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DIAGNOSTIC ANALYSIS OF FIVE DEEP TUBEWELL IRRIGATION SYSTEMS IN JOYDEBPUR, BANGLADESH

WATER MANAGEMENT SYNTHESIS PROJECT

WMS REPORT 15

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TABLE OF CONTENTS

Section	Page
Table of Contents	ii
List of Figures	iv
List of Tables	vi
Acknowledgments	x
Abstract	xii
I. INTRODUCTION	1
A. Purpose of Diagnostic Analysis Training Course	1
B. Irrigated Agriculture in Bangladesh	2
C. Purpose of Study	11
D. Contents of Report	13
II. STUDY AREA	15
A. Location and General Description	15
B. Climate, Soils, and Topography	15
C. Surface and Groundwater for Irrigation	20
D. Cropping Systems	20
E. Socio-economic Conditions	21
III. METHODOLOGY	25
A. Reconnaissance and Detailed Studies	25
B. Detailed Methodologies	26
1. Agronomy	26
2. Engineering	29
3. Economics	33
4. Sociology	35
IV. RESULTS AND DISCUSSION	39
A. Water Control	39
B. Productivity and Resource Allocation	[illegible]
C. Resource Conservation	59
V. SUMMARY OF FINDINGS AND RECOMMENDATIONS	63
VI. LITERATURE CITED	69

APPENDICES

A. Agronomy 73
1. Introduction 73
2. Crops 74
3. Irrigation 83
4. Soils 84
5. Expected Yields 89
6. Summary of Findings 89

B. Engineering 93
1. Irrigated Command Area of the Deep Tubewells 93
2. Irrigation Conveyance and Distribution System 104
3. Water Application Methods 122
4. Summary of Findings 130

C. Economics 133
1. Cropping Pattern and Intensity 133
2. Purchased Inputs 136
3. Labor and Utilization 137
4. Credit 139
5. Crop Output and Value 142
6. Irrigation Cost 142
7. Profitability Analysis 145
8. Summary of Findings 153

D. Sociology 155
1. Purpose of Sociology in Diagnostic Analysis 155
2. Land-holding and Ownership Patterns 156
3. The Organization of the Deep Tubewells 162
4. Farmers' Attitudes and Irrigation Behavior 169
5. Summary of Findings 193

E. List of Staff, Participants, and Workshop Schedule 199

F. Glossary 207

LIST OF FIGURES

Figure		Page
1.	Major Water Systems of Bangladesh	3
2.	Location of Study Sites Within the Thana of Joydebpur . . .	16
3.	Soil Types Within the Study Area	19

Appendix Figure		
B1.	Typical Pump Characteristic Curves as Supplied by BADC. . .	100
B2.	Longitudinal Profiles of the Surveyed Channels at the Mariali Site.	105
B3.	Longitudinal Profiles of the Surveyed Channels at the Porabari Site	106
B4.	Longitudinal Profiles of the Surveyed Channels at the Jogitola Site	107
B5.	Longitudinal Profiles of the Surveyed Channels at the Itahata Site.	108
B6.	Longitudinal Profiles of the Surveyed Channels at the Teknagapara Site.	109
B7.	Map of the Mariali Site	111
B8.	Map of the Porabari Site	112
B9.	Map of the Jogitola Site.	113
B10.	Map of the Itahata Site	114
B11.	Map of the Teknagapara Site	115
B12.	Bed Profiles of the Channels Surveyed at Itahata and Mariali	118
B13.	Bed Profiles of the Channels Surveyed at Porabari, Jogitola, and Teknagapara	119

B14. Field Plot Surveys at the Mariali Site 123

B15. Field Plot Surveys at the Porabari Site 124

B16. Field Plot Surveys at the Jogitola Site 125

B17. Field Plot Surveys at the Itahata Site. 126

B18. Field Plot Surveys at the Teknagapara Site. 127

LIST OF TABLES

Table		Page
1.	Land Utilization	5
2.	Water Availability and Irrigation Requirements During the Dry Season in Bangladesh	6
3.	Comparison of Various Irrigation Methods in Bangladesh	8
4.	Monthly Climatic Data for Joydebpur (Average of 35 Years or More)	17

Appendix Table		
A1.	Plant Variety, Height, and Population Data at the Five Study Sites	75
A2.	Mean and Standard Deviation of Fertilizer Applications	77
A3.	Qualitative Nitrogen, Phosphorus, and Potassium Tissue Test of Rice Plants	77
A4.	Planting Dates of Seedlings	79
A5.	Number of Plowings, Laddering, Weedings, and Age of Seedling at Transplant	80
A6.	Infestation of Insect, Diseases, and Weeds	82
A7.	Soil Properties in Different Study Sites	85
A8.	Expected Yields in Metric Tons Per Hectare	89
B1.	Discharges and Command Areas of Deep Tubewell	94
B2.	Rated and Operational Speeds of the Motors and Pumps	95
B3.	Pumping Plant Efficiency	98
B4.	Tubewell Data	101
B5.	Length and Density of Main Channels	116

B6. Conveyance Losses in Irrigation Channels 121

B7. Seepage and Deep Percolation Losses 129

C1. Cropping Pattern and Yield by Study Site, 1982-83 134

C2. Average Sample Farm Size, Average Cropped Area, and Cropping Intensity by Study Site 136

C3. Application of Fertilizers and Insecticides and Costs Per Hectare by Study Site 138

C4. Labor Requirement and Cost per Hectare of Boro Rice by Operation 140

C5. Percent of Farmers Obtaining Credit for 1983 Boro Rice Crop. 140

C6. Factors Affecting Borrowing 141

C7. Comparative Deep Tubewell Cost Estimation Among Five Study Sites 144

C8. Comparative Irrigation Costs Between Electric and Diesel Pumps 145

C9. Cost and Returns Per Hectare of Boro Rice 146

C10. Comparison of Three Organizations 147

C11. Per Hectare Costs and Returns of Boro Rice at Mariali . . . 148

C12. Per Hectare Costs and Returns of Boro Rice at Porabari. . . 149

C13. Per Hectare Costs and Returns of Boro Rice at Jogitola. . . 150

C14. Per Hectare Costs and Returns of Boro Rice at Itahata . . . 151

C15. Per Hectare Costs and Returns of Boro Rice at Teknagapara . 152

D1. Land-holding Pattern Within Tubewell Command Areas by Study Site 157

D2. Total Land-holdings Based on Ownership Both Within and Outside the Tubewell Command Areas by Study Site. 160

D3. Land Tenure by Study Site 162

D4. Farmer Reports of Knowledge and Use of Institutional Services by Study Site: Union Agricultural Assistant (UAA) 170

D5. Frequency of Irrigation Information by Study Site 172

D6. Most Important Farming Problem Inhibiting Production as Reported by Farmers by Study Site 174

D7. Reported Irrigation Problems by Study Site. 176

D8. Mean Number of Hours/Week/Pakhi That Water is Available for Rice Growing as Reported by Sample Farmers by Study Site. 179

D9. Mean Number of Hours Required to Irrigate An Average Pakhi by Study Site 179

D10. Mean Number of Days Required to Repair Pump After Breakdown Occurs by Study Site. 181

D11. Farmer Reports of Prevalence of Deviant Irrigation Practices by Study Site 183

D12. Presence of Discrimination in Water Distribution by Study Site. 185

D13. Farmer Reports of Whether Annual Meeting is Held at Proper Time by Study Site 187

D14. Organizational Management Issues by Study Site. 188

D15. Prevalence of Informal Rules Violations by Study Site . . . 190

D16. Quantity and Quality of Farmer Participation in Organizations by Study Site 191

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Z. Karim, Coordinator

Larry Nelson, Coordinator

ABSTRACT

A Diagnostic Analysis professional development program was held March 5 to April 6, 1983, in Joydebpur, Bangladesh to train Bangladeshi professionals to analyze deep tubewell irrigation systems. This program was requested by the Bangladesh Agricultural Research Council to further governmental efforts in improving the performance of existing irrigation systems.

The major objective of this field oriented training program was to provide the participants with an understanding of the interdisciplinary method of investigating existing irrigation systems. This program involved 26 professionals from the fields of irrigation engineering, agronomy, sociology and economics.

The participants were divided into interdisciplinary teams, each being assigned to one of five tubewell sites. An initial day-long reconnaissance survey served as the foundation for subsequent detailed studies. After completion of the detailed studies, a final week included data analysis and report writing by individual teams.

The report presented here is based upon the data and reports generated during the training program. Data collection was limited because the program was not intended as a research program, but rather as a training program. However, we think that the findings are of sufficient value to warrant their presentation here. Significant findings of this study include:

- The discharge rate of deep tubewells was substantially lower than the design.
- Given this actual discharge, the command area irrigated was near optimal in most of the systems.
- The deep tubewell settings may be too shallow. Future problems may develop if there is a decline in the regional water table and/or the usage of deep tubewells is increased.
- Deep percolation losses in rice fields were minimal.
- Conveyance losses from the main channels were primarily lateral and were reused within the command area.

- With the introduction of deep tubewell irrigation, the rice cropping patterns for the Aus, Aman, Boro seasons has shifted from a local/local/fallow to a fallow/local/high yielding and local/local/high yielding.

- Nitrogen deficiencies appeared throughout the study sites in spite of reported relative high inputs of nitrogen based fertilizers.

- The Boro season high yielding rice varieties are profitable in spite of the large investments required.

- Access to credit significantly increased the rate of borrowing.

- All the farmer groups were informal, possessing few, if any, written rules or procedures. There was little institutional penetration of these tubewell groups by government agencies.

- The leadership of the tubewell groups was composed of one individual or a small group of individuals who made most of the important decisions.

- The farmers at these sites appeared to be more interested in water reliability and adequacy than in participation in the tubewell organization.

These findings could serve as a guide for further investigation. Some important areas that might be examined are:

- The reasons for the lower than designed discharge rates of the deep tubewells and the possible shallow pump settings;

- The economic and financial cost of irrigation for both diesel and electric powered pumps;

- The profitability of tubewell irrigation given the changing cropping patterns; and

- How different management, leadership, and organizational structures affect the water management of tubewell sites.

I. INTRODUCTION

A. Purpose of the Diagnostic Analysis Training Course

In the past the Government of the People's Republic of Bangladesh directed its efforts toward creating irrigation facilities. Now that many of these facilities are completed, the government recognizes that the creation of facilities alone will not solve its water utilization and irrigation problems. If maximum benefit is to result from the expanded irrigation facilities, greater emphasis must be placed on training a large number of irrigation personnel, ranging from field-level workers to senior executives. Such a trained staff, in turn, can engage in research, extension, and general training for the farmers.

To address these training needs, the Water Management Synthesis Project II conducted a five-week training program for professional development at the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Bangladesh. The training program's sponsors were the Bangladesh Agricultural Research Council (BARC), the Government of Bangladesh, the United States Agency for International Development (USAID), and the Consortium for International Development (CID). Of the 26 professionals attending the interdisciplinary program, 25 were from eight Bangladesh governmental agencies and one was from the Water and Land Management Institute, Maharashtra, India. The participants represented the disciplines of sociology, economics, agronomy, and irrigation engineering (Appendix E).

The field-oriented training program attempted to provide the participants with an understanding of the concepts, principles, and procedures used in Diagnostic Analysis, an interdisciplinary method of examining established irrigation systems. To accomplish this objective, the program combined traditional classroom activities with actual field studies (Appendix E). Five deep tubewell irrigation systems, located near BARI in the Thana (an administrative area) of Joydebpur were selected as study sites.

This report summarizes the procedures used in this particular Diagnostic Analysis along with the preliminary observations of the participants. While the information presented in this report is of value, it is important to understand that the training objective inherently restricts the amount of data collected. Consequently, the findings of this report simply indicate areas of constraints in the system; more detailed studies are needed to confirm the findings noted here.

B. Irrigated Agriculture in Bangladesh

Bangladesh's 14.3 million hectares (ha) lie in the flat delta of three of the world's large rivers--the Ganges, the Brahmaputra, and the Meghna (Figure 1). The low-lying alluvial plain, comprising most of the land surface in Bangladesh, rises gradually from the Bay of Bengal in the south, towards the foothills of the Assam Hills in the northeast, and the Himalayas in the northwest. Most of the country is less than 20 meters (m) above mean sea level. The highest part of the flood plain, on the northwestern border, is about 85 m above mean sea level: the

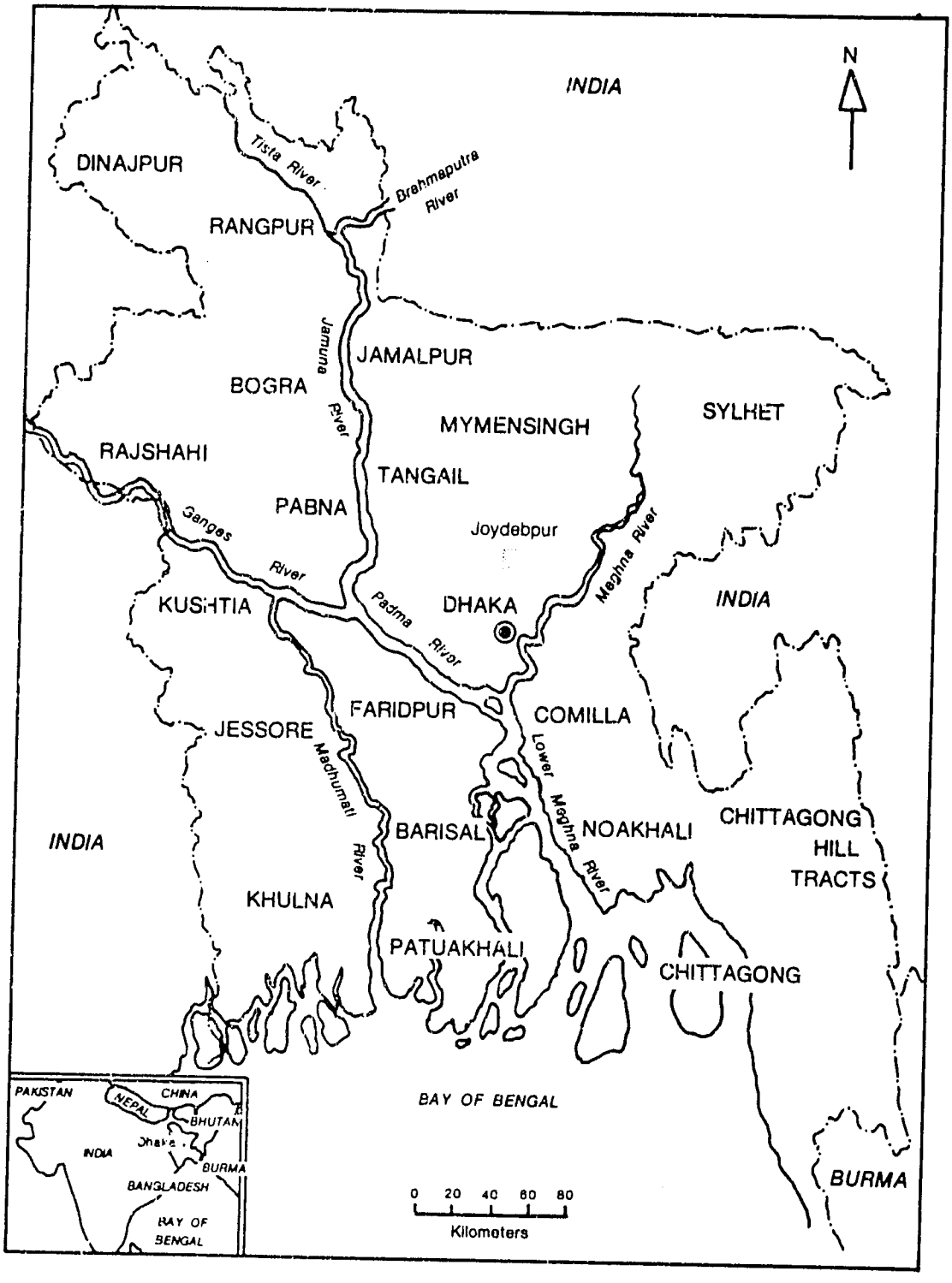

Figure 1. Major Water Systems of Bangladesh

coastal tidal land is only slightly above sea level. This flat topography, while ideal for agriculture, is prone to drainage and flood problems during the monsoon season.

A great variety of soils have developed over recent alluvium, Madhupur clay and Tertiary sediments; the soils formed over the alluvium comprise about 75 percent of the country's land area. At present 8.4 million ha, or almost all the arable lands, are cultivated. In general, rice and jute are grown in the monsoon season on the seasonally flooded wetlands; upland crops are grown in the dry season on lands that drain quickly through in soils with good moisture retaining capacity.

More than any other environmental factor, hydrological conditions determine the present and future agricultural uses of Bangladesh's cultivated land. Rainfall varies widely in different seasons and in different areas of the country, from about 150 centimeters (cm) annually in the western part of the country to almost 450 cm annually in the northeast. However, about 90 percent of the total rainfall occurs in the six monsoon months (May-October). During monsoons, the flat, low-lying topography impedes drainage and causes flooding. As a result, the storage capacity of the soil profile is exceeded and considerable percolation of water to deeper layers occurs recharging the groundwater.

The hydrologic regime of the rivers is determined mainly by the huge runoff of monsoon rainfall outside Bangladesh, and the snow melt in the Himalayas. During the early part of the monsoon season, large amounts of water flow from the Assams and Himalayas through the Brahmaputra, the Ganges, and the Meghna river systems causing adjoining rivers and river tributaries to rise rapidly. The increase in river

rivers and river tributaries to rise rapidly. The increase in river levels blocks drainage outlets thereby increasing ponding of rainfall. Most of the plains are flooded in this manner. Because of soil saturation or flooding, 85 percent of all agricultural land is suitable only for rice and jute production during the monsoon months. On the other hand, during the dry period (November-February), the rainfall (40-140 millimeters) does not meet the water requirements of crops. However, other climate-dependent factors, such as temperature, daylight, and soil conditions are favorable for year-round crop cultivation.

At present, approximately 0.65 million ha are triple cropped, 3.16 million ha are double cropped, and 4.62 million ha are single cropped (Table 1). About 15 percent of the cultivated area is

Table 1. Land Utilization

Land Uses	Amount of Land (million hectares)			
	5-year Average Ending 1959-60	5-year Average Ending 1964-65	1969-70	1978-79
Forest	2.21	2.21	2.24	2.19
Not available for cultivation	2.26	2.24	2.63	2.70
Cultivable waste	0.79	0.74	0.30	0.25
TOTAL NON-CULTIVABLE LAND	5.26	5.19	5.17	5.14
Current Fallow	0.53	0.40	0.30	0.71
Net cropped area	8.23	8.47	8.81	8.42
TOTAL CULTIVABLE AREA	8.76	8.87	9.11	9.13
TOTAL CROPPED AREA	10.49	11.28	13.29	12.89
CROPPING INTENSITY (%)	127	133	151	153

Source: Bangladesh Bureau of Statistics (1979).

irrigated. Given increased irrigation facilities, there is a strong potential for the cultivation of more crops in the dry season.

Large volumes of water are required to control salt water intrusion (Table 2) as well as maintaining minimum water depth in streams for navigation, fisheries, and municipal and domestic uses. The aggregate demands for such various purposes must be met by rainfall, surface water, or groundwater. During the dry period, the available water, as noted above, is insufficient to irrigate the cultivated area. The available water includes 50 percent of the discharges of Ganges, the

Table 2. Water Availability and Irrigation Requirement During the Dry Season in Bangladesh

Month	Irrigation Requirement (million hectare meters)		Available* Water (million hectare meters)	
January	1.44	(11.7)**	1.37	(11.10)
February	1.56	(12.6)	1.14	(9.20)
March	2.13	(17.27)	1.25	(10.15)
April	1.57	(12.75)	1.57	(12.69)

*Includes 50 percent of the discharges of the Ganges, the Brahmaputra, the Meghna; 60 percent of the discharge of minor rivers, and all the extractable groundwater.
**Figures in parentheses represent million acre feet.

Brahmaputra, and the Meghna; 60 percent of discharges of minor rivers; and all the extractable groundwater (Khan, 1982). Such large-scale withdrawal from the minor rivers will greatly increase the salinity in southern Bangladesh (Karim et al., 1982). Thus, any reduction of the present flow of major and minor rivers will adversely affect the future agricultural development program.

Most of Bangladesh contains groundwater aquifers suitable for pumping. There are two major exceptions: (1) the area south of a line stretching from Jessore to Comilla, where the groundwater is saline and there are no tubewells; and, (2) the eastern and northern hill areas, together with closely adjacent piedmont and floodplain land, where evidence indicates that significant groundwater is available, but that the distribution is erratic (Khan, 1982). The groundwater is in dynamic equilibrium on an annual basis with the water level rising near the surface towards the end of the monsoon season. The water table declines in the dry season an average of 3.6 m to be recharged again during the next monsoon.

For generations the people of Bangladesh have practiced irrigation using various traditional devices such as swing baskets, dons, dugwells, and even earthen jugs. An estimated 0.49 million ha are now irrigated by these traditional devices (Table 3). The first form of mechanized irrigation was initiated about 20 years ago with the introduction of a low-lift centrifugal pump (LLP) powered by a 16-18 hp diesel engine and designed to produce 56.6 l/s (2 cusecs) from a 6 m pumping head. At present about 665,000 ha are irrigated by LLP. Due to limited

Table 3. Comparison of Various Irrigation Methods in Bangladesh

Comparative Measure	Don	Swing Basket	Dug-well	MOSTI*	Low Lift Pump	Deep Tube Well	Shallow Tube Well	Large Proj
Area Irrigated (thousand ha)	369	83	4	30	665	162	162	150
(percent)	23	5	0.2	1.8	41	10	10	9
Water Source (surface/ groundwater)	S	S	G	G	S	G	G	S
Source of Energy (diesel/electric/ manual)	M	M	M	M	D/E	D/E	D/E	D/E
Maximum Discharge (l/s)	7.36	2.27	0.57	0.76	56.64	56.64	14.16	—
Pumping Height (meter)	0-1.5**	0-1.8**	0-4.6	1.5-6.1	0-6.1	12.2	0-6.1	0-9.1
Capital Cost (Taka)***	300	20	150	1,500	45,000	400,800	35,000	—
Working Life (years)	4	2	3	6	7	10	7	-
Command Area (ha of dry season paddy)	0.4-1.6	0.4-0.6	0.13	0.20	16.2	16.2	4.1	-
Government Subsidy (percent)	0	0	0	0	48	66	10	98

* Manually Operated Shallow Tubewell for Irrigation
** A double stage system can be used for greater lifts
*** 24 Bangladesh Taka (Tk) = 1 US $
Source: Khan (1983).

availability of surface water, both shallow and deep tubewells are used to tap the groundwater for irrigation. Approximately 325,000 ha presently are irrigated by tubewells. The deep tubewells are constructed primarily with imported, technologically complex, pumps and engines of 56.6 l/s (2 cusec) capacity or more, and are sunk by power rigs. Shallow tubewells are made with locally constructed pumps and engines involving simple technology with less than 28.3 l/s (1 cusec) capacity, and are sunk by labor intensive, percussion methods.

In addition, about 150,000 ha are irrigated by large-scale irrigation projects. In such projects water is lifted from rivers because of the very low water levels during dry season. These are the most expensive irrigation projects in Bangladesh.

The Bangladesh Water Development Board (BWDB) and the Bangladesh Agricultural Development Corporation (BADC) are the two major agencies that plan and implement water development projects. Small-scale irrigation projects are being implemented through the Rural Works Program (RWP) and The Bangladesh Krishi Bank (BKB). BWDB mainly implements large-scale irrigation projects, while BADC is concerned with the LLP and tubewells (deep and shallow). All these organizations are responsible for creating irrigation facilities.

The procedure to procure deep tubewells begins with farmers who either organize themselves or are organized into user groups. Mandal (1982) provides examples in which the farmers themselves took the initiative to form a management committee to procure a deep tubewell. K.B. Karim (1977) provides a different example from the Bogra district,

where farmers and government officials worked jointly to establish an organization to manage a deep tubewell. Some of these groups remain informal and are run by management committees. Although some groups register with the Directorate of Cooperatives and sometimes receive credit from the Cooperative Bank, most groups receive almost no supervision or credit from the government. The only emerging formal institution, at the grass roots level, is the Farmer's Cooperative Society of the Bangladesh Rural Development Board (BRDB). In those villages where there are cooperative societies, they often own and manage the tubewells. The village-level societies are linked at the thana level with the Thana Central Cooperative Association (TCCA). The TCCA secures credit for the primary societies and arranges training classes for the manager, chairman, and model farmers. These classes are held at the Thana Training and Development Center (TTDC) in collaboration with the different departmental officers.

Other inputs such as seeds, fertilizer, and oil fuel are provided by the BADC, and credit provided through BKB and other nationalized banks. The Department of Agriculture (Extension and Management) is responsible for extension activities utilizing a large number of staff down to the village level. A few organizations, like BARI and the Bangladesh Rice Research Institute (BRRI), among others, are doing research on irrigation water management. BARC is currently sponsoring a nationally coordinated Irrigation and Water Management Project involving seven national institutes. While pertinent information is emerging from this research, the full benefit will come with the transfer of technology to the farm level.

Since no one organization is solely responsible for on-farm water management, many facilities are operating at low efficiencies. The combination of the increasing cost of irrigation facilities coupled with their decreasing efficiency has stimulated great concern for the maximum utilization of these facilities. During the last few years several organizations have taken various measures to increase the command areas of such facilities, but due to the complex nature of the problem few results have ensued. An interdisciplinary team approach including engineering, agronomy, economics, and sociology was considered necessary.

C. Purpose of Study

At present, deep tubewell irrigation commands 162,000 ha, or about 10 percent of the total irrigated land in Bangladesh. This irrigation system is expensive and complex compared to shallow tubewell and low lift irrigation. One deep tubewell unit costs about Taka (Tk) 350,000 (24 Tk = 1 US $); therefore, this equals approximately $16,000). The government has heavily subsidized this system (over 90 percent) and, in the past, groups of farmers have received the use of a deep tubewell on a rental basis of Tk 3500 (approximately $145) per year. However, rental procedures were discontinued in 1981, and the 56.6 l/s (2 cusec) deep tubewell now sells for Tk 70,000 (approximately $3,000).

The average performance of the deep tubewells is extremely poor. Nationally, the average area commanded by each deep tubewell is about 9.7 ha (Ghani, 1983). Recent BADC unpublished records show that the coverage has improved considerably, but it is still less than 16.2 ha.

Recent studies suggest that a deep tubewell can irrigate as much as 38 ha (Khan, 1979, and Ministry of Local Government, 1980). This indicates a large potential for increasing the size of the command areas.

Many factors including soils, agronomic practices, engineering, and socio-economic conditions of farmers determine the efficiency of deep tubewells. In addition, a farmer's activities are interdisciplinary by nature: he grows crops, designs the layout of the farm and channels, maintains irrigation facilities, and participates in social and cultural activities. Therefore, an interdisciplinary understanding of deep tubewell irrigation, at the farm level, is more appropriate than single discipline approaches.

Joydebpur was selected as the training site for several reasons. First, due to the limited availability of surface water in Joydebpur, the area has a large number of deep tubewells commanding 9,134 ha. Second, rice, the major crop in this area, requires intensive irrigation. Third, several large national institutes like BARI and BRRI are located at Joydebpur and were able to provide laboratory and field support to carry out this program.

Field studies for this training program, conducted at five selected deep tubewell sites, had the following major objectives:

(1) To foster interdisciplinary team work by mid-level irrigation staff members;

(2) To create groups of future trainers who could identify water management problems using Diagnostic Analysis procedures; and

(3) To identify technical and socio-economic constraints on the irrigation system.

It was hoped that the knowledge and skill gained would apply also to LLP, shallow tubewell, and large-scale irrigation projects. In other words, this initial group would develop future interdisciplinary training programs for different irrigation projects in Bangladesh. Another possible result may be the development of a national manual on the interdisciplinary approach to water management problems using Diagnostic Analysis as its basis.

D. Contents of Report

The remaining chapters of the report are essentially the product of this first Diagnostic Analysis training program. A brief description of the study area is presented in the next section. This description was largely derived from the presentations made by guest lecturers during the first week of the training program. Section III describes the disciplinary methodologies used by the participants during the field studies, which lasted approximately three weeks. The major interdisciplinary findings of the field studies are discussed in Section IV with a summary of the findings and recommendations presented in Section V. The findings are based upon the data each team collected and their written reports prepared during the final week of the training program. The literature citations in Section VI closes the main body of this report.

The Appendices contain the more detailed findings of agronomy, engineering, economics, and sociology for the reader who is interested

in a specific discipline. The Appendices also include a list of the staff and participants, and the schedule of the training program. A Glossary, including Abbreviations, Definitions of Terms, and Units of Measurement, concludes the entire report.

II. STUDY AREA

A. Location and General Description

This study examined five deep tubewell sites in the Thana of Joydebpur within the district of Dhaka. Joydebpur is located about 35 kilometers (km) north of the city of Dhaka. BARI, the largest research organization in Bangladesh, and BRRI are located in the Thana of Joydebpur. Adjacent to them are the Bangladesh Seed Certification Agency and Central Extension Resource Development Institute (CERDI). The Bangladesh College of Agricultural Sciences, an auxiliary branch of BARI, is located at Salna about 11 km north of Joydebpur. This area is accessible by rail, highway, and airline.

The deep tubewell sites included in the study are located at Mariali, Teknagapara, Porabari, Jogitola and Itahata. The first three sites are within the Kaultia Union, 2 to 5 km northwest of Joydebpur. The latter two sites are within Basan Union; Jogitola is 3 km southwest and Itahata is about 5 km west of Joydebpur (Figure 2).

B. Climate, Soils, and Topography

Rainfall in the Joydebpur Thana occurs mostly from May to September (Table 4). During these five months, rainfall exceeds 200 millimeters (mm) and the aridity index values vary from 2.0 to 5.9, indicating the wet period of the year. Mean monthly rainfall greater than 100 mm starts in April and ends in October. On the average, there

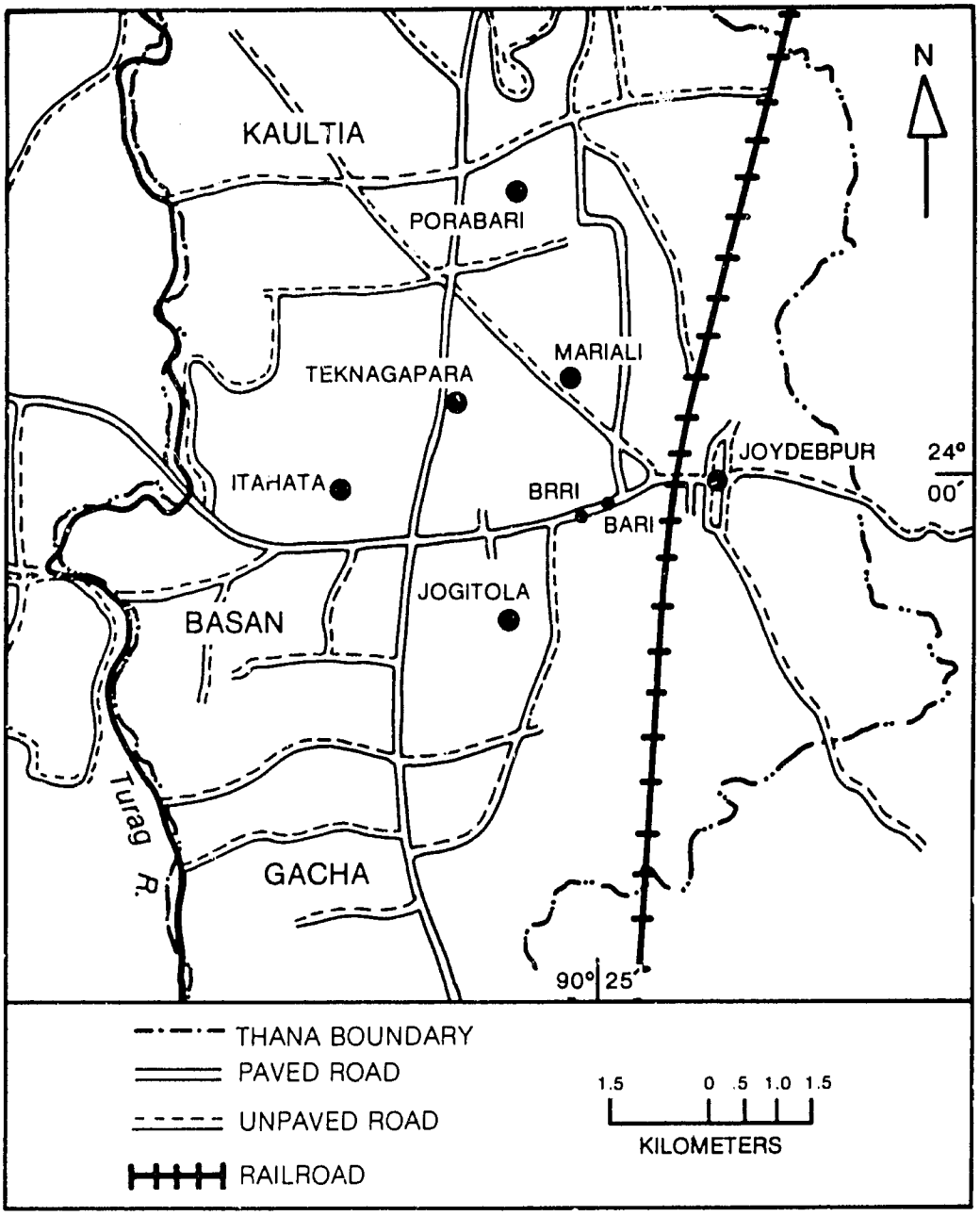

Figure 2. Location of Study Sites Within the Thana of Joydebpur

Table 4. Monthly Climatic Data for Joydebpur (Average of 35 Years or More)

Parameter	Months of the Year												
	J	F	M	A	M	J	J	A	S	O	N	D	Total
Mean monthly rainfall (mm)	18.5	28.2	60.3	149.8	234.7	368.2	353.2	387.1	266.7	148.7	40.2	13.6	2069.3
Max. monthly rainfall (mm)	025.2	116.8	364.4	474.9	546.6	843.2	879.8	1755.1	579.8	457.4	184.1	71.1	2703.0
Min. monthly rainfall (mm)	0.0	0.0	0.0	2.5	34.0	122.6	11.4	69.8	40.1	4.8	0.0	0.0	1098.5
Median rainfall (mm)	7.6	17.1	47.6	141.8	215.6	348.7	347.2	352.4	256.6	112.3	27.9	18.2	1883.0
Monthly rainfall (mm) during 1982	-	7.0	160.0	222.0	194.1	515.6	153.3	275.1	150.9	31.0	28.4	-	1737.4
Probability of 100mm monthly rain. (%)	2	4	15	67	91	100	98	98	96	56	7	0	-
Probability of 200mm monthly rain. (%)	0	0	0	0	54	91	88	88	68	24	0	0	-
Mean monthly evaporation (mm)	64.2	82.9	137.1	143.6	154.1	103.2	98.9	87.4	91.0	81.3	67.6	55.2	1166.5
Potential evapo-transpiration (mm)	100.7	131.6	170.4	159.8	118.1	74.3	55.1	66.9	73.7	88.9	106.9	96.2	-
Aridity index (PP/PE)	0.11	0.16	0.27	0.74	2.03	4.73	5.92	5.16	3.21	1.64	0.22	0.02	-
Extreme temp. Max°C	30.6	35.0	39.4	42.2	42.2	37.2	35.0	36.1	35.0	33.9	32.2	30.6	-
Extreme temp. Min°C	5.6	7.2	12.8	15.6	18.9	21.1	22.8	23.3	21.7	17.2	11.7	6.7	-
Mean temp. Max° C	25.3	28.3	32.8	34.3	33.5	31.5	30.1	30.9	31.3	30.7	28.7	25.9	-
Mean temp. Min° C	11.9	14.1	19.3	23.3	25.1	25.8	26.1	26.2	25.8	23.6	17.7	12.8	-
1982 temp. Max°C	27.5	27.9	31.7	34.0	35.6	32.2	33.2	31.9	33.4	33.3	28.4	27.0	-
1982 temp. Min°C	14.5	16.2	21.4	23.9	26.1	27.0	27.5	27.2	26.8	24.1	18.3	14.8	-
Hours of bright sunshine	8.8	8.8	8.6	8.4	8.7	5.0	5.4	5.6	5.9	7.3	9.2	9.1	-
Day length (hrs)	10.8	11.4	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	11.0	10.6	-

Source: Maniruzzaman (1983)

are five months with rainfall greater than 200 mm and five months with less than 100 mm.

