	16	0.78	1.85	0.42
1-3	Middle	172	0.14	1.29	0.11
1-5	Tail	249	0.19	0.91	0.21
2-1	Head	24	0.07	0.37	0.19
2-5	Middle	290	0.20	0.73	0.27
2-10	Tail	359	0.61	1.36	0.45
3-2	Head	171	0.11	0.52	0.21
3-3	Middle	297	0.34	1.18	0.29
3-6	Tail	551	0.29	1.04	0.28

* First digit indicates pipeline number and second digit indicates outlet number

clear from the analysis of data in Table 5.5 that the water distribution patterns were non-uniform in all the three main schemes. This was also true from one area to other areas (head to tail) in the same scheme under the study. The performance of the irrigation system in terms of equity, reliability and availability in distribution of water using buried pipe systems was not satisfactory. Various reasons have been attributed for non-uniform water distribution. These were:

a) all outlets were not equally used (refer to Table 4.14),
b) types of land and position of outlet (e.g., highland or lowland or sloping land),
c) farmers categories (e.g., reluctance of large farmers),
d) crops grown (e.g., upland crops require less water than boro-rice),
e) on demand water supply and variable depth of water application using own fuel system,
f) varied outlet command areas and number of waterusers,
g) farmers affordability (e.g., lack of financial resources),
h) frequency and time of irrigation varied widely,
i) amount of unirrigated and fallow land under each outlet,
j) dominance of large farmers as well as the manager,
k) conflicts among the waterusers.

Table 5.5 also shows that distances between the outlet and the deep tubewell varied widely and these variations did not influence the depths of water application. A thorough discussion about the water availability in the root zone with different factors, which impede this aspect is described in chapter 6.

Biswas and Mandal (1993) argued that inefficiency in the under utilization of irrigation equipment and inequality in the distribution of irrigation water result from improper use of equipment, unequal access to credit, and imperfect product market facilities.

5.1.2.6 Rotational Irrigation Systems

According to the IMP procedure the command area is usually divided into six blocks. Six blocks are supposed to be irrigated on six days of a week. The remaining day is kept for routine maintenance and/or minor repairs (if needed) or irrigating the land which could not be irrigated on the scheduled date. But in the field, it is observed that farmers and/or KSS managements do not like to follow the block rotation rigidly rather they prefer the pipeline rotation system (i.e. rotation between pipeline branches) which seems to be quite alright from a technical point of view, in particular, for buried pipe systems. Basically, there is not much difference between block rotation and pipeline rotation in the case of buried pipeline systems. In a pipeline, some sorts of outlet rotation is important based on soils, crops, land topography and climatic conditions. Duration or interval of rotation is to be decided by the management, for example, for light soil under boro-rice a short duration is required. Here the important point is the sequence of rotation, not the duration or the interval. None of the schemes followed any sort of rotation, which resulted in greater water loss, higher irrigation cost, unequal water distribution and unsatisfaction with the supply of irrigation water. Social conflicts and mistrust might be the reasons for not following rotational systems.

5.1.2.7 Field Channels' Distributions

Average field channel lengths (FCLs) used per plot on the eight schemes are shown in Table 5.6. As can be seen from the table the average FCL of the Chulabar scheme was the highest (86 m) followed by East Kutubpur (84 m) and then the Shaplapara scheme (80 m). Highly fragmented holdings was the probable

Table 5.6 Flow Distribution Path Per Plot

Schemes	Average length (m) of		No. of observation
	Pipeline	Field channel	of field channels
Taltolapara	730	51	178
East Kutubpur	589	84	69
Shaplapara	620	80	232
Baila	916	45	42
Vailpara	585	71	36
Chulabar	620	86	33
Hazipara	658	75	18
Binnakhaira	998	61	39
Average	715	69	-

reason for these longer field channels (for example, refer to Figures 4.7). It was found that the average FCL of buried pipe schemes was 69 m which occupied the command area of about 1.5 ha by each outlet. If the command area falls to 1 ha, field channel length approaches 56 m.

The numbers of landowners of some outlets are large because of significant fragmentation (for example, at East Kutubpur, Table 4.17). Operation may be simplified by providing an additional outlet, which can help to reduce the extent and complexity of the field channel network. In order to maintain realistic field channel lengths, schemes where the irrigable command area is fragmented will require more outlets, with smaller command areas, than suggested for consolidated command areas.

Field channels were commonly originated from each outlet and distributed over the plots' boundary within the outlet command area. However, conditions of field channels were found to be very disappointing. Generally, they were undersized, uncompacted, irregular in shape and having very low banks. As a result, spillage above the bank occurred very frequently. These undersized field channels resulted in running the engine at a low speed (refer to section 4.1.2.1). About half of the channels were constructed during the irrigation period on a very temporary basis. No maintenance work was observed during this study.

5.1.2.8 Land Occupied by Channels

Information on land occupied by channels before buried pipe and after buried pipe situations for three schemes are shown in Table 5.7. Although the total area covered by channels increased after buried pipe systems, the area covered per unit of command area decreased significantly in all the schemes due to the replacement of feeder channels by buried pipes and increased in the command area. The area occupied by channels constructed before buried pipes, still existed but was unused as shown in Table 5.7. The main reason for retaining the channel unused was that farmers did not like (or could not afford) to spend money to abolish these channels. On average the unused area was 0.17%.

Land saving due to installation of buried piped systems is often quoted, but there is little information quantifying the net saving. By this study, the percentage of land saving by buried pipe systems ranges from 0.64% to 2.58% with an average of 1.40%, which is 0.56 ha out of 40 ha designed command area. Irrigation of this extra saved land would increase the command area.

5.1.2.9 Irrigation Timings

Irrigation intervals for different crops under farmers practices are shown in Tables B.1 and B.2 (Appendix B). No scientific or recommended irrigation scheduling was followed and large variations in irrigation intervals were observed. In general, irrigation intervals practised were usually larger than that recommendation for all crops. The main reason for such a large irrigation interval was the use of own fuel by the farmers to get tubewell water. As earlier mentioned farmers prefer to wait for rainfall than buy fuel with cash money and get water. Nonetheless, oil cost and operators salaries were paid by the KSS management. Due to irregular payment of the water charge, sometimes the pump was not used smoothly or timely which also resulted in varied and/or longer irrigation intervals.

Table 5.7 Land Occupied by Earthen Channels

Parameters	Schemes			
	Taltolapara	East Kutubpur	Shaplapara	Average
Gross command area(ha)				
a) Before buried pipe	17.91	17.75	35.85	23.84
b) After buried pipe	43.46	41.56	41.56	42.19
Channel length(m)				
a) Before buried pipe	2,234.66	4,807.55	4,250.39	3764.20
b) After buried pipe	4,954.78	5,244.49	4,021.80	4740.36
Channel density(m/ha)				
a) Before buried pipe	124.77	277.27	118.56	173.53
b) After buried pipe	114.01	126.19	96.77	112.32
Area under channel(m^2)				
a) Before buried pipe	3,550.59	7,195.76	6,826.48	5857.61
b) After buried pipe	6,601.06	6,864.94	5,154.35	6206.78
Area under channel per unit com.area(m^2/ha)				
a) Before buried pipe	198.25	405.39	190.42	264.69
b) After buried pipe	151.89	165.18	124.02	147.03
Saving of land by buried pipelines (%)	0.46	2.40	0.66	1.20
Unused earth channel(%)	0.19	0.18	0.16	0.17
Land saved if unused earth channel is included (%)	0.65	2.58	0.82	1.37

5.2 AGRONOMIC PRACTICES

5.2.1 Methodology

5.2.1.1 Agronomic Parameters

Planting and harvesting times of different crops, and other cultural practices such as mulching and weeding were recorded by fieldmen through a set of questionnaires by field visits and interviewing the cultivators of the sample plots with sample outlets.

5.2.1.2 Input Supplied

Input supplied to the crops on sample outlets, for example, fertilizer doses, insecticides were recorded in the fields by interviewing the farmers using a questionnaire.

5.2.1.3 Crop Yields

Before harvesting the sample crops, an appointment was made with the respective farmers to confirm the date when they were going to harvest their crops. On the specific date, field staff were engaged to stay with them until they harvested the crops. Harvested crops from the specified plot areas were separated from the other crops which could be harvested from non-sample plots and then the sample crops were brought to the threshing floor and/or home yard. After threshing and winnowing the crops, grain weight was taken by fieldmen. The weight was then converted into yield (Kg/ha). Crop-cut procedures were not followed.

5.2.2 Results and Discussion

5.2.2.1 Crops Grown and Area Under Crops

Crops grown in the three main schemes in the two irrigation seasons (dry seasons) are given in Table 5.8. It is evident from Table 5.8 that more diversified crops were grown under the buried pipe DTW schemes in this area in comparison to other DTW schemes in other areas of the country where mostly boro-rice was grown.

Table 5.8 Irrigated Area (ha) Under Different Crops

Crops	Schemes						Average (% of CA)
	Taltolapara		East Kutubpur		Shaplapara		
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	
Wheat	6.74	3.83	3.67	4.45	5.54	4.24	4.75(29)
Boro-rice	4.13	1.23	0.18	1.90	4.12	3.09	2.44(15)
Watermelon	1.96	4.25	0.91	1.97	3.72	2.63	2.57(16)
Chilli	1.37	1.27	0.86	1.72	1.05	1.30	1.26(8)
Banana	1.05	0.89	0.87	0.87	1.72	1.63	1.17(7)
Soybean	1.04	1.58	0.90	0.11	1.56	6.89	2.01(12)
Onion	0.50	0.32	0.13	-	0.40	-	0.23(1.39)
Cauliflower	0.40	0.08	0.05	-	0.03	0.10	0.11(0.66)
Sweetpotato	0.38	0.12	0.02	0.33	1.10	-	0.33(2)
Cotton	0.34	-	0.43	0.28	-	0.08	0.19(1.15)
Lentil	0.32	0.34	-	-	-	0.08	0.12(0.72)
Potato	0.27	-	0.13	0.12	0.15	0.16	0.14(0.85)
Coriander	0.12	-	0.02	0.04	0.02	0.02	0.04(0.24)
Gram	0.07	-	-	-	-	-	
Cucumber	0.06	-	-	-	-	-	
Snakegourd	0.04	-	-	-	-	-	
Turmeric	0.04	0.06	0.11	0.18	-	-	0.07(0.42)
Radish	0.04	-	-	-	-	0.14	
Brinjal	0.01	0.17	0.02	0.12	-	-	0.05(0.30)
Aroids	-	-	0.08	0.03	0.26	0.08	0.08(0.48)
Pineapple	-	-	0.09	0.19	0.24	0.29	0.14(0.85)
Datashak	-	0.34	0.05	0.32	0.21	0.09	0.17(1.03)
Mustard	-	-	0.39	0.13	0.19	0.16	0.15(0.91)
Bittergourd	-	-	0.008	-	0.07	-	
Sweetgourd	-	0.16	-	0.11	0.05	-	0.05(0.30)
Bean	-	-	-	-	0.04	-	
Garlic	-	-	0.08	-	-	-	
Sugarcane	-	0.14	0.05	-	-	0.10	0.05(0.30)
Ginger	-	-	0.03	0.20	-	-	
Cabbage	-	-	0.02	-	-	0.08	
Turnip	-	-	0.02	-	-	-	
Teaslegourd	-	0.27	-	0.22	-	0.26	0.13(0.79)
Maize	-	0.11	-	-	-	-	
Cabbage	-	-	-	-	-	0.08	
Ashgourd	-	-	-	0.55	-	0.13	
Tomato	-	-	-	0.01	-	-	
Papaya	-	0.01	-	-	-	-	
Intercropping							
Sugarcane + onion	-	-	-	-	0.10	-	
Watermelon + onion	-	-	-	-	0.06	-	
Banana + watermelon	-	-	-	-	0.03	-	
Total	18.87	15.15	9.25	13.85	20.66	21.55	16.56(100)

Note: CA stands for command area

Table 5.8 shows that most of the crops were grown on a small scale. Boro-rice, wheat, watermelon (and soybean at Shaplapara scheme only) were the major crops covering larger areas. It is also seen that the average irrigated area of the three main schemes for the two irrigation seasons was 16.56 ha of which 29% was under wheat, 15% was under boro-rice, 16% was under watermelon, 12% was under soybean, and 28% was occupied by other crops. In intercropping systems, more benefit was noticed by the farmers.

5.2.2.2 Used Fertilizer and Manure

Generally farmers applied very low doses of fertilizer for all crops at all the schemes as can be seen from the survey shown in Table B.3 (Appendix B). This table showed that farmers did not use urea fertilizer as a basal dose. Farmers seem to think that urea fertilizer is used only for top-dressing. All the farmers used TSP and MP as basal, but not in correct amounts. Few farmers used gypsum and zinc for crops as a basal dose even though gypsum and zinc deficiency was not found in the scheme areas (see Table 2.3). This indicates that farmers were not aware of the above facts.

5.2.2.3 Insect and Disease Infestation

Insect attacks were always observed in the HYV crops, but farmers used only two insecticides namely Basudin-10 and Diazinon-60. Insecticides like Dimecron, Nogos, Sumithion, Sumisidin, Roxion and Curater were found to be used outside the sample plots, but no use of these insecticides was reported by the farmers questioned.

Survey results revealed that on average Basudin-10 was applied at a rate of 3.74 kg/ha which was only 23% of the recommendation (16.08 kg/ha) and Diazinon-60 was applied at a rate of 0.6 litre/ha which was 35% of the recommendation (1.70 litre/ha). The above insecticides were used only for boro-rice and watermelon. It is evident from the above information that farmers applied insecticides at a very low dose due to the high prices of insecticides. Moreover, pure insecticides were hardly ever found in the market as noticed by the farmers, because a few local traders mixed pure insecticides with other low price chemicals in order to make it go further and sold them to the farmers at slightly less price which encouraged farmers to buy. In spite of the low quality of the insecticides the farmers applied very low doses, resulting in no improvement.

5.2.2.4 Weed Infestation

Farmers did not remove weeds from the wheat fields. From other crop fields they usually removed weeds one to three times (Rashid and Mridha, 1990). The common weeds were bathua and various small grasses. Weeding is essential to increase yield for any crop.

5.2.2.5 Different Crop Periods

Planting and harvesting dates, areas and number of plots of different crops under sample outlets in the two dry seasons are shown in Tables B.4 and B.5 (Appendix B). From these Tables it is seen that wheat was the first major crop in all the schemes. Low investment, less intercultural practices, and lower water requirements were probably the reasons that encouraged wheat cultivation. It was also observed that wheat was sown even in December. Literature on wheat (Guler, 1986) shows wheat yield reduce by 1% per day's delay of sowing starting from December 1. It was observed that planting time for each crop varied widely from scheme to scheme. Possible causes were:

a) maturity of the preceding crop,

b) shortage of draft power and financial resources (for small and marginal farmers,

c) non availability of seeds and/or other inputs,

d) reluctance of large farmers to irrigate land, and

e) lack of man power in case of large farmers.

5.2.2.6 Crop Yields

The yields of various crops at the sample outlets in the three schemes in the two dry seasons are shown in Table 5.9. Tables show that the yield for each crop was much lower than the national average. This was probably due to low application of fertilizers and insecticides, irrigation water, and outdated cultural practices; in other words, poor crop management. To promote and sustain irrigated agricultural crops, yield should be increased by addressing agronomic and wateruse related problems.

Table 5.9 Crop Yields in the Three Main Schemes

Crops	Yield (kg/ha)						National average
	Taltolapara		East Kutubpur		Shaplapara		
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	
Wheat(HYV)	970-2391 (1712)	307-2402 (920)	610-1923 (990)	576-3074 (1506)	576-1845 (1023)	494-1337 (1186)	4000-4900
Boro-rice (HYV)	2864-4658 (3407)	1823	-	3233	1556-4364 (3066)	1213-5600 (3361)	4500-7000
Watermelon (HYV)	34594-36570 (35582)	2270-21168 (8270)	8380	5381-12472 (9130)	6950-18688 (12766)	2817-18780 (9799)	60000-80000
Soybean(HYV)	812-955 (830)	173-1372 (578)	781-1125 (854)	-	612-1214 (913)	288-1902 (875)	1500-1800
Potato (HYV)	16560	-	8300-8414 (8357)	-	13835-16767 (15301)	-	3500-4000
Sweetpotato (LV)	1449-5854 (3280)	5320	-	2786-5560 (4173)	9319-10686 (9888)	-	15000-35000
Mustard (LV)	-	-	95-639 (289)	288-995 (642)	833	53-220 (113)	1200-1500
Onion (LV)	455-1249 (720)	-	-	-	1383-2450 (1917)	-	10000-15000
Banana (HYV)	-	-	30424-83286 (56688)	-	36457-86913 (59593)	-	75000-85000
Cauliflower (HYV)	15127	1680-2225 (2068)	-	-	-	4715-8374 (6545)	25000-35000
Chilli (LV)	3386-5207 (4375)	432-913 (673)	2995-6182 (4647)	-	-	7493-8523 (8008)	10000-14000
Cabbage (HYV)	-	-	-	-	-	7276	30000-40000

Note: Figure in parentheses indicate average value

CHAPTER 6
WATER AVAILABILITY IN THE ROOT ZONE

This chapter is particularly concerned with hypotheses 1 and 2.

6.1 WATER AVAILABILITY (UPLAND CROPS)

6.1.1 Introduction

Water in the root zone plays an important role in the production of crops. The topic of water availability in the root zone has been emphasised because of getting the maximum benefit from the crops. Literature on water availability in the root zone in general and on its function in agriculture, in particular, is expanding day by day (BARI, 1988). However, there are several factors involved in the context of applying irrigation water in the field, for example, soil, climatic parameters and crops. Generally, increasing soil moisture encourages the vegetative as well as reproductive growth of plants resulting in higher rate of photosynthesis and greater metabolism functions from various plant organs to develop grains. At the same time over irrigation wastes large amounts of water, leaches out soil nutrients which cause reducing soil fertility and lowering crop yields.

A number of water balance approaches have been used to determine water availability and irrigation scheduling. However, few approaches take into account crop development from sowing to harvesting through plant and soil evaporation modifications (Tuzet et al, 1992). Teixeira and Pereira (1992) used the ISAREG model for defining an optimal irrigation scheduling based on the soil moisture balance method proposed by Doorenbos & Pruitt (1977) and Doorenbos & Kassam (1979). There are several irrigation scheduling models that are supported by similar soil moisture balances, for example, Raes et al (1988) and Smith (1991b). The inputs of these models are the meteorological data which allows daily or decade (10 days) or monthly computation of ET_0, effective rainfall and other crop and soil data. The above authors have either conducted experiments and examined crops in the field with control care, for instance, different treatments, replications and variable cultural practices or compiled data from available literature. However, this study is different in that all the data in relation to crop management were recorded from farmers' fields from what they were practising. A total of 35 plots for wheat crops, 13 plots for soybean and 22 plots for watermelon from 9 sample outlets in the three main schemes were randomly selected for this study.

Doorenbos and Pruitt (1977) recommended four different methods, which are the Blaney-Criddle method, the Penman method, the Radiation method and the Pan evaporation method for predicting the crop water requirements of crops maximum evapotranspiration (ETm). Of these methods, the Penman method gave ETm values close to maximum crop water requirements followed by the Radiation method (Rami Reddy et al, 1983). However, FAO (Smith, 1991a) recommended the Penman-Monteith approach as the best combination method available to compute the reference crop ET. This method was also confirmed in a seminar of the 15th Congress on Irrigation and Drainage (ICID), in The Hague, the Netherlands, September 1993. Hence this method was used in CROPWAT to compute ET_0.

In this case study, the water balance is monitored through a determinist model of farmer-managed irrigation schemes where all climatic factors are taken into account according to Doorenbos & Pruitt (1977) and Doorenbos & Kassam (1979). The water balance is analysed on a daily basis for upland crops.

6.1.2 Methodology

Measurements of sample outlet discharges, field discharge and plot areas have been described in the sections 4.4.1.3, 4.4.1.4 and 4.4.1.5, respectively. Other parameters are described below:

6.1.2.1 Field Application Depth

Depth of water application (d) was calculated considering field discharge, time of irrigation and field application efficiency of 70%, which was assumed by following Doorenbos and Pruitt (1977). Depth of water application has been calculated as follows:

$$d = \{(Q_F \times t \times E_a)/A\} \times 60 \quad \ldots\ldots \; \ldots\ldots \; \ldots\ldots \quad (6.1)$$

Where, d = depth of water application, (mm); Q_F = field discharge, (l/s); t = time of irrigation, (minute); E_a = 0.70, field application efficiency and A = plot area, (m^2).

6.1.2.2 Effective Rainfall for Upland Crops

Effective rainfall means useful or utilisable rainfall which is the most important factor in agriculture for crop production (Dastane, 1974). Hence, precise knowledge of this phenomenon of effective rainfall is essential for quantifying the correct amount of irrigation which is necessary for satisfying crops evapotranspiration demand. However, rainfall amount, frequency and intensity are the three main characteristics of rainfall and these characteristics vary widely from place to place, day to day, month to month and even year to year.

To calculate effective rainfall from the total rainfall, it is essential first to know correctly the amount of total rainfall occurring in the scheme areas during the crop growing time. In connection with this, a standard rain gauge was installed in an open field surrounded by wire net fencing at 1 metre radius with top side open. Care was also taken to place the gauge in order to avoid splashing of striking rainfall on the ground surface which could disturb the rain gauge. In addition, the gauge was free from all sorts of obstruction within 100 metre radius. The rain gauge was within sight of the office and no interference occurred during the project period and the author carried out readings immediately after rainfall stopped. Therefore, collecting the total amount of rainfall was assumed to be 100% accurate. In most cases, frequency of rainfall was once per day and the highest amount of rainfall was 26 mm on 23rd April '91 during the dry season and intensity of rainfall was about average for the region.

For upland crops such as wheat, watermelon and soybean, effective rainfall was considered to be the whole amount of rainfall only excluding amounts less than 5 mm per day (Table 6.1). Effective rainfall for dry times was calculated on a daily basis by using the following formulae during the crop growing period (planting to harvesting):

$$Er = 0 \qquad \text{for } Tr = < 5 \text{ mm}$$
$$Er = Tr \qquad \text{for } 5 \text{ mm} < Tr < 30 \text{ mm}$$
$$Er = Tr \times 0.60 \qquad \text{for } 30 \text{ mm} < Tr < 60 \text{ mm}$$
$$Er = Tr \times 0.50 \qquad \text{for } 60 \text{ mm} < Tr < 80 \text{ mm}$$
$$Er = Tr \times 0.40 \qquad \text{for } 80 \text{ mm} < Tr < 90 \text{ mm}$$
$$Er = Tr \times 0.30 \qquad \text{for } 90 \text{ mm} < Tr < 100 \text{ mm}$$
$$Er = Tr \times 0.20 \qquad \text{for } Tr = > 100 \text{ mm}$$

Where, Er = effective rainfall, (mm/day) and Tr = total rainfall, (mm/day). Rainfall excess over 125 mm in one day and 150 mm in successive 3 days are to be omitted.

Table 6.1 Example of Effective Rainfall Calculation (Bangladesh Method)

Date	Outlet flow (l/s)	Channel loss (l/s)	Net flow (l/s)	Irrig. time (mins)	Rainfall per day (mm)	Er (mm)	Depth of water (mm)
08/12/90	27.63	3.69	23.94	30			63
18/12/90					3	0	0
02/01/91					11	11	11
03/01/91					7	7	7
07/01/91	27.12	4.56	22.56	11			22
25/01/91	26.78	5.12	21.66	25			47
04/02/91					5	5	5
21/02/91	26.31	5.97	20.34	18	2	0	32
25/02/91	26.31	5.97	20.34	36			64
27/02/91					12	12	12
01/03/91					10	10	10
05/03/91					2	0	0
12/03/91					2	0	0
24/03/91					7	7	7
29/03/91					14	14	14
Total effective rainfall (Er)						66	
Total depth of water = (Irrigation + Er) =							294

Note: R = rainfall, (mm); Crop = wheat; Planting time = 20 December; Harvesting time = 30 March; Cropped area = 688 m^2; and Er = effective rainfall, (mm) = 66 mm

This method is widely used for upland crops in Bangladesh and recommended by experienced researchers (Rashid, personal communication, 1991). Calculations made for this study show that the amount of effective rainfall calculated by this method is exactly the same value (Table 6.2) obtained by using the USDA Soil Conservation Service Method (Smith, 1991b) which is internationally accepted where effective rainfall can be calculated seasonally according to:

$P_{eff} = P_{tot}(125 - 0.2P_{tot})/125$ for $P_{tot} < 250$ mm and

$P_{eff} = 125 - 0.1P_{tot}$ for $P_{tot} > 250$ mm

Where, P = rainfall, (mm); eff = effective and tot = total

Table 6.2 Example of Effective Rainfall Calculation (USDA Method Followed by Smith, 1991b)

Date	Outlet flow (l/s)	Channel loss (l/s)	Net flow (l/s)	Irrig. time (mins)	Rainfall per day (mm)	$P_{eff.}$ (mm)	Depth of irrigation (mm)
08/12/90	27.63	3.69	23.94	30			63
18/12/90					3		
02/01/91					11		
03/01/91					7		
07/01/91	27.12	4.56	22.56	11			22
25/01/91	26.78	5.12	21.66	25			47
04/02/91					5		
21/02/91	26.31	5.97	20.34	18	2		32
25/02/91	26.31	5.97	20.34	36			64
27/02/91					12		
01/03/91					10		
05/03/91					2		
12/03/91					2		
24/03/91					7		
29/03/91					14		
Total rainfall (R)					75		
Total effective rainfall (Peff)						66*	
Total depth of irrigation (d)							228
Total depth water = (d + Peff) =							294

Note:* $P_{eff} = P_{tot}(125 - 0.2P_{tot})/125$ (for $P_{tot} < 250$ mm)
$= 75(125 - 0.2x75)/125 = 66$ mm

6.1.2.3 Used Climatological Data

The study area is surrounded by Mymensingh (to the east) and Sirajganj (to the west, refer to Figure 2.1). All climatological data (on average 36 years) for the reference crop evapotranspiration (ET_0) measurement, such as maximum and minimum temperature, humidity, wind velocity and sunshine hours were taken from Mymensingh meteorological station (Table 6.3) except rainfall, which was directly measured in the scheme sites as described in the preceding section 6.1.2.2. The Penman-Monteith Method was used for calculating the ET_0 by CROPWAT (Smith, 1991b). At the same time, climatic data (averaging 73 years) from Sirajganj (Table 6.4) were also used for ET_0 and compared to that obtained from Mymensingh. Difference in ET_0 per year between Mymensingh and Sirajganj was about 1% (Tables 6.3 and 6.4) using the CROPWAT on the computer, but Sirajganj is situated in another climatic zone according to the FAO/UNDP (1988) report. Therefore, meteorological data taken from Mymensingh was logical for representing the study area.

Table 6.3 Reference Crop Evapotranspiration (ET_0) by CROPWAT for Mymensingh Region

Country : BANGLADESH Meteo Station: MYMENSINGH (36 yr)
Altitude: 19 m Coordinates : 24.43 NL 90.26 EL

Month	Max Temp °C	Min Temp °C	Humid %	Wind Km/day	Sunshine hours	Solar radia MJ/m²/day	ET_0-Penman mm/day
January	25.2	11.6	76	35	8.7	15.9	2.3
February	27.6	13.8	72	52	9.0	18.5	3.0
March	32.0	18.2	69	69	9.7	22.2	4.2
April	33.8	22.0	72	86	9.6	23.7	5.1
May	32.4	23.5	82	95	8.3	22.5	4.9
June	31.2	24.9	87	86	5.4	18.2	4.0
July	31.3	25.7	86	86	4.7	17.0	3.8
August	31.3	25.6	86	69	4.4	16.0	3.6
September	31.5	25.4	85	60	5.2	16.1	3.5
October	30.7	23.8	82	52	7.9	17.8	3.6
November	28.7	18.2	81	35	8.9	16.7	2.9
December	26.4	13.6	80	35	9.0	15.6	2.3
Year	30.2	20.5	80	63	7.6	18.4	1315

Source: Smith, 1991b

Table 6.4 Reference Crop Evapotranspiration (ET_0) by CROPWAT for Sirajganj Region

Country : BANGLADESH Meteo Station: SIRAJGANJ (73 yr)
Altitude: 15 m Coordinates : 24.47 NL 89.42 EL

Month	Max Temp °C	Min Temp °C	Humid %	Wind Km/day	Sunshine hours	Solar radia MJ/m²/day	ET_0-Penman mm/day
January	25.1	11.7	79	52	8.4	15.7	2.4
February	28.2	13.4	72	60	8.7	18.2	3.0
March	32.6	17.9	65	86	9.4	21.7	4.3
April	35.3	22.1	69	130	9.2	23.2	5.4
May	33.6	24.3	79	147	7.9	21.9	5.1
June	31.6	25.3	88	130	5.0	17.6	4.0
July	30.9	26.0	93	130	4.3	16.4	3.6
August	31.1	26.4	86	181	4.0	15.5	3.6
September	31.3	25.9	86	95	4.9	15.7	3.5
October	30.9	23.4	83	78	7.5	17.4	3.6
November	28.5	17.8	82	69	8.6	16.4	3.0
December	26.3	13.6	79	35	8.7	15.3	2.3
Year	30.4	20.2	80	99	7.2	17.9	1333

Source: Smith, 1991b

6.1.2.4 Groundwater Contributions

Contribution from groundwater is determined by its depth below the root zone of crops, the capillary properties of the soil and the soil moisture content in the root zone (Doorenbos and Pruitt, 1977). In this study, depths to groundwater table were recorded fortnightly in the three scheme areas during the study period. Results from the recorded data show that depths to groundwater table varied from 4.50 m to 10.30 m (refer to section 4.1.2.5) throughout the year and these depths to groundwater table indicated that there was no contribution of ground water to the crop ET demand. Therefore, groundwater contribution has been assumed to be zero in this calculation.

6.1.2.5 Decade Calculations

The procedure outlined by Smith (1991b) was followed:

- The calculation of crop water requirement has been carried out per decade and for reasons of simplicity all months are taken to have 30 days, subdivided into 3 decades of 10 days.

- Each decade is normally taken to be 10, except in the first and last decade when planting date and harvest date do not necessarily coincide with the beginning or end of the decade, so all calculations have been carried out considering the fraction days (such as 1,2,....9 out of 10 days) at the beginning decade and at the end decade of crop growing period. At the same time, to compensate for deviations the maximum and minimum months, a reiteration has been carried out to fulfil the condition that the 3 decade values average the given monthly average.

6.1.2.6 Different Growth Stages

To begin with, the different growth stages of upland crops for the growing season such as planting until harvest were calculated on the basis of the total number of effective days required according to Smith (1991b) following the principle of Doorenbos and Pruitt (1977), who describe the length of growing season for different crops in their publications, but most of the stages were of longer duration. In this calculation, the length of different growing stages has been reduced proportionately based on the effective crop days. The length of growing season for the upland crops has been reported by Doorenbos and Pruitt (1977). These are:

a) Initial stage: germination and early growth when the soil surface is not or is hardly covered by the crop with groundcover (GC) less than 10%.

b) Development stage: from end of initial stage to attainment of effective full groundcover (GC in between 70% and 80%).

c) Mid-season stage: from attainment of effective full GC to time of start of maturity as indicated by discolouring of leaves (beans) or leaves falling off (cotton).

d) Late season stage: from end of mid-season stage until full maturity or harvest. Late season is usually from 25 to 35 days.

Smith (1991b) reported that the length of the growing stages depend on variety and growth conditions, in particular.

6.1.2.7 Crop Factor

The crop factor, Kc is determined for each decade. Values for initial stage, development stage, mid-season stage and at harvest were taken from FAO report, irrigation and drainage paper No.33, where values were given considering relative humidity and wind velocity. The average daily crop evapotranspiration (ETc) was determined according to Smith, (1991b) followed by Doorenbos and Pruitt (1977):

$$ETc = Kc.ET_0 \quad \ldots\ldots \; \ldots\ldots \; \ldots\ldots \quad \ldots\ldots \quad (6.2)$$

Where, ETc = crop evapotranspiration, (mm/day); Kc = crop coefficient and ET_0 = reference crop evapotranspiration, (mm/day).

Wickham and Sen (1978) also suggested the same formula be used for measuring the daily average crop evapotranspiration. Crop evapotranspiration per decade has been calculated by multiplication of the number of effective crop days.

6.1.2.8 Rooting Depth

Ploughing depths were measured in the field and depths were in between 50 mm and 85 mm with an average of 65 mm. Seeds were always broadcast over the field and then a harrow was used to make the surface level. Sowing depths were measured randomly in the field and these were found to be in the range of 0 mm to 40 mm and on average 18 mm. Sowing depths were quite low in comparison to other areas, because farmers in the scheme areas used their traditional plough having a small share.

In this calculation, initial rooting depth was assumed to be 0.00 m and increased 0.03 m per day for the first 10 days and then again increased 0.035 m per day until the following 20 days of some crops (e.g., wheat and soybean). This calculation was carried out on the basis that the depth of root system varies from crop to crop and from time to time up to a certain stage during growth (Dastane, 1974). This indicates that the root development is dynamic at the initial stage and then constant. For the first 10 days after sowing, rooting depth can be calculated as:

$$D = 0.03 \times N \qquad (6.3)$$

Where, D = daily rooting depth, (m) and N = number of days varies from 0 to 10. For the next 20 days, equation of daily rooting depth is as follows:

$$D = (0.03 \times 10) + (0.035 \times N) \qquad (6.4)$$

Where, notations are the same as equation 6.3, only N varies from 1 to 20. (N=1, indicates on 11th day and when N=20, indicates on 30th day).

Smith (1991b) calculated crop water requirements considering the initial rooting depth of wheat crop was 0.3 m and for the rest of the period had the same rooting depth which was 1 m.

6.1.2.9 Total Available Soil Moisture Content

Total available soil moisture content (Sm) may be defined as the difference between the soil water content at field capacity and the soil moisture content at wilting. It represents the amount of water available to the crop and depends on texture, structure and organic matter content of the soil, expressed in mm/metre. In this Sm calculation, the value was assumed to be 160 mm/m, because silty clay loam soil has a value in between loamy and clayey soils.

6.1.2.10 Initial Soil Moisture Depletion

Initial soil moisture depletion indicates how much soil moisture deficits at the beginning of a growing season. A fully wetted soil profile indicates 0% depletion (at field capacity) and 100% depletion represents the soil is at wilting point. In this calculation, soil moisture depletion at the beginning of the growing season has been assumed to be zero, that is it is assumed that the soil is at field capacity level.

6.1.2.11 Allowable Depletion Level

Doorenbos and Kassam (1979) report the proportion of the total available soil moisture (Sm) that can be depleted without affecting ETa to become less than ETm is defined by the fraction (p) of the Sm. The values of p depend on crop characteristics, maximum evapotranspiration (ETm) rate and soil characteristics. The p values vary from crop to crop. Therefore, crops can be grouped according to fraction (p) to which Sm can be depleted while maintaining ETa equal to ETm (Figure D.1 in Appendix D).

In general, soil water can be more easily transmitted to and taken up by the plant roots in light textured than in heavy textured soils but somewhat higher values of p would seem to apply to light textured soils than to heavy textured soils. Hence, consideration of soil texture would add little to accuracy (Doorenbos and Kassam, 1979). For this study, allowable depletion level, i.e. fraction (p) available in the soil has been calculated on the basis of the crop evapotranspiration and is shown in Figure D.1 (Appendix D).

6.1.2.12 Yield Response Factor

Doorenbos and Kassam (1979) explained that the response of yield to water supply is quantified by the yield response factor (Ky) which relates relative yield decrease (1-Ya/Ym) to relative evapotranspiration deficit (1-ETa/ETm). Water deficit of a given magnitude, expressed in the ratio of actual evapotranspiration (ETa) and maximum evapotranspiration (ETm), may either occur continuously over the total growing stages of the crop or during any one of the individual growth periods. The yield response factor, Ky, is required to assess the effect of water stress on yield so has been added to the CROPWAT (Smith, 1991b) for crop water requirement calculation.

Crop factor (Ky) has been used for estimating yield reductions due to drought stress and included for each growth stage (Doorenbos and Kassam, 1979). Therefore, Ky is one of the most important factors which is taken into account for this crop water requirement calculation.

6.1.2.13 Planting Date

The date of planting is a separate crop data input which has a significant role in the water balance calculation because variation of planting date influences crop evapotranspiration rate which depends largely on climatic conditions (e.g., rainfall).

6.1.2.14 Water Balance Calculation

For water balance calculation, the procedure outlined by Doorenbos and Pruitt (1977) was followed:

- A curve of seasonal irrigation demand was drawn by the cumulative soil moisture status without irrigation over the root depth on each day. This was calculated as follows: (note that all the measurements are in mm/day):

$$Dsm = Bsm + Gw + Er - ETc \quad \text{...... ....} \quad (6.6)$$

Where, Dsm = daily stored soil moisture over the root depth; Bsm = beginning soil moisture (note that Dsm at the end of each day was equal to Bsm at the beginning of the next day); Gw = groundwater contribution; Er = effective rainfall and ETc = crop evapotranspiration.

- A detailed discussion about Bsm has been presented in the preceding section 6.1.2.10.

- Groundwater contribution has been assumed to be zero in the water balance calculation (see section 6.1.2.4)

- Calculation of effective rainfall has been discussed in section 6.1.2.2.

- Three different sowing dates from three different schemes for each upland crop were considered for ETc (refer to section 6.1.2.7), which were used for calculating the soil moisture fraction (see section 6.1.2.11). Available soil moisture (Sm) was assumed to be 160 mm/m depth of silty clay loam soil and rooting depths (D) were calculated according to discussion in section 6.1.2.8. The product of p, Sm and D was used for calculating average allowable soil moisture depletion.

- Net irrigation depth (d) was added to equation 6.6 (Equation 6.7) to give the soil moisture status on each day according to farmers' practices. This was plotted together with the line of average allowable depletion (p.Sm.D) to give a visual representation of water availability to the crop during the season, including the depth of irrigation applied as well as intervals of irrigation on the graph. The equation is as follows, note that all notations have the same meanings as equation 6.6 except d, which indicates depth of water application (section 6.1.2.1):

$$Dsm = Bsm + Gw + Er - ETc + d \quad \text{...... ......} \quad (6.7)$$

Graphs for all sample fields are shown in Figures C.1 to C.70 in Appendix C. The Spreadsheet (Quattro Pro) and Statgraphics software packages were used for overall analysis and drawing of figures.

6.1.3 Results and Discussion (Wheat)

6.1.3.1 Amount of Under-irrigation Vs. Yield

As has been stated earlier the actual amount of irrigation water applied was calculated by estimating the field discharge, irrigation time, field application efficiency and irrigated area (section 6.1.2.1). The amount of under-irrigation was calculated by the following formula:

$$Ui = (ETc - Er - Gw) - Td \times Ef \quad \ldots\ldots\ \ldots\ldots\ \ldots \quad (6.8)$$

Where, Ui = total amount of under-irrigation, (mm); ETc = total crop evapotranspiration, (mm); Er = total effective rainfall, (mm); Gw = groundwater contribution, (mm); Td = total depth of irrigation, (mm) and Ef = field application efficiency = 0.70.

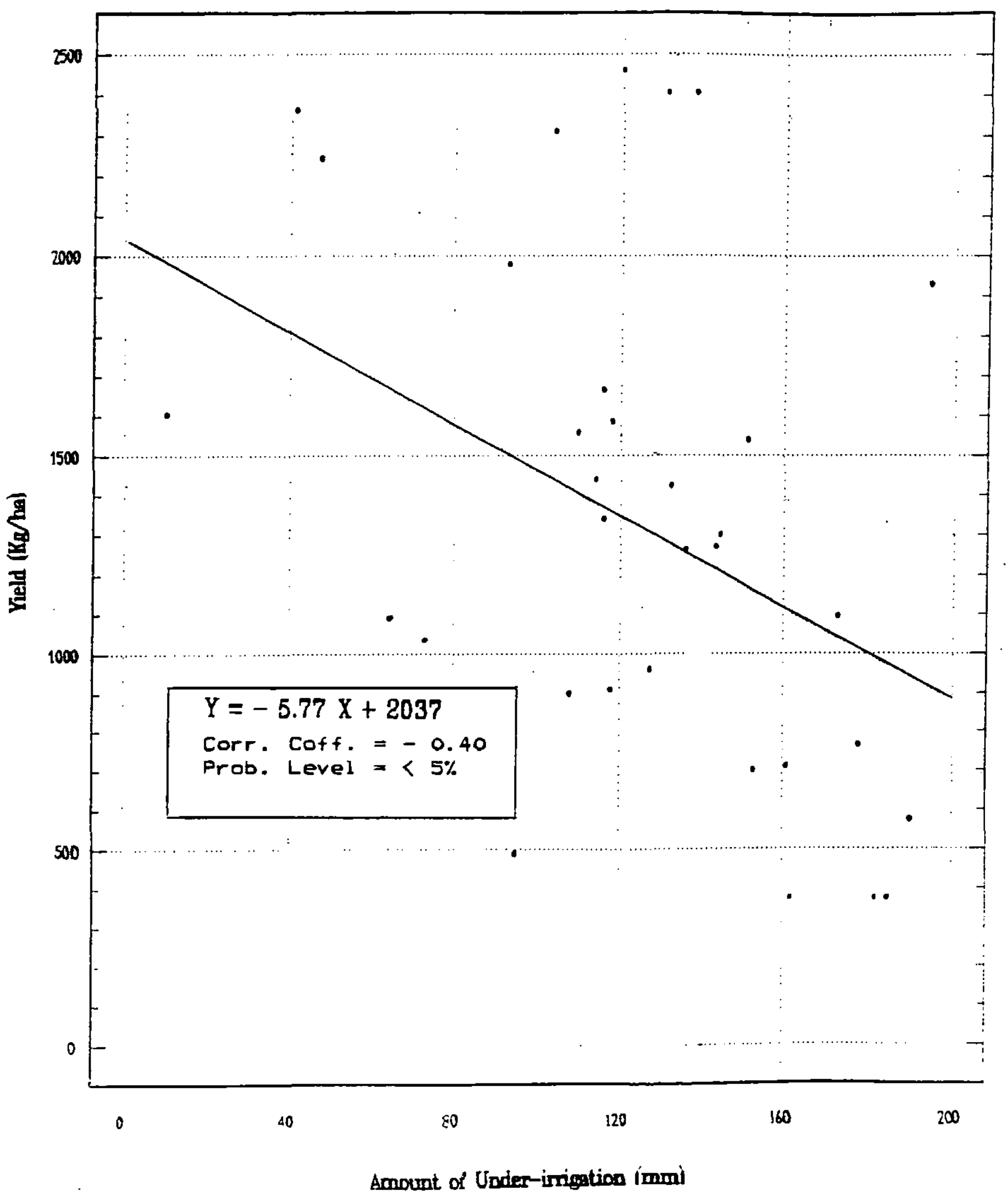
The amount of under-irrigation varied from 10 mm to 194 mm and with an average of 123 mm (Table 6.5). The study shows that in all the cases wheat was underirrigated which indicates either unawareness by the farmers or they were not motivated to agriculture because of getting low return from crops. A few farmers were found reluctant to apply adequate irrigation for fear of buying excess fuel. Farmers' fuel systems and high fuel prices were the main reasons for under-irrigation. Other reasons for under-irrigation might be the "first come first served", waiting for rainfall and lack of farmers' resources.

Regression analysis between the amount of under-irrigation and the yield showed that they were significant at 5% probability level. Figure 6.1 shows the maximum yield when the amount of under-irrigation is minimum. Under-irrigation causes crop stress and induces reduction in yield according to evapotranspiration demand. The equation from the analysis can be written as:

$$Y = -\,5.77\,X + 2037 \quad \ldots\ldots\ \ldots\ldots\ \ldots\ldots \quad (6.9)$$

Where, Y = yield of wheat, (Kg/ha) and X = amount of under-irrigation, (mm).

Figure 6.1
Regression of Yield on Under-irrigation (Wheat)



Equation 6.9 shows that each 3.60 mm of under-irrigation causes reduction in yield of 1%. However, the cost of 1 mm of irrigation water was estimated Tk 30.76 and the value of 1% yield was estimated Tk 139.00.

6.1.3.2 Distances from Plot to Outlet Vs. Yield

Table 6.5 showed that distances from plot to outlet varied widely from 2 m to 102 m, with an average distance of 45 m. At the same time, a wide range of yield variations (376 Kg/ha to 2459 Kg/ha) were found at the sample plots and their average value was 1327 Kg/ha, which was only 30% of the national average (refer to Table 5.9). The reasons for these variations of yield were due to the different management practised by the farmers, because lots of management factors (e.g., fertilizer, insecticides) were also involved in the buried pipe schemes.

Correlation and regression analysis is made between the distance from plot to outlet and the yield. This analysis shows that all the data have shown poor correlations. Many other social and managerial factors existed in the farmer-managed irrigation schemes, for example, own fuel system, conflicts among farmers and other relatives resulted in different intercultural operation, which might have caused reduction in yield (refer to chapters 5 and 7). Sometimes lack of financial resources led to different management, for instance, numbers of irrigation with time or intervals (refer to Appendix B in Tables B.1 and B.2) varied widely from plot to plot. In other words, whatever the distance, different management aspects including irrigation were mainly responsible for getting different yields. Therefore, distance is not a factor of yield in the buried pipe scheme, although flow rate to each outlet within the pipeline was the same as described earlier.

6.1.3.3 Distances from Plot to DTW Via Outlet Vs. Yield

Distances from plot to DTW via outlet were measured and found in the range of 160 m to 610 m and their average value was 353 m, which is about 8 times higher than the average distance from plot to outlet (Table 6.5). Despite covering a high distance by a DTW, results were found to be insignificant. Therefore, in the buried pipe irrigation schemes under farmers' practices, distance is not a factor that affects yield.

The correlation study shows that distances from plot to water source DTW via outlet have shown no relationship with yield. This indicates that there is no linkage between distance and yield. The insignificant results indicated no interaction on distance from plot to water sources from both the outlet and the DTW with respect to yield.

Table 6.5 Irrigation Requirements for Wheat

Sowing date	Outlet no. (Plot)	Distance from outlet(m)	Distance from DTW(m)	Crop days	Irrig. Reqt. (mm)	Irrig. Applied (mm)	Under Irrig. (mm)	Yield (Kg/ha)
Taltolapara								
01 Dec	3-3(20)*	40	261	108	241	123	118	1583
01 Dec	3-3(23)	45	266	108	241	148	93	1978
01 Dec	3-3(24)	52	273	108	241	98	143	1266
01 Dec	3-3(25)	43	264	108	241	125	116	1662
01 Dec	3-3(22)	57	278	108	241	109	132	1425
13 Dec	3-3(16)	15	236	99	228	67	161	711
13 Dec	3-3(18)	33	254	99	228	101	127	960
13 Dec	3-3(17)	21	242	99	228	218	10	1602
15 Dec	1-5(22)	04	512	107	248	138	110	1556
15 Dec	1-5(36)	02	510	107	248	207	41	2365
15 Dec	1-5(35)	12	520	107	248	201	47	2241
16 Dec	1-5(16)	87	595	103	247	116	131	2402
16 Dec	1-5(15)	97	605	103	247	109	138	2402
16 Dec	1-5(18)	36	544	103	247	69	178	769
18 Dec	1-5(14)	76	584	104	241	166	75	1301
18 Dec	1-5(12)	74	582	104	241	88	153	702
20 Dec	1-5(19)	82	590	101	234	116	118	910
20 Dec	1-5(30)	102	610	91	210	48	162	376
20 Dec	1-5(24)	90	598	91	210	25	185	376
20 Dec	1-5(29)	96	604	91	210	28	182	376
East Kutubpur								
13 Dec	1-6(01)	45	367	108	249	55	194	1927
07 Dec	1-6(11)	78	400	108	243	92	151	1537
10 Dec	2-2(02)	10	165	101	224	124	100	737
11 Nov	2-2(15)	44	199	120	261	71	190	576
19 Dec	2-2(25)	17	172	94	214	70	144	1297
07 Dec	2-2(05)	26	181	105	241	127	114	1438
07 Dec	2-2(01)	05	160	104	237	64	173	1095
07 Dec	2-2(04)	22	177	105	241	105	136	1258
11 Nov	3-2(11)	45	212	115	240	167	73	1032
11 Dec	3-2(27)	81	248	101	233	129	104	2306
14 Nov	3-2(02)	33	200	112	231	123	108	899
14 Dec	3-2(03)	20	187	98	227	107	120	2459
Shaplapara								
11 Dec	1-3(09)	20	192	95	208	92	116	1337
13 Dec	1-3(08)	12	184	100	233	169	64	1087
20 Dec	2-10(4)	42	394	95	221	126	95	494
Average		45	353	103	235	112	123	1327

Note: * = First digit indicates line number and second digit indicates outlet number (refer to Figures 2.4, 2.5 and 2.6) and figure in parentheses indicate plot number (see Figures 4.6 to 4.14)

The results from the study show that there was no significant difference between top landers and tail landers on the buried pipe system (for example, refer to Table 5.5), and position in the scheme did not influence yield. This is in marked contrast to open channel distribution systems, as has been described in section 4.1.2.9.

6.1.3.4 Irrigation Loss

Irrigation loss has been calculated from the water balance Figures C.1 to C.35 (Appendix C) and data extracted from the Appendix are shown in Table 6.6. An excess amount of irrigation at a time causes irrigation loss, which might be in the form of seepage, leakage and spillage excluding the normal infiltration rate and evaporation. If farmers applied more irrigation water at a time, it caused a drainage problem too, which also caused irrigation loss. Irrigation loss can be shown by an equation (note that all measurements are in mm):

$$IL = Td - (Dp + Ro + Lk) \quad ...... \quad ...... \quad ...... \quad (6.10)$$

Where, IL = irrigation loss, Dp = deep percolation, Ro = runoff and Lk = leakage.

Farmers irrigated wheat crops without knowing the amount of irrigation that could apply to bring the soil moisture into a field capacity level. As discussed earlier farmers always bought fuel from small traders using a plastic container of specified size to carry fuel, that was used once to run the engine (refer to section 4.1.2.1). The traditional fuel buying systems made farmers irrigate crops either more or less. Moreover, farmers followed a "rule of thumb" principle, which was that excess water makes an excess yield. As a result, irrigation loss occurred for most of the irrigation time. From study of the water balance, it was seen that irrigation loss occurred in 57% of cases and an average of 23% irrigation water applied was recorded as irrigation loss (Table 6.6).

It is commonly believed that excess irrigation application incurs extra charges and similarly inadequate irrigation results in low yield and incurs economic losses too. Lack of awareness and uncontrolled application of water might be the reasons for irrigation losses. In other words, improper timing with quantity of irrigation results in irrigation losses, which usually occur either by surface runoff or by deep percolation.

Table 6.6 Soil Moisture Status for Wheat

Figure no.	ETc (mm)	Irrig. no.	Irrig. applied (mm)	Irrig. loss (mm)	Actual applied (mm)	Excess depletion* (mm)	Depleted days	Yield (Kg/ha)
Taltolapara								
C.1	286	2	123	73	50	72	33	1583
C.2	286	2	148	87	61	62	30	1978
C.3	286	2	98	36	62	60	30	1266
C.4	286	2	125	73	52	70	33	1662
C.5	286	2	109	35	74	49	25	1425
C.6	273	2	67	0	67	52	33	711
C.7	273	2	101	0	101	30	22	960
C.8	273	2	218	51	167	15	9	1602
C.9	314	2	138	27	111	35	17	1556
C.10	314	2	207	90	117	14	7	2365
C.11	314	2	201	85	116	14	7	2241
C.12	299	2	116	32	84	48	22	2402
C.13	299	2	109	31	78	53	24	2402
C.14	299	1	69	0	69	64	41	769
C.15	307	3	166	61	105	21	12	1301
C.16	307	3	88	21	67	56	26	702
C.17	300	4	116	0	116	5	5	910
C.18	255	1	48	25	23	76	29	376
C.19	255	1	25	6	19	79	30	376
C.20	255	1	28	6	22	76	29	376
East Kutubpur								
C.21	315	2	55	0	55	76	36	1927
C.22	295	3	92	4	88	41	28	1537
C.23	276	3	124	0	124	0	0	737
C.24	306	2	71	0	71	98	63	576
C.25	266	2	70	0	70	34	19	1297
C.26	286	3	127	0	127	32	18	1438
C.27	282	2	64	0	64	60	35	1095
C.28	286	3	105	0	105	36	31	1258
C.29	285	3	167	0	167	13	6	1032
C.30	278	3	129	4	125	0	0	2306
C.31	276	3	123	0	123	27	19	899
C.32	272	3	107	0	107	8	11	2459
Shaplapara								
C.33	253	2	92	4	88	7	7	1337
C.34	278	3	169	0	169	3	1	1087
C.35	273	2	126	68	58	50	23	494
Average	286	2	112	23	89	41	22	1327

Note: * = Excess depletion refers to the depletion below maximum allowable depletion level (refer to Figures C.1 to C.35 in Appendix C)

6.1.3.5 Excess Depletion Vs. Yield

Soil moisture depleted below the average allowable depletion level (the product of soil moisture fraction, p; soil moisture between the field capacity and the wilting point, Sm; and the rooting depth, D) is called an excess depletion. Findings emerging out of this specific analysis confirm some of assumptions that appear as general discussion on the availability of soil moisture in the root zone. Table 6.6 shows that maximum yield could be possible by keeping zero excess depletion. In fact, there is no way to know the actual level at which an excess depletion starts, but there is a way to estimate this level from the soil moisture status in the soil reservoir.

The data have shown poor correlations between the excess depletion and the yield. The main reason for this poor correlation was that the yield of crops varied widely by other management factors (e.g., fertilizer, intercultural operation etc.), not only the excess depletion. Avoiding excess depletion could help to make yields more stable in the irrigated agriculture.

6.1.3.6 Number of Depleted Days Vs. Yield

Days below the average allowable depletion level are called the depleted days which also reduce the yield. Depleting days and depleting amount are interrelated. Therefore, the depleting day should be pinpointed for avoiding throughout the crop season in order to get the maximum yield.

The correlation study showed an insignificant result between the excess depleted days and the yield. The reason for this poor relationship has been discussed in the preceding section 6.1.3.5.

