DIAGNOSTIC ANALYSIS OF FARM IRRIGATION SYSTEMS ON THE GAMBHIRI IRRIGATION PROJECT, RAJASTHAN, INDIA: VOLUMES I-V

WATER MANAGEMENT SYNTHESIS PROJECT

WMS REPORT 17

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WATER MANAGEMENT SYNTHESIS PROJECT

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DIAGNOSTIC ANALYSIS OF FARM IRRIGATION SYSTEMS ON THE GAMBHIRI IRRIGATION PROJECT, RAJASTHAN, INDIA

VOLUME I

Interdisciplinary Report

ACKNOWLEDGMENTS

This report is based on the studies conducted in the Diagnostic Analysis Workshop held in Rajasthan, India. Credit for collection of data, the preliminary analysis, and the preliminary discipline and interdisciplinary reports should go to the workshop participants and the training staff that closely supervised and monitored the study.

The Diagnostic Analysis Workshop manuals, videotaped lectures, and other instructional materials used in the Rajasthan Workshop are the result of the efforts of professional teams from various disciplines and the experiences of the Pakistan Water Management Research, Egypt Water Use and Management, and Water Management Synthesis Projects.

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GLOSSARY

Chak	A piece of command area of a canal which receives irrigation from a single outlet in the canal.
Charas	A leather bag with a spout which allows it to be emptied automatically, usually worked by one pair of bullocks.
Chowkidar	Gatekeeper (or watchman).
Gram Sevak	Village extension worker.
Kharif	Monsoon or rainy season.
MATE	Maintenance and modernization official.
Munshi	Field clerk.
Methi	Clover.
Nakka	Irrigation control structure used to divert water from the watercourse to the field channel in a farm (also called field outlet).
Panchayat	The smallest local body at the village level.
Patwari	Revenue official.
Pora	A single-row seed drill.
Pradhan	Elected head of Panchayat Samiti (development block consisting of a number of Panchayats).
Pucca	Improved, concrete or high quality structure.
Rabi	Winter season.
Sarpanch	Elected head of a Panchayat.
Vikas Adhikari	Executive head of Panchayat Samiti.
Warabandi	Rotation of water supply according to a fixed schedule.
Zaid	Hot weather season.

UNITS CONVERSION TABLE

1 chain	=	100 feet = 30 meters (approximately)
1 cusec	=	28.3 liters/second
1 bigha	=	0.22 hectare
1 acre	=	0.4047 hectare
1 Rs	=	0.102 U.S. dollars
1 quintal	=	220.46 U.S. pounds = 100 kilograms

I. INTRODUCTION AND WORKSHOP OBJECTIVES

A professional development workshop titled "Diagnostic Analysis of Farm Irrigation Systems" was held on the Gambhiri Irrigation Project at Chittorgarh, Rajasthan, India from January 18 to February 20, 1982. The workshop was sponsored by the Irrigation Department, Government of Rajasthan, India, and the United States Agency for International Development, and the Water Management Synthesis Project, Colorado State University, Fort Collins, Colorado, U.S.A. The workshop leaders were from Colorado State University, and the Irrigation and the Agriculture Departments, Government of Rajasthan.

Of the 16 participants, 8 were from Rajasthan and 8 were from Gujarat. They belonged to the Irrigation and Agriculture Departments and represented the disciplines of agronomy, economics, sociology/extension, irrigation engineering, and on-farm engineering. Three interdisciplinary teams consisting of at least one member from each of the disciplines were formed (for names of workshop participants, see Appendix A).

During the first week of the workshop, lectures and videotapes concerning concepts, principles, procedures, and skills of Diagnostic Analysis were given as well as guest lectures about the project. During the second week, a reconnaissance survey of the irrigation system, a discipline skills session, and detailed studies of the selected outlets by three interdisciplinary teams were conducted. During the third and fourth weeks, detailed studies of the irrigation system were continued. During the fifth week, an interdisciplinary report was prepared and presented by each team. A copy of the program schedule appears in Appendix B.

Following the workshop the leaders reviewed the discipline and interdisciplinary reports and conducted further analysis of the data collected during the workshop. The discipline and interdisciplinary reports were then revised. Post-workshop data analysis and report writing further enhanced the knowledge of Diagnostic Analysis techniques of the workshop leaders (host country team). A preliminary report on diagnosis of the water management and related problems for the Gambhiri Irrigation Project was developed during this period.

This interdisciplinary report proceeds with a description of the study area, followed by a synthesis of the findings of the five disciplines in context of the five project objectives of water control, productivity, resource conservation, resource allocation, and farmer involvement and institutional support. A summary of the findings and recommendations for improving the water management system of Gambhiri Irrigation Project is also presented.

Briefly, the objectives of the Diagnostic Analysis Workshop were:

(1) to describe the actual operation of an irrigation system in relation to the design and operational criteria and identify the systems constraints through an interdisciplinary analysis; and

(2) to provide the participants with the skills required to monitor and evaluate irrigation projects, thus enhancing the capacity and the capability of the government to improve irrigation facilities and management.

In realizing the above objectives, the participants were expected to benefit by (1) learning to work in a team within an interdisciplinary setting; (2) understanding the complexities of the farm and farmer's role in managing the farm and the irrigation system; and (3) expanding their discipline knowledge and field study skills.

II. STUDY AREA

A. General Description

The Gambhiri Irrigation Project was constructed from 1953-57 to use the monsoon flows of the Gambhiri River, a tributary of Berach about 30 km south of Chittorgarh in Rajasthan, India. The reservoir has a live storage of 2,300 million cubic feet (65.37 million cubic meters) of water and was designed to serve a cultivable command area of 24,196 acres (9,796 ha) with an irrigation intensity of 60 percent. There are two main canals: the left main canal and right main canal (Figure 1).

The left main canal was designed for a discharge of 95 cusecs (2.7 m^3/s) at the head and has a total length of 1,340 chains* (40.8 km) to serve a cultivable command area of 15,649 acres (6,336 ha). Besides irrigation from direct outlets along the main canals, several minors initiate from the left main canal (Table 1).