Table 4 shows the typical cool and warm seasons for Bangladesh. The temperature is highest in either April or May (34-35 C). During the monsoon season clouds limit the amount of solar radiation that reaches the ground, lowering temperatures. As the rains decrease, the temperatures increase again. Periods of bright sunshine are longer in the dry winter months and the hot pre-monsoon months than during the wet season.

Soils in the study areas are on the Madhupur tract underlain by unconsolidated Tertiary sediments. About 3 m of thick compact Madhupur clay underlie the Madhupur tract, which has been considerably altered by weathering into mottled clay. The specific study area contains the following soils types (Figure 3):

(1) Grey Terrace Soil--imperfectly to poorly drained, grey, medium acid, friable clay to silty-clay loams, brown mottled red--found in Jogitola, Porabari, and Teknagapara;
(2) Red Brown Terrace Soil--moderately well drained, brown to red brown, medium acid, friable to firm silty clay loams--found in Itahata and Mariali; and
(3) Grey Valley Soil--seasonally moderately flooded, poorly to very poorly drained, grey acidic, heavy clay to silty clay loam--found in Mariali.

The study area is situated above the river's flood level. The clays have been uplifted tectonically to form a terrace about three to seven meters above the adjoining flood plains. This terrace has been dissected by valleys with some terraces remaining between the valleys. Areas of closely dissected rolling topography with low relief also occur.

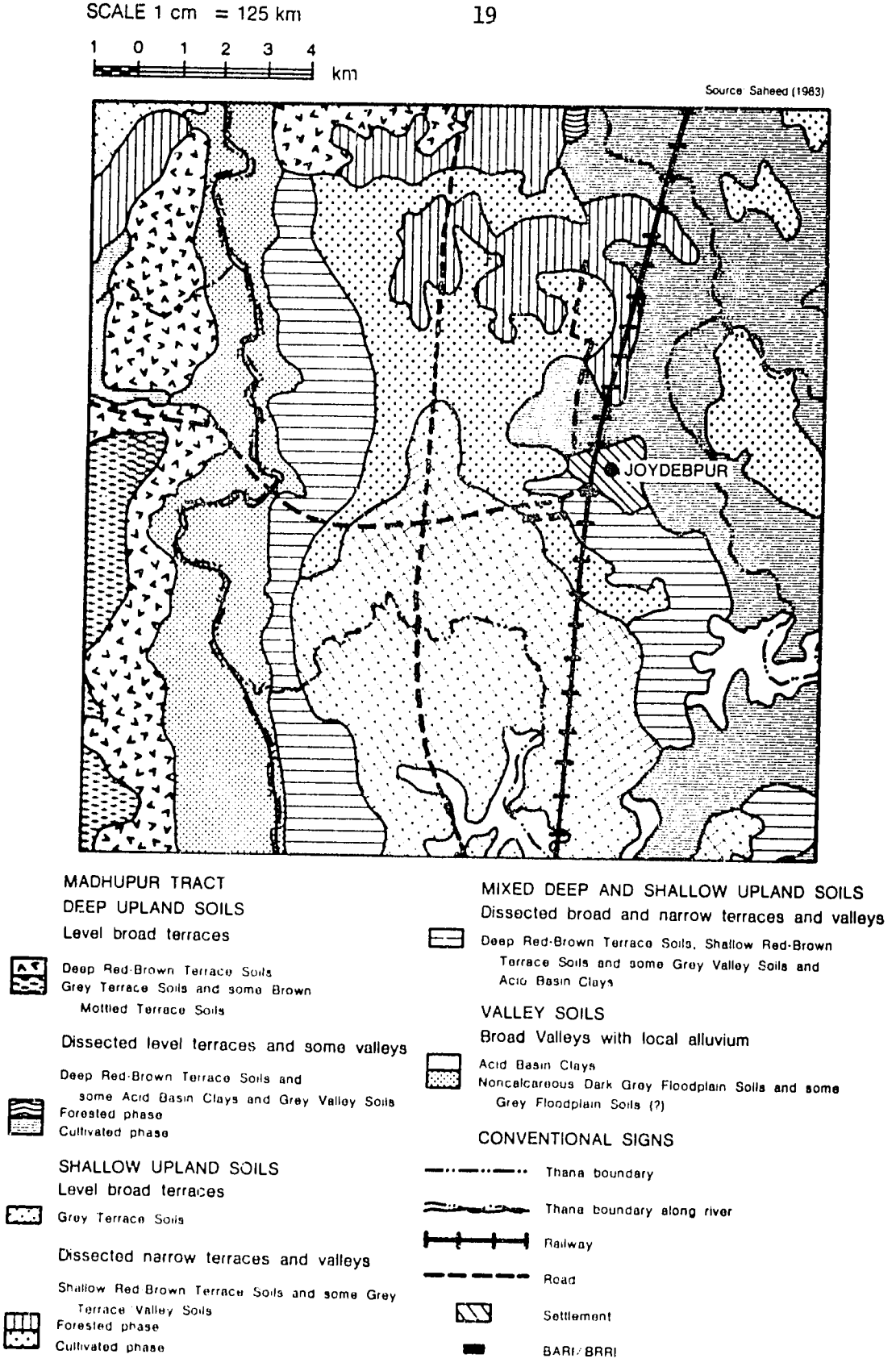

Figure 3. Soil Types Within the Study Area

C. Surface and Groundwater for Irrigation

Little surface water is available for irrigation at Joydebpur. Only one small river, the Turak, flows in a north-south direction about 2 to 3 km west of Itahata. Farmers cultivating on the banks of this river use LLP for irrigation. They also utilize the few canals and ponds in the areas for irrigation using traditional devices such as swing baskets and *dons*.

Tubewell irrigation plays a significant role in this area. During the dry season, groundwater falls to a depth where hand tubewells cannot work. As a result, the deep tubewells are the only devices lifting groundwater. The Joydebpur *Thana* now has 468 deep tubewells covering 9,134 ha.

Tapping groundwater from the stratified sediments under the Madhupur clay does not involve a salt problem. However, there is an urgent need to investigate whether supplies of groundwater are adequate for on-going tubewell irrigation throughout this tract.

D. Cropping Systems

Rice is by far the most extensive and important crop grown in the area. It is grown in three different rice seasons:

Aus (April-August),

Aman (August-December), and

Boro (December-May).

Aman and *Boro* paddy are important for the area. Jute occupies a small area during the *Aus* season. During the *Boro*, or dry season, there are

smaller areas cultivated with mustard and winter vegetables such as tomato, cabbage, cauliflower, potato, chili, and eggplant.

Jackfruit, mango, litchi, banana, pineapple, and lemon are the important fruit crops of the area. The non-irrigated area mainly produces rice crops during the Aus and Aman seasons; the fields lie fallow during Boro season. The principal cropping systems of the irrigated area for the Aus-Aman-Boro seasons are:

(1) fallow - HYV - HYV,

(2) HYV/local - HYV/local - HYV, and

(3) HYV - HYV/local - Vegetable/wheat.

The first pattern is the most dominant in the area and the third one is practiced in only a very small area. Both local (Pukhi, Naizarsail, Latisail, and Pajam) and HYV (BR3, BR9, BR8, Chandina, and BR1) are included in the cropping systems. Some of the farmers now grow three rice crops in a year with one being a local cultivar.

E. Socio-economic conditions

About 80 percent of the population of the area is dependent on farming, while others are engaged in businesses and services. Within the five tubewell sites, sample farm sizes ranged from .05 to 2.7 ha. Though not part of the farms sampled, some farmers at these sites owned up to 5 ha of land within the tubewell areas and more outside the areas. Three quarters of the sample are classified as "small farmers," who own less than 2 acres (0.81 ha) of land. There are very few landless farmers in the area--less than 10 percent of the sample farmers. Many of the farmers, however, while owning small parcels of land, also

sharecropped other land. When the land is sharecropped, the yield of grain is divided into two equal portions--one for the landowner and another for the sharecropper. The sharecropper usually provides the cost of all inputs including seed, fertilizer, water, labor, and power.

Approximately 30 percent of the population is educated, a figure which includes all persons who can read and write the Bengali language. The area has adequate facilities for primary and secondary education. Within 5 km of the study area the Bhawal Boder-E-Alam Government College provides many students from the area with higher education.

Since the entire study area is located above the normal flood level of the country, the area has a good network of roads. A brick road passes through Porabari and Teknagapara villages. Many areas have no electricity: of the study sites, only Porabari and Mariali have electricity.

Institutions in the five deep tubewell sites are somewhat similar, except for Jogitola where there is no farmers' organization. There the owner-manager of the deep tubewell supplies water to the farmer on a cash payment basis. In Mariali, Porabari, Itahata, and Teknagapara informal farmers' groups operate the deep tubewells. All of these groups have a management committee of nine to 11 members, who run the deep tubewells. The group in Mariali has been supported since 1981 by Cooperative for American Relief Everywhere (CARE), a voluntary organization. CARE provides training and extension facilities and ensure credit facilities for the farmers both in cash and kind through the BKB. In addition, the BADC provides technical support (repair and maintenance) to all the groups. In Porabari, there was an Agricultural

Cooperative Society of the BRDB, but it stopped functioning a few years ago.

With regards to agricultural extension services, the Department of Agriculture (Extension and Management) has placed Union Agricultural Assistants (UAA) in each Union. The Union Agricultural Assistant is responsible for disseminating agricultural information to the farmers.

III. METHODOLOGY

A. Reconnaissance and Detailed Studies

During the first week of the training program the 26 participants were divided into five interdisciplinary teams consisting of at least one sociologist, an economist, an agronomist, and two engineers. Each team was assigned to one of the five previously selected deep tubewell sites.

Each team conducted a one-day reconnaissance survey of their assigned site. Observations made during this reconnaissance survey were used by the team to plan the subsequent detailed field study. These studies were conducted for nine days.

Specific methodologies employed by the team members are described in the following sections dealing with agronomy, engineering, economics, and sociology. After completion of the field studies, each team prepared reports. These five reports consisted of an interdisciplinary report and four supporting discipline reports. These reports, together with the collected data, were subject to a more detailed analysis by the trainers. This final report is a result of that analysis.

B. Detailed Methodologies

1. AGRONOMY

The goal of irrigation is to increase crop production through the use of efficient management practices. Farmers need to know the properties of their soils and the nature of the crops to be grown before ever applying irrigation water. In addition, the quality of the water itself influences soil properties and crop growth. In other words, there is an intrinsic interrelationship between water and soil, including the soil's properties and ultimate productivity. The agronomist examines this interrelationship using samples of soil, water, and a variety of crop data. The selected methods employed at the five deep tubewells under investigation are described below.

a. Soils

Soils from fields at the head, middle, and tail of the command area of each deep tubewell were sampled. Five to nine soil samples from each field were composited into one sample; a textural analysis, using the touch and feel method (Lowdermilk et al., 1981), was made while in the field. Soil pH was determined colorimetrically using a Lamotte soil testing kit and was later verified in the laboratory utilizing a hydrogen ion probe in a 1:2 soil to water mixture (volume basis). The trainees analyzed soil samples for available nitrogen (N), phosphorus (P), and potassium (K) using a Hach soil testing kit. This exercise was designed to give the agronomists experience with the analytical procedures employed for testing soils. However, the resulting data was not

utilized in this report as time was not available to correlate the soil testing kit to Bangladesh conditions.

The participating agronomists determined soil infiltration rates in the rice fields under submerged conditions using the single ring infiltrometer method (Trout et al., 1982). They then measured the bulk density of fallow soils using a bulk density sampler (Lowdermilk et al., 1981) with samples taken from 0-10 cm and 10-20 cm soil depth.

Electrical conductivity (EC) of soil and tubewell water was determined using a conductivity meter (Lowdermilk et al., 1981). Soil EC was determined on a saturated soil paste extract; the EC of tubewell water was determined directly.

b. Crops

The agronomists visually observed and recorded the general growth conditions of the rice. Any deficiency symptoms within a deep tubewell area were noted. The data collected for the studies included height, tiller counts, number of hills per square meter, and insect and/or disease damage. To find plant heights, the agronomists measured from the soil surface to the leaf tips of several plants within a hill. The plant heights in three different locations within a field were selected and measured to obtain an average value for each field. The number of tillers per hill were counted in three different locations within a field, and recorded to obtain the average for each field. In addition, the number of hills per square meter were calculated by averaging the number of hills found within a square-meter frame placed in three areas of each field.

Data on seedling age, planting date, number of weedings, and expected yields were obtained from the farmer interviews conducted by the economists.

Rates of fertilizer application, including top dressings, were obtained either through farmer interviews on paddy sites or from information gathered by the economists. The status of N, P, and K in plant tissues was qualitatively determined using a Lamotte colorimetric tissue test kit.

Agronomists assessed the insect and pest damage to crops by counting the affected plants in 50 to 100 selected hills in each paddy and recording the number on a percentage basis. Names of observed diseases and/or pests were recorded. An evaluation of weed infestation was based on visual observation; whenever possible, the names of weeds were recorded.

c. Irrigation

Interviews with the farmers and chowkidars provided information on irrigation scheduling. When it was impossible to contact selected farmers and chowkidars, necessary information was derived from the questionnaires used by the sociologists and economists.

Visual observations of soil water status in the paddies during the study period were recorded under three classifications, i.e., either cracked soil, saturated soil, or standing water (0-2.5 cm or 2.5-5.0 cm).

2. ENGINEERING

The procedures used to collect engineering data are briefly described below. The same procedures were followed on all five study sites.

a. Discharge of the Deep Tubewells

The discharge of the pump was measured by means of cutthroat flumes and V-notch weirs. The flumes and weirs were locally fabricated in Akboria Engineering Works, Mymensingh, according to standard specifications (Skogerboe et al., 1973; USDI Bureau of Reclamation, 1975). Some of the flumes and weirs were checked for their accuracy of measurement by the use of a current meter. The flow measurements by flumes and weirs were almost identical to those obtained through the use of the current meter. The flow measuring instruments were placed in the main channel within 10 m of the pump house. The measurement for pump discharge was taken when the flow through the flumes and/or weirs became steady.

b. Efficiency of the Pumping Plants

Pumps at the Mariali and Porabari sites were operated by electric motors; those in Jogitola, Teknagapara, and Itahata were operated by diesel engines. Since the efficiencies of the electric motors and diesel engines were not known, we measured wire-to-water or fuel-to-water efficiency of the whole pumping plant, i.e. the engine and the pump was measured.

Efficiency of the pumping plant in case of diesel engine operated pumps $= \dfrac{\text{Output horsepower}}{\text{Input horse power to engine}}$

$$= \frac{Q \times H}{76 \times G \times (HP - h)}$$

where, Q = pump discharge (l/s)

H = total head in meters: pumping water level + height of discharge pipe from the point of measurement

G = Fuel consumption in U.S. gallons per hour.

HP - h = Horsepower - hour produced per U.S. gallon of diesel fuel

To calculate the output horsepower of the pump, it is necessary to convert the work output (QH) to horsepower assuming that the density of water is 1 g/cm^3 or 1 kg/l.

$$\text{Output horsepower} = Q(l/s) \times H(m) \times \frac{1\ kg}{l} \times \frac{9.81\ m}{s^2} \times \frac{1\ hp}{746\ W}$$

$$= \frac{Q \times H}{76}$$

Efficiency of the pumping plant in case of electric motor operated pumps $= \dfrac{\text{Output horsepower}}{\text{Input horsepower to motor}}$

$$= \frac{Q \times H}{76 \times (k/0.746)}$$

where k = kWh supplied to motor per hour.

In calculating the input horsepower to the engine, it was assumed that one U.S. gallon of diesel produced 140,000 Btu. Therefore, input horsepower to engine

$$= \frac{\text{U.S. gallon of diesel}}{\text{h}} \times \frac{140{,}000 \text{ Btu}}{1 \text{ U.S. gallon of diesel}} \times \frac{778 \text{ ft-lb}}{1 \text{ Btu}} \times$$

$$\frac{1 \text{ hp} \times \text{s}}{550 \text{ ft - lb}} \times \frac{1 \text{ h}}{3600 \text{ s}} = \text{U.S. gallon of diesel used per hr.} \times 55$$

The static water level in the well was measured prior to starting the pump: the pumping water level was measured at the time when there was no further fall in water level in the well. The draw-down is the difference between the pumping water level and the static water level. The rpm of the motor or engine was determined by means of a tachometer. The pump rpm was determined from the motor or engine rpm and the gear head ratio, the latter being read from the gear head plate.

To determine the fuel consumption, the diesel engine was run for more than one hour and the drop of fuel level in the tank was measured. It was refilled to the original mark using a measuring cylinder to determine volume of fuel used. The input horsepower to the engine was calculated from the fuel consumption using the procedure given above.

c. Command Area of Deep Tubewells

The existing distribution channel layout and cropped areas were plotted on the site maps (Appendix B). The channel layout and the command area sizes were established by (1) consultation with the

tubewell manager, (2) use of land-holding maps, and (3) walking through the project sites.

d. Topographic Survey of Distribution Channels

The elevations of channel bed, water surface, and ground surface on both sides of the main channel were measured to check the appropriateness of the channel layout. Standard surveying equipment and procedures were used.

e. Conveyance Losses in Irrigation Channels

The inflow-outflow method (Lowdermilk et al., 1981) was used for determining the conveyance losses in irrigation channels. This measurement was confined to one representative channel of each site. Cutthroat flumes were used to determine flow through the channel.

f. Water Application

To classify the existing water application methods, i.e., level basin or wild flooding, it was necessary to do a topographic survey of selected plots.

In order to check the levelness, plots were selected at the head middle and tail end of the main channel. The relative elevation of different points in the selected plots were taken. A grid method of sampling was followed to select the reading stations.

g. Water Use

The sum of evapotranspiration (ET) and seepage and deep percolation (S&P), as reflected by the water level subsidence was measured for several days during which time there was no inflow or outflow of water.

To measure the daily water level subsidence, a sloping gauge was installed above the soil surface in each observation plot. Data on ET was obtained from previous investigations in the study area (Karim and Akhand, 1982). An estimate of water loss due to seepage and deep percolation was made by subtracting ET from the water level subsidence measurements. Deep percolation was measured using a ring infiltrometer. The method and results are described in Appendix A. Subtraction of deep percolation from the S & P reading gives an estimate of the seepage.

3. ECONOMICS

a. Data Collection

Information on the various economic facets of the irrigated Boro, i.e., dry season, rice crop was gathered by administering a survey questionnaire to sample of farmers. The size of the survey sample ranged from 16 to 50 percent of the total farms within the five tubewell study sites; 11 to 16 farmers were surveyed within each site. Information on the cost of pumping irrigation water was obtained from the tubewell manager and operator. Background economic information on tubewell irrigation was obtained from BKB, CARE, The Bangladesh Institute of Development Studies (BIDS), BAU, and BADC.

The questionnaire was structured in the form of a table with columns to record a wide spectrum of answers and remarks. A separate table was designed for each major production activity. This facilitated the collection of data, the review for completeness and consistency, and tabulation.

Questionnaires previously used in Bangladesh and the insight gained during the reconnaissance phase were utilized for designing the study questionnaire. The questionnaire was pretested then on six farmers and revised. The final version of the questionnaire consisted of seven sections. The information categories for which these sections were designed are as follows:

i. farm size, land tenureship, and rental practices;

ii. cropping pattern, including variety of crops grown in the area;

iii. Boro rice production activities and the associated resource requirements and costs;

iv. rice grain and straw output and their market prices;

v. sources and uses of credit;

vi. ownership of farm implements; and

vii. farmers' views on the difficulties associated with obtaining credit, fertilizer, insecticides, and irrigation water on a timely basis and in the required quantities.

Before starting the field survey, a complete list of farmers for each deep tubewell site was collected from the manager. Then, the farmers were divided into two groups: (1) head group, that is, farmers with croplands adjacent to the tubewell; and (2) tail group, that is, the farmers with croplands at the edge of the command area. From both groups, head and tail, a total of 69 farmers were selected to constitute the sample for the study.

The farmers were interviewed jointly by sociologists and economists for a period of two and one half hours. The sociological segment of the interview preceeded the survey by the economists.

b. Analytical Procedure

Cropping pattern, land use pattern, and the cropping intensity represent the 1982-83 cropping year. Cultural practices, use of fertilizer and other purchased inputs, and labor and animal utilization in production of Boro rice are presented in Tables C11-C15.

Irrigation costs as determined for each tubewell included rental charges, cost of diesel or electricity, maintenance, and salary for tubewell operators. Total cost of maintaining and operating the tubewell was then divided by the respective command area of each tubewell in order to determine per hectare irrigation cost. This cost was then incorporated in the Boro rice crop budget. The payment made for irrigation by farmers prior to each Boro season often varied from actual cost incurred because of the reserve balance maintained.

Budgeting techniques were used to determine the costs and returns associated with production of Boro rice in the five deep tubewell sites. Profitability comparisons were made between electric and diesel pump study sites and among three types of deep tubewell organizations.

4. SOCIOLOGY

The overall goal of the sociologist in Diagnostic Analysis is to identify the key social and organizational factors constraining agricultural productivity. During this process, the sociologist also should

begin to identify resources that facilitate change. To accomplish this goal, farmers and officials from the selected tubewells were interviewed using structured questionnaires. Basically, the surveys collected two types of information: (1) quantitative data on attitudes and irrigation behavior from sample farmers who are the real users of the irrigation water, and (2) qualitative data from people in the village who are either directly involved in the management of the tubewell or are particularly influential or knowledgeable within the village, referred to hereafter as "key informants". The main purpose of interviewing these key informants was to obtain an overall view of the tubewells and their operation and maintenance procedures, and then to compare their responses with those of the farmers.

a. Questionnaire Construction

Two different questionnaires were prepared for interviewing the farmers and the key informants. Before the training session actually began, the sociology trainers worked together at Colorado State University to draft the questionnaires. Once at the training site, the questionnaires were pretested and finalized.

The interview questionnaires for the sample farmers contained primarily closed-ended questions designed to obtain data on farmers' behavior and attitudes. Specifically, it examined the farmers' knowledge and use of institutional services, the quantity and quality of water control, water allocation, and system maintenance, as well as the quality and extent of farmers' participation in the deep tubewell groups.

The questionnaire for the key informants contained primarily open-ended questions designed to obtain more qualitative information about the operational procedures of the deep tubewell organization. This interview schedule examined such organizational issues as group leadership, budgets, punishment for violators of rules, and farmer involvement in the management of the irrigation system.

b. Sample Selection and Interviewing

The sample farmers were selected in consultation with the engineers and agronomists from each interdisciplinary team. The engineers and agronomists initially chose a representative main channel in each system to take their measurements. The sociologists and economists then selected sample farmers from the plots around these main channels to allow correlation with the engineering and agronomic data. A purposive or judgmental sampling procedure was used to select farmers at the head and tail of the channel. To ensure that a broad spectrum of farmers was represented, sample farmers also were chosen from other areas of the tubewell command area and even at times, from outside the command area.

Five sociologists conducted the interviews over nine days. The sociologist and economist from each team usually conducted their interviews together, gathering information from the same set of farmers. The number of farmers interviewed in each site varied from 13 to 16, with a total of 75 farmers interviewed. Usually one hour was required to complete the sociological interview. The interviewers were asked to think critically about the farmers' responses during the interview and

use probe questions, not included in the questionnaires, to clear up any confusion regarding the responses. They were urged to record these additional responses on the interview schedule.

Managers of all the deep tubewells were interviewed as key informants on the management of the tubewells. These persons then were used to identify other village leaders, educated farmers, and influential persons within the area. Additional key informants included management committee members, government employees, and prominent farmers. The number of key informants interviewed varied from three to four in each village, with a total of 17 key informants interviewed. Because the key informant interview was more open-ended, it usually required one and a half to two hours to complete.

c. Data Analysis

At the end of each day the sociology trainers checked each questionnaire for omitted or confusing items. The following day, before the field work began, these items were discussed with the interviewers. At the completion of the field study, data from the sample farmer interviews were coded, checked, and stored on the computer at Colorado State University for further quantitative analysis. The key informant interviews were analyzed qualitatively, particularly noting the similarities or differences among the five study sites.

IV. RESULTS AND DISCUSSION

A. Water Control

Within any irrigation system, the issue of water control is of central importance. How farmers and irrigation officials control the flow of water from its source to the fields will, to a great degree, determine the ultimate success or failure of the irrigation process. Both the degree and methods of water control are particularly relevant in the deep tubewell areas of Bangladesh. In these areas, many farmers cultivate scattered plots of land within a relatively small command area. A dependable supply of water, which can be directed to their fields, is of vital importance to increased agricultural productivity.

Water control, however, is a very broad, complex concept which can be defined in many ways. Indeed, there are as many definitions of water control in the relevant literature as there are authors. For the purposes of this report, water control will be analyzed by looking at some of the key dimensions of the concept. Rather than supplying a relatively narrow, strict definition, certain critical aspects of water control will be studied. Specifically, this report will address: (1) the quantity of water supplied and the resulting irrigated command area; (2) the system of water distribution at the five sites, including equity considerations; (3) the predictability or reliability of water delivered

to the farmers; and (4) the farmers' ability to apply that water properly to the crop.

With these dimensions of water control in mind, the following sections will analyze the causes and consequences of different water control situations at the five study sites. This analysis is interdisciplinary in nature and attempts to synthesize the socio-economic dimensions and the engineering/agronomic dimensions of water control. The end result is intended to provide the reader with a better understanding of both the constraints and positive aspects of deep tubewell irrigation in the Joydebpur area of Bangladesh.

1. Water Supply and Irrigated Command Area

The actual discharge of the deep tubewell pumps has an effect on water control. Theoretically, the greater the pump discharge, the greater the quantity of water available for irrigation use. All of the pumps in the five study sites have a designed discharge capacity of 56.6 l/s (2 cusecs) which, considering the soils of the Joydebpur area, should be capable of irrigating up to 36 ha of land. Field measurements, however, indicated that the pumps were discharging from 28.3 l/s to 37.1 l/s (Appendix B). It is reasonable to assume that inadequate design, selection, and installation of the pump are the primary causes of this low discharge. Though no data were collected regarding pump design, one could speculate that impeller design, operating speed of the pump, pump setting, and the specific yield of the aquifer are all possible factors affecting the low discharge of these

pumps. In only one of the five sites is the command area close to 36 ha.

It was also found that the duration of pump operation was very limited, averaging approximately 12-14 hours/day. The pumps could be operated for 18-22 hours/day, which could help to increase the irrigated command area. The farmers' non-familiarity with tubewell technology is undoubtedly one reason for the relatively limited number of operating hours. In addition to various maintenance problems, many farmers feel that the pumps require rest.

The lower than designed discharge and restricted number of operating hours result in a decrease in the irrigated command area. Therefore, there are many farmers in the five deep tubewell areas who conceivably could be receiving water if the pumps were supplying the designed quantity of water.

2. Water Distribution and Equity

The distribution of water from the deep tubewell to the fields, and then from field to field, will have a large impact on the degree of water control exercised by the farmer. How water is distributed throughout the command area also has implications on the overall direction and pattern of development within that area. If one sector of the deep tubewell command area is receiving water at the expense of another sector, large differences in yield and profitability between the two areas may arise. If equity of water distribution is to be a goal of water management in Bangladesh, then this dimension of water control must be addressed.

The location of the pump within the command area has great bearing on the equity of water distribution. When the pump is located at a higher elevation relative to the rest of the area, then the potential exists to deliver the correct quantity of water at the appropriate time to all the farmers concerned. Conversely, when the pump is located at a lower elevation relative to a portion of the command area, it is difficult to achieve efficient and equitable water distribution.

In the study sites, topographic features of the pump location were found to be very important in water control. The pumps at Porabari and Jogitola were located at lower elevations relative to part of the surrounding areas (Appendix B). At Porabari, a desirable elevated site is only a short distance from the present pump location. Because of the current pump location, a channel had to be constructed from the lower elevation through an area of higher elevation. The channel bottom therefore is very low, making it difficult to command the land adjacent to the channel. Some farmers in Porabari actually lift the water from lower elevations to irrigate their fields. Additional data from the sociological survey (Appendix D) indicate that the mean number of hours required to irrigate a unit of land is more than twice as much in Porabari as compared to the rest of the sites.

At Jogitola the pump also is located at a lower elevation. The topographically inappropriate pump location is largely a result of the influence of a local large landowner. This landlord owns approximately 20 ha of land, most of which is located not in Jogitola but in a neighboring village. This individual originally arranged for the installation of the deep tubewell in the neighboring village, but his request

was refused due to objections from users of another tubewell. Consequently, the Jogitola pump was installed in a location benefiting the landowner's land in both villages. The farmers of Jogitola had little, if any, involvement in the decision making process. Whenever water was desired, the farmers had to pay the large landowner before the pump was turned on. Many farmers refused to pay and decided not to irrigate their lands in 1983. Large areas of the Jogitola site remained fallow, even though tubewell water could be supplied to them. Thus, there is no effective farmers' involvement and an inequitable form of water distribution has evolved.

Water losses within the irrigation system itself will affect water distribution in a particular deep tubewell area. If water losses are high, it is likely that both the reliability of water supplies and the ability to distribute it equitably will be correspondingly reduced. The magnitude and location of water losses therefore have an impact on water control.

In the Joydepbur area, the quantity of water loss is closely related to the soil properties in the region. The area irrigated by the selected deep tubewells includes soils that are formed over Madhupur clay which is ideal for irrigated rice cultivation. The soils are mainly ultisols and some oxisols with texture ranging from clay to silty clay loam. These soils have a well defined plowpan within 8 to 10 cm of the soil surface. The plowpan substantially decreases deep percolation losses in all of the paddy fields studied. The small deep percolation losses contributed to command areas in four out of the five sites that

were larger than would normally be expected given the existing pump discharge.

Conveyance losses in the channel have a direct effect on the system of water distribution. The magnitude of conveyance loss in the five sites varied from 1.31 to 4.01 l/s/100 m. The maximum water losses were observed in Jogitola, with Mariali possessing the second highest losses. The large losses of irrigation water in Jogitola are considered to be due to the following factors: (1) channels in this area have an unnecessarily large cross-section; (2) there is excessive weed growth; (3) uneven bed slopes cause considerable ponding of water; and (4) large cracks in the channel brought about by alternate wetting and drying conditions caused by less frequent irrigation in the smaller command area.

It also should be pointed out that the poor maintenance of the Jogitola channels has a strong socio-economic component. As mentioned previously, the tubewell is managed by an individual who has little contact with the farmers. The relationship between the manager and the farmer is merely that between a seller and a buyer. No one is responsible for maintenance. The farmers whose lands are close to the channel are benefiting from these conveyance losses through seepage to their fields. This minimizes their variable costs of fuel for pump operation, lubricants, and operating costs; thus, they have no incentive to maintain the channels. Farmers at the tail of the channel who wish to irrigate, however, have the entire burden of maintenance placed on them, along with the resultant higher irrigation costs (Appendix C).

In Mariali, the length of the channel is very long and meanders through the residential areas. This channel layout has accentuated the losses which, however, are much smaller than those reported for Jogitola. This difference could be because of a more organized system of maintenance in Mariali.

Water losses are not always an absolute detriment to effective system operation. Seepage losses from the channel are used by many farmers as additional irrigation water for their crops. However, the farmers have no real control over the seepage water and the use of this water can become critical as discussed in the subsequent section on water application. It is important to keep in mind that losses for a part of the system may not necessarily be losses for the entire system. It is true that lining of the channels could reduce this seepage, and the water saved could then be distributed through the channels with improved control. On the other hand, lining the channel may be uneconomical and detrimental to those farmers who rely on this seepage water for irrigation.

3. Predictability/Reliability of Water Supplies

Water control is also a function of the predictability of the timing and quantity of water delivered to the farmer's field. If the irrigator is assured that a certain amount of water will be delivered to his fields at an appropriate time, and over a certain period, that irrigator can make farming decisions to enhance his agricultural productivity.

Pump breakdowns and repair time has an effect on this dimension of water control. If a pump breakdown occurs, for instance, the reliability of water deliveries is effectively reduced to zero. Breakdowns did occur. The average time required to repair the pump ranged from three days to two weeks (Appendix D). During this repair time, the farmers were receiving no water and consequently, water control was nonexistent.

It should be pointed out that the supply and general maintenance of these deep tubewell pumps is at least partially the responsibility of governmental organizations. These organizations, and the contractors who install the pumps, must bear some responsibility for the poor performance and maintenance. The local deep tubewell groups, whether effective or not, have neither the technical expertise nor the financial resources to ensure a proper discharge of 56.6 l/s if the pump is neither installed nor maintained correctly. Without more effective communication and cooperation between the deep tubewell groups and the responsible govermental organizations, the maintenance of the pumps will probably remain poor. It should be pointed out, however, that in many locations throughout Bangladesh, the tubewell operators depend increasingly on private mechanics. The government is beginning to encourage this trend.

It is interesting to note that all the sites possessed a number of ponds, which were created by the removal of earth for housing construction. Though no technical nor socio-economic data were collected regarding these ponds, it has been suggested that if the pumps could discharge water into the ponds, effective water storage facilities

could be created. This storage water could be used for irrigation during the breakdowns of the pumps, thereby increasing the certainty of the timing and quantity of water deliveries. A more assured supply of water also would have equity implications; more water could be allocated to a greater number of farmers. The feasibility of developing these ponds as water storage devices should be explored further.

In addition to the physical aspects of water reliability, there is also the key element of irrigation information. With a consistent flow of accurate information regarding the timing and quantity of water to be distributed, the farmer can better plan his production activities. Information is received on water delivery dates, pump operation schedule, and pump maintenance schedule. The frequency of this irrigation information is higher in Porabari and Itahata, than in Mariali and Teknagapara (Appendix D). On the basis of just these variables, the degree of water control theoretically should be slightly better at Porabari and Itahata. These findings, however, must be read in conjunction with the other data presented in this section. For example, the pump in Porabari is not appropriately located therefore decreasing water control by the farmers. These same farmers, however, receive a fairly consistent flow of irrigation information that partially offsets their decreased water control.

4. Water Application

In addition to supply, distribution, and reliability of water, water control refers to the ability (or inability) of the individual farmer to direct or command irrigation water onto his own fields. Even

if the distribution system is equitable, and the timing and quantity of water is predictable and known, the farmer still will have little water control if his field application of water is poor.

In all five sites water flows from the main channel to the fields, and then is successively spilled from basin-to-basin. Thus, the irrigators in this area do not have individual access to water, but rely on this paddy-to-paddy flow method of irrigation. Such a method of water application increases the potential for conflict among the irrigators, in addition to decreasing the degree of water control. If paddy-to-paddy flow decreases the farmers' water control, it is the particular soils at these sites and the resulting low percolation rate, that makes the relatively large command area possible.