6.1.4 Results and Discussion (Soybean)

6.1.4.1 Amount of Under-irrigation Vs. Yield

The calculation of under-irrigation has been described in the section 6.1.3.1. This statement is quite surprising, because of showing insignificant results. In this study, under-irrigation for each crop always has shown good correlations but soybean crop is the exception. Reasons for this insignificant result were:

a) soybean was a completely new crop and introduced after installation of buried pipe systems,

b) farmers were still in a trial and error stage to accommodate this crop into a stable cropping pattern, and

c) calculating under-irrigation was taken from the CROPWAT where Kc values were used from available literature, not from the exact field situation.

Therefore, farmers had little knowledge about this crop, resulting in surprise results. Table 6.7 shows that in 50% of cases soybean crops were under irrigated.

6.1.4.2 Distances from Plot to Outlet Vs. Yield

Table 6.7 shows distances between plot and outlet were distributed unevenly all over the scheme. It was observed in the field that farmers gave more emphasis to this crop to cultivate even from a far distance using irrigation water, because this crop was newly introduced in the scheme areas.

Table 6.7 Irrigation Requirements for Soybean

Sowing date	Outlet No. (Plot)	Distan. from outlet(m)	Distan. from DTW(m)	Crop days	Irrig. Reqt. (mm)	Irrig. Applied (mm)	Under Irrig. (mm)	Yield (Kg/ha)
Taltolapara								
03 Jan	1-4(02)	58	388	101	209	149	60	850
03 Jan	1-4(22)	45	375	101	209	225	0	1200
08 Jan	1-5(04)	74	581	95	199	195	4	1372
08 Jan	1-5(03)	55	562	95	199	199	0	1285
08 Jan	1-5(40)	68	575	95	199	123	76	990
Shaplapara								
01 Feb	1-3(17)	15	187	85	192	111	81	734
02 Jan	1-3(13)	20	192	112	235	160	75	607
30 Dec	2-5(07)	18	308	105	216	151	65	692
26 Dec	2-10(15)	91	443	111	229	202	27	1902
26 Dec	2-10(14)	107	459	114	238	39	199	922
01 Jan	2-10(11)	240	592	110	232	36	196	807
01 Jan	2-10(12)	252	604	111	232	90	142	576
01 Jan	2-10(16)	67	419	110	232	197	35	1844
Average		85	437	103	217	144	74	1060

From the correlation study between the distance from plot to outlet and yield, it is seen that all data show insignificance. This appears to indicate no linkage between them.

6.1.4.3 Distances from Plot to DTW Via Outlet Vs. Yield

Distances from plot to either outlet or DTW have the same effect on yield in case of buried pipe systems. Moreover, position of the DTW and the outlet have no influence on yield. This is one advantage of a buried pipe system and all the farmers benefited equally from this system.

A correlation analysis was made between distances from plot to DTW via outlet and yield. Average distance between plot and DTW was 5 times greater than the distance from plot to outlet (Table 6.7), though results were insignificant. Results indicate that distance in the buried pipe scheme has no influence on yield.

6.1.4.4 Excess Depletion Vs. Yield

Soil moisture depletion can be allowed to a depth of an average allowable depletion level and below this level shows an excess depletion (refer to Figures C.36 to C.48 in Appendix C), which has a negative impact on the yield. The data are shown in Table 6.8. From the correlation study, it was observed that the data showed poor correlations. The reasons for this aspect have been described in the preceding section 6.1.4.3.

Some new crops were introduced by the TADP Agricultural Extension Unit in the areas. Farmers were trying to grow new crops and soybean was one of them. However, a few farmers thought that TADP provided seeds and other facilities so that they could take care of it. Available facilities given by the TADP encouraged farmers to undertake soybean cultivation.

6.1.4.5 Number of Depleted Days Vs. Yield

There was no relationship between the depleted days and the yield from the correlation analysis (Table 6.8). Most important consideration was the time when the depleting started and when it terminated. It is seen that depleting days just before harvesting time had less effect on the yield than depleting at other times within the crop growing period.

As mentioned earlier TADP supplied soybean seeds and fertilizer to the farmers so that farmers accepted it as a cash crop. Rashid and Mridha (1992) reported that soybean was a new crop in the scheme areas and had no marketing opportunities.

6.1.4.6 Irrigation Loss

Table 6.8 reveals that the amount of irrigation varies significantly from plot to plot. The own fuel system is responsible for this. Nevertheless, improper irrigation intervals (refer to Appendix B in Tables B.1 and B.2) and quantity were the prime causes for irrigation loss which could be minimized as long as they knew what was taking place below the soil surface even though it was hypothetical.

Table 6.8 Soil Moisture Status for Soybean

Figure no.	ETc (mm)	Irrig. no.	Irrig. applied (mm)	Irrig. loss (mm)	Actual applied (mm)	Excess depletion (mm)	Depleted days	Yield (Kg/ha)
Taltolapara								
C.36	298	3	149	3	146	0	0	850
C.37	298	3	225	80	145	0	0	1200
C.38	284	5	195	46	149	0	0	1372
C.39	284	4	199	72	127	0	0	1285
C.40	284	1	123	117	6	76	30	990
Shaplapara								
C.41	292	2	111	55	56	27	13	734
C.42	347	3	160	61	99	18	10	607
C.43	308	2	151	49	102	0	0	692
C.44	326	3	202	146	56	56	23	1902
C.45	340	1	39	36	3	122	43	922
C.46	333	1	36	12	24	104	37	807
C.47	336	7	90	23	67	15	7	76
C.48	333	2	197	62	135	0	0	1844
Average	313	3	144	59	86	32	13	1060

Note: Figures C.36 to C.48 are shown in Appendix C

6.1.5 Results and Discussion (Watermelon)

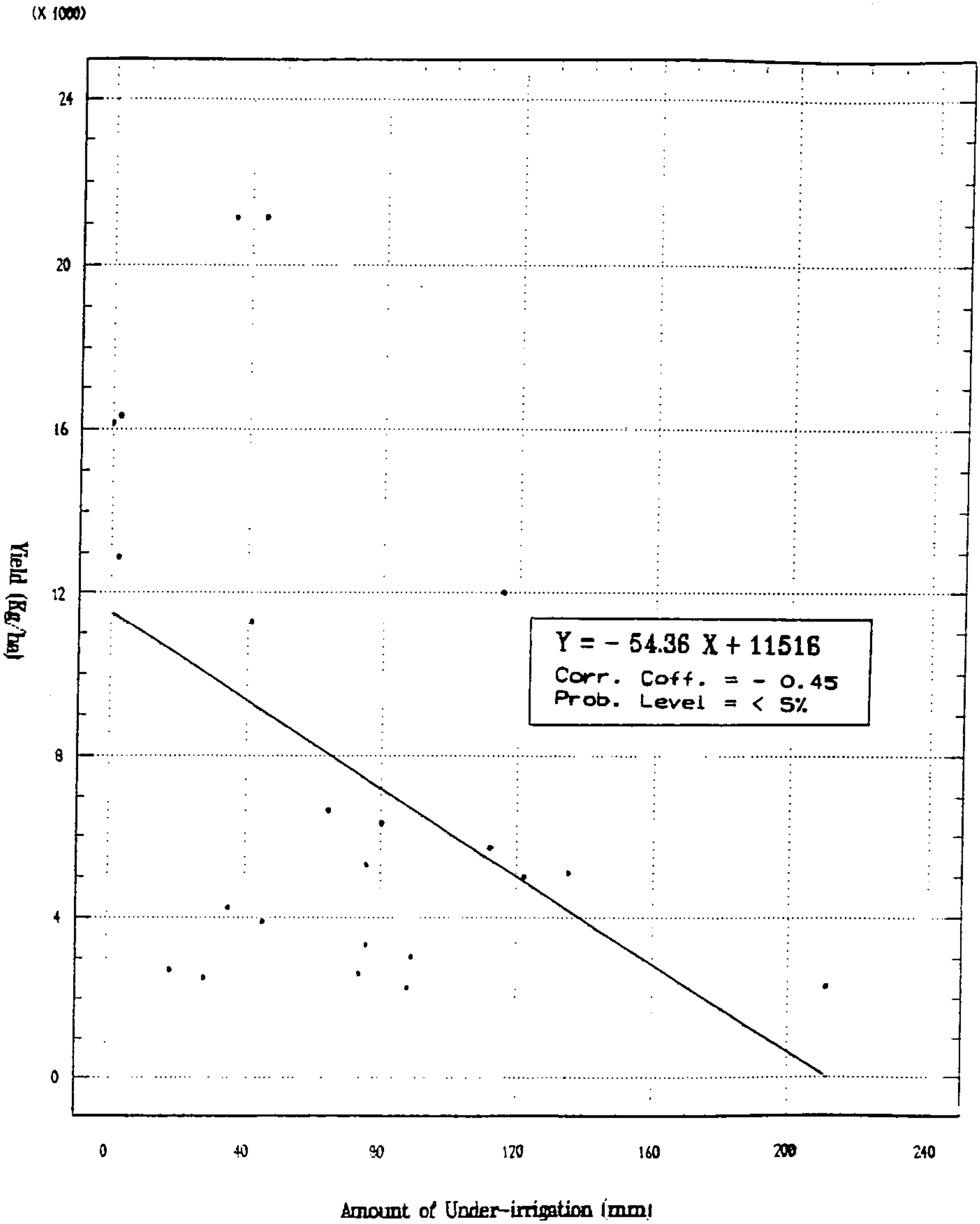
6.1.5.1 Amount of Under-irrigation Vs. Yield

The amount of under-irrigation has been described in the section 6.1.3.1. Figure 6.2 shows that yield increases with the decrease in the amount of under-irrigation. This statement is significant at 5% probability level. Each 2.13 mm of under-irrigation causes a reduction in yield of 1%. Nevertheless, the cost of 1 mm of irrigation water was estimated Tk 21.40 and the value of 1% yield of watermelon was equivalent to Tk 118.00. The equation can be stated as follows:

$$Y = - 54.36 X + 11516 \quad \ldots\ldots \ \ldots\ldots \ \ldots\ldots \quad (6.11)$$

Where, Y = yield of watermelon, (Kg/ha) and X = underirrigation,(mm).

Figure 6.2
Regression of Yield on Under-irrigation (Watermelon)



6.1.5.2 Distances from Plot to Outlet Vs. Yield

The correlation study (Figure 6.3) shows that the yield of watermelon increases by 3.69% in the plots which are far away by every 1 m from the outlet. The value of 3.69% yield was estimated and equivalent to Tk 435.00. It seemed to be absurd, but it took place practically in the field. Reasons attributed against the statement were:

a) Watermelon among other crops in the scheme areas was found more profitable and farmers usually got maximum benefit from this crop, so farmers gave more emphasis to cultivating this crop.

b) Plots which were very close to the water source sometimes observed water-logging problems (always damp and/or wet) resulting in reduction of the yield. Therefore, plots located at far distance gave the highest yield (Table 6.9).

c) More fertilizer and insecticides (refer to section 5.2.2.3) were used for this crop and a special additive (oilcake) was used only for this crop (refer to Table B.3 in Appendix B).

d) Unlike other crops farmers can sell this crop from their field.

This argument is significant at 5% probability level. Equation of this analysis is:

$$Y = 118\, X + 3084 \quad \ldots\ldots \ldots\ldots \ldots\ldots \ldots\ldots \quad (6.12)$$

Where, Y = yield of watermelon, (Kg/ha) and X = distance between the plot to be irrigated and the source of water, outlet, (m).

6.1.5.3 Distances from Plot to DTW Via Outlet Vs. Yield

This statement is quite similar to the preceding section 6.1.5.2 (Figure 6.4). Farmers used furrow irrigation for this crop. It was observed from the field situation that farmers gave more emphasis to this crop in comparison to other crops. Because farmers expected maximum return from this crop in the dry season. It was a high value crop in the area and it had good marketing opportunities. As described in the preceding section farmers used more fertilizer and insecticides than on boro-rice. The equation can be written as:

$$Y = 19.44\, X + 522.50 \quad \ldots\ldots \ldots\ldots \ldots\ldots \quad (6.13)$$

Figure 6.3

Regression of Yield on Distance (Plot to Outlet), Watermelon

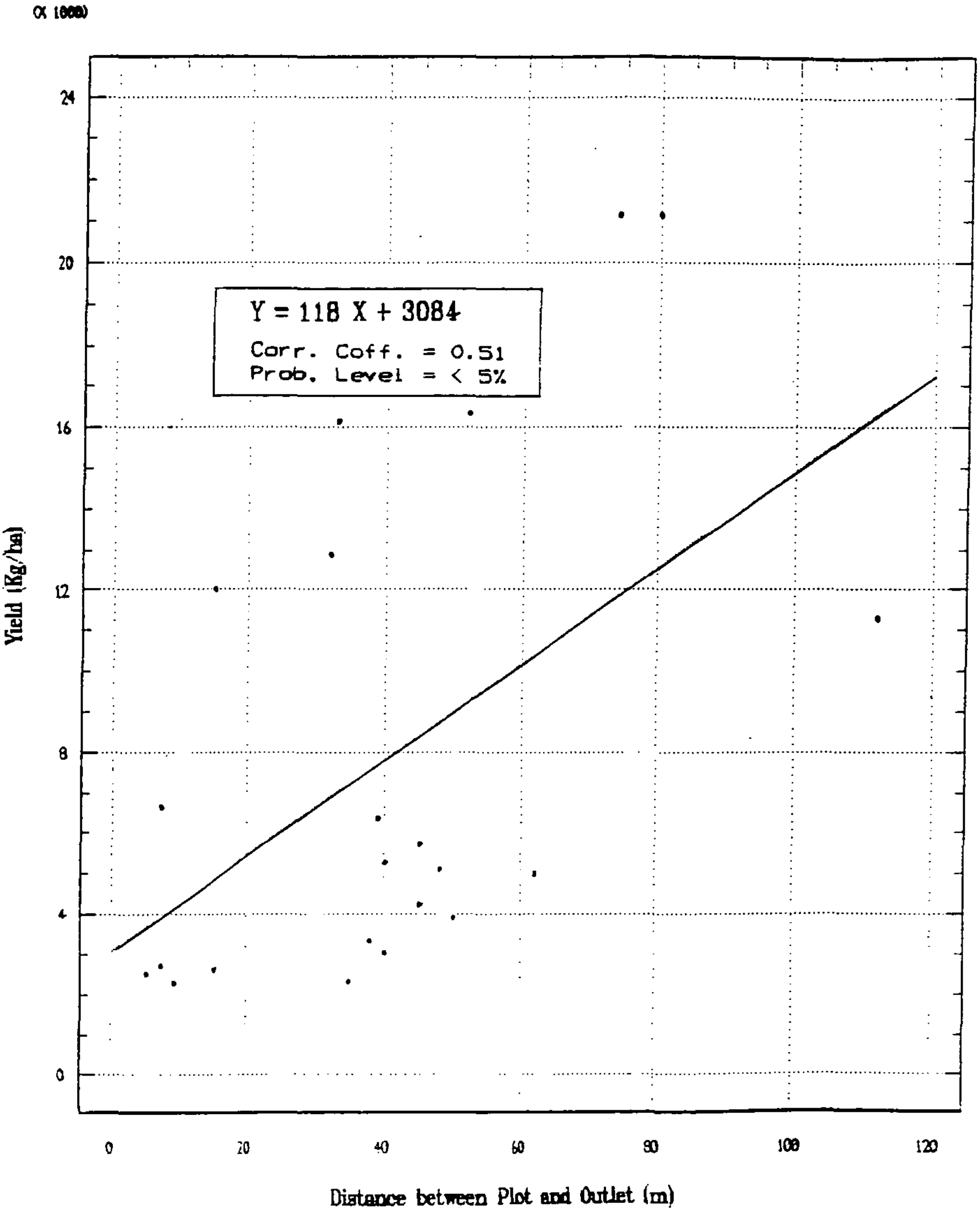
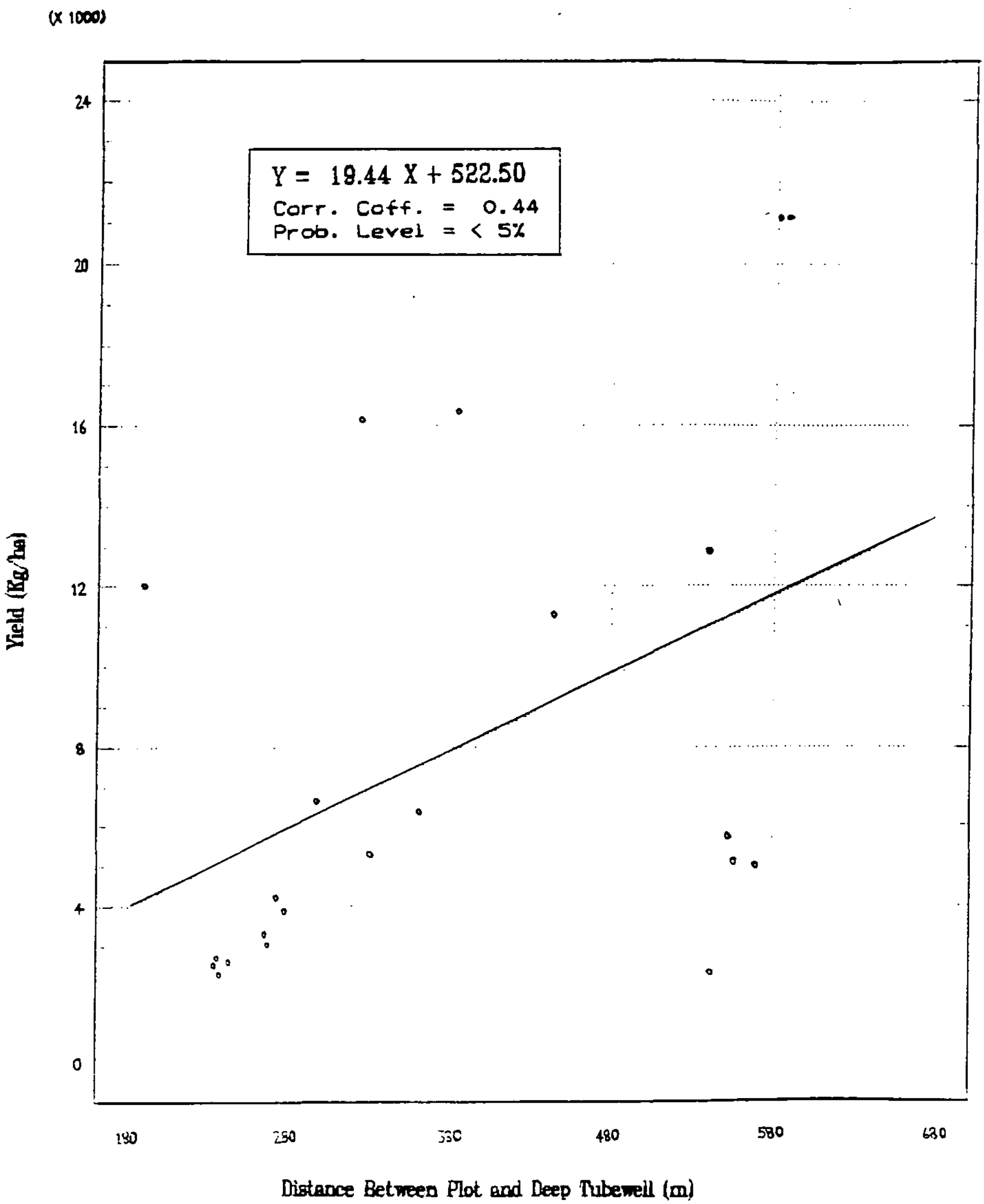


Figure 6.4
Regression of Yield on Distance (Plot to DTW), Watermelon



Where, Y = yield of watermelon, (Kg/ha) and X = distance between the plot to be irrigated and the source of water, DTW, (m).

From equation 6.13, it is seen that yield of watermelon increases by 3.59% in the plots which deviate by every 1 m from the DTW via outlet. The value of 3.59% yield was estimated Tk 424.00. However, since watermelon is a profitable crop, farmers gave more emphasis to cultivating this crop. It was also observed that farmers used more frequent irrigation for this crop (Table 6.10).

Table 6.9 Irrigation Requirements for Watermelon

Trans-planted date	Outlet no. (Plot)	Distan. from outlet(m)	Distan. from DTW(m)	Crop days	Irrig. Reqt. (mm)	Irrig. Applied (mm)	Under Irrig. (mm)	Yield (Kg/ha)
Taltolapara								
30 Dec	1-4(17)	112	442	120	243	202	41	11318
30 Dec	1-4(01)	52	382	119	241	239	2	16333
09 Jan	1-5(02)	35	542	102	239	28	211	2323
09 Jan	1-5(38)	48	555	102	239	104	135	5088
13 Jan	1-5(20)	32	539	91	200	198	2	12895
13 Jan	1-5(21)	45	552	91	200	88	112	5731
13 Jan	1-5(23)	62	569	91	200	78	122	5015
17 Jan	1-5(41)	74	581	99	210	175	35	21168
17 Jan	1-5(05)	80	587	99	210	166	44	21168
11 Jan	3-3(09)	15	242	100	235	161	74	2595
29 Jan	3-3(02)	07	234	83	202	184	18	2724
29 Jan	3-3(03)	05	232	83	202	174	28	2520
29 Jan	3-3(04)	09	236	83	202	114	88	2270
09 Jan	3-3(05)	45	272	100	230	195	35	4226
09 Jan	3-3(06)	38	265	100	230	154	76	3352
09 Jan	3-3(07)	40	267	100	230	141	89	3060
09 Jan	3-3(08)	50	277	100	230	185	45	3934
East Kutubpur								
27 Dec	1-6(03)	39	360	110	226	146	80	6384
Shaplapara								
09 Jan	1-3(02)	15	187	110	235	120	115	12038
10 Jan	2-5(10)	07	297	102	243	179	64	6668
05 Jan	2-5(01)	40	330	101	224	148	76	5295
08 Jan	2-5(11)	33	323	97	214	355	0	16144
Average		40	376	99	222	161	68	7830

Table 6.10 Soil Moisture Status for Watermelon

Figure No.	ETc (mm)	Irrig. no.	Irrig. applied (mm)	Irrig. loss (mm)	Actual applied (mm)	Excess depletion (mm)	Depleted days	Yield (Kg/ha)
Taltolapara								
C.49	375	6	202	39	163	0	0	11318
C.50	370	6	239	57	182	0	0	16333
C.51	316	1	28	0	28	53	23	2323
C.52	316	2	104	9	95	0	0	5088
C.53	276	3	198	72	126	0	0	12895
C.54	276	4	88	23	65	0	0	5731
C.55	276	3	78	6	72	0	0	5015
C.56	321	7	175	15	160	0	0	21168
C.57	321	7	166	44	122	0	0	21168
C.58	312	4	161	61	100	0	0	2595
C.59	279	3	184	87	97	0	0	2724
C.60	279	3	174	81	93	0	0	2520
C.61	279	3	114	21	93	0	0	2270
C.62	307	3	195	44	151	0	0	4226
C.63	307	3	154	4	150	0	0	3352
C.64	307	3	141	0	141	0	0	3060
C.65	307	3	185	37	148	0	0	3934
East Kutubpur								
C.66	322	2	146	59	87	0	0	6384
Shaplapara								
C.67	352	4	120	25	95	0	0	12038
C.68	320	5	179	0	179	0	0	6668
C.69	301	4	148	0	148	0	0	5295
C.70	291	3	355	176	179	0	0	16144
Average	310	4	161	39	122	2	1	7830

Note: Figures C.49 to C.70 are shown in Appendix C

6.1.6 Graphical Methods for Analysing Soil Moisture Balance

All the water balance graphs for upland crops are shown in Figures C.1 to C.70 (Appendix C). These figures represent a soil water balance model to define the total available soil water in the soil profile throughout the growing season. In the Figures, the average allowable depletion level (section 6.1.2.14) represents the maximum allowable depletion area. If the depletion depth exists within the area, there will be no effect on the yield of crop, but if the depletion depth exceeds this limit, the crop yields will be reduced. The soil moisture depletion curve resulting from the environmental conditions (e.g., crop evapotranspiration, effective rainfall and groundwater contribution) indicate the trend of soil moisture depletion within the growing period whereas an irrigation curve represents the timing of irrigation as well as irrigation interval and depth of application. This irrigation curve is very important for representing the use of minimum irrigation water. Most of the Figures show that 2 to 3 irrigations is enough to keep the soil moisture available within the allowable depletion area throughout the growing season. Therefore, much water can be saved following the trend of the soil moisture curve. Hence, from the discussion above, hypothesis 2 is accepted, that is "graphical methods based on FAO procedures are useful for representing and extending data on the timing and application depths of field irrigation".

6.2 WATERUSE BY BORO-RICE

6.2.1 Introduction

Rainfall distribution in Bangladesh is uneven throughout the year, because, occurring rainfall is limited to a few months, for example, highest rainfall occurs in June to August (Figure 2.3). Rainfall characteristics and intensity of drought have tremendous effect on the production of rice. In the dry season, the evapotranspiration demands of boro-rice can be satisfied only by irrigation.

In Bangladesh, only about 29% of the cultivable land area has been brought under irrigation facilities and 78% of the irrigated area is used to grow rice only (BBS, 1990).

The optimum yield of boro-rice depends on several factors. Shortage of water is one factor, which should be planned in time with quantity, considering the water availability in the root zone, to meet the crop water needs for optimum growth. ILRI (1983) argues that a more stable or regular water supply and good water management are pre-requisites for all these various methods of increasing rice production.

6.2.2 Methodology

Collected data from farmer-managed irrigation schemes were tested thoroughly and then analysed for the regression and correlation tests, which were carried out between different variables with respect to yield. The variables were: distances between plots and water sources both from outlet and from deep tubewell, amount of under-irrigation, number of days and depleting depths below saturation levels. Methodologies for this calculation have been described in the preceding section 6.1.2. A few additional methodologies are described below:

6.2.2.1 Effective Rainfall for Boro-rice

Effective rainfall calculation for boro-rice is different from those for upland crops in that boro-rice only thrives under conditions of abundant water supply and land is always kept submerged. Rainfall less than 5 mm on any day and similarly any amount over 60 mm per day during the crop period were considered as ineffective. A fixed percentage (60%) of the rest of total rainfall including land preparation was assumed to be effective. The following formulae were used on a daily basis during the crop period (nursery to harvesting):

$Er = 0$ for $Tr = < 5$ mm

$Er = Tr \times 0.60$ for $Tr = < 60$ mm

$Er = 0$ for $Tr = > 60$ mm

Where, Er = effective rainfall, (mm/day) and Tr = total rainfall, (mm/day). Kung (1971) reported for India that a percentage of total seasonal rainfall varying from 50% to 80% is assumed to be effective.

6.2.2.2 Crop Water Requirements Calculation

The procedure outlined by Smith (1991b) was followed:

- The Penman-Monteith Method was used for calculating the ET_0 using CROPWAT (Smith, 1991b).

- The methods outlined by Doorenbos and Pruitt (1977) and Doorenbos and Kassam (1979) were used for different growth stages and crop coefficients.

- Percolation loss (P) from boro field was calculated using two double ring infiltrometers which were placed in three experimental boro-fields. One of them was kept open to measure the evaporation as well as percolation. The other one was covered on top by a polythene sheet to restrict any evaporation, but only percolation was allowed. Readings were recorded by a fieldman in the morning on a daily basis.

6.2.2.3 Water Balance Calculation

The procedure outlined by Smith (1991b) was followed:

- Groundwater (Gw) contribution has been assumed to be zero in the water balance calculation (section 6.1.2.4).

- A cumulative crop water requirement curve from transplanting to harvest was drawn by the following formula (note that all measurements are in mm/day):

$$Dsm = Bsm + Gw + Er - ETc - P \quad \ldots\ldots\ \ldots. \quad (6.14)$$

Where, Dsm = stored soil moisture after a day (available soil water over the root depth at the end of a day); Bsm = beginning soil moisture at transplanting time, note that Dsm at the end of each day was equal to Bsm at the beginning of the next day; Gw = groundwater contribution; Er = effective rainfall; ETc = crop evapotranspiration and P = seepage and percolation loss. Note that this calculation was done based on transplanting to harvesting.

- An irrigation curve (equation 6.15) was drawn by adding the amount of irrigation water to equation 6.14 (considering field application efficiency of 70%, which was assumed). This can be written as follows (note that the legend explanations are the same as equation 6.14, except d, which indicates irrigation):

$$Dsm = Bsm + Gw + Er - ETc - P + d \quad \ldots\ldots \quad (6.15)$$

The Spreadsheet (Quattro Pro) software package was used for analysing the data as well as plotting the water balance figures. Finally statgraphics was used for the correlation and regression analysis and also plotting the figures.

6.2.3 Results and Discussion

6.2.3.1 Amount of Under-irrigation Vs. Yield

The actual amount of irrigation water applied has been described in section 6.1.2.1. Then calculating the amount of under-irrigation has been discussed in section 6.1.3.1. The amount of under-irrigation varied from 75 mm to 435 mm, with an average of 117 mm (Table 6.11). The main reason for this under-irrigation was mainly the "own fuel system".

Poor correlation was found from the correlation analysis. Main reasons for poor correlations were that farmers used less irrigation water plus improper irrigation intervals (refer to Tables B.1 and B.2 in Appendix B). Moreover, the study shows that in all the cases boro-rice was under-irrigated which indicates that the amount of irrigation was not sufficient for the cultivation of boro-rice. Again the own fuel system of pump operation and the first come first serve principle were the main reasons for under-irrigation.

At irrigation time it sometimes seemed to be over irrigation but practically within an hour no water was found in the field. This meant that the boro field always had a moisture deficit even immediately after irrigation. Insufficient soil moisture to crop field was the main reason for such a phenomenon of the irrigation water.

6.2.3.2 Distance from Plot to Outlet Vs. Yield

It was observed that the number of irrigations was less in the plot nearer to the water source than the plot far away in the case of boro-rice. Boro-rice requires standing water, farmers thought that the engine/pump might cause trouble at any time, hence they gave more emphasis to the plots far away from the water source, resulting in a high yield in the far-distant plots (Table 6.11).

The correlation study shows that data between the distance and the yield have shown poor correlations, which indicate that the distances between plots and outlets have no influence on the yield of boro-rice.

Table 6.11 also shows that distances from plot to outlet varied from 5 m to 226 m and with an average distance of 82 m. A wide range of yield (1359 to 5600 Kg/ha) variations were found at the sample plots and their average value was 3143 Kg/ha. The reasons for these variations were due to the different management practices by the farmers. Improper fertilizer doses and insecticides were examples of improper management (refer to sections 5.2.2.2 and 5.2.2.3).

6.2.3.3 Distance from Plot to DTW Via Outlet Vs. Yield

This analysis has an almost similar trend to the distance from plot to outlet versus yield. From the correlation study, it was observed that distances from plot to DTW via outlet showed insignificant result with yield. Therefore, this relationship indicated no linkage between distance and yield,

Table 6.11 Irrigation Requirements for Boro-rice

Trans-Planted date	Outlet no. (Plot)	Distance from (m) Outlet	DTW	Nursery Period days	Total Crop days	Perc. Rate (mm/d)	Deep perc. (mm)	Land Prep. (mm)	Irrig. Reqt. (mm)	Irrig. applied (mm)	Under irrig. (mm)	Yield (Kg/ha)
Taltolapara												
17 Mar	3-3(01)	05	233	35	102	5.7	376	341	856	725	131	1823
10 Mar	3-3(11)	15	243	39	113	5.7	418	243	828	698	130	1823
08 Mar	0-0(11)*	54	54	30	105	5.7	422	305	900	747	153	3213
East Kutubpur												
21 Feb	0-0(07)	150	150	30	120	6.0	522	293	1049	804	245	3233
Shaplapara												
10 Feb	2-5(17)	65	355	36	125	6.4	556	250	1086	1011	75	3788
18 Feb	2-5(06)	32	322	32	115	6.4	516	269	1040	895	145	2921
08 Feb	2-10(10)	226	579	29	117	6.4	544	305	1149	976	173	4467
10 Feb	2-10(05)	82	435	41	125	6.4	526	300	1127	692	435	2697
18 Feb	2-10(08)	90	443	30	113	6.4	516	249	1022	753	269	1359
20 Feb	2-10(09)	105	458	35	113	6.4	491	267	1019	933	86	5600
25 Feb	2-10(07)	78	431	45	125	6.4	512	298	1054	944	110	3651
Average		82	337	35	116	6.2	491	284	1012	834	177	3143

* = "0-0" indicates the command area under the pump (like the command area under each outlet)

even though the distance between plot and main water source DTW via outlet was 4 times more than the distance from plot to outlet. This was due to the use of a buried pipe system at which distance was not a function of yield.

As described earlier if an open earthen channel is used instead of a buried pipe system, the flow of water from the DTW dramatically reduces at a rate of 7.69 l/s/100 m of channel length (refer to Table 4.7). As a result, depth of water application is necessarily low in the long-distant plots, leading to induced reduction in yield. In the case of a buried pipe, however, the loss is only 0.69 l/s/100 m, which is 11 times lower than the open channel system. Therefore, whatever the distance from water sources either from any outlets or a DTW, irrigation water distribution patterns through buried pipe systems are uniform all over the scheme areas.

The result from the study shows that there was no significant difference between land holders on the buried pipe irrigation system, and position in the scheme did not influence yield.

6.2.3.4 Number of Days Below Saturation Level Vs. Yield

A saturation level is an imaginary level from which there is considerable scope to drain out excess water from the soil and then it reaches a field capacity level. The number of days below saturation level varied from 4 to 53, with an average of 31 days (Table 6.12). This was due to the large irrigation intervals (refer to Tables B.1 and B.2 in Appendix B) and less amount of irrigation water applied. In this analysis, the days below saturation were not continued at a time throughout the growing period. Water balance figures for boro-rice are shown in Appendix C (Figures C.71 to C.81).

6.2.3.5 Depletion Depth Vs. Yield

Depletion depths below the saturation level varied from 5 mm to 281 mm, with an average of 92 mm. A great influence for depletion depths has been found in this analysis. This was mainly due to the variation of irrigation intervals. A large depletion depth was found while the irrigation interval was high.

Table 6.12 Soil Moisture Status for Boro-rice

Figure no.	Trans-Plant. date	Total Crop days	Irrig. reqt. (mm)	Irrig. applied (mm)	Below Satur. (days)	Deple. depth (mm)	Yield (Kg/ha)
Taltolapara							
C.71	17 Mar	102	856	725	5	5	1823
C.72	10 Mar	113	828	698	4	20	1823
C.73	08 Mar	105	900	747	35	76	3143
East Kutubpur							
C.74	21 Feb	120	1049	804	53	171	3233
Shaplapara							
C.75	10 Feb	125	1086	1011	11	22	3788
C.76	18 Feb	115	1040	895	52	79	2921
C.77	08 Feb	117	1149	976	48	97	4467
C.78	10 Feb	125	1127	692	49	281	2697
C.79	18 Feb	113	1022	753	39	182	1359
C.80	20 Feb	113	1019	933	9	8	5600
C.81	25 Feb	125	1054	944	31	73	3651
Average		116	1012	834	31	92	3143

Note: Figures C.71 to C.81 are shown in Appendix C

The amount of depletion has a negative impact on the yield of boro-rice. From study of the water balance, it is seen that low depletions give more yield of boro-rice. The correlation study shows the insignificant result, because the depleting amount was distributed all over the growing season.

6.2.4 Depths of Water Application Vs. Distances from DTW to Outlet

Altogether 81 measurements were tested for this study from the three main schemes. It was found that the relationships between depth of water application and distance from the deep tubewell to different outlets for all the crops were shown to be insignificant (see Figures D.2 to D.5 in Appendix D). This results from buried pipe irrigation schemes where depths of water application have no influence on the position of the schemes. Hence, hypothesis 1 is true, that is "with a buried pipe distribution system the quantity of water delivered to a field is independent of the position of the outlet which serves that outlet".

CHAPTER 7
SOCIO-ECONOMICS AND INSTITUTIONAL ASPECTS

This chapter is particularly concerned with objective 4 and hypothesis 3.

7.1 SOCIO-ECONOMICS

7.1.1 Methodology

7.1.1.1 Water Charge

Water charge payments for the three main schemes were collected weekly from the scheme registers and the data were checked through interviewing KSS and non-KSS farmers. The same was also obtained from the Bangladesh Rural Development Board (BRDB) office.

7.1.1.2 Loan Repayment

Loan repayment on eight deep tubewells as well as buried pipe systems were collected from the BRDB office.

7.1.1.3 Management System

Management systems were studied through observations, field visits, and interviewing the farmers and concerned personnel.

7.1.1.4 Irrigation Cost

Irrigation cost was recorded weekly throughout the season by interviewing the KSS or non-KSS farmers. The gathered data were checked with the registers.

7.1.1.5 Economic Performance of Some Crops

There are various methods to calculate profit from a crop. In this study, the fixed cost such as rent, taxes and interest on value of land have not been added in the cost, only the variable costs are taken in this calculation. The cost of human labour, animal power, seeds, manure, fertilizer, pesticides, irrigation cost and interest on operating capital have been taken in the calculation of cost and yield of main product and by-product have been added in the calculation of gross return. A sample example for the calculation of economic performance of potato is shown in Table 7.1.

Table 7.1 **Calculation for Economic Analysis of Potato**

Observations	Quantity	Family	Hired	Unit price(Tk)	Value (Tk/ha)
Human labour(days/ha)	325	260	65	45.00	14,625.00
Animal power(days/ha)	51	51	-	35.00	1,785.00
Seed rate(kg/ha)	1846			10.00	18,460.00
Manure(kg/ha)					
Oilcake	125			4.50	563.00
Fertilizer(kg/ha)					
a) Urea	115			5.00	575.00
b) TSP	80			5.00	400.00
c) MP	55			4.25	234.00
d) Gypsum	52.5			2.30	121.00
Insecticide(Tk/ha)					1,090.00
Irrigation cost(Tk/ha)					3,724.00
Interest on operating capital (Tk/ha)(at 16%)					2,247.00
Total variable cost(Tk/ha)					
Full cost basis					43,824.00
Cash cost basis					30,339.00
Yield					
a) Product(kg/ha)	16,560			8.57	-
b) By product				-	
Gross return(Tk/ha)					1,41,919.00
Gross margin(Tk/ha)					
a) Full cost basis					98,095.00
b) Cash cost basis					1,11,580.00
Benefit cost ratio					
a) Full cost basis					3.24
b) Cash cost basis					4.68

a) Total Variable Cost

Both the cash invested and the inputs supplied have been considered. Full cost refers to the total variable costs which include the cash spent on purchasing inputs as well as the family inputs. Cash cost refers to the cash spent excluding the family inputs.

b) Return

The values of the main product and by product during the harvested time have been considered as gross return.

c) **Benefit Cost Ratio (BCR)**

Benefit Cost Ratio (BCR) has been calculated on a full cost and cash cost basis by dividing the gross return by the variable cost under full and cash cost basis.

7.1.1.6 Net Benefits from Buried Pipe Schemes

In this analysis, the discounted value of net benefit is divided by the discounted value of cost calculated over the project life (Singh, 1977). The present value of incremental benefit has been estimated using the following formulae:

$$PV = B_n/(1+r)^n \quad \text{and} \quad PC = C_n/(1+r)^n \quad ...... \quad (7.1)$$

Where, PV = present value of benefits; PC = present value of costs; B_n = incremental benefit in the nth year; C_n = incremental cost in the nth year; r = rate of discount and n = number of years, for example, 1, 2, .. 30. The benefit-cost-ratio (BCR) was calculated by the following equation:

$$BCR = PV/PC = \{B_n/(1+r)^n\}/\{C_n/(1+r)^n\} \quad ...... \quad (7.2)$$

Cost data were collected from field as well as from other sources, such as TADP office, KSS and non-KSS farmers and scheme managers. The crop production cost was calculated by summing up all costs of land preparation, seed, manure and fertilizer, insecticide and pesticide, intercultural operation and harvesting for both the dry (see example, Tables 7.1 and 7.7) and wet seasons. The repair and maintenance costs and fuel-oil costs were obtained from the pump register (Table 7.4). The total variable cost per year was obtained as:

Vc = Crop production cost + Fuel-oil cost + Repair and Maintenance cost + Operator's wage

The fixed cost comprises the depreciation, interest on investment and the engineering cost (design and supervision cost). The depreciation is calculated as:

$$D = (P - S)/L \quad ...... \quad ...... \quad ...... \quad ...... \quad (7.3)$$

Where, P = total installation cost; S = salvage value and L = life of the system.

Salvage value of a DTW was considered 10% of the purchase price (refer to Table 2.15), but it was nil for buried pipe systems. The life of the DTW was assumed to be 12 years and that of buried pipe 30 years (Mayer, personal communication, 1991). The engineering cost is considered 12.50% of the purchase price of the DTW (Singh, 1977) and the buried pipe and is included in the total system installation cost. The interest on investment has been calculated as: $I = \{(P + S)/2\} \times i$. Where, i = bank interest rate of 16% (bank rate by the Government of Bangladesh, 1991). Thus the total fixed cost per year is obtained by summing up the depreciation and the interest on investment. Hence the total fixed cost per year is: $Fc = D + I$. Thus, the total cost per year of a scheme is as: $Bt = Vc + Fc$.

The gross benefit per year was obtained from the yield of crops and their prices (Rashid and Mridha, 1990). The yield of a particular crop for the whole scheme was determined by averaging the individual yield obtained from the individual plot under the sample outlets.

In calculating BCR, the present values of costs and benefits were derived for 30 years and are shown in Appendix E (Table E.2). The total cost obtained for the dry season 1989-90 was kept constant (refer to Table E.1 in Appendix E) each year in calculating the present value of costs. However, an additional benefit equal to the salvage value of the DTW was added to the yearly benefits of the 13th and 25th years (Singh, 1977) as the life of the DTW has been considered as 12 years.

7.1.2 Results and Discussion

7.1.2.1 KSS Meetings

The basic data on KSS history and membership is shown in Table 2.15. Each KSS (Krishak Samabay Samity) has a six member managing committee first formed at the time of registration and then elected every year. The structure of the managing committee is as follows: **a)** President, **b)** Vice President, **c)** Manager, **d)** Director **e)** Assistant Director and **f)** Member.

Information on KSS meetings, for example, procedure of holding meetings, types of decision and meeting records are shown in Table 7.2. Though the managing committee is supposed to be the actual management of the scheme, the president and manager act as the chief executives. From the table, it is observed that a total of 10 meetings at Taltolapara, 8 meetings at East Kutubpur and 6 meetings at Shaplapara held during 1990-91 irrigation season and the average number of meeting per season was 8. In most (50% to 80%) cases the manager was the chief decision maker. Usually, the meetings were held on seasonal budget preparations, fixation of irrigation charges, oil charges, driver's salary etc.

At Shaplapara, 100% proposals in the meeting were approved whereas at Taltolapara and East Kutubpur scheme few meetings were ended without any decision (Table 7.2). Once the KSS meeting at East Kutubpur was postponed due to poor attendance of the members, and at Taltolapara one meeting was postponed due to a good TV programme. It was observed from the meetings held in 1990-91 that only 15% to 26% members were present at the Taltolapara scheme, 10% to 56% at East Kutubpur and 29% to 56% at the Shaplapara scheme. An average of 27% members were present per meeting, but records often showed higher figures. Reasons for this poor attendance were:

a) the large farmers (refer to Table 2.6) are not at all interested in agriculture as they find other business (brokery, shop keeping, teaching and local medicine) more profitable than that of agriculture,

b) most of the farmers had perceptions that their ideas would not be given due consideration, the decision of the managing committee would take the final decisions, so they avoid the meetings;

c) KSS members do not show much interest in such frequent meetings,

d) defaulters are always afraid of being asked to pay their arrears. Existing inefficient management systems, low education and improper training of the members give rise to internal conflicts and misunderstanding among the waterusers.

A tentative budget was specially prepared prior to the irrigation season by the KSS showing detailed break-ups of seasonal expenditure, this was mainly due to use as a tool to satisfy the BRDB requirements. But in practice, these budgets were never seen to be followed or implemented. No KSS meeting was held at the Shaplapara scheme during the period from February to May, 1991, as the committee did not feel it necessary, even though the meeting was supposed to be held weekly as for resolution. However, the resolution book was regularly updated showing weekly KSS meeting with the attendance of at least two-third members (not less than 20) in a meeting.

Table 7.2 KSS Meetings and Decisions

Date	Present member Water users (%)	Managing committee (out of 6)	Proposer	Proposal maker(s)	Types of decision	Decision approved or not)
Taltolapara						
09-01-91	15(25)	4	President	President	No decision	No
16-01-91	9(15)	4	Manager	Manager	DTW + Budget	Approved
10-02-91	15(25)	4	Manager	Manager	Budget preparation	Approved
13-02-91	16(26)	5	KSS	KSS	Fixing oil cost	Approved
16-03-91	14(23)	4	Manager	Manager	Oil charge	Approved
27-03-91	12(20)	4	KSS	KSS	Saving fund	Approved
07-04-91	16(26)	5	KSS	KSS	Driver salary	Approved
21-04-91	11(18)	4	Manager	Manager	Oil charge	Approved
09-05-91	14(23)	4	Manager	Manager	DTW + BP loan	Approved
07-06-91	12(20)	4	KSS	KSS	No decision	Approved
East Kutubpur						
05-12-90	6(10)	4	Manager	Manager	Budget preparation	No
19-12-90	17(27)	5	Manager	Manager	Service + share	Approved
16-01-91	15(24)	6	KSS	KSS	Loan distribution	Approved
10-02-91	18(29)	4	Manager	Manager	Oil charge	Approved
07-03-91	12(19)	4	Manager	Manager	DTW loan	Approved
01-04-91	9(14)	3	Manager	Manager	Oil + driver	Approved
08-05-91	18(29)	6	KSS	KSS	Committee	No
05-06-91	35(56)	6	Manager	Manager	Short term loan	Approved
Shaplapara						
27-12-90	24(39)	6	Manager	Manager	DTW loan	Approved
03-01-91	22(35)	6	Manager	Manager	Repairing	Approved
09-01-91	36(56)	6	President	KSS	DTW + BP loan	Approved
					Driver salary	Approved
16-01-91	24(39)	6	Manager	Manager	Oil charge	Approved
20-01-91	18(29)	5	Manager	Manager	Oil charge	Approved
29-01-91	20(32)	6	Manager	Manager	Collected charges	Approved
February to May no KSS meeting was held at Shaplapara scheme						

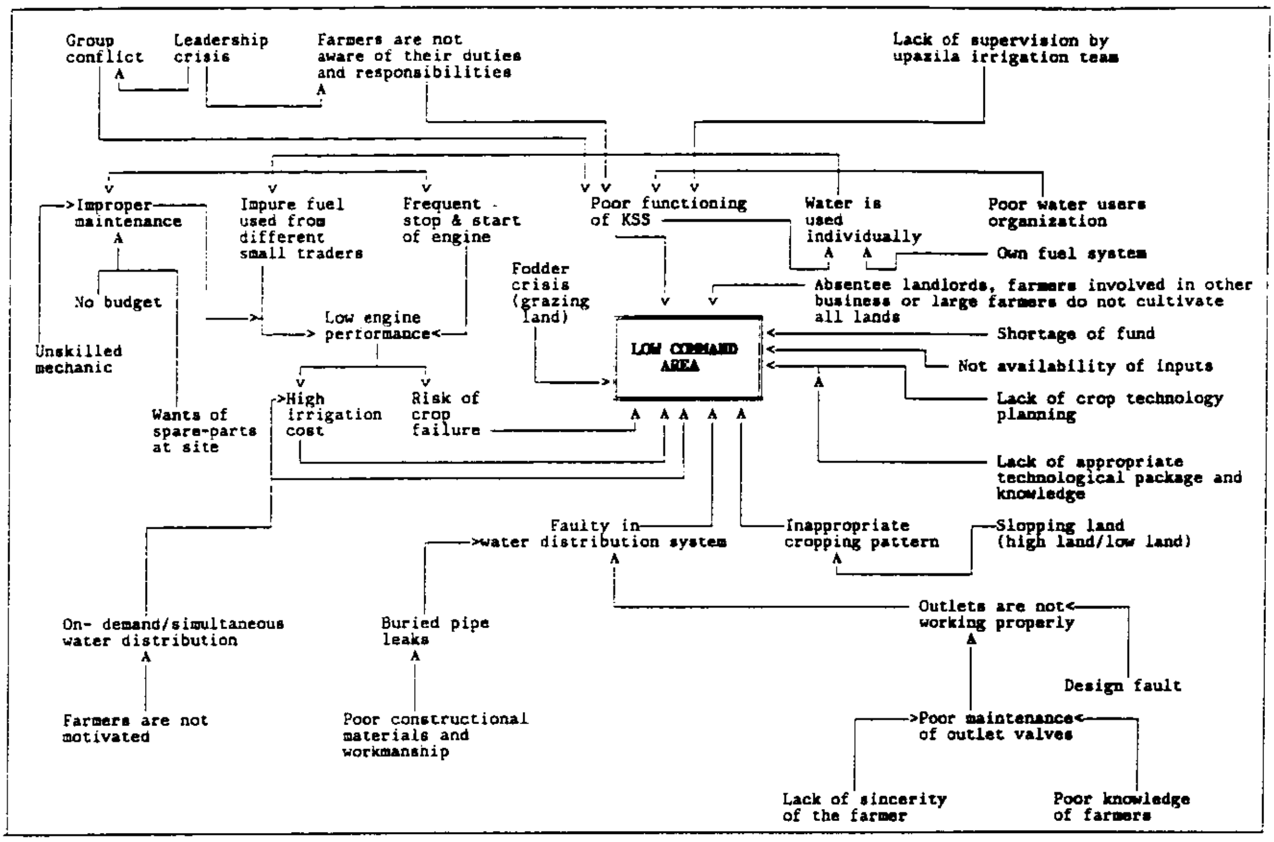
Note: If members present at KSS meeting was less than 7, regulation book was filled up by false signature and shown at least 20

7.1.2.2 Various Constraints to Low Command Area

Interactions among different socio-economic constraints to command area development in irrigated agriculture under buried pipe schemes are presented in Figure 7.1 in the form of a flow chart. Enormous problems related to socio-economic and institutional aspects were surveyed through informal discussions and interviews without any questionnaire. The data were critically analysed considering field oriented situations and the results thus identified were confirmed in one group meeting. Summarized results are shown in Figure 7.1, which has explained why the farmers left their land fallow and why they were not motivated to agriculture.

Figure 7.1

Constraints to Low Command Area



7.1.2.3 Farmers' Problems

Farmers' problems were surveyed and analysed according to their thinking. Then farmers statements were generalized and the observations of the interviews were added. These are presented in tabular form below:

Problem/Situation	Causes of problem	Remarks
Small farmers face food shortage	a) Small land holding b) Low labour wages c) No work during rainy season d) Unfavourable tenancy systems	a) Lack of financial resources
Shortage of draft power	a) Fodder crisis b) Maintenance cost is high c) Low quality breed d) Cows are used for ploughing e) High price of cattle f) Bulls are rarely found	a) Mechanical power can recover this
Low output of cattle	a) Poor health of cattle - Imbalance rationing - Disease infestation - Insufficient health care facilities b) Fodder crisis - Limited grazing areas - Lack of fodder yielding crops - Indigenous breed	a) High breed cattle may help producing high output of cattle
Poor marketing opportunities	a) Bad communication b) Small traders	a) Good communication might solve this problem
Inadequate crop management practices	a) Lack of financial resources b) High prices of agril. inputs c) Availability of agril. inputs d) More care of HYV crops e) Proper planting date could not be met f) Most farmers prefer rainfed farming g) Low investment for local varieties h) Lack of interest i) Lack of literacy j) Very low ploughing depth k) Poverty	
Poor extension services	a) Concerned officers/staff do not visit farmers' field weekly b) BRDB staff go to farmers for collecting loan only not for advice	a) Low facility from the Government

7.1.2.4 Collection of Water Charges

Water charge collected in one irrigation season at the three main schemes are shown in Table 7.3. The water charge includes the expenses related to pump operation, maintenance and management of the schemes. However, farmers usually supply fuel to get water from the pump. Usually, total expenses on oil, repairing and maintenance, staff salary, instalment of deep tubewell costs were distributed over the total area irrigated. It was found that at the Taltolapara scheme about 70% of the targeted amount of water charge was collected, and 100% of the collected amount was spent. Similarly, the collected amounts at East Kutubpur and Shaplapara schemes were about 85% and 64% of the targeted amounts, respectively. The expenditure incurred for these two schemes were about 129% and 91% of the collected amount, respectively. It is seen that at East Kutubpur the cost exceeded the collected amount by 29%. This was due to the fact that all the pipelines of this scheme needed repairing which cost Tk 18,000.00 (Table 7.3). However, this money required for repairs was paid by the TADP. Maximum water charge was collected at East Kutubpur (85%). Because, with the help of police BRDB people collected this money. Police actions made the farmers anxious about the loan payments and some of them repaid it by selling out land, which could have serious social consequences. Table 7.3 showed that the whole amount collected as water charge at East Kutubpur was not spent, a portion was reserved for the future.

7.1.2.5 Irrigation Cost

From Table 7.4, it is seen that the cost of fuel was the highest (Tk 37,845.00) at Shaplapara during the 1990-91 irrigation season, because, the area irrigated and the total pumping hours were higher than those of other schemes (refer to Tables 5.3 and 4.13). An amount of Tk 19,805.00 was spent for spare parts at East Kutubpur in the 1989-90 irrigation season, this amount was only 3% (Tk 578.00) in the 1990-91 irrigation season. This was due to overhauling the engine in the 1989-90 irrigation season when many spare parts were changed.

Irrigation costs per hectare ranged from Tk 1,901.00 to Tk 5,616.00 with an average value of Tk 3,445.00 in the two irrigation seasons. It was found that where maintenance and servicing were poor, irrigation costs were high, as more engine trouble occurred. Since the manager did not get any salary from the scheme, he did not take a keen interest in the proper maintenance of the engine. A thorough discussion has been made in section 7.2.4.2.