Table 1. Name of Minor, Location of Takeoff and Capacity

Number	Name of the Minor	Location of Take off (chains)	Capacity at Head (cusecs)
1	Thikaria Minor	326	13.3
2	Arnia Minor	662	12.8
3	Khor Minor	864	10.6
4	Ochari Minor	977	13.7
5	Senthi Minor	990	12.7
6	Bojunda Minor	1170	7.8
7	Rithola Minor	1225	12.5

* One chain equals 100 feet and is approximately equal to 30.48 meters.

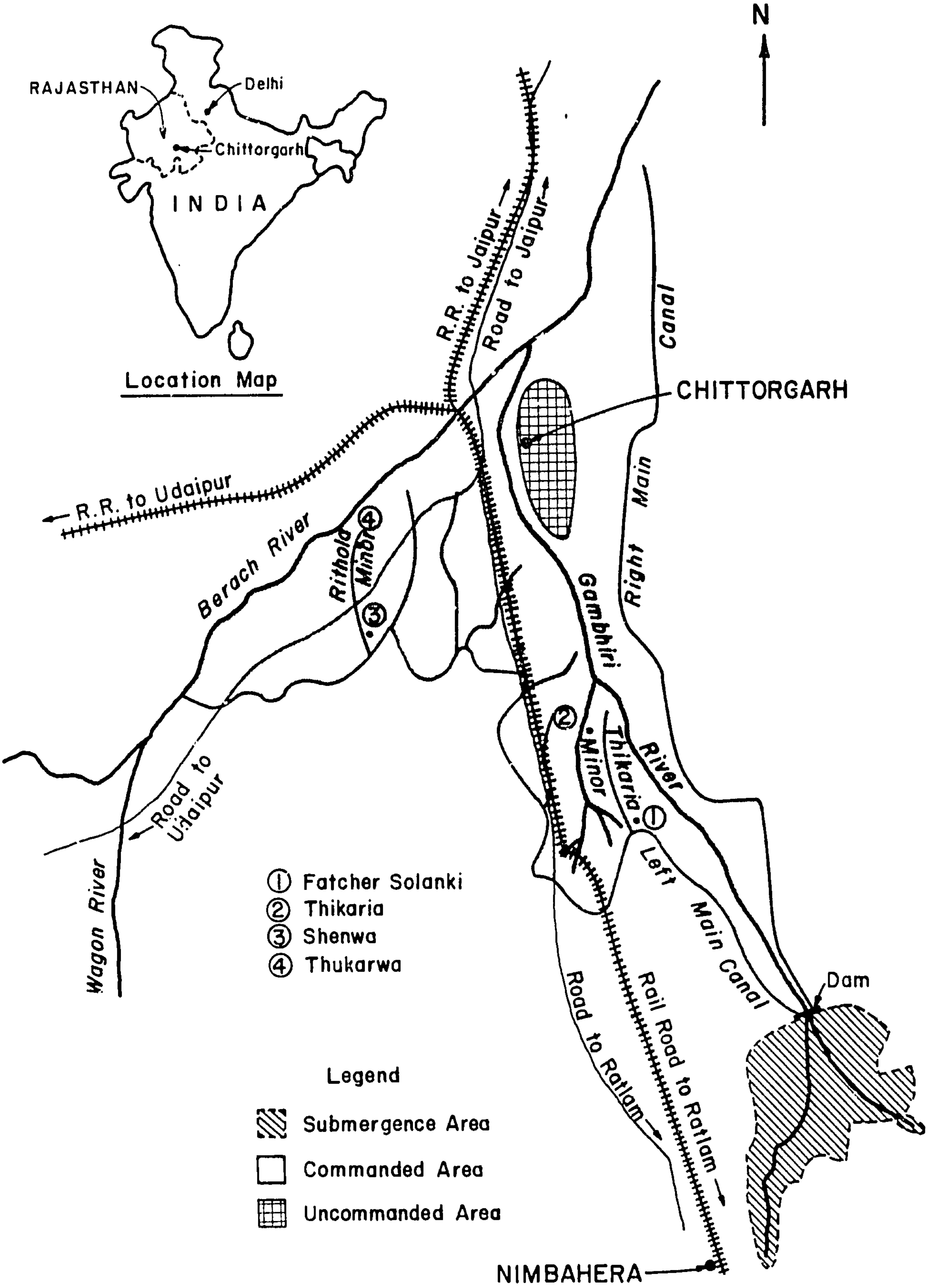

Figure 1. Command Area and Canals of the Gambhiri Irrigation Project

Similarly, the right main canal with a capacity at the head of 55 cusecs (1.6 m^3/s) commands a cultivable area of 8,547 acres (3,460 ha). The right main canal has a total length of 1,160 chains (35.4 km). This canal serves the land through direct outlets and the Kaka and Manpura minors (Table 2).

B. Climate

The project area is in a semi-arid climatic zone having three seasons during the year: a cool and dry winter from October to February, a hot and dry summer from March to mid-June, and a rainy season from mid-June to September. The annual average rainfall in the project area is 32 inches (813 mm), of which only about 6 inches (150 mm) falls during winter and the rest falls during the rainy season. Summer temperatures reach a maximum of 111° F (44° C); however, in the winter the minimum temperature seldom reaches the freezing point.

C. Soils and Ground Water

The soils of the project area are alluvial and colluvial in nature. The colluvial soils were deposited at the bottom of the foothills while the alluvial soils form part of the alluvial plains of the Gambhiri River. The soils vary from clay-loam to sandy clay-loam and overlay a hard calcareous deposit. The depth of the soil varies from 450-900 mm. The area is undulating and shows some variations in morphological characteristics such as color and texture. The water table generally varies from 16.4 ft (5 m) to 49.2 ft (15 m) during rainy and summer seasons, respectively. The 5,622 wells in the project area supplement canal irrigation to varying degrees.