Channel density also affects this dimension of water control. Maximum density of the main channels was found in the villages of Mariali (396 m/ha) and Jogitola (165 m/ha). Both the areas have increased seepage losses due to frequent and often unnecessary changes in channel direction. The winding and twisting nature of these channels often occurred because farmers refused to allow channels through their land, in the belief that too much of their land would be taken out of cultivation.

The meandering channels in Porabari are similar to Mariali's, but the main channel density in Porabari is much less than in Mariali. The lower channel density in Porabari is because farmers have constructed shorter main channels dividing them into smaller field channels. The reason for the high main channel density in Jogitola is that the lands of the influential landlord are at a considerable dis-

tance from the pump's location and channels have been constructed to deliver water to this remote area. Both Itahata and Teknagapara have compact command areas, but channel density is almost twice as great in Teknagapara (112 m/ha) as compared to Itahata (62 m/ha). In Itahata, the farmers located the tubewell in a relatively central location and irrigation water is diverted through three main channels which reduces the total channel length. Teknagapara has constructed what appear to be rather unwieldy and lengthy channels because of the presence of residential and uncropped areas in the center of the irrigation command area.

At the field level, selected plots were found to be relatively well leveled, leading to a level-basin type of irrigation adequate for rice cultivation. Water application is on an intermittent basis, rather than continous flooding, to facilitate fertilizer application, weeding, and tillering. The level-basin irrigation and intermittent flooding indicates that some of the farmers are using appropriate water management practices. However, it is important to note that these conclusions are based on a specific area using specific criteria: they may not apply to Bangladesh generally.

At the same time, however, none of the five study sites possessed any kind of water control structures. Bed slopes of the main channel changed abruptly, with slopes varying from 0.20 to 1.90 percent in various sections of the same channel in different irrigation sites. Without any drop structure this sloping pattern could cause some degree of soil erosion from the upstream reaches of the channel. Indeed, in some locations the water level in the channel has been lowered making it difficult at times to irrigate the land adjacent to the channel bank.

In some locations, the profile of the channel water surface was not adequate to irrigate the surrounding field elevations. This was particularly true in Mariali and Porabari. To irrigate the lands with higher topography, some farmers must raise the channel water level by placing earth across the channel. Such practices, as seen at these two sites, foster greater conveyance losses due to overspilling and temporary ponding of water.

Any measures to increase the farmer's ability to direct or command the water to the field would require some form of collective action which is best carried out by the deep tubewell groups. Proper social and economic incentives would have to be evident to the farmers before they would attempt such tasks. Yet, the organizational structure at some of the sites is presently insufficient to induce the farmers to work collectively. Without a style of leadership emphasizing collective welfare instead of individual gain, the benefits of improved water control will be considerably reduced. The individual farmers, the present informal deep tubewell organizations, and concerned goverment agencies have not coordinated or involved each other in issues of on-farm water control. Cooperation at all three levels is needed to ensure success.

B. Productivity and Resource Allocation

The limited land resources of Bangladesh, coupled with the high cost of tubewell irrigation, warrants the selection of an optimal cropping pattern, efficient use of various agricultural inputs, and appropriate production practices. The study of tubewell irrigation's impact on cropping pattern, and intensity, use of supplementary inputs, gross value of output, and net income of cultivators should help identify areas of constraints. Additionally, a study should provide information for making sound investment decisions with respect to irrigation in Bangladesh.

This section describes the present cropping pattern, the use of inputs, and the yield achieved. Evaluation is made in terms of recommended practices and the potential yield for the area. Costs, including that of irrigation, associated with the production of *Boro* rice are discussed. The *Boro* crop's profitability is likewise examined.

1. Cropping Pattern

In the five tubewell sites studied, rice was the only crop grown in *Aus* and *Aman* seasons, and in irrigated plots in the *Boro* season. *Aus* and *Aman* rice crops, which depend mainly on rainfall are grown over the period from March to August and from August to December, respectively. *Boro* rice is grown from December to May under tubewell irrigation. The transplanting of *Boro* rice begins around mid-December and continues over a two month period. About 15 percent of the study area was transplanted between December 15 and January 15; 69 percent between January 15 and

February 15; and the remaining 16 percent between February 16 and March-7.

The optimum transplanting age for rice seedlings is from 30 to 45 days. Within the study sites, the age of the seedlings transplanted varied from 30 to 90 days. Approximately 16 percent were 30 to 45 days old; 25 percent were 45 to 60 days old; and 59 percent were 60 to 90 days old.

The most common cropping pattern was fallow-local-HYV which was practiced on 34 percent of the land under tubewell irrigation. The second most common cropping pattern, practiced on 23 percent of the area, was local-local-HYV. With the introduction of tubewell irrigation, the cropping pattern has shifted from a two season cropping pattern with fallow in the Boro season to a two season cropping pattern with fallow in the Aus season. This shift has resulted in greater output per hectare of land. It should be noted, however, that approximately 49 percent of the land has become fallow in the Aus season.

Because of a complete breakdown in tubewell organization in Jogitola, 62 percent of the land remained fallow for the 1983 Boro season. The irrigated area under the tubewell had declined from 22.7 ha in 1982 to 6.5 ha in the 1983 Boro season.

In Teknagapara, about 8 percent of the land which was cultivated the last Boro season was kept fallow this season. About 1 ha of land in the Mariali site that was not included in the survey sample also was removed from cultivation this season. The parcels of land that were kept fallow were mostly of higher elevations relative to adjacent

fields. Difficulty of maintaining standing water, high cost of weeding, higher fertilizer requirement, and lower yield compared to other fields were cited by farmers as reasons for not cultivating these parcels. Increased cost of irrigation because of increased pump rent charged by BADC and higher energy cost may have further lowered the profitability of these land parcels.

Cropping intensity for the four study sites that have been under tubewell irrigation for several years ranged from 224 to 248 percent. Cropping intensity for the Itahata site, where the first Boro rice crop was produced in 1983, was 287 percent. The shift in fallow from the Boro to Aus season cropping pattern may result in a decline in cropping intensity in Itahata in the next crop year. This decline has been already noted in other sites. Experimental studies (Haque et al., 1981) have indicated the potential for growing two HYV rice cultivars with wheat in the Boro season. The cropping patterns suggested for the area are listed below.

	Aus Season		Aman Season		Boro Season
(1)	Chandina/BR3	-	Pajam/BR4	-	Pajam
(2)	Chandina	-	Pajam/BR4	-	Wheat

The above recommended cropping patterns would result in a cropping intensity of 300 percent. Since continuous wetting of the soil due to three rice crops may reduce significantly the yields, the resource requirements, profitability, and acceptance by farmers of these patterns needs to be studied further.

2. Use of Fertilizers and Pesticides

Higher use of fertilizers and insecticides is needed in the production of high yielding rice varieties during the Boro season. Urea, triple super phosphate and muriate of potash are the three major types of fertilizers used by farmers in the five study sites. Ranges of different fertilizers used varied widely from site to site, and from plot to plot: urea from 63 to 123 kg N/ha, phosphate from 38 to 78 kg P_2O_5/ha, and potash from 17 to 50 kg K_2O/ha.

Recommended levels of N for HYV-BR3 Boro rice varies from 80 to 112 kg/ha (BARC, 1979, Islam, 1979). The application of P_2O_5 and K_2O as reported by farmers is somewhat less than the recommended applications of 60 to 90 kg P_2O_5/ha and 40 to 67 kg K_2O/ha (BARC, 1979).

At the time of the field study, the plants were about one to one and a half months old. Visual symptoms of N deficiency were observed and subsequently confirmed by tissue and soil tests. The discrepancy between the reported nearly optimal nitrogen application rate and the observed and measured deficiencies may be due to poor timing of fertilizer application. The observed practice of applying fertilizer only when the deficiency has become apparent may result in a lower yield.

Although the amount of P and K fertilizers applied were marginally below the recommended application rates, there were no visual symptoms of deficiencies in any of the five deep tubewell areas studied. Tissue tests of rice plants showed adequate to high amounts of P and K. This indicates that the fertility status of these nutrients was adequate.

The warm and humid climate of Bangladesh favors the proliferation of insects and pests. The extent of damage caused by insects and pests can be considerable. Stemborers and hispa were the most common insects observed within the five study sites. The damage caused from stemborers was much more severe than from hispa and the extent of the damage varied between the sites. In some areas, nearly 15 percent of the crop was damaged by stemborers.

The insecticides used by farmers included Basudin, Dimacron, Furadan and Diazinon. The amount of insecticides applied in different sites ranged from 1 to 6 kg/ha. This is considerably below the recommended dose of 10 to 30 kg/ha (Pathak, 1970). The low application rate of insecticides can be attributed to the high cost of insecticides and marginal involvement of extension personnel in the deep tubewell sites.

The highest insecticide application rate (6 kg/ha) sites was found in Mariali. About half the farmers at this site have been contacted by the Union Agricultural Assistant (UAA) in Boro season. In addition, 86 percent of farmers received credit as cash and/or in kind through CARE-BKB credit program. Access to credit and extension for other four sites was poor (Tables C5, C6 and D1).

3. Profitability

The average yield reported by farmers for four of the five sites where rice crop was cultivated in 1982 Boro season ranged from 4.2 to 5.3 t/ha. The majority of the farms surveyed had achieved a yield higher than the national average of 3.5 t/ha.

Given the variation in yield, the value of Boro rice grain and rice straw ranged from Tk 15,741 to Tk 20,093/ha. Total production cost varied from Tk 7,005 to Tk 8,463/ha. As an average for all sites, cash expenses (i.e., the purchase of fertilizers and insecticides, irrigation cost, and hired labor) accounted for 55 percent of total production cost. Average investments in fertilizers and insecticides was Tk 1,480/ha. Among the five sites, the highest average investment in these two inputs was made by farmers at the Mariali site (Tk 1,413/ha) and the lowest by farmers at Itahata (Tk 1,111/ha), where the first irrigated Boro rice crop was produced in 1983. The per hectare cost of irrigation among the study sites varied from a low of Tk 818 in Mariali to a high of Tk 2,145 in Jogitola.

The tubewell at Mariali was electric operated and had an irrigated command area of 31.5 ha. The costs incurred for pump rent, operation, and maintenance for the season were proportionately shared between farmers on the basis of their cultivated land area under the tubewell.

Jogitola's tubewell was diesel operated and had an irrigated command area of 6.5 ha. The tubewell organization had been disbanded at this site. Those farmers who did cultivated in the 1983 Boro season paid Tk 900/ha as rent to the tubewell manager, individually purchased the necessary fuel, and paid an hourly charge for the tubewell operator's salary and pump maintenance.

Comparison of irrigation cost between electric and diesel operated pumps for the two sites of Porabari (23.12 ha) and Teknagapara (23.98 ha), respectively, indicated the irrigation cost for electric

pump to be Tk 456/ha less than diesel (Table C8). It should be noted that the electric rate charged for operating the tubewell is below the commercial rate.

In view of the differences in yield and production costs, particularly the cost of irrigation between study sites (Itahata excluded), return from Boro rice crop varied from Tk 8,567 to Tk 12,527/ha. It should be noted, that return from Boro rice crop attained by farmers will be different from the economic profitability of irrigated Boro rice due to subsidization of irrigation costs and fertilizers. In assessing the overall profitability of tubewell irrigation, the changes in cropping pattern and intensity brought about by cultivation of rice in Boro season needs to be considered.

C. Resource Conservation

The subject of resource conservation is concerned with the preservation of resources. Water is a resource, a renewable resource, but it must be utilized wisely so that it is available throughout the growing season and irrigates the maximum potential area. Soil is a resource which likewise must be managed properly to maintain fertility and to prevent erosion. Soil erosion can degrade water quality, decrease soil fertility when top soil is removed, and decrease water control when channel bottoms are eroded. The deep tubewell is also a resource. It is a capital resource utilized to increase agricultural production and income. The pump must be designed, installed, operated, and maintained to preserve its continued use.

Deep tubewell irrigation started about two decades ago; thus, the idea of viewing groundwater as a resource is a relatively new concept to Bangladesh. Tubewells which make the use of groundwater for irrigation possible need to be properly installed. The capacity and longevity of a deep tubewell may be limited by a number of factors. It was observed that pumps were set at a depth of approximately 22 m from the ground surface, even though the casings have been set at much greater depths. Groundwater levels were found to be very close to the pump setting depth. If the water level fall below the pump setting, the

pumps would be unable to lift water. This possibility increases with the continued installation of new tubewells.

Water quality is an extremely important issue to irrigated agriculture. Irrigation water with a high salt content has the potential to adversely affect soil structure decreasing crop yields. The use of saline water in irrigated agriculture is a problem in many areas of Bangladesh. However, for the five deep tubewell sites, the electrical conductivity of irrigation water ranged from 0.28 to 0.52 mmhos/cm, indicating that there is no salinity hazard from irrigation water to these tubewell sites.

Maintaining soil productivity is of paramount importance. The removal of topsoil for building materials or roadfill, however, is a widespread practice. For example, at Porabari the top soil was being removed from fields that were higher than the irrigation channel. This was being done for two reasons: (1) to lower the fields to an elevation at which they could be irrigated without lifting water; and (2) the removed soil was being utilized for the construction of dwellings. The owner was aware that removal of the top soil would lower the productivity of the land, but thought that the decreased labor costs of lifting water would offset the reduced productivity. Proper topographical placement of the pump would have made removal of this top soil unnecessary; there were more appropriate areas, closer to the homesites, from which to borrow soil. This farmer made a value judgement as to the benefits of obtaining building materials as opposed to the losses from decreased soil productivity. This loss of productivity is not permanent since the soils within the Joydebpur area are fairly uniform with depth

and can be brought back to a normal level of productivity within five to six years.

V. SUMMARY OF FINDINGS AND RECOMMENDATIONS

The Diagnostic Analysis revealed that the farmers at the five deep tubewell sites studied were competent rice farmers who are doing a good job with the resources available to them. General farming practices were good; fields were well prepared and relatively well leveled, with the majority of fields being weed free. There were few, if any, shortages of water within the irrigated areas.

The most striking constraint limiting the size of the command areas was the low discharge of the pumps. All of the pumps were operating at 50 to 66 percent of the 56.6 l/s design capacity; however, the farmers were utilizing this water remarkably well. They were irrigating a total area that was equal to, or greater than estimated, based on the actual pump discharge.

The principal reason for the large command areas, considering the less than designed pump discharge, was the dominance of heavy, clay-like soils that limited water losses due to seepage and deep percolation. The low soil percolation rates promoted effective use of plot to plot flow and allowed for the efficient use and reuse of water.

The water distribution systems at all sites were designed with factors other than water control in mind. Some of the main channels tended to be unnecessarily long with frequent turns. Low soil percolation losses permit these irrigation systems to operate effectively.

The topographic locations of two pumps were not at the highest elevation within the potential command area; therefore, the physical size of their command areas was restricted automatically at the time of tubewell installation. Other problems involving tubewell installation include the low discharge rates, and the fact that all of the pumps were set at 22 m from the ground surface. This depth was shown to be dangerously close to the measured water table depth. There is a very real possibility that if the water table should drop 1 or 2 m, these tubewells could become inoperative.

The dominant cropping patterns has shifted from local-local-fallow to either local-local-HYV or fallow-local-HYV. The predominant change has been to shift the fallow season from Boro to Aus. The installation of the tubewell has meant that approximately one-third of the irrigated land is now triple cropped rather than double cropped. Where two crops were produced prior to tubewell irrigation, the cropping intensities were not dramatically altered. However, the replacement of local rice in the Aus season by HYV rice in the Boro season resulted in a significant increase in output.

Agricultural inputs of fertilizer as reported by the sample farmers were at or near the recommended levels for the production of HYV rice. However, most fields at all tubewell sites displayed nitrogen deficiency symptoms at some time during the field study. Deficiency symptoms would suggest that maximum yields would not be obtained. Also, the practice of transplanting two month old seedlings to fields was very widespread. Normally this would be considered a poor agronomic practice leading to decreased yields. However, yield data as reported by the

farmers suggest that they are achieving excellent results with an average of about 5 t/ha for the five sites. This average is about 1.5 t above the national average for Boro rice.

Production of Boro rice entails high investments in agricultural inputs. An average per hectare investment of Tk 1,487 was attributed to fertilizers and insecticides, with irrigation costs varying from a low of Tk 818 at Mariali to a high of Tk 2,145 at Jogitola. Lower irrigation costs at Mariali were associated with low pump operation costs (electricity) and the larger command area. Financial return from Boro rice under tubewell irrigation ranged from Tk 7,413 to Tk 12,527/ha.

All of the tubewells were run by informal organizations, with no written irrigation rules and regulations, and with few linkages to governmental agencies. Though the villages had strong communication links with Thana headquarters, there was still very little involvement at the village level by organizations responsible for local institution building. Few extension services actually reach the village.

Extension services through or because of CARE were greater in Mariali than the other sites. The CARE-BKB credit program at Mariali made credit more available to these farmers; thus, credit was utilized more than at the other sites. On an average, 65 percent of the farmers at all of the sites did not obtain credit for the 1983 Boro season. About half of this group indicated that credit was not needed.

Irrespective of the type of organization or management, all of the tubewells were essentially managed and controlled by either one individual or a small group of farmers. The person(s) who had made the initial effort to obtain the tubewell subsequently controlled its

management for years. Most of the tubewells had informal groups with a management committee, but one or two persons within the committee planned and implemented decisions. The potential for abuse of power exists as is already evident at some sites.

Recommendations

A list of recommendations regarding improved water management in Bangladesh is given below. The list is necessarily indicative by nature, rather than conclusive, due to the inherent restrictions of any training program. The recommendations, therefore, merely indicate general directions for future action.

(1) The prevalence and causes of low pump discharge need to be examined further. What specifically are the reasons for the less than designed discharge? Once identified, how can the existing and future deep tubewells be improved to overcome this constraint?

(2) The economic and financial cost of irrigation for both diesel and electric pumps needs to be reviewed. What is the impact of command area size on the per hectare cost of irrigation?

(3) The profitability of tubewell irrigation in Bangladesh should be investigated further in light of the potential changes in cropping pattern and intensity.

(4) Research is needed on how different types of organizations, both formal and informal, affect the water management procedures of deep tubewells. Additionally, the reasons for past organizational failures should be examined.

(5) Most fields displayed nitrogen deficiencies; however, close to optimum rates of nitrogen had been applied based on farmer surveys. Factors that merit investigation include rates and timing of fertilizer applications, and the interaction with soil factors.

(6) There is a need for increased attention to the danger of pump settings which are too shallow. If the water level drops only a short distance, the present pump setting of 22 meters will be above the water table.

(7) Extension services and governmental organizations responsible for institution-building should concentrate their efforts at the field level. Institutional support should be provided to the present informal groups. This support should include educating all classes of farmers in proper water management procedures.

(8) The reasons why farmers use older than recommended seedlings at transplant needs further study. Field research needs to determine if this is a common practice for the Joydebpur area, and if so, does this practice have any deleterious effects on yields?

(9) The impact of credit availability on productivity and the use of purchased inputs needs to be explored.

(10) Technical and organizational feasibility of using the numerous man-made ponds as public water storage merits attention. The proper development of these ponds could increase the potential water control of the farmers.

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APPENDICES

A. Agronomy

1. Introduction

When an agronomist evaluates an irrigation system he is concerned primarily with the physical, chemical, and biological factors that affect crop yield. The agronomist prioritizes these factors as to the most limiting with respect to total crop production.

During the reconnaissance phase a list of parameters, or factors, that could be effectively examined within the framework of the Diagnostic Analysis was developed. No attempt was made to make the list comprehensive; however, the selected parameters were deemed the most significant, especially for a monoculture system of rice as it exists in the Joydebpur area.

The soil parameters selected to be examined included: pH, texture, moisture status, bulk density, percolation rate, salinity, and the potassium (K) and phosphorus (P) status. Crop parameters included: visual assessment and qualitative analysis of tissue nitrogen (N), P, and K, age of seedlings at transplant, plant population, disease incidence, and pest damage. In addition, the cultural practices of land preparation, leveling, and fertilizer and pesticide applications were also examined.

An absence of quantitative yield data made it difficult to examine and correlate these parameters with crop yields as thoroughly as might be desired. Because of time constraints, the agronomists had to depend on information collected by the economists concerning yield data and fertilizer applications.

2. Crops

a. Varieties of Rice

The varieties of rice grown during the Boro season of 1983 in the study areas were BR1 (Mala), BR3, BR8, BR9, Pajam, Muktahar, Ratna, and Sufala (Table A1). Among these varieties, BR3 and Pajam were the most popular. At Mariali, 17 plots were selected to study the agronomic parameters of rice plants. Eleven plots contained BR3, five Pajam, and one Sufala. Ten plots at Jogitola were selected, eight were BR3, one BR1, and one Ratna. At the Itahata site, 24 BR3 and seven Pajam plots were examined. Fields were selected at Teknagapara and Porabari to concentrate on their predominate varieties. Five BR3 and five Pajam plots were examined at Teknagapara and four BR3 and four Pajam plots were selected for study at Porabari.

Table A1. Plant Variety, Height, and Population Data at the Five Study Sites

Study Site	No. of Plots by Variety		Hills/m^2 Mean	Hills/m^2 Range	Tillers/Hill Mean	Tillers/Hill Range	Plant Height (cm) Mean	Plant Height (cm) Range
Mariali	BR3	11	32	30-36	15	10-19	42	36-46
	Pajam	5	35	31-39	14	10-15	55	47-68
	Sufala	1	--	-----	--	-----	--	-----
Jogitola	BR3	8	32	27-35	15	12-18	36	33-40
	BR1	1	28	-----	15	-----	51	-----
	Ratna	1	28	-----	10	-----	30	-----
Itahata	BR3	24	33	24-41	13	8-19	47	18-65
	Pajam	7	36	29-43	12	9-15	56	45-68
Teknagapara	BR3	5	32	27-36	13	10-15	32	30-34
	Pajam	5	36	35-36	13	12-17	44	43-45
Porabari	BR3	4	32	28-40	13	10-18	36	32-38
	Pajam	4	28	20-38	13	10-19	43	36-50

b. Land Preparation

After an initial plowing, the rice fields were puddled and plowed five to six times before planting. Successive plowing operations were performed perpendicular to the direction of the previous plowing after each cross-plowing. The fields were laddered, or leveled. One or more additional ladderings are usually required to finish leveling the field and to incorporate basal fertilizer applications. Laddering is accomplished while the field is flooded; thus, high and low spots are easily seen and corrected. This results in a relatively level field.

Plowing was accomplished using a traditional country (stick) plow and bullocks. The depth of plowing does not exceed 9 to 10 cm and

creates a dense plowpan at this depth. The creation of the plowpan facilitates the use of bullocks under wet soil conditions. The plowpan is also advantageous in that it limits the amount of deep water percolation; however, it has the disadvantage of limiting root growth to the upper 9 to 10 cm of soil.

c. Fertilizer Applications

Basal applications of urea, triple super phosphate, and muriate of potash were made before transplanting. Table A2 shows the amounts of N, P and K applied during the growing season. Approximately 20 to 30 kg N/ha was applied as a basal dose with the remainder applied in two to three splits as top dressings. From the data shown in Table A2, it appears that the farmers were applying amounts of N fertilizer that are at or close to recommended practices. Recommended levels of N for HYV-BR3 Boro rice varies from 80 to 112 kg/ha (Alam, 1979; Islam, 1979). Actual applications of P_2O_5 and K_2O (Table A2) appear to be slightly less than the recommended doses of 60 to 90 kg P_2O_5/ha and 40 to 67 kg K_2O/ha (BARC, 1979). However, low P and K fertilizer applications were not reflected in plant tissue analyses which generally showed adequate levels (Table A3).

Table A2. Mean and Standard Deviation of Fertilizer Applications*

Study Site	N kg/ha	P_2O_5 kg/ha	K_2O kg/ha	No. of Top Dressings of N Fert.
Mariali	98 ± 21 ab**	52 ± 20 ab	34 ± 16 a	3
Jogitola	102 ± 21 a	36 ± 22 b	24 ± 10 ab	3
Itahata	85 ± 22 b	48 ± 10 ab	20 ± 3 b	2
Teknagapara	101 ± 21 a	58 ± 20 a	29 ± 14 ab	2
Porabari	90 ± 25 ab	55 ± 18 a	24 ± 8 ab	2
Recommended Application	80 - 112	60-90	40-67	2

* Data collected during economic survey of farmers
** Values within a column and followed by different letters are significantly different at the 5% level using Students t-test

Table A3. Qualitative Nitrogen, Phosphorus and Potassium Tissue Test of Rice Plants

Study Site	Number of Fields								
	Nitrogen			Phosphorus			Potassium		
	Low	Med.	High	Low	Med.	High	Low	Med.	High
Mariali	2	8	0	0	6	4	0	0	10
Jogitola	6	3	0	4	5	0	0	1	8
Itahata	18	13	0	3	28	0	0	0	31
Teknagapara	0	3	0	0	0	3	0	0	3
Porabari	2	4	2	1	6	1	0	3	5

d. Planting of Seedlings

In all the study areas the rice seedlings were established in seed beds and then transplanted into rows. Three to four seedlings were planted in each hill. Plant to plant distance within the rows was maintained around 20 cm; row to row distance was approximately 25 cm. Plant populations and hills per square meter were essentially the same in all five areas with an average of about 32 (Table A1).

Planting of seedlings started the third week of December and continued until the last week of March. The planting data (Table A4) shows that in Mariali, most plantings were accomplished in January; in Jogitola and Porabari, from December to February; in Itahata in January and February with a few plantings in March; and in Teknagapara, during the month of February.

e. Tillers

The number of tillers per hill depends on a number of factors, such as variety of rice, planting age, number of seedlings, stage of growth, plant population, soil fertility, rate of fertilizer application, and depth of water. The BR3 variety of rice in Mariali and Jogitola had an average of 15 tillers per hill. The average number of tillers for the Pajam variety was 13.6, 12.0, 13.2 and 13.0 in Mariali, Itahata, Teknagapara and Porabari, respectively (Table A1). From the data shown in Table A1 there did not appear to be a difference among the deep tubewell areas, but there were insufficient data to conduct a statistical analysis. However, it is known that the maximum number of tillers of BR3 rice, as reported by Idris (1979), was 16.3, obtained

under saturated soil moisture conditions. In addition, tillering was found to be reduced drastically when stress occurred at the tillering stage.

Table A4. Planting Dates of Seedlings

Study Site														
Mariali			Porabari			Jogitola			Itahata			Teknagapara		
No.	Mo	Wk	No.	Mo	Wk	No.	Mo	Wk	No.	Mo	Wk	No.	Mo	Wk
1	Jan	4	14	Feb	2	25	Jan	3	39	Feb	1	50	Feb	3
2	Jan	2	15	Jan	1	26	Jan	2	40	Feb	1	51	Feb	2
3	Jan	3	16	Jan	4	27	Feb	1	41	Feb	1	52	Jan	3
4	Jan	4	17	Jan	3	28	——		42	Feb	1	53	Feb	1
5	Jan	4	18	Dec	3	29	Jan	4	43	Jan	3	54	Feb	3
6	Jan	3	19	Dec	4	30	Feb	2	44	Jan	4	55	Feb	3
7	Jan	4	20	Jan	2	31	Dec	4	45	Jan	4	56	Feb	2
8	Jan	4	21	Jan	3	32	Feb	4	46	Jan	4	57	Feb	1
9	Jan	4	22	Dec	3	33	Jan	3	47	Jan	4	58	Feb	3
10	Feb	2	23	Jan	3	34	Feb	4	48	Jan	4	59	Feb	3
11	Feb	4	24	Jan	4	35	Dec	4	49	Jan	4	60	Feb	3
12	Jan	4	—	——		36	Feb	2	—	——		61	Feb	3
13	Jan	4	—	——		37	Feb	3	75	Mar	1	62	Feb	2
	——		—	——		38	Jan	4	76	Jan	3	63	Feb	2
	——		—	——		—	——		77	Jan	1	81	Jan	2
	——		—	——		—	——		78	Mar	4	—	——	

No. = Farmer's Assigned Serial Number on Questionnaires

f. Seedling Age

The optimum transplanting age for seedlings is from 30 to 45 days. Although the transplanting ages varied among the deep tubewell command areas, on an average, they were all shown to be older than optimum (Table A5). Age of the seedlings planted in different areas varied from 30 to 90 days; while the average age at each site ranged from 47 to 62. These data would indicate that yields should be

Table A5. Number of Plowings, Ladderings, Weedings, and Age of Seedlings at Transplant*

Study Site	Plowings Mean**	Ladderings Mean	Seedling age (days) at Transplant		Mean No. of Weedings
			Mean	Range	
Mariali	6 ± 2	6 ± 2	60 ± 13 ab***	35-75	2
Jogitola	5 ± 1	5 ± 1	47 ± 10 c	30-60	2
Itahata	5 ± 1	5 ± 1	62 ± 5 a	60-75	2
Teknagapara	5 ± 1	6 ± 2	60 ± 18 ab	30-90	2
Porabari	5 ± 1	8 ± 3	51 ± 11 bc	35-75	2

* Data collected during economic survey of farmers
** Mean ± standard deviation
*** Values within a column and followed by different letters are significantly different at the 5% level using Students t-test

decreased due to the late transplanting age of seedlings. It is assumed that when seedlings are transplanted late, more seedlings should be placed in each hill and the distance between hills reduced to offset the decreased tillering of late planting. No information concerning the

number of seedlings actually transplanted to each hill was collected. However, plant spacing did appear to have been decreased to compensate for the older seedlings.

g. Weeds and Pesticides

Weeds reduce rice yield by competing with rice plants for nutrients, sunlight, space, and sometimes water. Weed growth can be reduced if the fields are kept submerged with water continuously. Fields in the study areas were irrigated rotationally once every six to twelve days, some fields remained dry part of the time, thus weeding becomes necessary.

The farmers removed weeds manually two to three times before the plants attain the reproductive stage. Weed control is particularly necessary until plants develop sufficient canopy to suppress weed growth. Grasses and sedges were the weeds most commonly observed within the study areas (Table A6). Duckweeds and algae also were noted. However, for the most part, fields were free from weeds having been weeded at least twice.

Table A6. Infestation of Insect, Disease, and Weeds

Parameters	Study Site				
	Mariali	Jogitola	Itahata	Teknegapara	Porabari
Insect Damage	Low to Medium (2-7%)	Low to Medium (1-15%)	Low to Medium (1-10%)	Low (3-5%)	Low to Medium (1-10%)
Principal Insects	Stemborer Hispa	Stemborer Hispa	Stemborer Hispa	Stemborer Hispa	Stemborer Hispa
Insecticides applied (kg/ha)	6	2	1	3	3
Disease Damage	Low (Leaf Blast)	Low (Leaf Blast)	Medium (Leaf Blast)	Low (Leaf Blast)	Low (Leaf Blast)
Weed Infestation	Low	Low	Medium	Low	Low
Name of Weeds	Sedges Algae Duckweeds	Sedges Algae Duckweeds	Sedges	Sedges	Sedges

h. Insect and Disease Infestation

The most commonly occurring insects observed in the study areas were stemborers and hispa (Table A6). Stemborer was identified as the most prolific and harmful insect. Though hispa was observed in all areas, the damage caused by stemborers was much more severe. The extent of damage in different areas varied, but in a few fields nearly 15 percent of the crop was damaged by stemborers. Crops at Jogitola were the most affected (1-15 percent) and those at Teknagapara least affected (3-5 percent).

The following insecticides were used by the farmers of the study areas at the rates shown: Basudin - 6.5 kg/ha; Dimacron - 1.0 kg/ha; Furadan - 3.0 kg/ha; and, Diazinon - 1.0 kg/ha. Insecticides were generally applied as a liquid foliar application and were broadcast using a wisk. Basudin was also applied with broadcast applications of urea. On the average, the total amount of insecticides used in different locations varied from 1 to 6 kg/ha. This is below the recommended dose of 10 to 30 kg/ha to be applied two to three times during the growing period (Pathak, 1970).

Disease symptoms were almost absent except for leaf blast. Itahata appeared to be the most severely affected by leaf blast, but it was observed in all areas (Table A6).

3. Irrigation

Each deep tubewell area was divided into a number of blocks. The command area and topography varied considerably, thus the number of blocks in each area varied from four to six and their sizes were not equal. Ideally, irrigation water is to be applied on a rotational basis taking one to three days to irrigate each block. In most cases the chowkidar decided when and how much water to apply in each block. Therefore, each farmer had an opportunity to get water in six to twelve days time. Farmers applied from 5 to 7.5 cm standing water to their plots. Most plots became dry and sometimes dried up to cracking before the irrigation.

Though some cracked soils were observed during reconnaissance, no shortage of water was recorded during the detailed study. Soil

moisture status from saturation to 5.0 cm standing water was observed during the study period. This was due in part to rainfall which occurred during the study time period.

4. Soils

The soils of the Joydebpur area are in the Madhupur tract and for the most part, are situated above river flood plains. The soils are mainly ultisols with some oxisols occupying ridges.

Water movement into and through soil is largely influenced by soil texture. Seepage and percolation losses as well as capillary rise of water from deep soil layers to the root zone are all affected by soil texture. Fine textured soils tend to have high water retaining capacities, and lower permeabilities and infiltration rates. Soils of the study area were poorly drained and ranged from clays to clay loams (Table A7).

Table A7. Soil Properties

Soil Property	Study Site				
	Mariali	Jogitola	Itahata	Teknagapara	Porabari
Soil Texture*	C to SiCl	SiC to Cl	SiCl	SiCl	C to SiC
Soil pH (Range)	5.6 - 6.2	5.4 to 6.1	6.0 to 6.2	6.8	6.2 to 6.6
Bulk Density of Surface Soil (g/cm^3)	1.5 to 1.6	-	1.5 to 1.7	1.5	1.3 to 1.69
Percolation Rate (mm/day)	1.5	1.5	1.5	1.6	2.0
EC** of Soil Paste Extract mmhos/cm	0.11 to 0.21	0.22	-	-	0.15
EC of Irrigation Water (mmhos/cm)	330	520	480	480	280

* C = Clay; Si = Silt; l = Loam
** EC = Electrical conductivity

a. Bulk Density

Bulk density is the weight of soil solids per unit volume of total soil. Water retaining capacity, porosity, air and water movement, and root penetration are all affected by bulk density. Bulk density of mineral soils usually range from 1.0 to 1.6 g/cm^3. The variation results mostly from differences in total pore space. Generally fine textured soils have lower bulk densities than coarse textured soils. Other factors that affect

bulk densities are compaction, organic matter content, soil structure, tillage, and other management practices.

Bulk densities of fallow soils from the five study areas varied from 1.3 to 1.7 g/cm^3. The bulk density of the surface soil (0-10 cm depth) was 1.5 g/cm^3 in Mariali, Itahata, and Teknagapara, and ranged from 1.30 to 1.65 g/cm^3 in Porabari. The bulk density value of subsurface soils (10-20 cm) ranged from 1.58 to 1.76 g/cm^3; the higher values compared to the surface soils are due to the compacted plowpan layer.

b. Percolation

Since rice is grown primarily under submerged conditions, the percolation rate of soil is an important factor in determining the irrigation requirement. Percolation rates at all five study sites were low, an average of 1.5 mm/day. The presence of a dense plowpan within 9 to 10 cm of the soil surface contributed to the low percolation rates. However, such low rates of percolation, in turn, permit large areas to be irrigated in four of the five tubewell command areas despite recorded low discharge rates for the pumps (Appendix B).

c. Electrical Conductivity

The electrical conductivity (EC) of the saturated paste extract of soil is a measure of the salt content of soil. A saline soil is considered to have an EC greater than 4 mmhos/cm at 25 C. If irrigation water is high in soluble salts, salts may accumulate in the soil and ultimately reduce crop yields. However, the EC of saturated paste extracts in the study areas were

found to be low with an electrical conductivity and varied from 0.110 to 0.480 mmhos/cm (Table A7).