Table 7.3 Water Charge Collection (Excluding Fuel)

Parameters	Decision by	Crops	Charge (Tk)	Area (ha)	Expected target(Tk)	Actually collected, (Tk)	Amount spent (Tk)	Remarks
Taltolapara								
DTW Loan								
a) Kharif II	KSS	Aman	118/pakhi	20.23	11750.00	6500.00	6500.00	1 pakhi = 50 decimal
b) Rabi	KSS	Rabi	273/pakhi	15.15	20400.00	20000.00	20000.00	(it collected at Rabi time)
BP loan	KSS	Rabi	100/pakhi	15.15	7487.00	0.00	0.00	
BP repairing	TADP	Rabi	50/leakage	-	-	-	500.00	TADP repaired and paid
Oil Charge								
KSS, non KSS, and waterusers	KSS	Boro	2/decimal	1.27	625.00	320.00	510.00	Oil + engine repairs + driver salaries
		Others	1/decimal	13.88	3430.00	2750.00		
Pump repaired	KSS	Rabi	(from oil charge)				660.00	Spare-parts + mechanics transport + miscellaneous
Driver salary	KSS	Rabi	(from oil charge)				2500.00	
Reserved fund	KSS					1200.00		
Total					43692.00	30770.00	30670.00	
East Kutubpur								
DTW Loan								
a) Kharif II	KSS	Aman	215/pakhi	18.81	20800.00	20800.00	20800.00	1 pakhi = 48 decimal
b) Rabi	KSS	Rabi	200/pakhi	13.85	14260.00	14100.00	14100.00	
BP loan	KSS	Rabi	100/pakhi	13.85	7130.00	0.00	0.00	
BP repaired	TADP	Rabi	50/leakage	-	-	-	18000.00	TADP repaired and paid
Oil Charge								
KSS, non KSS, and waterusers	KSS	Boro	5.50/dec.	1.90	2585.00	2500.00	1722.00	
		Others	1.5/dec.	11.95	4430.00	4430.00	16.00	
Pump repaired	KSS	Rabi	(from oil charge)				578.00	
Driver salary								
a) Kharif II	KSS	Aman	35/pakhi	18.81	3389.00	3200.00	3200.00	
b) Rabi	KSS	Rabi	20/pakhi	13.85	1426.00	1150.00	1000.00	
Total					54020.00	46180.00	59416.00	
Shaplapara								
DTW Loan								
a) Kharif II	KSS	Aman	300/pakhi	24.28	36000.00	28150.00	28150.00	1 pakhi = 50 decimal
b) Rabi	KSS	Rabi	200/pakhi	21.55	21300.00	11000.00	10360.00	
BP loan	KSS	Rabi	100/pakhi	13.85	10650.00	0.00	0.00	
BP repaired	TADP	Rabi	50/leakage	-	-	-	100.00	TADP repaired and paid
Oil Charge								
KSS, non KSS, and waterusers	KSS	Boro	4.00/dec.	3.08	3040.00	2120.00	1643.00	
		Soybean & Wheat	2.00/dec.	11.13	5500.00	5200.00		
		Others	1.00/dec.	7.28	1800.00	1370.00		
Pump repaired	KSS	Rabi	70/pakhi	18.21	6300.00	5282.00	7950.00	
Driver salary	KSS	Rabi	30/pakhi	21.55	3195.00	3195.00	3035.00	
Total					87785.00	56317.00	51238.00	

Note: Total amount spent is shown including DTW loan of kharif II

Table 7.4 Seasonal Irrigation Expenditure (Taka)

Parameters	Schemes					
	Taltolapara		East Kutubpur		Shaplapara	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
DTW loan paid	20520.00	20000.00	20520.00	14100.00	20520.00	10360.00
Diesel	19669.00	29865.00	7633.00	22695.00	13076.00	37845.00
Oil + Grease	371.00	510.00	866.00	1722.00	567.00	1643.00
Spareparts	672.00	570.00	19805.00	578.00	1494.00	7093.00
Mechanic	300.00	0.00	150.00	0.00	225.00	350.00
Salaries						
a) Manager	0.00	0.00	0.00	0.00	0.00	0.00
b) Operator	2332.00	2500.00	457.00	4200.00	3062.00	3035.00
c) Lineman	0.00	0.00	0.00	0.00	0.00	0.00
d) Book keeper	0.00	0.00	0.00	0.00	0.00	0.00
Transportation	56.00	30.00	1970.00	16.00	248.00	325.00
BP repaired	0.00	500.00	0.00	18000.00	0.00	100.00
Miscell. cost	15.00	60.00	548.00	0.00	92.00	182.00
Total spent	43944.00	54035.00	51949.00	61311.00	39284.00	60933.00
Spent(Tk/ha)	2329.00	3567.00	5616.00	4427.00	1901.00	2828.00
Expenditure excluding fuel						
a) Total(Tk)	24275.00	24170.00	44316.00	38616.00	26208.00	23088.00
b) Tk/ha	1286.00	1595.00	4791.00	2788.00	1269.00	1071.00

Note: Above figures are actual expenditure except for loan payment where the amount due is shown for the season 1989-90

7.1.2.6 Services from Governmental Departments

The Bangladesh Agricultural Development Corporation (BADC), Department of Agricultural Extension (DAE) and Bangladesh Rural Development Board (BRDB) are assigned with the responsibility to provide the necessary services to the irrigation schemes. Due to the German aid involvement (GTZ) in TADP, BADC`s role was limited to DTW installation only. Out of the Government departments and the donor agencies only TADP was found very active in the scheme areas. But it is necessary for the Upazila officers and local staff (Block Supervisor or BS) concerned to visit the farmers and their fields to get acquainted with the field situations and know the problems, so that they can offer the right solution and proper advice.

Poor coordination among the service providing departments was always observed. The problems in modern agriculture are quite complex. They can not be solved by a single discipline (Rashid and Mridha, 1992). Therefore, a multi-disciplinary approach and coordinated efforts are essential to solve the problems. The first effort of the service providing agencies is to motivate the farmers, to engage them in agriculture in such a way that they can understand about the potential benefits that may be obtained from irrigated agriculture. In a buried pipe scheme, crop diversification might be beneficial.

7.1.2.7 Deep Tubewell Loans

The repayment position of DTW (cost) loan is given in Table 7.5. The table shows that none of the scheme cleared their dues completely. On 30th June, 1991, dues (unpaid) varied from Tk 20,133.00 (at Baila) to Tk 94,861.00 (at East Kutubpur). The Binnakhaira scheme showed better repayment records (unpaid dues amounted to only 18%) in comparison to other schemes and the Hazipara scheme showed very poor payments (unpaid amount was 68%), followed by Chulabar (63%) and then the Vailpara scheme (56%). The reasons for these unpaid amounts were:

Table 7.5 Repayments of Deep Tubewell Loans (Taka)

Schemes	Date due	Amount due	Amount paid	Unpaid amount
Taltolapara	30-06-91	143640.00 (100)	92512.00 (64)	51128.00 (36)
East Kutubpur	30-06-91	184680.00 (100)	89819.00 (49)	94861.00 (51)
Shaplapara	30-06-91	143640.00 (100)	68210.00 (48)	75430.00 (52)
Baila	30-06-91	102600.00 (100)	82467.00 (80)	20133.00 (20)
Vailpara	30-06-91	147150.00 (100)	64835.00 (44)	82315.00 (56)
Chulabar	30-06-91	82580.00 (100)	30400.00 (37)	52180.00 (63)
Hazipara	30-06-91	102600.00 (100)	33220.00 (32)	69380.00 (68)
Binnakhaira	30-06-91	133380.00 (100)	108885.00 (82)	24495.00 (18)

Note: Figure in parentheses indicate percentage. Balance is shown upon 30th June, 1991

a) farmers do not pay water charges on time, because of shortage of financial resources, sometimes crop damage by natural hazards, or crop failure or engine breakdown;

b) money collected from farmers is used sometimes in personal businesses of the manager, so the DTW loan is not paid;

c) sometimes because of social conflicts or grouping, the water charge is not properly collected.

The KSS at Baila, Vailpara, Chulabar and Hazipara did not pay their last instalments, as they expected that this would be covered by the government programme to exempt agricultural loans up to Tk 5000.00 and the interest thereof. Most of the farmers fell under this policy, and others also did not make their loan repayments, presuming that the Government might exempt a greater amount in future. One instalment at Shaplapara and two instalments at Chulabar scheme were rescheduled for payment for decision of the UCCA (Upazila Central Cooperative Association) managing committee because of the engine breakdown and the crop failure of these two schemes.

7.1.2.8 Buried Pipe Loans

From Table 7.6, it is observed that no payment was made against buried pipe loans by the schemes at Taltolapara, East Kutubpur, Shaplapara and Chulabar up to 30th June, 1991. At these schemes, whenever an instalment had fallen due the management had raised the question of repairing the leaks and avoided payments. Only Baila, Hazipara and Binnakhaira schemes made regular payment of the instalments except for the last instalments which were due on 30th June 1991. This was mainly due to the change of government policy as described in the preceding section 7.1.2.7.

Table 7.6 Buried Pipe Loans (Taka)

Schemes	Date due	Amount due	Amount paid	Unpaid amount
Taltolapara	30-06-91	31552.80	0.00	31552.80
East Kutubpur	30-06-91	27700.00	0.00	27700.00
Shaplapara	30-06-91	26190.00	0.00	26190.00
Baila	30-06-91	18240.00	9120.00	9120.00
Vailpara	30-06-91	27360.00	300.00	27060.00
Chulabar	30-06-91	27360.00	0.00	27360.00
Hazipara	30-06-91	7600.00	3800.00	3800.00
Binnakhaira	30-06-91	44320.00	20040.00	24280.00

7.1.2.9 Economics of Some Irrigated Crops at Sample Plots

The economic performance of some irrigated crops at sample outlets are shown in Table 7.7. At the Taltolapara scheme, the maximum Benefit Cost Ratio (BCR) on full cost basis was found to be the highest (3.24) for the potato crop and the minimum (0.61) for sweet-potato. However, the latter showed its poor performance due to improper management. At East Kutubpur, the highest BCR value on a full cost basis was found to be 5.88 for garlic, followed by banana (3.59) and then potato (1.69). Table 7.7 shows calculated BCR values of some irrigated crops, were less than unity. This was mainly due to the low return from the cultivated crops. Inadequate irrigation, fertilizer application, and improper planting time were the main reasons for such results (refer to chapter 5). Taking the area of each crop into account, these figures seem to indicate a successful season for farmers who cultivated their own land at Taltolapara and Shaplapara, but a very poor season at East Kutubpur when the gross returns generally did not cover even the cash costs of the crop.

Table 7.7 Economic Performance of Some Crops at Sample Plots

Crops	Area (m^2)	Total variable cost(Tk/ha)		Gross Return (Tk/ha)	BCR	
		Full cost basis	Cash cost basis		Full cost basis	Cash cost basis
Taltolapara						
Wheat	3700	10,676.00	7,646.00	12.680.00	1.19	1.66
Boro-rice	1100	13,557.00	9,822.00	22,411.00	1.65	2.28
Soybean	3100	14,528.00	10,058.00	12,074.00	0.83	1.20
Watermelon	400	20,680.00	9,545.00	36,570.00	1.77	3.83
Potato*	700	43,824.00	30,339.00	1,41,919.00	3.24	4.68
Sweetpotato	300	21,925.00	11,705.00	13,444.00	0.61	1.15
Chilli	500	15,868.00	6,063.00	13,385.00	0.84	2.21
East Kutubpur						
Wheat	1500	13,474.00	12,254.00	7,462.00	0.55	0.61
Soybean	2400	17,997.00	15,587.00	11,784.00	0.65	0.76
Watermelon	500	15,129.00	10,579.00	8,380.00	0.55	0.79
Potato	1000	42,721.00	40,251.00	72,108.00	1.69	1.79
Chilli	200	21,964.00	14,329.00	13,096.00	0.60	0.91
Mustard	1200	16,884.00	11,788.00	9,979.00	0.59	0.85
Garlic	400	28,380.00	24,880.00	1,66,794.00	5.88	6.70
Radish	600	20,262.00	19,962.00	3,748.00	0.18	0.19
Banana	6100	40,176.00	38,566.00	1,44,142.00	3.59	3.74
Shaplapara						
Wheat	810	12,583.00	8,005.00	11,125.00	0.88	1.39
Boro-rice	2300	14,555.00	6,140.00	26,507.00	1.82	4.32
Soybean	800	10,678.00	7,558.00	12,855.00	1.20	1.70
Watermelon	2600	14,736.00	9,165.00	15,398.00	1.04	1.68
Potato	400	45,773.00	33,756.00	1,43,693.00	3.14	4.26
Sweetpotato	300	22,913.00	13,826.00	28,703.00	1.25	2.08
Mustard	800	7,539.00	4,779.00	12,827.00	1.70	2.68

Note: * = Calculation of this horizontal line is shown in Table 7.1

7.1.2.10 Economic Feasibility of Buried Pipe Schemes

The economic feasibility of the selected schemes are tested using benefit-cost-ratio (BCR). Table 7.8 shows that all the three schemes under the study are economically attractive, because the BCR value is greater than 1.0 for all the schemes. Among the three schemes, Shaplapara has the highest BCR value (3.26) and East Kutubpur has the lowest (2.14). The main reason for the low BCR value at the East Kutubpur scheme was low return or low yields. A cause of low return was the low command area (only 9.25 ha during 1989-90 irrigation season, refer to Table 5.2), which was again due to breakdown of the engine. Moreover, the frequent breakdown of the engine at this scheme made the farmers reluctant to rely on the system for irrigation. It was also noticed that large farmers (29% of the total farmers, refer to Table 2.6) at this scheme did not cooperate with the KSS body. What is more, the farmers (30% of the total farmers come in the small group) at East Kutubpur scheme are economically poor and their social conflicts are higher than those of other schemes.

Table 7.8 Benefit Cost Ratio (BCR) of Buried Pipe Schemes

Schemes	Present value ('000 Tk) of		BCR
	Cost	Benefit	
Taltolapara	3969	10586	2.67
East Kutubpur	3358	7201	2.14
Shaplapara	4212	13711	3.26

7.2 INSTITUTIONAL ANALYSIS

7.2.1 Introduction

The Krishak Samabay Samity (KSS) is a farmers' co-operative society. In other words, a group of progressive farmers have associated to develop a common irrigation system for their properties and jointly farm their land. The main purpose for the KSS institution is to run a Buried Pipe Deep Tubewell Irrigation (BPDI) scheme properly so as to get the best results and long-term maximum benefits from the irrigated agriculture.

The KSS institution, of course, follows some specific management systems which were provided by the service providing agencies. As described earlier the Department of Agricultural Extension (DAE), BRDB, BADC, and TADP were engaged in providing services to the KSS institution. However, some important questions are necessarily involved analysing an institution of the KSS. For instance, the constitutional and legal status, legal responsibilities, required finance and operational performance and constitutional obligations are the vital things to be considered when diagnosing an institution (Franceys, 1992).

The process of analysing these aspects requires a fundamentally different approach to problem identification. In the past, most efforts have paid insufficient attention to institutional problem analyses. MMP (1987) documented about IMP (Irrigation and Management Programme) that administration and cooperative development occurred where the IMP rules were emphasised. These could have been followed by the cooperatives. However, in this analysis, more emphasis has been placed on the KSS institution in order to sort out the major constraints from the overall management systems and to analyse them. Nevertheless, KSS problems are qualitatively different from specific technical or procedural problems. Lack of attention, responsibilities and insincerity are examples. Several reasons for these aspects and possible alternative improvements are discussed in this section.

7.2.2 Methodology

All institutional data were collected by interviewing, consulting the scheme people or TADP staff, direct observation and surprise visits without notice.

Analysis procedures for different types of organisations have been published in books/reports, e.g. Cullivan et al, (1986); Sagardoy et al, (1982) and Franceys, (1992), where a sample institution taken for analysis, was either a government organisation or an autonomous organisation. In addition, these organisations were funded either by the government or by a donor agency. From this viewpoint, a KSS institution differs from other organisations in that a KSS institution is a self funding organisation and no one is responsible for any activities. Therefore, methodologies used for analysing KSS institutions are partly taken from the above references.

7.2.3 Results and Discussion

A KSS institution as an irrigation co-operative has as its main function to deliver a timely and equitable distribution of irrigation water resulting in maximum benefit from the irrigated agriculture. Nonetheless, this objective has never been seen to be followed in the scheme areas because the KSS institution is not working properly.

Some major constraints within the KSS institution were observed (Figure 7.1). After analysing the constraints, performance indicators to measure a KSS institution were identified and listed according to their activities and achievements (note that most results were based on eight buried pipe schemes).

7.2.3.1 Performance Indicators

a) Command Area

The command area is the first performance indicator to measure a KSS institution. The design command area is about 40 hectares per scheme per deep-tubewell (refer to Table 5.1). On average the actual command area was 16.64 hectares (see section 5.1.2.2) which was less than 50% of the design. On average a KSS institution has a performance efficiency of 42% (Table E.3 in Appendix E). The major constraints are shown in a flow chart (Figure 7.1). It was observed that collecting the water charge was based on only the irrigated area under the scheme (see section 7.1.2.4). If the water charge was distributed over the whole area under the scheme, it would be possible to increase the command area up to the design target.

b) Pump Operation

Pump operation is the second performance indicator of the KSS. Descriptions of pump operation time have been discussed in the section 4.3.2.1, where the result shown is quite surprising because an average of pump operation time was found to be only 12% of advised time (Table E.3 in Appendix E). Pump operation was only 23% based on hours/day and also 53% considering days/month. What is more, diversified cropping patterns were partly responsible for this low pump operation. Reducing fuel prices may increase pump operation time.

c) KSS Fuel System

The study result shows that 7 schemes (out of 8) were run by own fuel systems. As discussed earlier farmers individually buy small quantities of fuel from small traders and use it whenever they feel irrigation necessary (refer to section 4.1.2.1). The quality of this type of fuel is not good and causes breakdown of the engine. Smout (1992) reported that the farmers' fuel system is usually unsatisfactory because diesel available in a local market is likely to be poor quality and may damage the engine.

At the same time, "own fuel system" causes enormous problems on management systems, for example, it reduces co-operation among other farmers, linkage between the managing committee and the farmers, and responsibility for the institution. This problem might be overcome by using project fuel, that is KSS fuel.

d) Unirrigated Land

As has been described in section 5.1.2.2 (Tables 5.2 and 5.3) the unirrigated area varied from 5.34% to 21.54% of the actual command area with an average of 13.73% in the dry seasons. From the field observations, it was concluded that frequent engine troubles created farmer reluctance. Good engine condition might increase the tendency of the farmers to irrigate.

e) Waterusers

A survey of eight schemes showed that an average of 55 waterusers per scheme of whom 80% were KSS members (refer to Table 2.15) and about 94% of the KSS members were found to be using irrigation water. Another survey of 40 schemes was reported by Mayer (1991), who showed 59 waterusers per scheme of whom 60% were KSS members.

Field observation revealed that many non-KSS farmers using irrigation water was reducing the strength of the institution. KSS and non-KSS members are different in that KSS members usually have the legal right to get water from the pump but non-KSS members have no such right.

f) Non-KSS Farmers

On average 11% of waterusers per scheme are non-KSS farmers of whom 90% are treated as KSS members (for example, they pay the same as the KSS farmers pay). The other 10% non-KSS farmers pay double charges. This variation often caused conflicts among them. The reason for double charges was that the farmers were less co-operative.

g) Usages of Outlet

The study reveals that 9% of outlets were never used at all, during the study period, even though each outlet of a scheme had been given equal importance during construction (Mayer, personal communication, 1990). On average 91% of the outlets were found to be working (Table E.3 in Appendix E). Some large farmers' influence is the main reason for this, because a few large farmers have a tendency to make them dominant over others in all activities.

h) Equity of Water Supply

Since the use of outlets is not equal it is not possible to maintain equity of water distribution. Farmers do not follow any method. This is essential to enable equity of water distribution (refer to sections 5.1.2.4 and 5.1.2.5). They follow the "first come first served" principle. Sagardoy et al (1982) concludes that the selection of the water distribution method is an important matter where social, technical and economic characteristics must be taken into consideration. However, the own fuel system and a few prominent individuals were mainly responsible for the inequity of water distribution.

i) Water Distribution System

No systematic rules were followed in any of the schemes. Due to the own fuel system, a long queue of farmers near the pump house with a fuel container in their hand was often observed. This leads to frequent switching between the pipelines which results in unnecessary losses of water through repeatedly filling the pipelines, for instance, 8.52% of pump operation time is lost by filling the pipeline (refer to section 4.3.2.2). To overcome this problem, following an outlet rotation for the pipelines might be the solution.

j) Rotational Irrigation System

In this system farmers receive water by turns in the allowed quantity in allowed time. Farmers are grouped linewise first and then outletwise. This has been discussed in detail in section 5.1.2.6.

k) KSS Meeting and Decisions

As for regulation, all KSS farmers have to meet together weekly at a co-operative house. Unfortunately, only 2 out of 8 schemes have a co-operative house. An average of 8 out of 20 meetings (which were designed for the dry season), were held in 1990-91 irrigation season and on average 27% farmers were present per meeting (refer to section 7.1.2.1). The number of meetings and members present were quite low. This might be increased if weekly meetings were changed to fortnightly because a few farmers did not like such frequent meetings.

Decisions were taken, but not implemented, for example, in the KSS meeting the management body had decided that they would follow the IMP rules (refer to section 5.1.2.4), but practically it was not implemented. From the study, it feels that decisions could be more effective if the president was a strong decision maker.

l) Log-book with List of Expenses

From the investigation, it is seen that only 1 scheme has an up-to-date log-book with list of expenses. TADP provided log-books to each scheme for keeping records of pump operation time with fuel-oil consumption so that TADP mechanics can look at the engine condition and assess the next servicing time. However, to avoid the cost of servicing the engine, most of the pump operators did not keep records. Illiteracy, inexperience, dishonesty of the pump operator and saving on engine servicing costs were the main reasons for this. A little literacy and honesty of the pump operator could improve this aspect.

m) Pump Operator

It is felt from the field experience that none of the pump operators were efficient in terms of understanding everything about the engine. It was also reported that one pump operator stole oil from the engine but he was not even punished and two pump operators used burnt oil, to avoid oil charge collections, which caused engine breakdown. Some operators were absent for a few days even more than 7 days from the scheme without any notice to the KSS. This indicates irresponsibilities of the pump operators. Smout (1986) documented that each operator needs to be supplied with a clear operation and maintenance manual specific to the operator's tasks and basic training in these and he emphasised the importance of keeping an accurate log should be stressed, to provide a record of running hours, consumption of fuel and lubricants, and servicing. A person with a little literacy and honesty and experience with the engine could be appointed as a pump operator.

n) Fieldman

A fieldman is essential to operate the scheme efficiently. Observation showed only one scheme out of the 8 had a fieldman paid by the KSS. The function of a fieldman is to operate outlet valves and to divert the flow into different directions according to the demand of the crops and also to follow a rotational water distribution system. Appointment of a fieldman to each scheme might improve the distribution system and reduce damage to outlet valves, justifying his salary cost.

o) Half-yearly Details Budget

A budget is a tentative statement which is made according to a plan of the future expected expenditure in terms of money. Generally, instalments for loans are fixed half-yearly so it is necessary to do the budget in time. As described earlier budgets were prepared each season, but not followed due to farmers dishonesty and lack of financial resources.

p) Repairing and Servicing of Engine

Due to lack of proper servicing of the engine most of the engines had shown poor performance (for example, see section 4.3.2.3). The low speed of an engine could not be increased. This led to low discharges (see section 4.1.2.1). Proper servicing might ensure good performance of the engine.

q) Outlet Conditions

Collecting data on eight schemes showed that an average of 18% outlets per scheme were observed completely damaged by the interference of the villagers. An average 82% of outlet valves were in good condition (Table E.3 in Appendix E). Restriction on touching the outlets by the villagers could solve this problem, as is already practised in one scheme out of eight. At the Baila scheme, only the fieldman operates the outlet valves.

r) Newly Released Varieties of Crops

It was reported that farmers were still accustomed to cultivating only the traditional varieties of crops with a few exceptions (Rashid and Mridha, 1992). The main reason for this is that investment costs for the traditional varieties of crops were very low. Extension work might change this custom.

s) Cropping Intensity

This is one of the performance indicators of the KSS institution. Cropping intensity indicates how much farmers have been motivated to agriculture and how much they have been involved in farming their land. For the study area, Tangail, present cropping intensity under irrigated conditions is 233% (refer to Table 2.9). This could possibly be increased up to 300% by following the IMP management rules, for example, date of sowing or planting of different crops, proper fertilizer doses with other cultural practices and proper irrigation timing with quantity specified by the researchers.

t) Overdue Loans

From the collected data, it is seen that none of the scheme had cleared their due loans completely (refer to Tables 7.5 and 7.6). An overdue loan is one performance indicator of the KSS institution. No overdue loan indicates 100% good performance.

u) Marketing Opportunity

As stated earlier a few farmers were observed to be reluctant which might be because of the commercial disadvantages that frequently appear with farm products especially with perishable outputs. It was also observed that farmers could not always sell their outputs which ultimately became damaged e.g. papaya, banana and so on. Sometimes they sold their products at very low prices. On the other hand, the price of agricultural commodities were observed to be very high (for example, see section 5.2.2.3). Hence the marketing opportunity is an indirect performance indicator of the KSS institution. A strong cooperative would create marketing opportunities through communicating with higher authority. Good marketing opportunities may at least ensure satisfaction of the farmers.

v) High Return Per Unit Land

High return per unit land is basically the final output of the KSS institution. Sagardoy et al (1982) reports that greater production is only possible when water, other inputs and resources are available at the correct time and are all used in an appropriate way. Constraints on return are discussed in section 5.2.2.6.

w) Quality Seeds/Seedlings

It was observed that good quality seeds/seedlings were often unobtainable. Service providing agencies hardly ever provide good quality seed to the farmers. Quality seed is very important. For example, once TADP provided soybean seed to the farmers, but the seeds did not germinate. As a result, farmers lost money buying seeds and at the same time one crop. In this case, farmers might have been encouraged by a little compensation.

x) Availability of Agricultural Inputs

It has been reported that farmers often left their land fallow due to lack of agricultural inputs (for example, see section 5.1.2.3). It was also seen that inputs were available but prices were reported more than double which showed inconsistency between the buyer and the seller. A good marketing facility with a fixed price for the agricultural commodities might help farmers buying goods.

y) Willingness to Pay

Willingness to pay for water charge is the most important performance indicator of the KSS institution. The study reveals that most of the farmers show unwillingness to pay for water charges for various reasons. For example, they do not get maximum return from the irrigated crops.

The above 25 performance indicators can be taken into consideration when analysing a KSS institution.

7.2.3.2 Identified Problems

Some of the key problems encountered in the institution are shown below:

a) inefficiency of the service providing agencies,

b) institutional structure not well defined,

c) lack of execution and motivation,

d) KSS body very weak due to lack of prominent leader or poor management systems,

e) prominence of some large farmers,

f) not following the operating and maintenance procedures,

g) linkage between the KSS and the service providing agencies not clear.

7.2.4 KSS Assessment

7.2.4.1 Introduction

KSS institutional assessment is a hard task in which several disciplines and sub-disciplines overlap (Sagardoy et al, 1982). In this section on the KSS institution, present concepts and present methods of its activities are illustrated and examined for assessment. Assessing procedures for evaluation in the institution, particularly that of irrigated agriculture, is suggested and guidelines for work on this are discussed. In addition, these efforts would benefit from clearly specified suggestions for conducting the assessments in the BPDI schemes.

7.2.4.2 KSS Institutional Structure

Figure 7.2 shows the KSS institutional structure which was constructed by interviewing the KSS farmers during the study period. A KSS institutional structure is made up of a number of governing bodies acting independently. They are supposed to work in a co-ordinated manner in order to achieve the maximum profits from the irrigated agriculture. But in practice, they have no relation with one another. However, among the service providing agencies, BRDB is responsible for providing short term loans to the KSS farmers, DAE is designed for extension services through demonstration and TADP carries all technical expenses relating to major repair work. Additionally, TADP has its own extension services through which they are trying to motivate the farmers, for example, following demonstration plots. Although this appears a highly desirable approach according to the specific needs of the KSS institution, experience from observation and interviewing the KSS/non-KSS farmers reveals that the KSS institution was not influential. Poor marketing opportunities and high prices of the agricultural inputs might be the probable reasons for this. These reasons lead to the KSS farmers being involved in other professions rather than agriculture (Table 7.9). Therefore, motivation of the KSS farmers is only possible when a good marketing opportunity is developed in the scheme areas.

Figure 7.2 also illustrates that the manager is the only contact point for all services through the managing committee (refer to section 7.1.2.1), which is supposed to conduct the actual management of the scheme. According to the constitution, the managing committee would be changed yearly by election but this was not possible, because the people on the managing committee were all from the large farm group (refer to Table 2.6).

A survey of eight schemes shows that 58% of the managing committee members was found to be engaged in other professions with little concern for agriculture (Table 7.9). The manager was not given any incentive from the management, although he acted as the chief executive of the KSS. Why should he take a keen interest in the scheme ? A small incentive would compensate the manager and increase the efficiency of the management.

There was no fieldman except one scheme out of eight. The pump operator often did this work, as a result he frequently left the pump house which might cause engine trouble. Therefore, a fieldman may help water distribution to improve.

No cashier was included in the KSS organisation structure, so the manager acted as cashier and dealt with the cash, which resulted in corruption. Moreover, as described earlier the money collected from the KSS and non-KSS farmers was sometimes used for the personal business of the manager, so loans were not paid on time.

There were no written documents about the KSS institutional structure. Only the manager was a known figure in the KSS. As for the constitution, other members on the managing committee were suppose to help the manager from time to time, but in practice, this did not happen.

Figure 7.2
Existing KSS Structure

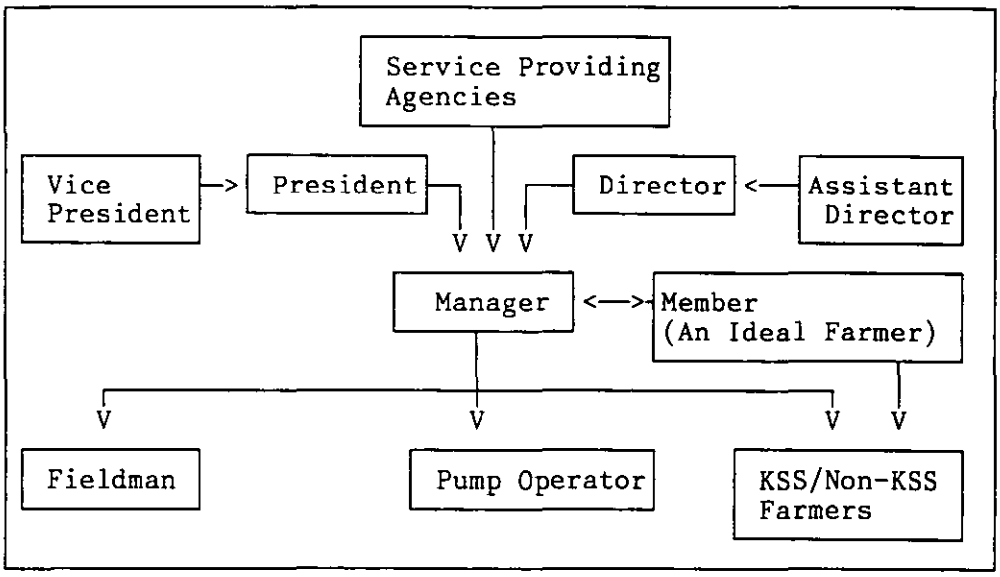


Table 7.9 Professional Distribution of Managing Committee Members

Schemes	President	Vice President	Director	Assistant Director	Manager	Member
Taltolapara	0	A	A	0	0	A
East Kutubpur	A	A	0	0	0	A
Shaplapara	0	0	0	0	A	A
Baila	0	0	A	0	A	A
Vailpara	0	A	0	0	A	A
Chulabar	0	0	0	0	A	A
Hazipara	A	0	0	0	A	A
Binnakhaira	0	0	0	0	0	A
	0 = 6 A = 2	0 = 5 A = 3	0 = 6 A = 2	0 = 8 A = 0	0 = 3 A = 5	0 = 0 A = 8

Note: 0 = other professions and A = agriculture

7.2.4.3 Leadership

Leadership of a KSS institution is the ability to inspire farmers to perform the institutional mission, to commit themselves to that mission, and to work toward its fulfilment. It goes well beyond proficiency in management skills. In order to perform its functions in a competent manner, an institution in any sector needs to have effective leadership at many different levels (Cullivan et al, 1986).

Effective leaders can provide motivation for institutional staff to carry out their function properly. In the KSS institution, the president is the leader but he leads only the manager. The investigation result shows that six out of eight presidents were involved in other professions which caused the poor performance of the management (Table 7.9). Moreover, the president is called a "village leader". Generally, a village leader looks after the village people in terms of adjudicating in any of the conflicts often found between the village people. The president has a legal right to enforce somebody to do something, so it is a hard task for the village people to change the president yearly. If someone tries to change the president, he could be punished by village politics, so the honourable post is always reserved for the same president. However, there is little responsibility with the other posts which are not so important in the KSS involvement in relation to the KSS management because other members on the managing committee are treated as general KSS farmers. A custom is observed that managers cannot do any work or take any decision without the consent of the president.

As a leader, the president should be superior to the management and he should have the right to keep other farmers involved in the KSS institution. In addition to that the manager should be responsible for what has to be done and then gets other farmers to do it.

7.2.4.4 Management and Administration

Management and administration systems are essential for a KSS institution, specially in the context of irrigation management schemes, because these involve the performance of many different activities which lead to the institution moving ahead. Management follows systematic rules and regulations which are controlled by the administration.

The feasibility of the KSS institution depends on the quality of its management systems, and in this connection the personality of the manager is of particular importance. A manager has to plan, organise, direct and control the overall system and consult the president. To begin with, a manager has to identify the objectives and then the priorities which should be clearly defined. Very specific methodologies and easily measurable performance standards should be developed in order that the efforts of the manager and his staff will be directed to attaining these objectives. However, the manager can change his mind within the existing system if he feels this would lead to improvement.

A buried pipe deep-tubewell irrigation scheme requires a good management system which will provide guidelines both for the performance of the overall scheme management function and for the performance of the specialized field activities. According to the investigation results the following management rules are suggested. Similar suggestions were made by Sagardoy et al, (1982). Recommended components of a good management system are:

a) A programming exercise should be carried out half-yearly and held just before the loan repayment. This is a general meeting at which all the KSS and non-KSS farmers concerned with cultivation under the scheme jointly and freely draw up phased work programming for the next season.

The study suggests the following stages in this programming exercise:

- Agreement for purchase of project fuel,
- Listing and agreeing the operations to be carried out,
- Agreement of any short-term loan required and method of repayment,
- Open discussion about conflicts,
- Questioning of defaulters,
- Loan repayment directly into the bank,
- Financial incentive for manager,
- Checking for feasibility, agreement and acceptance of target.

b) A general KSS meeting should be held fortnightly at which the same farmers review progress against the phased work programme, identify any problems which are impeding the progress and agree on what remedial action should be taken.

c) A monthly management report should be prepared which briefly summarises the progress made and problems encountered with the institution. Further movement is to solve the problems through the service providing agencies.

7.2.5 Non-engineering Factors Involved in Buried Pipe Schemes

The non-engineering factors can be grouped into four categories, such as **a)** Social factors, **b)** Economic factors, **c)** Institutional factors, and **d)** Political factors.

These are summarized in tabular form:

Non-engineering factors			
Social	Economic	Institutional	Political
Group conflicts	Lack of financial resources	Leadership crisis	Wages too low
Lack of interest	No budget	No experience	Lack of supervision by Upazila team
Poor knowledge of farmers	Fodder crisis for animal grazing	Poor organisation of water users	
Involvement in other professions	Lack of agricultural inputs	Poor functioning of KSS	

Many other non-engineering factors have been described in detail in the preceding sections 7.1 and 7.2. Hence, hypothesis 3 is justified, that is "non-engineering factors prevent buried pipe distribution systems in Bangladesh being utilized to their full potential".

CHAPTER 8
CONCLUSIONS AND RECOMMENDATIONS

Introduction

The study area contains varied topography and dispersed housing. It was found difficult to construct and operate open channel systems successfully in the area. Under the circumstances, buried pipe systems were found effective for distributing irrigation water over the command area. Therefore, the study was conducted to know the performance of concrete buried pipe systems. The conclusions drawn from the results of the study and recommendations are discussed in this chapter.

Conclusions and Recommendations on Performance of the Buried Pipe Distribution Systems (Objective 1)

Average pump discharge on eight schemes was 32.48 l/s, which was 58% of the design discharge (56 l/s) and the outlet discharge was 84% of the pump discharge. Own fuel system for pump operation, declining static water levels, short air vents, low engine speeds (poor performance of engines), low capacity of field channels and on demand water supply were responsible for a wide variation of pump discharges.

The measured head loss values agreed with the theoretical values where the Colebrooke-White Equation was used, with Ks (roughness height) equal to 0.6 mm. Head losses between the header tank and the first outlet were high at every scheme. Entrance loss at the inlet and maximum leakages due to higher hydrostatic head at this section might be the reasons for high head loss.

Shallow tubewells in the areas were not feasible owing to the thick sequence of upper clay and high depths to static water levels ranging from 4.5 m to 10.30 m. In the month of April, all the dugwells were about to dry and water scarcity was observed. Depletion period started from mid August and continued up to early May then the recharge period started and continued up to mid August.

Knowledge of extent and variation in conveyance losses from earthen field channels is a pre-requisite for developing strategies for irrigation systems in a region. Studies on the eight schemes showed that there were significant variations in the water losses from scheme to scheme. These varied from 5.88 l/s/100 m to 9.37 l/s/100 m, averaging to 7.69 l/s/100 m of channel length whereas the water losses from buried pipelines varied from 0.35 l/s/100 m to 1.44 l/s/100 m and with an average of 0.69 l/s/100 m length of pipeline.

This is in agreement with Rashid et al (1990), who found water losses as 9 l/s/100 m in the farmers' built open channels and 7 l/s/100 m in the improved (compacted) earth channels in the Manikganj district, Bangladesh. Water losses would be reduced by 91% by adopting buried pipelines instead of earthen open channel systems. This represents considerable saving in water and energy by the pipeline system. Moreover, due to lower transit losses in the pipelines, low conveyance losses occurred in the conveyance system and hence buried pipe systems can supply water more efficiently in both duration and timing which may not be possible in open channel systems. In buried pipe schemes, the average deep tubewell efficiency (combined efficiency of pipelines and field channels) was 69%.

Conclusions and Recommendations on the Technology of Low Pressure Buried Pipe Systems (Objective 2)

Machine made or spun pipes were superior to vertical moulded or hand made pipes which had irregular wall thickness, higher pore-space, high incidence of leakages, and generally lower strength. Machine spun pipes were found to perform better than vertical moulded pipes in terms of reducing leakages. For example, the ratio of leakages from hand made pipe to machine made pipe was about 6:1. Therefore, vertical moulded pipes should be avoided in buried pipe schemes.

A few outlets (about 20) in the systems require longer earthen field channels. For instance, on average 69 m channel length was used per plot. This longer channel led to high conveyance losses. The interviews with farmers revealed that under the circumstances, 1 cusec (28 l/s) capacity outlets, operating one at a time may be convenient instead of 2 cusec (56 l/s) capacity outlets operating one at a time. In this situation, 1 cusec deep tubewell might be appropriate.

Few outlets were damaged due to mishandling. For example, an average 18% of outlet valves were found to be collapsed. The operation of outlet valves by a specified man could reduce such damage. A few outlets were also found to be out of order due to differential settlement of freshly formed earth works under the structures. This might be overcome by making a low cost outlet structure. A few air vents were constructed unnecessarily high and outlet valves too low, even below field levels. There is considerable scope for improving the pipes, design, and construction of buried pipe systems. For instance, a field block of 1 ha provided with a separate outlet of 1 cusec (28 l/s) capacity, with the valve located at about 15 cm above the field level would be convenient.

Leakage problems were observed at all the schemes averaging 2.1 leaks for each 100 m of pipelines. This leakage problem was severe at the East Kutubpur scheme (360 leaks) and followed by the Binnakhaira scheme (43 leaks). Leakages were observed both at pipe joints and through pipe bodies. However, more leaks (58%) were found at joints. The leakage problems at joints can be attributed to inadequate jointing technology (for example, bellmouth-socket and spigot joints showed severe leakages), inexperienced masons, improper supervision during construction, use of poor quality materials and poor compaction of bed soils inside the trench on which the pipeline is laid. This may be overcome in many cases using improved technology, quality materials, and through proper supervision. On average 72% leaks were found in the section between the pump and the first outlet of each scheme. This was perhaps due to the high operating pressure. Special attention should be given to this section while constructing the system. Special care is also necessary for the pipeline that passes beneath the road.

Outlets with flat lids proved to be more water-proof than those with grooved and/or slanting edged lids. On average 42% outlet valves were found to be leaking water which was due to the mishandling of the outlet valves. Restrictions on touching the outlets by the villagers might be the solution to this problem. From the study, it was seen that 17.50% air vents were observed leaking water through their bodies which were due to the use of vertical moulded (hand made) pipes. Replacement of hand made pipes by the machine made pipes might prevent such leakages.

Very low (only 12% of advised) pump operation on the eight schemes was recorded in the buried pipe schemes. This was very disappointing. There is ample scope to increase the period of irrigation up to 8 times. Again own fuel system, low area under boro-rice, high fuel cost, farmers preferring to wait for rainfall rather than buying fuel and getting water, disturbance of the engine, conflicts among the farmers and shortage of financial resources or the inefficient management and management systems were mainly responsible for this low pump operation.

It was found that the "farmers fuel" and the "first come first served" systems (refer to section 2.2.9) have certain disadvantages. For example, rotational water distribution could not be followed, frequent switching of the operation from pipeline to pipeline could not be stopped, and flow to more than one channel from an outlet could not be allowed. Only one outlet was opened at a time, receiving the full tubewell discharge through that outlet. Moreover, water was supplied to the farmers in the order in which they arrived at the pump house. This led to frequent switching between pipelines and resulted in unnecessary losses of water in repeatedly filling of the pipelines. On average 8.52% pumping time was lost by this method of operation. The lost time depends on the number of changes of pipelines during each day of pump operation. The lost time could be recovered by following outlet rotation within the pipeline. Farmers could be grouped outletwise i.e. water supply to the farmers' under an outlet should be completed and then move to the next outlet. An outlet rotation within the pipeline is important based on soils, crops, land topography and climatic conditions. Duration of rotation is to be decided by the management. The important point is the sequence of rotation and not the duration. More irrigation costs, unequal water distributions, social conflicts and dissatisfaction in getting the irrigation water could be overcome by following an outlet rotation.

Some outlets were never used because of absentee landowners. The use of many outlets were very low throughout the season. For example, on average 3.47 outlet alfalfa valves were used per day of pump operation. To justify the buried pipelines economically the use of these low use outlets will have to be increased significantly. However, most field channels were observed very poor, undersized, uncompacted, irregular in shape and with very low banks. Spillage occurred most frequently. Therefore, scheduling maintenance work is essential.

In own fuel system, the use of different graded fuel creates trouble to the nozzle of the engine, resulting in poor performance of the engine. There was no fixed budget for servicing the engine, leading to high oil consumption (greater than 1% of fuel consumption in five schemes out of eight). Reason for not servicing the engine was probably the weak KSS management. Moreover, the poor performance of the scheme resulting from the use of own fuel system led to irregular payment of water charge and thus the pump was not run smoothly nor according to schedule. This also resulted in varied and/or longer irrigation intervals. Sometimes the engine was unused for 5 to 10 days for want of lubricating oil, as oil charge was not collected in time. The high rise (double) in prices of spare-parts within a year was another reason for the poor maintenance of engine.

Conclusions and Recommendations on the Water Management Practices Under Buried Pipe Distribution Systems (Objective 3)

The average command area was only 16.64 ha, which was about half of the intended command area which could be irrigated. This is very similar to the reported values under open channel systems elsewhere in Bangladesh. The inefficient pump operation and ineffective management systems were mainly responsible for the low command area and not the shortcomings of the technology. Extremely low pump operation (3.47 hrs/day and 14 days/month) and much fallow land (40% of the gross command area) were observed. The main reasons for more fallow land were the use of own fuel system for pump operation, large farmers involved in other businesses, absentee landowners, fear of pump breakdown, fodder crisis for animal, shortage of funds, high prices of agricultural inputs, shortage of draft power, sloping land, inappropriate cropping pattern, inability of small and marginal farmers to manage inputs, natural hazards and conflicts among the farmers. These constraints need to be overcome to increase the irrigated area to around 40 ha and the pump operation which can be advised up to 20 hours/day and 26 days/month, so that the economic performance of the buried pipelines can be improved.

Although flow rate through every outlet on the same pipeline was the same, water distribution patterns under farmers' practices were non-uniform for all the three main schemes. This was also true for one area to other areas (head to tail) in the same scheme under the study. The performance of the irrigation system in terms of equity, reliability and availability in distribution of water using buried pipe systems was not satisfactory. This was mainly for hotch-potch management systems and not the shortcomings of the technology.

Replacement of earth channels by buried pipes showed land saving which was 1.40% of the gross command area that could be used for extending the command area. Saving of land by 1.40% indicates the land area of 0.56 ha with values estimated at Tk 1,38,376.00[1] during 1991.

Areas of irrigated cultivation under most crops were small. For example, 15% area was covered by boro-rice, 29% by wheat, 16% by watermelon and 12% area was occupied by soybean. These were the major crops in the scheme areas. Wheat was the first major crop. Low investment, less intercultural practices,

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[1] Tk = Taka, Bangladesh currency
1 $ US = Tk 38.40, 1991

and less water requirements were the reasons for wheat cultivation. The intercropping system was more profitable than single cropping systems.

Farmers applied low doses of fertilizer for all the crops at all the schemes. Farmers were not aware of the above facts. However, insect attacks were also observed in the crop fields. On average Basudin-10 was applied 23% of the recommendation and Diazinon-60 was applied 35% of the recommendation. Farmers applied insecticides at a very low dose due to high prices of the insecticides. Moreover, pure insecticides were rarely found in the market.

Planting time for each crop was found to vary widely from scheme to scheme. Possible causes were the maturity of preceding crops, shortage of draft power, lack of agricultural inputs and lack of manpower in the case of large farmers.

Yield for each crop was much lower than the national average. Low application of fertilizer and insecticides, irrigation water, and outdated cultural practices and poor crop management were the reasons for low yield. To promote and sustain irrigated agricultural crop yield, agronomic and wateruse related problems should be addressed.

The yields of wheat and watermelon were significantly influenced by the decrease in the amount of under-irrigation (total irrigation water requirements using CROPWAT minus total irrigation applied), which has a great negative impact on crop yields. Under-irrigation leads to excess depletion (soil moisture depletion below the average allowable depletion level) as well as depleted days, which have significant effects on crop yields in irrigated agriculture. For wheat crops, the average cost of 1 mm of irrigation water has the value of Tk 30.67 and each 3.60 mm of under-irrigation causes a reduction in yield of 1%, which has a value of Tk 139.00, that is, Tk 28.59 more than the cost of the water. For watermelons, each 2.13 mm of under-irrigation causes a reduction in yield of 1%. The average cost of 1 mm of irrigation water for watermelon was estimated Tk 21.40 and the value of 1% yield of watermelon was Tk 118.00, that is, Tk 72.42 more than the cost of the water. In the case of soybeans, no response to under-irrigation was found because soybean was a new crop and farmers were still in a trial and error stage to accommodate this crop into a stable cropping pattern.

Excess irrigation application incurs extra charges and similarly inadequate irrigation results in low yield and incurs economic losses too. Lack of awareness and uncontrolled application of water might be the reasons for irrigation losses. In other words, improper timing with quantity of irrigation results in irrigation losses, which usually occur either by surface runoff or by deep percolation.

Depleted days just before the harvesting time for any crops have less effect on the crop yield than depletion at other times within the crop growing period.

Conclusions and Recommendations on Institutions (Objective 4)

The president and the manager in the KSS act as the chief executives in each scheme. The average number of the KSS meetings per season was 8 (the prescribed number of meetings per dry season is 20) and poor attendance averaging only 27% members were present per meeting. In practice, they do not now meet weekly.

Irrigation charge was distributed over the total area irrigated. The average water charge was collected 73% of the targeted amount, which was high in comparison to other areas in Bangladesh. Maximum water charge (85%) was collected at East Kutubpur because of the interference of police, which had serious social consequences.

Maintenance and servicing were very poor, resulting in more engine trouble and high irrigation cost averaging Tk 3445.00/ha. As the manager did not get any salary from the management, he did not take a keen interest in the proper maintenance of the engine. A small incentive would compensate the manager and could increase the efficiency of the schemes.

Poor coordination among the service providing departments was observed. It is necessary for the Upazila (sub district) officers and local staff concerned to visit the farmers as well as fields to get acquainted with the field situations and know the problems so that they can offer the right solution and proper advice. In modern agriculture, a multi-disciplinary approach and coordinated efforts are essential. In addition to that, effective extension services are essential to make the buried pipe schemes attractive and profitable.

Loan payments were found irregular in the scheme areas. Shortage of funds, lack of motivation, crop damage by natural hazard, crop failure due to engine breakdown, money collected from farmers being used sometimes for the personal business of the manager, social conflicts, grouping and also non-interest were the reasons for not paying the due loans on time.

Poor crop management (e.g., inadequate irrigation, fertilizer application, improper planting time and outdated cultural practices) was probably the reason for the poor Benefit-Cost-Ratio (BCR) values of some crops. Considering the economic feasibility, the buried pipe schemes were estimated to be economically attractive, because the BCR value was greater than 1.0 for all the schemes, even though the farmers were found to be not well organised.

Twenty-five performance indicators have been listed as the output measures of a KSS institution under buried pipe irrigation schemes. These indicators are invaluable for development, control and evaluation. These performance indicators also indicate the strengths and weaknesses of a KSS institution.

All the members of the managing committee should have the necessary technical knowledge to solve any management problems that may arise in the KSS body. However, some large farmers' influence have sometimes had negative impacts on sustaining an effective management system which could be controlled by the help of service providing agencies.

It is possible to strengthen the existing system in such a way that service providing agencies encourage the farmers to participate in the KSS meeting and make the farmers understand the maximum benefits and profit potentials that they may obtain from the proper utilization of irrigation water.

Conclusions and Recommendations on Improvement and Extension of the Buried Pipe Distribution Systems in Bangladesh (Objective 5)

The buried pipe distribution systems in Bangladesh need some improvements in terms of design and distribution of water. These improvements are described in the preceding sections of conclusions on objectives 1, 2, 3 and 4 separately. However, these are also summarized below. It is possible to extend the use of the buried pipe system in Bangladesh by following the improvements suggested in this section.

Improvements on design aspects

1. Pipes must be sized and designed to deliver the design discharge within the allowable friction. In pipe distribution systems, this is set by the difference between the head available at the inlet to the pipe system and the operating pressure required at the critical outlet.

2. After confirming the pipe network and alignment, position of air release structures can be selected. The height of air vents is selected according to the hydraulic design. Hand made or vertical moulded pipe should be avoided for construction of the air vents.

3. Machine spun pipes performed better than hand made or vertical moulded pipes. Vertical moulded pipes should be avoided in buried pipe schemes.

4. The plane-end pipe jointing has proved less expensive and simpler to construct.

5. Outlets with flat lids proved to be more water-proof than those with grooved and/or slanting edged lids.

6. A low cost concrete structure or non-eroding materials like small stone or brick-chips (acting like covers) with a thickness of 150 mm and radius of 1 m surrounding the outlet structure can control erosion in the vicinity of each outlet.

7. Buried pipe systems are more economical than earthen open channel systems in terms of reducing seepage loss and costs.

Improvements on distribution of water

1. Pump operation could be possible to increase the period of irrigation up to 8 times.

2. An appointment of a fieldman for each scheme might help to improve the overall distribution system. A small incentive would compensate the manager and could increase the efficiency of the schemes.

3. One cusec (28 l/s) capacity outlets, operating one at a time may be convenient instead of 2 cusec (56 l/s) capacity outlets operating one at a time and 1 cusec deep tubewell might be appropriate.

4. An outlet rotation within the pipeline is important based on soils, crops, land topography and climatic conditions. The important point is the sequence of rotation and not the duration. Farmers could be grouped outletwise i.e. water supply to the farmers' under an outlet should be completed and then move to the next outlet on the same pipeline and after that move to the next pipeline.

5. To keep engine condition good, project fuel (farmers' cooperative fuel) is essential instead of farmers' fuel system, which causes an enormous problems in the management system.

6. Field visits by staff of the extension service should be sufficient and interaction between farmers and extension workers should be increased. Coordination between field departments within the extension services should be strengthened.

Conclusions on Hypothesis 1

The hypothesis was tested considering 81 measurements. It was found that the relationships between depth of water application and distance from the deep tubewell to different outlets for all the crops were shown to be insignificant (from statistical analysis). This results from buried pipe irrigation schemes where depths of water application have no influence on the position of the schemes (see Figures D.2 to D.5 in Appendix D). Hence, hypothesis 1 is true, that is "with a buried pipe distribution system the quantity of water delivered to a field is independent of the position of the outlet which serves that outlet".

Distances between the plot and the water sources either from outlets or from deep tubewells via outlet have no influence on yield of wheat, soybean and boro-rice in the buried pipe irrigation schemes. The result from the study shows that there was no significant difference between top enders and tail enders on the buried pipe system, and the position in the scheme did not influence yield. This is in marked contrast to open channel distribution systems elsewhere in Bangladesh. This is one advantage of the buried pipe scheme where all the farmers benefit equally from this system.

The yield of watermelon increases with distance from the outlet and distance from the deep tubewell. The reasons are that farmers give more emphasis to this crop because it is more profitable, and water-logging was observed on plots close to the water source.

Conclusions on Hypothesis 2

Water balance figures have been prepared satisfactorily, following FAO procedures, and used to assess the adequacy of irrigation. From the water balance figures, the average allowable depletion level represents the maximum allowable depletion area. If the depletion depth exists within the area, there will be no effect on the yield of crops, but if the depletion depth exceeds this limit, the crop yields will be reduced. The soil moisture depletion curve resulting from the environmental conditions indicates the trend of soil moisture depletion within the growing period whereas an irrigation curve represents the timing of irrigation as well as irrigation interval and depth of application. This irrigation curve is very important for representing the requirement of irrigation water. Most of the Figures show that 2 to 3 irrigations is enough to keep the soil moisture sufficient within the allowable depletion area throughout the growing season. Therefore, much water can be saved following this water balance model. Hence, hypothesis 2 is accepted, that is "graphical methods based on FAO procedures are useful for representing and extending data on the timing and application depths of field irrigation".

Conclusions on Hypothesis 3

Important factors and their effects are described in the conclusions on objectives 2, 3 and 4. Non-engineering factors were categorized such as social, economic, institutional and political affairs. For example, group conflicts under social factors were due to the poor knowledge of farmers; constraints of financial resources were under the economic factors; lack of leadership was the institutional factor; and under the political issue, low wage rate was one of the factors. These factors were observed to be followed by the farmers' cooperative. These prevent the proper operation of the buried pipe scheme in the study area. Many other non-engineering factors have been listed in detail in the sections 7.1 and 7.2. Hence, hypothesis 3 is justified, that is "non-engineering factors prevent buried pipe distribution systems in Bangladesh being utilized to their full potential".