Table 2. Salient Features of Gambhiri Irrigation Project

Number	Particulars	Data	
		English Units	S.I. Units
1	Gross catchment area	400 sq miles	1036 sq km
2	Intercepted catchment area	40 sq miles	103.60 sq km
3	Free catchment area	360 sq miles	932.36 sq km
4	Estimated normal yield	3,512 mcft[1]	99.39 mcum[2]
5	Gross capacity of tank at full tank level	2,700 mcft	76.00 mcum
6	Live storage capacity	2,300 mcft	65.00 mcum
7	Total length of earthen dam	10,500 ft	3200.4 metres
8	Length of overflow	2,100 ft	640.08 metres
9	Flood discharge	108,000 cusecs[3]	3056 cumecs[4]
10	Full tank level R.L.	1,477 ft*	431.90 m
11	Maximum water level	1,482 ft	433.40 m
12	Sluice sill level		
	(a) Right Canal R.L.	1,394 ft	424.90 m
	(b) Left Canal R.L.	1,394 ft	424.90 m
13	Discharge of canal at head		
	(a) Right Main Canal	55 cusecs	1.6 cumecs
	(b) Left Main Canal	95 cusecs	2.7 cumecs
14	Duty designed	8 acres/mcft	114.40 ha/mcum
15	Gross commanded area	31,617 acres	12800 ha
16	Cultivable commanded area	24,196 acres	9796 ha
17	Length of left main canal	1,340 chains	40.8 km
18	Length of right main canal	1,160 chains	35.4 km
19	Number of minors		
	(a) Left Main Canal	7	
	(b) Right Main Canal	2	

*Arbitrary Bench Mark
[1] mcft = million cubic feet
[2] mcum = million cubic meters
[3] cusecs = cubic feet per second
[4] cumecs = cubic meters per second

D. Cropping Pattern and Yield

The three cropping seasons are *Kharif* (during rainy season), *Rabi* (during winter) and *Zaid* (during hot weather). The important crops in *Kharif* are maize, groundnut, sorghum, blackgram, and in *Rabi* season, wheat, barley, gram, mustard, and opium. In *Zaid*, the crops are green gram and maize for grain (Table 3).

Table 3. Crop Rotation Before and After the Introduction of the Irrigation Project

Before the project	After the project
1. maize - fallow	1. maize - wheat
2. groundnut - fallow	2. groundnut - wheat
3. sorghum - fallow	3. sorghum - *methi* (clover)
4. blackgram - fallow	4. blackgram - mustard
5. fallow - wheat	5. maize - opium
6. fallow - gram	6. blackgram - mustard
	7. sugarcane - ratoon

With the introduction of irrigation, the single cropping system was replaced by a double cropping system over the project area. In addition, the introduction of irrigation facilities stimulated increased crop production, as evidenced by crop cutting surveys conducted by the Department of Agriculture. These surveys indicated a substantial improvement in the yields of crops common to the area after the introduction of irrigation. Although the introduction of new high-yielding varieties, fertilizers, and other improved practices was responsible for the improvement in the crop yields, the availability of irrigation facilities stimulated the adoption of the new technologies (Table 4). Despite impressive gains in production over the past 25 years, the current yield is considerably below the potential for this area.

Table 4. Yield Achieved by Farmers and the Government Experimental Farm for Wheat and Gram

Crop	Average Farm Yield (Kg/ha)*		Experimental Farm Yield (Kg/ha)
	1955-56	1980-81	1930-81
Wheat	690	1850	3500
Gram	250	490	2500

* One hectare is equal to 2.47 acres.

E. Socio-Economic Conditions

The population of the command area consists of Jats, Rajputs, Kumawat Brahmins, and Vaisyas and tribals like Bhils. Out of the total farmer population in the command area, about 84 percent are small and marginal* farmers having a landholding of less than 5 acres (2 ha). About 3 percent of the farmers have holdings larger than 10 acres (4 ha). The survey indicated a high degree of land fragmentation in this area. The number of farms in different farm size catagories is shown in Table 5.

Table 5. Farm Size Category

Number	Range of Landholding	Number of Farms
1	0 - 4 acres (0-1.6 ha)	2045
2	4 - 5 acres (1.6-2.0 ha)	102
3	5 - 10 acres (2.0-4.0 ha)	345
4	10 - 15 acres (4.0-6.0 ha)	50
5	15 - 20 acres (6.0-8.0 ha)	6
6	20 - 25 acres (8.0-10.0 ha)	5
7	25 - 30 acres (10.0-12.0 ha)	3
8	more than 30 acres (12.0+ ha)	2

In the entire Gambhiri Irrigation Project area, there were 80 tractors, 225 threshers, 1,725 electric and diesel pumpsets, and 3,000

* Farms with size of less than 2.49 ha are classified as marginal, and farms of 2.5 ha to 4.99 ha are classified as small.

improved implements in 1980-81. However, the data from the study sites indicated that 58 percent of farmers did not use tractors in the 1980-81 crop year. Five of the 64 farmers interviewed owned a thresher and about three-fourths rented threshers.

The small holdings coupled with inadequate application of chemicals and poor management have produced a level of output and income which is not sufficient to adequately maintain the average five- to six-member farm family. Farmers, particularly at Rithola, were maintaining milch animals for milk production in order to supplement their income. Due to shortage of green fodder and feed supplements, the volume of milk produced and marketed was also low.

F. Irrigation

The project was designed to provide irrigation water in the Rabi season and supplemental water during the Kharif season. The project has been operating for the last 25 years and the tank has filled every year. However, the targeted irrigated area was only exceeded in two crop years, 1974-75 and 1977-78. Even in these years, the total irrigated area increased in Kharif whereas the irrigated area in Rabi remained the same. The maximum duty achieved was 6.5 acres/mcft (million cubic feet) (93 ha/mcum) of water against the designed duty of 8 acres/mcft (114 ha/mcum). Figures 2 and 3 show the amount of water received, the area irrigated by year, and the duty of water achieved. Table 6 shows the average area of the various crops irrigated over the last 25 years. More than 47 percent of the cultivable area was irrigated in Rabi while about 7 percent was irrigated in Kharif totaling to about 54 percent irrigation intensity. Irrigation in Kharif season is limited to emergencies (Table 6).