The electrical conductivity of the irrigation water at the five sites ranged from 0.28 to 0.52 mmhos/cm indicating that there is little to no salinity hazard from irrigation water in the Joydebpur area.

d. Soil pH

Soil pH affects plant growth primarily by affecting nutrient availability for plant uptake. The most desirable pH range for normal growth of rice is between pH 6 and 7. Soil pH varied from 5.4 to 6.8 in the study areas, an optimum range for the growth of rice (Table A7).

e. Fertility

General observations during the study period indicated that many of the fields were suffering from N deficiency; fields, which initially showed no signs of deficiency, displayed symptoms by the end of the second week of the field studies. Observations of farming practices during the two weeks showed that farmers usually applied a basal dose of N (approximately 20 to 30 kg/ha) during land preparation followed by two to three broadcast applications of urea. Therefore, many fields that initially appeared deficient again showed no sign of deficiency by the end of this period.

Soils at all five areas contained a very dense plowpan at a depth of 9 to 10 cm. This plowpan had a beneficial effect in that it contributed to limiting the deep percolation to approximately 1.5 mm per day (Table A6), but it also had the negative effect of restricting root growth to the surface 9 or 10 cm of soil. The rapid appearance of nitrogen deficiency symptoms

would indicate that these soils were depleted rather quickly because of the limited amount of top soil available for root growth.

This situation necessitates frequent top dressings of N and farmers in these areas expect to apply two to three top dressings during the Boro season. Table A2 indicates that 85 to 102 kg N/ha would be applied to the crop thus, the amount of nitrogen being applied during the growing season would appear to be optimum. However, the fact that many fields periodically showed signs of nitrogen deficiency would indicate that these fields are probably not achieving maximum yields. This may be because the farmers are regulating nitrogen applications judiciously because of the high cost of urea fertilizers. Alternatively, there may be a need for more experimental work to determine the optimum rates and frequency of nitrogen applications for this particular area.

The amounts of P and K fertilizers applied (Table A2) were below recommended application rates. However, there were no visual symptoms of deficiencies in any of the five areas studied. Tissue analyses of rice plants generally showed adequate to high amounts of P and K (Table-A3); thus, it would appear that the fertility status of these nutrients was adequate. Whether there would be a yield response to additional applications of P and K would have to be verified with more extensive field trials. However, it may be prudent to investigate optimum rates for P and K recommendations.

No micronutrient problems were observed. However, a number of area agronomists reported that soils in the Joydebpur area are deficient in sulfur and zinc. Field trials were being conducted with foliar aplications of gypsum ($CaSO_4$) at Mariali. However, no overt symptoms of zinc or

sulfur deficiencies were observed at Mariali or in any of the other areas that we examined. During the period of investigation, there was no observable response from the gypsum applications at Mariali, but this does not rule out the fact that there may have been a yield response.

5. Expected Yields

As mentioned previously, actual yield data were not obtained, but rather based on the economic surveys of the farmers. This data appears to be somewhat optimistic since the average yield for the five sites was about 5 t ha (Table A8), which is about 1.5 t above the national average. Data from Itahata would suggest that their expected yields are exceptionally optimistic since N applications were significantly less than the other study areas (Table A2) and less than recommended rates.

Table A8. Yields in Metric Tons Per Hectare

Study Site				
Mariali	Jogitola	Itahata*	Teknagapara	Porabari
5.3 ± 1.0 ab**	4.9 ± 0.7 ab	5.4 ± 0.5 ab	4.5 ± 0.6 bc	4.2 ± 1.2 c

*Expected yield for 1983 season
**Values followed by different letters are significantly different at the 5% level using Students t-test

6. Summary of Findings

General farming practices within the five study sites were good. The fields were well prepared, leveled, and the vast majority of fields were free of weeds. Most of the farmers used HYV rice. Seedlings were

transplanted in lines maintaining spaces between hills and rows that were in accordance with BRRI recommendations. Plant populations were mostly optimum to near optimum.

Seedling age was a possible constraint. Some farmers used seedlings that were much older than optimum which might affect yield.

While pest damage was observed, the amount of damage was not excessive and only a very limited number of fields appeared to have suffered significant damage from either diseases or pests.

Soil texture of the study area varied from clay to silty clay loam. This type of texture is favorable for retaining water and nutrients for plant use. Seepage, percolation loss of water, and erosion hazards are also minimum in this soil type.

The electrical conductivity of both soil and water were low indicating that there was little or no salinity hazard from irrigation water in the Joydebpur area.

The most significant agronomic constraint at all five study sites appeared to be nitrogen deficiencies. As noted earlier, nitrogen deficiencies were observed in almost all fields during the time of the Diagnostic Analysis. Farmers were aware of the problem, but were restricted, (from their perspective) by the high cost of nitrogen fertilizers. On the other hand, data collected by the economists would indicate close to optimum rates of nitrogen were being applied. Thus, it is unclear whether there is an actual nitrogen problem. Factors that warrant further investigation to resolve this paradox include application rates, timing of applications, cost of nitrogen fertilizers, and interactions of possible soil factors.

The low amounts of P and K fertilizers that were applied would suggest that less than optimum yields would be attained, however, this can only be verified through field trials. Past experience may have taught the farmers that they can achieve satisfactory yields with low applications of these fertilizers.

During the Diagnostic Analysis there was no observed shortage of water within the irrigated areas. The presence of a dense plowpan and compact subsurface clays produced soils that had low infiltration rates. The low soil percolation rates promoted effective use of plot to plot flow and allowed for the efficient use and reuse of water despite a lack of water control. Water not utilized in one field would pass or seep to the field below with little loss to deep percolation. In this manner water was continuously reused by downstream fields. However, the dense plowpan has a negative effect of limiting root growth to the upper 9 to 10 cm of soil. This could produce serious soil fertility problems if this land were to be used for the production of upland crops.

B. Engineering

1. Irrigated Command Area of the Deep Tubewells

For the soil type and climatic conditions in the Joydebpur area, a 56.6 l/s (two cfs) deep tubewell is estimated to irrigate approximately 36 ha (90 acres) of paddy lands. However, the actual command area tends to be much less. In this study, one of our objectives was to estimate a reasonable figure for the command area of the deep tubewells.

The command area of a deep tubewell is affected by the following factors:

- discharge of the pump,
- duration of pump operation,
- location of pump in the command area,
- soil texture,
- land topography,
- kinds of crop grown, and
- socio-economic and organizational factors.

In our five study sites (Jogitola, Porabari, Teknagapara, Itahata, and Mariali), crops grown (rice), soil texture (clay-loam to clay) and land topography (gentle slopes) were the same. It was therefore expected that the differences in command areas could be explained by the differences in pump discharge and operative hours, pump location, and/or socio-economic and organizational factors.

a. Discharge and Operating Hours of the Pumps

As mentioned above, all of the tubewells were rated to have a design discharge of 56.6 l/s (2 cfs). During this training course, the discharges of the deep tubewells were measured and are given in Table-B1.

Table B1. Discharges & Command Areas of Deep Tubewells

Study Site	Discharge l/s (cfs)	Irrigated Area hectares (acres)	Irrigated area per unit discharge ha/l/s (ac/cfs)
Mariali	35.68 (1.26)	31.51 (77.8)	0.88 (61.7)
Porabari	28.32 (1.00)	23.98 (59.2)	0.85 (59.2)
Teknagapara	37.10 (1.31)	23.24 (57.4)	0.63 (43.8)
Jogitola	34.13 (1.21)	6.48 (16)	0.19 (13.2)
Itahata	36.82 (1.30)	25.91 (64)	0.70 (49.2)

The data clearly shows that all of the deep tubewells were discharging much below their rated capacity. Thus, one of the major constraints in increasing irrigated command area was the low discharge of the pumps. Impeller design, operating speed of the pump, pump setting, and specific yield of the aquifer are some of the important factors that could account for these low discharges.

Because of time constraints we could not obtain data on the impeller and pump designs from BADC. However, they did provide data on

the pump setting based on the well logs. There was insufficient data to evaluate the specific yield of the aquifer.

The motor (engine) and pump operating speeds were determined and are given in Table B2 together with the rated speeds. All pumps were observed to be operating at speeds higher than their rated speed. High operating speeds may have an adverse effect on the pump discharge. However, in the absence of the actual pump characteristic curves, we can not be sure whether this overspeeding is the major reason for the low discharges rates. Also, the data on pump and impeller design were not available to evaluate any design deficiencies.

Table B2. Rated and Operational Speeds of the Motors and Pumps

Study Site	Rated Motor or Engine rpm	Observed rpm of Motor or Engine	Rated rpm of Pump	Observed rpm of Pump
Mariali	1460	1420	1470	1950
Porabari	1460	1460	1470	2000
Teknagapara	1500	1340	1470	1720
Jogitola	1500	1400	1470	1800
Itahata	1500	____	1500	____

Duration of the pump operation was reported to be very low--an average of about 12-14 hours in the four areas excluding Jogitola. Because of a lack of organization, each farmer in Jogitola personally purchased fuel and ran the tubewell for his own use, thereby making it

difficult to estimate operational hours. This method of operation is considered to be very inefficient due to increased channel losses.

One of the principal reasons for reported low operational hours averaged over the season was because the agency responsible for repair and maintenance (BADC) did not respond quickly when a breakdown was reported. Non-availability of spare parts, uncertain fuel supply, and frequent breakdown in the supply of electricity are other causes of reduced duration of pump operation. In addition, the lack of familiarity on the part of the farmers with the tubewell technology contributed to limited pump usage. The communities felt that the pumping machines needed to be "rested" like the other power sources with which they were familiar, i.e., animals.

b. Pump Location and Its Effect on the Command Area

Topographic surveys of the irrigation system showed that at three sites, Itahata, Mariali, and Teknagapara, the pumping plants were located at the highest location in comparison to the surrounding lands. In the other two systems, Porabari and Jogitola, the pumps were located in lower lying areas.

Indications are that in the cases of Porabari and Jogitola, considerations other than engineering influenced the site selection. In Porabari, the pump was located on the lands of an influential landlord who owned about 8.1 ha out of the total command area of 24 ha. The same social factors might have influenced the site selection in Jogitola, where the pump was virtually controlled by one influential landlord who

owned 4.5 ha out of a total command area of 6.5 ha. It should be noted that the average landholding in Bangladesh is less than 0.44 ha.

An interesting point regarding the pump location deserves serious exploration. In every hamlet there is a big pond (known locally as a pukur or tank) resulting from earth removal for building houses. Since the houses are built on elevated grounds, and since it is desirable to dig the borrow pits nearest to the construction site, these ponds are at higher elevations compared to the adjacent agricultural lands. If the pumps were located adjacent to these ponds and could discharge into the ponds, a storage capability could be built into the tubewell irrigation systems at virtually no additional cost. Given the frequent breakdown rate of the pumps, having reservoir capacity would greatly enhance the reliability of water supply.

c. Factors Affecting Pump Discharge

Measurements for pumping plant efficiency of the five tubewells are presented in Table B3.

The data shows that all of the deep tubewells were operating at low levels of efficiency. However, the efficiency of the electrically operated units was much higher than the diesel operated units. This was due to the large differences between the efficiencies of the electric motor and diesel engine. In practice, the electric motor can operate with an efficiency of approximately 90 percent; the maximum efficiency of a diesel engine is 25 percent.

Table B3. Pumping Plant Efficiency

Study Site (1)	Pump Discharge l/s (cfs) (2)	Static Water level, m (3)	Pumping Water level, m (4)	Total Head m (5)	HP input to engine/ motor (6)	WHP (7)	Pumping Plant Eff. % (8)
Mariali(E)*	35.68 (1.26)	13.43	18.54	18.64	18.77	8.75	46.6
Porabari(E)	28.32 (1.00)	13.47	18.44	18.54	17.42	6.91	39.6
Teknagapara (D)**	37.10 (1.31)	12.98	18.29	18.39	55.2	8.96	16.2
Itahata(D)	36.82 (1.30)	12.70	21.20	21.40	59.9	10.36	17.3
Jogitola(D)	34.13 (1.21)	12.72	18.35	18.45	57.2	8.28	14.5

*E = Electric
**D = Diesel

col. (5) = col. 4 + Height of discharge outlet above the point from where the measurements are taken for determining static and pumping water levels.

For diesel engine: col. (6) = Fuel consumption in U.S. gallon per hour x HP-h produced per U.S. gallon of fuel.

$$= \frac{\text{U.S. gallon of diesel} \times 55}{h}$$

For electric motor: col. (6) = $\frac{\text{kWh consumed}}{h \times 0.746}$

$$\text{col. (7)} = \frac{\text{col. (2)} \times \text{col. (5)}}{76}$$

$$\text{col. (8)} = \frac{\text{col. (7)}}{\text{col. (6)}}$$

We were not able to measure the efficiency of the pump separately from the motor since the shaft horsepower delivered to the pump could not be measured independently. However, we could estimate the pump efficiency by assuming a value for the efficiency of the engine or motor. If the efficiency of the electric motor used in Porabari site is assumed to be 90 percent, then the efficiency of the pump is 44 percent. From typical pump characteristic curves (Figure B1), this pump is designed to discharge 63 l/s (2.2 cfs) at a head of 18.5 m with an efficiency of 75 percent. Therefore, the measured efficiency is much less than the design efficiency. The primary reason for this low efficiency is the low actual discharge of the pump due to apparent inadequate pump design.

In the case of diesel operated pumps, low discharges also appear to be the main cause of low efficiencies. For example, let us consider the deep tubewell at the Jogitola site. If we assume the efficiency of the diesel engine as 25 percent, then the efficiency of the pump is 58 percent. But from the pump characteristic curves, it is seen that this pump should deliver a discharge of 63.7 l/s (2.25 cfs) at a head of 18.45 m with an efficiency of 74 percent.

Information on depth of the wells, depths to the aquifer and pump settings were obtained from the bore logs which were obtained from the Bangladesh Agricultural Development Corporation. The information is contained in Table B4. The average well depth is 94.6 m while the average depth to aquifer is 44.7 m. The average aquifer depth per well is 52.8 m, indicating sufficient exposure of the aquifer in the wells.

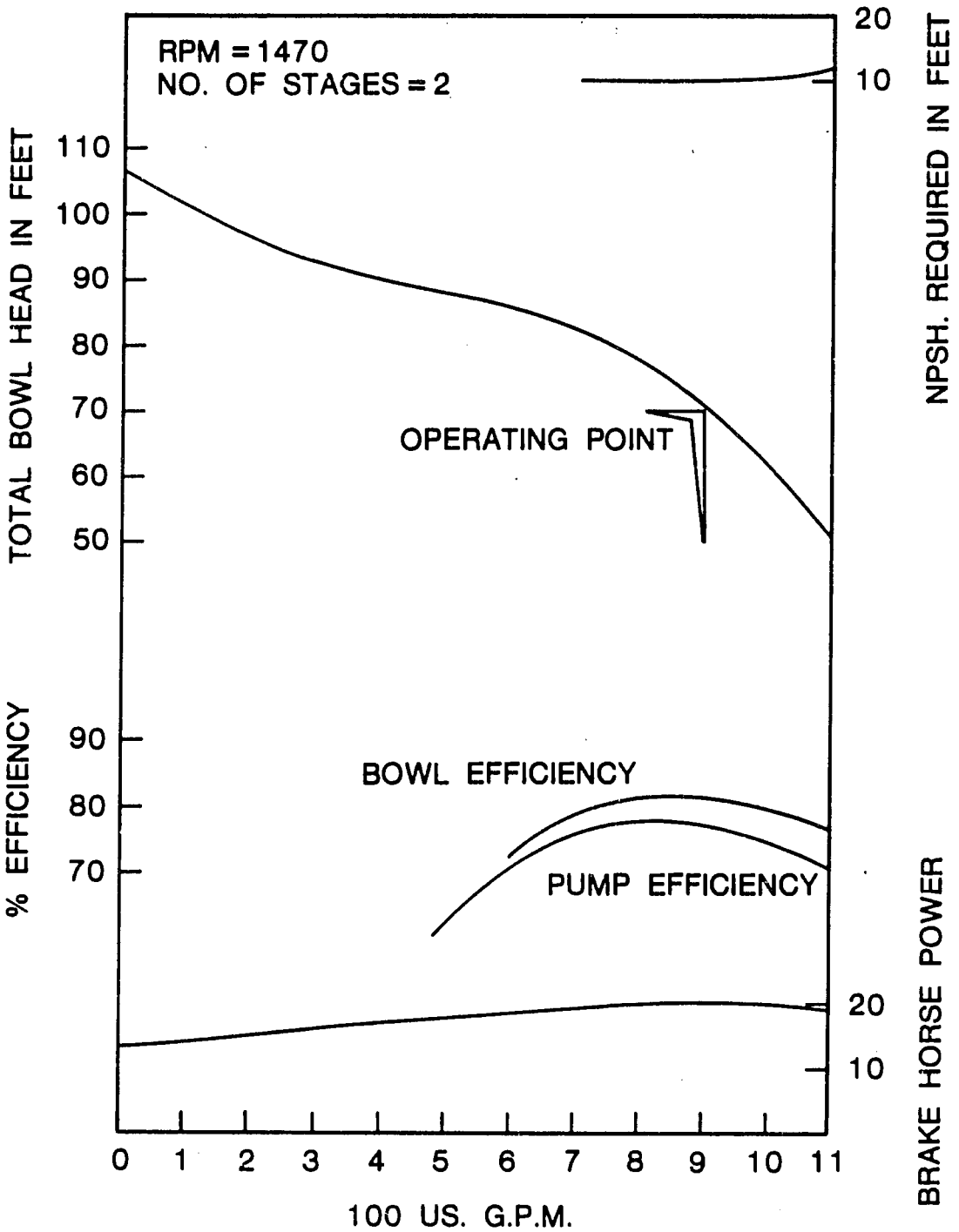


Figure B1. Typical Pump Characteristic Curves as Supplied by BADC

Table B4. Tubewell Data

Study Site	Depth of Tubewell (m)	Depth to Aquifer (m)	Depth of Aquifer in Well (m)	Pump Setting Depth (m)	Pumping Water Level (m)	Difference Between Pump Setting and Pumping Water Level (m)
Mariali	86.0	31.5	54.5	21.9	18.54	3.36
Porabari	92.0	49.3	42.7	21.9	18.44	3.46
Teknagapara	110.3	45.1	65.2	23.4	18.29	5.11
Jogitola	86.0	46.7	39.3	23.4	18.35	5.05
Itahata	98.8	48.8	50.0	22.2	21.20	1.00
Average	94.6	44.7	52.8	22.6	18.96	3.60

The average pump setting depth is 22.6 m and the average pumping water level is 18.96 m. The average difference between the pump setting and pumping water level is 3.60 m. The maximum differences are about 5 m for the Teknagapara and Jogitola sites, while the minimum difference is 1.00 m for the Itahata site. During the pump testing there was no evidence of the pumping water level falling below the pump setting. However, the differences between the pump settings and pumping water levels were sufficiently small that concern for future water supplies should be expressed. Decline in regional water table elevations could reduce or eliminate pumping from the wells studied. All the pump settings are relatively shallow (22-23 m), but the total depths of the wells is large (86-110 m). There is no information on the reasons for the shallow pump settings. However, potential causes could include (1) inadequate length of housing pipe supplied; (2) nonverticality of the well; and (3) improper pump installation. It would appear that the pump settings could be increased with a small addition to the cost of pump installation. The increased pump setting depth would provide a larger margin of reliability of water supply in these wells for the future.

d. Available Water Supply for Irrigation

In contrast to the usual assumption of farmer inefficiency, our results show that most farming communities were irrigating the maximum possible area with the available amount of water. Table B1 shows that in four out of five irrigation systems, the command areas varied from 0.63 to 0.88 ha/l/s of irrigation water. The low command area

(0.19-ha/l/s) in Jogitola occurred because of unfavorable socio-organizational factors. The high command areas in Porabari and Mariali are partly due to favorable topography which is rolling with moderate slopes. Consequently, there is a greater reuse of drainage water and rainfall from upstream areas by the downstream farmers.

Should the farming communities be expected to irrigate more paddy lands than are being irrigated presently? A very simple and quick calculations provides an answer to this question.

For the Joydebpur area, evapotranspiration (ET) for the month of March is estimated to be 5 mm/day (Karim and Akhand, 1982). For Madhupur heavy-clay soils, the deep percolation rate was measured to be 1.5 mm/day; therefore, the total water requirement = 6.5 mm/day = 0.195 m /month. Assuming that the pump is operated 18 hours/day and 6 days/week (i.e., 25 days per month), with a discharge of 1 l/s:

$$\text{Irrigation water available per month} = \frac{1 \times 18 \times 60 \times 60 \times 25 \times 1000}{(100)^3}$$

$$= 1620 \text{ cubic meters}$$

Research on the irrigation system of Indonesia has established that the rice irrigation systems cannot operate at Relative Water Supply (RWS) levels less than 1.3 (or a system water-use efficiency greater than 77%) (Oad, 1982). Based on the findings in Indonesia, we can assume the minimum operational RWS for irrigation systems in Bangladesh to be 1.3.

$$\text{Potential command area} = \frac{1620}{1.3 \times 10{,}000 \times 0.195}$$

$$= 0.64 \text{ hectare per l/s}$$

Note that even with assumptions regarding pump operating hours and system efficiency being on the higher side, farmers are cultivating more land than expected according to the water requirement calculations (see Table B1). It should be noted that some of the requirement is met by rainfall.

2. Irrigation Conveyance and Distribution System

a. Profiles of Water Surface and Surrounding Field Elevation

The profiles of water surface and surrounding fields along the main channel are presented in Figures B2 to B6 for each of the five deep tubewell sites. In case of Mariali and Porabari, the elevation of water surface is lower than some of the surrounding fields. The results indicate that the channels are improperly located to supply water to adjacent fields. Since farmers' lands are higher than the water surface in the main channel, they resort to the practice of checking the main channels to raise the water level.

Farmers in Mariali and Porabari normally check the main channel by placing earth across the channel. The earth is obtained by cutting the banks; this, in turn, weakens the channel banks resulting in considerable water loss through seepage. A considerable amount of water also is lost as dead storage in the channel after the irrigation is completed. Such losses could be decreased if proper check structures

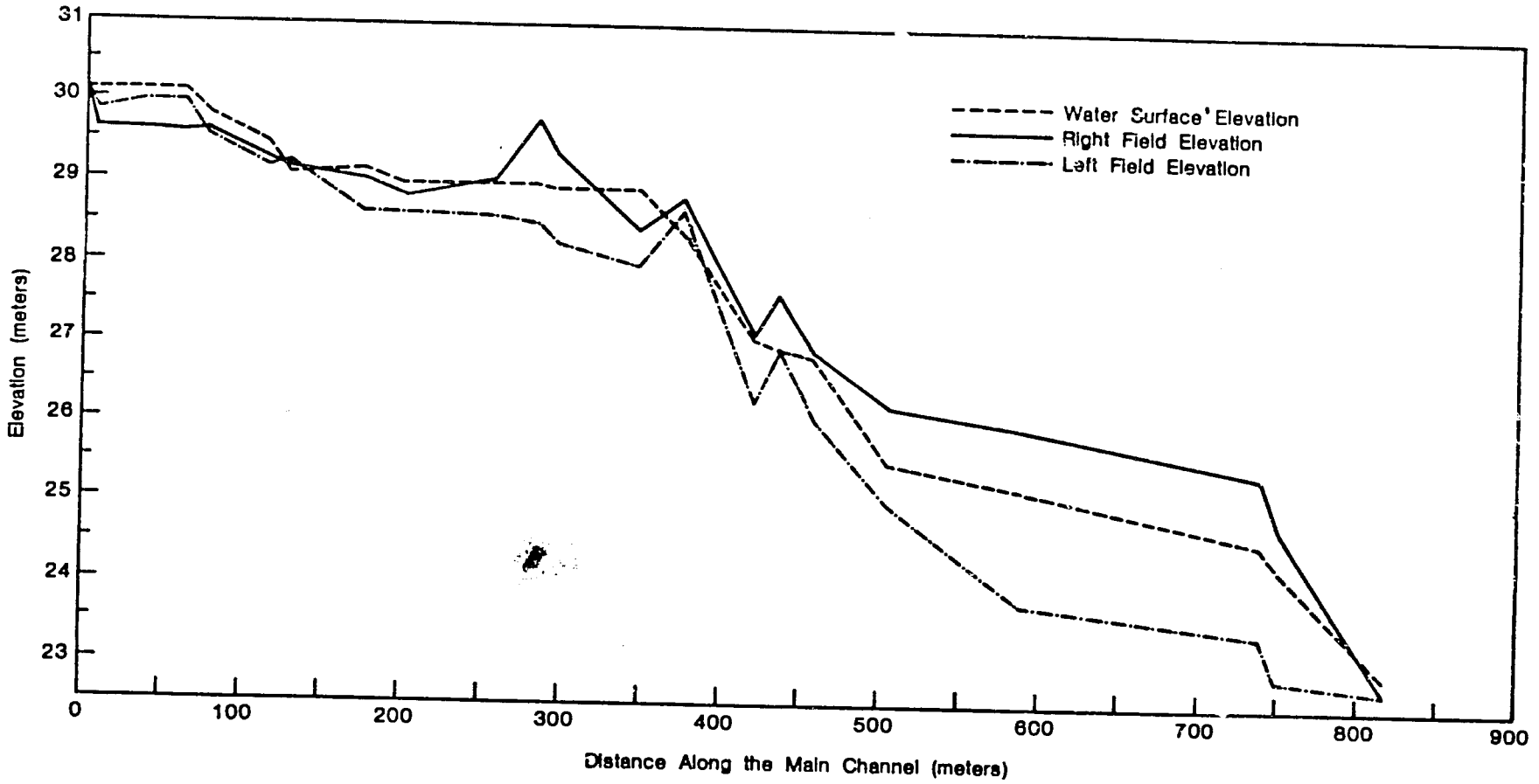


Figure B2. Longitudinal Profiles of the Surveyed Channel at the Mariali Site

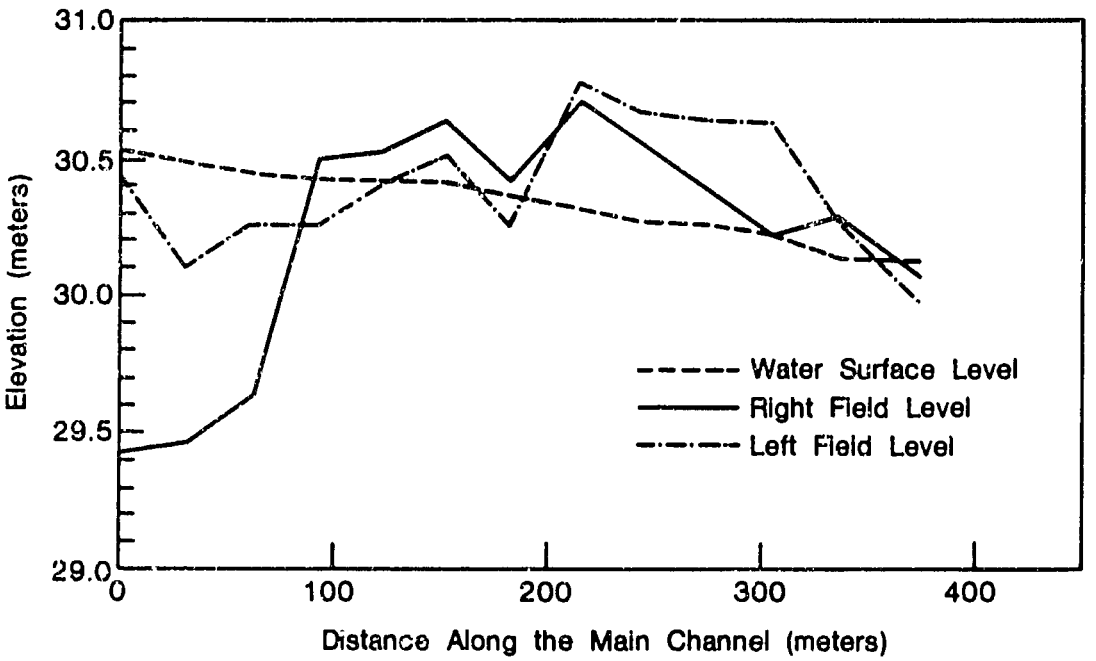


Figure B3. Longitudinal Profiles of the Surveyed Channel at the Porabari Site

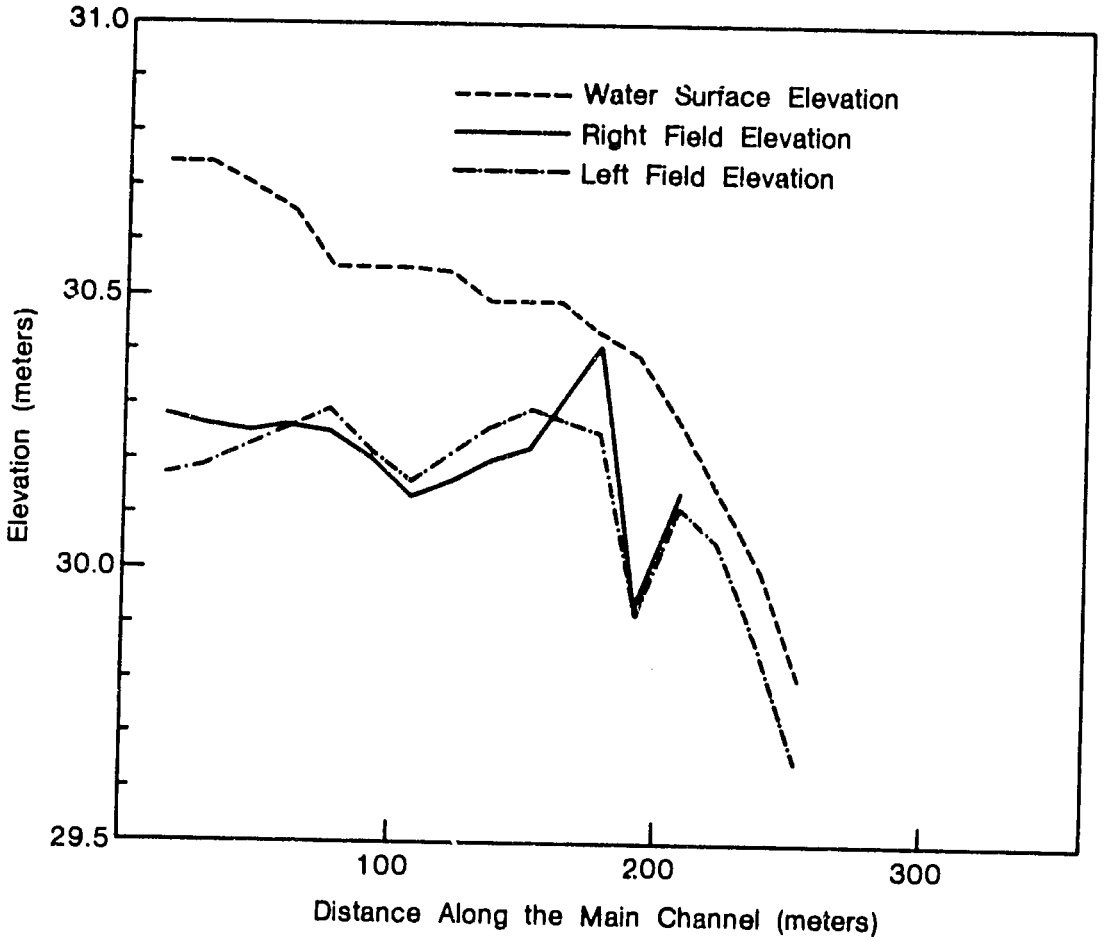


Figure B4. Longitudinal Profiles of the Surveyed Channel at the Jogitola Site

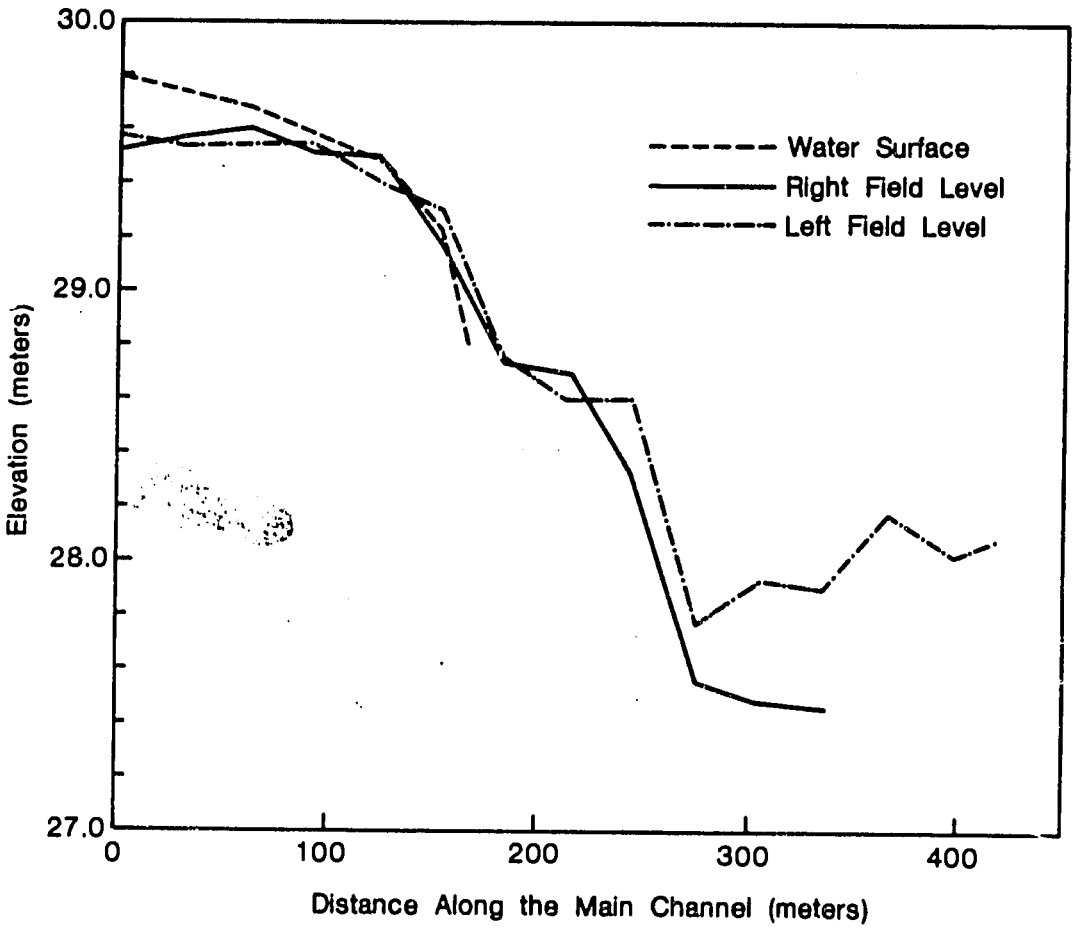


Figure B5. Longitudinal Profiles of the Surveyed Channel at the Itahata Site

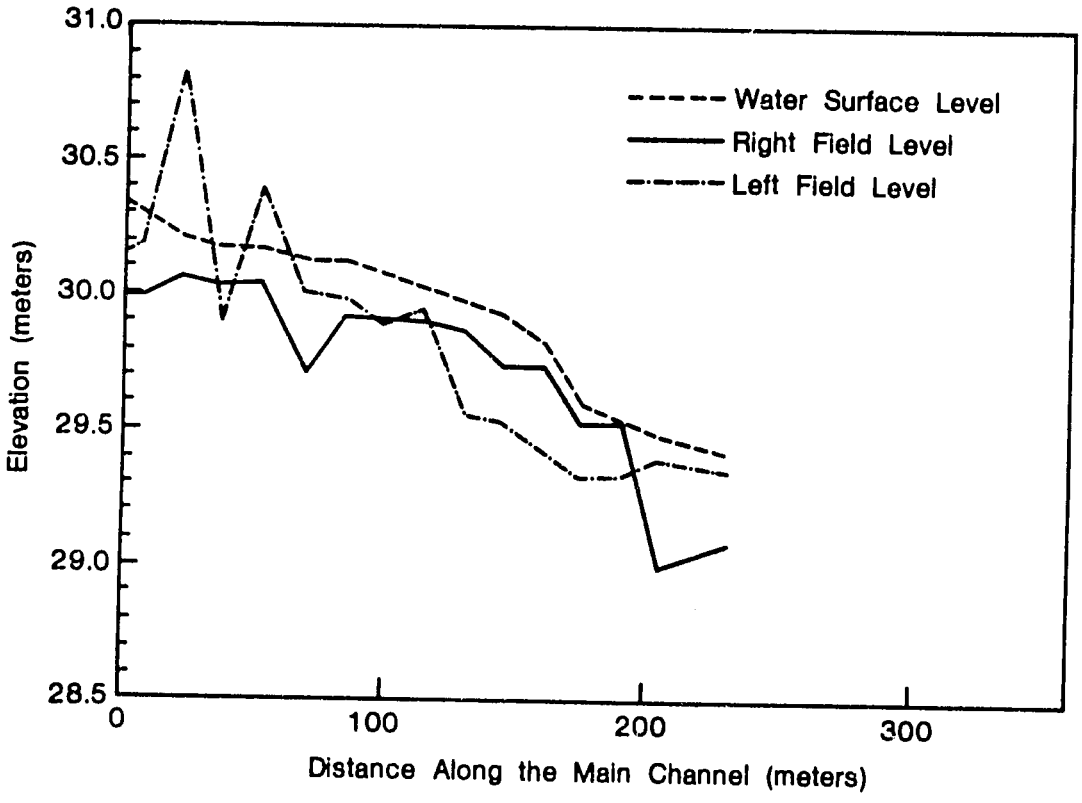


Figure B6. Longitudinal Profiles of the Surveyed Channel at the Teknagapara Site

are provided at suitable points along the channel sections. Currently, no permanent structures exist on any of the five sites studied.