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APPENDIX A (Figures A.1 to A.5)

Figure A.1

Buried Pipe Layout (Baila)

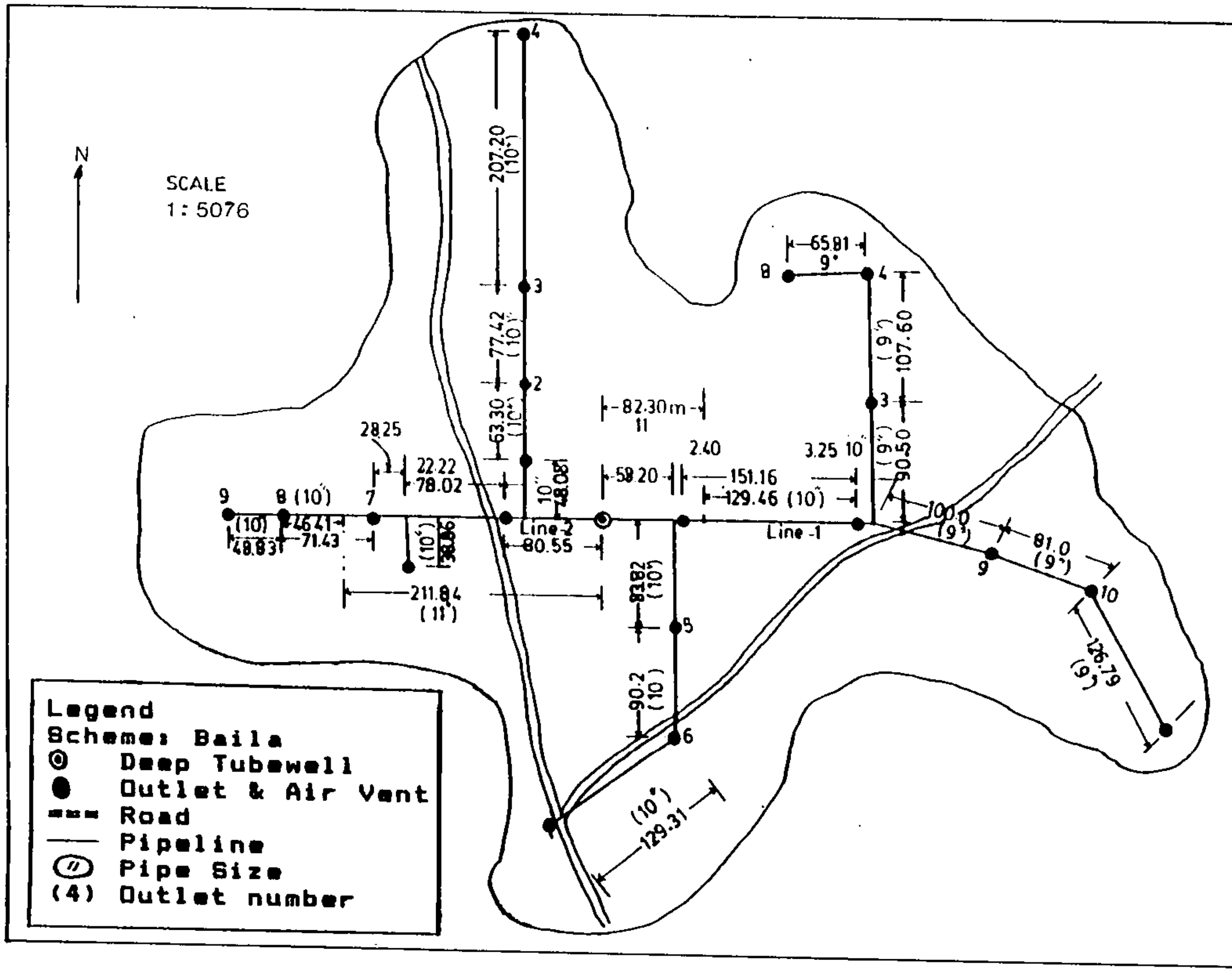


Figure A.2

Buried Pipe Layout (Vailpara)

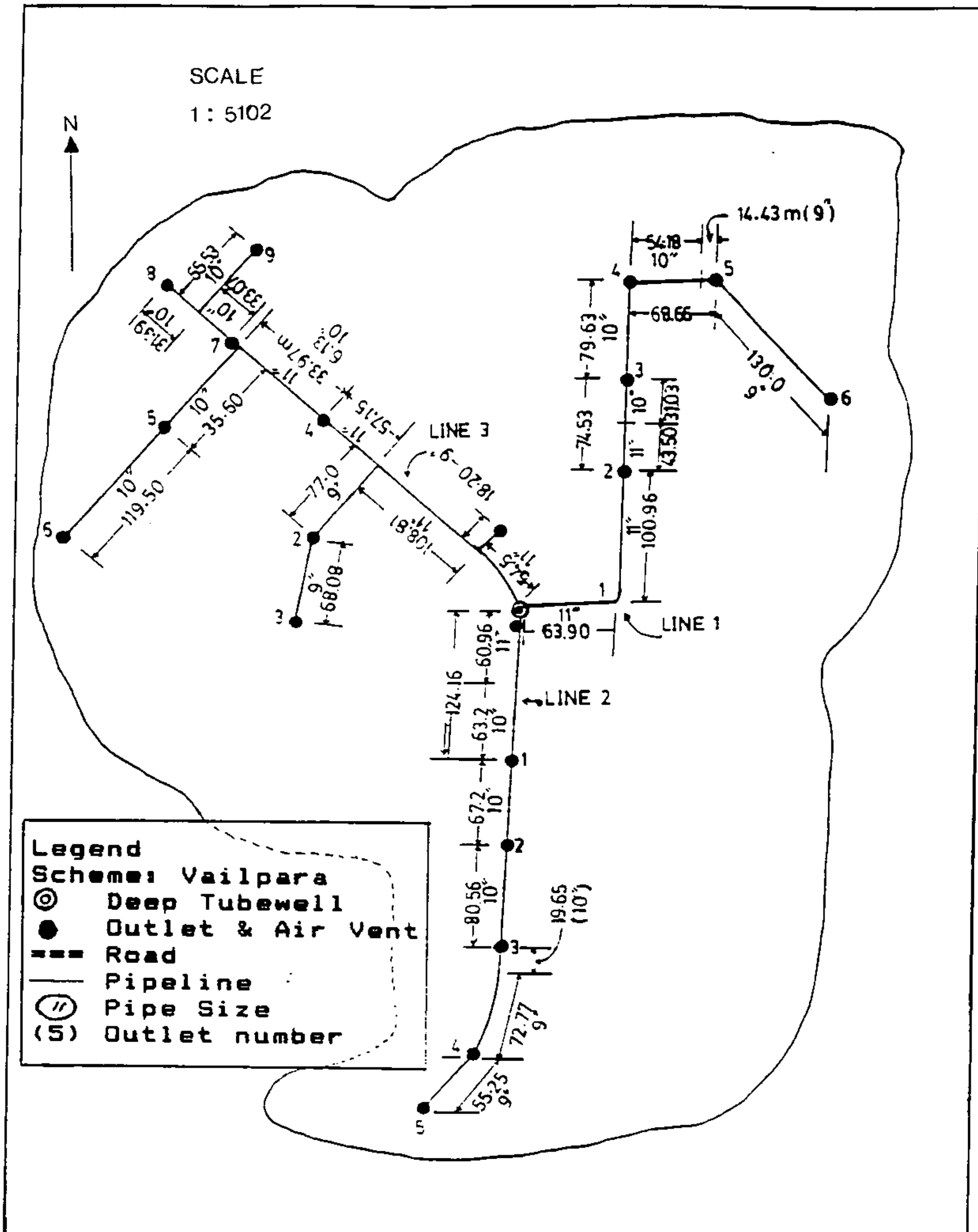


Figure A.3

Buried Pipe Layout (Chulabar)

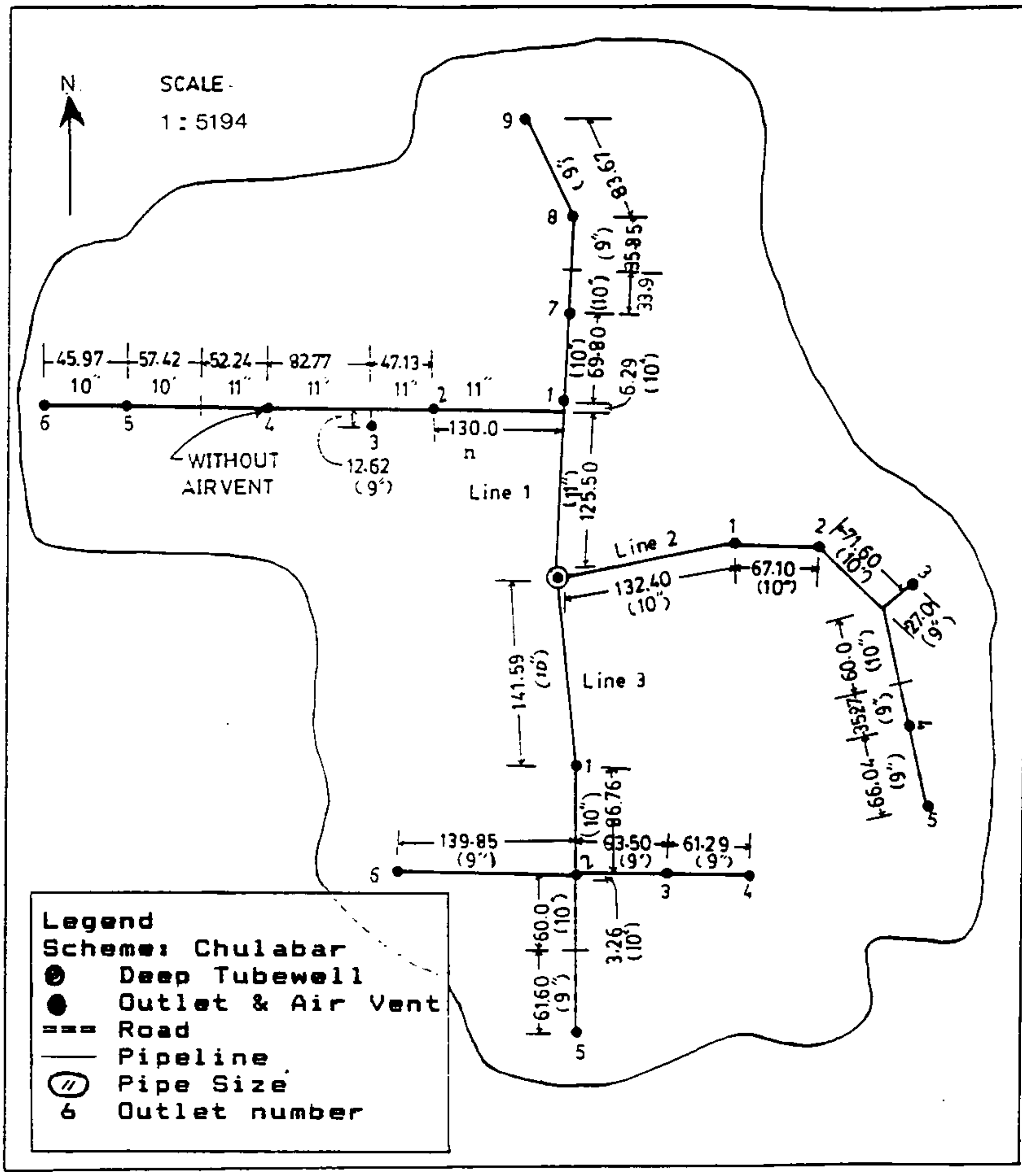


Figure A.4

Buried Pipe Layout (Hazipara)

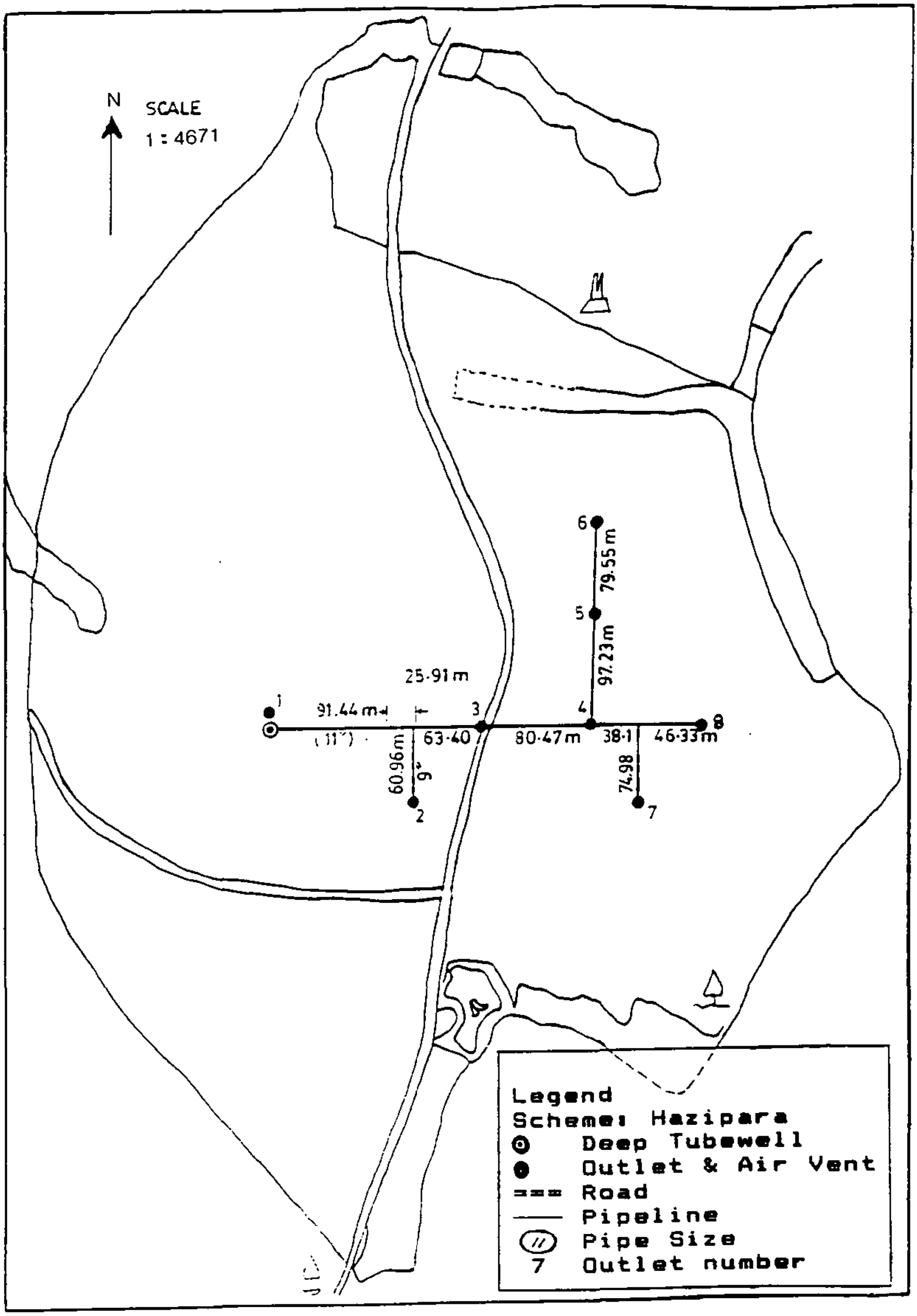
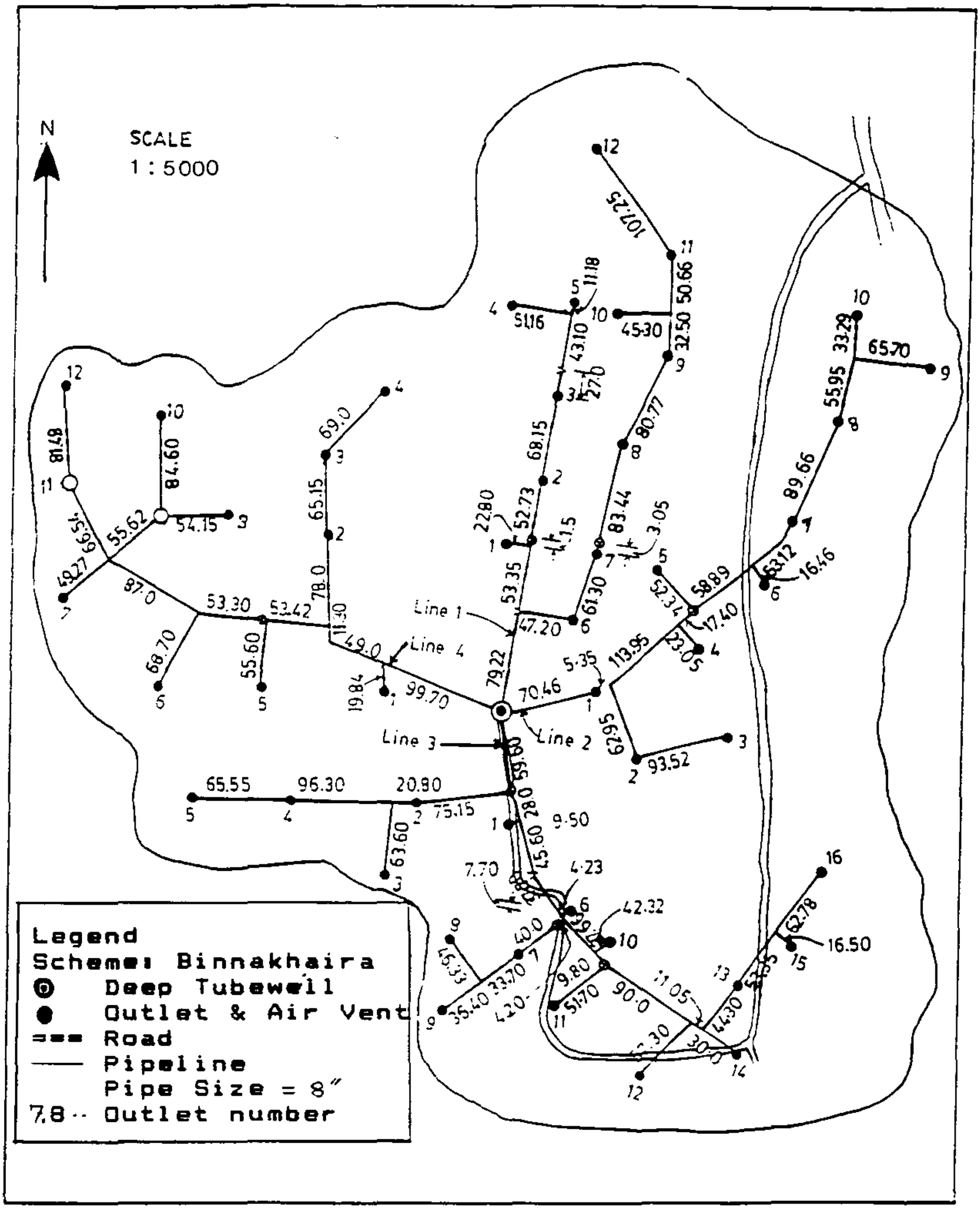


Figure A.5

Buried Pipe Layout (Binnakhaira)



APPENDIX B

Table B.1 Intervals and Numbers of Irrigation (1989-90)

Schemes	Crop	Intervals (days)		Irrig.	Observation
		Ranges	Average	no.	no.
Taltolapara	Wheat (HYV)	9-41	31	2-4	35
	Soybean (HYV)	32	32	1-2	8
	Chilli (LV)	20-40	31	2-3	6
	Boro-rice (HYV)	1-12	3	19-22	7
	Sweetpotato (LV)	31-51	37	2	4
	Watermelon (HYV)	18-22	20	4	2
	Cauliflower (HYV)	20	20	6	2
	Potato (HYV)	20-30	24	4	2
East Kutubpur	Wheat (HYV)	14-40	26	1-3	18
	Soybean (HYV)	12-35	24	1-3	11
	Chilli (LV)	26-55	40	1-3	4
	Potato (HYV)	33	33	1-2	2
	Mustard (LV)	25-50	38	2-3	5
	Garlic (LV)	24-49	39	3	2
	Cotton (HYV)	25-31	28	5	1
	Banana (HYV)	110-114	112	3	4
Shaplapara	Wheat (HYV)	7-42	30	2-4	11
	Soybean (HYV)	23	23	1-2	3
	Boro-rice (HYV)	1-25	8	9-17	10
	Watermelon (HYV)	2-76	46	1-6	33
	Sweetpotato (LV)	31	31	2	5
	Banana (HYV)	31-34	33	3	2
	Potato (HYV)	31	31	2	2

Table B.2 Intervals and Numbers of Irrigation (1990-91)

Schemes	Crop	Intervals (days)		Irrig.	Observation
		Ranges	Average	no.	no.
Taltolapara	Wheat (HYV)	8-47	33	1-5	25
	Soybean (HYV)	13-43	20	1-6	8
	Chilli (LV)	20-61	36	2-3	3
	Boro-rice (HYV)	1-19	3	12-22	2
	Watermelon (HYV)	6-56	39	2-8	18
	Cauliflower (HYV)	15-22	19	3-5	3
East Kutubpur	Wheat (HYV)	14-49	27	2-3	14
	Chilli (LV)	19-55	33	3-4	3
	Boro-rice (HYV)	1-3	2	22	1
	Watermelon (HYV)	41-44	43	3	1
Shaplapara	Wheat (HYV)	24-36	30	3	3
	Soybean (HYV)	4-71	21	2-5	9
	Boro-rice (HYV)	1-14	4	10-20	7
	Watermelon (HYV)	9-57	16	4-6	4
	Chilli (LV)	20-52	35	2-4	2

Table B.3 Used Fertilizer at the Sample Plots

Crops	Fertilizer doses	Farmers`practices (Average kg/ha)	Recommendation(kg/ha) Low fertile soil	Medium fertile soil
Wheat(HYV)	Urea(Basal)	-	87	58
	Urea(Top dress)	25 - 80	174	116
	TSP(Basal)	45 - 115	178	133
	MP(Basal)	35 - 95	133	100
	Gypsum(Basal)	-	111	56
	Zinc(Basal)	-	22	5.5
Boro-rice(HYV)	Urea(Top dress)	90 - 215	304	217
	TSP(Basal)	45 - 165	222	178
	MP(Basal)	32 - 112	167	100
	Gypsum(Basal)	47 - 85	167	83
	Zinc(Basal)	-	22	11
Soybean(HYV)	Urea(Basal)	-	22	22
	Urea(Top dress)	30 - 42	22	22
	TSP(Basal)	45 - 136	133	89
	MP(Basal)	33 - 124	133	67
	Gypsum(Basal)	-	111	-
	Zinc(Basal)	-	11	-
Sweetpotato (LV)	Urea(Basal)	-	87	65
	Urea(Top dress)	-	87	65
	TSP(Basal)	43 - 150	178	89
	MP(Basal)	23 - 58	200	100
	Cowdung(Basal)	340 - 520	10000	5000
	Ash(Basal)	850 - 1200	-	-
Potato (HYV)	Urea(Basal)	-	196	152
	Urea(Top dress)	110 - 155	196	152
	TSP(Basal)	80 - 162	311	222
	MP(Basal)	53 - 205	300	233
	Gypsum(Basal)	53 - 85	111	56
	Zinc(Basal)	-	11	5.5
Chilli(LV)	Urea(Basal)	32 - 115	217	174
	TSP(Basal)	45 - 177	333	222
	MP(Basal)	-	200	117
	Gypsum(Basal)	-	111	56
	Zinc(Basal)	-	11	-
	Cowdung(Basal)	1000-1200	10000	6000
Mustard(LV)	Urea(Basal)	-	217	196
	Urea(Top dress)	63 - 133	217	196
	TSP(Basal)	110 - 212	311	267
	MP(Basal)	55 - 95	100	67
	Gypsum(Basal)	-	111	111
	Zinc(Basal)	-	11	11
	Cowdung(Basal)	1250-1300	10000	8000
	Ash(Basal)	450-850	-	-

Table B.3 Continued

Onion(LV)	Urea(Basal)	-	109	76
	Urea(Top dress)	43 - 76	109	76
	TSP(Basal)	105 - 172	333	178
	MP(Basal)	42 - 70	333	250
	Gypsum(Basal)	-	222	111
	Ash(Basal)	350-500	-	-
Radish(LV)	Urea(Basal)	-	163	109
	Urea(Top dress)	85	163	109
	TSP(Basal)	85	178	133
	MP(Basal)	85	133	100
	Cowdung(Basal)	1950	-	-
Garlic(LV)	Urea(Basal)	-	109	76
	Urea(Top dress)	50	109	76
	TSP(Basal)	183	267	178
	MP(Top dress)	151	333	250
	Gypsum(Basal)	33	111	56
	Manure (Basal)	-	5000	5000
Brinjal(HYV)	Urea(Basal)	-	367	293
	Urea(Top dress)	135	448	359
	TSP Basal)	175	222	178
	MP(Basal)	135	188	150
	MP(Top dress)	-	229	183
	Cowdung(Basal)	-	15000	10000
	Ash(Top dress)	2700	-	-
Cotton(HYV)	Urea(Basal)	-	87	65
	Urea(Top dress)	125	174	130
	TSP(Basal)	80	178	111
	MP(Basal)	130	150	100
	Gypsum(Basal)	-	111	56
	Zinc(Basal)	-	14	-
	Cowdung(Basal)	1600	10000	7000
	Ash(Basal)	1600	-	-
Watermelon (HYV)(2500 pits/ha)	Urea(Basal)	-	109	87
	Urea(Top dress)	(22.5 g/pit)56	109	87
	TSP(Basal)	(100 g/pit) 250	178	89
	MP(Basal)	(50 g/pit) 125	167	125
	Cowdung(Basal)	(2 kg/pit) 5000	30000	22000
	Oilcake(Basal)	(50 g/pit) 125	-	-
Banana(HYV) (2225 pits/ha)	Urea(Basal)	- -	163	109
	Urea(Top dress)	(45 g/pit) 100	163	109
	TSP(Basal)	(225 g/pit) 500	111	56
	MP(Basal)	(110 g/pit) 250	333	167
	Oilcake(Basal)	(110 g/pit) 250	500	-
	Cowdung(Basal)	(3.5 kg/pit) 8000	15000	-

Note: HYV = high yielding varieties and LV = local varieties

Table B.4 Crops Period (1989-90)

Schemes	Crops	Crop period: Planting time	Crop period: Harvesting time	Area deci.(m^2)	Obs. (plot No.)
Taltolapara	Wheat(HYV)	11-11-89 to 21-12-89	09-03-90 to 10-04-90	415(16,795)	35
	Soybean(HYV)	20-01-90 to 25-01-90	28-04-90 to 04-05-90	82(3318)	8
	Boro-rice(HYV)	11-02-90 to 13-02-90	12-05-90	76.5(3065)	7
	Chilli(LV)	06-10-89 to 17-10-89	02-04-90 to 29-04-90	44(1781)	6
	Sweetpotato(LV)	12-11-89 to 18-11-89	01-03-90 to 17-04-90	38.5(1558)	4
	Onion(LV)	13-01-90 to 14-01-90	29-04-90 to 01-05-90	29(1174)	3
	Watermelon(HYV)	16-12-89 to 27-12-89	02-05-90 to 04-05-90	34(1376)	2
	Cauliflower(HYV)	19-11-89 to 21-11-89	24-01-90	20(809)	2
	Potato(HYV)	21-12-89	11-03-90	17(688)	2
	Brinjal(HYV)	07-10-89	26-04-90	3(122)	1
East Kutubpur	Wheat(HYV)	09-12-89 to 24-12-89	31-03-90 to 01-04-90	187(7568)	18
	Soybean(HYV)	15-12-89 to 10-02-90	09-04-90 to 18-05-90	86(3480)	11
	Mustard(LV)	14-10-89 to 30-10-89	02-02-90 to 27-02-90	97(3926)	5
	Chilli(LV)	15-09-89 to 24-09-89	28-02-90 to 11-04-90	16(648)	3
	Watermelon(HYV)	16-12-89	23-04-90 to 24-04-90	12(486)	2
	Potato(HYV)	09-11-89 to 15-11-89	12-02-90 to 13-02-90	20(809)	2
	Garlic(LV)	12-11-89 to 15-11-89	05-04-90 to 14-04-90	20(809)	2
	Datashak(LV)	02-03-90 to 03-03-90		9(364)	2
	Cotton(HYV)	30-08-89	22-03-90	20(809)	1
	Banana(HYV)	25-03-89 to 15-04-89	10-04-89 to 15-05-90	25(1012)	3
	Radish(LV)	21-11-89	05-02-90	10(405)	1
	Aroids(LV)	13-11-89	06-03-90	5(202)	1
		07-03-90	-	5(202)	2
Shaplapara	Watermelon(HYV)	01-01-90 to 13-01-90	24-04-90 to 10-05-90	329(13,314)	33
	Wheat(HYV)	01-12-89 to 04-01-90	28-03-90 to 05-04-90	103(4168)	11
	Soybean(HYV)	08-01-90 to 15-01-90	28-04-90 to 04-05-90	45(1821)	3
	Boro-rice(HYV)	11-02-90 to 28-02-90	13-05-90 to 22-05-90	228(9227)	10
	Sweetpotato(LV)	15-11-89 to 22-12-90	28-04-90 to 08-05-90	33(1335)	5
	Onion(LV)	04-02-90 to 08-02-90	28-04-90 to 03-05-90	20(809)	2
	Potato(HYV)	10-11-89 to 15-11-89	13-02-90 to 28-02-90	14(567)	2
	Mustard(LV)	30-10-89	02-02-90	18(728)	1
	Banana(HYV)	14-04-89 to 30-04-89	09-04-90 to 13-04-90	42(1700)	2

Table B.5 Crops Period (1990-91)

Schemes	Crops	Crop period: Planting time	Crop period: Harvesting time	Area deci.(m^2)	Obs. (plot No.)
Taltolapara	Wheat(HYV)	01-12-90 to 26-12-90	18-03-91 to 31-03-91	325(13153)	42
	Watermelon(HYV)	28-12-90 to 29-01-91	13-04-91 to 29-04-91	234(9470)	20
	Soybean(HYV)	03-01-91 to 19-01-91	11-04-91 to 14-04-91	66(2671)	8
	Cauliflower(HYV)	02-11-90 to 27-11-90	25-01-91 to 28-02-91	20(809)	4
	Chilli(LV)	03-10-90 to 01-03-91	06-04-91	28(1133)	3
	Boro-rice(HYV)	17-03-91	25-05-91	26(1051)	1
	Sweetpotato(LIV)	14-11-90	03-04-91	4(162)	1
	Brinjal(HYV)	28-10-90	14-04-91	10(405)	1
	Sugarcane(LV)	23-12-89	05-03-91	12(486)	1
East Kutubpur	Wheat(HYV)	11-11-90 to 19-12-90	05-03-91 to 30-03-91	346(14002)	36
	Watermelon(HYV)	27-12-90 to 09-01-91	16-04-91 to 28-04-91	46(1862)	4
	Sweetpotato(LIV)	09-09-90 to 10-09-90	07-02-91 to 14-02-91	26(1052)	2
	Sweetgourd(LV)	28-08-90 to 09-09-90	01-02-91 to 07-02-91	20(809)	2
	Mustard(LV)	10-11-90 to 14-11-90	02-01-91 to 04-01-91	33(1335)	2
	Chilli(LV)	11-01-91 to 22-02-91	-	42(1700)	5
	Cotton(HYV)	24-08-90	18-02-91	30(1214)	1
	Boro-rice(HYV)	08-02-91	11-05-91	10(405)	1
Shaplapara	Wheat(HYV)	11-12-90 to 20-12-90	15-03-91 to 24-03-91	74(2995)	8
	Watermelon(HYV)	05-01-91 to 04-02-91	14-04-91 to 30-04-91	175(7082)	19
	Boro-rice(HYV)	26-01-91 to 09-03-91	03-05-91 to 24-05-91	215(8701)	9
	Soybean(HYV)	25-12-90 to 01-02-91	14-04-91 to 26-04-91	359(14529)	24
	Cauliflower(HYV)	20-10-90 to 02-11-90	20-01-91 to 23-01-91	25(1012)	2
	Mustard(LV)	04-12-90 to 08-12-90	11-02-91	39(1578)	3
	Lentil(LV)	04-12-90 to 08-12-91	11-02-91 to 13-02-91	21(850)	3
	Chilli(LV)	13-10-90 to 10-02-91	20-03-91 to 06-06-91	21(850)	2
	Cabbage(HYV)	07-12-90	06-03-91	6(243)	1
	Radish(LV)	30-11-90	05-01-91	34(1376)	1
	Ashgourd(LV)	09-01-91	10-06-91 to 15-06-91	32(1295)	2
	Coriander(LV)	20-10-90	20-03-91	6(243)	1

APPENDIX C

Water Balance for Wheat (Figures C.1 to C.35)

Fig C.1 Water Balance for Wheat Crop
at Taltolapara (Sample 3-3, Plot 20)

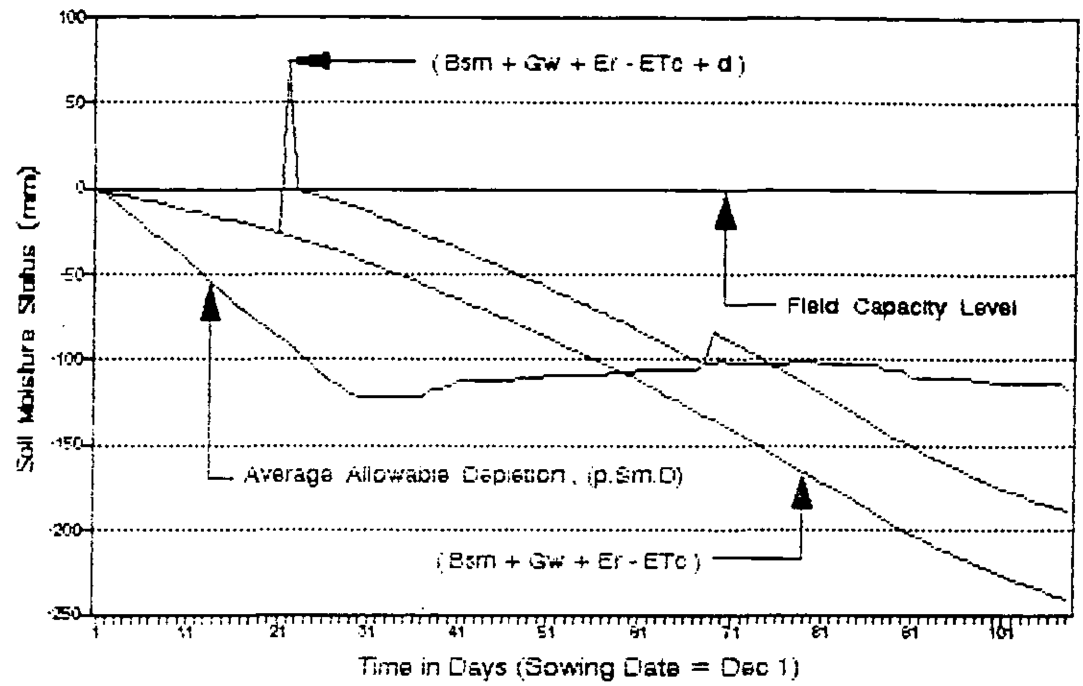


Fig C.2 Water Balance for Wheat Crop
at Taltolapara (Sample 3-3, Plot 23)

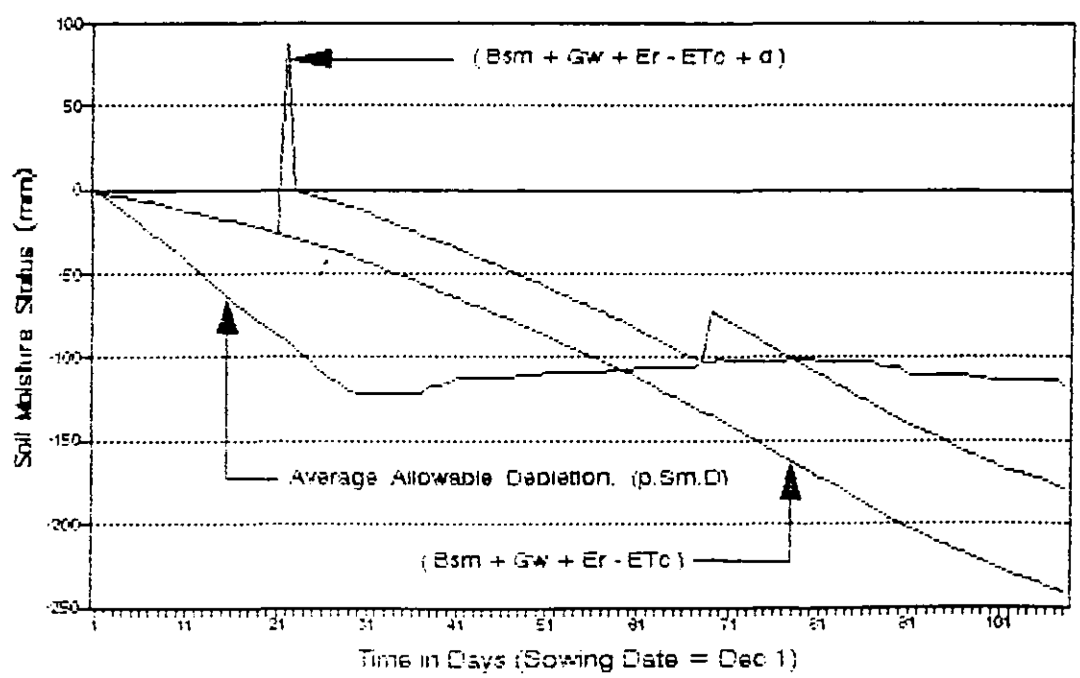


Fig C.3 Water Balance for Wheat Crop at Taltolapara (Sample 3-3, Plot 24)

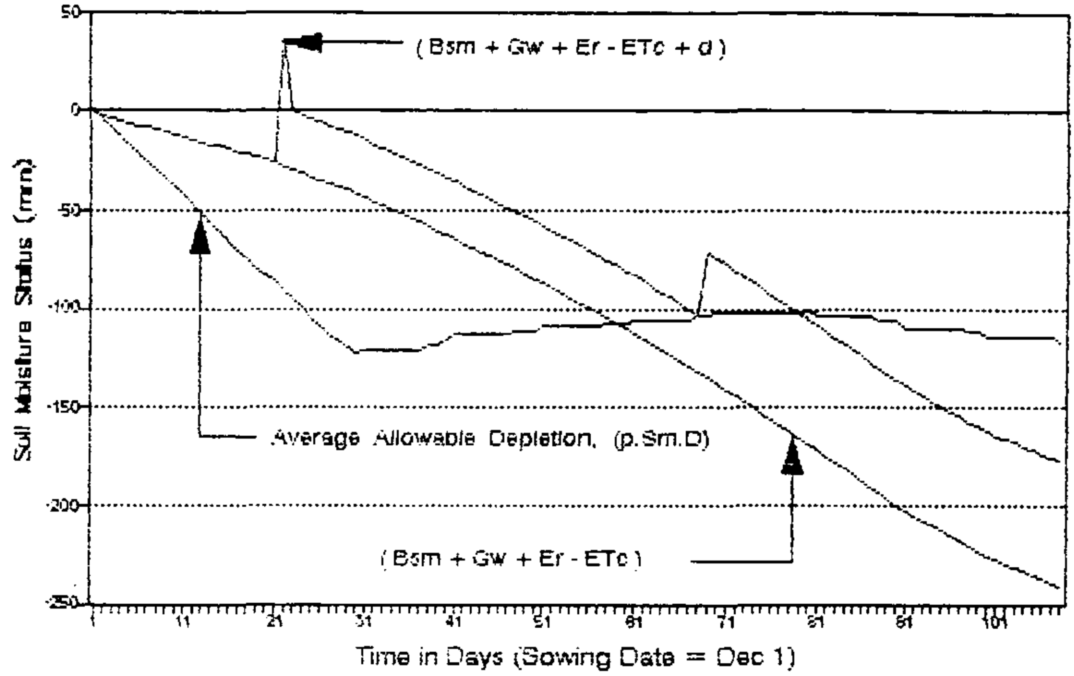


Fig C.4 Water Balance for Wheat Crop at Taltolapara (Sample 3-3, Plot 25)

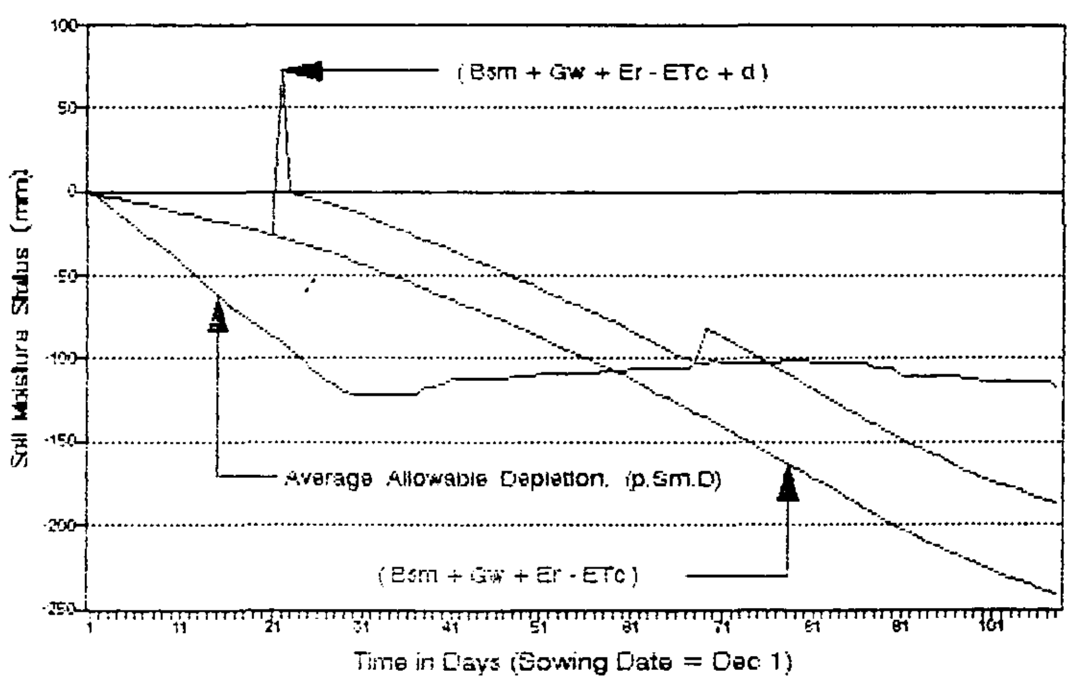


Fig C.5 Water Balance for Wheat Crop at Taltolapara (Sample 3-3, Plot 22)

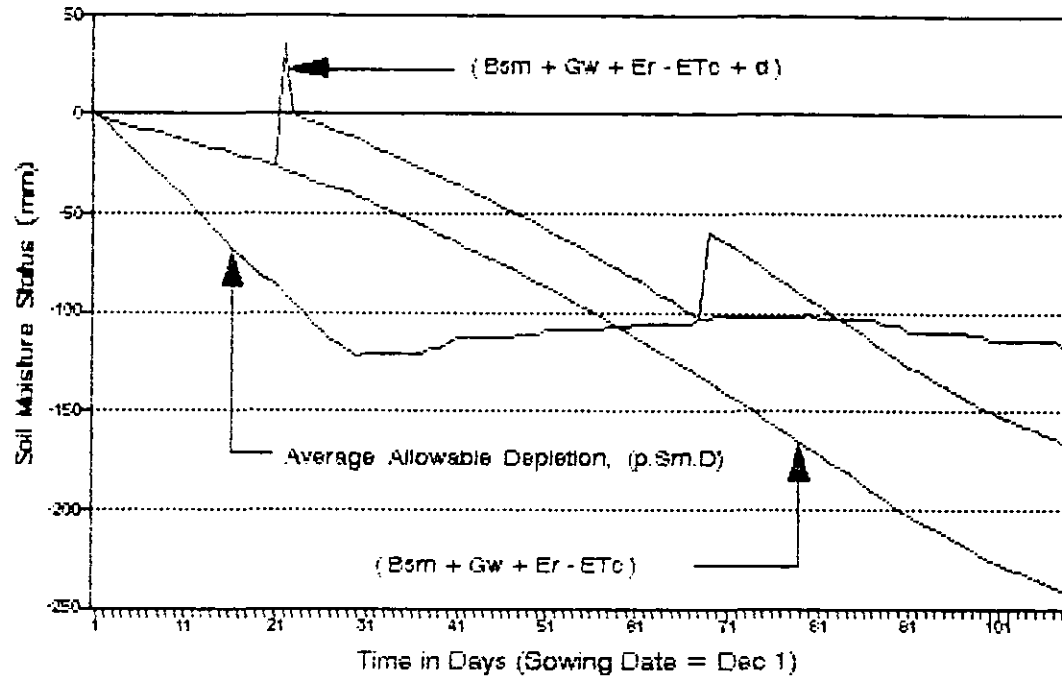


Fig C.6 Water Balance for Wheat Crop at Taltolapara (Sample 3-3, Plot 16)

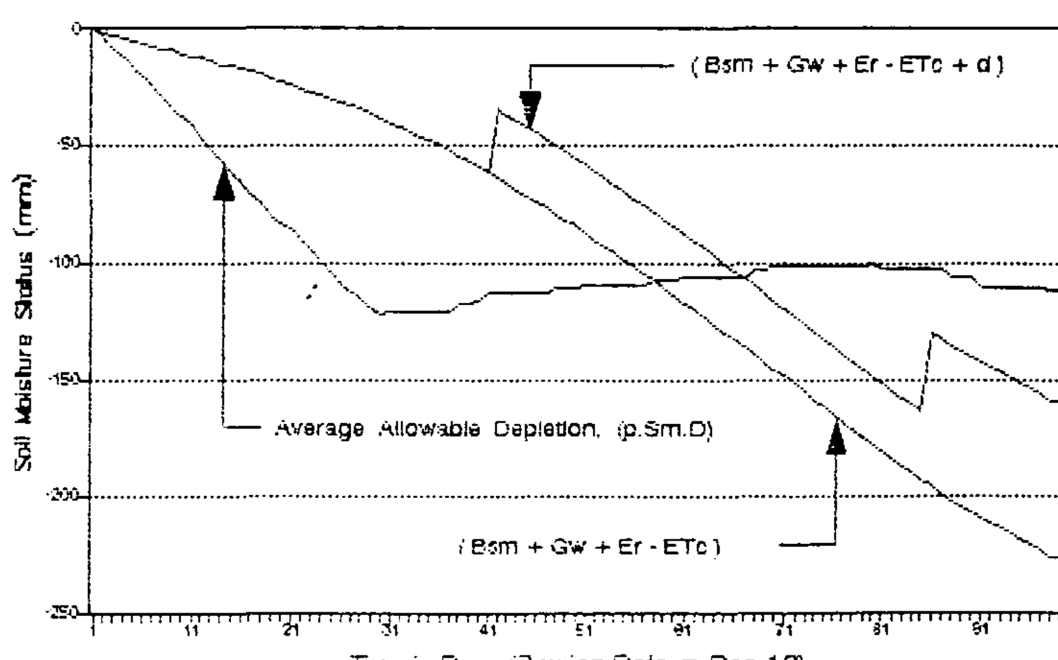


Fig C.7 Water Balance for Wheat Crop at Taltolapara (Sample 3-3, Plot 18)

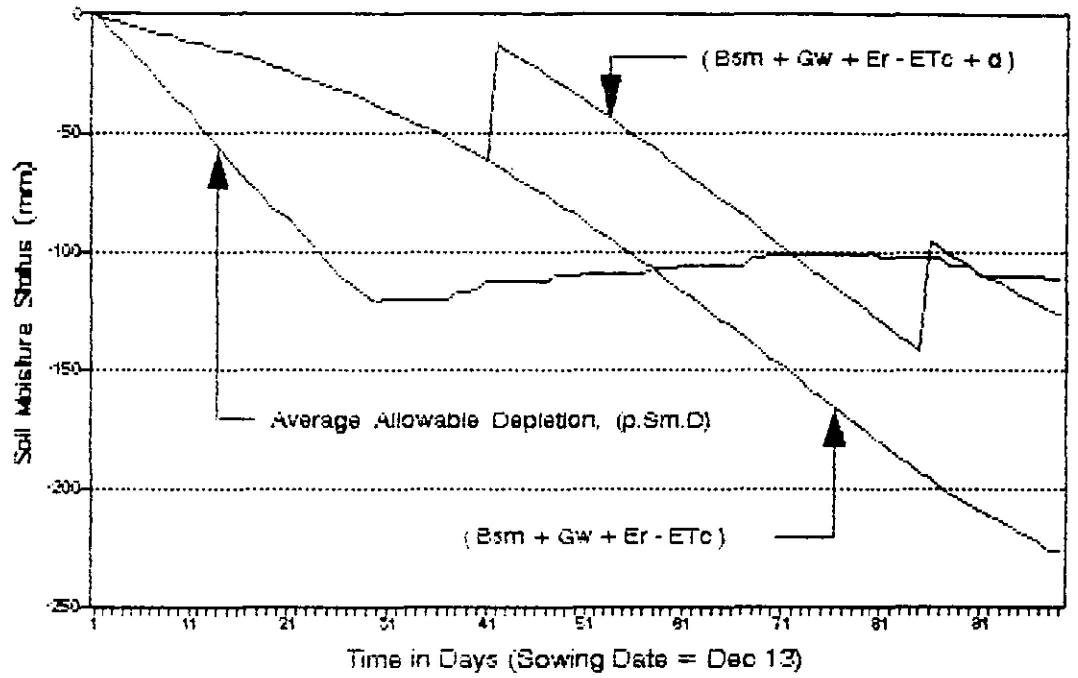


Fig C.8 Water Balance for Wheat Crop at Taltolapara (Sample 3-3, Plot 17)

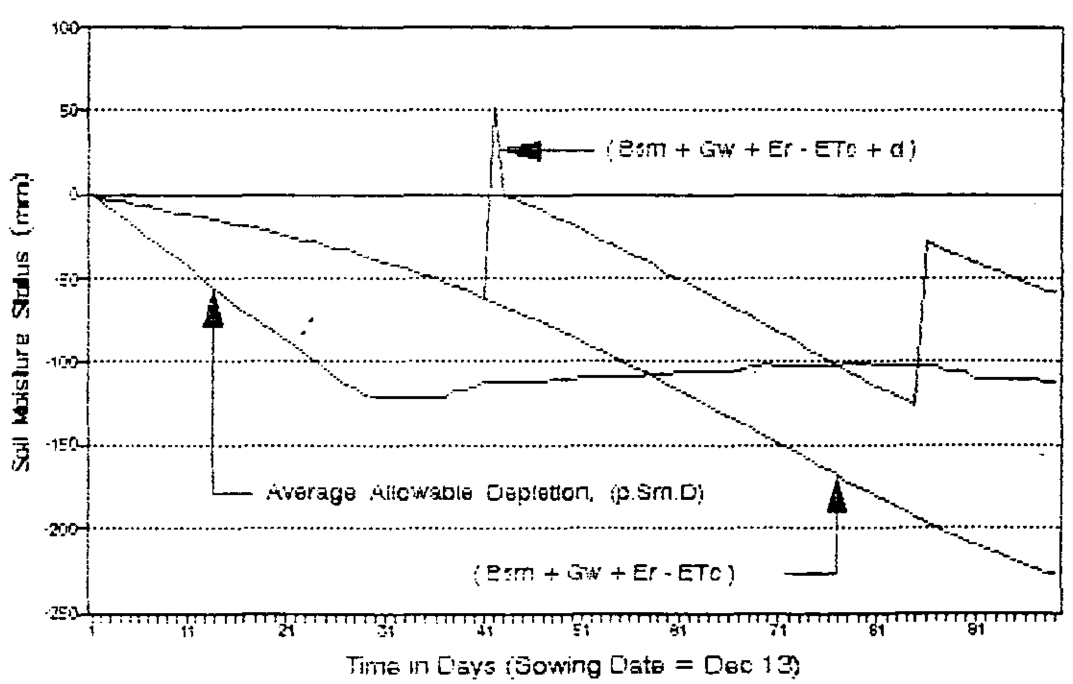


Fig C.9 Water Balance for Wheat Crop at Taltolapara (Sample 1-5, Plot 22)

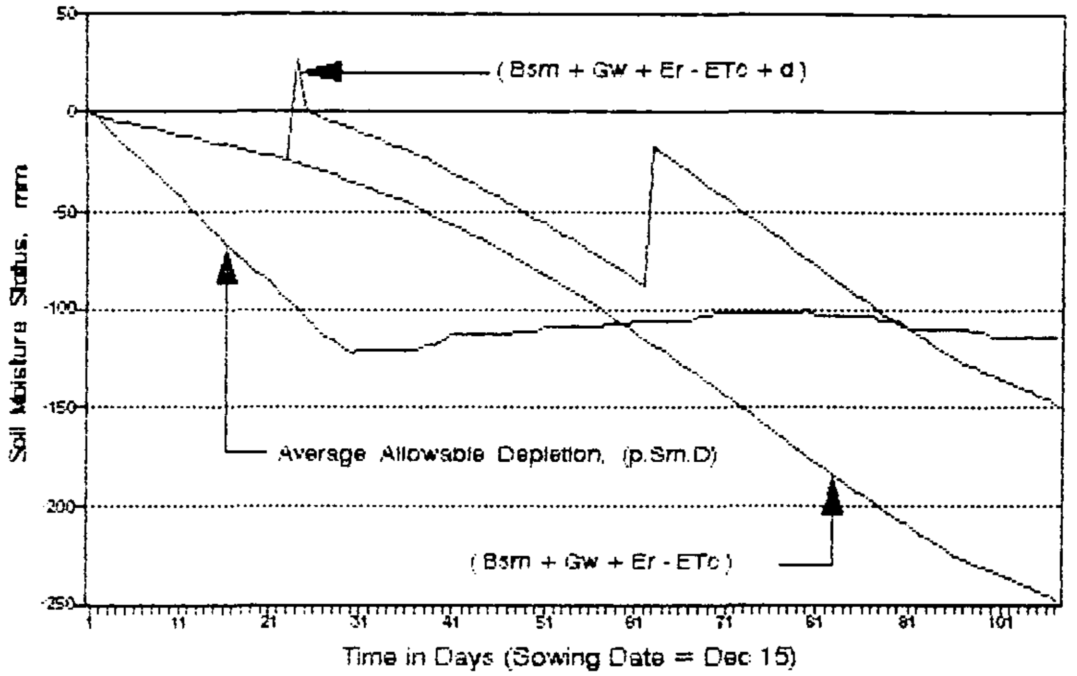


Fig C.10 Water Balance for Wheat Crop at Taltolapara (Sample 1-5, Plot 36)