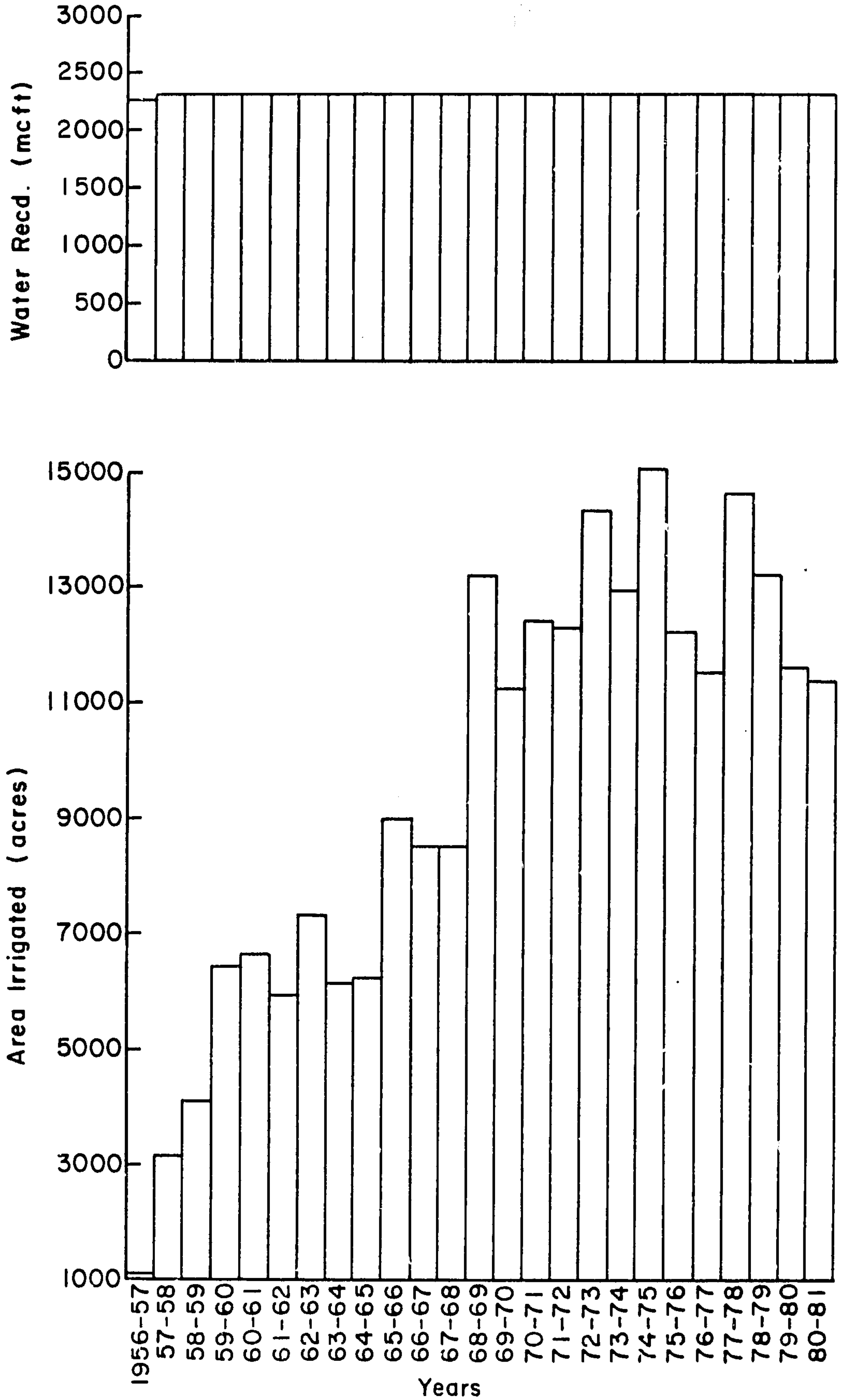

Figure 2. Water Received in Tank and Area Irrigated

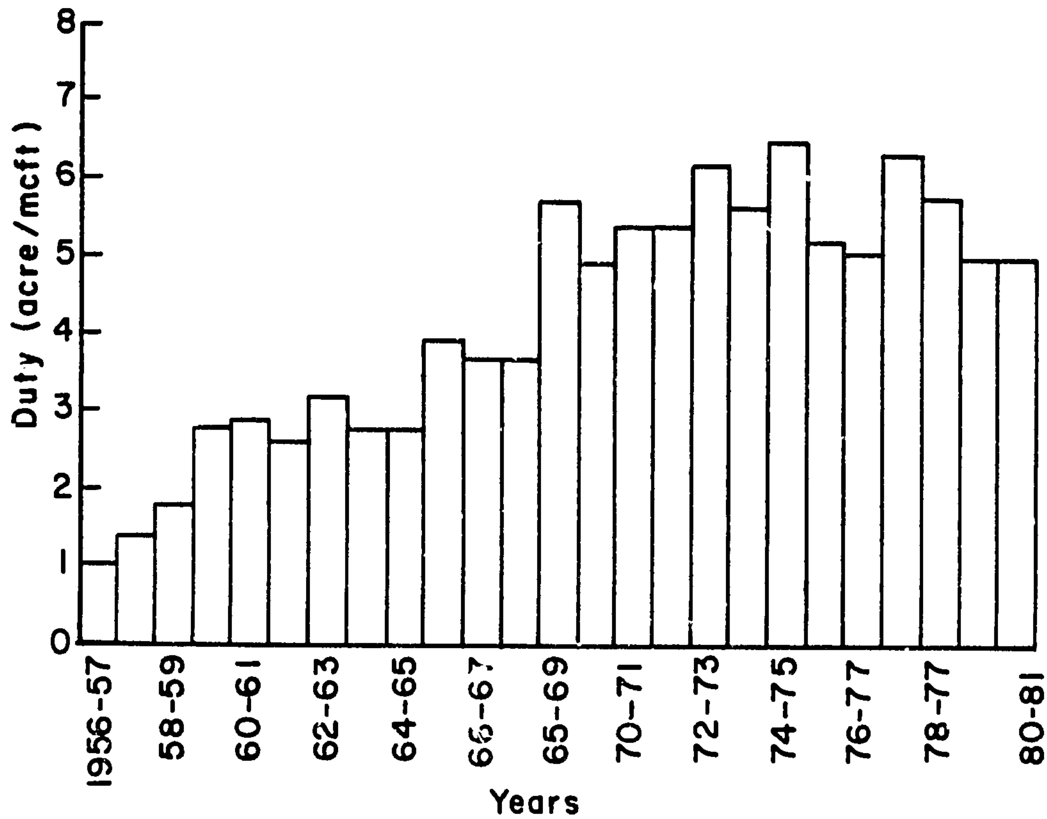

Figure 3. Irrigation Duty Per Million Cubic Feet (MCFT) of Water

Table 6. Average Cropping Pattern over the Last Five Years on Gambhiri Project

Crop	Average Area Irrigated in the Last 5 years, 1976-77 to 1980-81 (acres)	Percent of Area Irrigated	Percent of C.C.A.**
Rabi:			
1. Wheat	8,242.0	72.13	34.06
2. Barley	422.2	3.67	1.7
3. Gram	791.2	6.92	3.3
4. Wheat & Gram	71.8	0.63	0.30
5. Green fodder	309.0	12.71	1.28
6. Lentil	3.4	0.03	0.01
7. Mustard	75.0	0.66	0.31
8. Vegetables	29.4	0.22	0.12
9. Clover	783.4	6.86	3.24
10. Opium	399.4	3.50	1.65
11. Sugarcane*	285.8	2.50	1.18
12. Barley & Wheat	9.6	0.08	0.04
13. Garden	1.6	0.01	.005
14. Misc. Crops	2.8	0.02	0.01
TOTAL	11,126.0	100.00	47.20
Kharif:			
1. Sugarcane*	290.0	16.56	1.19
2. Cotton	6.3	0.36	-
3. Maize	832.3	47.53	3.40
4. Rice	120.0	6.85	0.49
5. Green fodder	59.7	3.41	0.25
6. Sorghum	16.3	0.93	0.06
7. Groundnut	266.0	15.19	1.09
8. Pulses	5.0	0.29	-
9. Misc. Crops	155.3	8.87	0.06
TOTAL	1,751.0	100.00	6.54
GRAND TOTAL	12,877.0	-	53.74

*Sugarcane is a perennial crop and is, therefore, cultivated in both <u>Rabi</u> and <u>Kharif</u>

**C.C.A. = Cultivable Command Area

Two minors originate from the right main canal and seven minors originate from the left main canal. Some of the minors are lined.

Wild flooding is the common method of irrigation. In some places, border and basin irrigation methods are also practiced. Tubewells are also present in the command area. The number of tubewells increases towards the tail of the left main canal and tail minors (Rithola).

III. METHODOLOGY

A. Diagnostic Analysis Approach

Diagnostic Analysis is one phase of a development model for improving irrigation water management. The central problems are identified in the this phase. This is followed by a Search for Solution phase which utilizes applied, adoptive, and evaluative research methods to identify technically feasible solutions for the problems identified. The alternative solutions are then assessed in terms of cost-benefit, social acceptance, institutional capabilities, and environmental impact. These two phases are followed by Implementation of a pilot project.

The Diagnostic Analysis phase consists of a sequence of activities. First, a reconnaissance of the system is conducted. System boundaries, problem areas, and possible variables to be investigated are defined in the reconnaissance stage. The detailed study that follows provides data that define the causes and measure the magnitude of the problems. All problems cannot be included; therefore, it is necessary to rank the problems according to their importance in limiting crop production and income that can be achieved. The findings are systematically presented in discipline and inter-disciplinary reports.