It will be futile to ask the farmers not to check the channel as they cannot irrigate without raising the water level. In the Porabari area, for example, it is necessary to raise the water level for irrigating the lands on the right side of main channel reach over the distance of 91.4 to 335.3 m. For irrigating the lands situated on the left side of the channel, the water level in the channel reach must be raised at 213.36 to 335.21 m from the pump house. Farmers in this area follow the same practices as in the Mariali area. It was observed that overspilling of water from the channel is common in both areas. This loss is substantial, particularly when the farmers are irrigating.

In the other three study sites, namely Itahata, Jogitola, and Teknagapara, water surface elevations are higher than the adjacent field elevations (Figures B4 to B6). The need for raising the water level in the main channel by checking is minimal. Another positive aspect of these three irrigation systems is that their command areas consist of contiguous and compact land blocks. Therefore, the lengths of the main channels and other field channels are smaller as compared to Mariali and Porabari.

b. Alignment of Distribution Channels

The layout of main field channels on the sites maps is shown in Figures B7 to B11. From a topographic point of view, it was observed that the channels frequently and unnecessarily change directions.

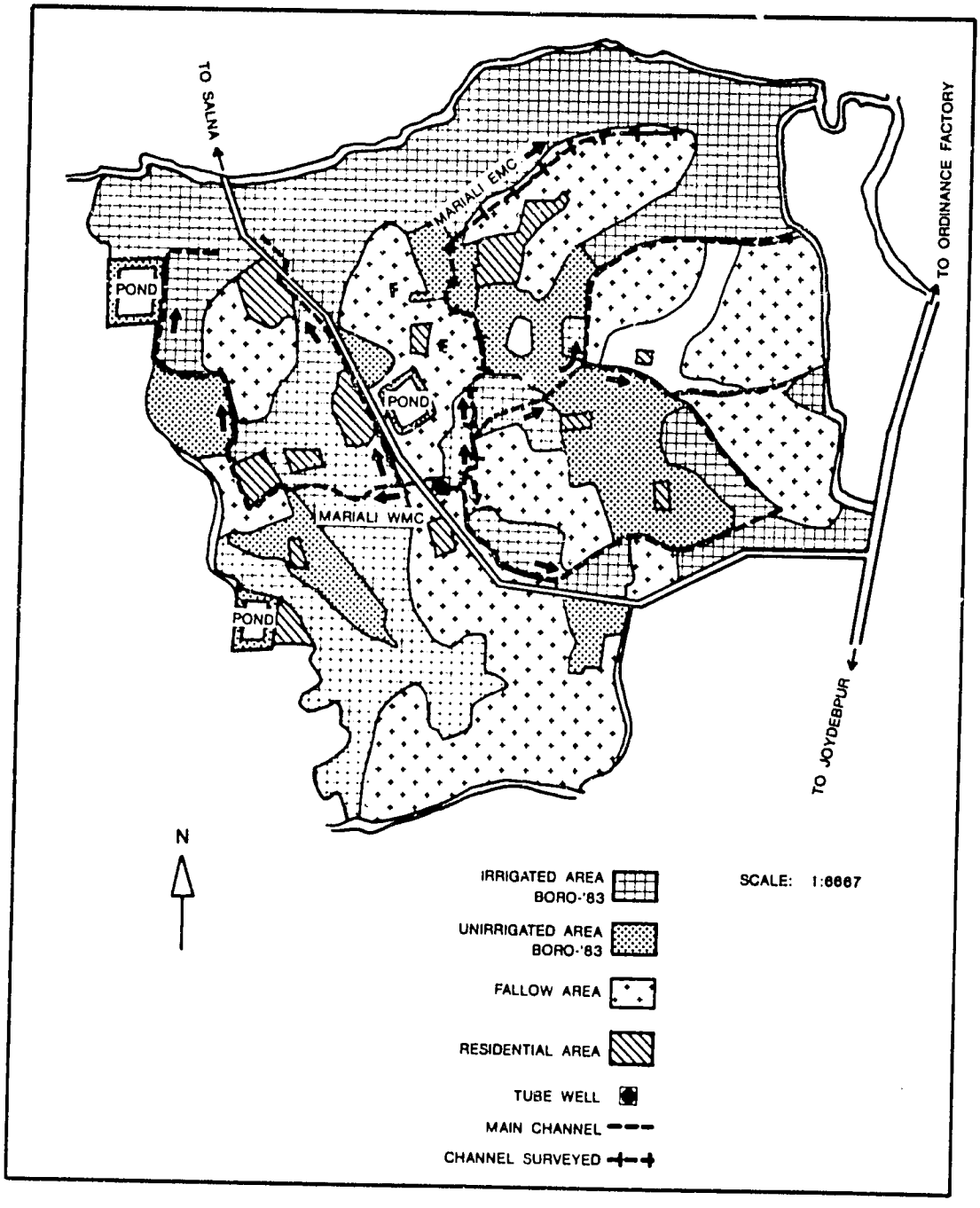


Figure B7. Map of the Mariali Site

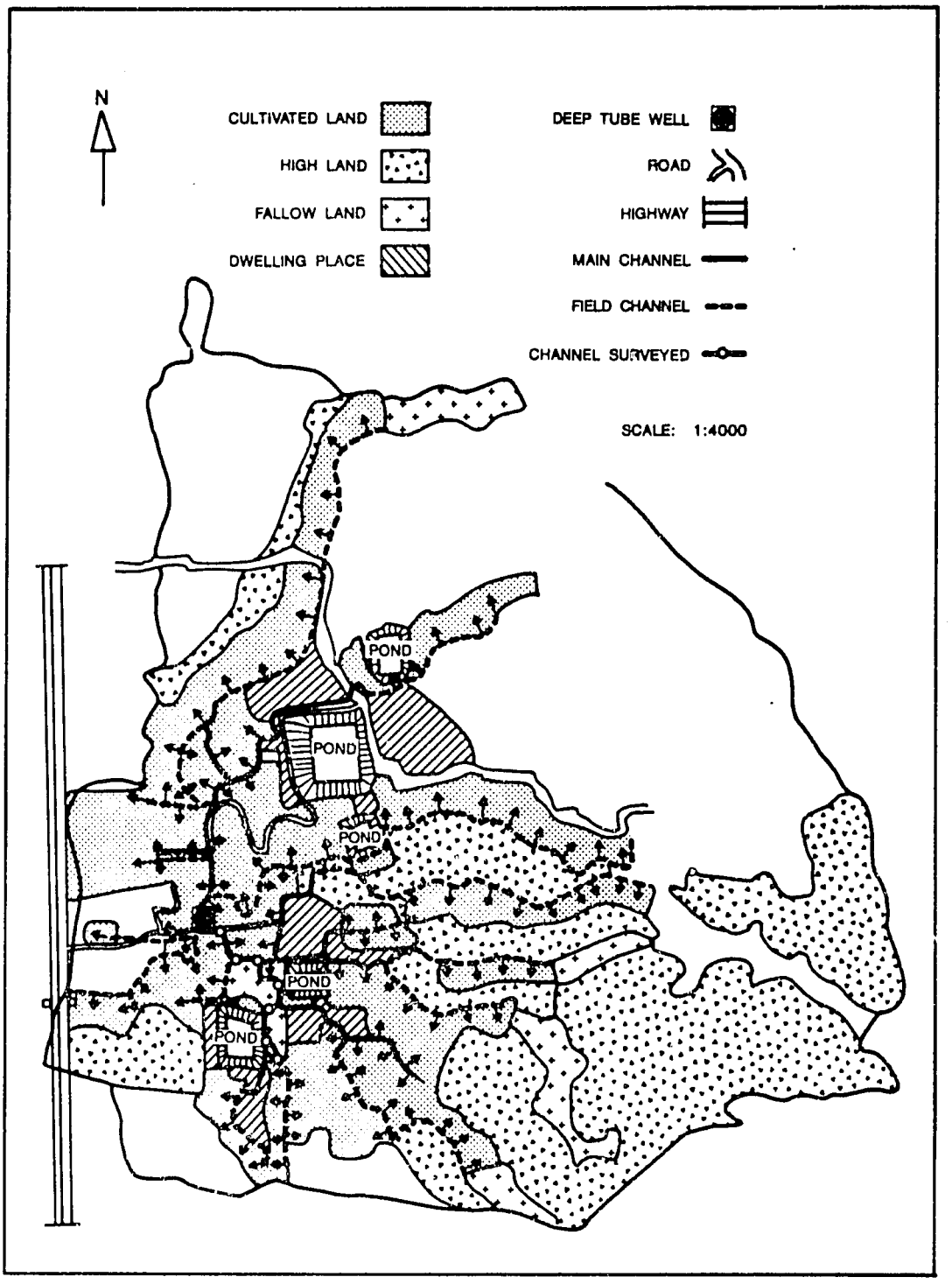


Figure B8. Map of the Porabari Site

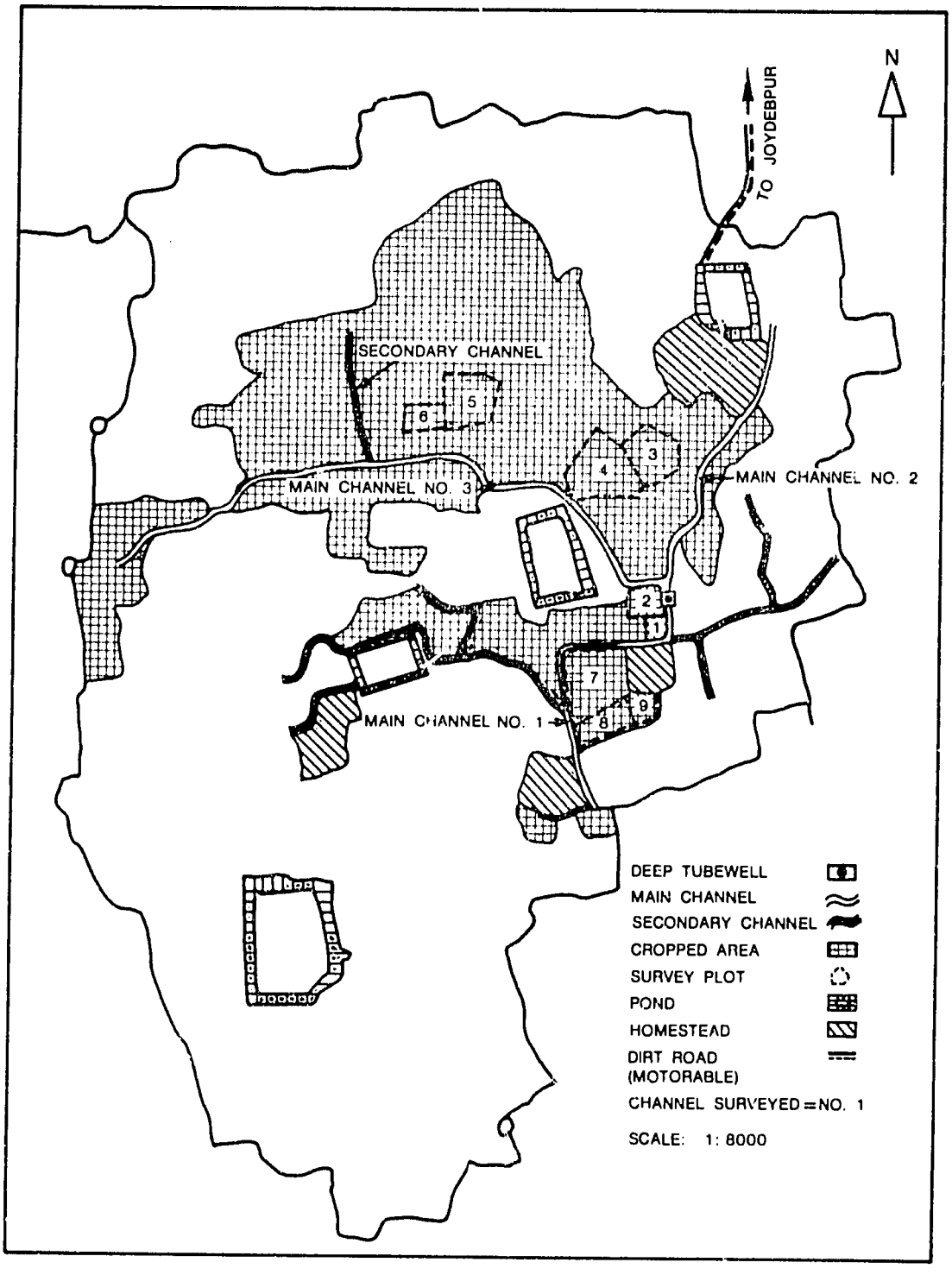


Figure B9. Map of the Jogitola Site

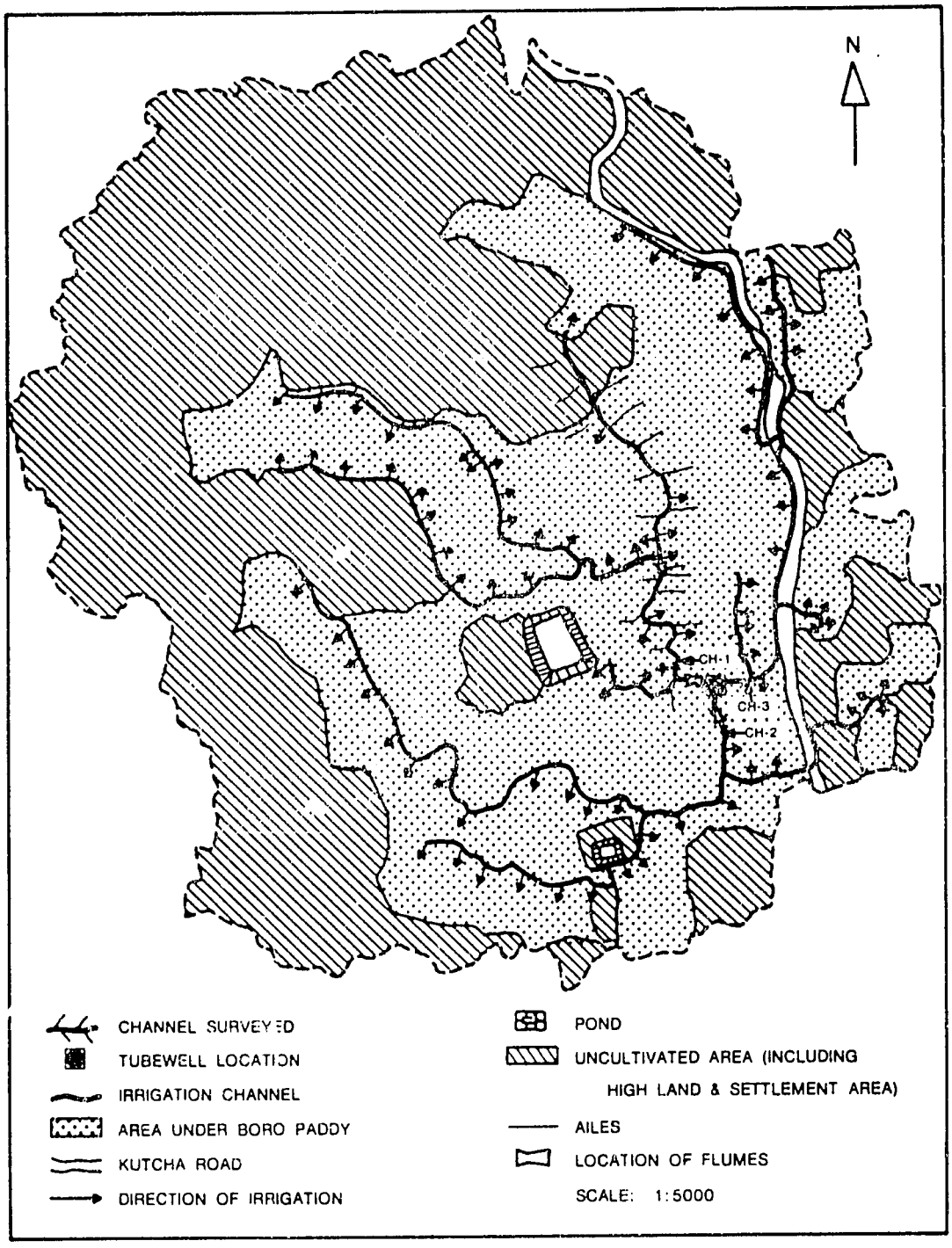


Figure B10. Map of the Itahata Site

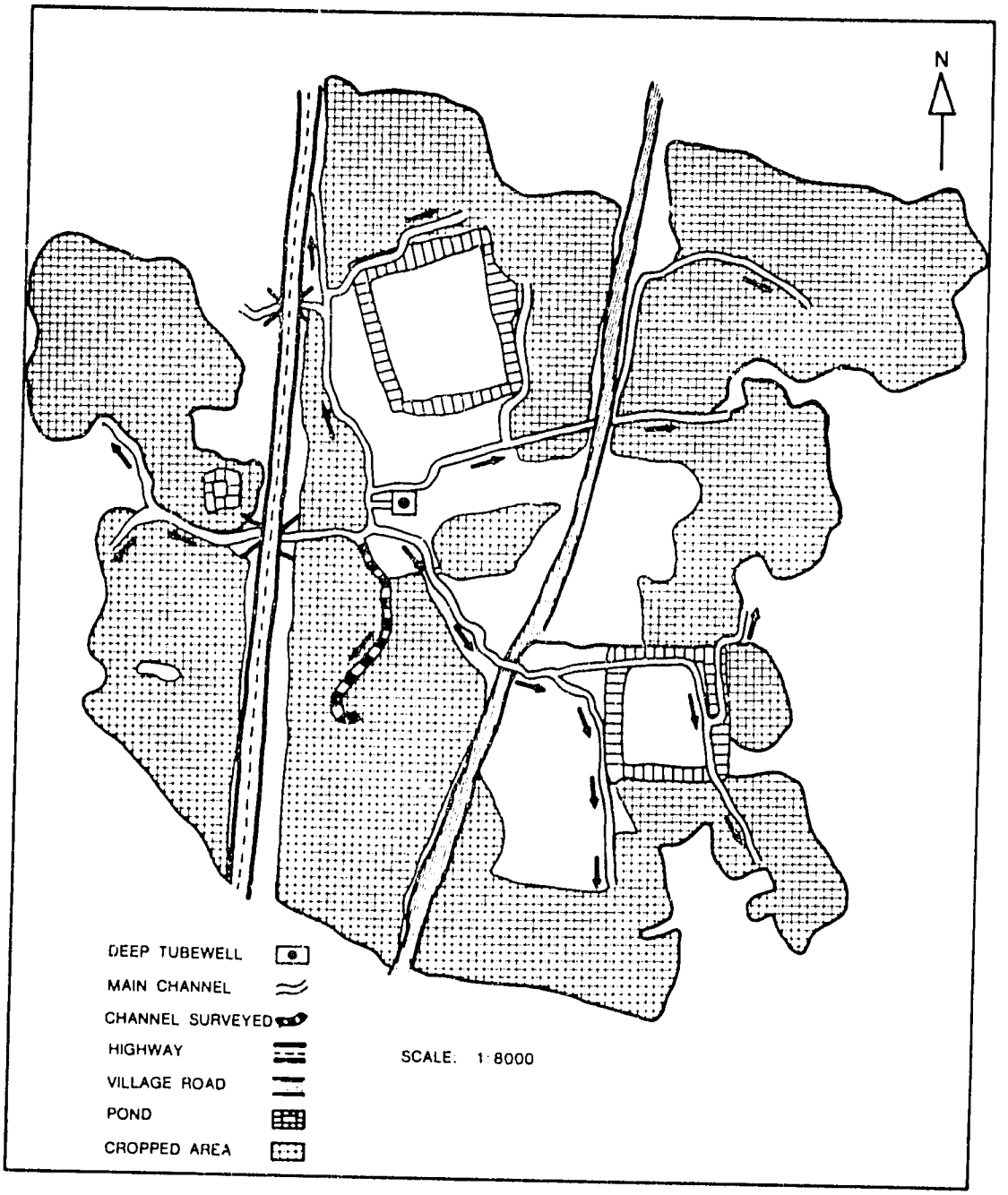


Figure B11. Map of the Teknagapara Site

Consequently, the channels are longer than actually required. Table B5 shows the length of main channels in the five study sites.

Table B5. Length and Density of Main Channels

Study Site	Total length of main channels (meters)	Density of Main Channels (meters/ha)
Mariali	12,472	396
Porabari	1,913	80
Teknagapara	2,590	112
Jogitola	1,070	165
Itahata	1,600	62

The density of main channels, i.e., length of main channels per unit of irrigated command area, was highest in Mariali. The command area of the deep tubewell in Mariali consists of noncontiguous and scattered parcels of lands with residential areas in between. This has necessitated longer channels which meander around the residential areas. One of the reasons for high conveyance losses in this area is due to the greater length of main channels. The topographic situation of Porabari is similar also to Mariali, but the density of main channels is much less than Mariali. The reason is that they have constructed the main channels for shorter lengths and then branched them into many smaller field channels.

Unlike the above two irrigation systems, the Itahata system is very compact. The density of main channels was only 62 m/ha. Although

the main command area of Teknagapara is a compact one, the density of main channels is almost double that of the Itahata area. The reason is that main channels have been constructed through some fallow lands for irrigating a few distant lands. The reason for higher density of main channels in Jogitola is that the lands of an influential landlord are at a considerable distance from the pump.

The channel bed profiles of main channels in five sites are shown in Figures B12 and B13. The profiles show abrupt changes in bed slopes. The channel bed slopes in Mariali for sections between 60.9 to 126.8 m, 347.2 to 457.2 m, 457.2 to 530.6 m, 530.6 to 748.6 m, and 748.6 to 817.2 m were 1.6, 1.9, 1.8, 0.56, and 0.20 percent, respectively (Figure B12). The channel bed slopes of Teknagapara between the section 143.26 to 173.74 m was 1.7 percent (Figure B13).

The bed slopes of main channels in Porabari and Itahata are not so steep as those of Mariali and Teknagapara. The average bed slopes in the Porabari and Itahata sites are 0.45 and 0.68 percent, respectively. All the slopes mentioned above are higher than the standard design value of 0.1 percent for channels on loamy soils (Michael, 1978). The soils of the study sites are clay loam to clay. Flow velocities can be excessive on such steep slopes resulting in the scouring of the bed material. The water level in the channels drop and farmers resort to the practise of checking in order to irrigate their fields.

In order to reduce the steepness of the bed slopes, it is suggested that drop structures be placed at suitable places in the main channel. For example, in Mariali, we suggest at a distance of 347.2 m, 457.2 m, 530.6 m, and 748.6 m from the pump. Otherwise, the portion of

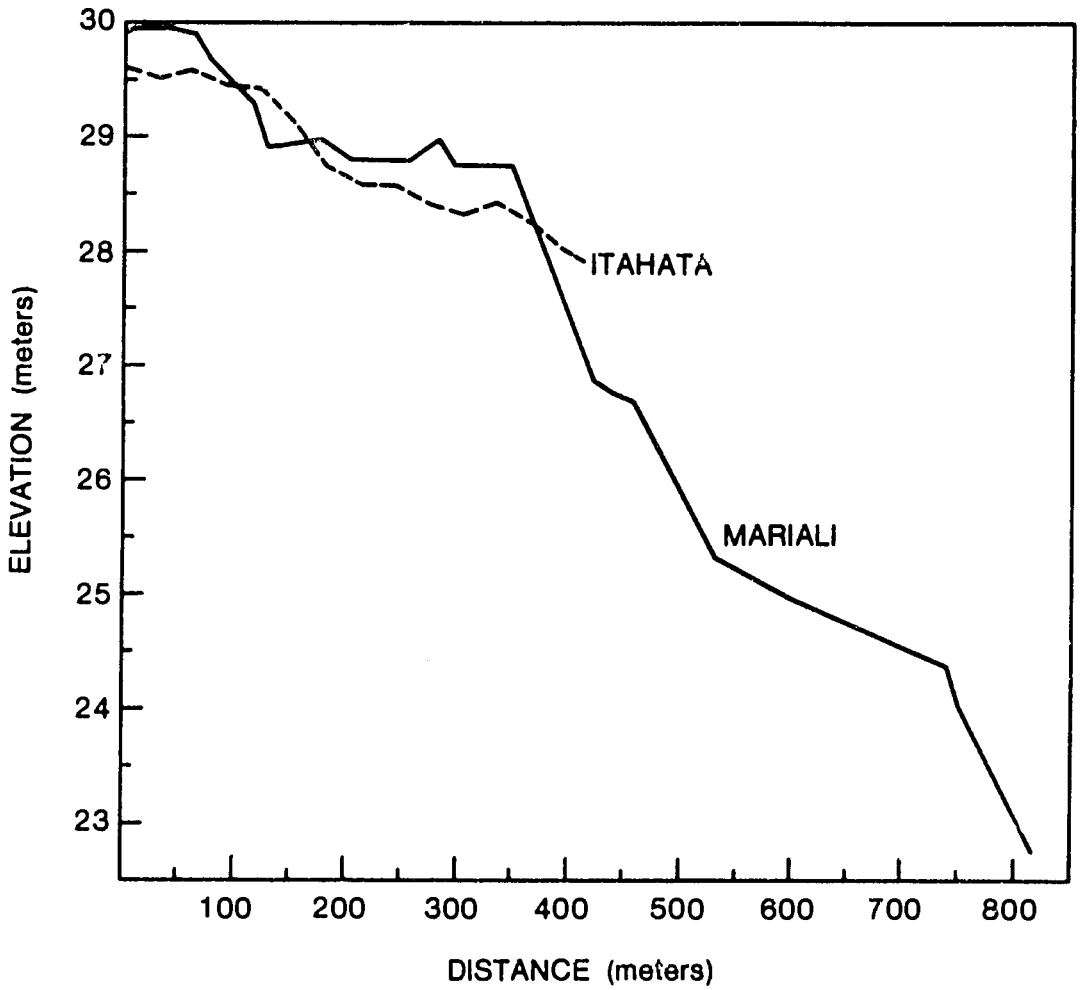


Figure B12. Bed Profiles of the Channels Surveyed at Itahata and Mariali

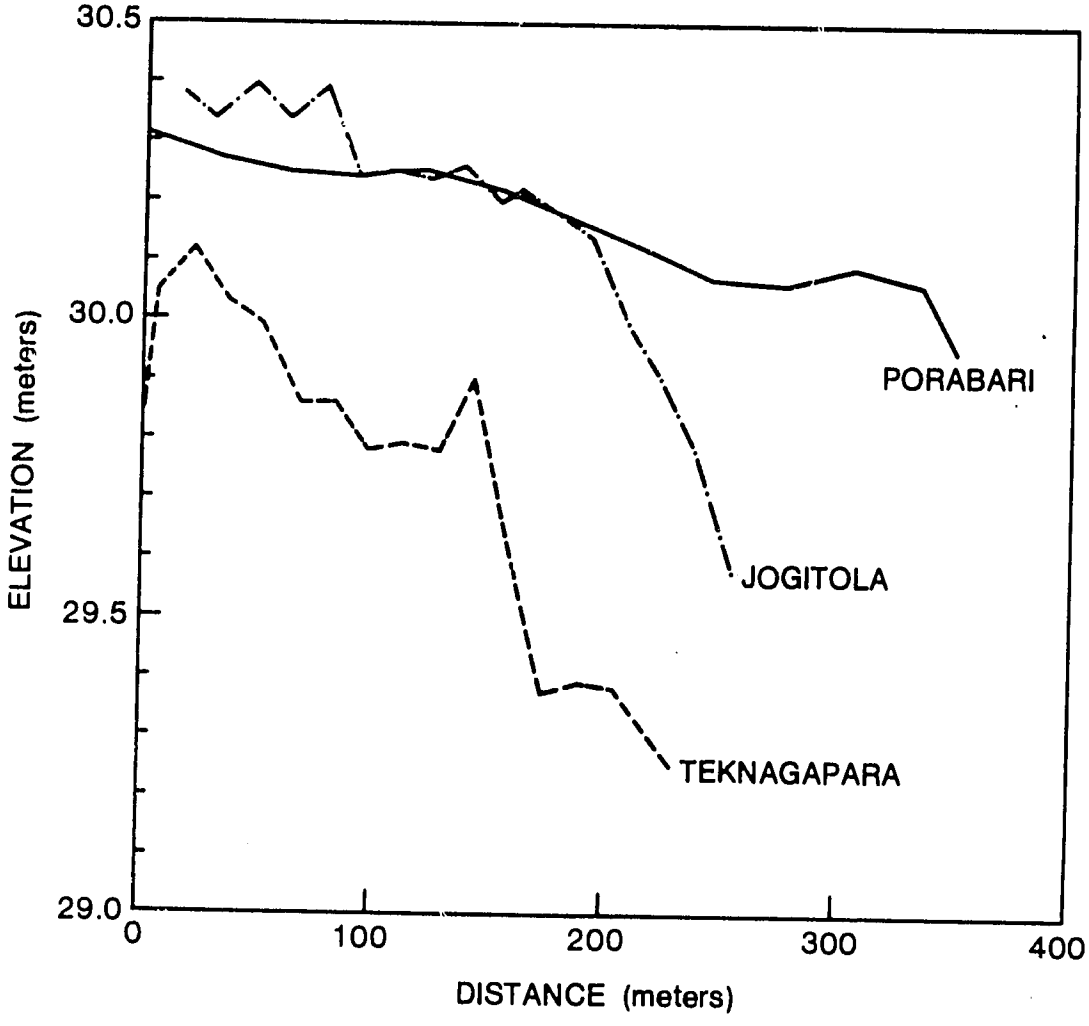


Figure B13. Bed Profiles of the Channels Surveyed at Porabari, Jogitola, and Teknagapara

the channel where the slope is steep can be lined if economically feasible. Similarly, a drop structure could be placed in the Jogitola main channel at a distance of 192.3 m from the pump. In Teknagapara, a drop structure would be required at a distance of 143.2 m from the pump house. However, even with the drop structures, efforts should be made to maintain a uniform bed slope.

c. Conveyance Losses

The conveyance losses from the main channels of the five sites are presented in Table B6. These included losses due to seepage from sides and bottom of the channels and due to overspilling. The losses in Mariali, Porabari, Teknagapara, and Itahata study sites were 2.20, 1.51., 1.71, and 1.31 l/s/100m, respectively. The amount of losses in Jogitola system was 4.01 l/s/100m, the highest among the five study sites. Some reasons for high losses in the Jogitola irrigation system may be as follows:

-- The use of unnecessarily wide channel cross sections increases the amount of seepage loss through the channel bottom and sides since this loss is directly proportional to the perimeter of the channel section.

-- As the command area is very small, the channel frequently remains without flow; therefore, the clay soil develops large cracks in the channel banks due to alternate wetting and drying conditions with a considerable amount of water being lost because of the seepage through these cracks.

Table B6. Conveyance Losses in Irrigation Channels

Study Site	Flow at Section 1 (l/s)	Flow at Section 2 (l/s)	Flow at Section 3 (l/s)	Distance Sections 1 & 2 (m)	Distance Sections 1 & 3 (m)	Loss Between Sections 1 & 2 (l/s/100m)	Loss Between Sections 1 & 3 (l/s/100m)	Percent Loss While Reaching Section 2	Percent Loss While Reaching Section 3
Mariali	35.7	30.9	20.0	218.0	729.4	2.20	2.15	13.4	44.0
Porabari	7.4	5.1	4.5	152.4	350.5	1.51	0.83	31.1	39.2
Jogitola	17.0	11.3	---	142.0	---	4.01	---	33.5	---
Teknagapara	7.1	4.5	---	152.4	---	1.71	---	36.6	---
Itahata	16.8	14.7	---	160.9	---	1.31	---	12.5	---

-- Main channel and other distribution channels are not kept clean of weeds.

-- The ponding of water in the channel due to uneven bottom profile increases the amount of seepage loss.

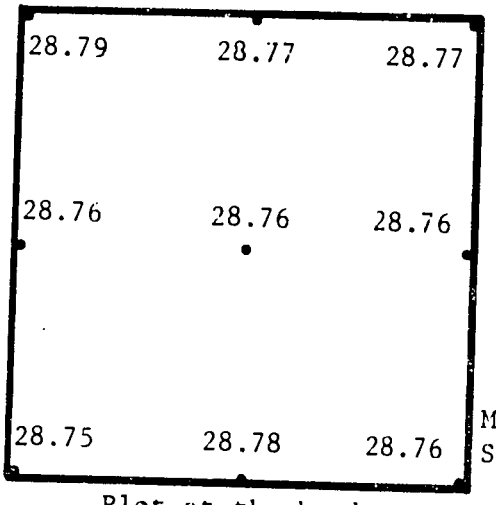
-- The earth in the channel banks is not properly compacted.

It should be mentioned that not all seepage water is a loss, particularly in rice agriculture. Because of the plowpan, the seepage water spreads laterally into adjacent fields. Thus water lost due to seepage in the upper reaches of the main channel becomes available to the fields at the lower reaches of the channel. However, this argument cannot be used to justify excessive water loss due to seepage because hydraulic control over that portion of water is lost. Irrigation water moving in the channel is subject to much more managerial control, a necessary component for an equitable and efficient distribution.