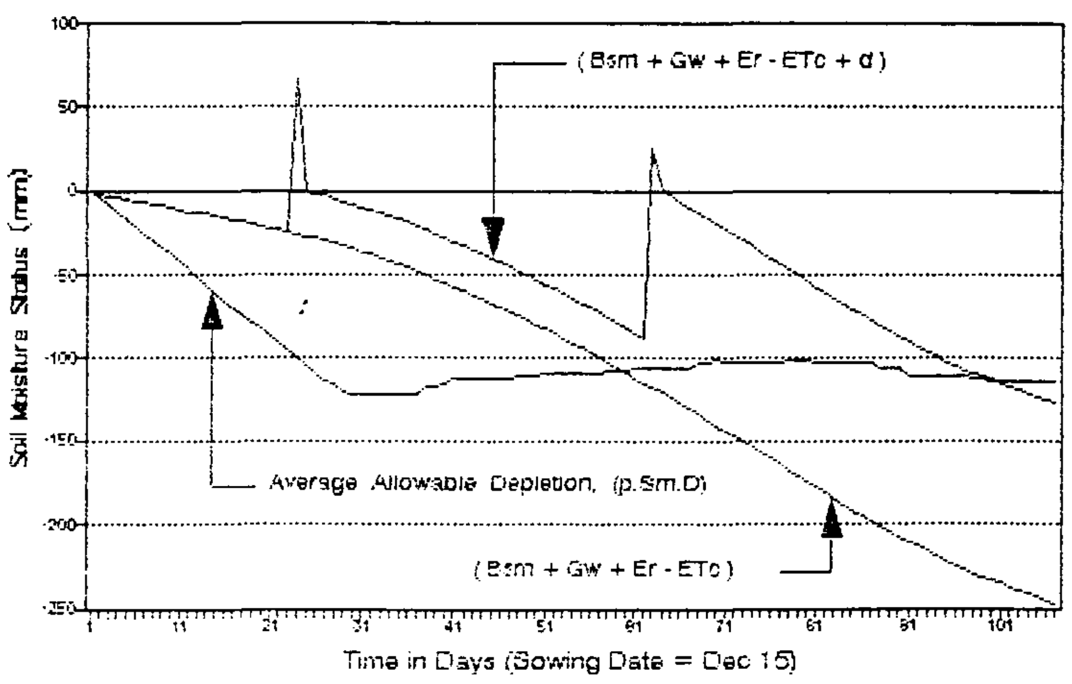


Fig C.11 Water Balance for Wheat Crop at Taltolapara (Sample 1–5, Plot 35)

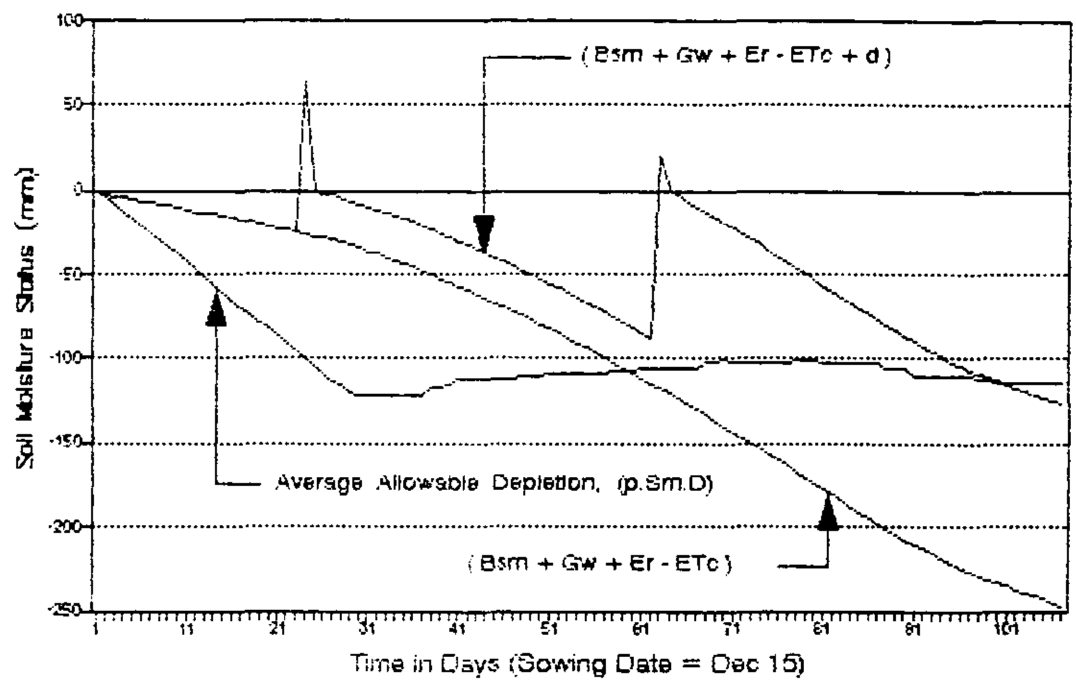


Fig C.12 Water Balance for Wheat Crop at Taltolapara (Sample 1–5, Plot 16)

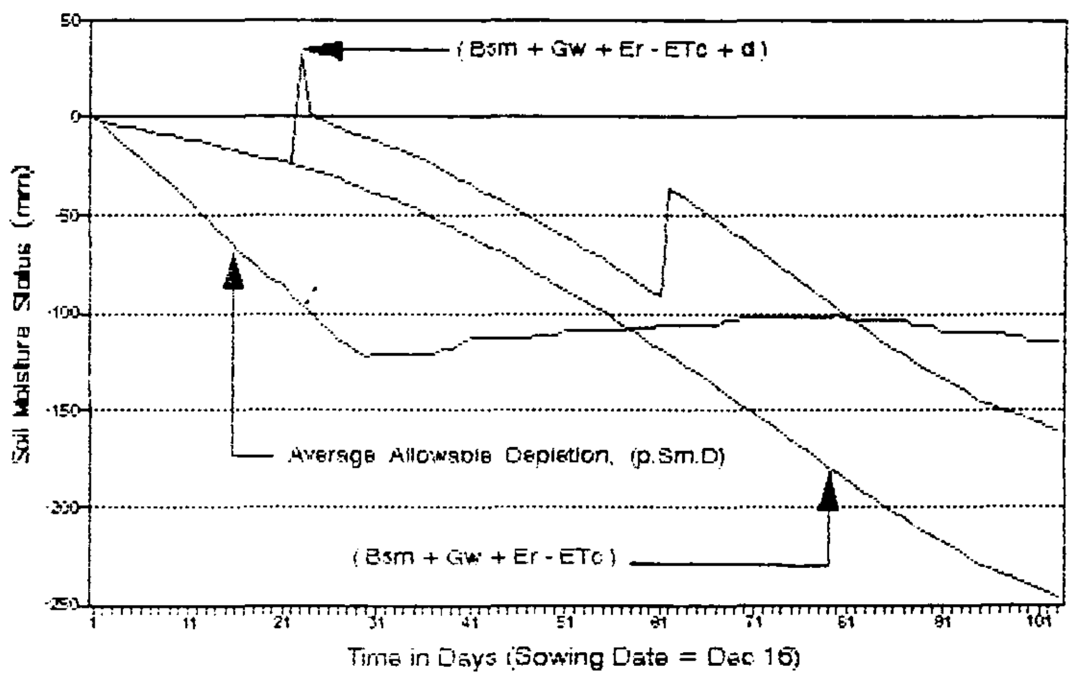


Fig C.13 Water Balance for Wheat Crop at Taltolapara (Sample 1-5, Plot 15)

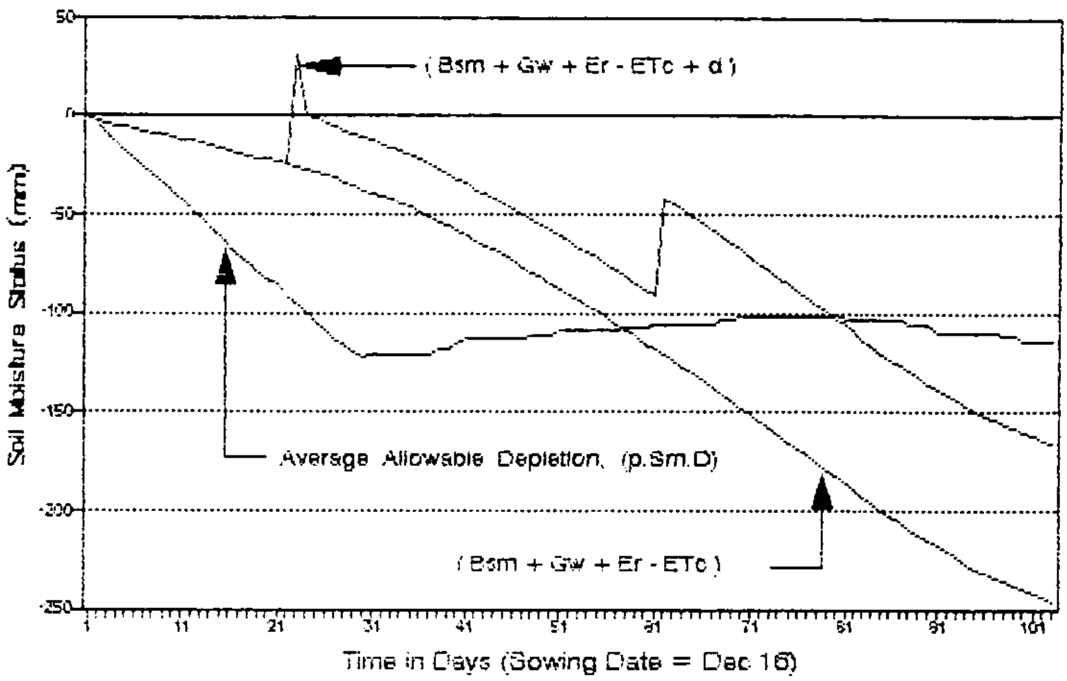


Fig C.14 Water Balance for Wheat Crop at Taltolapara (Sample 1-5, Plot 18)

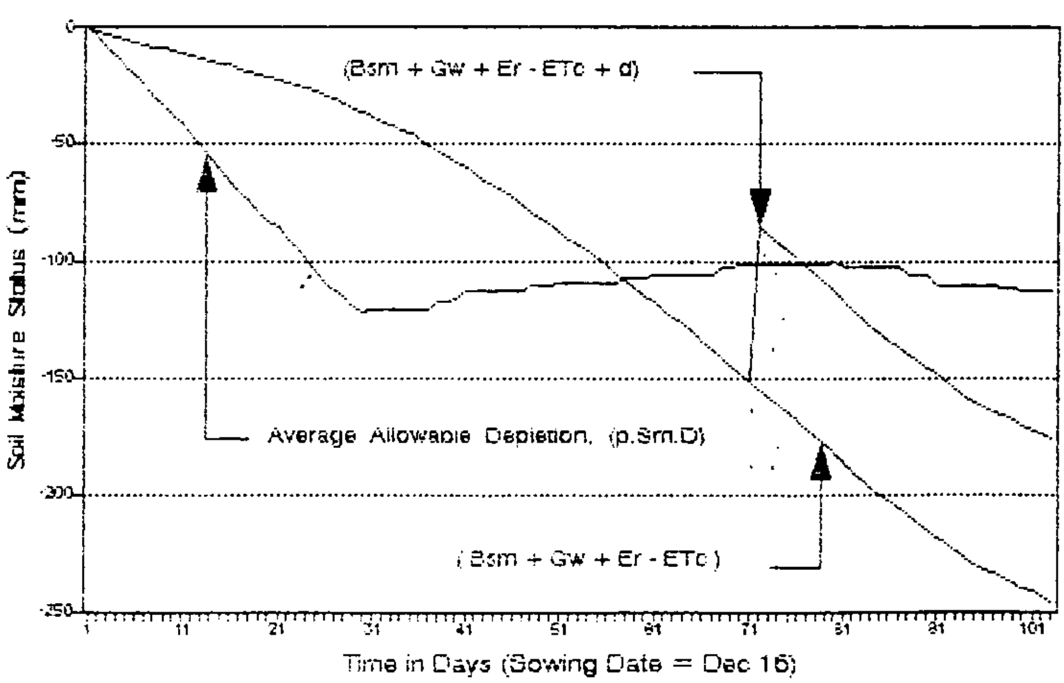


Fig C.15 Water Balance for Wheat Crop
at Taltolapara (Sample 1-5, Plot 14)

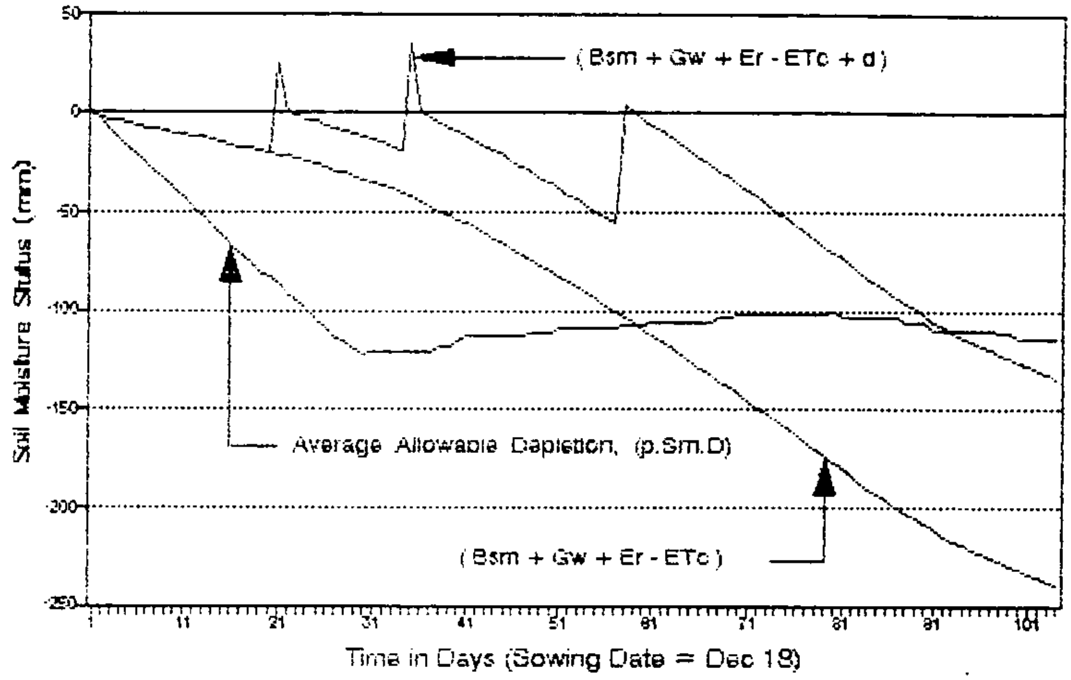
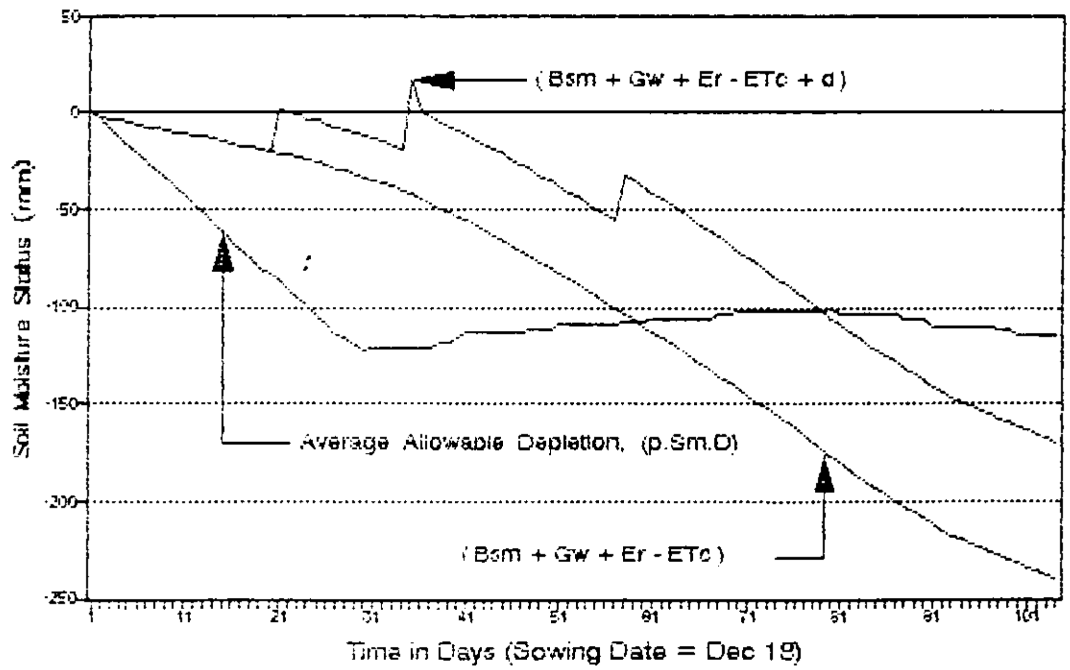


Fig C.16 Water Balance for Wheat Crop
at Taltolapara (Sample 1-5, Plot 12)



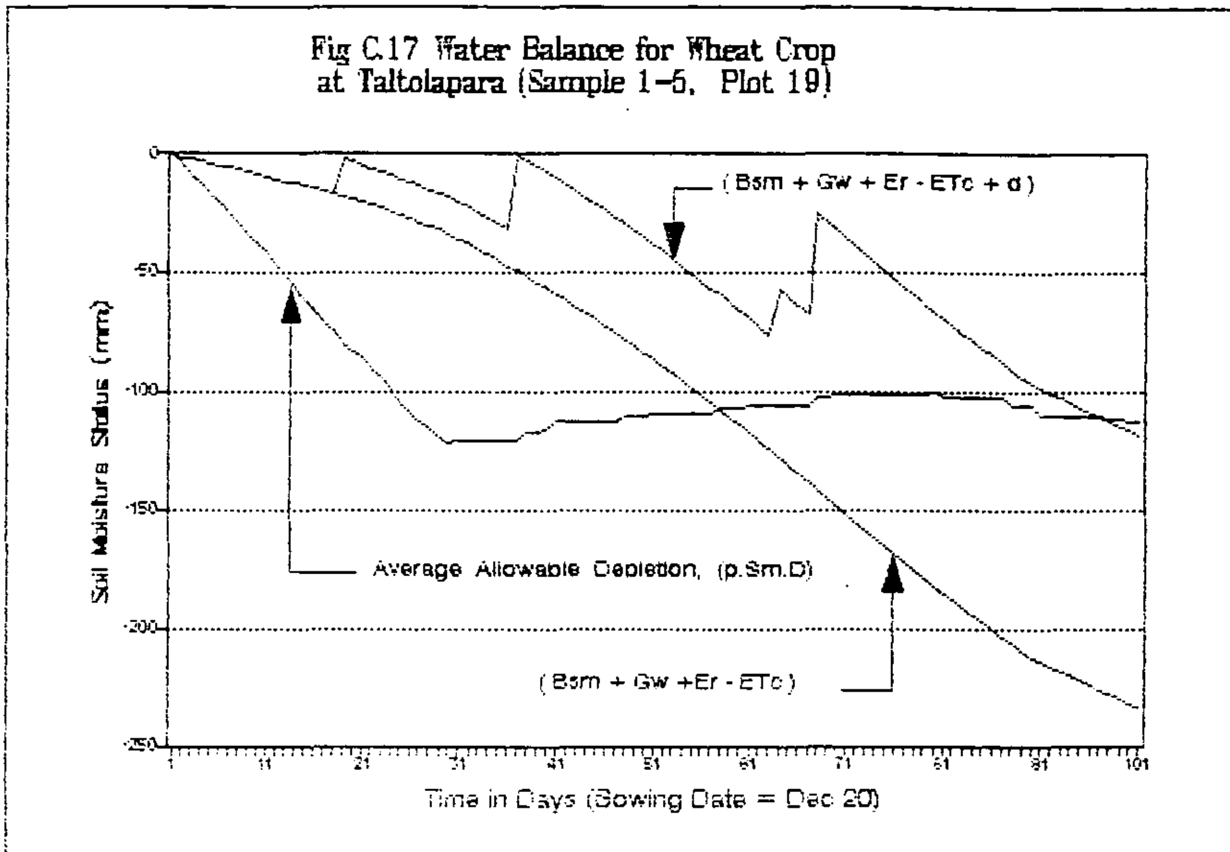


Fig C.17 Water Balance for Wheat Crop
at Taltolapara (Sample 1-5, Plot 19)
(Bsm + Gw + Er - ETc + d)
Average Allowable Depletion, (p.Sm.D)
(Bsm + Gw +Er - ETc)
Soil Moisture Status (mm)
Time in Days (Sowing Date = Dec 20)

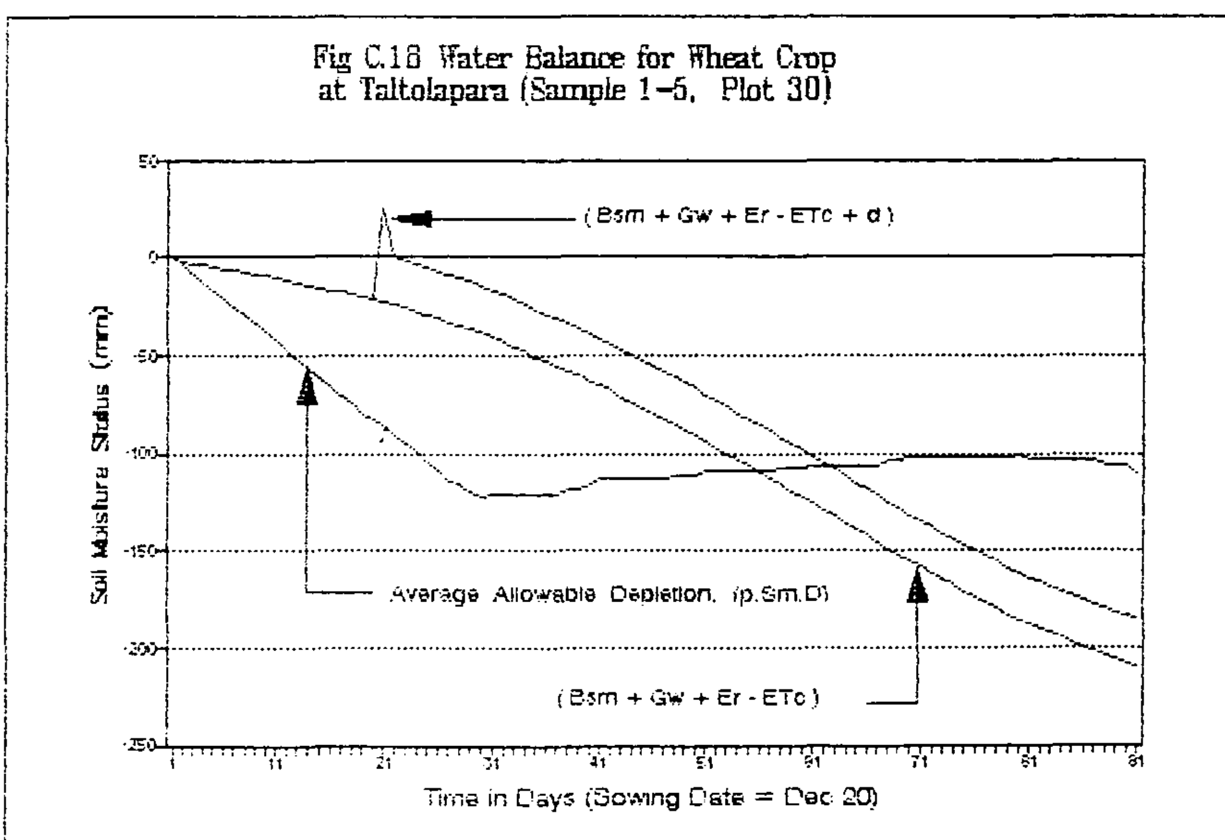


Fig C.18 Water Balance for Wheat Crop
at Taltolapara (Sample 1-5, Plot 30)
(Bsm + Gw + Er - ETc + d)
Average Allowable Depletion, (p.Sm.D)
(Bsm + Gw + Er - ETc)
Soil Moisture Status (mm)
Time in Days (Sowing Date = Dec 20)

Fig C.19 Water Balance for Wheat Crop at Taltolapara (Sample 1-5, Plot 24)

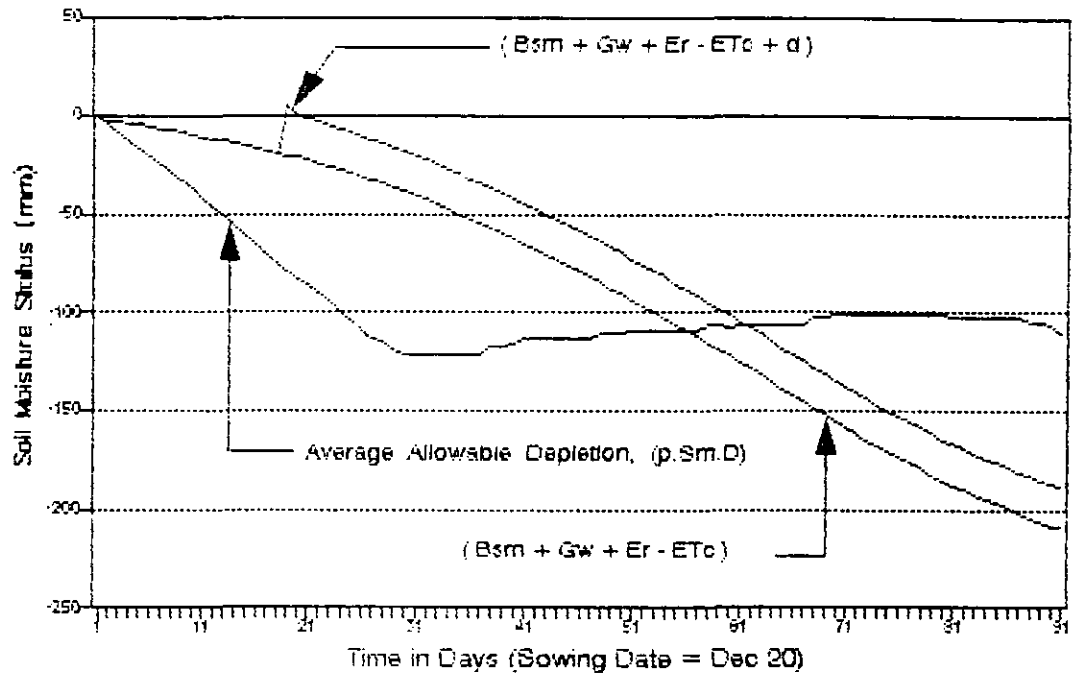


Fig C.20 Water Balance for Wheat Crop at Taltolapara (Sample 1-5, Plot 29)

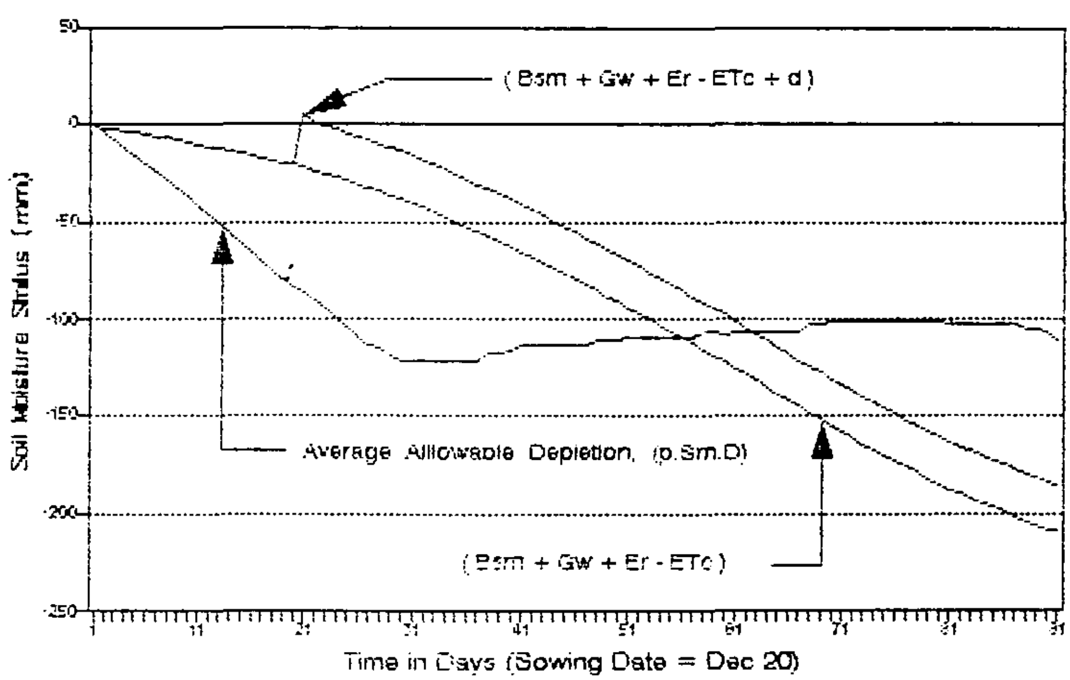


Fig C.21 Water Balance for Wheat Crop at East Kutubpur (Sample 1-6, Plot 1)

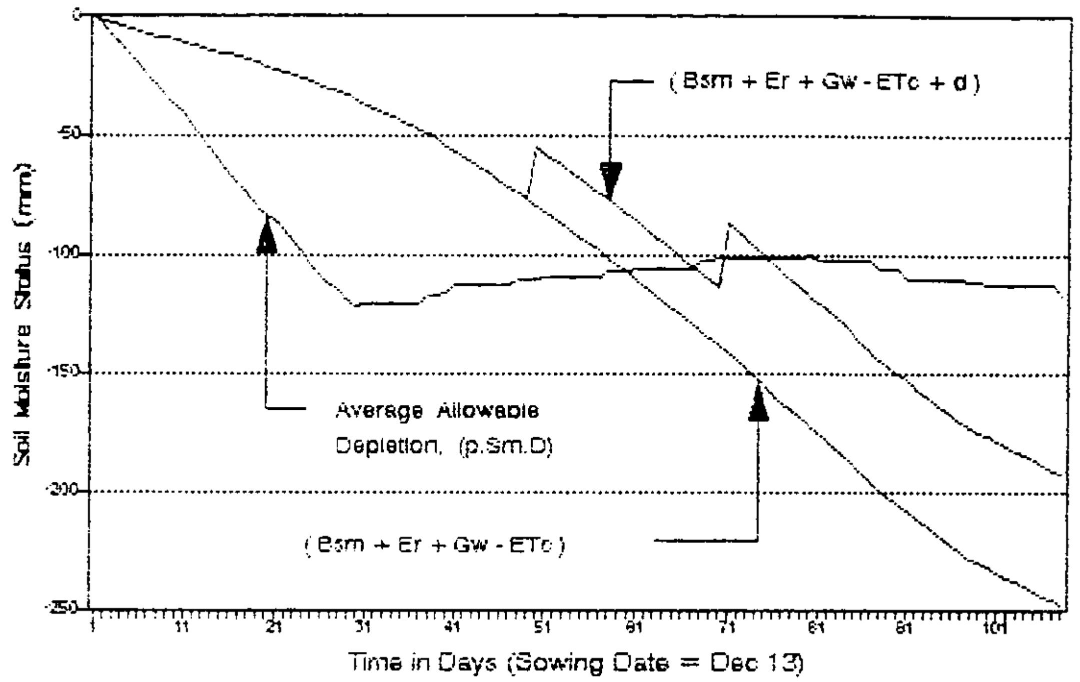


Fig C.22 Water Balance for Wheat Crop at East Kutubpur (Sample 1-6, Plot 11)

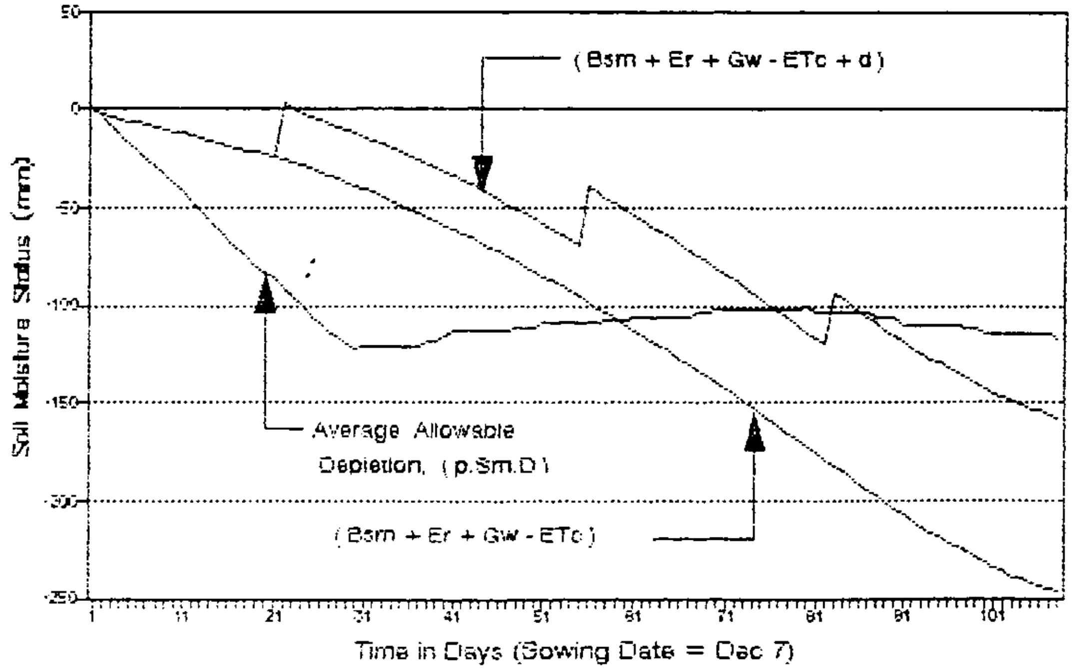


Fig C.2.3 Water Balance for Wheat Crop at East Kutubpur (Sample 2-2, Plot 2)

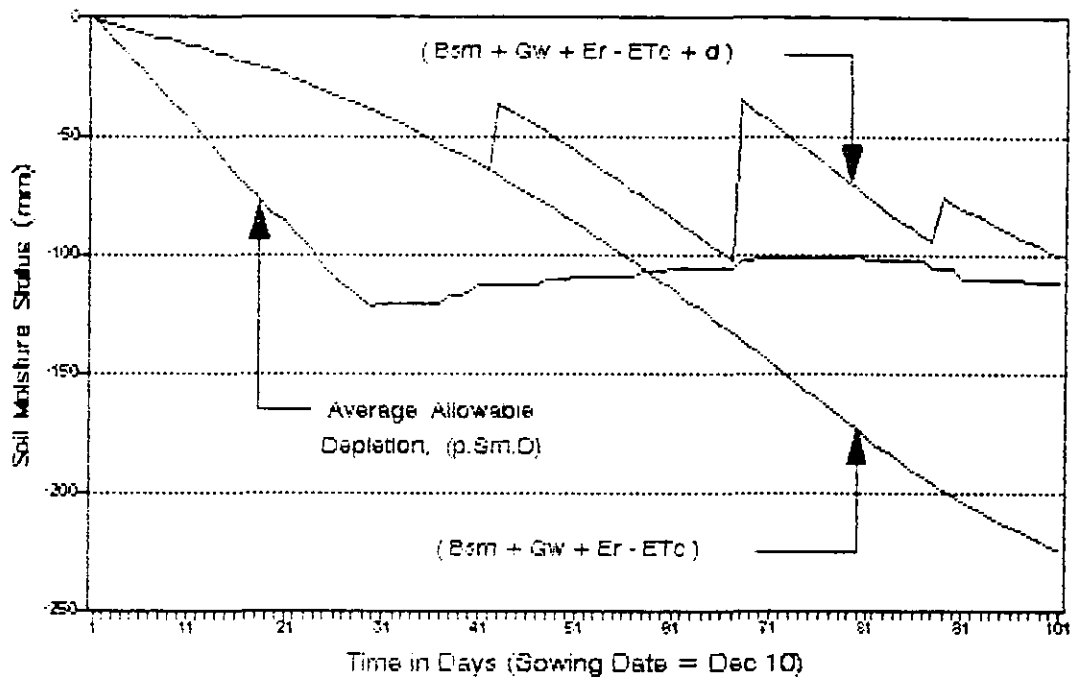


Fig C.2.4 Water Balance for Wheat Crop at East Kutubpur (Sample 2-2, Plot 15)

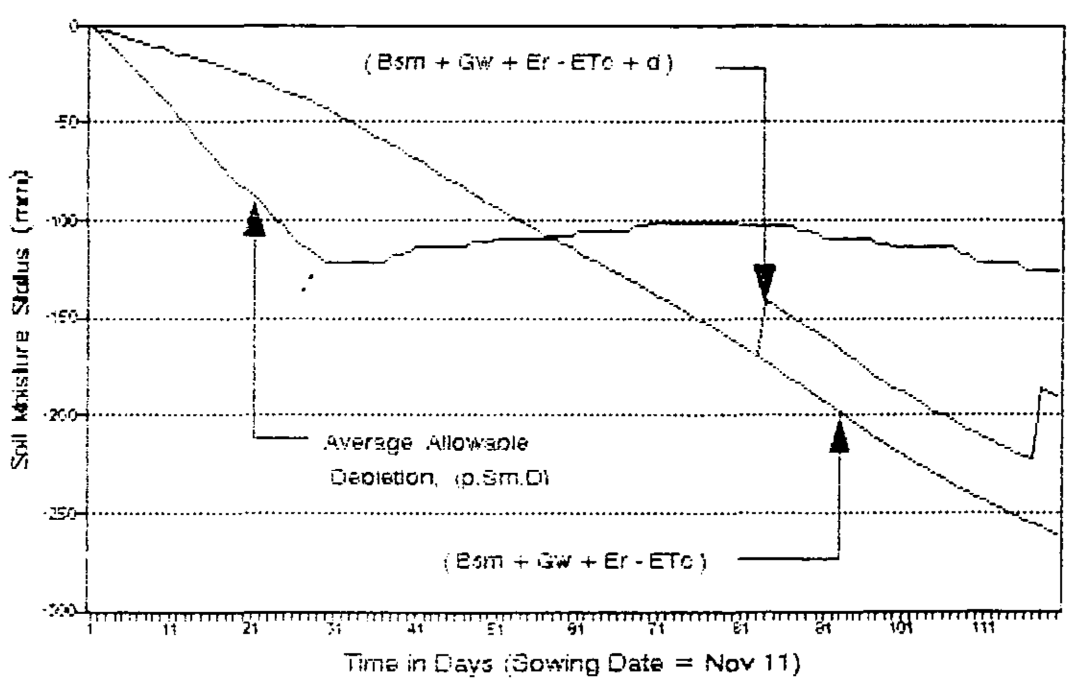


Fig C.25 Water Balance for Wheat Crop at East Kutubpur (Sample 2-2, Plot 25)

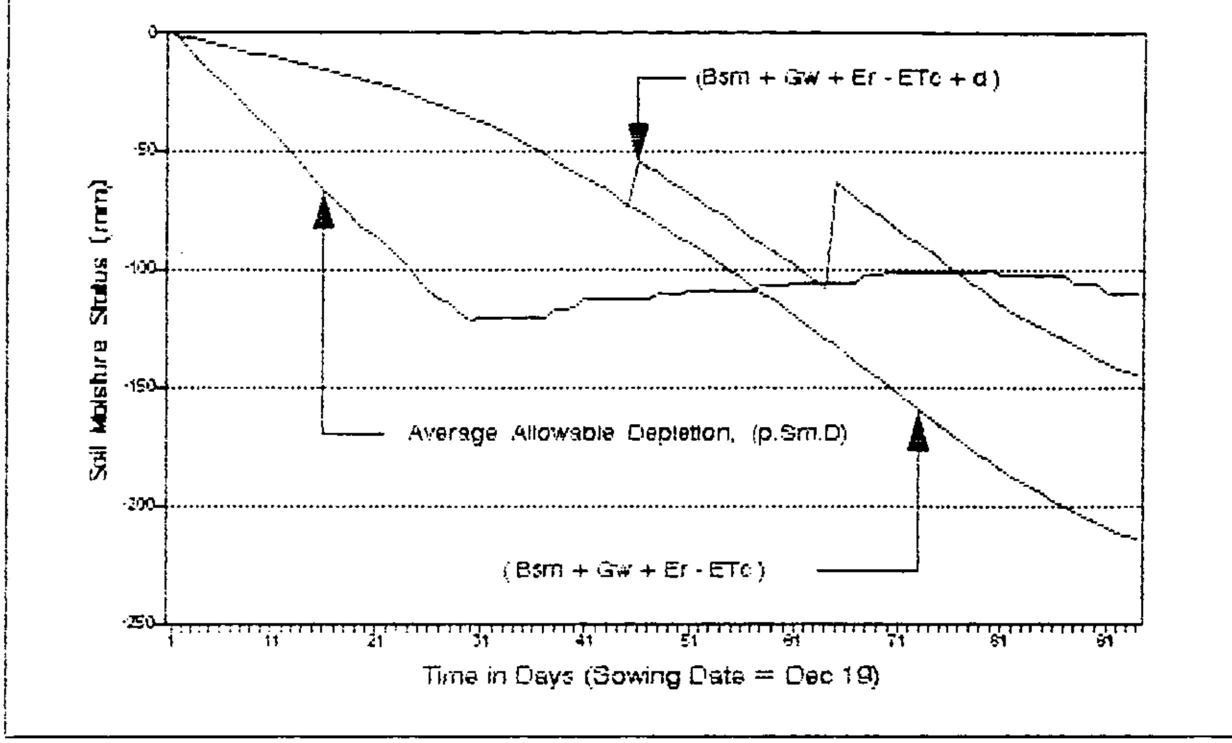
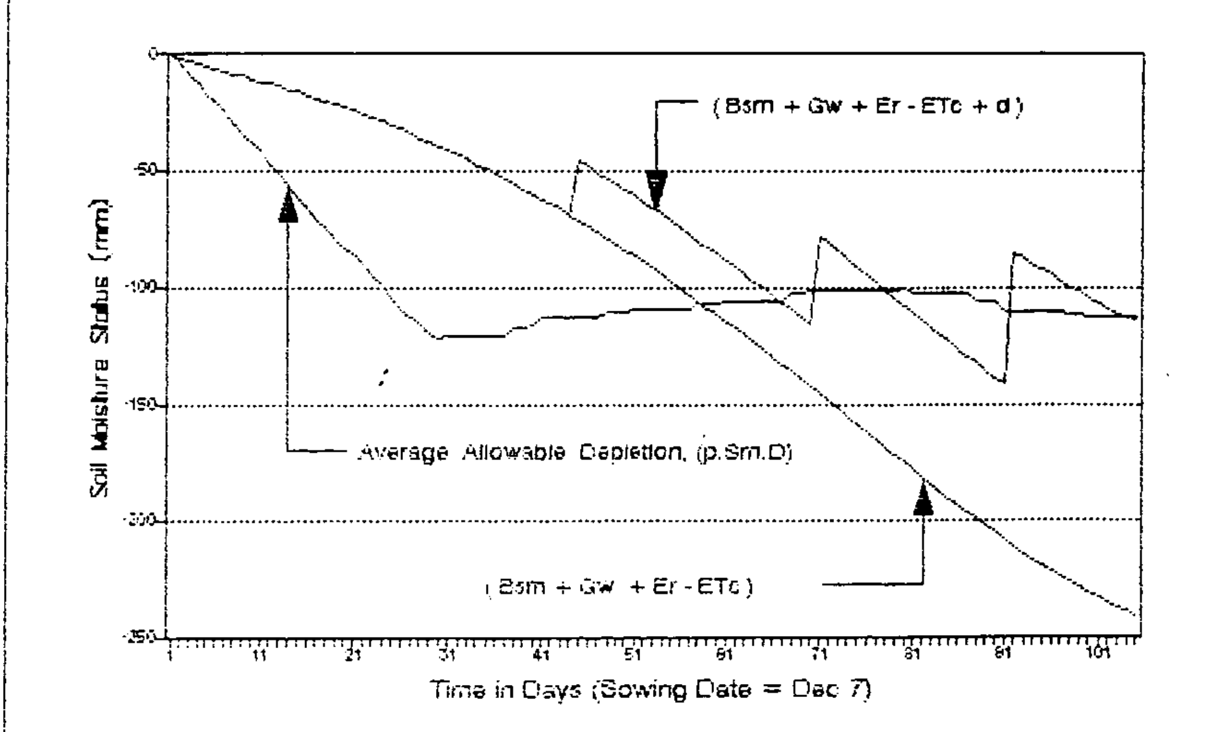


Fig C.26 Water Balance for Wheat Crop at East Kutubpur (Sample 2-2, Plot 5)



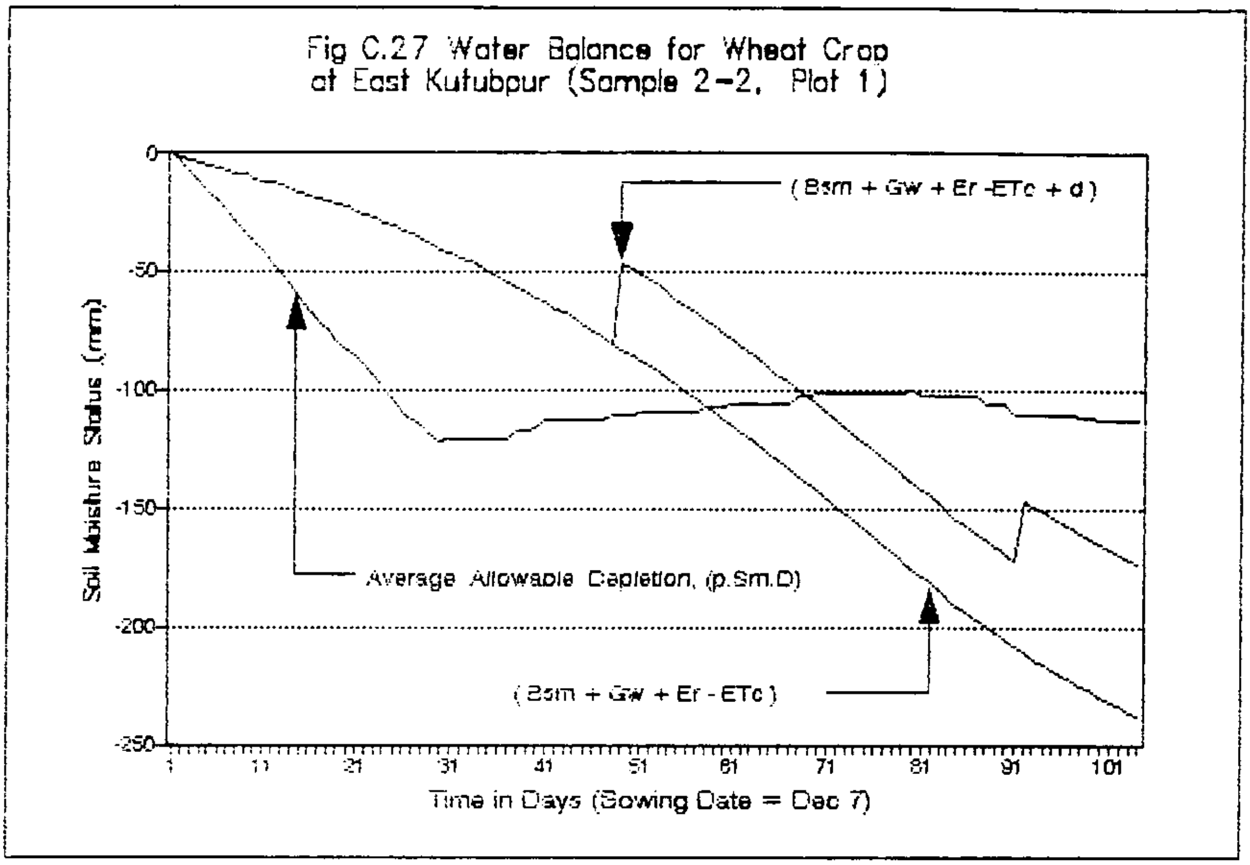


Fig C.27 Water Balance for Wheat Crop
at East Kutubpur (Sample 2-2, Plot 1)
(Bsm + Gw + Er -ETc + d)
Average Allowable Depletion, (p.Sm.D)
(Bsm + Gw + Er - ETc)
Soil Moisture Status (mm)
Time in Days (Sowing Date = Dec 7)
0
-50
-100
-150
-200
-250
1
11
21
31
41
51
61
71
81
91
101

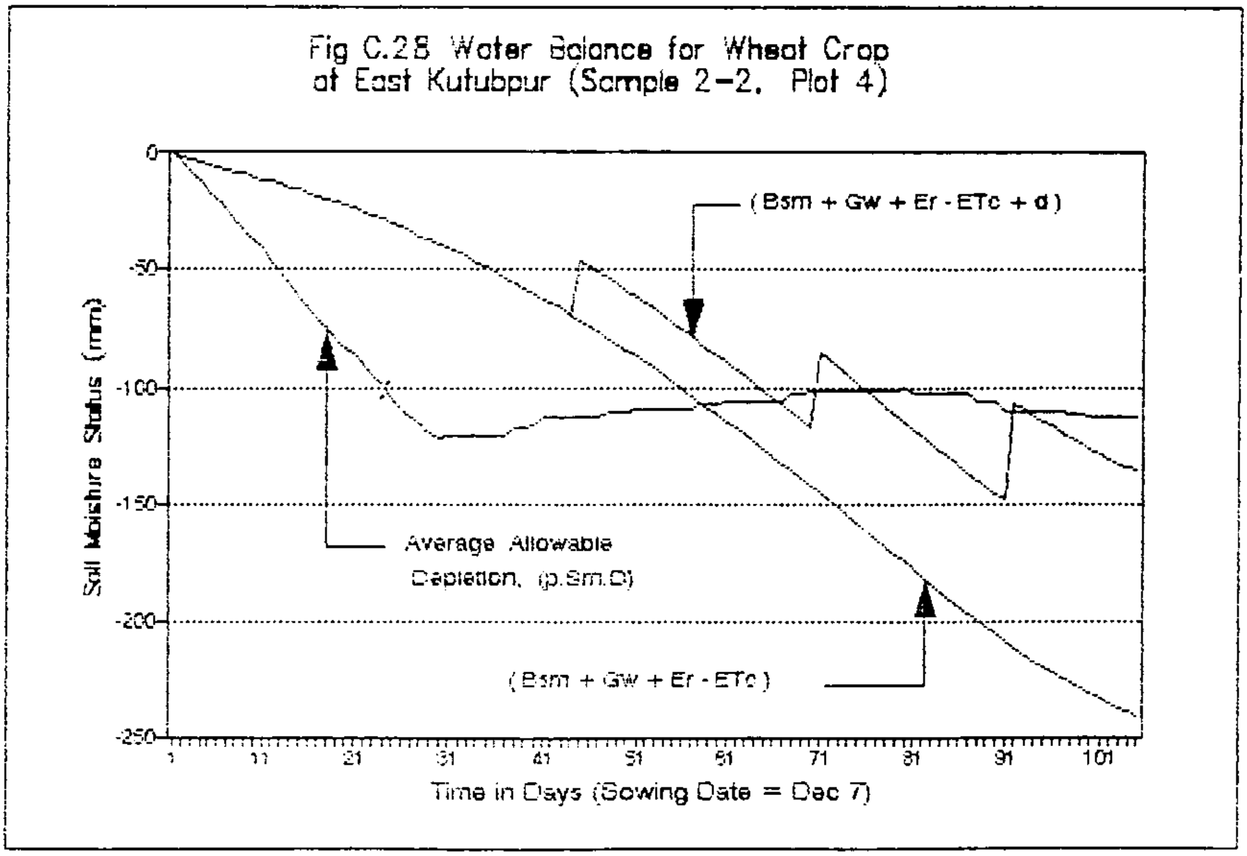


Fig C.28 Water Balance for Wheat Crop
at East Kutubpur (Sample 2-2, Plot 4)
(Bsm + Gw + Er - ETc + d)
Average Allowable
Depletion, (p.Sm.D)
(Bsm + Gw + Er - ETc)
Soil Moisture Status (mm)
Time in Days (Sowing Date = Dec 7)
0
-50
-100
-150
-200
-250
1
11
21
31
41
51
61
71
81
91
101

Fig C.29 Water Balance for Wheat Crop at East Kutubpur (Sample 3-2, Plot 11)

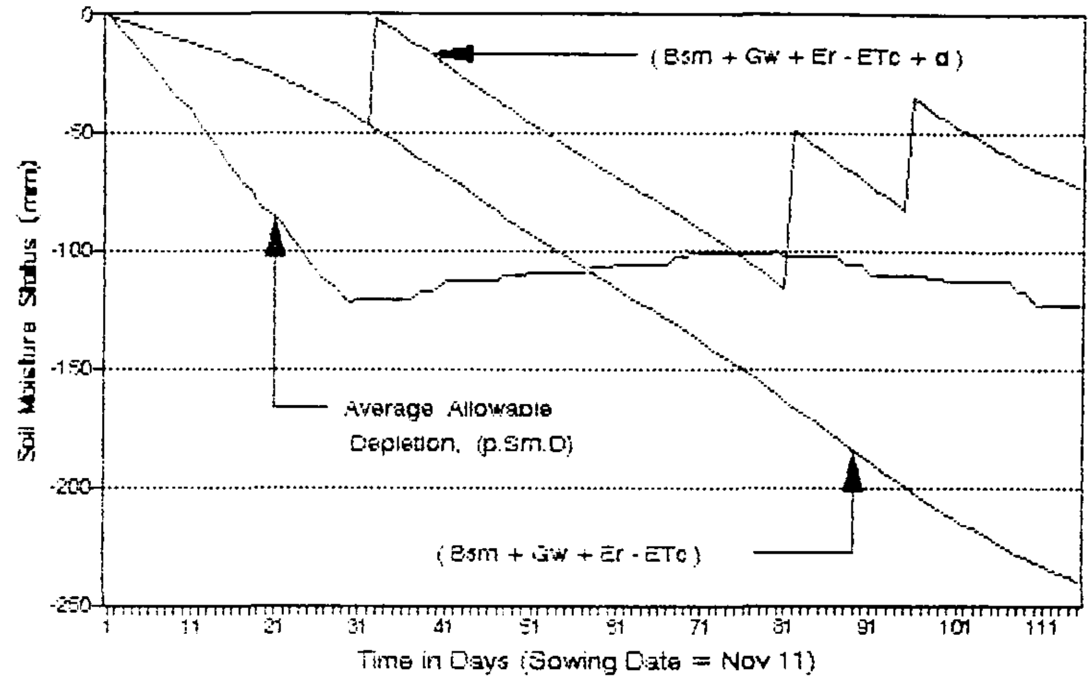


Fig C.30 Water Balance for Wheat Crop at East Kutubpur (Sample 3-2, Plot 27)