Special focus in a Diagnostic Analysis study is given to the participation of farmers, the understanding of farmers needs and their perception of major constraints. This procedure helps increase the awareness and interest of farmers in solving farm problems, and build credibility for institutions and individuals involved with farmers.

Problems associated with the farming system are multidimensional and require a strong interdisciplinary approach. Teamwork is highlighted for all major activities and this requires good management if the Diagnostic Analysis process is to produce the desired results (Lowdermilk et al., 1981).

B. Data Collection Procedure

1. Socio-economics

The sociologist and economists of the interdisciplinary team conducted brief interviews with farmers in the reconnaissance phase. Following the reconnaissance, detailed sociology and farm management survey questionnaires were prepared and administered to farmers.

The sociology questionnaire was administered to 64 farmers from four villages of Fatcher Solanki, Thikaria, Shenwa, and Thukarwa. The questionnaire was designed to determine farmers knowledge of proper irrigation practices and identify factors that influence farmers' irrigation and adoption behavior. Farmers were also asked to identify and rank what they considered as major constraints affecting the productivity and profitability of their farms. Separate questionnaires were developed and administered to key farmer informants and irrigation officials in order to gain more insight into the irrigation and related problems.

The team of economists prepared and administered a farm management survey questionnaire in order to obtain detailed information on costs and returns of various crops, cropping pattern, availability of essential inputs, and level of input utilization. The outlets studied were divided into three segments of head, middle, and tail for survey purposes, and a minimum of two farms were surveyed from each of these locations.

2. Agronomy

Agronomic data on the Thikaria and Rithola minors was obtained using methods described in the Monitoring and Evaluation Manual, Volume II (Lowdermilk et al., 1981). Briefly, the data consisted of soil texture, bulk density, soil and water salinity levels, soil pH, soil moisture, plant populations, tissue levels of major nutrients in wheat and barley, relative degrees of pest damage and weed infestations, as well as general observations on the crop condition, field preparation and methods of irrigation used.