3. Water Application Methods

a. Wild Flooding or Level-Basin Method

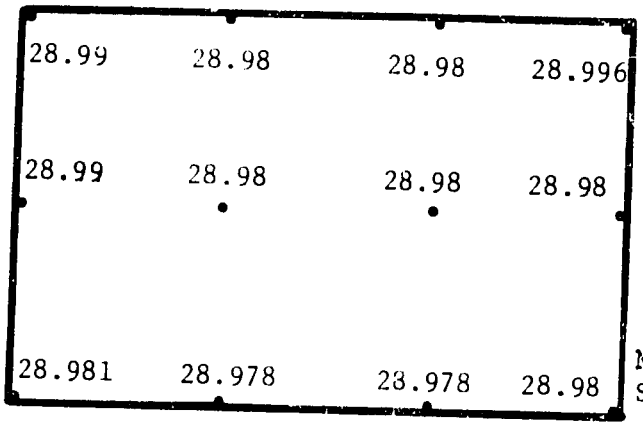
In order to classify the water application methods, the levelness of rice plots was checked using the grid method of sampling. The topographic data gathered are presented in Figures B14 to B18. Maximum deviations in land elevations found in Mariali, Porabari, Teknagapara, Jogitola, and Itahata were 4.0, 4.0, 2.6, 10.7, and 3.0 cm, respectively. The maximum limitations are near the construction levelness criterion of ± 3 cm (USDA Soil Conservation Service, 1961) except for those of the Jogitola site. The sample plots in Jogitola have been divided into smaller land units so that each has a nearly level surface.



Not to Scale

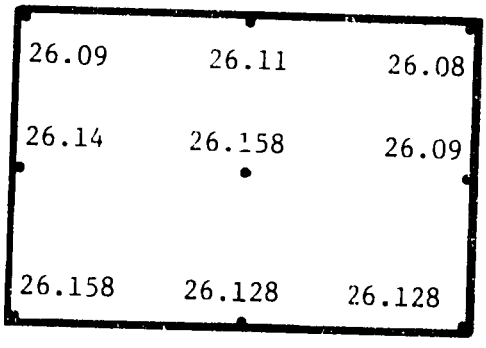
Mean = 28.767
STD = 0.012 m

Plot at the head



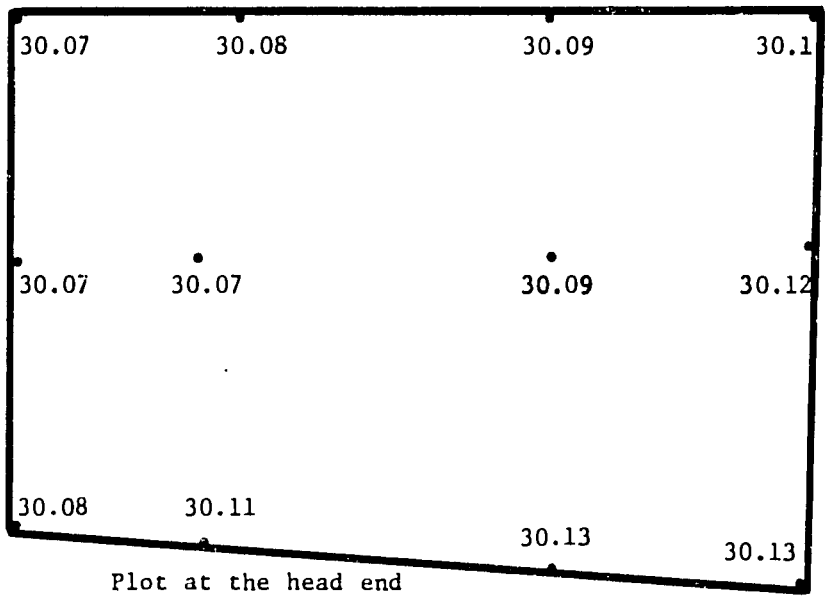
Mean = 28.983 m
STD = 0.006 m

Plot at the middle



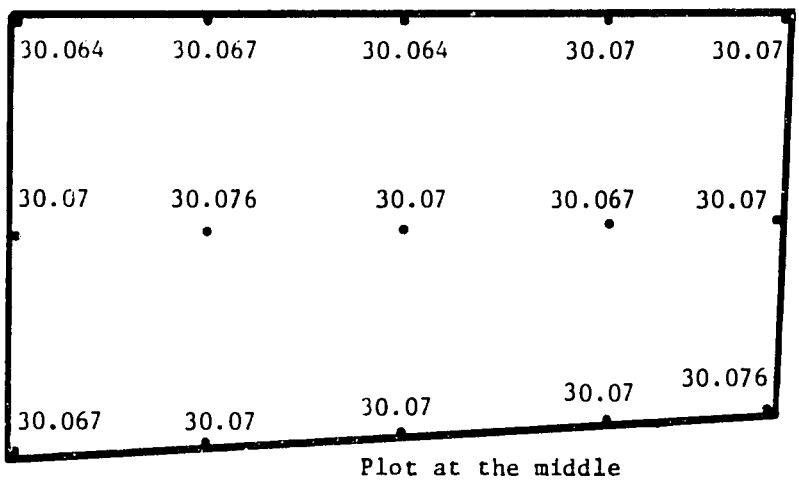
Mean = 26.12 m
STD = 0.028 m

Figure B14. Field Plot Surveys at the Mariali Site



Plot at the head end

Area = 0.051 ha
Mean = 30.095 m
STD = 0.022 m

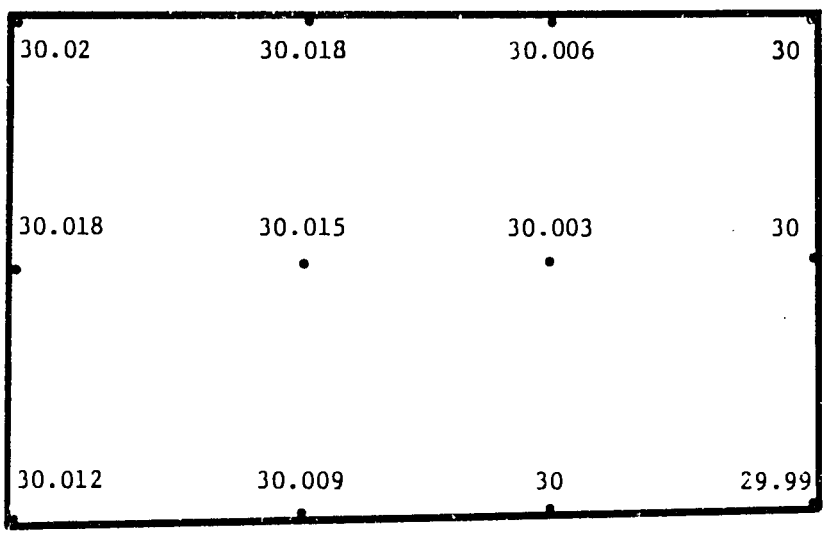


Plot at the middle

Scale:

1 cm = 2.41 m

Area = 0.039 ha
Mean = 30.069 m
STD = 0.003 m



Plot at the tail end

Area = 0.048 ha
Mean = 30.008 m
STD = 0.009 m

Figure B15. Field Plot Surveys at the Porabari Site

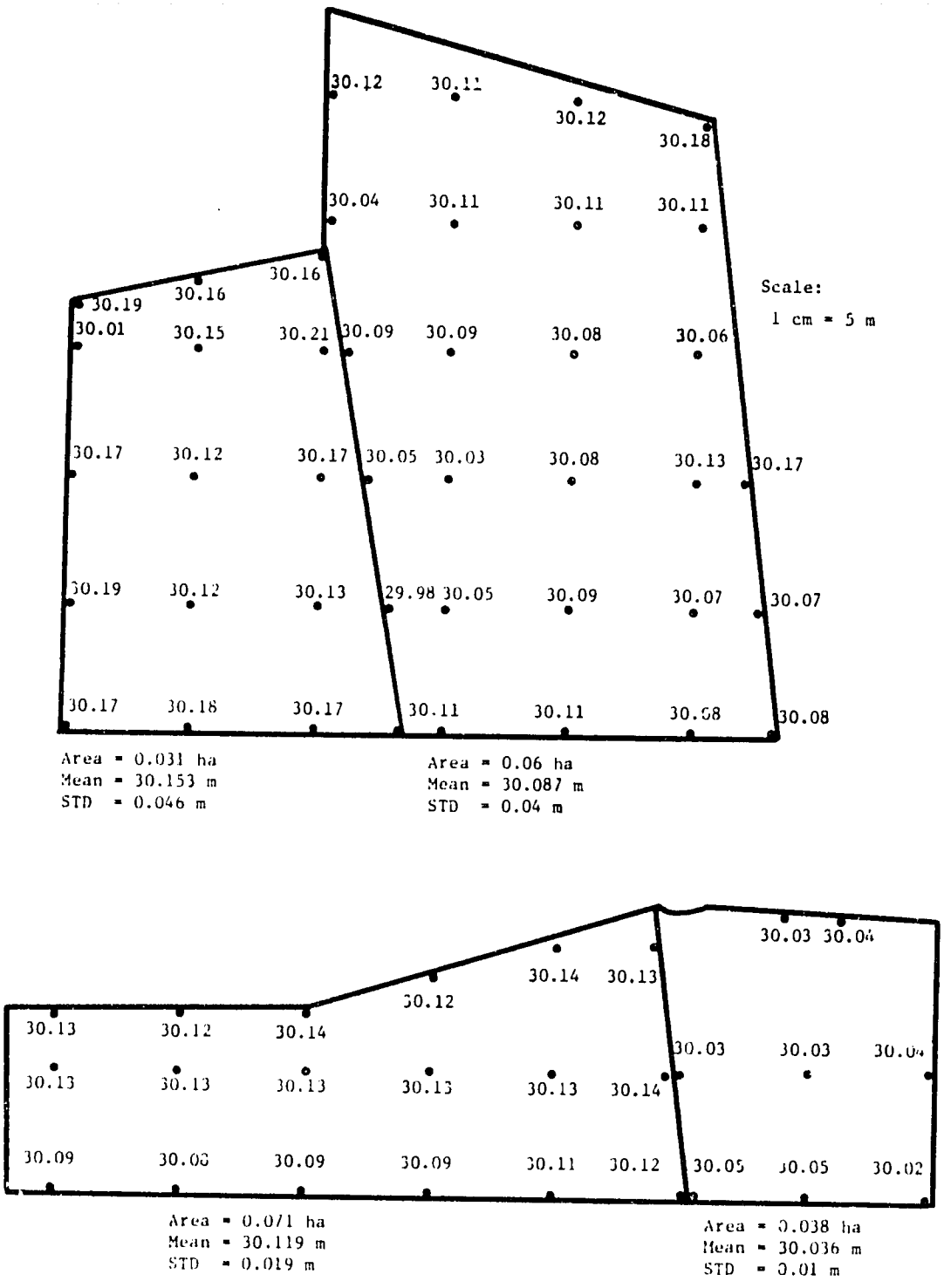
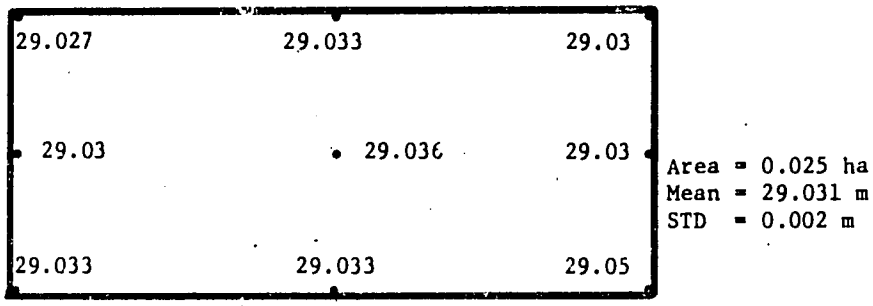
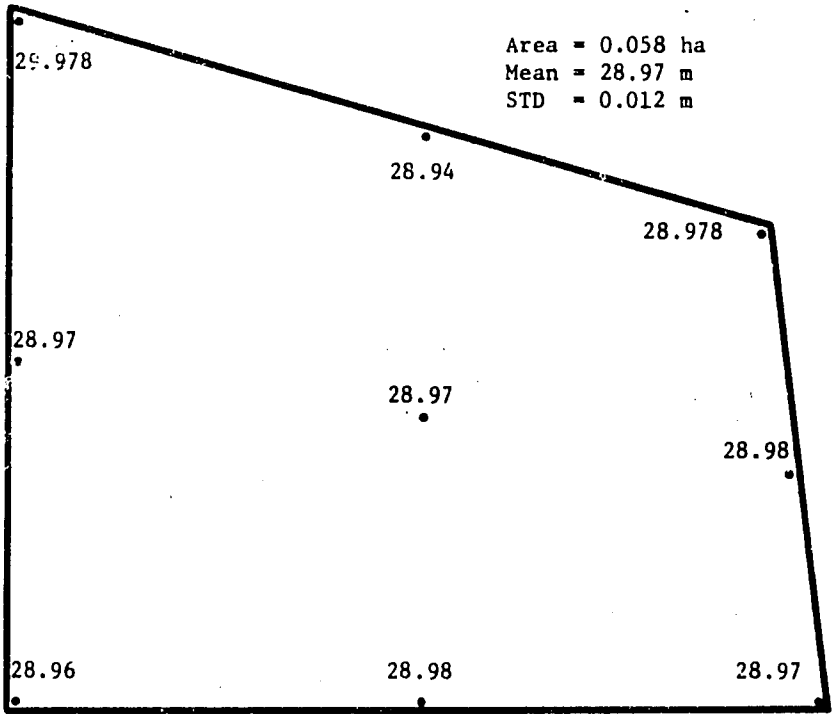


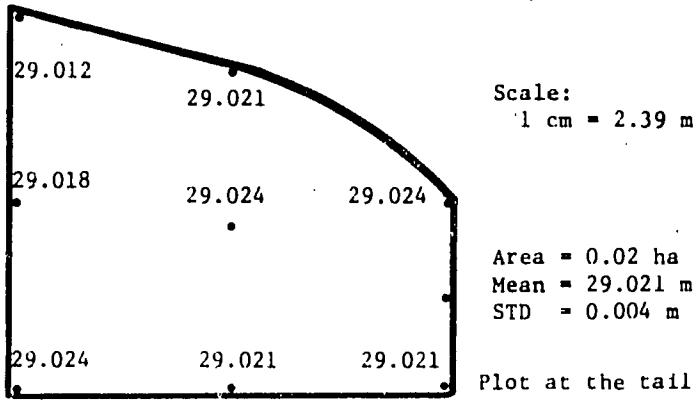
Figure B16. Field Plot Surveys at the Jogitola Site



Plot at the head



Plot at the middle



Plot at the tail

Figure B17. Field Plot Surveys at the Itahata Site

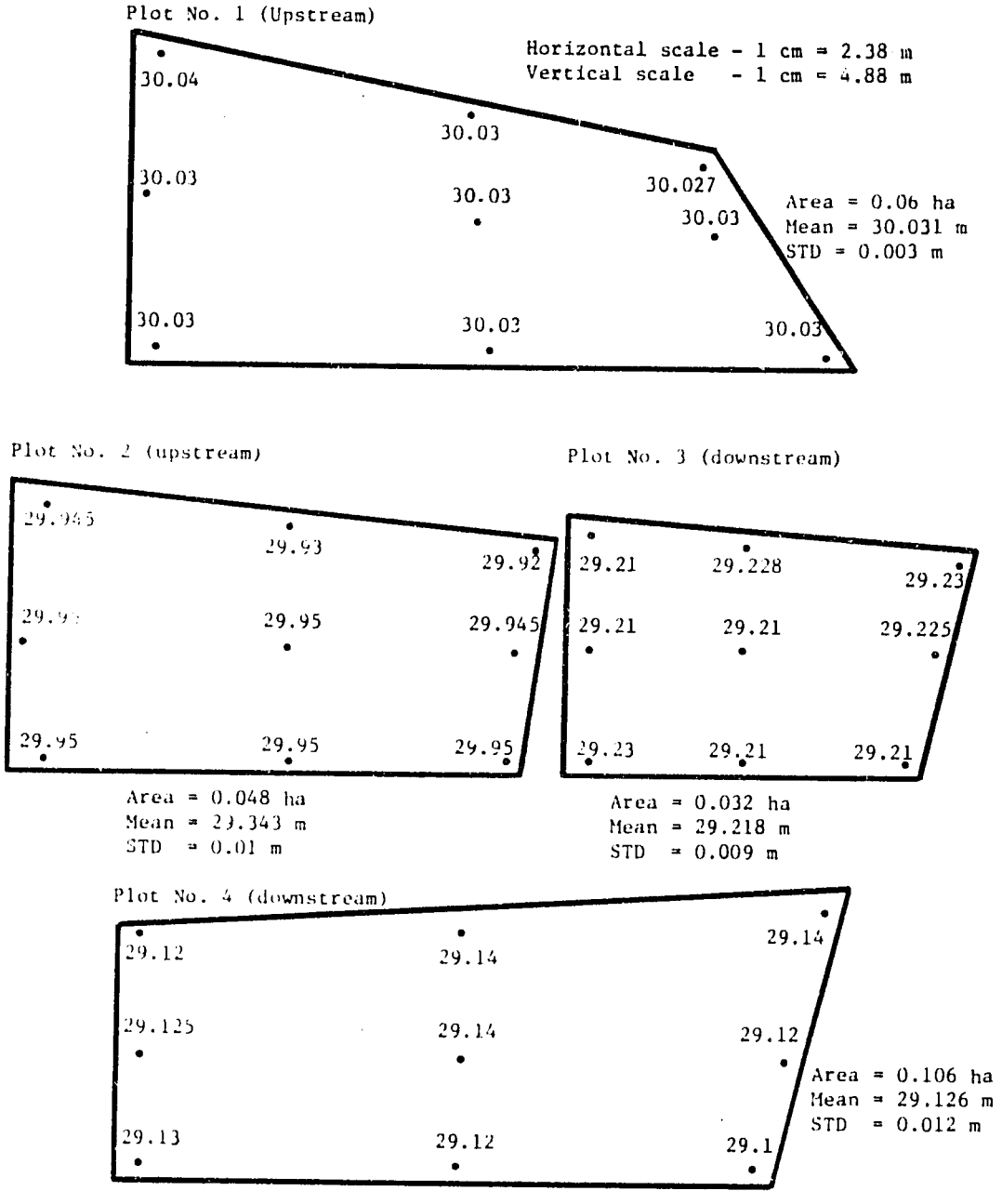


Figure B18. Field Plot Surveys at the Teknagapara Site

It should be noted that other sources have considered a levelness criterion of ± 1.5 cm for level-basin irrigation. For the fields studied, only 50 percent meet this more severe criterion compared to 70 percent which meet the ± 3 cm standard. For this study on rice irrigation, the fields were considered to be relatively well-leveled and the water application system was classified as level-basin irrigation.

Water is conveyed from the main channel to the plots; it is then successively spilled from basin to basin. This form of irrigation is called paddy-to-paddy flow method of irrigation. As there is different ownership of adjacent plots, there is a high potential in such a method for conflict among farmers. Therefore, farmers increasingly are constructing more and more field distribution channels to have direct access to irrigation water. The basins are filled to the desired depth and the water is retained until it either evaporates or infiltrates into the soil.

Farmers in the Joydebpur area usually do not keep the land submerged with water all the time. Rice fields need to be drained periodically for fertilizer application, weeding, and to enhance tillering. Irrigation is therefore on an intermittent basis, a good practice for water conservation. The practice of intermittent irrigation, however, requires more labor for weeding. Farmers reported three to four weedings per growing season; the paddies observed during this study were kept quite clean of weeds.

Farmers in the Joydebpur area seem to be very conscious of the seepage water from channels and try to capture and make good use of it. They build low dikes inside their fields that run parallel to the main

channel. Farmers at the downstream side take this seepage water from the adjacent upstream areas. In this way, they minimized the amount of water lost in their irrigation systems.

b. Water Loss Due to Deep Percolation

Estimates of seepage and deep percolation losses were obtained by subtracting an assumed ET value (5.2 mm/day) from the water level subsidence measurements (ET + S & P). The results are presented in Table B7.

Table B7. Seepage and Deep Percolation Losses

Study Site	(ET + S & P) mm/day	Assumed ET mm/day	S & P mm/day
Mariali	Data not available	----	----
Porabari	7.41	5.2	2.41
Teknagapara	7.40	5.2	2.2
Jogitola	Data not available	----	----
Itahata	6.3	5.2	1.3

Deep percolation losses were measured by the ring infiltrometer and have been reported in Appendix A. It was reported that the losses due to deep percolation of water were approximately 1.5 mm/day. Thus the rate of water loss due to seepage is about 1.0 mm/day except at the Itahata site. This rate of water loss due to deep percolation is very

small if compared to other rice growing countries like Indonesia and Philippines. On Java, Indonesia, seepage and percolation rates are reported to be as high as 6-10 mm/day (Oad, 1982). The high irrigated command area per unit of discharge in the Bangladesh study sites is primarily due to the low seepage and deep percolation losses. Heavy soil texture (clay to clay-loam) and good puddling practices are the main reasons for the low seepage and percolation losses.

4. Summary of Findings

One of the major constraints in increasing irrigated command area of the five deep tubewell sites studied was the low discharge of pumps. The discharges of the tubewells ranged from 28.3 to 37.1 l/s which are much less than their design capacity of 56.6 l/s. Farmers in four of the five study areas are irrigating 0.63 to 0.88 ha/l/s of rice which is equal to or higher than the estimated area of 0.64 ha/l/s. All of the factors affecting the pump discharge were not identified clearly during the training course. However, the possible factors have been discussed in the preceeding section. In addition to pump discharge, we found that all of the deep tubewells were operating at low levels of efficiency ranging from 14.5 to 46.6 percent. The efficiencies of the electrically operated units (39-46 percent) were much higher than the diesel operated units (14-17 percent).

The pumping plants were found to be located at the highest point in the three sites out of the five sites studied. Considerations other than engineering influenced the site selection in the other two areas which have affected the command area.

Differences between the pump settings in the well and pumping water levels were found to be small which is a cause for concern for future water supplies.

Duration of pump operation, another factor affecting the command area, was found to be low (12-14 hours daily). This was due to (1) delay in repairing and maintenance, (2) non-availability of spare parts, (3) uncertain fuel supply, and (4) frequent breakdown in the supply of electricity.

The density of main channels was found to have an influence on the amount of conveyance losses. Maximum density was found in the villages of Mariali (396 m/ha) and Jogitola (165 m/ha). The conveyance losses were 4.01 l/s/100 m in Jogitola and 2.2 l/s/100 m in Mariali. Factors associated with the highest losses in Jogitola have been discussed in the preceeding section.

It was observed that the layout of main channels in some areas was not appropriate. There were frequent and unnecessary changes of direction of the channels which made the channel longer than actually required. Moreover, there were abrupt changes in bed slopes of the channels. The slopes also were much higher than the standard design value in some reaches of the same channel. The farmers did not place any water regulatory structures at the head of steep slopes for control of water.

Minimum channel density, uniform bed slopes, and the presence of structures are suggested to provide some measure of water control not only on a system wide basis, but also at the farm level.

Losses due to seepage and deep percolation were found to be low in the study area. The high command area per unit of discharge was primarily due to the low seepage and deep percolation losses.

In conclusion, the lower than designed pump discharge is the most significant factor causing reduced command area. However, the water available is used efficiently for rice production by the farmers. The soils and topography of the area allow movement of water from paddy to paddy which contributes to the high command area per unit of pump discharge.

C. Economics

1. Cropping Pattern and Intensity

Rice was the only crop produced in the Aus and Aman seasons and in the irrigated plots in the Boro, i.e., dry season (December-May), in the five tubewell sites studied. In small, nonirrigated sections of the command area, vegetables such as tomatoes, chilies, and potatoes were grown during the Boro season. Aus rice was grown from April to August, and Aman rice was grown from August to December. Aus and Aman rice crops depend mainly on rainfall. Low rainfall from December to March is the major constraint in production of winter crops. As mentioned above, Boro rice is grown under deep tubewell irrigation in the five study sites. The transplanting of Boro rice begins around mid-December and continues over a two-month period. About 15 percent of the area is transplanted between December 15 and January 15; 69 percent between January 16 and February 15; and, the remaining 16 percent between February 16 and March 7.

The most dominant cropping pattern was fallow-local-HYV, constituting about 34 percent of total cultivated land. The second most common cropping pattern, practiced in 23 percent of the area, was local-local-HYV. Fifty-two percent of the land in Mariali and Porabari was under the first pattern and 67 percent of the land in Itahata was under the second pattern (Table C1). Fallow-HYV-HYV was the third major cropping pattern practiced in eight percent of the area. Local rice

varieties were produced in eight percent of the area in the Boro season. Farmers' consumption preferences and higher prices for certain local varieties are viewed as the rationale for the production of low yielding local varieties in the Boro season.

Table C1. Cropping Pattern and Yield by Study Site, 1982-83

Cropping Pattern	Percent of Total Area					Average All Sites
	Mariali	Porabari	Jogitola	Itahata	Teknagapara	
Aus - Aman - Boro						
Fallow-Local-HYV	52	52	3	10	29	34
Local-Local-HYV	0	25	41	67	0	23
Fallow-HYV-HYV	3	1	0	3	34	9
Fallow-Local-Local	5	18	0	0	1	6
HYV-Local-HYV	4	0	2	6	8	4
Local-Local-Local	0	0	2	4	4	2
Local-Local-Fallow	0	0	46	4	8	5
Others	36	4	6	6	16	17

The introduction of tubewell irrigation has led to a major shift from traditional varieties to high yielding varieties. The cropping pattern has been shifting from local-local-fallow to fallow-local-HYV. This shift has resulted in greater output per acre of land. It should be noted, however, that approximately 49 percent of the land has become fallow in Aus season.

The pattern local-local-fallow accounts for 5 percent of irrigable land as an average for all five sites. However, this figure results from the high 46 percent pattern found for the surveyed farms at the Jogitola site. Breakdown in tubewell organization of farmers at this site led to a decline in irrigated command area from 22.7 ha in 1982 to 6.5 ha in the 1983 Boro season.

In Teknagapara, about eight percent of the land which was cultivated the last dry season was kept fallow this season. About 1 ha of land at the Mariali site (not included in the survey sample) was removed from cultivation in 1983. The parcels of land that were kept fallow were mostly of higher elevations relative to adjacent fields. Difficulty of maintaining standing water, high cost of weeding, higher fertilizer requirement, and lower yield compared to other fields were cited by farmers as reasons for not cultivating these parcels. Increased cost of irrigation because of increased pump rent charged by BADC and higher energy cost may have further lowered the profitability of these land parcels.

Cropping intensity ranged from 224 to 287 percent among the five study sites. Itahata tubewell site, which produced its first Boro crop in 1983, had the highest cropping intensity. However, if the Boro crop partially replaces the production of rice crop in one Aus season (as has occurred in the other sites), the cropping intensity in Itahata may decline in the next crop year (Table C2).

Table C2. Average Sample Farm Size, Average Cropped Area, and Cropping Intensity by Study Site

Study Site	Average Farm Size (ha)	Average Cropped Area* (ha)	Cropping Intensity
Mariali	0.59	1.32	224
Porabari	0.65	1.61	248
Jogitola	0.45	1.03	229
Itahata	0.83	2.38	287
Teknagapara	0.56	1.32	236

*Cropped area = area cropped over a twelve month period.

2. Purchased Inputs

Inputs purchased for production of Boro rice included seed or seedlings, chemical fertilizers, and insecticides. Seventy-eight percent of total area cultivated under the five tubewell sites in the Boro season was planted with high yielding seed varieties, predominantly BR-3, BR-8, and BR-9. Seed or seedlings were purchased by only 13 percent of surveyed farmers. The other 87 percent of farmers used their own seed from previous Boro season crops.

Urea, triple super phosphate, and muriate of potash are the three major types of fertilizer applied to Boro rice. On the average, farmers at the Porabari site made the highest investment Tk 1,423/ha (24 Tk = 1 US $) in fertilizer, followed by farmers in the Mariali site with a fertilizer investment of Tk 1,413/ha. Farmers in the Itahata

deep tubewell command area reported the lowest expenditure for the five sites studied (Tk 1,111/ha) (Table C3).

As an average for all five study sites, 56 kilograms (kg) of urea was applied as basal dose per hectare with an additional 150 kg applied in the two subsequent top dressings. The average per hectare application of triple super phosphate and muriate of potash was 100 kg and 44 kg, respectively. Investment in fertilizers on the average was Tk 1300/ha, or 32 percent of total cash expenses.

Fertilizers were purchased from village market dealers. Farmers in the CARE tubewell sites (Mariali) used purchase vouchers obtained as part of loan from BKB to pay for fertilizer. Such purchases were obtained from specified dealers. Purchase price of urea was Tk 3.88/kg; triple super phosphate, Tk 3.74/kg; and muriate of potash, Tk 3.04/kg.

Sixty percent of the surveyed farmers had applied insecticides. The insecticides used included Diazonon, Basudin, Dimacron, Melathion, and Furadan. On an average, 3 kg/ha of insecticides were applied. The average price of insecticides purchased was Tk 60/kg.

3. Labor Utilization

Production of 1 ha of Boro rice on the average required 135 man days of labor ranging from land preparation to drying and storing activities. Weed control was the highest labor intensive activity followed by transplanting operations. Approximately 60 percent of labor for these two activities were hired.

Post harvest operations involved a nearly equal participation by men and women; all other activities were carried out predominantly by

Table C3. Application of Fertilizers and Insecticides and Costs Per Hectare by Study Site*

Study Site	Fertilizers Applied			Total Fertilizer Cost (Tk)	Insecticides	
	Urea	T.S.P.**	M.P.***		Amount (kg)	Cost (Tk)
	- - - - (kg) - - - -					
Mariali	216	105	60	1,413.38	6	360.00
Porabari	206	131	44	1,422.98	3	180.00
Jogitola	234	70	50	1,321.72	2	120.00
Itahata	186	87	21	1,110.90	1	60.00
Teknagapara	187	107	45	1,262.54	3	180.00
Average All Sites	206	100	44	1,306.30	3	180.00

*Costs Exclusive of Government Subsidy
**T.S.P. = Triple Super Phosphate
***M.P. = Muriate of Potash

men. Land preparation activities of plowing and laddering, application of fertilizer, pest control, and post harvest operations were primarily carried out by family labor.

Hired labor was paid an average wage of Tk 19 per day for transplanting and weeding operations, and Tk 18 per day for most other operations. When computing a wage rate for family labor equal to hired labor, the total labor cost for rice production was Tk 2,572/ha or 35 percent of total production cost (Table C4).

4. Credit

The production of irrigated Boro rice requires a higher amount of cash investment than does the Aus or Aman rice crop. This is due to the irrigation expenses, higher fertilizer costs, and hired labor requirements. Of the total 69 farmers interviewed in the five tubewell study sites only 36 percent had obtained credit. Nine percent of the farmers obtained credit in the form of cash; nine percent obtained credit in kind, mostly fertilizers; and, another 18 percent of farmers obtained credit both in cash and in kind. It is noteworthy that 86 percent of farmers in Mariali site, which is under DTICP, a joint venture of CARE, BKB, and BADC, had obtained credit. However, 64 to 80 percent of the farmers in the other three sites did not obtain credit. Of the farmers surveyed in the Itahata site, none had obtained credit (Table C5).

Table C4. Labor Requirement and Cost per Hectare of Boro Rice by Operation

Operations	Labor Required (man days)	Percent Hired	Percent Family	Total Labor Cost (Tk)
Plowing & Laddering	25	8	92	425.00
Uprooting & Transplanting	33	61	39	635.00
Fertilizer Applications	2	27	73	29.00
Weed Control	42	60	40	798.00
Pest Control	1	20	80	22.00
Harvesting & Threshing	15	47	53	263.00
Winnowing, Drying & Storing	17	29	71	400.00
TOTAL	135			2,572.00

Table C5. Percent of Farmers Obtaining Credit for 1983 Boro Rice Crop

Credit Obtained	Percent of Farmers By Site					Average All Sites
	Mariali	Porabari	Jogitola	Itahata	Teknagapara	
Cash	--	9	29	--	7	9
In Kind	43	--	--	--	--	9
Cash and In Kind	43	27	7	--	13	18
Did not Obtain Credit	14	64	64	100	80	64

As indicated in Table C6, of the 45 farmers who did not obtain credit, 47 percent indicated that credit was not needed. Cumbersome procedures and difficulty of obtaining credit in time were cited by 41 percent of this group as reasons for not obtaining credit. Only four percent of farmers indicated high cost of borrowing as a constraint for borrowing.

Table C6. Factors Affecting Borrowing

Reasons for Not Obtaining Credit	Percent of Farmers
Credit was not needed	47
Cumbersome procedure and difficulty in obtaining credit in time	41
Difficulty with loan repayment	8
High cost of borrowing	4

The case of the Mariali site illustrates that farmers will make use of credit when it is readily available and the borrowing procedure is facilitated by good organizational structure. Mariali farmers are provided with credit, at the interest rate of 13 percent through BKB. The individual farmer can obtain a cash loan of Tk 2,470/ha of land, with a maximum of Tk 2,000 per farmer. Farmers also can obtain fertilizer from selected dealers at the government rate; the dealers are paid by the BKB upon completion of the distribution. The cost of fuel and oil, salaries for the manager, pump operator, and chowkidar, pump rent, and other tubewell operation and maintenance expenses also are

paid by the BKB. At the end of the season, BKB divides the total expenses among farmers on the basis of their respective land area cultivated within the tubewell command area. The individual loans are repaid to BKB after the harvest with CARE assisting in the loan collection process.

5. Crop Output and Value

The output of rice grain and rice straw for the detailed survey plot is based on 1982 Boro rice production for four of the five study sites not including Itahata. Yield data for the Itahata tubewell site, which started operation only in 1983 reflects farmers' expectations. The Mariali tubewell site had achieved the highest rice yield of 5302 kg/ha; Porabari had the lowest yield at 4171 kg/ha. The average rice yield for all five study sites was 4,900 kg/ha compared to a national average of 3,500 kg/ha (Tables C11-C15).

The average price received by farmers for Boro rice in 1982 was Tk 3.50/kg. The price varied between Tk 2.40 and Tk 4.80/kg based on the quality of rice and time of marketing. Rice straw is predominantly consumed on the farm as livestock feed. The average price of straw quoted by farmers was Tk 0.29/kg.

6. Irrigation Cost

The irrigation cost incurred for the tubewell consists of rent, diesel or electricity cost, maintenance, and operator's salary. Four of the five tubewells studied are owned by BADC which charged an annual rent of Tk 3,500 in 1983. Tubewell rent was Tk 1,800 per year in 1981

and 1982. Deep tubewells received a government subsidy of 65 percent in 1981 (Khan, 1983).

Two of the five tubewells studied (Mariali and Porabari) are electric. The energy component of irrigation cost was considerably lower for the electric pump than for diesel. Maintenance cost which ranged from Tk 896 to Tk 4,524 for the five tubewells included the cost of lubricants, oil, and spare parts. The pumps are repaired by BADC engineers free of charge. The spare parts supplied by BADC also are subsidized (Table C7).

The Itahata tubewell was installed by BADC in 1982 and was first used for the 1983 Boro season. This pump was purchased by the farmers rather than rented. A group of 11 farmers formed a committee and jointly contributed Tk 20,000 as a down payment. The balance of the Tk 60,000 purchase price was paid by a loan from BKB at an interest rate of 13 percent. The loan was amortized over a five-year period to be paid in 10 installments. A total cost of Tk 39,500 was estimated for 1983 Boro season and an irrigation cost of Tk 1,525/ha was assessed.

Irrigation cost incurred per hectare varied from a low of Tk 818 in Mariali to a high of Tk 2,145 in Jogitola. The low per hectare cost of irrigation achieved in Mariali site was because of low energy (electricity) cost for operating the pump and the larger command area. When comparing the irrigation cost of Porabari (electric) and Teknagapara (diesel), both having similar command areas, the cost difference between diesel and electric pumps becomes more apparent. As shown in Table C8, the per hectare irrigation cost was Tk 456 less for the electric pump compared to the diesel pump.