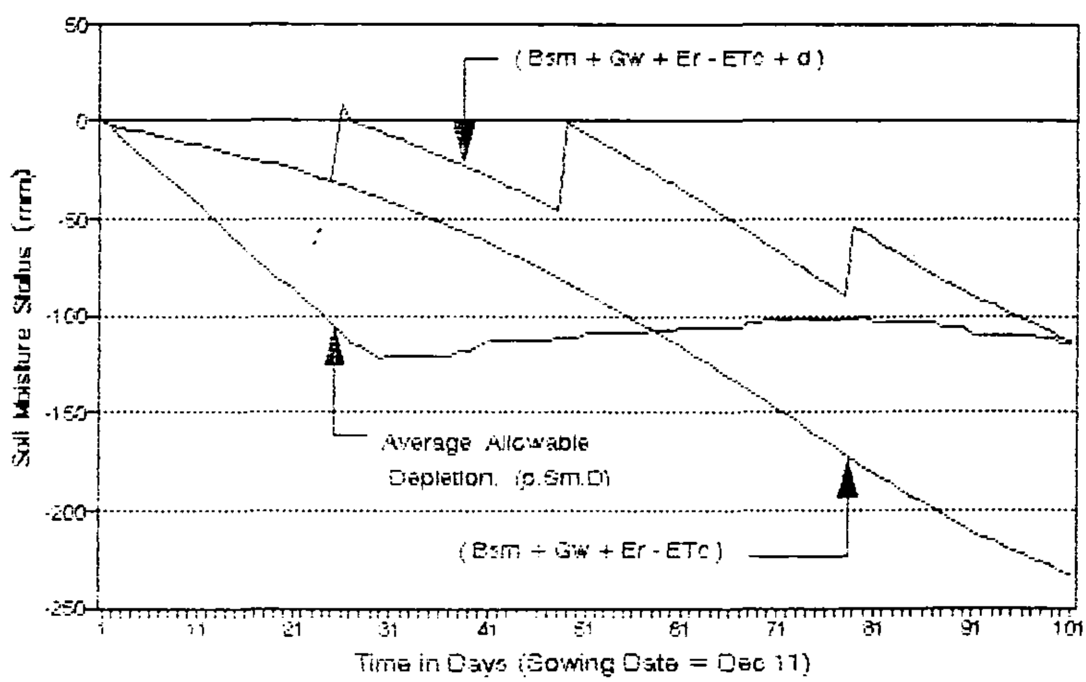


Fig C.31 Water Balance for Wheat Crop at East Kutubpur (Sample 3-2, Plot 2)

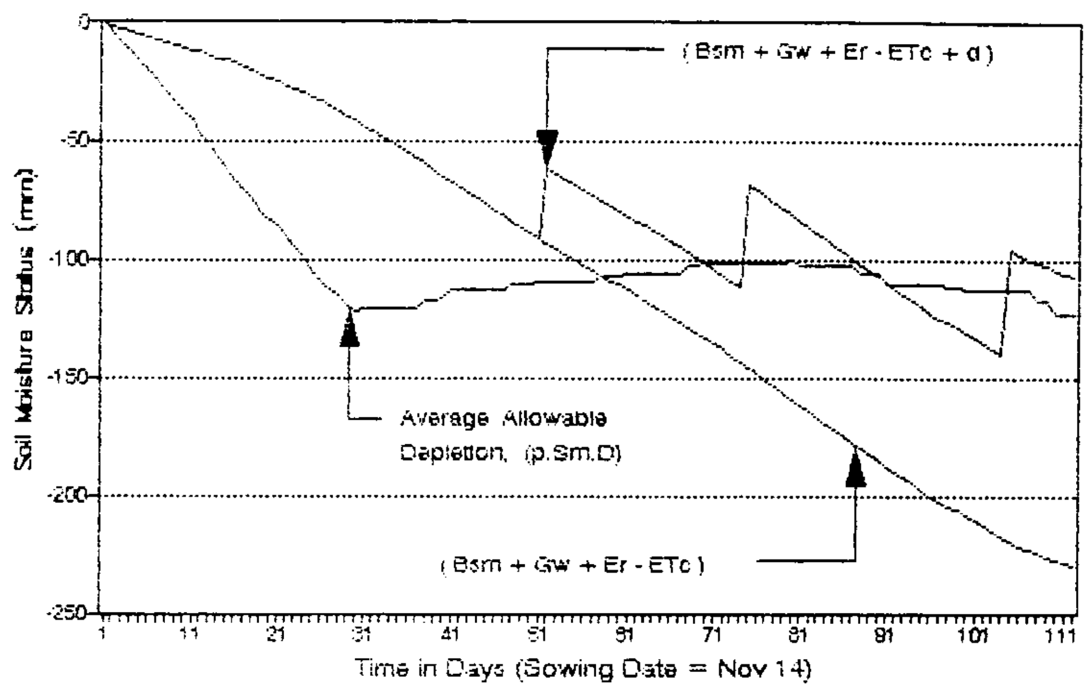


Fig C.32 Water Balance for Wheat Crop at East Kutubpur (Sample 3-2, Plot 3)

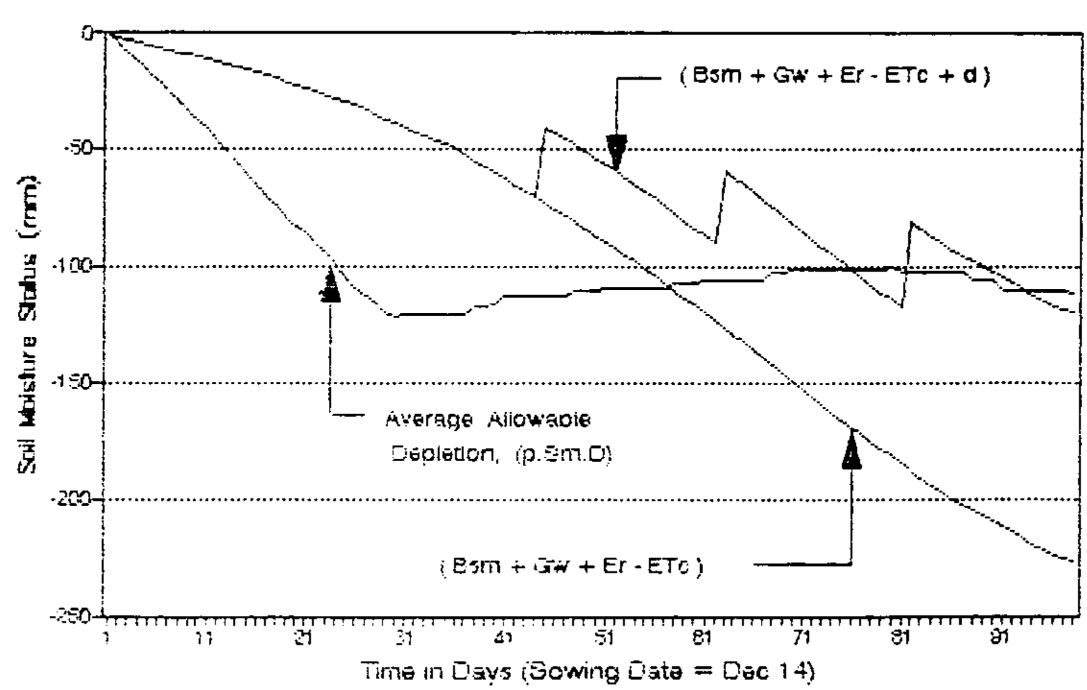


Fig C.33 Water Balance for Wheat Crop at Shaplapara (Sample 1-3, Plot No. 9)

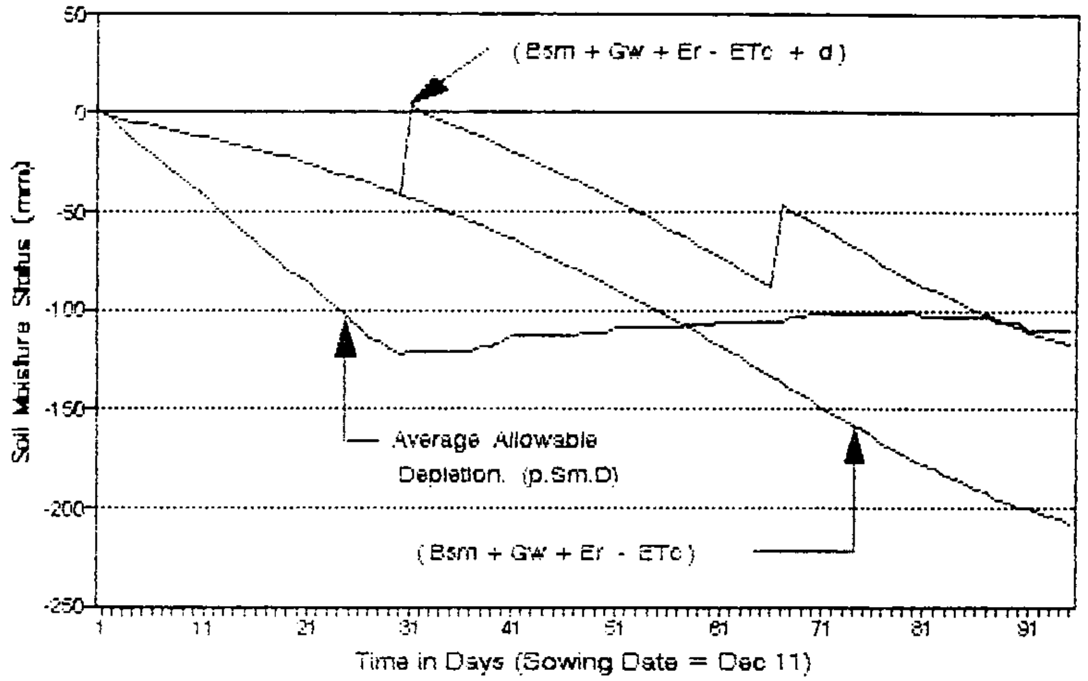
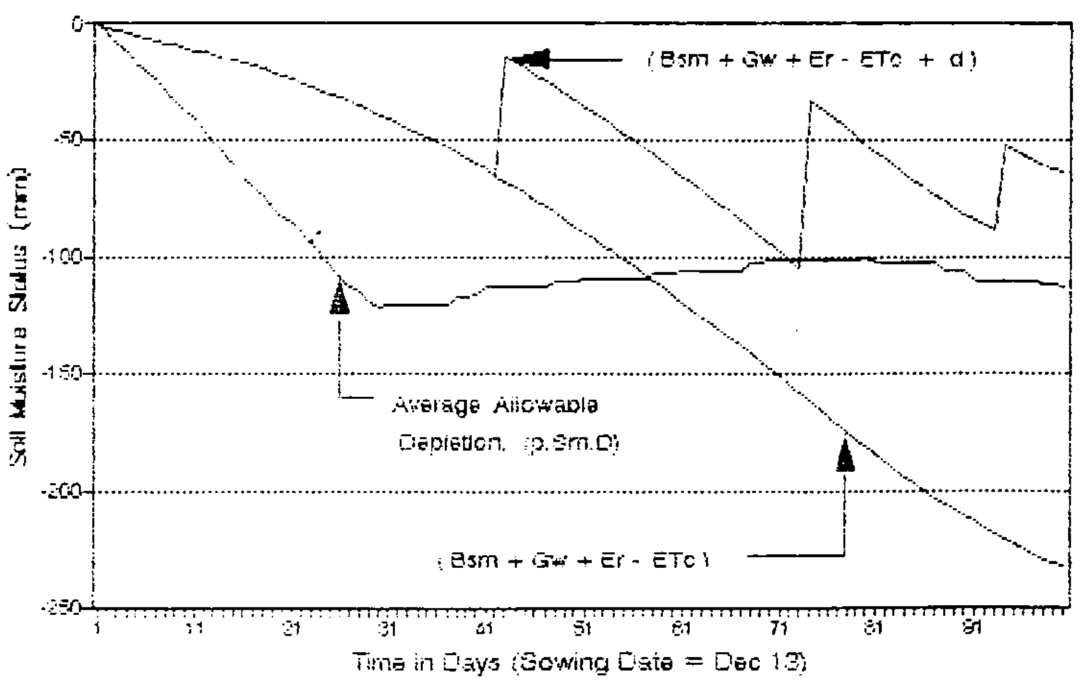


Fig C.34 Water Balance for Wheat Crop at Shaplapara (Sample 1-3, Plot No. 8)



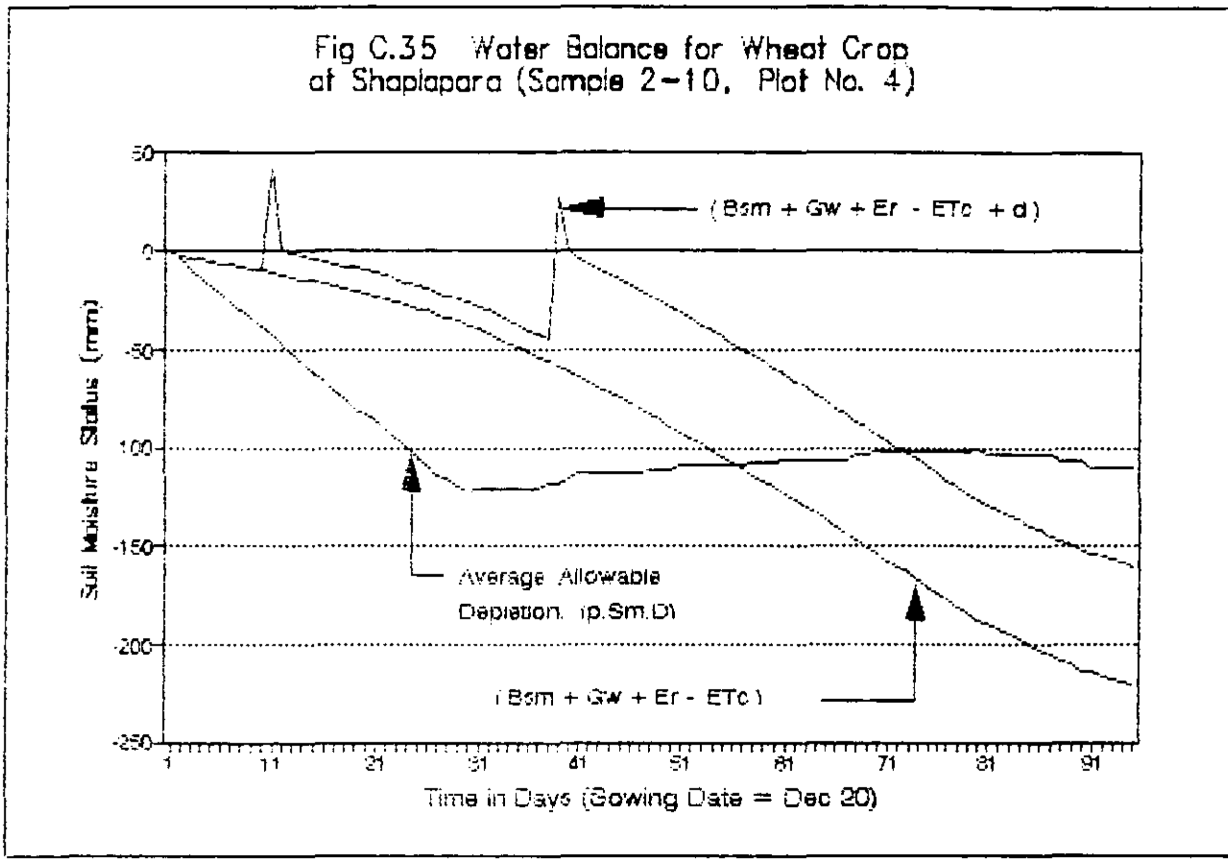


Fig C.35 Water Balance for Wheat Crop
at Shaplapara (Sample 2-10, Plot No. 4)
(Bsm + Gw + Er - ETc + d)
Average Allowable
Depletion. (p.Sm.D)
(Bsm + Gw + Er - ETc)
Soil Moisture Status (mm)
Time in Days (Sowing Date = Dec 20)
50
0
-50
-100
-150
-200
-250
1
11
21
31
41
51
61
71
81
91

APPENDIX C

Water Balance for Soybean (Figures C.36 to C.48)

Fig C.36 Water Balance for Soybean Crop at Taltolapara (Sample 1-4, Plot No. 2)

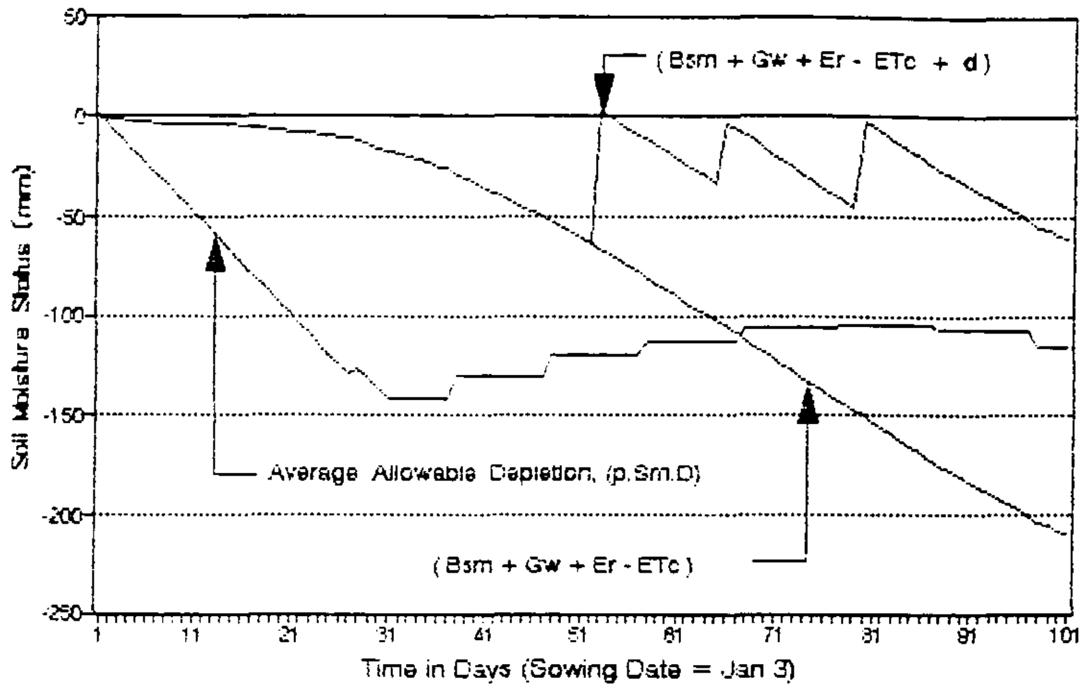


Fig C.37 Water Balance for Soybean Crop at Taltolapara (Sample 1-4, Plot No.22)

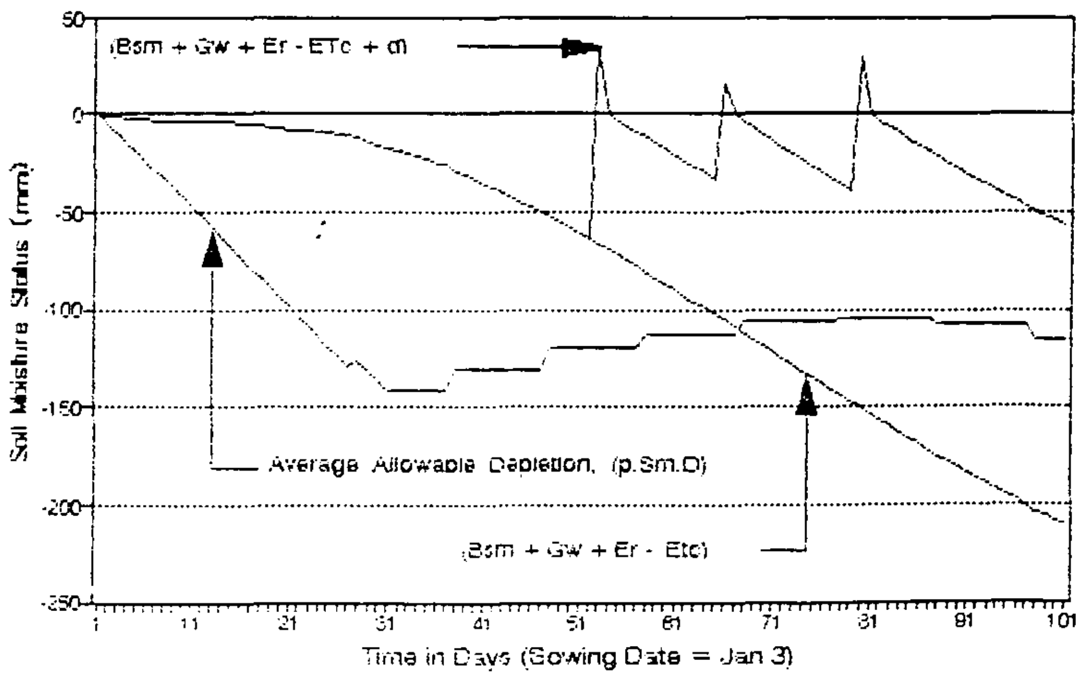


Fig C.38 Water Balance for Soybean Crop at Taltolapara (Sample 1–5, Plot No. 4)

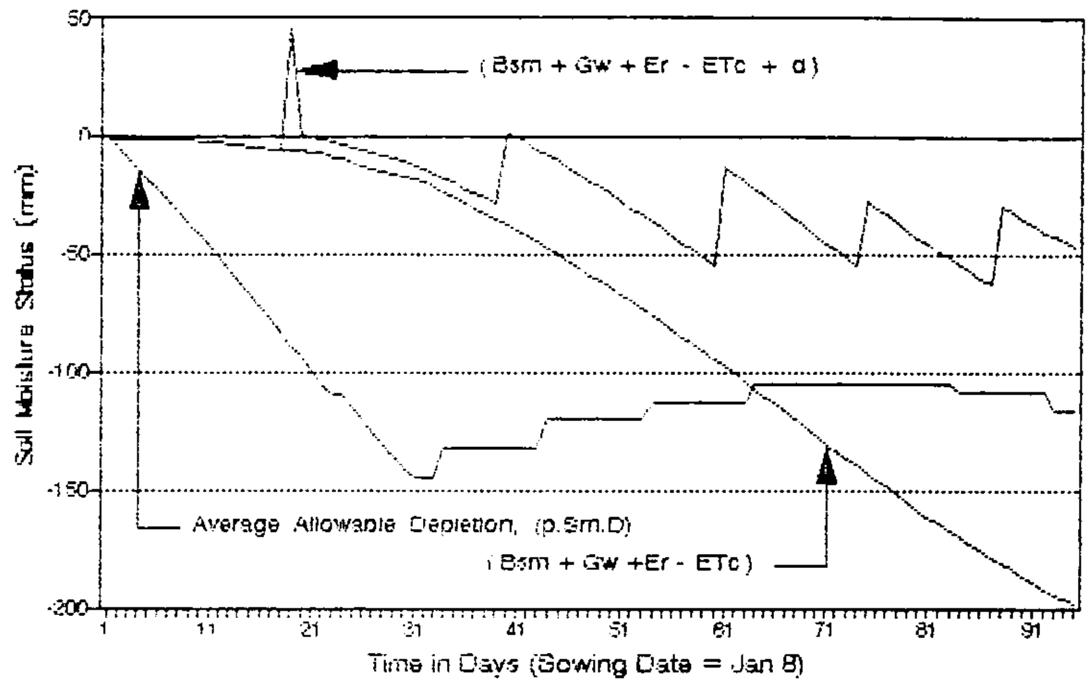


Fig C.39 Water Balance for Soybean Crop at Taltolapara (Sample 1–5, Plot No. 3)

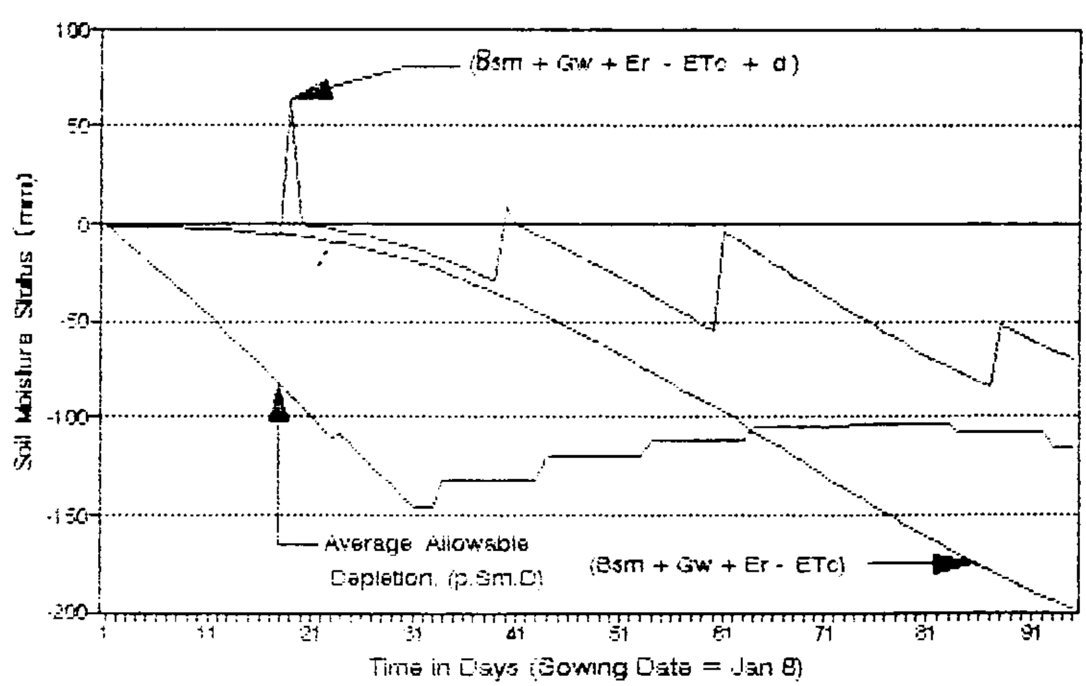


Fig C.40 Water Balance for Soybean Crop at Taltolapara (Sample 1-5, Plot No.40)

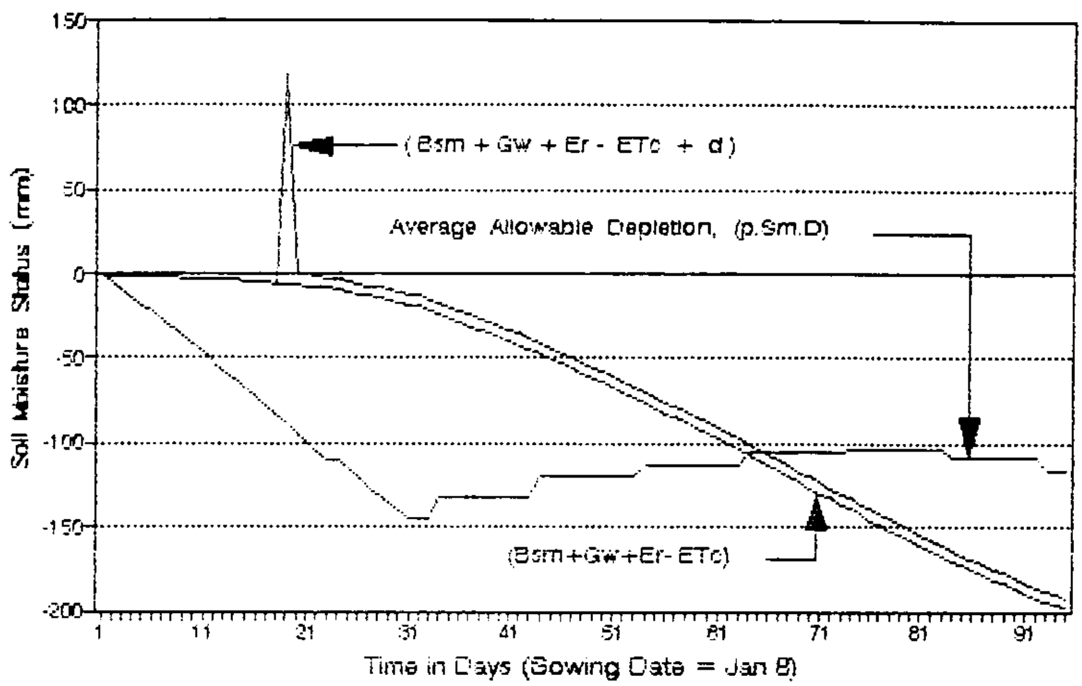
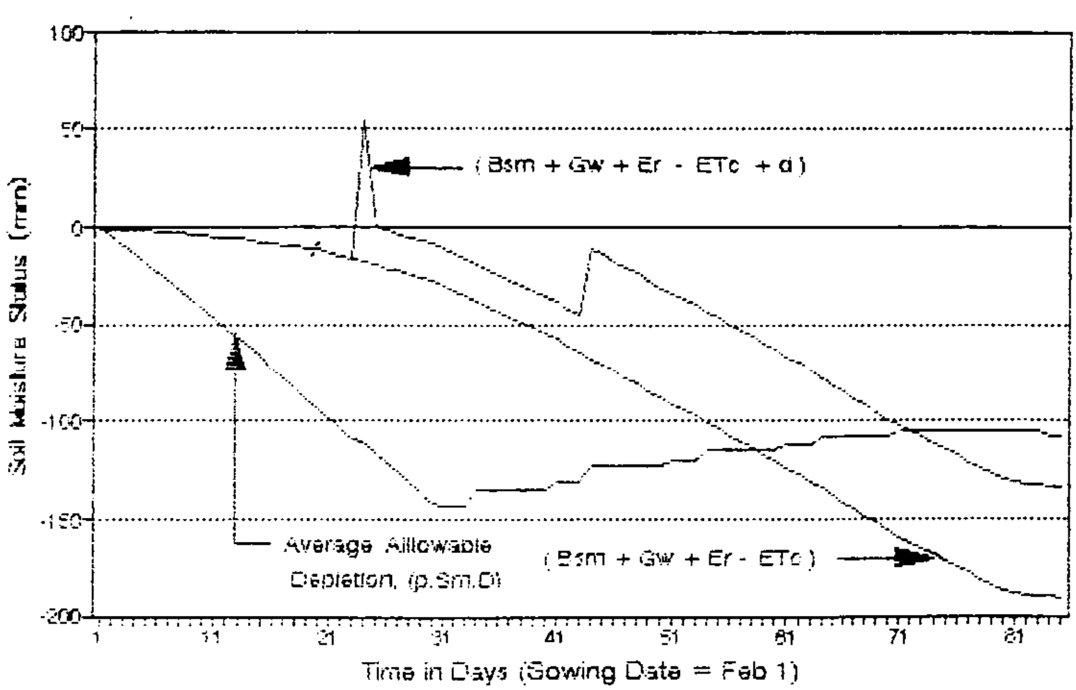


Fig C.41 Water Balance for Soybean Crop at Shaplapara (Sample 1-3, Plot No. 17)



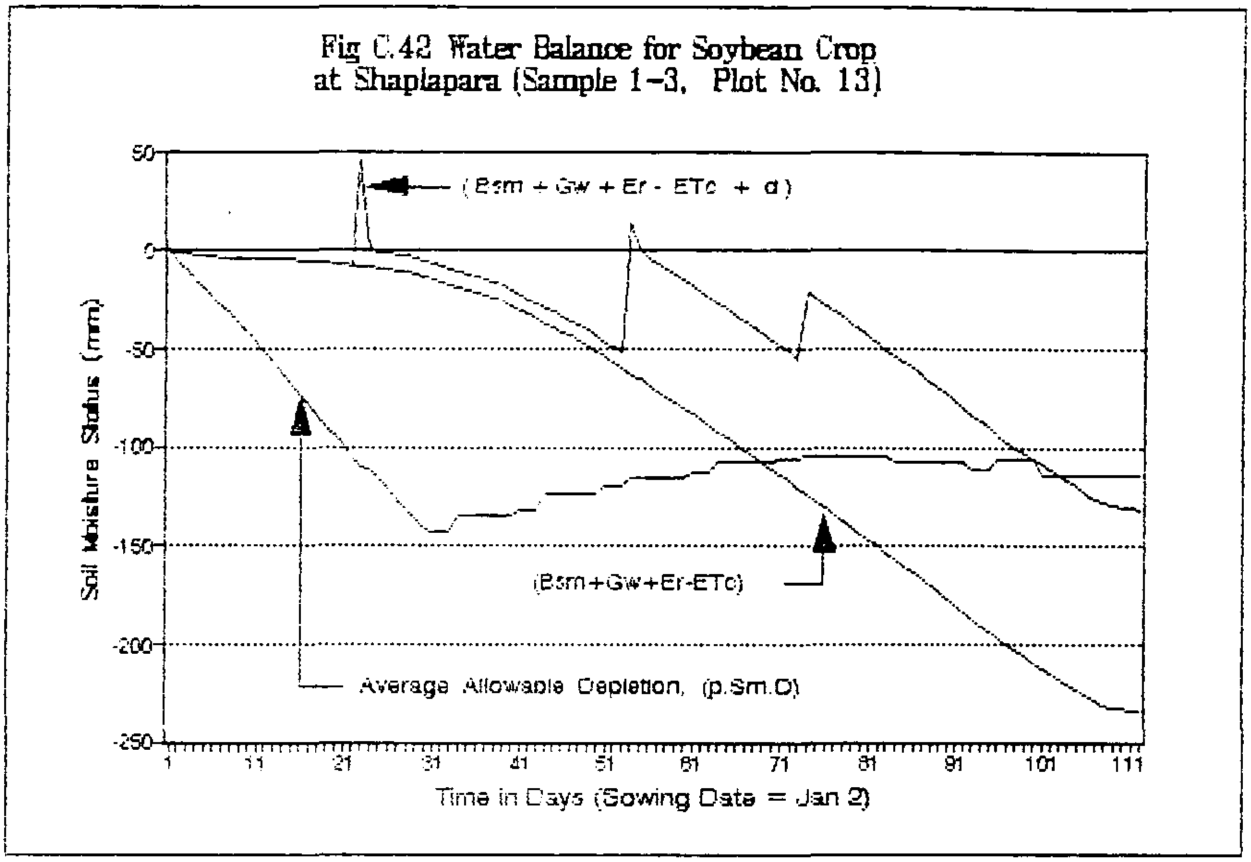


Fig C.42 Water Balance for Soybean Crop
at Shaplapara (Sample 1-3, Plot No. 13)
50
0
-50
-100
-150
-200
-250
Soil Moisture Status (mm)
(Bsm + Gw + Er - ETc + d)
(Bsm+Gw+Er-ETc)
Average Allowable Depletion, (p.Sm.D)
1
11
21
31
41
51
61
71
81
91
101
111
Time in Days (Sowing Date = Jan 2)

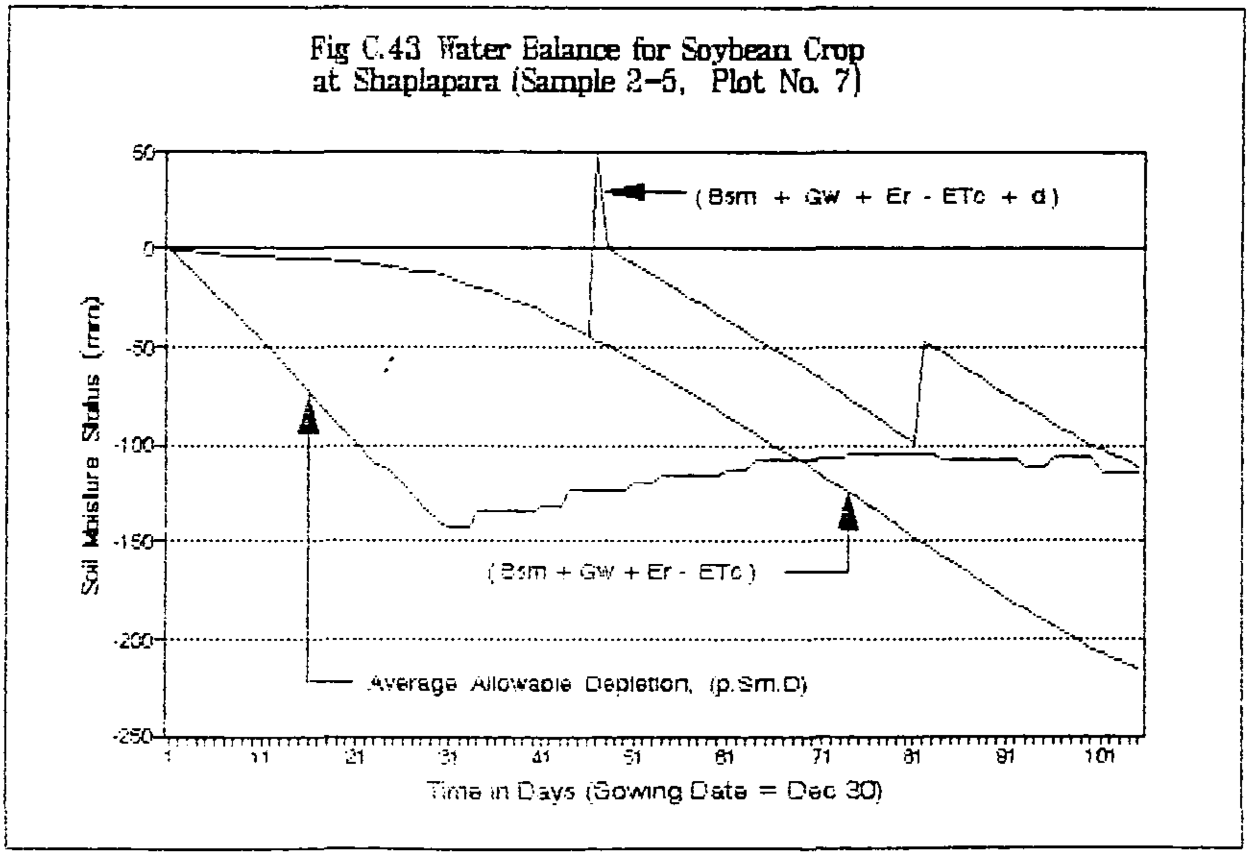


Fig C.43 Water Balance for Soybean Crop
at Shaplapara (Sample 2-5, Plot No. 7)
50
0
-50
-100
-150
-200
-250
Soil Moisture Status (mm)
(Bsm + GW + Er - ETc + d)
(Bsm + GW + Er - ETc)
Average Allowable Depletion, (p.Sm.D)
1
11
21
31
41
51
61
71
81
91
101
Time in Days (Sowing Date = Dec 30)

Fig C.44 Water Balance for Soybean Crop at Shaplapara (Sample 2-10, Plot No.15)

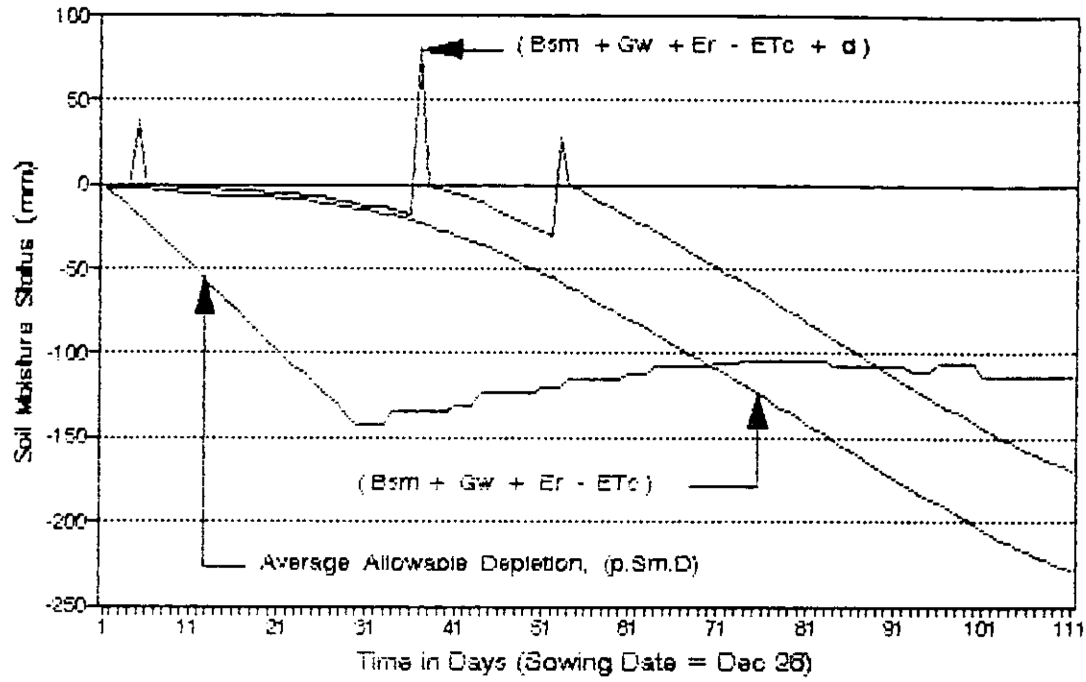


Fig C.45 Water Balance for Soybean Crop at Shaplapara (Sample 2-10, Plot No.14)

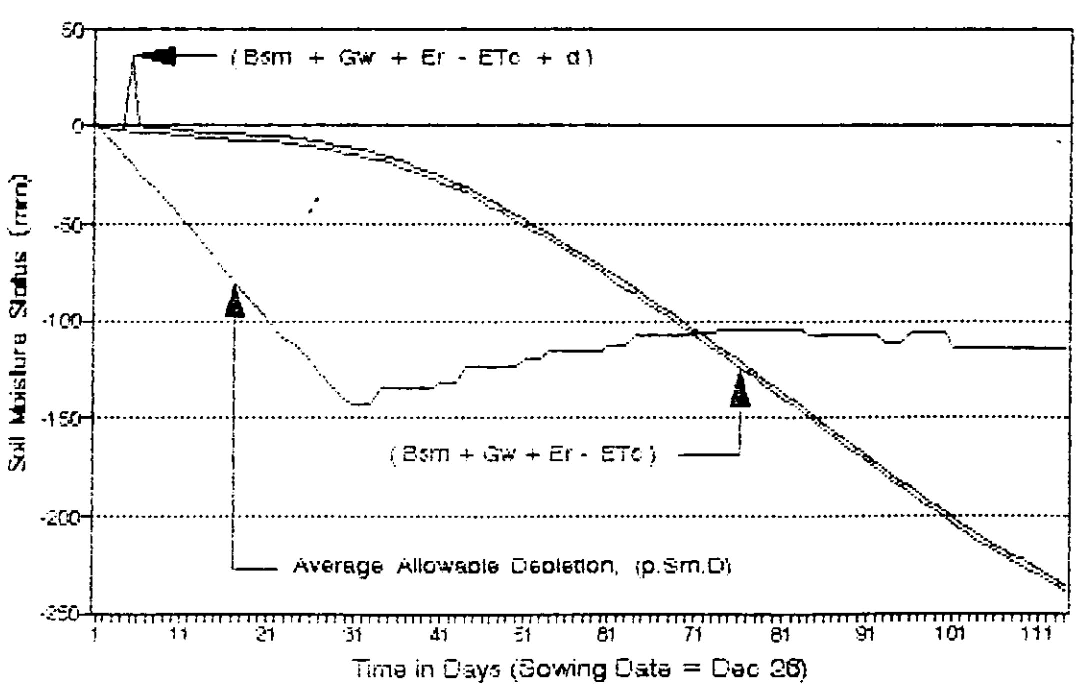


Fig C.46 Water Balance for Soybean Crop at Shaplapara (Sample 2-10, Plot No.11)

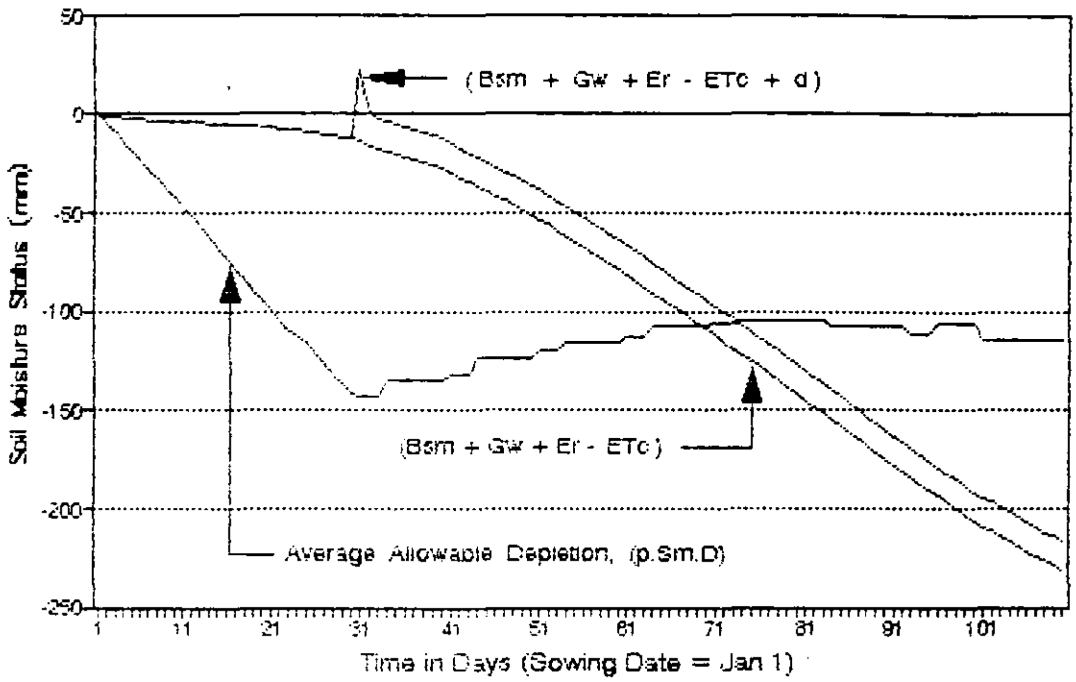


Fig C.47 Water Balance for Soybean Crop at Shaplapara (Sample 2-10, Plot No.12)

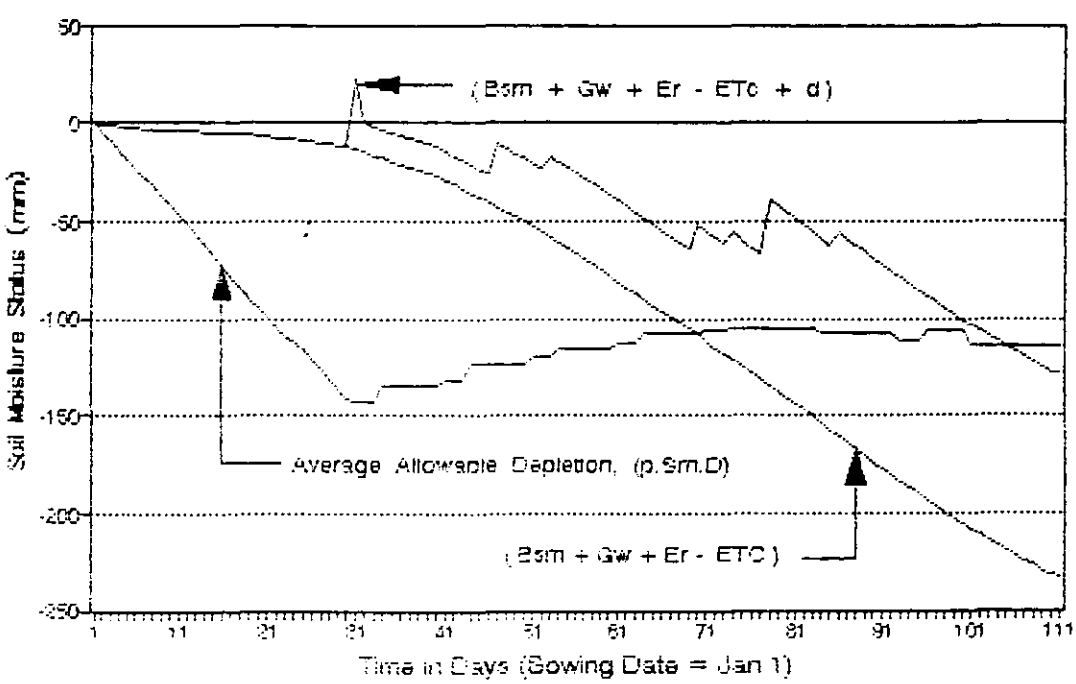
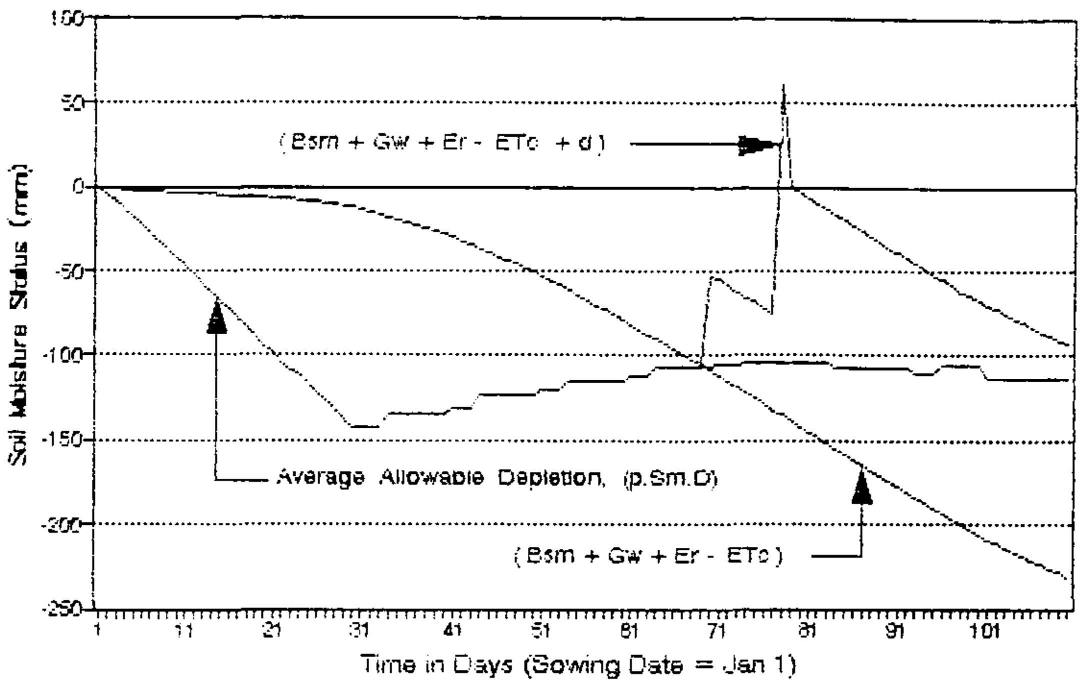


Fig C.48 Water Balance for Soybean Crop
at Shaplapara (Sample 2-10, Plot No.16)



APPENDIX C

Water Balance for Watermelon (Figures C.49 to C.70)

Fig C.49 Water Balance for Watermelon at Taltolapara (Sample 1-4, Plot 17)

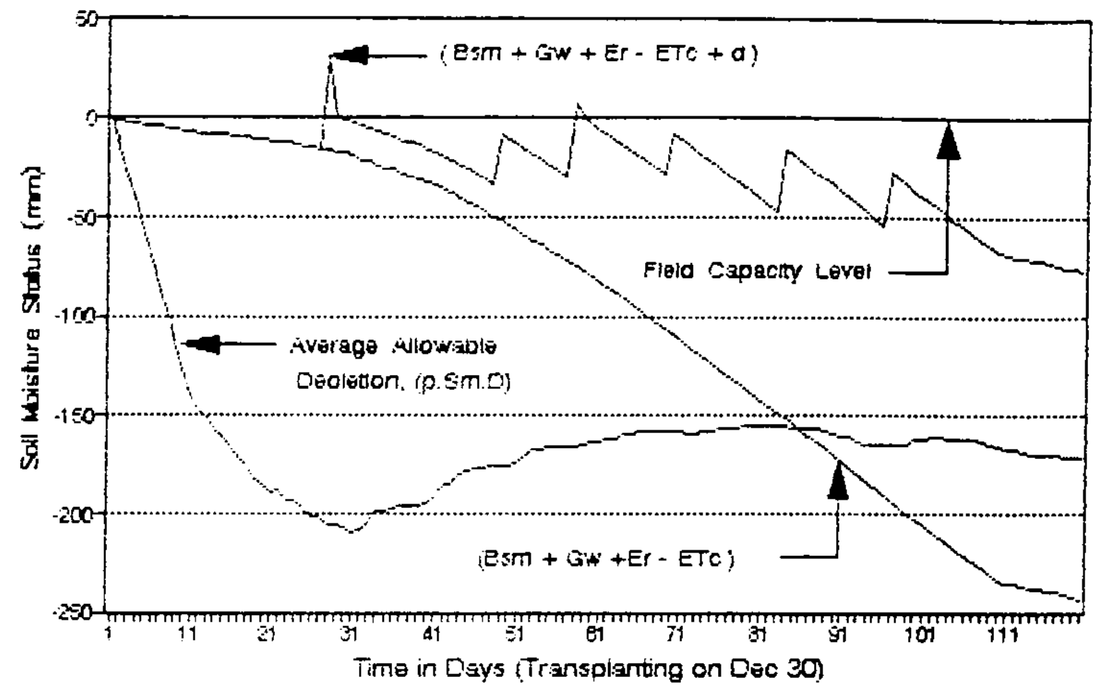


Fig C.50 Water Balance for Watermelon at Taltolapara (Sample 1-4, Plot 1)