The agronomist used the following specific methods for collecting data on the soils and the crops. Soil texture was determined by touch and feel method, pH by calorimetric and electrometric methods, Ec by conductivity bridge, bulk density by the core method, soil moisture deficits by touch and feel and gravimetric methods, plant populations by random counts in a one meter square frame, and nutrients status by tissue testing. In addition, the agronomist relied on the sociologist and economist to provide him with information regarding the amount and types of inputs used by farmers on both minors.

3. Engineering

The reconnaissance survey suggested that the low irrigation intensity and inadequate performance of the irrigation system was due partly to the improper design, operation and management of the irrigation system. First, the existing design was surveyed to check its appropriateness under the given conditions. Later on, the effect of design, operation and maintenance, and management of the system was related to the performance of the system.

The elevations of the canal bed, water surface, right and left bank, and right and left ground were surveyed. These data were used to calculate the gradient of the minors and watercourses; the same information was used to delineate the uncommandable area in a given chak (command area served by an outlet).

Flow rates were measured, using flumes, to estimate seepage losses and to determine the adequacy, dependability, and equity of water supply in the command area. The ponding method was also used to estimate seepage.

On the application system, cylinder infiltrometer readings, inflow rate into the field, advance and recession, and soil-moisture deficiency before irrigation were measured to estimate the efficiency, adequacy, and uniformity of the irrigation application. The depth of the water table was also measured to find out any imminent problem of subsurface drainage.

IV. FINDINGS

An irrigation project functions to achieve specific objectives. An analysis of the operation of an irrigation project should relate to how the project achieves those objectives. This section presents the findings on the operation of the Gambhiri Irrigation Project as related to the objectives of water control, productivity, resource conservation, resource allocation and farmer participation.

A. Water Control

Water control has the objective of equitable, adequate, and dependable distribution of water supplies. This following discusses the aspects of system operation for water control.

The canal distribution system was operated on a monthly rotation. It was divided into three groups: 1) tail end direct outlets and minors; 2) head reach outlets and minors; and 3) middle reach outlets and minors. For the first 10 days, full water was released in group 1, group 2 received partial supplies, and group 3 was kept closed. In the next 20 days, group 1 was completely closed whereas groups 2 and 3 were run full. Thus, the rotational program was grossly unequitable in favor of head reaches. This rotational program, however, was not pursued.

In the left main canal, the bed level was higher than designed in certain reaches. This and its cross-section have resulted in a discharge capacity which was not sufficient to feed all the minors and outlets simultaneously.

The inequity of canal water distribution is also reflected by the number of wells, which are considerably more in the tail minor (Rithola minor) than head minor (Thikaria minor). There were only two wells on the head outlet of Thikaria minor while the 145 chain and 158 chain outlets had three and four wells, respectively. Farmers also lifted water from a nearby drainage. The tail outlet of Rithola (tail minor) had 21 wells. The wells in Thikaria minor were used as a supplemental source of irrigation, while at Rithola wells were the primary source of irrigation water.

Because of the absence of regulating structures, the minors with steep slopes had flow depths which were not sufficient to provide outlets with the designed flow. Farmers added stones to minors to raise the water level and increase the outlet discharge. This practice resulted in a fluctuating discharge in outlets downstream and caused further inequity in distribution of water.

Since the minor canals were run for a shorter period than the designed duration for each outlet, the farmers opened unauthorized outlets. Consequently, all the outlets could not be operated simultaneously even with the higher discharge in the minor. As a result, the tail outlets did not receive equitable or dependable supplies. The rotational running of outlets on a minor was not enforced.

Further, the alignment, grade, and sections of the watercourses were not proper. The average slope varied from 1 in 110 to 1 in 540. There were no control or drop structures, division boxes, or field outlets of permanent structures. Lack of proper control structures resulted in erosion of the channel bed, and consequently fields that were adjacent to the watercourse could not be commanded. An additional watercourse was brought by another route to command these fields. Improper alignment also resulted in longer lengths of watercourses. In tail chaks of Rithola minor, the existing watercourses commanded only one-third of the cultivable command area. Maintenance of watercourses was also poor. Conveyance losses were estimated at about 40 percent.

The effects of structures and operational problems on water control was worsened by the disorganization of farmers at the outlet level. There were no widely accepted rules below the outlet in this system for distribution of water. No organized efforts were made by farmers to clean and maintain the channels. The Irrigation Department policy was that "water distribution below the outlet was the responsibility of the farmers."

Wild flooding, the general method of irrigation, resulted in ineffective distribution of water. Even the graded border systems in use were far from satisfactory. The fields had unleveled topography and the difference between the maximum and minimum levels exceeded the standard by several magnitudes. The division and subdivision of flow rate when several fields were irrigated simultaneously resulted in a low rate of discharge into a field. Coupled with variability of surface shape and improper design, this resulted in a variable depth of application. From the limited data available, fields were under-irrigated and under highly stressed conditions, as evidenced by poor crop stands and yields in the area.

Because of the fluctuating discharge in the minor, the farmers on outlets downstream in general, and that of tail minors in particular, were not certain about the time and volume of water that would be made available to them. The unreliability of water had affected the selection of crops, use of inputs, cropping practices, and management decisions. An example of unreliability of canal water supplies was observed at the 158 chain outlet of Thikaria Minor. A farmer had applied irrigation from a well just three days before canal water arrived because he was unaware of the timing and volume of canal water that would be made available to his farm. He also irrigated again after three days of well irrigation from canal water due to the uncertainty over when canal water would again be available.

B. Productivity

The availability of water can be directly related to the use of other inputs and the crop yield. On the average, the use of improved crop varieties was more prevalent at the head minor of Thikaria than at the tail minor of Rithola. Fertilizer and other purchased inputs were applied more by the farmers who had better access to irrigation water. In the case of wheat, farms located at Thikaria Minor obtained a yield of 3,830 kg/ha, while wheat yield averaged 1,590 kg/ha at Rithola Minor.

Use of fertilizer and other inputs for a particular crop also varied by farm size. Because of better cash flow and access to credit, large farms were able to invest more in fertilizer and other yield-increasing inputs compared with small farms and achieved higher yield.