Table C7. Comparative Deep Tubewell Cost Estimation Among Five Study Sites

Items	Study Sites				
	Mariali*	Porabari	Jogitola**	Itahata***	Teknagapara
Command Area (hectare)	31.51	23.98	6.48	25.91	23.21
DTW Rent to BADC (Tk)	3,500.00	3,500.00	3,500.00	---	3,500.00
Maintenance Cost (Tk)	1,200.00	4,524.00	896.00	---	4,200.00
Fuel Cost (Tk)	15,075.00	10,200.00	---	---	21,140.00
Operator's Payment (Tk)	6,000.00	2,500.00	---	---	1,800.00
Total Cost (Tk)	25,775.00	20,724.00	---	39,500.00	30,640.00
Cost per Hectare (Tk)	818.00	864.00	2,145.00	1,525.00	1,320.00

*Mariali and Porabari sites have electric pump and the other three sites have diesel pumps

**Irrigation cost for 1983 Boro season include Tk 927 rent charged per hectare by the manager, and Tk 900 per hectare fuel cost. Individual farmers pay Tk 3.75 per hour for lubricant and Tk 3.00 per hour for pump operator.

***The tubewell is purchased and controlled by a group of 11 farmers. An irrigation cost of Tk 1,525 per hectare was assessed for the first Boro season on the basis of loan payment, diesel fuel, pump installation cost and operator's salary.

Table C8. Comparative Irrigation Costs Between Electric and Diesel Pumps

Items (Tk)	Porabari Site (Electric Pump)	Teknagapara Site (Diesel Pump)
DTW Rent	3,500.00	3,500.00
Maintenance Cost	4,524.00	4,200.00
Fuel/Electricity Cost	10,200.00	21,140.00
Operator's Payment	2,500.00	1,800.00
Total Cost	20,724.00	30,640.00
Cost per Hectare	864.00	1,320.00
Command Area (Hectare)	23.21	23.98

7. Profitability Analysis

Production of rice in the Boro season, as made possible by tubewell irrigation, has resulted in a return to land of Tk 8,567 to Tk 12,527/ha for the 1982 Boro season in four of the five sites. The rather large variation in profitability among the study sites was primarily due to differences in yield and cost of irrigation (Table C9).

The highest yield was achieved by farmers in Mariali. However, investments in fertilizers and insecticides per hectare by farmers in Mariali site were the highest for all five sites. This might be attributed to the farmers having better access to credit and extension personnel through the DTICP. The Mariali tubewell site also achieved the lowest per hectare irrigation cost because of the lower energy cost of the electric pump and the larger command area.

Table C9. Cost and Returns Per Hectare of Boro Rice

Items (Tk)	Study Sites				
	Mariali	Porabari	Jogitola	Itahata*	Teknagapara
Gross Income	20,093.23	15,740.58	18,137.59	19,759.38	16,321.88
Cash Expenses**	4,303.44	3,670.88	4,696.02	3,978.90	3,655.54
Return Above Cash Expenses	15,789.79	12,069.70	13,441.57	15,780.48	12,666.34
Noncash Expenses***	3,262.70	3,502.38	3,766.78	2,618.46	3,349.16
Return to Land	12,527.09	8,567.32	9,674.79	13,162.02	9,317.18

*Itahata tubewell started operation in 1983 Boro season. The yield and cost of operations that were not completed at the time of the survey are based on farmers' estimation.
**Cash expenses included hired labor, purchased inputs, and irrigation cost.
***Noncash expenses consisted of opportunity cost of family labor and interest on operating capital.

Comparisons of tubewells under CARE management (Mariali), informal organization (Teknagapara and Porabari), and no organization (Jogitola) in terms of command area, cropping intensity, yield, irrigation cost, and returns are presented in Table C10. The CARE-managed tubewell achieved the highest benefit-cost ratio, followed by those with informal organization. Jogitola, on the other hand, had the lowest with a benefit-cost ratio of 2.14. These findings are based on a limited sample of five tubewells and therefore may not apply to all tubewells. For detail of production expenses and profitability of Boro rice, see Tables C11 to C15.

Table C10. Comparison of Three Types of Organizations

Items	CARE* Management	Informal** Organization	No*** Organization
Command Area (ha)	31.51	23.60	6.48
Cropping Intensity	229.00	257.00	229.00
Rice Yield (kg/ha)	5,301.65	4,292.82	4,936.00
Irrigation Cost (Tk/ha)	818.00	1,092.00	2,145.00
Gross Income (Tk/ha)	20,093.23	16,031.23	18,137.59
Return to Land (Tk/ha)	12,527.09	8,942.25	9,674.79
Benefit-cost Ratio	2.66	2.26	2.14

*Mariali Site
**Mean of Teknagapara and Porabari Sites
***Jogitola Site

Table C11. Per Hectare Costs and Returns of Boro Rice at Mariali

Items	Unit	No. of Unit	Price Per Unit (Tk)	Income or Cost (Tk)
Income:				
Rice grain	kg	5,301.65	3.50	18,555.76
Rice straw	kg	5,301.65	0.29	1,537.47
Total Income				20,093.23
Purchased Inputs:				
Seedlings	kg	56	18.46	1,033.76
Fertilizers:				
Urea	kg	216	3.88	838.08
T.S.P.	kg	105	3.74	392.90
M.P.	kg	60	3.04	182.40
Insecticides	kg	6	60.00	360.00
Production Practices:				
Land Preparation				
Labor	days	25	17.00	425.00
Draft Animal	days	23	35.00	805.00
Transplanting & Uprooting	days	46	19.00	874.00
Top-dressing	days	21	18.00	36.00
Weed Control	days	49	19.00	931.00
Pest Control	days	2	18.00	36.00
Harvesting/ Threshing	days	15	18.00	270.00
Winnowing & Storing	days	17	18.00	306.00
Irrigation Cost	ha	1	818.00	818.00
Interest on Operating Capital				258.00
Total Production Cost				7,566.14
Return to Land				12,527.09

Table C12. Per Hectare Costs and Returns of Boro Rice at Porabari

Items	Unit	No. of Unit	Price Per Unit (Tk)	Income or Cost (Tk)
Income:				
Rice grain	kg	4,170.82	3.50	14,597.87
Rice straw	kg	3,940.39	0.29	1,142.71
Total Income				15,740.58
Purchased Inputs:				
Seedlings	kg	68	18.46	1,255.28
Fertilizers:				
Urea	kg	206	3.88	799.28
T.S.P.	kg	131	3.74	489.94
M.P.	kg	44	3.04	133.76
Insecticides	kg	3	60.00	180.00
Production Practices:				
Land Preparation				
Labor	days	26	17.00	442.00
Draft Animal	days	24	35.00	840.00
Transplanting & Uprooting	days	29	19.00	551.00
Top-dressing	days	2	18.00	36.00
Weed Control	days	48	19.00	912.00
Pest Control	days	1	18.00	18.00
Harvesting & Threshing	days	12	18.00	216.00
Winnowing & Storage	days	12	18.00	216.00
Irrigation Cost	ha	1	652.00	864.00
Interest on Operating Capital				220.00
Total Production Cost				7,173.26
Return to Land				8,567.32

Table C13. Per Hectare Costs and Returns of Boro Rice at Jogitola

Items	Unit	No. of Unit	Price Per Unit (Tk)	Income or Cost (Tk)
Income:				
Rice grain	kg	4,936.00	3.50	17,276.00
Rice straw	kg	2,971.00	0.29	861.59
Total Income				18,137.59
Purchased Inputs:				
Seedlings	kg	48	18.46	886.08
Fertilizers:				
Urea	kg	234	3.88	907.92
T.S.P.	kg	70	3.74	261.80
M.P.	kg	50	3.04	152.00
Insecticides	kg	2	60.00	120.00
Production Practices:				
Land Preparation				
Labor	days	35	17.00	595.00
Draft Animal	days	33	35.00	1,155.00
Transplanting & Uprooting	days	30	19.00	570.00
Top-dressing	days	1	18.00	18.00
Weed Control	days	38	19.00	722.00
Pest Control	days	1	18.00	18.00
Harvesting & Threshing	days	12	18.00	216.00
Winnowing & Storage	days	23	18.00	414.00
Irrigation Cost	ha	1	2,145.00	2,145.00
Interest on Operating Capital				282.00
Total Production Cost				8,462.80
Return to Land				9,674.79

Table C14. Per Hectare Costs and Returns of Boro Rice at Itahata

Items	Unit	No. of Unit	Price Per Unit (Tk)	Income or Cost (Tk)
Income:				
Rice grain	kg	5,347.74	3.50	18,717.09
Rice straw	kg	3,594.10	0.29	1,042.29
Total Income				19,759.38
Purchased Inputs:				
Seedlings	kg	51	18.46	941.46
Fertilizers:				
Urea	kg	186	3.88	721.68
T.S.P.	kg	87	3.74	325.38
M.P.	kg	21	3.04	63.84
Insecticides	kg	1	60.00	60.00
Production Practices:				
Land Preparation				
Labor	days	15	17.00	255.00
Draft Animal	days	13	35.00	455.00
Transplanting & Uprooting	days	24	19.00	456.00
Top-dressing	days	2	18.00	36.00
Weed Control	days	43	19.00	817.00
Pest Control	days	1	18.00	18.00
Harvesting & Threshing	days	16	18.00	288.00
Winnowing & Storing	days	22	18.00	396.00
Irrigation Cost	ha	1	1,525.00	1,525.00
Interest on Operating Capital				239.00
Total Production Cost				6,597.36
Return to Land				13,162.02

Table C15. Per Hectare Costs and Returns of Boro Rice at Teknagapara

Items	Unit	No. of Unit	Price Per Unit (Tk)	Income or Cost (Tk)
Income:				
Rice grain	kg	4,414.82	3.50	15,451.87
Rice straw	kg	3,000.04	0.29	870.01
Total Income				16,321.88
Purchased Inputs:				
Seedlings	kg	46	18.46	849.16
Fertilizers:				
Urea	kg	187	3.88	725.56
T.S.P.	kg	107	3.74	400.18
M.P.	kg	45	3.04	136.80
Insecticides	kg	3	60.00	180.00
Production Practices:				
Land Preparation				
Labor	days	24	17.00	480.00
Draft Animal	days	22	35.00	770.00
Transplanting & Uprooting	days	38	19.00	722.00
Top-dressing	days	1	18.00	18.00
Weed Control	days	32	19.00	608.00
Pest Control	days	1	18.00	18.00
Harvesting & Threshing	days	18	18.00	324.00
Winnowing & Storing	days	13	18.00	234.00
Irrigation Cost	ha	1	1,320.00	1,320.00
Interest on Operating Capital				219.00
Total Production Cost				7,004.70
Return to Land				9,317.18

8. Summary of Findings

The dominant cropping patterns for the five tubewell study sites were found to be local-local-HYV, 30 percent of the area, followed by fallow-local-HYV, 27 percent. Tubewell irrigation has resulted in a shift in cropping pattern from local-local-fallow to fallow-local-HYV. This shift has resulted in greater output per hectare of land; however, approximately 46 percent of the land is kept fallow in the Aus season.

Seventy-eight percent of the total area cultivated in the Boro season was with high yielding varieties predominantly BR-3, BR-8 and BR-9. The use of high yielding seed varieties was supplemented with an average investment of Tk 1,487/ha in fertilizers and insecticides. This is equivalent to 37 percent of total cash expenses.

The CARE-BKB credit program, which was functioning at the Mariali site, had resulted in borrowing in kind (fertilizer and insecticides) by 43 percent of the farmers and borrowing in combined cash and in kind by another 43 percent of the farmers.

As an average for all five sites, 65 percent of the surveyed farmers had not obtained credit for the 1983 Boro season. About half of this group indicated that credit was not needed. Forty-one percent of the farmers who had not obtained credit indicated the cumbersome procedure and difficulty of obtaining credit in time as constraints. Difficulty of loan repayment and high cost of borrowing was cited by farmers as other factors discouraging borrowing.

Following investment in fertilizers and insecticides, cost of irrigation made up the second major component of cash expenses (33%).

Irrigation cost incurred per hectare varied from a low of Tk 818 in Mariali to a high of Tk 2,145 in Jogitola. The low per hectare cost of irrigation achieved in Mariali was due to low energy (electricity) cost of operating the pump and the larger command area. The per hectare irrigation cost for an electric pump was Tk 456 less than for a diesel pump.

The return from Boro rice crop under tubewell irrigation ranged from Tk 8,567 to Tk 12,527/ha. The variation in profitability between the tubewell sites are primarily because of differences in yield and cost of irrigation. The Mariali site, under CARE management and with certain formal procedures, had achieved the highest benefit-cost ratio of 2.66; Jogitola, where no farmer organizations existed, had the lowest benefit-cost ratio of 2.14.

D. Sociology

1. Purpcse of Sociology in Diagnostic Analysis

Irrigation is very much a social process. Water springs from the ground, flows through canals and field channels, and enters the plant root zone only with some form of human intervention. To ensure an adequate and predictable supply of water to the fields, an organizational structure is required, be it small farmers' organizations or large irrigation bureaucracies. In the five deep tubewells studied in the Bangladesh Diagnostic Analysis Workshop, small groups of farmers were responsible for the operation of the system. These groups are critical to the ultimate success or failure of irrigated agriculture within this area.

The role of sociology in Diagnostic Analysis is to identify the social and organizational constraints to successful irrigated agriculture. To learn which human and bureaucratic factors inhibit increased agricultural productivity, the sociologist analyzes and evaluates the major tasks of any irrigation system: water allocation/distribution, system maintenance, and conflict management. Each of these tasks can be studied at three different levels of analysis: the individual farm level, the farmer organizational level, and the irrigation bureaucracy level.

Most of the studies conducted during the workshop in Bangladesh focused on the farm and organizational levels. The

sociologists attempted to analyze the quantity and quality of the linkages between these levels. They examined the amount of participation and contact between the farmers and their deep tubewell organizations, and between the deep tubewell groups and the higher bureaucratic levels of government. One of the principle questions we attempted to answer in this investigation was whether or not a particular type of organization at a given tubewell site had an effect on the management of the irrigation water.

The results of these studies appear in this appendix, which describes the land-holding patterns and the organizational structures at the five sites along with an analysis of the farmers' irrigation behavior. A summary of findings including a prioritized list of social constraints to increased agricultural productivity.

2. Land-Holding and Ownership Patterns

a. Tubewell Area

As the data in Table D1 indicate, the majority of farmers at all five sites are classified as small, i.e. less than 2 acres (0.81 ha). These same farmers, however, own disproportionately less land; large farmers, on the other hand, own disproportionately more land. Considering only the land within the sample sites, there is an unequal distribution of land. These findings are similar to the conclusions reached by Biswas (1982)* regarding all of Bangladesh, and Mandal (1982)

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* Biswas, M.R. 1982. Need for an action plan in irrigation management. In M.R. Biswas and M.A.S. Mandal (eds.). On-Farm Irrigation Water Management Problems. Bureau of Socioeconomic Research and Training, Bangladesh Agricultural University, Mymensinghe, Bangladesh.

Table D1. Land-Holding Pattern Within Tubewell Command Areas by Study Site

Category	Mariali		Porabari		Itahata		Teknagapara		Jogitola	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
1. Number of Farms										
Small*	13	(87)	12	(75)	8	(62)	12	(75)	12	(75)
Medium	2	(13)	3	(19)	4	(31)	4	(25)	3	(19)
Large	0		1	(6)	1	(7)	0		1	(6)
2. Sum of Land-Holdings Owned Within Command Area (ha)**										
Small	5.6	(78)	3.8	(43)	1.2	(14)	3.3	(44)	2.2	(28)***
Medium	1.6	(22)	2.7	(31)	5.4	(63)	4.2	(56)	3.0	(38)
Large	0		2.3	(26)	2.0	(23)	0		2.7	(34)
All Sample Farms	7.2	(100)	8.8	(100)	8.6	(100)	7.5	(100)	7.9	(100)

* Farm sizes are defined by Mandal (1982) as:
Small = 1.99 acres and below (0.81 ha and below)
Medium = 2.0 to 4.99 acres (0.82 to 2.0 ha)
Large = 5.0 acres and above (2.1 ha and above)

** The figures in this part of the table are the sum of all the land-holdings within the tubewell command area for that particular size. For example, in Mariali, the sum of all the land-holdings for the 13 small farmers is 5.6 ha, which is 78 percent of all the sample land-holdings for that site.

*** The Jogitola figures are based on the command area from the 1982 Boro season

who studied three deep tubewell areas in the Mymensingh District of Bangladesh.

The most unequal distribution and the largest concentration of land exists in Jogitola. At this site, 6 percent of the sample farmers own 34 percent of the land, while 75 percent of the farmers own only 28-percent of the land. Under such conditions of land inequality, Biswas (1982) contends that the establishment and operation of effective irrigation cooperatives may prove to be very difficult.

The Mariali tubewell site, on the other hand, displays a comparatively equal distribution and a smaller concentration of land. At this site, 87 percent of the sample farmers own 78 percent of the tubewell area land.

Mariali, along with Teknagapara, contains no large farmers among the sample farmers. The rest of the selected sites contain only a few large farmers.

b. Total Area

The data in Table D2 display the distribution of land-holding sizes of the sample farmers including both land owned within the selected tubewell areas and any land owned outside the area. Even when considering total land-holdings, most of the sample farmers are still classified as small. There is still an unequal distribution of land; a few large farmers own disproportionately large centrations of land. There is, however, a significant increase in the number of farms clas-sified as medium-sized land-holdings.

The most unequal distribution of total land owned occur in Jogitola and Itahata. Itahata shows a particularly large concentration of land in the hands of few farmers, where 38 percent of the sample farmers own 83 percent of the land. The figures suggest significant numbers of small and large farmers in Itahata, but few medium-sized farms. The dichotomy between the large and small farmers at this site might prove to be a disadvantage to future farmer organizations.

Table D2. Total Land-Holdings Based on Ownership Both Within and Outside the Tubewell Command Areas by Study Site

Category	Mariali		Porabari		Itahata		Teknagapara		Jogitola	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
1. Number of Farms										
Small*	9	(60)	8	(50)	6	(46)	12	(75)	11	(69)
Medium	6	(40)	6	(38)	2	(16)	4	(25)	4	(25)
Large	0		2	(12)	5	(38)	0		1	(6)
2. Sum of Land-Holdings Owned Within and Outside Command Areas in ha**										
Small	4.1	(38)	3.0	(20)	1.1	(6)	3.9	(44)	3.7	(30)
Medium	6.6	(62)	6.3	(40)	2.1	(11)	4.9	(56)	5.6	(45)
Large	0		6.3	(40)	15.7	(83)	0		3.1	(25)
All Sample Farms	10.7	(100)	15.6	(100)	18.9	(100)	8.8	(100)	12.4	(100)

* Farm sizes are defined by Mandal (1982) as:
Small = 1.99 acres and below (0.81 ha and below)
Medium = 2.0 to 4.99 acres (0.82 ha to 2.0 ha)
Large = 5.0 acres and above (2.1 ha and above)

** The figures in this part of the table are the sum of all the land-holdings both within and outside the tubewell command area for that particular size. For example, in Porabari, the sum of all the land-holdings, both in Porabari and elsewhere, for the eight small farmers is 3.0 ha, which is 20 percent of all the external and internal land-holdings for that site.

c. Tenancy

Table D3 outlines some important characteristics of tenancy of the five study sites. The majority of sample farmers were owners of the land they cultivated and did not participate in sharecropping activities. Only in Porabari do over half the sample farmers engage in some form of tenancy. Many of these farmers own some parcels of land, but also sharecrop other land. These owners-cum-tenants are neither solely owners nor solely tenants. There are very few farmers who are simply tenants, that is, completely landless, Itahata being the only exception. This may be because of previously discussed dichotomy between large and small farmers.

The percent of land under tenancy within the sample generally corresponds to the Bangladesh average of 25-percent (Mandal, 1982). Jogitola, with the most unequal distribution of land, however, had an above average amount of land under tenancy. Teknagapara had much less land under tenancy than the national average. The average size of the sharecropped land is smallest at Teknagapara which also has the lowest percent of land under tenancy. The largest average size of sharecropped land, the last category displayed in Table D3, is at Jogitola and Itahata. These two sites also had the highest inequality of land distribution as displayed in Table D1. Additionally, all the sites except for Jogitola report that the costs of sharecropping is borne completely by the tenant, while the output is divided into equal shares between the tenant and owner. However, and somewhat surprisingly, in Jogitola where land concentration and tenancy is the highest, half of the sharecropping

farmers reported that the land owner paid for half of the incurred costs. Mandal (1982) also found a great variety of cost-sharing arrangements at sites he studied.

Table D3. Land Tenure by Study Site

Category	Mariali		Porabari		Itahata		Teknagapara		Jogitola	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
1. Tenancy										
a. Owner	9	(60)	7	(44)	8	(62)	12	(75)	9	(56)
b. Owner/ Tenant	6	(40)	8	(50)	1	(8)	4	(25)	6	(38)
c. Tenant	0		1	(6)	4	(31)	0		1	(6)
2. Percent of Land at Sample Farms Under Tenancy	26		30		29		5		44	
3. Mean Size of Land Being Sharecropped	0.31		0.30		0.50		0.09		0.50	

3. The Organization of the Deep Tubewells

The management of deep tubewells in Bangladesh varies a great deal. At one extreme are legal farmers' organizations, such as the registered Farmer's Cooperative Societies of BRDB. These societies are guided by formal rules and regulations established by cooperative acts and laws, and they receive other institutional support (credit, extension services) from the government. At the other extreme is a one-man dictatorial type of management with no written rules or regulations and no legal status. The latter organizations have an entirely informal management structure.

Regardless of the type of organization, BADC supplies all the deep tubewells to the farmers. Most tubewells supplied in the past to the farmers were rented on a yearly basis, but recently they have been sold to farmers' groups for cash payment at a subsidized rate.

All five deep tubewells selected for this Diagnostic Analysis were not registered with the government and were managed informally, i.e., without a formal organization with written rules and regulations. Four of the five systems were operated by informal groups of farmers who had organized on their own to procure and operate a deep tubewell. The fifth system was the product of just one individual farmer. Therefore, it is important to keep in mind that the findings presented here will reflect only one specific type of rural organization in Bangladesh, namely informal.

a. Jogitola: Deep Tubewell Without Organization

From the management point of view, Jogitola was at one extreme as it was managed by only one man. The deep tubewell was procured in 1980 on a rental basis from the BADC through the influence and initiative of this individual, a large landlord who owns about 20 ha of land throughout the Joydebpur area. This landlord has remained on good terms with the BADC personnel and stated that BADC services were satisfactory. Initially, an informal group of 20 farmers was formed, possibly as part of the official procedure of applying for the tubewell. A management committee also was formed with the landlord as the manager. From that time to the present, he has officially held the same position, but group activities and the management committee have been nonexistent. No

annual budget has been prepared for this system and the farmers have been virtually excluded from any decision-making process. The landlord himself, in consultation with the BADC personnel, decided where to place the pump and where to place the irrigation channels. He pays the annual rent on the tubewell and, as a result, considers himself the tubewell owner.

According to the manager, during the last two years he fixed the water charge in joint meetings with the farmers, and they agreed to pay the charge. The farmers originally received water according to their individual farming needs. At the end of the irrigation season, however, the manager claimed that many expenses were unpaid by the farmers. In 1982, the command area covered 22.7 ha, and the deficit stood at Tk 8,500. Thus, in the 1983 Boro season he decided to supply irrigation water only to those who would pay Tk 926/ha as a rental charge, supply diesel fuel, pay Tk 3.75 per hour for lubricant, and pay Tk 3.00 per hour as operator's renumeration. Consequently, the command area decreased from 22.7 ha in 1982 to 6.5 ha in 1983, as most farmers were unwilling to pay water charges at that rate. Those farmers no longer included in the command area simply did not grow a rice crop in the 1983 Boro season. Additionally, of the commanded 6.5 ha, about 4.5 ha belonged to the manager.

The farmers of Jogitola disagreed with the manager's account of the system's operation. The farmers interviewed stated that he had consistently overcharged them for the past years and that there was a sufficient reserve balance to operate the tubewell for 1983. As no

accounts or budget figures had been presented to the farmers, they mistrusted the manager and refused to pay the current fees.

The channel maintenance procedures at Jogitola further reflected this schism between the manager and the farmers. The manager maintained two of the main channels and other field channels which served his lands using paid laborers. The channels serving the farmers' fields, on the other hand, were maintained by the farmers themselves, without any assistance from the manager.

b. Mariali: CARE Supported Deep Tubewell

From a management point of view, the deep tubewell at Mariali was at the other extreme from Jogitola. Though the management structure of the tubewell was still informal and officially unregistered, it had developed certain structured management procedures, e.g., applying for credit, with the involvement of CARE, a voluntary organization. Any farmer receiving irrigation water from the tubewell was considered to be a member of the group. The responsibility of running the tubewell rested with a management committee. The committee was comprised of a chairman, a vice-chairman, a manager and six directors, who were selected by the farmers in a general meeting by consensus. Of all the officers, the manager was the most important and was officially responsible for running the tubewell. The present manager has held the office for the last two years. For making major decisions, general meetings of all the farmers were convened, at least twice a season, and the management committee by itself also met frequently, at least twice a month.

For distribution of water, the whole command area had been divided into five blocks that were supervised by the five directors. Within each block, water was delivered from the tail portion and ends with the head portion. For maintenance of main channels, the farmers having land under each channel worked jointly; for maintenance of the field channels, individual farmers were responsible. The decisions for repair and maintenance were made in the general meetings.

CARE included this deep tubewell under their project in 1981. CARE mainly has provided extension services and channels credit and other inputs to the farmers through BKB and BADC. Credit has been given to the farmers on the basis of their requirements and landholding. The maximum ceiling on credit has been set at Tk 6,916/ha, of which Tk 2,470 has been given in cash and the rest in the form of fertilizer and pesticide. Each individual farmer indicated his needs to the CARE authority who, after approval, sent the paperwork to BKB, which then distributed the loan among the farmers. At the end of the season, the farmers paid back their loan payment to the Bank. Those farmers who did not pay have been excluded from the credit program.

The group received credit for running the deep tubewell in the same manner and divided the total cost among the farmers according to area irrigated. The farmers paid the water charge at the end of the season together with their loan money to the bank.

For repair and maintenance of the tubewell, the management committee informed BADC through CARE and paid for the spare parts. Among the management committee at Mariali, however, there was a great deal of dissatisfaction regarding BADC operations. The committee

members stated that if their pump needed repair, it required a considerable amount of time, and requests, before the BADC personnel arrived at the site.

c. Porabari, Itahata, Teknagapara: Informal Deep Tubewell Groups

Between the two management extremes of Jogitola (no organization whatsoever) and Mariali (an informal organization with some formal procedures) were the other study sites. The three deep tubewells located at Teknagapara, Porabari, and Itahata villages had similar types of organization, possessing no written rules. All were informal deep tubewell groups with some degree of organization. Among these, Itahata was somewhat different in the sense that the tubewell had started operating only in 1983. Also, the tubewell at Itahata had been purchased from the BADC on cash payment, while the Teknagapara and Porabari tubewells had been acquired on a rental basis.

In all the three deep tubewells there was no limit to membership in the tubewell group; whoever received irrigation water from the tubewell automatically became a member of the group. At all of these sites, there were management committees who run the tubewells. The composition of the committees and the procedure of selection of the committee members was almost similar to Mariali. There was no fixed date for holding meetings in these groups; rather they held meetings whenever necessary. In all, the group manager was the principal man who decided about the placement of the pump and construction of channels. However, all of them received formal approval for their decisions from

the farmers in general meetings. As the Itahata tubewell just started to operate this season, the present manager was comparatively new. In Porabari and Teknagapara, however, the present managers had been in office for at least five years. The farmers in Porabari did choose a different manager for a few months in 1982, but due to perceived financial irregularities, the old manager was reappointed for 1983.

As this was its first year of operation, the management committee in Itahata had not prepared a budget while in Porabari the budget was discussed and approved in a general meeting before the irrigation season started. In Teknagapara, the manager reported that the annual budget was decided upon in a general meeting, while other key informants stated that in reality, only the management committee developed the budget.

The water allocation system was slightly different in these three tubewells. At Teknagapara some contradictory information was provided by the key informants. The manager reported that the entire command area had been divided into four blocks and each block receives water on five day intervals, but other key informants reported that there was no fixed schedule for water distribution. They stated that the water was distributed according to the wishes of the manager.

The Porabari manager reported that he decided the water distribution schedule each morning in consultation with other members of the management committee or the chowkidar. It was also reported that the manager considers farmer's requests. At Itahata, the manager himself decided the rotation schedule after assessing the farmers' needs every day.

With regard to the maintenance of irrigation channels, the Itahata system was new and the channels did not need maintenance or repair. For the other two tubewells, the key informants indicated that they had given low priority to maintenance. Usually, no routine maintenance was done. The individual farmer maintained his own field channels and worked jointly on the main channel at the request of the management committee.

For repair and maintenance of the pump, the managers were responsible for communicating with the BADC office. Expenditures made for procuring the spare parts were submitted to the management committee for approval. In the Itahata system, the key informants stated that they were generally satisfied with the performance of the BADC personnel. The reports from the older systems of Porabari and Teknagapara, however, gave an unsatisfactory rating to the performance of the BADC.

4. Farmers' Attitudes and Irrigation Behavior

This section presents the data collected from the sample farmers on different issues related to deep tubewell irrigation. These issues include farmers' knowledge and use of institutional services, water allocation and maintenance procedures, farmer's irrigation behavior, and the extent of farmers' participation in the organizations.

a. Knowledge and Use of Institutional Services

Adoption of modern methods of agriculture, including irrigation, depends to a great extent on the institutional services available to the farmers. Particularly the extension services provided by government

agencies or the farmers' own organizations play a vital role in changing the farmers attitudes and behavior. In the tubewell sites examined for this study, the government extension agent located nearest to the farmers is the Union Agricultural Assistant (UAA) of the Department of Agriculture (Extension and Management). He is supposed to disseminate knowledge about improved agricultural practices to the farmers. Table D4 indicates how much the farmers were aware of these agents and how many extension services they actually received.

Table D4. Farmer Reports of Knowledge and Use of Institutional Services by Study Site: Union Agricultural Assistant (UAA)

Question	Mariali No.(%)*	Porabari No.(%)	Itahata No.(%)	Teknagapara No.(%)	Jogitola No.(%)
Knows Office/Home Location of U.A.A.?					
No	8 (57)	10 (63)	11 (85)	15 (94)	8 (57)
Yes	6 (43)	6 (38)	2 (15)	1 (6)	6 (43)
Missing Data**	1	0	0	0	1
Knows Name of U.A.A.?					
No	12 (86)	16 (100)	13 (100)	16 (100)	14 (100)
Yes	2 (14)	0	0	0	0
Missing Data	1	0	0	0	1
Mean No. of Purposeful Contacts with U.A.A. in *Boro* Season	0.5	0.0	0.0	0.0	0.0
Helpfulness of U.A.A.					
Highly	0	0	0	0	0
Some	3 (21)	0	0	0	0
None	11 (79)	16 (100)	13 (100)	16 (100)	13 (100)
Missing Data	1	0	0	0	2

* Throughout the sociological tables, percentages have been rounded off and may not always sum to 100 percent.

** Missing data throughout the sociological tables are either due to errors in data collection or the inability of some farmers to respond to a certain question.

Table D4 shows that most of the farmers were not at all aware of the existence of the UAA. Virtually no sample farmers in any village knew the name of this official, and the number of purposeful contacts with him in the Boro season (December-May) was equally low. Only a small percent of farmers in Mariali felt that the UAA was of some help to them. These data indicate that the farmers in these villages were not getting sufficient extension services from this government agency. The few contacts made by the UAA at Mariali village may have been due to involvement of CARE in that village.

In addition to certain government agencies, the farmers had their own informal deep tubewell organizations which could provide other useful knowledge to the farmers. The frequency of irrigation information received by the farmers from their own organizations is presented in Table D2.

Table D5 indicates that except for Mariali, the majority of the sample farmers usually received information on irrigation charges. Regarding information on group meetings, water delivery dates and pump operation schedules, the sample farmers in Porabari and Itahata usually received information, but the farmers of Mariali and Teknagapara received the information sometimes. Information on the pump maintenance schedule was received very infrequently at Teknagapara, and slightly

Table D5. Frequency of Irrigation Information by Study Site

Type of Information	Mariali No.(%)	Porabari No.(%)	Itahata No.(%)	Teknagapara No.(%)	Jogitola No.(%)
Irrigation Charge					
Never	3 (20)	0 (0)	0 (0)	0 (0)	Not Applicable
*Sometimes	9 (60)	2 (13)	1 (8)	0 (0)	
**Usually	3 (20)	14 (88)	12 (92)	16 (100)	
Missing Data	0	0	0	0	
DTW Group Meetings					
Never	1 (7)	0 (0)	1 (8)	1 (6)	Not Applicable
Sometimes	11 (73)	4 (25)	4 (31)	10 (63)	
Usually	3 (20)	12 (75)	8 (62)	5 (31)	
Missing Data	0	0	0	0	
Water Delivery Dates					
Never	1 (7)	0 (0)	0 (0)	3 (19)	Not Applicable
Sometimes	12 (80)	4 (25)	2 (17)	9 (56)	
Usually	2 (13)	12 (75)	10 (83)	4 (25)	
Missing Data	0	0	1	0	
Pump Operation Schedule					
Never	0 (0)	0 (0)	2 (15)	5 (31)	Not Applicable
Sometimes	14 (93)	6 (38)	2 (15)	8 (50)	
Usually	1 (6)	10 (63)	9 (69)	3 (19)	
Missing Data	0	0	0	0	
Pump Maintenance Schedule					
Never	0 (0)	0 (0)	1 (8)	7 (44)	Not Applicable
Sometimes	14 (93)	8 (50)	4 (31)	6 (38)	
Usually	1 (7)	8 (50)	8 (62)	3 (19)	
Missing Data	0	0	0	0	
Water Use Practices On-Farm					
Never	0 (0)	2 (13)	1 (8)	6 (38)	Not Applicable
Sometimes	13 (87)	11 (69)	6 (46)	8 (50)	
Usually	2 (13)	3 (19)	6 (46)	2 (13)	
Missing Data	0	0	0	0	

*Sometimes - at least once a month in Boro season
**Usually - at least once a week in Boro season

more consistently at Mariali. Most farmers in all the tubewells received information at least sometimes on water use practices on-farm. Additionally, no responses are shown for Jogitola as the irrigation procedures here were very different from the other sites and no organization existed at Jogitola.

Evidently, in spite of having a fairly well organized informal group in Mariali, the flow of irrigation information was not regular. Similarly, though Teknagapara and Porabari are older deep tubewells having the same type of organization, the flow of information was more irregular at Teknagapara. The frequency of irrigation information, then, seems somewhat divorced from the mode of organization.

b. Perceived Problems of the Farmers

For increasing crop production, farmers face innumerable problems. Still, out of their own farming experience they usually perceive certain problems as more serious than others. Moreover, farmers' perceptions of a problem might vary from place to place depending on the resources and institutional services available to them.

Table D6 lists the most important farming problems reported by the farmers at the five deep tubewells. Fertilizer (price) seemed to be the most prevalent problem in Porabari, Jogitola, and Itahata. In Teknagapara, fertilizer and water were reported to be the most serious problems. It is interesting to note that none of the farmers at Mariali considered fertilizer as a major problem. Rather, one-third of the Mariali sample farmers considered water as a major problem. This may be

because at Mariali the farmers were receiving credit to procure desired amounts of fertilizer through the CARE/BKB credit system, and now they wanted to be assured of a desired quantity of water for their crops.