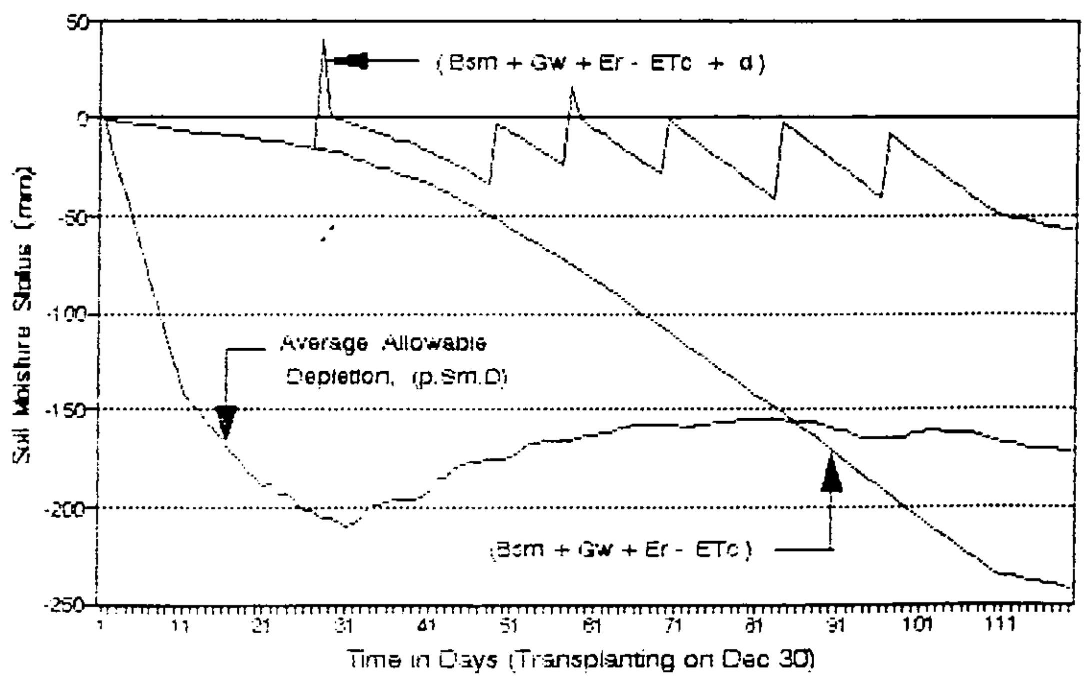


Fig C.51 Water Balance for Watermelon at Taltolapara (Sample 1-5, Plot 2)

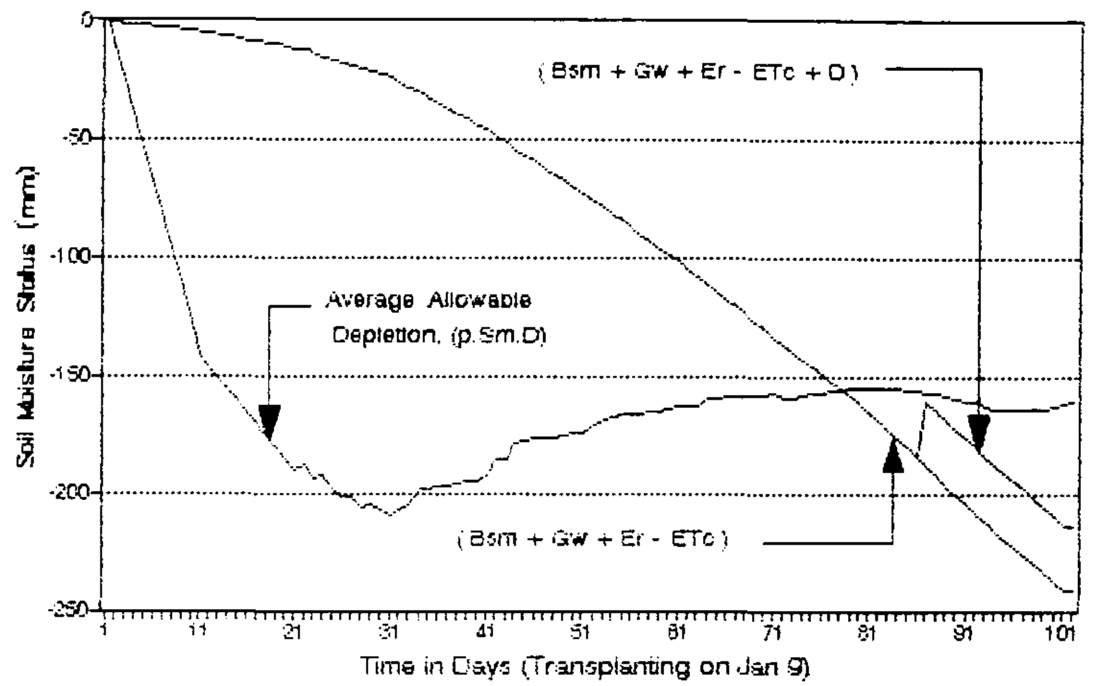


Fig C.52 Water Balance for Watermelon at Taltolapara (Sample 1-5, Plot 38)

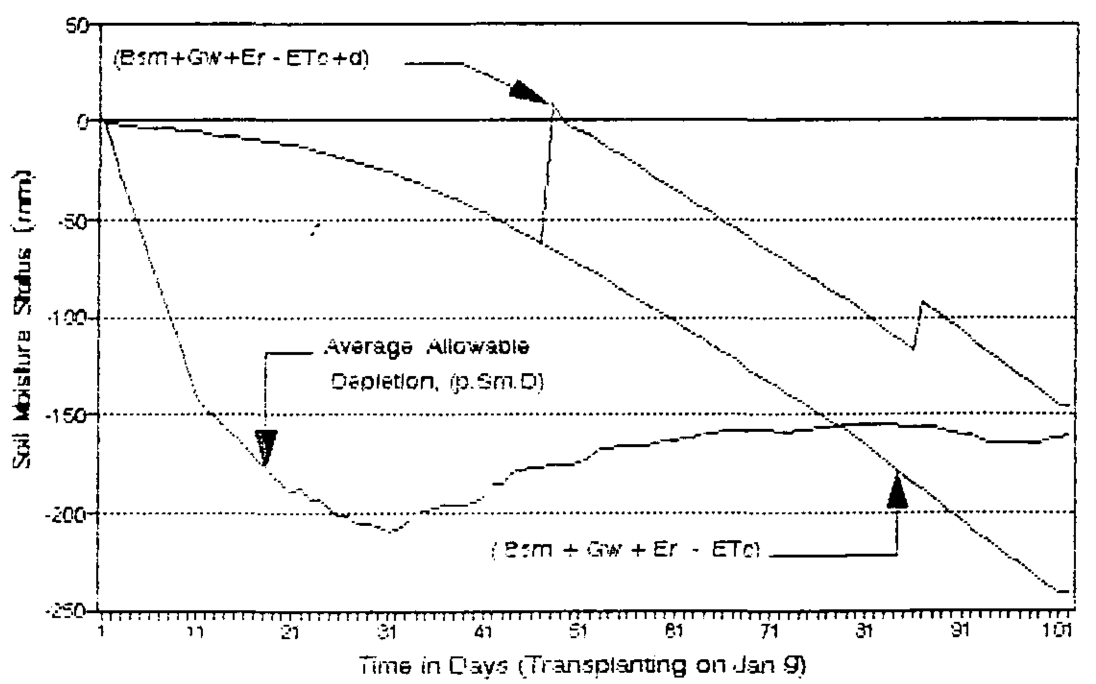


Fig C.53 Water Balance for Watermelon
at Taltolapara (Sample 1-5, Plot 20)

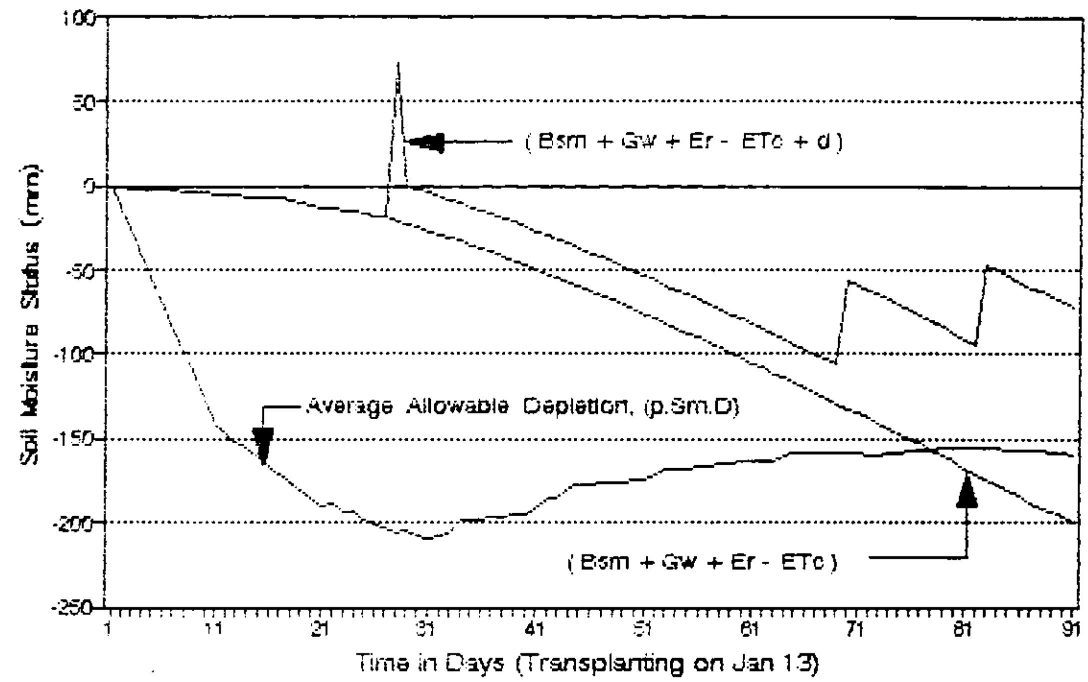


Fig C.54 Water Balance for Watermelon
at Taltolapara (Sample 1-5, Plot 21)

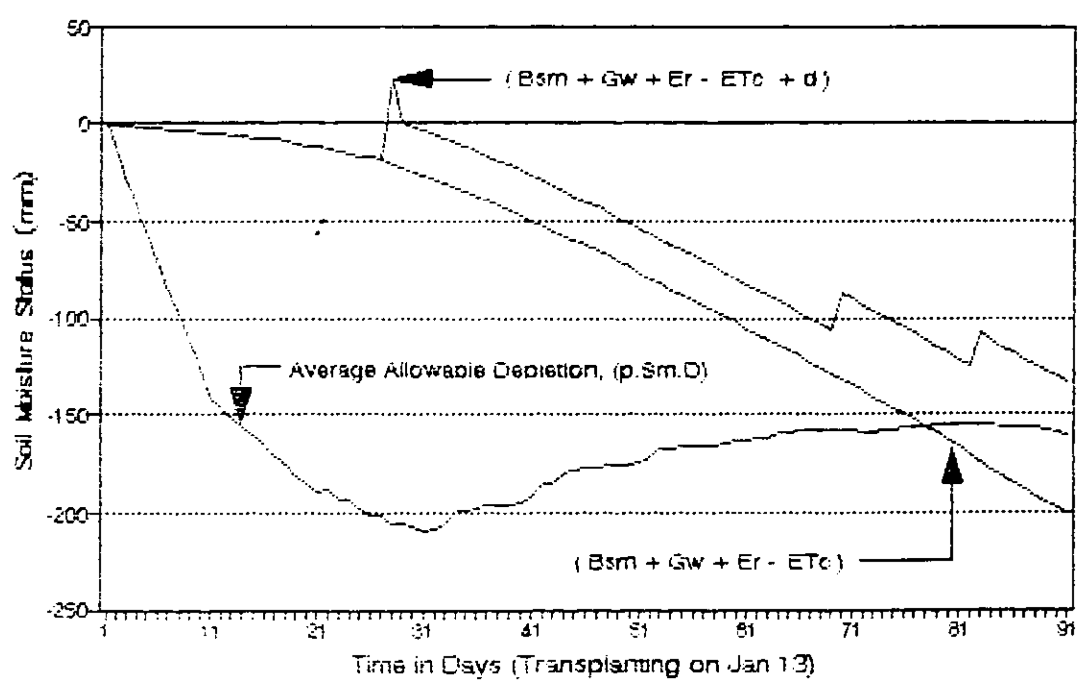


Fig C.55 Water Balance for Watermelon at Taltolapara (Sample 1–5, Plot 23)

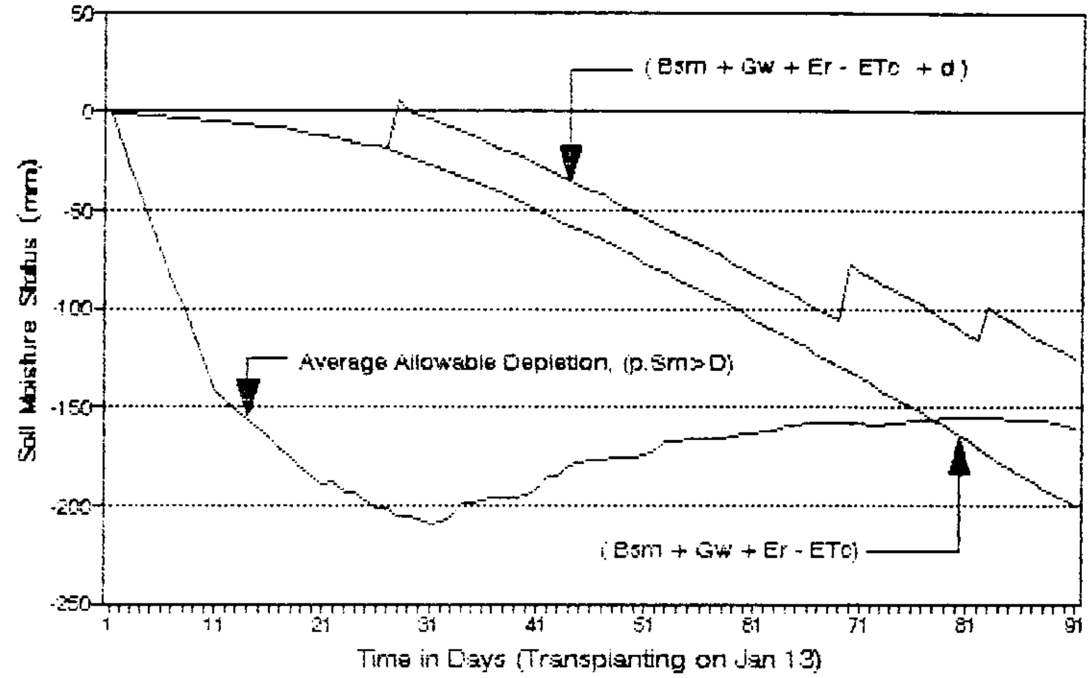


Fig C.56 Water Balance for Watermelon at Taltolapara (Sample 1–5, Plot 41)

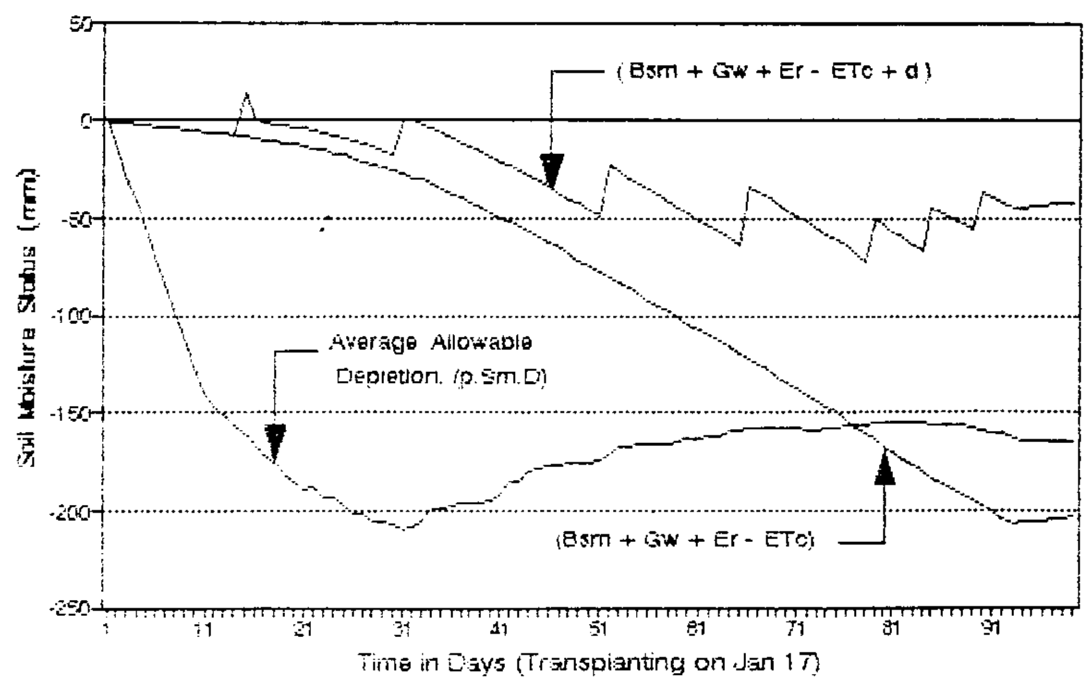


Fig C.57 Water Balance for Watermelon at Taltolapara (Sample 1-5, Plot 5)

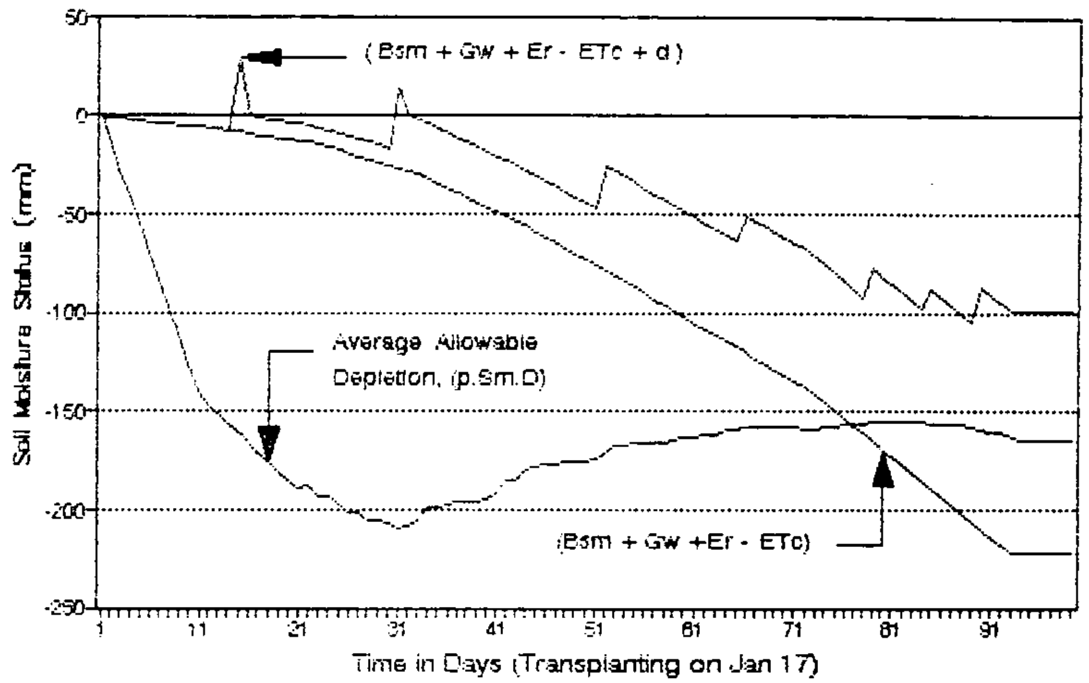


Fig C.58 Water Balance for Watermelon at Taltolapara (Sample 3-3, Plot 9)

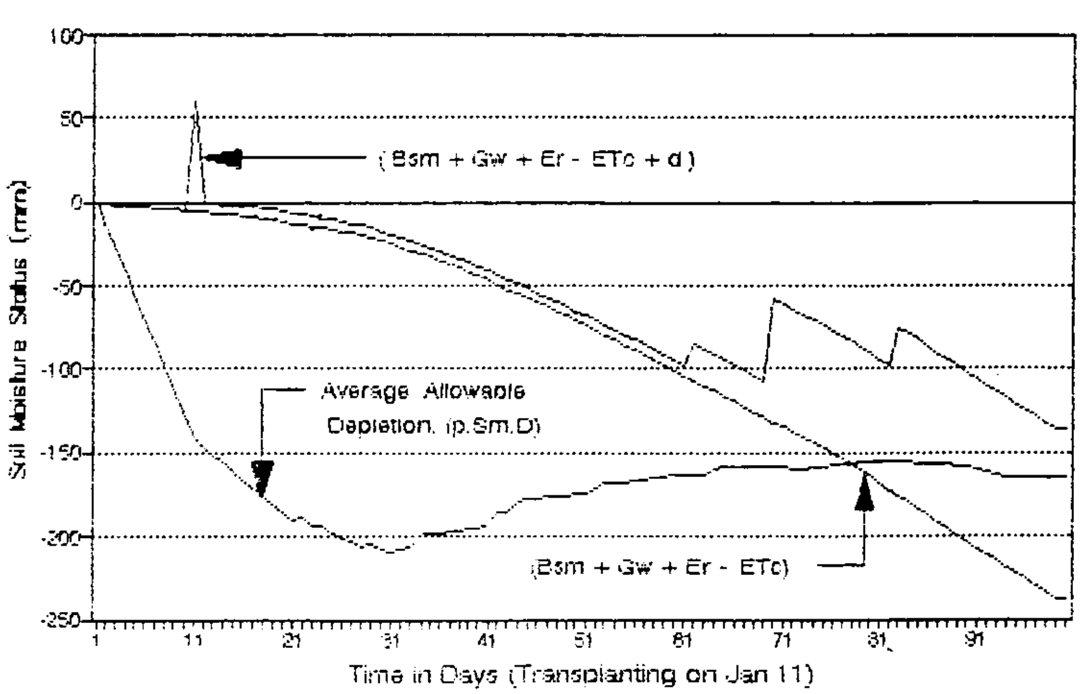


Fig C.59 Water Balance for Watermelon at Taltolapara (Sample 3-3, Plot 2)

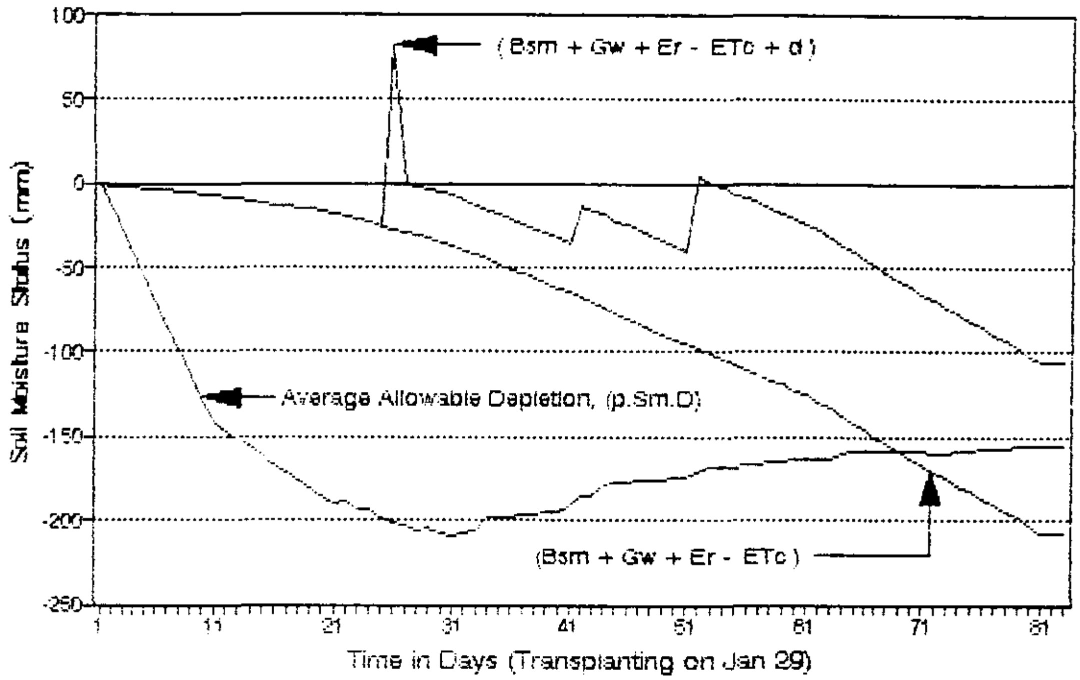


Fig C.60 Water Balance for Watermelon at Taltolapara (Sample 3-3, Plot 3)

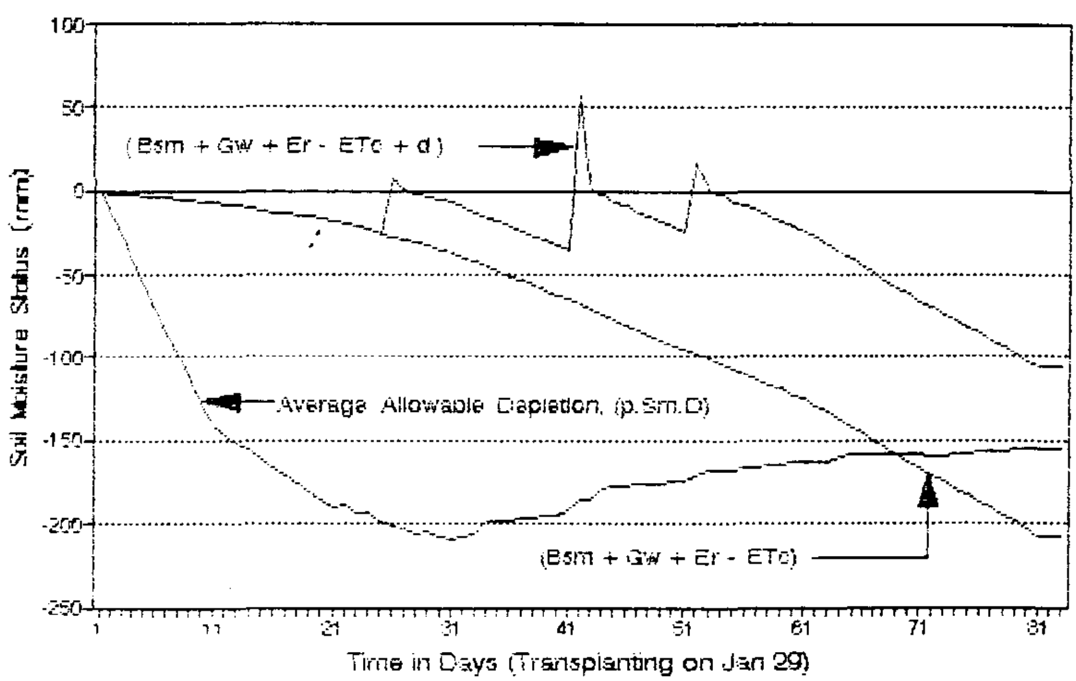


Fig C.61 Water Balance for Watermelon at Taltolapara (Sample 3-3, Plot 4)

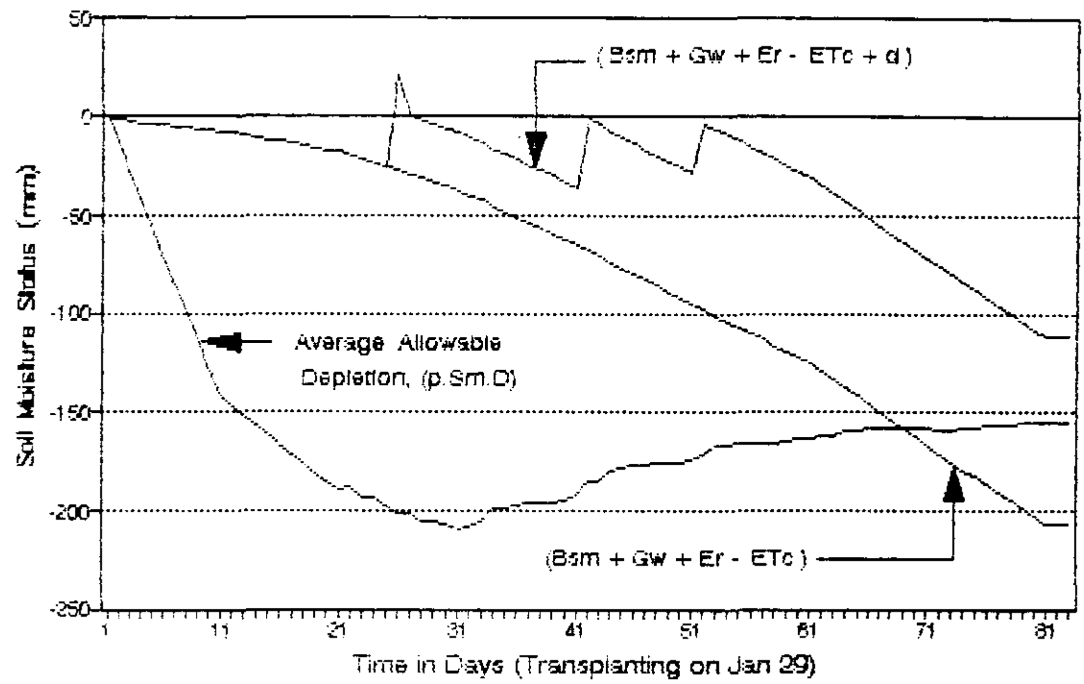


Fig C.62 Water Balance for Watermelon at Taltolapara (Sample 3-3, Plot 5)

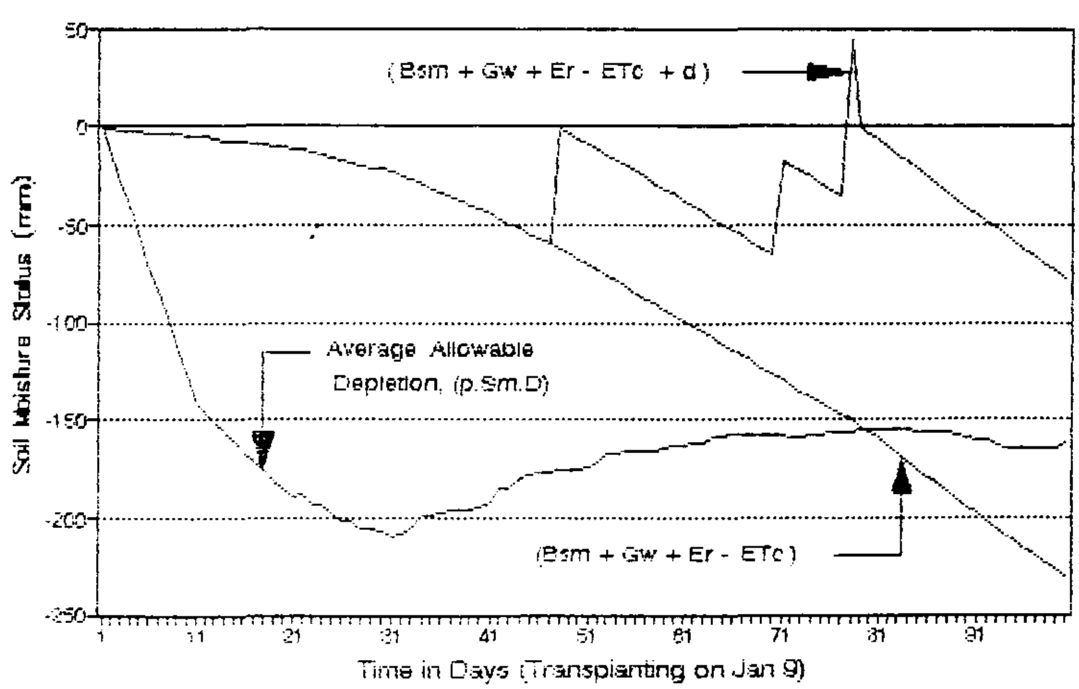


Fig C.63 Water Balance for Watermelon
at Taltolapara (Sample 3-3, Plot 6)

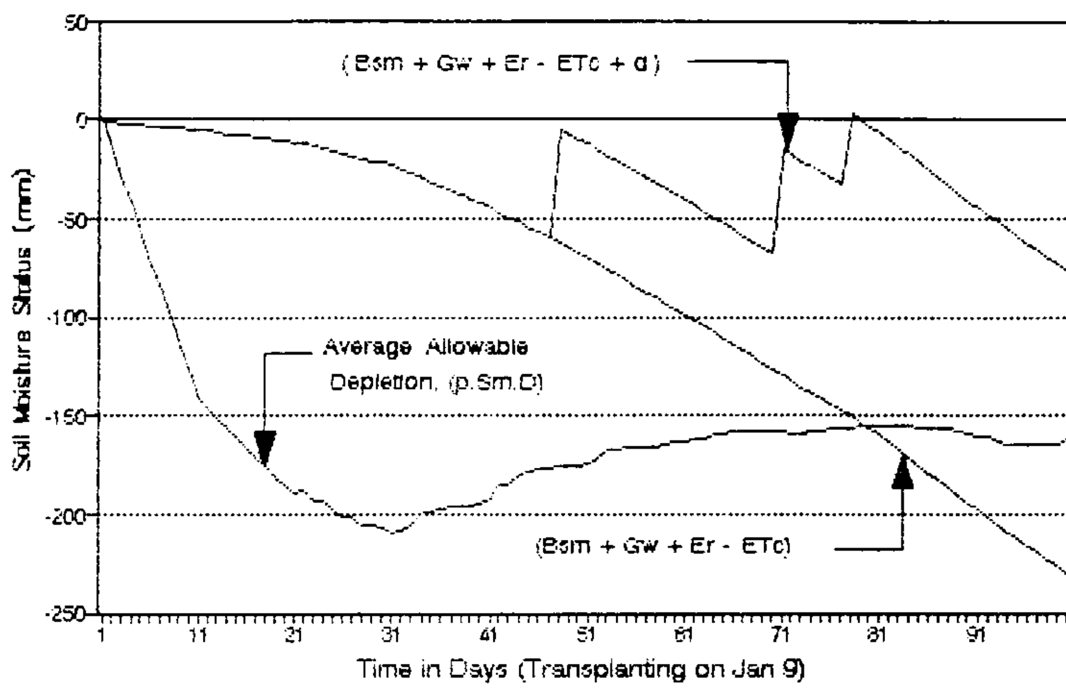


Fig C.64 Water Balance for Watermelon
at Taltolapara (Sample 3-3, Plot 7)

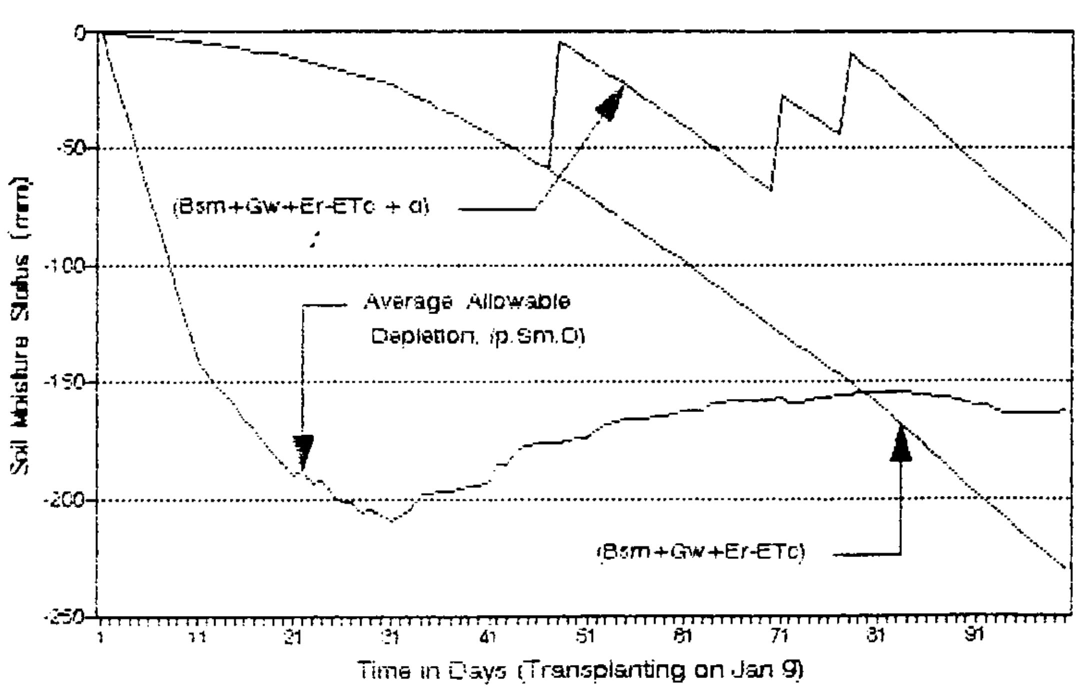


Fig C.65 Water Balance for Watermelon at Taltolapara (Sample 3-3, Plot 8)

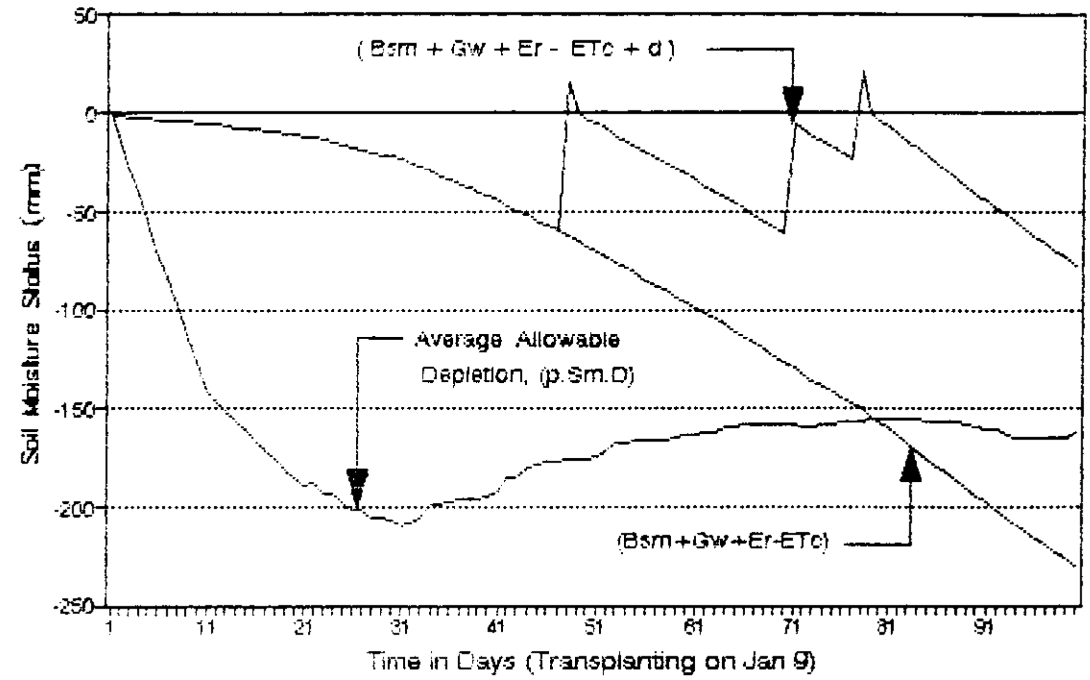


Fig C.66 Water Balance for Watermelon at East Kutubpur (Sample 1-6, Plot 3)

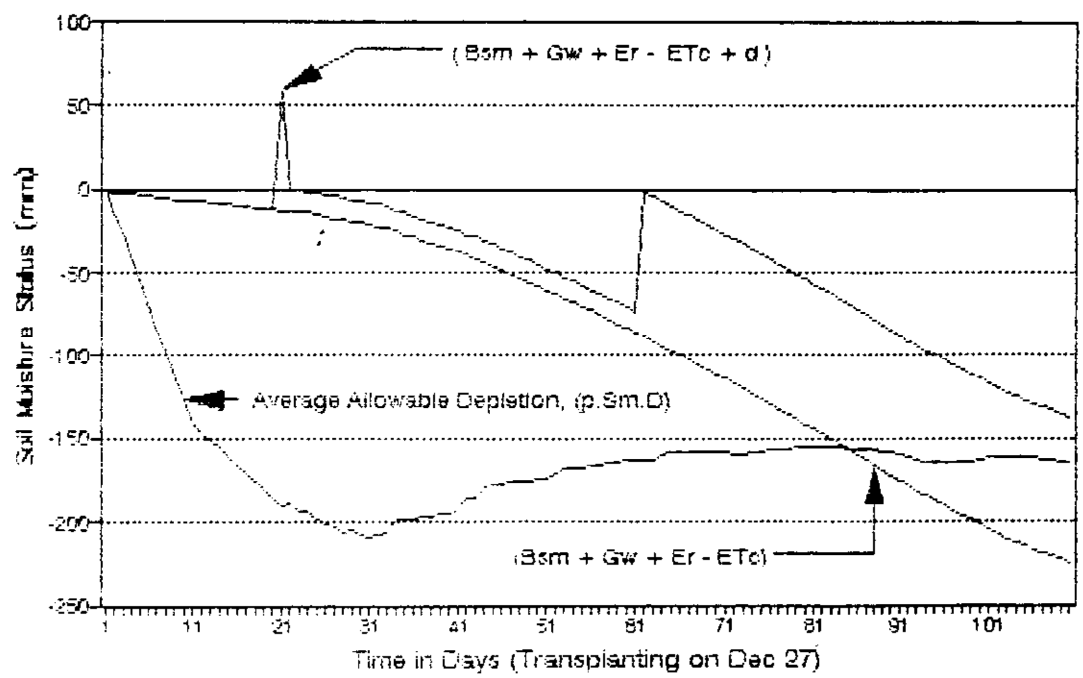


Fig C.67 Water Balance for Watermelon at Shaplapara (Sample 1-3, Plot 2)

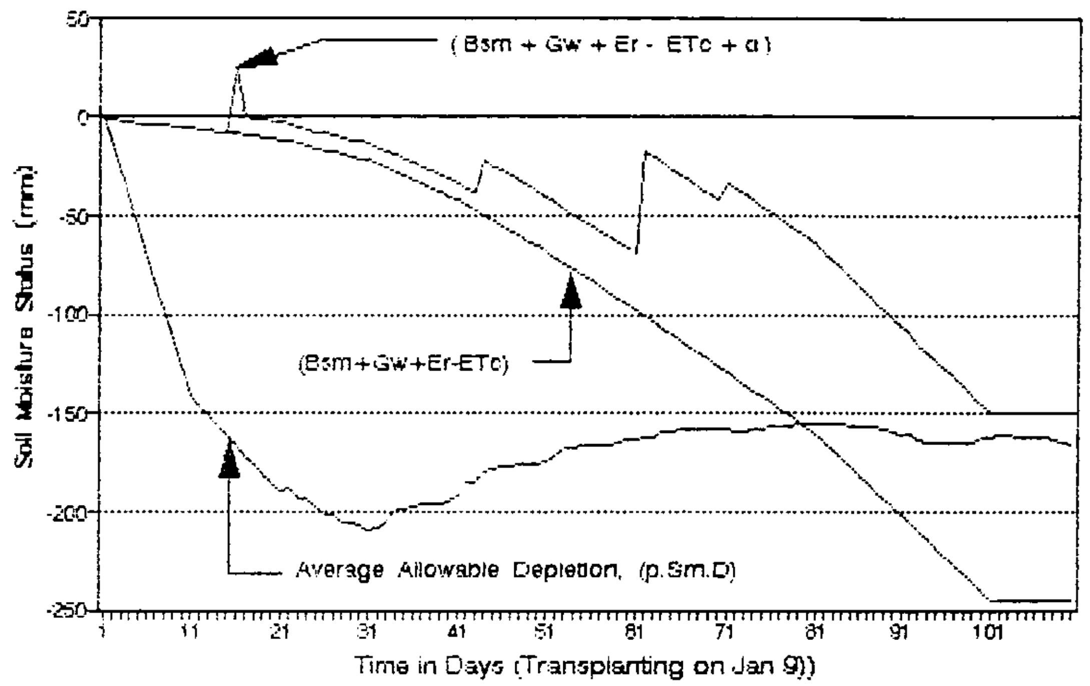


Fig C.68 Water Balance for Watermelon at Shaplapara (Sample 2-5, Plot 10)

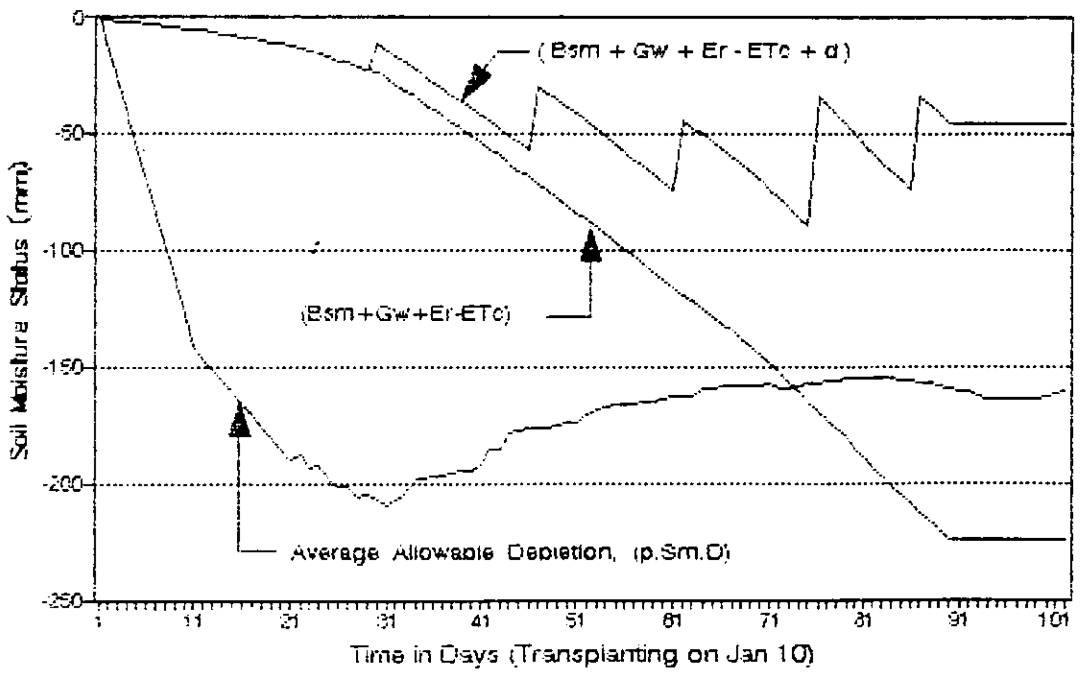


Fig C.69 Water Balance for Watermelon at Shaplapara (Sample 2-5, Plot 1)

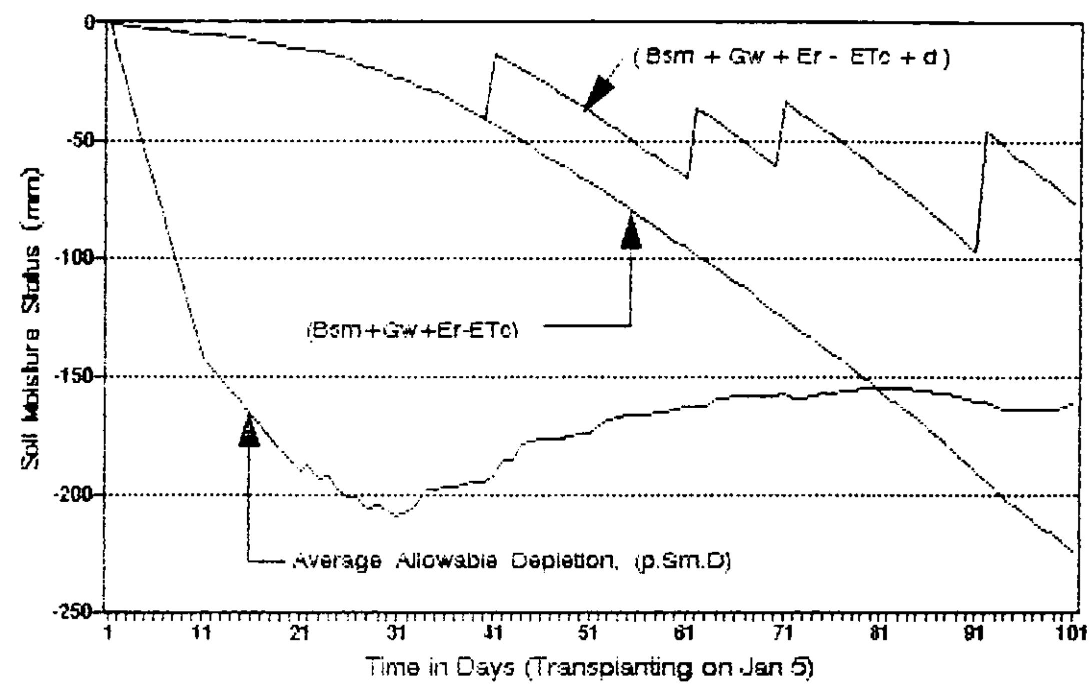
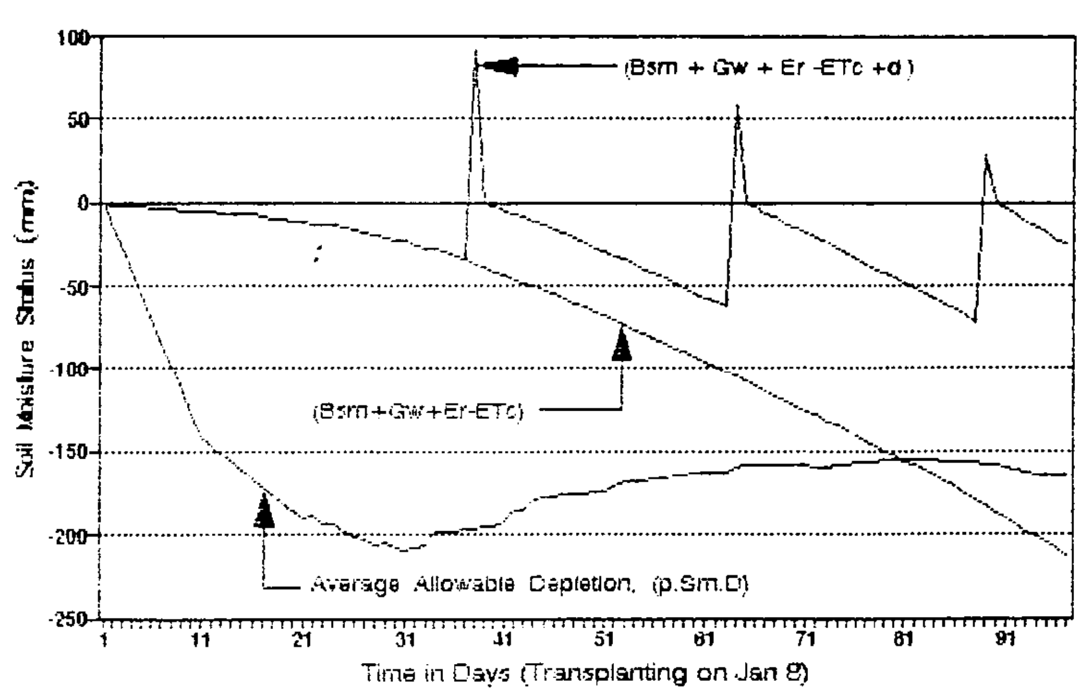


Fig C.70 Water Balance for Watermelon at Shaplapara (Sample 2-5, Plot 11)



APPENDIX C

Water Balance for Boro-rice (Figures C.71 to C.81)

Fig C.71 Water Balance for Boro-rice at Taltolapara (Sample 3-3, Plot No.1)

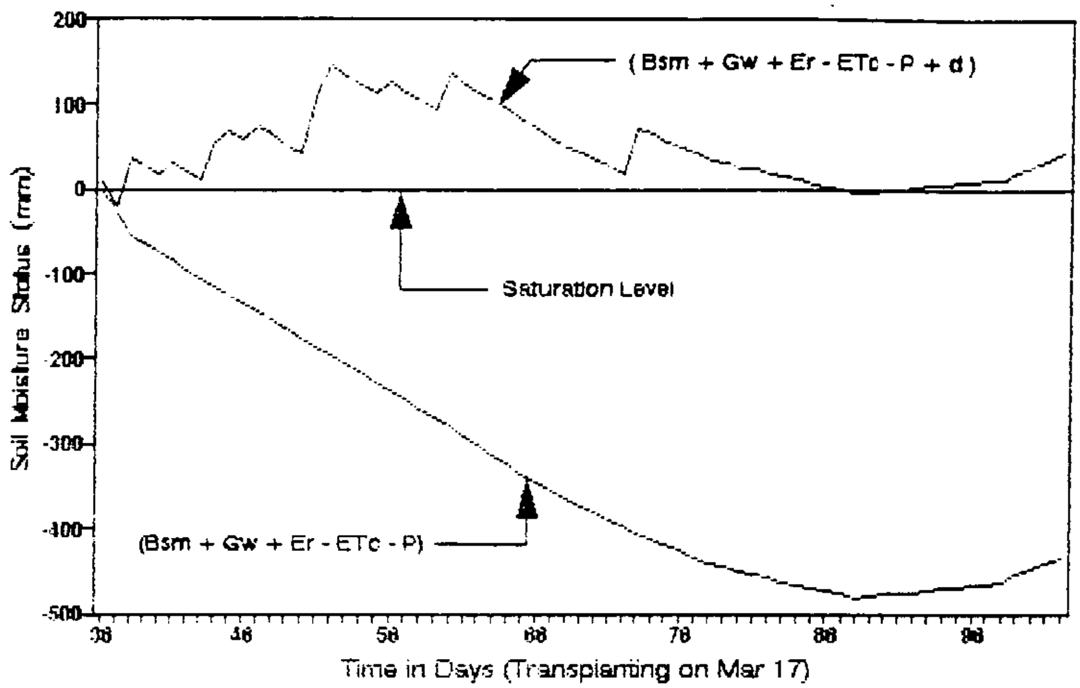


Fig C.72 Water Balance for Boro-rice at Taltolapara (Sample 3-3, Plot No.11)