C. Resource Conservation

Soils of the Thikaria and Rithola Minors are calcic cambisols (UNESCO, 1977). Calcic cambisols are soils formed from alluvial and colluvial deposition over limestone. Although these soils possess favorable chemical and physical properties, they are often too shallow for agricultural use.

Observations of soil profiles in wells, eroded field channels, and road cuts suggested that a substantial portion of the soils commanded by the Ghambiri Irrigation Project are shallow, or less than 60 cm. Similar evidence was obtained from soil samples taken from randomly selected fields in the outlets studied. The extent to which the efficiency of the Ghambiri Irrigation Project can be improved will partly depend upon the portion of the command area having deep soils. It is difficult to improve the water use efficiency in soils that can only store 5 to 8 cm of water for plant use.

Calcic cambisols are also susceptible to erosion problems. Uneven topography, improperly designed field channels and the use of large stream flows with wild flooding irrigation practices have resulted in moderate to severe erosion problems throughout both minors. If allowed to continue, soil erosion will eventually cause the demise of the Ghambiri Irrigation Project. Improving the design and operation of the conveyance system and land shaping can decrease erosion to levels considered acceptable for these soils.

Because canal water is both unreliable and inadequate, private wells are often used for supplemental irrigation water on both minors. The salinity levels of the groundwater are high (950 to 2,400 μmhos per cm). Where the wells are used to supplement irrigation water supplied by the canal, there is little reason to believe that salinity buildup will occur. Since the Ghambiri irrigation project was designed to provide less water than required for maximum crop production, the use of well water as a supplementary source is considered important.

On the lower reaches of the Thikaria and throughout the Rithola Minor, many farmers relied exclusively on wells as the primary source of irrigation water. Increased salinity levels in these soils were attributed to the use of well water as the primary source of irrigation water. These areas should be monitored to determine whether this is only a seasonal buildup or a long-term buildup of salts associated with the use of saline groundwater for irrigation.

D. Resource Allocation and Farm Income

The allocation of farm resources; investment in improved seed, fertilizer, and other agrochemicals; and the resulting output of various crops and income for the sample farms studied at the Ghambiri Irrigation Project corresponded with the availability and dependability of irrigation water. This relationship becomes apparent by comparing the head minor of Thikaria and the tail minor of Rithola and the head and tail outlets within these minors.

Major crops in *Kharif* season are maize and groundnuts and in *Rabi* season wheat, gram, and barley. Farms with access to supplemental irrigation water (wells) also produced the cash crops of sugarcane. Large farms allocate a greater area to production of cash crops such as groundnuts and gram, while small farms devote most of their resources for production of staple crops for farm household consumption.

A profitability comparison of crops at Thikaria minor indicated groundnuts were the most profitable crop with a net income of Rs 1,461 per ha. Wheat was the second most profitable crop (Table 7).

Groundnuts require large investments in fertilizer and other purchased inputs which small farmers are unable to commit. Large farmers have also applied a greater amount of fertilizer and other inputs to staple crops of wheat, maize, and barley, and achieved higher yields than small farmers.

Table 7. Production Cost and Income in Rupees per Hectare for Major Crops at Thikaria Minor

Crop	Gross Income	Production Cost	Net Income
Groundnuts	4766	3305	1461
Gram	2036	1544	492
Maize	2990	2341	649
Wheat	3271	2533	730

The impact of availability of irrigation water on yield and profitability can be well illustrated by examining the case of wheat at Thikaria and Rithola minors. The socio-economic surveys indicated that farms at Thikaria averaged two more irrigations than farms at Rithola. The farms located at the head of Thikaria achieved an average yield of 32.22 quintal and a net income of Rs 870 per ha as opposed to a yield of 13.50 quintal and net income of Rs 281 per ha by farms located at the head of Rithola Minor (Table 8).

Table 8. Cost and Return per Hectare of Wheat by Location along the Watercourse

Location		Yield (Quintal)	Gross Income(Rs)	Production Cost (Rs)	Net Income (Rs)
Thikaria	Head	32.22	3,580	2,710	870
	Tail	22.95	2,860	2,433	427
Rithola	Head	13.50	2,745	2,464	281
	Tail	18.00	3,108	2,743	365

Major differences in output and income from the wheat crop were also observed between farms located at the head and tail of Thikaria Minor. The farms located at the head outlets of Thikaria minor achieved a yield of 32.22 quintal and a net income of Rs 870, compared to the yield of 22.95 quintal and income of Rs 427 per ha by farms located at the tail outlets. Because of greater certainty of receiving an adequate supply of water, the farm located at the head outlets of Thikaria Minor had invested more in their wheat crop in the form of fertilizer and use of other inputs and had achieved a higher yield and income compared to the tail outlet farms.

The farms at Rithola indicated a reverse pattern in terms of yield and income by location, consistent with water availability. The farms located at the tail outlets of Rithola depended more on well irrigation for their crops than farms situated at the head outlets of Rithola. Access to an assured source of irrigation water resulted in higher yield and income (Rs 365 per ha) for the tail end farms in spite of the higher irrigation cost for use of water-lifting devices. The farms located at the head end of Rithola Minor achieved an income of Rs 281 per ha from their wheat crop.

Overall, the farmers are aware of the importance of fertilizer and other chemicals in attaining higher output from their limited land resource. However, the shortage of capital for small and marginal farmers, and the uncertainty of getting adequate irrigation water for tail-end farmers, have resulted in fertilizer and other input application below the recommended rate. The availability of fertilizers and other agrochemicals is also a problem. Travel to distant markets needs to be made in order to obtain these inputs. A Cooperative Society exists for Thikaria farmers, but does not supply inputs in an adequate quantity and on time. Availability of credit for small and marginal farmers can be viewed as another constraining factor in use of purchased inputs and increasing farm income.