Table D6. Most Important Farming Problem Inhibiting Production as Reported by Farmers by Study Site

Problem	Mariali No. (%)	Porabari No. (%)	Itahata No. (%)	Teknagapara No. (%)	Jogitola No. (%)
None	5 (33)	0	0	0	0
Credit	3 (20)	2 (13)	5 (39)	0	2 (15)
Water	5 (33)	4 (25)	1 (8)	7 (44)	0
Seeds	0	1 (6)	0	0	0
Fertilizers	0	6 (38)	6 (46)	7 (44)	8 (62)
Pesticides	1 (7)	1 (6)	0	2 (13)	0
Marketing	0	0	0	0	0
Others: Receiving Agricultural Inputs, Lack of Knowledge, Lack of Plow Cattle	1 (7)	2 (12)	1 (8)	0	3 (24)
Missing Data	0	0	0	0	2

Despite the drastic decrease in irrigated area and the total lack of water supplied to many of the Jogitola farmers, water was not listed as a major problem by any of the sample farmers in Jogitola. It should be noted that the sample farmers in Jogitola fell into two distinct groups, those who had decided to purchase water, and those who had not. The farmers not receiving water were not cultivating a crop and perhaps did not perceive water as a problem. This group may not want to purchase water at a high price, or they may not be fully aware of the utility of irrigation, and/or they may have given up the expectation of receiving water. The sample farmers who were receiving water purchased

it directly from the manager and therefore exerted direct control over the water supply.

When questioned further about which aspect of their water problem troubled them most, the farmers who reported water as a major problem replied that predictability of supplies, quantity delivered, and the high price of irrigation concerned them most. None of these replies, however, formed a pattern across the five study sites.

The farmers of the five sites had other perceived problems related directly to irrigation. Table D7 shows that problems in some of the deep tubewells started from the very beginning when decisions were made concerning pump placement.

At Jogitola and Teknagapara there were some problems during the pump placement stage. The Jogitola farmers reported that objections were raised to the placement of the pump in its present location (on the manager's land) and at Teknagapara, some of the farmers wanted the pump to be placed closer to their land. There were also some problems during the channel construction stage, particularly at Jogitola, where some of the farmers thought that due to construction of the channel through their land, the amount of cultivable land had decreased.

The farmers were asked whether they have any problems with the existing water distribution system, cleaning and maintenance of the main and secondary channels, and maintenance of the pump. In all these issues, the majority of the sample farmers indicated that they did not face any major problem. Some of the farmers, however, have indicated problems in their tubewell areas. Half of the sample farmers at Porabari and one-third of the sample farmers at Teknagapara expressed

Table D7. Reported Irrigation Problems by Study Site

Problem	Mariali No.(%)	Porabari No.(%)	Itahata No.(%)	Teknagapara No.(%)	Jogitola No.(%)
Pump Placement					
No	14 (100)	11 (73)	13 (100)	10 (63)	8 (53)
Yes	0	4 (27)	0	6 (38)	7 (47)
Missing Data	1	1	0	0	0
Channel Construction					
No	14 (93)	13 (87)	13 (100)	12 (75)	6 (43)
Yes	1 (7)	2 (13)	0	4 (25)	8 (57)
Missing Data	0	1	0	0	1
Water Distribution					
No	11 (73)	11 (69)	12 (92)	12 (75)	10 (71)
Yes	4 (27)	5 (31)	1 (8)	4 (25)	4 (27)
Missing Data	0	0	0	0	1
Channel Cleaning/ Maintenance					
No	13 (87)	8 (50)	13 (100)	11 (69)	11 (85)
Yes	2 (13)	8 (50)	0	5 (31)	2 (15)
Missing Data	0	0	0	0	2
Pump Maintenance					
No	9 (60)	12 (75)	13 (100)	15 (94)	10 (83)
Yes	6 (40)	4 (25)	0	1 (6)	2 (17)
Missing Data	0	0	0	0	3

that they have problems with cleaning and maintenance of the main and field channels. These were primarily physical problems, such as rat holes, crumbling embankments, and presence of weeds. With regard to pump maintenance problems, the farmers of Mariali indicated that some

problems existed. According to them, they did not receive timely help from BADC when pumps broke down.

Other farmers also reported the presence of some irrigation problems specific to their area. Some of the farmers at Mariali and Teknagapara expressed that they were not receiving water on a fixed date or when they needed it most. At Porabari some of the farmers said that due to constant seepage of water from the channels they were facing waterlogging problems. At Jogitola, the farmers having no organization of their own were mostly facing the problem of high rate of water charge.

The agricultural and irrigation problems reported by the farmers in this section indicate that the farmers did perceive some constraints to increased agricultural production and effective water management. The majority of sample farmers seemed most concerned with the high price of fertilizer and the quantity and predictability of their water supplies. Those tubewells with more formal procedures seemed to report fewer problems specifically related to irrigation. The sites with more informal practices appeared to perceive greater problems with these irrigation matters.

c. Water Allocation Practices

One indicator of the efficiency of an irrigation system might be the amount of water being received by the farmer in his field. Table 98

Table D8 indicates that in all of the deep tubewell sites, the flow of water to the farmers' fields in each stage of rice growth was relatively constant. Except for Porabari, the hours of water availability were fairly constant across each site for each stage of rice growth. The greatest number of hours of water availability was usually during the land preparation stage, but the other four stages of growth showed relatively consistent water availability.

Among all the farmers, the farmers of Porabari received water for a longer duration in every stage. The Porabari farmers, in particular, were able to supplement their tubewell irrigation water with water from nearby ponds and channel seepage water. The figures in Table-D8 reflect only the tubewell water supplied. The inflated Porabari figures appeared because the average time needed to irrigate a pakhi of land was much higher at Porabari (Table D9). In other words, though the sample farmers in Porabari received water for the longest period of time at each stage of rice growth, it also took these same farmers longer to irrigate the same amount of land.

Table D8. Mean Number of Hours/Week/*Pakhi* That Water is Available for Rice Growing as Reported by Sample Farmers by Study Site

Stage of Rice Growth	Water Availability (mean no. hrs/wk/pakhi)				
	Mariali	Porabari	Itahata	Teknagapara	Jogitola
1. Land Preparation	2.07	4.17*	2.23	1.63	1.92
2. Seedling Establishment	1.60	3.90*	3.00**	1.00	1.43
3. Tillering	1.53	2.36*	1.92	1.06	1.15
4. Flowering	1.60	2.92*	-	1.00	1.35
5. Milking to Harvest	1.60	2.80*	-	0.88	1.25

* Seepage and pond water also used for irrigation purposes, but not included in these calculations.

**As this is the first year of operation for the Itahata deep tubewell, many farmers purchased their seedlings rather than planting them. This tended to distort these seedling establishment figures. Additionally, the rice here had not yet reached the flowering and milking to harvest stage.

Table D9. Mean Number of Hours Required to Irrigate An Average *Pakhi* by Study Site

Time	Mariali	Porabari	Itahata	Teknagapara	Jogitola
Mean No. of Hours	1.47	3.61	1.00	1.63	1.06

d. Maintenance

Maintenance of the pump and the irrigation channels is of vital importance in running an irrigation system. If maintenance procedures are poor, the finest allocation system in the world will be rendered ineffective. If, for instance, pump breakdowns are very common and require a number of days for repair, the farmers are at a great disadvantage regarding water control and the timely supply of water to their crops. Maintenance, of course, depends on the efficiency of the organization as well as the institutional support received from government or other agencies.

Table D10 reports the mean number of days required to repair the deep tubewell pump after a breakdown occurs. The low figure for Itahata is somewhat misleading as the pump was only installed in December, 1982. The most noteworthy figure in Table D10, however, is the inordinately long time required for pump repair in Mariali. Despite having a comparatively better management system and support from CARE, the Mariali pump required an average of two weeks for repair. This is all the more surprising as this is an electric pump, which theoretically requires less care. The implication is that the quality of maintenance and repair services provided by the BADC did not depend on the type of organization managing the deep tubewells.

In all five deep tubewells, farmers said that little attention was paid to maintenance and cleaning of the irrigation channels. All the sites except Jogitola had a common practice where the main channel was maintained by all the farmers receiving water from a particular channel, and the secondary channels were maintained by the individual

farmers. Most farmers said that they worked jointly with others in maintaining the main channel. For maintaining the secondary channels, most said that they themselves maintain them.

Table D10. Mean Number of Days Required to Repair Pump After Breakdown Occurs by Study Site

	Mariali	Porabari	Itahata	Teknagapara	Jogitola
Mean No. of Days Required to Repair Pump	14.0	7.8	2.6	7.6	6.9

e. Farmer Irrigation Knowledge and Behavior

Mechanized irrigation is a very complex process involving different technical, agronomic, economic, social, and behavioral factors. Among all these, the attitude and behavior of the farmers is one of the most important dimensions. The performance of an irrigation system depends very directly on how a farmer behaves. Through a better organizational effort, certain behavioral patterns of farmers could be changed.

The prevalence of certain deviant irrigation practices is one measure of how effectively the system is performing. All over the world, not merely in Bangladesh, farmers will attempt to subvert the rules of the irrigation system if those written or informal rules do not give them proper water management and control. These practices, then,

may be called deviant from the larger perspective of the entire irrigation system, but can still be quite rational from the point of view of the individual farmer.

Sometimes due to increased numbers of deviant irrigation practices by the farmers, the whole system may perform inefficiently. Table D11 shows the frequency of deviant irrigation practices reported by the sample farmers in their respective areas.

According to the farmers, most of the deviant irrigation practices did not occur frequently, except for disputes over irrigation turns. Among the five sites, Teknagapara had the most frequent deviant practices, followed by Mariali. The frequency of deviant practices was comparatively less at Porabari. Itahata, being a new deep tubewell, did not have any deviant practices. For Jogitola, the question of irrigation deviance was really not applicable, as a very different form of water management existed at this site.

The results displayed in Table D11 pose an interesting question. Why was this deviance comparatively more prevalent in Mariali, where a more participatory organizational structure existed? Perhaps some of the farmers at Mariali simply were not satisfied with the degree of water control they possessed, and despite help from CARE and BKB, they felt compelled to commit these deviant acts to increase their water control.

Table D11. Farmer Reports of Prevalence of Deviant Irrigation Practices by Study Site

Deviant Practices	Mariali No.(%)	Porabari No.(%)	Itahata No.(%)	Teknagapara No. (%)	Jogitola No. (%)
a. Farmers illegally opening outlets:					
Often	0	1(6)	0	0	Not Applicable
Sometimes	14(93)	3(19)	0	14(94)	
Never	1(7)	12(75)	13(100)	1(7)	
Missing Data	0	0	0	0	
b. Influencing irrigation management people to open outlets for extra water:					
Often	0	0	0	0	Not Applicable
Sometimes	13(87)	4(25)	0	12(75)	
Never	2(13)	12(75)	13(100)	4(25)	
Missing Data	0	0	0	0	
c. Illegal outlets on channel or breaking banks:					
Often	0	1(6)	0	0	Not Applicable
Sometimes	10(67)	3(19)	0	15(94)	
Never	5(33)	12(75)	13(100)	1(6)	
Missing Data	0	0	0	0	
d. Farmer taking more water than their regular turn allows:					
Often	0	0	0	0	Not Applicable
Sometimes	4(27)	6(38)	3(23)	15(94)	
Never	11(73)	10(63)	10(77)	1(6)	
Missing Data	0	0	0	0	

Table D11. Continued.

Deviant Practices	Mariali No.(%)	Porabari No.(%)	Itahata No.(%)	Teknagapara No.(%)	Jogitola No.(%)
e. Destructionn or damages to channel by animals:					
Often	0	1(6)	0	0	Not Applicable
Sometimes	1(7)	3(19)	0	14(88)	
Never	14(94)	12(75)	13(100)	2(13)	
Missing Data	0	0	0	0	
f. Destruction or damage to channel by farmers:					
Often	0	0	0	0	Not Applicable
Sometimes	0	5(31)	0	9(60)	
Never	15(100)	11(69)	13(100)	6(40)	
Missing Data	0	0	0	1	
g. Disputes over irrigation turns:					
Often	0	1(6)	0	0	Not Applicable
Sometimes	14(93)	10(63)	0	14(88)	
Never	1(7)	5(31)	13(100)	2(13)	
Missing Data	0	0	0	0	

The sample farmers were asked whether there was any discrimination in water distribution (Table D12). Among all the deep tubewell sites, only at Mariali did the majority of sample farmers express that there was discrimination in water distribution. Many farmers at Porabari and Teknagapara also reported that discrimination of water distribution took place in their respective organizations. The farmers stated that the sort of discrimination involved big or influential farmers taking water at the expense of small or poor farmers. Water was not distributed on a priority-need basis, and water was not provided at

a fixed date. Thus, though the prevalence of irrigation deviance was comparatively low in the five sites, the farmers reported a fair degree of water discrimination.

Table D12. Presence of Discrimination in Water Distribution by Study Site

Does Water Discimination Exist?	Mariali No.(%)	Porabari No.(%)	Itahata No.(%)	Teknagapara No.(%)	Jogitola No.(%)
No	7(46)	9(56)	12(92)	9(56)	11(79)
Yes	8(53)	7(44)	1(8)	7(44)	3(21)
Missing Data	0	0	0	0	1

To judge the farmers' irrigation knowledge, the sample farmers were asked to express their opinion on major sources of water loss in their tubewell areas. Across all five deep tubewell sites, about 90-percent of them stated that leakage and seepage in channel banks and channel bottoms was the major source of water loss. This source of water loss was later confirmed by the irrigation engineers, indicating that, at least on the issue of water loss, the farmers perceptions were close to empirical measurements.

f. Organizational Practices

A deep tubewell is both a costly and indivisible input which cannot be operated and managed by an individual farmer in a country where the average landholding is very small. For efficient and economic use of a deep tubewell, a group of farmers should join together or organize to manage the entire operation.

Among the five deep tubewells there was no organization at all in one tubewell site (Jogitola) and the four others possessed informal management groups, one being supported by the voluntary organization, CARE. This section presents farmers' views concerning the management of the deep tubewell organization and their participation in that management.

In any organization, holding meetings is an important indicator of the degree of organizational activity and how much an organization encourages its members' involvement. When the sample farmers in all the tubewells were asked whether the annual meeting of the organization was held properly, they generally responded positively (Table D13). At Teknagapara and Porabari, some farmers reported that their annual meetings were not held properly, while at Mariali, most of them expressed that their annual meetings were held properly. At Jogitola, however, since there was no organization, the farmers could not answer, and at Itahata where this was the first season of their operation, they had not yet held the annual meeting. Of course, since all these organizations were informal, they did not have any written documents indicating a specific time for holding the annual meeting. As such, the responses given by the farmers may not be fully reliable.

Table D13. Farmer Reports of Whether Annual Meeting is Held at Proper Time by Study Site

Response	Mariali No. (%)	Porabari No. (%)	Itahata No. (%)	Teknagapara No. (%)	Jogitola No. (%)
No	1(7)	5(36)	0	8(50)	Not Applicable
Yes	14(93)	9(64)	0	8(50)	
Missing Data	0	2	13	0	

The sample farmers in all the tubewells were asked questions about the procedure of leader selection, presentation of annual accounts, distribution of written receipts, and agreement with water charge expenditures (Table D14). All these variables are indicators of a healthy, viable irrigation organization in rural Bangladesh.

Table D14 shows that most farmers in all the deep tubewells, except Jogitola, reported that the leaders of their organizations were chosen by holding a meeting of the farmers. In Jogitola, the single leader in essence appointed himself manager.

In Bangladesh, a great deal of distrust and disbelief is created within the deep tubewell organization whenever there is hint of financial mismanagement. If the farmers receive annual accounts, however, they are able to judge for themselves whether their money is spent properly. Receiving these annual accounts, then, is a sign of an effective tubewell group. Most farmers in Mariali said they received these accounts. At Teknagapara and to some extent at Porabari, however, there

seemed to be some irregularities regarding making their accounts open to the members.

Table D14. Organizational Management Issues by Study Site

Organizational Issue	Mariali No.(%)	Porabari No.(%)	Itahata No.(%)	Teknagapora No.(%)	Jogitola No.(%)
Leaders Chosen at a Meeting?					
No	0	0	0	1(6)	13(93)
Yes	15(100)	16(100)	13(100)	15(94)	1(7)
Missing Data	0	0	0	0	1
Annual Accounts Open to Inspection?					
No	1(7)	6(38)	0	11(69)	14(100)
Yes	14(93)	10(63)	0	5(31)	0
Missing Data	0	0	13	0	1
Receive Receipts?					
No	2(14)	2(13)	0	5(31)	14(93)
Yes	12(86)	14(88)	13(100)	11(69)	1(7)
Missing Data	1	0	0	0	0
Agree With Water Charge Expenditures?					
No	1(7)	7(44)	0	5(31)	13(93)
Yes	14(94)	9(56)	13(100)	11(69)	1(7)
Missing Data	0	0	0	0	1

Most farmers at Mariali and Porabari said that they received a receipt from the management after paying the water charge. A smaller percentage of sample farmers at Teknagapara reported receiving receipts.

The sample farmers of Mariali also were satisfied about the expenditure of their water charge money, but several farmers at Porabari and Teknagapara had some doubt about how this money was being spent. This dissatisfaction, of course, is likely related to the problems with annual accounts and receipts at these two villages.

Overall, the management of financial affairs was more clear and open at Mariali, possibly due to strict supervision by CARE and the BKB. On the other hand, Teknagapara and Porabari, having no formal procedures, had more potential for financial mismanagement.

The farmers were asked about violation of organizational rules by the farmers and if any punishment was given to violators. As no written rules existed for any of these deep tubewells, these were actually informal irrigation rules or norms. If violations did occur, and no punishment was enforced, this would be an indicator of organizations either incapable or unwilling to police themselves.

A small number of farmers at Mariali, Porabari and especially Teknagapara reported that some farmers had violated rules (Table D15). They also reported that the violators were not generally punished. Though it is heartening to note the relative absence of rule violations at all sites, the lack of punishment for those who violated the rules indicates organizations either unwilling or unable to enforce their own operating codes.

Table D15. Prevalence of Informal Rules Violations by Study Site

Question	Mariali No.(%)	Porabari No.(%)	Itahata No.(%)	Teknagapara No.(%)	Jogitola No.(%)
Any Farmers Violated Rules?					
No	12(80)	12(75)	13(100)	10(63)	5(100)
Yes	3(20)	4(25)	0	6(38)	0
Missing Data	0	0	0	0	10
Violators Punished?					
Not applicable	12	12	13	10	5
No	2(67)	3(75)	0	4(67)	0
Yes	1(33)	1(25)	0	2(33)	0
Missing Data	0	0	0	0	10

Though it is difficult to judge the effectiveness of farmers' participation in an organization merely by recording some quantitative data, such data can give some indication of organizational effectiveness. Table D16 shows the participation of the farmers in two major decision making meetings of the organizations.

At Mariali and Porabari, most farmers attended the meeting in which the decision regarding channel construction and placement was made, but at Teknagapara and Itahata many farmers did not attend the meeting. Thus, at Teknagapara and Itahata the farmers had less involvement with this process from the very beginning. At Jogitola, the manager simply made unilateral decisions.

With regard to quality of participation, most farmers at Mariali and many at other tubewell sites, did not offer any suggestions about the construction and placement of the channel. Among those who offered suggestions, most farmers at all the sites said that their suggestion was adopted. This is at least a partial sign of effective participation in decision-making.

Table D16. Quantity and Quality of Farmer Participation in Organizations by Study Site

Issues and Effectiveness	Mariali No.(%)	Porabari No.(%)	Itahata No.(%)	Teknagapara No.(%)	Jogitola No.(%)
1. Participation in the Channel Construction/Placement Meeting?:					
No	2(13)	3(20)	5(39)	9(56)	Not Applicable
Yes	13(87)	12(80)	8(62)	7(44)	
Missing Data	0	1	0	0	
Suggestion Offered in Meeting or Elsewhere?:					
No	8(62)	7(47)	4(36)	4(50)	Not Applicable
Yes	5(39)	8(53)	7(64)	4(50)	
Missing Data	2	1	2	8	
Suggestion Adopted?:					
Not Applicable	10	8	5	12	Not Applicable
No	1(20)	3(38)	3(38)	2(50)	
Yes	4(80)	5(63)	5(63)	2(50)	
Missing Data	0	0	0	0	

Table D16. continued

Issues and Effectiveness	Mariali No.(%)	Porabari No.(%)	Itahata No.(%)	Teknagapara No.(%)	Jogitola No.(%)
2. Participation in the Water Distribution Meeting?:					
No	3(20)	5(33)	5(39)	8(50)	Not Applicable
Yes	12(80)	10(67)	8(62)	8(50)	
Missing Data	0	1	0	0	
Suggestion Offered in Meeting or Elsewhere?:					
No	11(73)	6(46)	7(54)	13(87)	Not Applicable
Yes	4(27)	7(54)	6(46)	2(13)	
Missing Data	0	3	0	1	
Suggestion Accepted?:					
Not Applicable	11	7	7	14	Not Applicable
No	1(25)	0	1(17)	0	
Yes	3(75)	7(100)	5(83)	2(100)	
Missing Data	0	2	0	0	

Most farmers at Mariali attended the meeting that decided upon water distribution, but half of the farmers at Teknagapara and some of the farmers at Itahata and Porabari did not attend the meeting. Except at Porabari, farmers in other areas did not have any opinion about water distribution to their fields. Most farmers said their opinion was accepted by the management, another indicator of real farmer involvement.

Tables D16 indicates that participation in decision-making was fairly widespread, though there were obvious incidents of poor farmer involvement. Equally significant is the finding that the quality of farmer participation was not ideal, but still fairly good. In other words, though a number of farmers apparently attended these decision-making gatherings, and the wishes of many of the sample farmers were not implemented, the majority of those who had specific requests had their appeals granted.

5. Summary of Findings

From the Diagnostic Analysis conducted in the five deep tubewells at Joydebpur, a very significant finding was that all the tubewells were being managed and controlled more or less by one individual, or a small group of individuals, irrespective of the type of organization or management. In all these sites, the person(s) who had put in the initial effort to bring the tubewell to the village had controlled the management, in most cases for years. Most of the tubewells had informal groups with a management committee. but one or two persons within the committee planned and implemented unofficial decisions. Later on, these decisions were put before the farmers either in a meeting or through personal contacts for their information or approval. No regular or scheduled meetings were held to discuss irrigation matters and, in fact, there was no mechanism for cultivating new leadership. In some cases this encouraged the leaders to adopt a despotic style of management.

Another common feature of all these tubewells was that they were all run by informal organizations, having no written rules and regulations and few linkages with government agencies. Though the villages had strong communication links with the thana headquarters, there was still very little penetration at the village level by agencies responsible for local institution building at the farm level.

One of the most interesting features of all these deep tubewells was that farmers apparently were more interested in the reliability and predictability of water than in participation. Whoever was confident about receiving water in his field at the right time in the right quantity was generally satisfied with the management and cared relatively little about his participation. In other words, he was ready to sacrifice his participation if he was satisfied with the water he received. If such a finding is true, a number of interesting questions are posed. For example, how important is participation per se if the manager is distributing water in an equitable manner to all farmers? What, if any, informal mechanisms exist to ensure that equitable distribution continues even if the management and/or leadership of the deep tubewell changes radically? Such questions deserve further thought and investigation.

This study was unable to answer one of the critical questions in irrigation research: does effective management of the system directly vary with the type of organization? As all five deep tubewells were informal (in the sense that they were not registered with the government and had no written rules) there was no way to compare them with the more formal, registered tubewell groups in Bangladesh. Yet, within this

informal management extreme, there were definite variations, ranging from the complete lack of a participatory organization in Jogitola to a group with some structured procedures in Mariali. Some variables measured in this study showed that irrigation effectiveness was highest in Mariali. However, because the data presented here are merely indicative in nature and not conclusive, the relation between organization and irrigation effectiveness needs further study.

Other findings point to certain social and organizational constraints which exist in this area. Each of the five deep tubewells had its own constraints different from each other, but certain elements were common in almost all of these tubewells:

-- None of these tubewells possessed an organizational structure with accountable leadership. The leadership structure was entirely arbitrary, which often leads (and has) to abuses of power. In the sample, some of the managers have held power since the time of tubewell installation. In some cases, this leadership style has proven beneficial to the farmers, but not always. Even in well managed sites there is nothing to prevent the future emergence of a less benevolent leader.

-- Little effort was made by government agencies to provide institutional support to the farmers. As a result, except for Mariali, farmers were not guaranteed delivery of agricultural inputs, such as fertilizer, pesticides, and credit. The farmers of these deep tubewells also were not receiving proper extension services from any government agency.

— At the farmers' level in all the sites, there was no organized effort to clean and maintain the irrigation channels. In most of the sites, there also was no fixed schedule for water distribution. The allocation of the irrigation water depended on the whims of the manager or the chowkidar.

— There was no facility for disseminating new agricultural or irrigation knowledge to the farmers. Neither formal nor informal training sessions were offered to the farmers or their leaders.

— Due to unreliable support of mechanical services from the BADC, minor repairs on the pumps sometimes took up to two weeks. If these delays in repairs occur at a critical stage in rice growth, yields could be significantly reduced.

In spite of the constraints mentioned above, the five deep tubewell sites studied all possessed beneficial characteristics. These advantageous features were a vital part of the irrigation management in the Joydebpur area. Many of these systems were operating very efficiently, even with the absence of any accountable leaders. Indeed, the overall level of farmer satisfaction was high in most of the sites. Some leaders did encourage efficient operation of the system. These leaders and the informal tubewell groups which they managed had developed procedures which at least in the short run contributed to a well-managed system.

The farmers in this area had the advantage of farming in close proximity to such research centers as the Bangladesh Agricultural Research Institute and the Bangladesh Rice Research Institute. The proximity of these facilities, and the urban center of Dhaka, helped to generate what appeared to be a more progressive outlook in these farmers. Indeed, despite a number of problems outlined above, most farmers at these sites were operating relatively efficient farming systems. It is a tribute to the farming and water management skills of these farmers that the systems were performing so efficiently.

E. List of Staff, Participants, and Workshop Schedule

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SCHEDULE

DATE	TIME	ACTIVITY	STAFF
5/3	1:00-09:00 pm	Participants arrival	All
6/3	9:00-10:00 am	Registration	All
	10:00-11:30 am	Opening Ceremonies	All
	11:30-12:00 pm	Tea	
	12:00-01:30 pm	Diagnostic Analysis (Slides) (Guests may participate)	LN/ZK
	1:30-02:30 pm	Lunch	All
	2:30-03:30 pm	Irrigation - It's Potential and Problems in Bangladesh	Dr. H. R. Khan
	3:30-03:45 pm	Tea	All
	3:45-04:45 pm	Research Development Process (Video)	RL/BK
7/3	8:30-09:00 am	Administration	ZK/LN
	9:00-10:00 am	Initial Evaluation	All
	10:00-10:45 am	Diagnostic Analysis Tape (Video)	RO/AK
	10:45-11:00 am	Tea	
	11:00-12:00	Irrigation Water Management Research and Development in Bangladesh	ZK
	12:00-12:30 pm	Pakistan: Investments in Water Management - (Video)	TP/AK
	12:30-01:30 pm	Irrigated Crops and Cropping Practices in Joydebpur	Dr. M. Zamman
	1:30-02:30 pm	Lunch	
	2:30-03:30 pm	D.A. in Gujarat, India (Video)	RL/BK
		EWUP & Mgmt Project (Video)	MH/IH
	3:30-03:45 pm	Tea	
	3:45-05:00 pm	What's in the bag? (game)	LN/ZK
		Who did it? (game)	RL/BK
8/3	8:30-09:00 am	Administration	All
	9:00-10:00 am	Current and Future Water Lifting Devices	Dr. K.A. Haq
	10:00-10:45 am	Role of Agronomist in D.A.	JB/MI
	10:45-11:00 am	Tea	
	11:00-11:45 am	Plant-soil-water relationships (Video)	JB/MI
	11:45-12:30 pm	Role of Irrigation Engineer in D.A.	TP/RO/AK
	12:30-01:15 pm	Role of Economist in D.A.	MH/IH
	1:15-02:30 pm	Lunch	

8/3 (continued)

2:30-03:30 pm	Deep Tube Well Irrigation Practices in Joydebpur	Mr. M. A.Ghani
3:30-03:45 pm	Tea	
3:45-04:30 pm	Role of Sociologist in D.A.	RL/BK

9/3	8:30-09:00 am	Administration	All
	9:00-10:00 am	Soils of Joydebpur	Mr. S.M. Saheed
	10:00-10:45 am	Water Movement in Soils (Video)	JB/MI
	10:45-11:00 am	Tea	All
	11:00-11:30 am	Team Work (Slides)	RL/BK
	11:30-12:30 pm	Individual Expectations	ZK/LN
	12:30-01:30 pm	Water Management Organizational Activities in Selected Rice Growing Countries	RO/BK
	1:30-02:30 pm	Lunch	
	2:30-03:30 pm	Economics of Crop Production in Joydebpur	Dr. S. M. Elias
	3:30-03:45 pm	Tea	All
	3:45-04:00 pm	Professional Attitudes	RL/BK
	4:30-05:00 pm	Root Growth (Video)	JB/ML
10/3	8:30-09:00 am	Administration	All
	9:00-09:30 am	Discussion on Reconnaissance	LN/ZK
	9:30-10:00 am	Team assignments	ZK/LN
	10:00-10:45 am	Team Meeting Format	LN/ZK
	10:45-11:00 am	Tea	All
	11:00-12:00 am	Discipline Planning for Reconnaissance	All
	12:00-12:45 pm	Team Meetings on Reconnaissance	
	12:45-01:30 pm	Professional Attitudes (Questionnaire)	RL/BK
	1:30-02:30 pm	Lunch	All
	2:30-03:30 pm	Farmer Involvement (Video)	RL/BK/ZK
	3:30-03:45 pm	Tea	All
	3:45-05:00 pm	Discipline Activities	
11/3		Weekend	
12/3		Weekend	
13/3	8:30-09:00 am	Administration	All
	9:00-09:30 am	Discipline Meeting on Reconnaissance Survey	All
	9:30-04:30 pm	Reconnaissance Survey by Disciplines	All

14/3	8:30-09:00 am	Administration	All
	9:00-09:45 am	Discipline Meeting on Reconnaissance Survey	All
	9:45-10:00 am	Tea	All
	10:00-01:30 pm	Reconnaissance Survey by Teams	All
	1:30-02:30 pm	Lunch	All
	2:30-03:45 pm	Team Reconnaissance Report Preparation	All
	3:45-04:00 pm	Tea	All
	4:00-05:00 pm	Team Report Preparation	All
15/3	8:30-09:00 am	Administration	All
	9:00-10:00 am	Team Presentations on Reconnaissance	All
	10:00-10:15 am	Tea	All
	10:15-01:30 pm	Discipline Group Meetings	All
	1:30-02:30 pm	Lunch	All
	2:30-05:00 pm	Team Preparation of Work Plan	All
16/3	8:30-09:00 am	Administration	All
	9:00-01:30 pm	Field Testing of Instruments by Disciplines	All
	1:30-02:30 pm	Lunch	All
	2:30-04:00 pm	Finalization of Team Work Plan	
17/3	8:00-08:30 am	Administration	All
	8:30-05:00 pm	Team Detailed Studies of Tubewells	All
18/3		Weekend	
19/3	8:00-08:30 am	Administration	All
	8:30-05:00 am	Detailed Studies	All
20/3	8:30-05:00 pm	Detailed Studies	All
21/3	8:30-05:00 pm	Detailed Studies	All
22/3	8:30-05:00 pm	Detailed Studies	All
23/3	8:30-05:00 pm	Detailed Studies	All
24/3	8:30-05:00 pm	Detailed Studies	All
25/3		Weekend	
26/3		Weekend	
27/3	8:30-05:00 pm	Detailed Studies	All
28/3	8:30-05:00 pm	Detailed Studies	All

29/3	8:30-05:00 pm	Detailed Studies	All
30/3	8:30-05:00 pm	Report Writing	All
31/3	8:30-05:00 pm	Report Writing	All
1/4		Weekend	
2/4	8:30-05:00 pm	Report Writing	All
3/4	8:30-05:00 pm	Report Writing	All
4/4	8:30-05:00 pm	Report Writing	All
5/4	8:30-08:30 am	Administration	
	8:30-01:30 pm	Team Report Preparation	
	1:30-02:30 pm	Lunch	All
	2:30-03:30 pm	Final Evaluation	
	3:30-03:45 pm	Tea	All
	3:45-05:00 pm	Expectations of Training Program	
6/4	8:00-09:00 am	Administration	All
	9:00-09:45 am	Final Report Presentation Team 1	
	9:45-10:30 am	Final Report Presentation Team 2	
	10:30-10:45 am	Tea	
	10:45-11:30 am	Final Report Presentation Team 3	
	11:30-12:15 pm	Final Report Presentation Team 4	
	12:15-12:30 pm	Break	
	12:30-01:15 pm	Final Report Presentation Team 5	
	1:15-01:30 pm	General Discussion on Final Reports	ZK/LN
	1:30-02:30 pm	Lunch	
	2:30-03:30 pm	Report on Self Evaluation	ZK/LN/BK/RL
	5:00-07:30 pm	Closing Ceremonies	

F. Glossary

ABBREVIATIONS

BADC - Bangladesh Agricultural Development Corporation
BARC - Bangladesh Agricultural Research Council
BARI - Bangladesh Agricultural Research Institute
BAU - Bangladesh Agricultural University
BIDS - Bangladesh Institute of Development Studies
BKB - Bangladesh Krishi Bank
BRDB - Bangladesh Rural Development Board
BRRI - Bangladesh Rice Research Institute
BUET - Bangladesh University of Engineering and Technology
BWDB - Bangladesh Water Development Board

CARE - Cooperative for American Relief Everywhere
CERDI - Central Extension Resource Development Institute

DTICP - Deep Tubewell Irrigation and Credit Program
DU - University of Dhaka

EC - Electrical conductivity
ET - Evapotranspiration

HYV - High-yielding variety

LLP - Low-lift pump

M.P. - Muriate of potash

RWP - Rural Works Program

S & P - Seepage and Deep Percolation

TCCA - Thana Central Cooperative Association
T.S.P.- Triple super phosphate
TTDC - Thana Training and Development Center

UAA - Union Agricultural Assistant

DEFINITIONS OF TERMS

Ail - Boundary between farmers' plots
Aman - Rice-growing season from August-December
Aus - Rice-growing season from March-August

Boro - Rice-growing season from December-May
Borrow Pit - A location from which earth has been removed for construction purposes

Chowkidar - Individual responsible for water delivery to farmers' fields

Cropped Area - Area cropped over a twelve-month period
Cultivar - Agronomic variety of a species

Don - A traditional trough-like water lifting device

Hill - A group of one or more plants that appear as one individual plant unit in a field

Laddering - A field leveling operation prior to planting

Main Channel Density - Length of main channels per unit of irrigated command area

Pakhi - 0.13 hectare
Plowpan - Compacted layer of soil resulting from plowing activities
Pukur - Pond

Thana - Small administrative area, literally translated as "police station"
Tiller - A shoot growing from the base of the stem of a grass plant

UNITS OF MEASURE

Btu	-	British thermal unit
cfs	-	cubic feet per second
cm	-	centimeter
cusec	-	cubic feet per second
ha	-	hectare = 2.47 acres
ha/l/s	-	hectare per litre per second
hp	-	horsepower
hp-h	-	horsepower hour
kg	-	kilogram
km	-	kilometer
kWh	-	kilowatt hour
l/s	-	litre per second
m	-	meter
mm	-	millimeter
mmhos	-	millimhos
rpm	-	revolution per minute
Tk	-	Taka, Bangladesh currency (approximately 24 Tk. = 1 US $)
whp	-	water horsepower