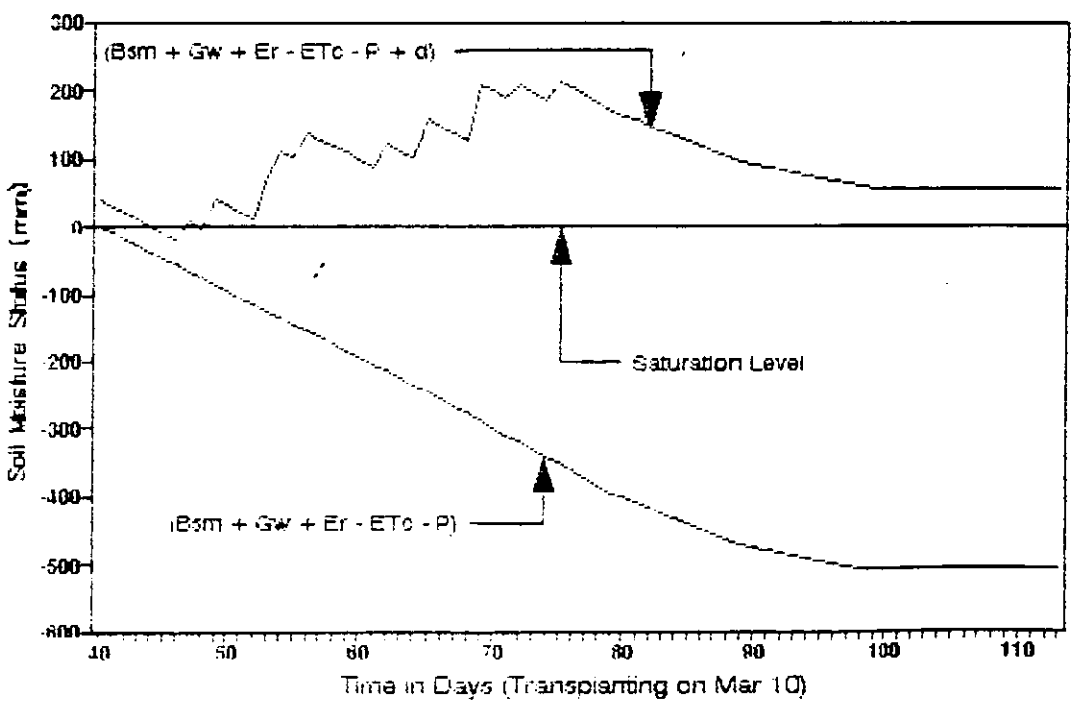


Fig C.73 Water Balance for Boro-rice at Taltolapara (Sample Pump, Plot 11)

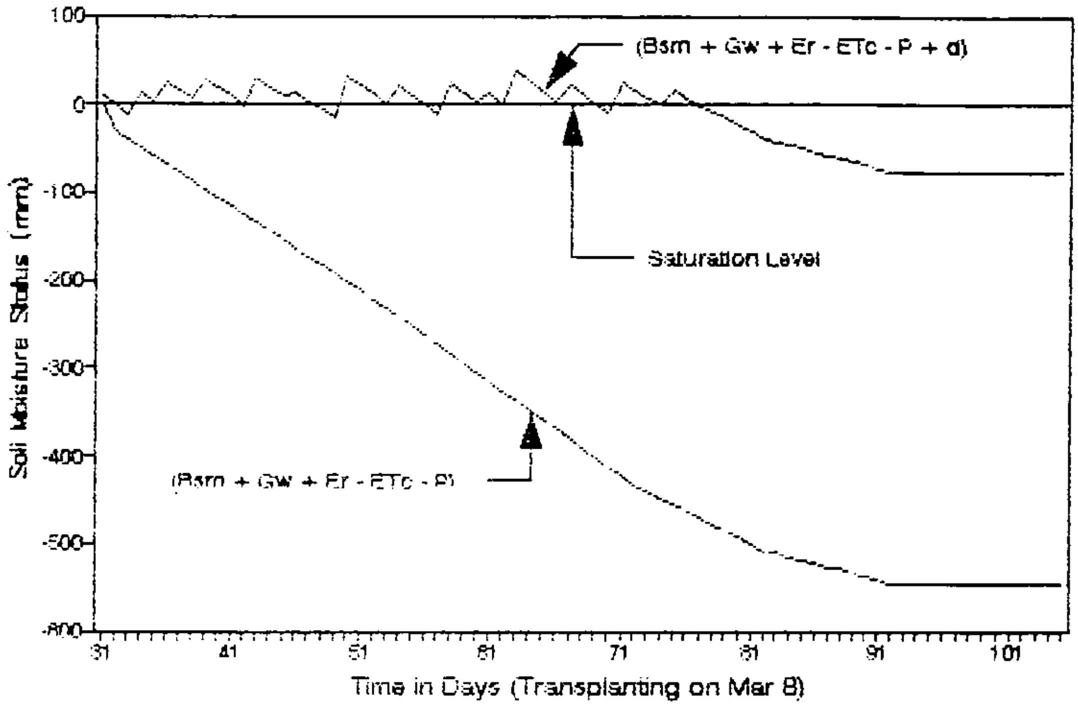


Fig C.74 Water Balance for Boro-rice at East Kutubpur (Sample Pump, Plot No.7)

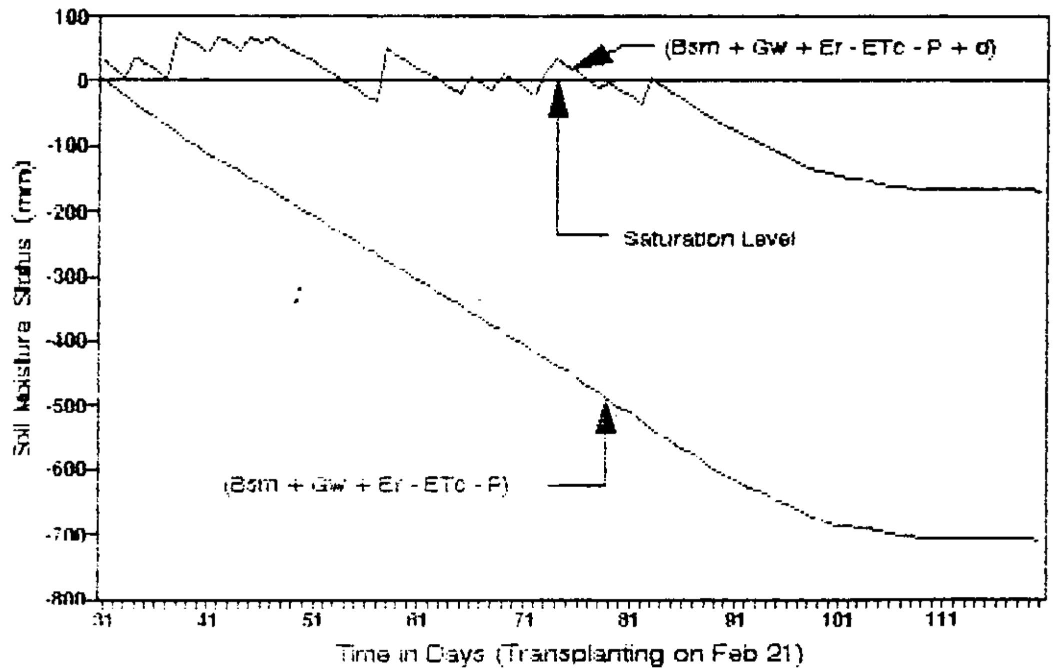


Fig C.75 Water Balance for Boro-rice at Shaplapara (Sample 2-5, Plot No.17)

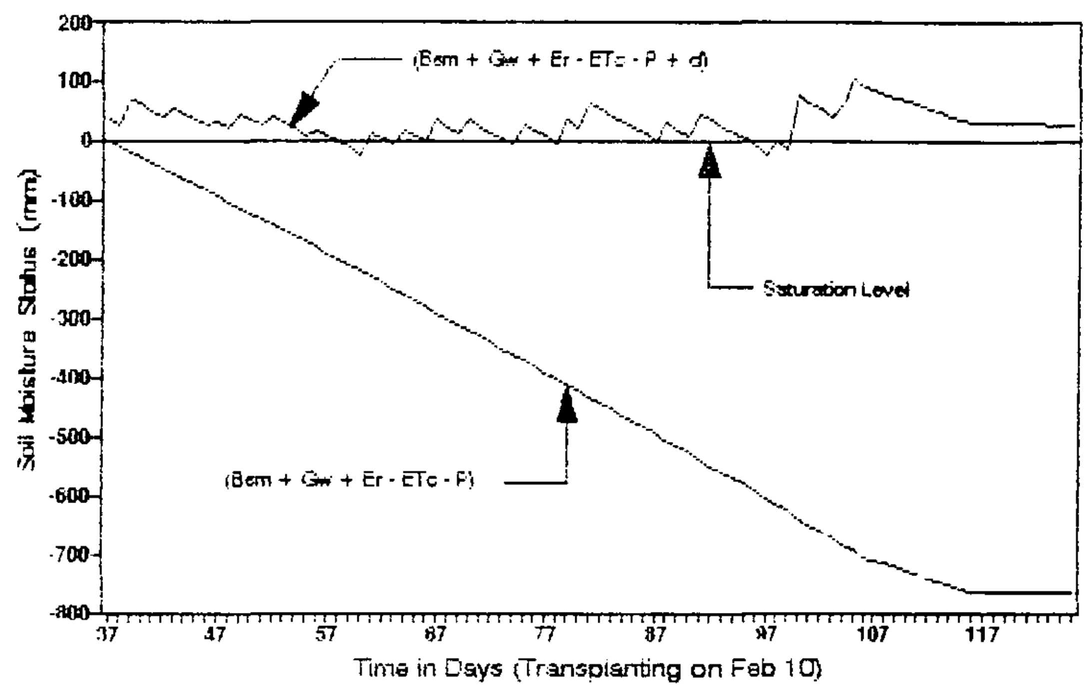
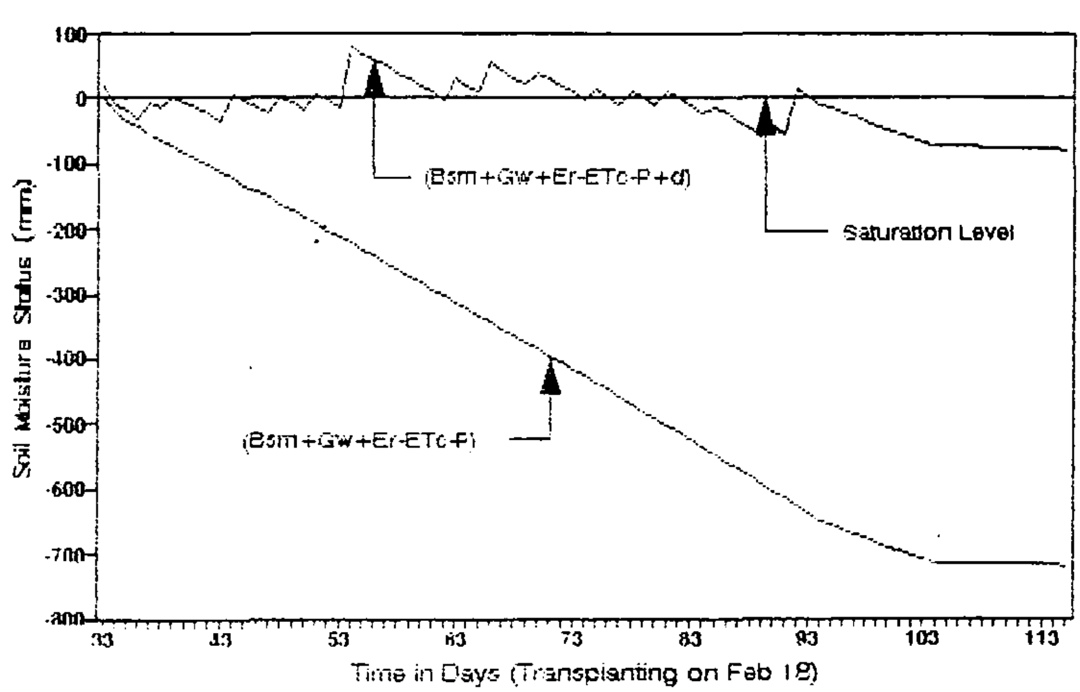


Fig C.76 Water Balance for Boro-rice at Shaplapara (Sample 2-5, Plot No. 6)



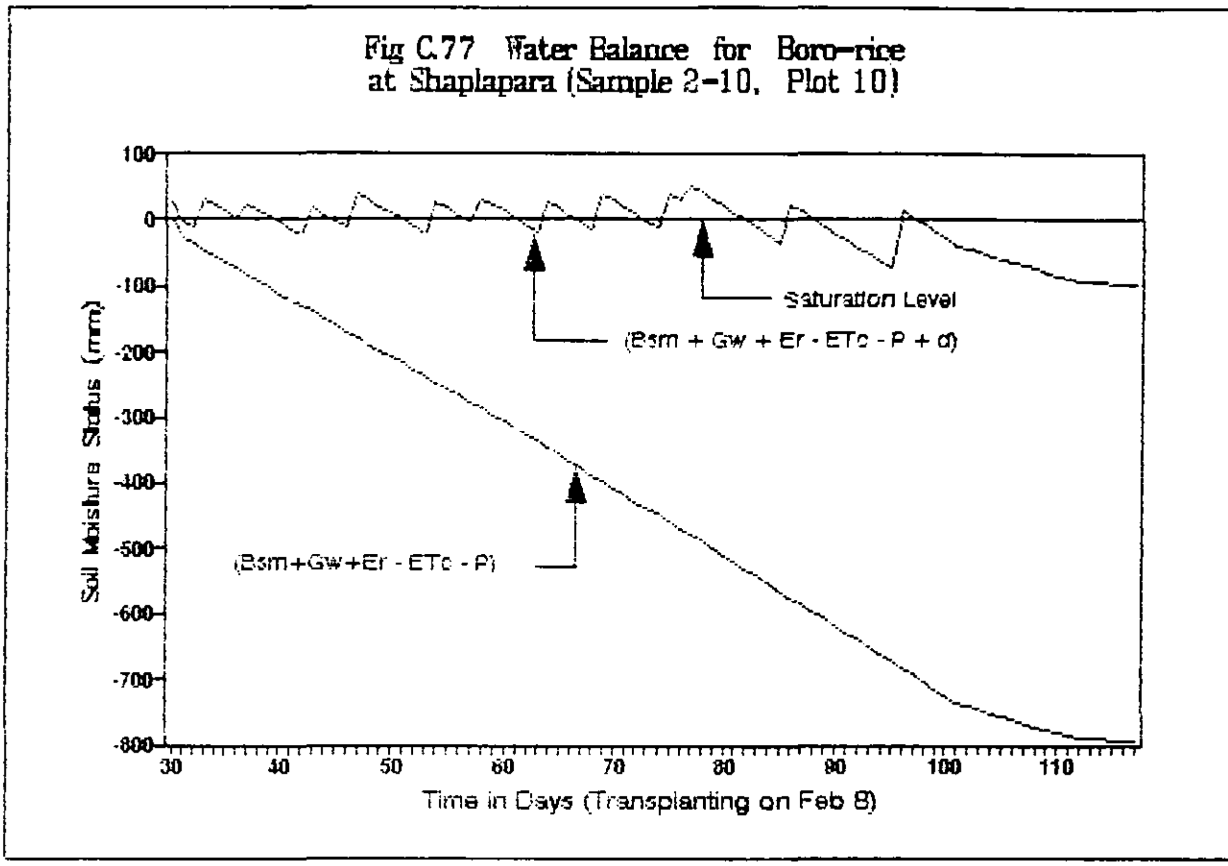


Fig C.77 Water Balance for Boro-rice
at Shaplapara (Sample 2-10, Plot 10)
Saturation Level
(Bsm + Gw + Er - ETc - P + d)
(Bsm+Gw+Er - ETc - P)
Soil Moisture Status (mm)
Time in Days (Transplanting on Feb 8)

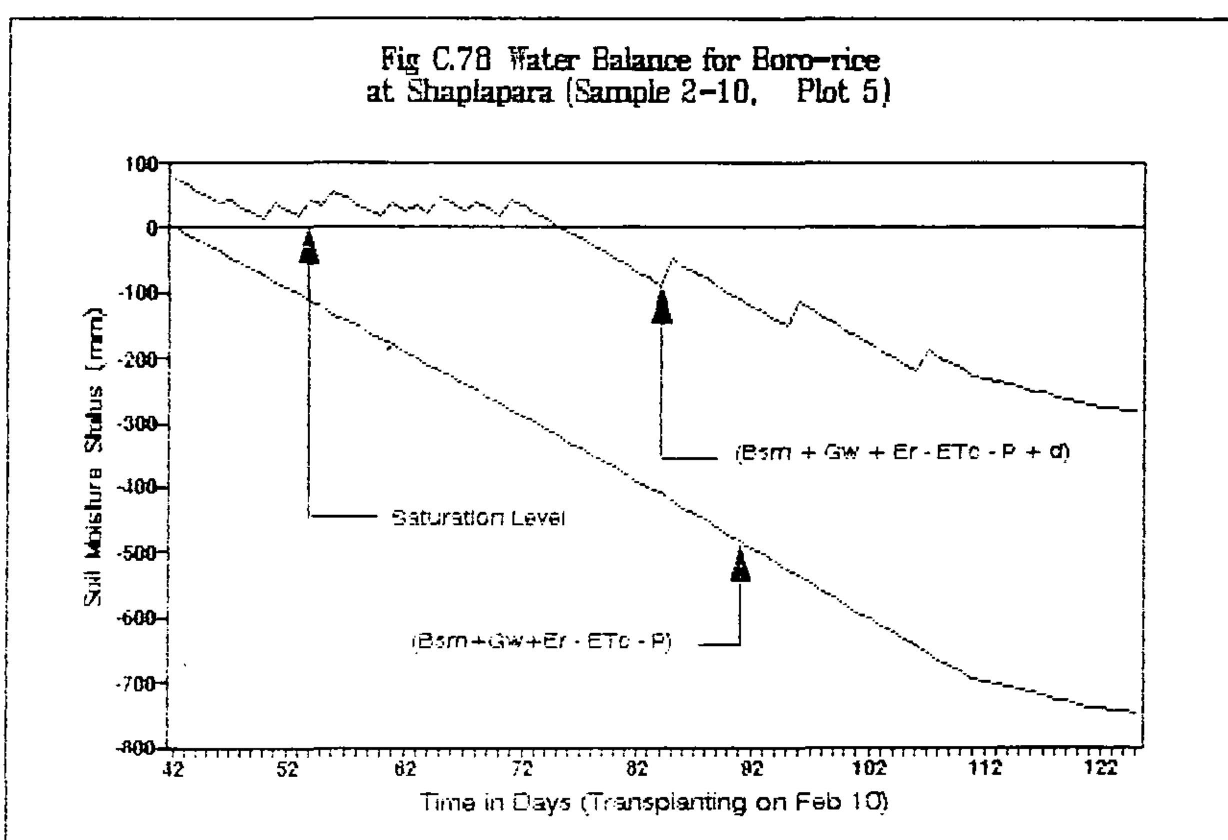


Fig C.78 Water Balance for Boro-rice
at Shaplapara (Sample 2-10, Plot 5)
(Bsm + Gw + Er - ETc - P + d)
Saturation Level
(Bsm+Gw+Er - ETc - P)
Soil Moisture Status (mm)
Time in Days (Transplanting on Feb 10)

Fig C.79 Water Balance for Boro-rice at Shaplapara (Sample 2-10, Plot 8)

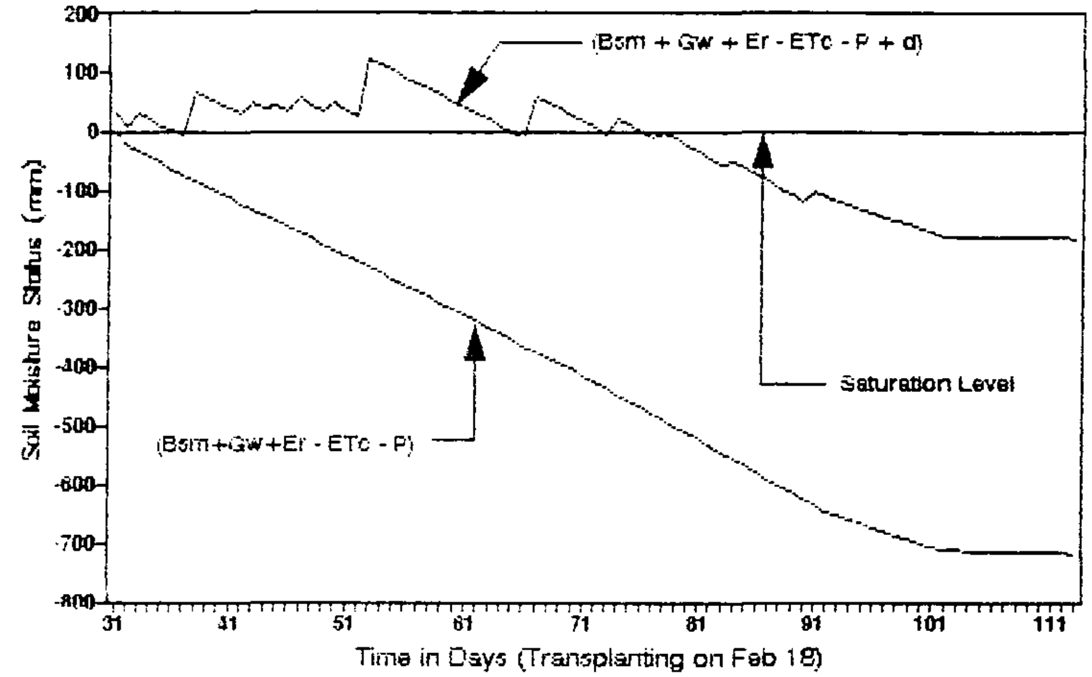


Fig C.80 Water Balance for Boro-rice at Shaplapara (Sample 2-10, Plot 9)

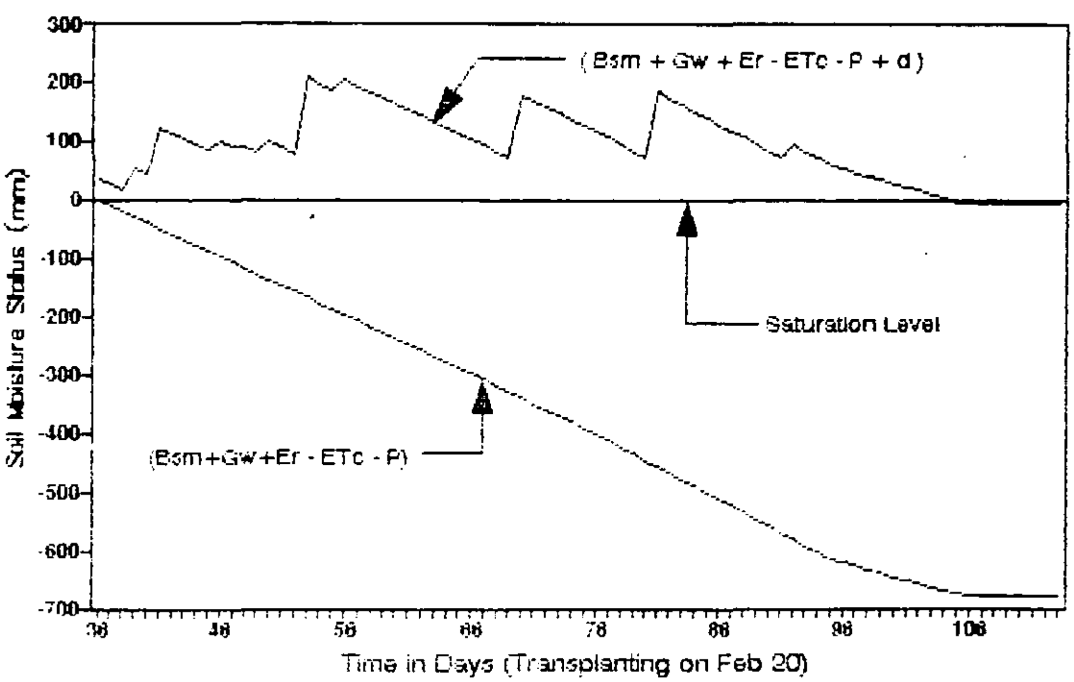
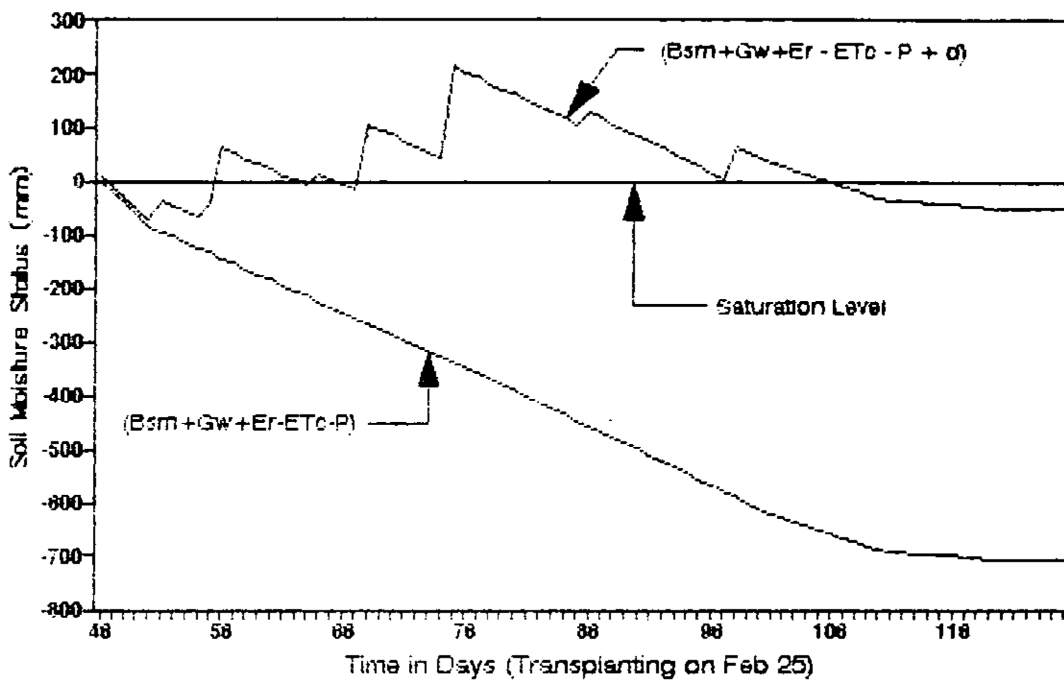


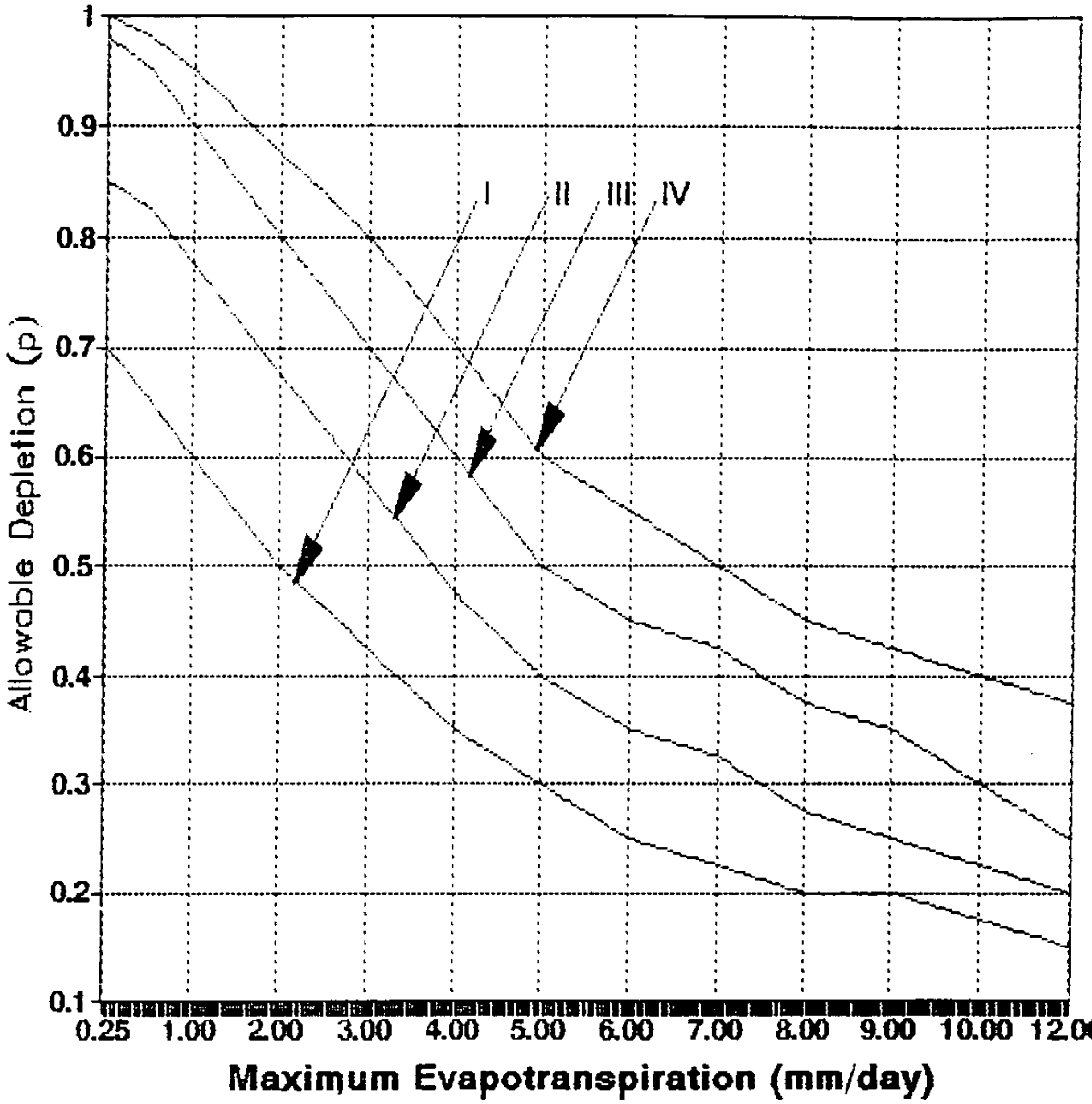
Fig C.81 Water Balance for Boro-rice
at Shaplapara (Sample 2-10, Plot 7)



APPENDIX D

Figure D1

Maximum Allowable Soil Water Depletion Fraction



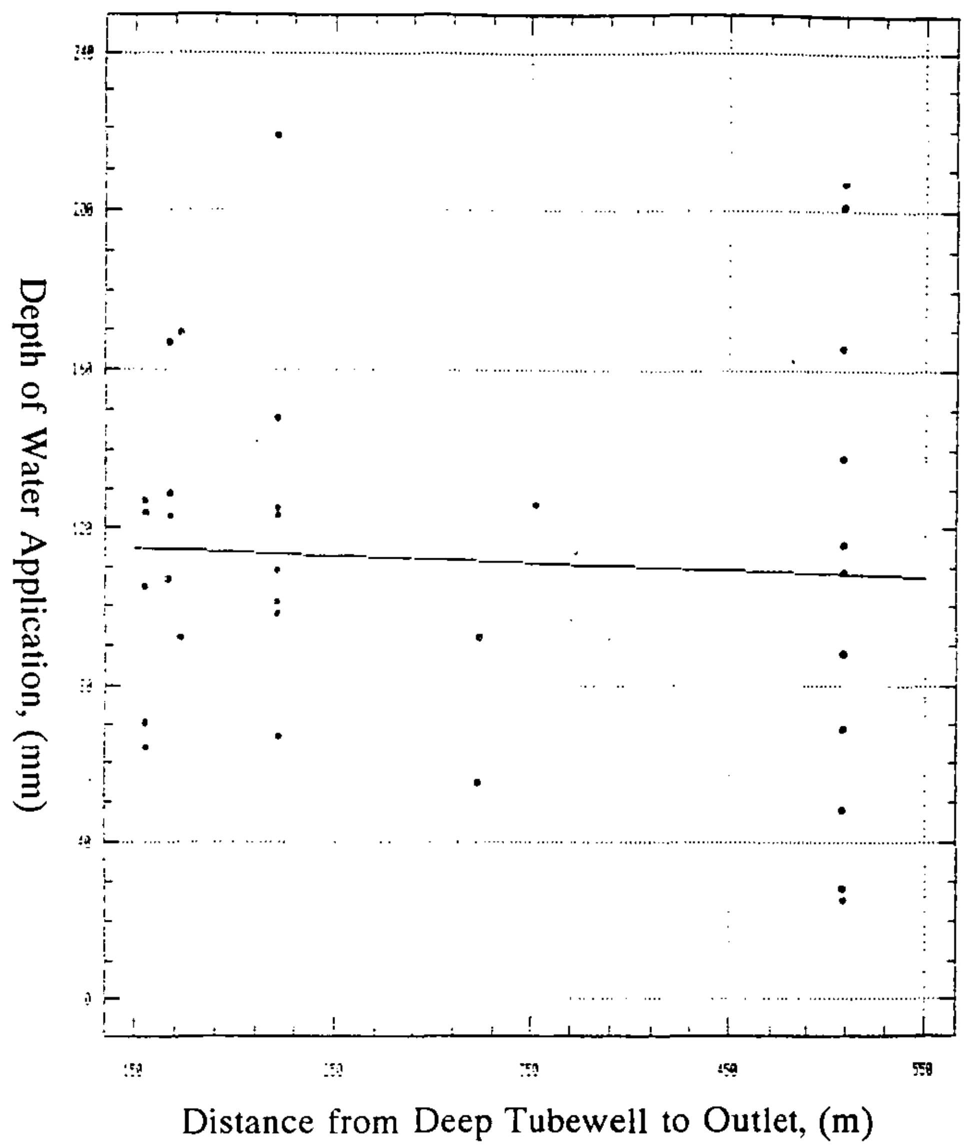
Note:

I	Onion, Pepper, Potato
II	Banana, Cabbage, Tomato
III	Groundnut, Watermelon, Wheat
IV	Cotton, Soybean, Sugarcane

Source: FAO, Irrigation and Drainage Paper No.33

Figure D.2

Regression of Depth of Application on Distance (Wheat)



Regression Analysis - Linear model: Y = a+bX

Dependent variable: WH.WHDEPTH   Independent variable: WH.WHDIS

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	117.[illegible]	[illegible]	[illegible]	.00000
Slope	[illegible]	[illegible]	-0.335841	.73912

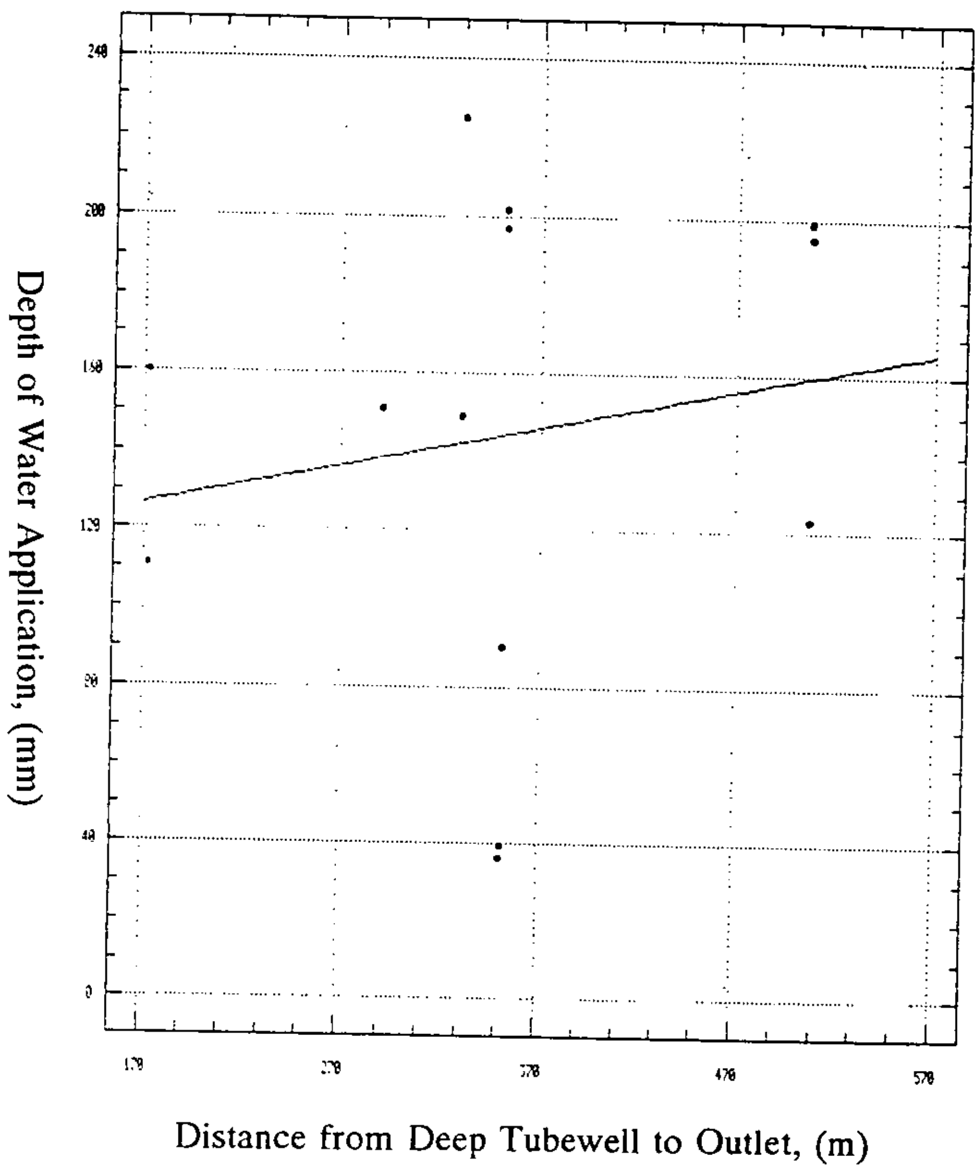
Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	[illegible]	1	252.12395	.1128	.73912
Residual	[illegible]	[illegible]	2235.359		
Lack-of-Fit	[illegible]	[illegible]	1667.8445	.714	.61831
Pure Error	[illegible]	[illegible]	2326.701		
Total (Corr.)	[illegible]	[illegible]			

Correlation Coefficient = -0.0[illegible]   R-squared = .34 percent
Stnd. Error of Est. = [illegible]

Figure D.3

Regression of Depth of Application on Distance (Soybean)



Regression Analysis - Linear model: Y = a+bX

Dependent variable: SO.SODEPTH Independent variable: SO.SODIS

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	109.836	61.9975	1.77163	.10412
Slope	0.0981699	0.168893	0.581255	.57279

Analysis of Variance

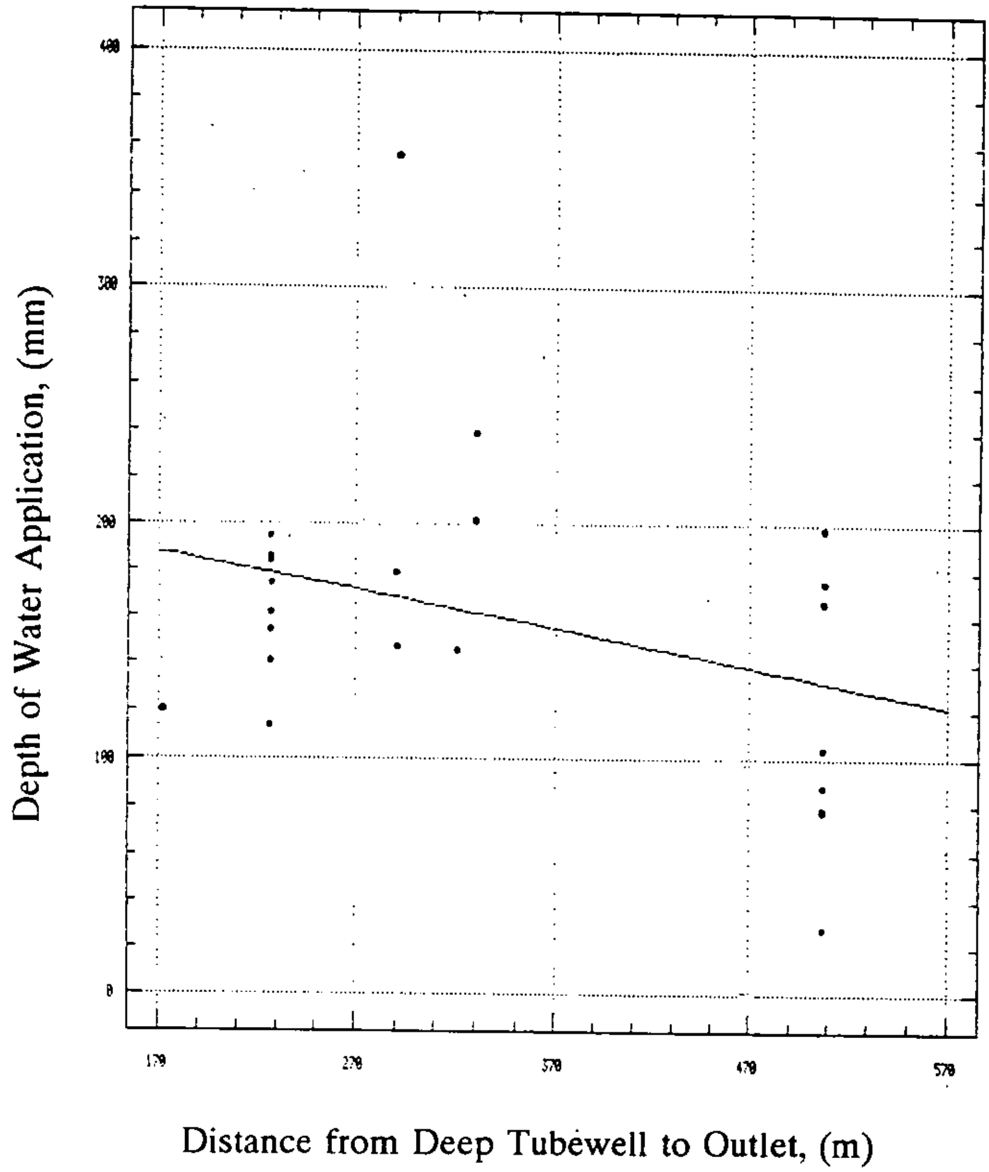
Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	1365.4823	1	1365.4823	.338	.57279
Residual	44457.595	11	4041.600		
Lack-of-fit	9799.6280	3	3266.5427	.754	.55031
Pure error	34657.967	8	4332.246		
Total (Corr.)	45823.077	12			

Correlation Coefficient = 0.172624 R-squared = 2.98 percent

Stnd. Error of Est. = 63.5736

Figure D.4

Regression of Depth of Application on Distance (Watermelon)



Regression Analysis - Linear model: Y = a+bX

Dependent variable: WA.WADEPTH | Independent variable: WA.WADIS

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	215.744	38.853	5.55283	.00002
Slope	-0.1641	0.10863	-1.51063	.14652

Analysis of Variance

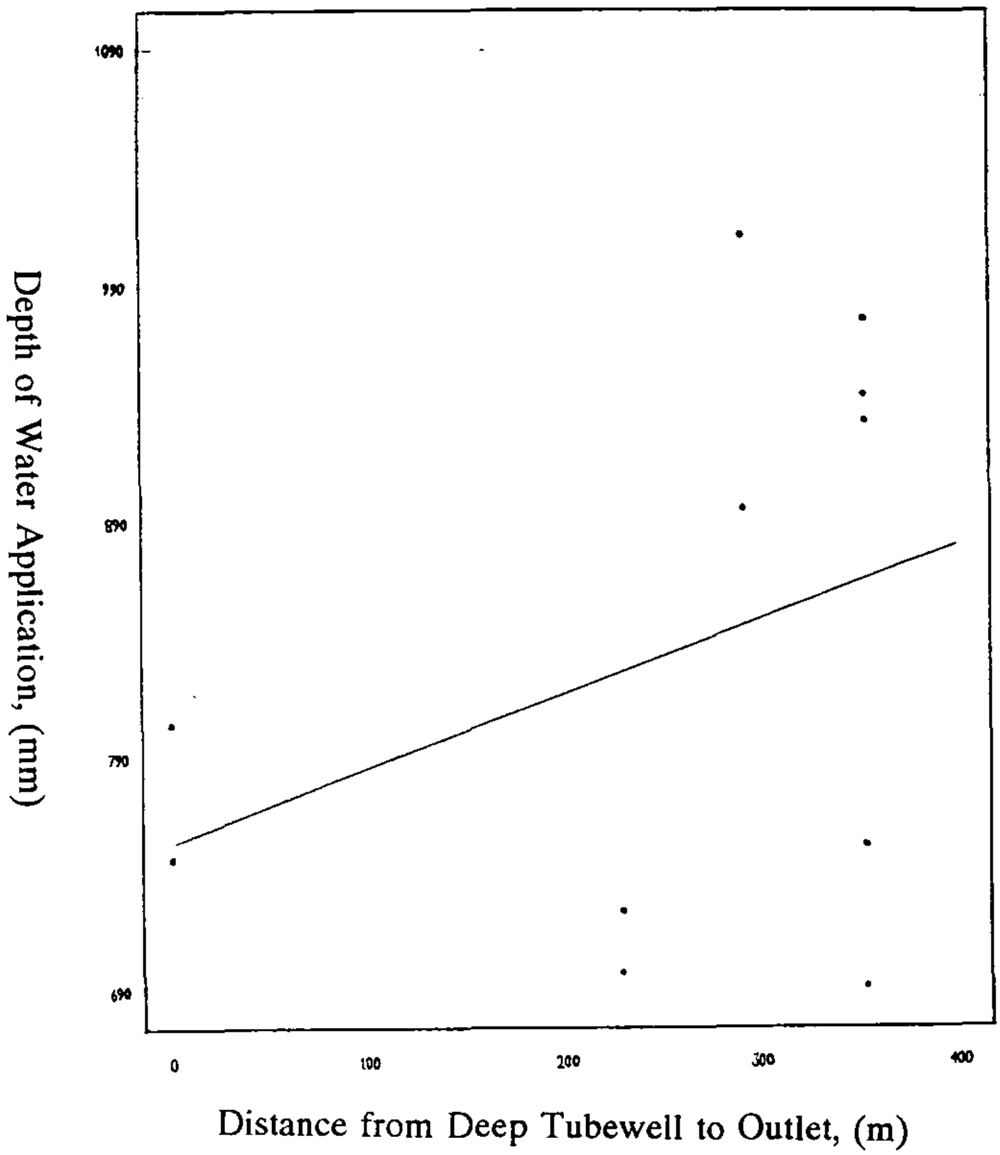
Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	8974.7007	1	8974.7007	2.282	.14652
Residual	78656.390	20	3932.820		
Lack-of-fit	25273.509	4	6318.377	1.89	.16072
Pure error	53382.881	16	3336.430		
Total (Corr.)	87631.091	21			

Correlation Coefficient = -0.320022 R-squared = 10.24 percent

Stnd. Error of Est. = 62.7122

Figure D.5

Regression of Depth of Application on Distance (Boro-rice)



Regression Analysis - Linear model: Y = a+bx

Depended variable: Depth of Application   Independent variable: Distance

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	754.149	78.6941	9.58329	.00001
Slope	0.315016	0.275852	1.14199	.28294

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	18058.414	1	18058.414	1.30	.28294
Residual	124626.13	9	13847.35		
Lack-of-fit	50395.932	2	25197.966	2.38	.16308
Pure error	74230.200	7	10604.314		
Total (Corr.)	142684.55	10			

Correlation Coefficient = 0.355755   R-squared = 12.66 Percent

Stnd. Error of Est. = 117.675

APPENDIX E

Table E.1 Cost Involvement in the Buried Pipe System (1989-90)

Parameters	Schemes ('000 Tk)		
	Taltolapara	East Kutubpur	Shaplapara
Fixed costs			
Deep Tubewell			
a) Depreciation	49	49	49
b) Interest on invest.	57	57	57
Buried Pipeline			
a) Depreciation	8.12	7.41	6.15
b) Interest on invest.	23.83	21.74	18.04
Engineering cost/yr	9.25	9.15	8.98
Total Fixed cost/yr	147.2	144.30	139.17
Variable costs			
a) Fuel & Oil	57.48	22.43	35.02
b) R & M of the system	5.02	23.73	4.26
c) Operator's wage	4.58	3.36	4.74
d) Crop production	420	350	499
Total Variable cost/yr	487.08	399.52	543.02
Total cost/yr	634.28	543.82	682.19

Table E.2 Present Values of Costs and Benefits

Year	Present value of costs('000 Tk)			Present value of benefits ('000 Tk)		
	Taltolapara	East Kutubpur	Shaplapara	Taltolapara	East Kutubpur	Shaplapara
1	596	468	588	1476	1003	1912
2	472	404	507	1273	865	1648
3	407	348	437	1097	746	1421
4	350	300	377	946	643	1225
5	302	259	325	815	554	1056
6	260	223	280	703	478	910
7	224	192	241	606	412	785
8	194	166	208	522	355	676
9	167	144	179	450	306	583
10	144	123	155	388	264	503
11	124	106	133	335	227	433
12	107	92	115	288	196	374
13	92	79	99	258	178	332
14	79	68	85	214	146	278
15	68	59	74	185	127	239
16	59	51	63	159	108	206
17	51	44	55	137	93	178
18	44	38	47	118	80	153
19	38	32	41	102	69	132
20	33	28	35	88	60	114
21	28	24	30	76	52	98
22	24	21	26	65	44	85
23	21	18	22	56	38	73
24	18	15	19	49	33	63
25	16	13	17	43	30	56
26	13	11	14	36	25	47
27	12	10	12	31	21	40
28	10	9	11	27	18	35
29	9	7	9	23	16	30
30	7	6	8	20	14	26
	3969	3358	4212	10586	7201	13711

Table E.3 Performace Efficiency of the Buried Pipe Scheme

Performance indicators	Schemes: Taltolapara	East Kutubpur	Shaplapara	Baila	Vailpara	Chulabar	Hazipara	Binakhaira	Remarks
a) Command area (ha)	17.01	11.55	21.11	19.28	16.74	13.36	14.81	19.56	Design = 40 ha; Average = 16.64 ha; Performance efficiency (PE) = (Average/Design) * 100 = 42%
b) Pump operation									
i) Hours/day	4.49	2.22	4.92	6.23	5.84	3.60	3.90	5.47	Average = 4.58 hrs; Advised = 20 hrs/day; PE = 23%
ii) Days/month	18	16	17	15	14	11	11	9	Average = 14 days; Advised 26 days/month; PE = 53%; Overal PE = 12%.
c) KSS fuel system	Own	Own	Own	Project	Own	Own	Own	Own	7 out of 8 schemes followed the own fuel system
d) Unirrigated area (ha)									
i) Unirrigated	1.97	2.54	2.12	1.97	1.62	2.88	3.40	3.98	Average unirrigated area = 2.56 ha/scheme, (14% of actual command)
ii) Fallow	16.16	23.90	12.01	NA	NA	NA	NA	NA	Average fallow land = 17.36 ha/Scheme, (41% of gross command)
e) Waterusers									
i) Total	61	63	62	39	35	56	48	77	Average = 55 waterusers per scheme
ii) KSS farmers	42	44	42	39	35	50	44	58	Average = 44 KSS farmers, which was 80% of Waterusers.
iii) Using irrigation	39	37	40	39	33	47	43	54	Average = 41.50 KSS farmers using irrigation (94% of average KSS)
f) Non-KSS farmers	19	19	20	00	00	06	04	19	Average = 11/scheme, which was 20% of average waterusers
g) Usages of outlet									
i) % of used	90.5	87.5	95.2	100	90.5	90.5	87.5	86.0	Average = 91%
ii) % of unused	9.5	12.5	4.8	0.0	9.5	9.5	12.5	14.0	Average = 9%
h) Equity of water supply	No	No	No	No	No	No	No	No	Equity of water distribution 0%
i) Water distribution system	FCFS	FCFS	FCFS	Few rules	FCFS	FCFS	FCFS	FCFS	Conflicts and mistrust caused this system
j) Rotational system	No	No	No	Medium	No	No	No	No	Large farmers' influenced caused non-rotational system
k) KSS meetings									
i) No. of meeting	10	8	6	NA	NA	NA	NA	NA	Average = 8 meetings; Design = 20 meetings for dry season; PE = 40%
ii) Attendance(%)	15-26	10-56	29-56	NA	NA	NA	NA	NA	Average = 27%, which was the performance efficiency of the KSS
l) Up-to-date log-book + list of expenses	No	No	No	Yes	No	No	No	No	Farmers believe, it is essencial
m) Experience of a pump operator	Low	Low	Low	Medium	Low to	Low	Low	Low	Who can start the engine is enough
n) Fieldman	No	No	No	Yes	No	No	No	No	Additional payment for a fieldman is unnecessary
o) Detail on budget	Partially	No	Partially	Yes	Yes	No	No	No	They do not rely on budget
p) Engine servicing	Bad	Very bad	Bad	Good	Medium	Very	Very bad	Very bad	No fixed budget
q) Outlet condition	1	7	1	0	2	5	2	11	On average 18% outlets were completely damaged; PE = 82%
r) Acceptance of newly released varieties of crops	Partially	Partially	Medium	Yes	Yes	No	No	Partly	Based on survey

Table E.3 Continued

Performance indicators	Schemes: Taltolapara	East Kutubpur	Shaplapara	Baila	Vailpara	Chulabar	Hazipara	Binakhaira	Remarks
s) Cropping intensity	241	213	258	243	233	223	223	230	Average = 233% (based on irrigated area only)
t) Overdue Loan (Tk)									
i) DTW loans	51,128	94,861	75,430	20,133	82,315	52,180	69,380	24,495	Unpaid amount of Deep Tubewell loans
ii) BP loans	31,552	27,700	26,190	9,120	27,060	27,360	3,800	24280	Unpaid amount of buried pipe loans
u) Marketing facility	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Very bad communication
v) Return	NS	NS	NS	PS	PS	NS	NS	NS	NS stands for not satisfied and PS for partially satisfied (based on survey results)
w) Quality seeds/seedlings	NA	NA	NA	NA	NA	NA	NA	NA	NA = Not available during the pick time
x) Availability of inputs	A	A	A	A	A	A	A	A	A = Available, but high Prices which varied frequently
y) Willingness to Pay	Low	Very low	Low	High	Very low	Low	Low	High	Non-interest and lack of financial resources

Note: FCFS = First come first served; Tk = Taka, Bangladesh currency (1 US $ = Tk 38.40, 1991)