E. Farmer Participation and Institutional Support

1. Farmer Participation

Farmer participation at the Ghambiri Irrigation Project is limited to the attendance of the farmers at yearly meetings of the Water Distribution Committee. This organization meets at least once a year and decides upon the timing and quantity of water to be released from the reservoir during the Rabi season. Though farmers are not official members of this Committee, they can attend these meetings to voice their concerns. The meetings, however, often turn very unruly, with arguments and counter-arguments expressed by a number of different interests. Farmer participation does exist via these Water Distribution Committee meetings, but it is not effective participation. With no local organization or discipline along the system, the farmers are unable to speak with a single voice. Even though this forum does exist, very few of the farmers interviewed at the study sites felt that this committee was helpful. Indeed, though many farmers knew of the existence of the Water Distribution Committee, few of them were aware of how irrigation decisions were made in the corporate body.

At the farm level, there is virtually no farmer participation, simply because there is no farmers' committee for the proper distribution of water along the outlets. The farmers, of course, are involved on a purely individual level in the allocation of water along the outlet, but there are no formal arrangements for two or more farmers to cooperate in water distribution.

One of the key constraints in this entire system is the lack of effective farmer participation, primarily because of the lack of local irrigation organization and discipline at the farm level. What little farmer participation that does exist occurs only at the higher bureaucratic level of the Water Distribution Committee, and even this minimal participation is highly inefficient. At the farm level, organized farmer participation is virtually nonexistent. This total lack of any local-level irrigation organization and farmer participation results in poor on-farm water control and a highly inequitable distribution of water.

2. _Institutional Support_

The institutional agricultural support received by the farmers is somewhat sporadic and uncertain, but does appear to be slightly more reliable than any institutional irrigation support. On the agricultural side, there are Cooperative Societies in the project area, but they are fairly ineffective. The "Training and Visit" extension system is instrumental in this area, but it has never been fully successful. The farmers generally knew the local _gram sevak_ (village extension worker) and rated his performance as generally high, but the farmers received no irrigation information from this agricultural official. The _gram sevak_ simply receives no irrigation training which he could pass on to the farmers. General agricultural information (like new crop varieties and fertilizer use) is received sometimes by the farmers, but with no degree of regularity.

The irrigation institutional support provided to the farmers is even less reliable. The farmers do know the canal _patwari_ and _chowkidar_, but the farmers rate the helpfulness of these officials as relatively low. The farmers are receiving a very uncertain and unreliable flow of information concerning irrigation matters from the irrigation authorities. This lack of information from institutional sources contributes to a sense of unpredictability about water supplies.

A major problem is simply that the farmers perceive the irrigation authorities as "enemies," and at the same time, the irrigation officials generally see the farmers as the "problem" in the effective operation of the system. Both parties, however, desire a stable and reliable supply of water.

Although the lack of communication and information flow between the farmers and authorities generates antagonism between these two parties, in reality they have the same goals.

V. CONCLUSIONS

A high degree of inequity seems to exist in the distribution of the canal water between the head minor (Thikaria) and the tail minor (Rithola), and between the head and tail outlets within each one of these two minors. The farms located closer to the main canal obtained all their irrigation water from the canal, farms located at the intermediate points supplemented the canal water with well water, and farms located at the end of the distribution system relied predominantly on well water for irrigation.

Due to an inadequate supply of canal water and the high cost of lifting water from the well, the farms located at the tail minor (Rithola) and tail outlets of Thikaria Minor followed a cropping pattern that would minimize the water requirement rather than maximize farm income. Further, the amounts of fertilizer and other inputs applied, and the yields achieved for most crops, were lower for farms with poor access to irrigation water. The uncertainty of the timing and volume of water available has resulted in farmers choosing a low input-low output farming operation.

The structural, institutional, and organizational problems which have led to the inequitable water distribution, inadequacy of irrigation water, and unreliability of the system are as follows:

(1) The operation of the canal system, both main canal and minors, occurs without specific regulation of discharge, elevation, timing, or duration, and with no consistent criteria for decisions, record of water levels and gate openings, nor any knowledge of the flow rate at any point in the system.

(2) The flow rate, elevation of water surface, and outlet discharge are not explicitly designed nor operationally managed. The designed rotation of outlets on a minor for operational control is not operationally managed. Operational discharge for an outlet command is increased by many magnitudes by farmer installed checks and many unauthorized outlets. Lack of discipline at both the farm level and bureaucratic level contributes to these practices.

(3) Below the outlet, farmers operate an inequitable and undependable rotation on each outlet without assistance from the government. With ineffective farmer participation and no local-level farmers' organization, the rotation schedule remains very unpredictable. Farmers design, construction, operation, and maintenance of field channels in a disorganized fashion have resulted in major water losses from the system.

(4) Field application of water is generally by wild flooding or modified wild flooding. This primitive and ineffective method of water application has resulted in waste and contributed to the inadequacy of water supplies.

The Diagnostic Analysis study of the Gambhiri Irrigation Project has highlighted a number of good attributes which reflect the effort already made by various organizations of the Government of Rajasthan. These attributes should prove valuable in further improving the outcome of the Gambhiri Irrigation Project in the future.

Some of the positive aspects of the Gambhiri Irrigation Project as determined by the Diagnostic Analysis Workshop are as follows:

(1) The Irrigation Department is attempting to improve the project through a modernization program.

(2) An agricultural research and extension training center has an effective program for improving crop production.

(3) In some villages of the project, institutional services and inputs are provided in an effective manner to farmers.

(4) Farmers have dug many wells, operate labor-intensive _charas_, or have adapted diesel or electric pumps to provide more adequate water supply with increased and improved inputs and higher crop yields.

(5) Farmers are receptive to new production techniques and use of new inputs.

VI. RECOMMENDATIONS

A detailed Diagnostic Analysis study followed by an evaluation of alternative solutions is needed in order to arrive at appropriate recommendations for resolving the irrigation and related problems at the Gambhiri Irrigation Project. In order to accomplish this, further training in Diagnostic Analysis procedure, and improvements in technical knowledge and skills of the project personnel is essential.

A list of preliminary recommendations is as follows:

(1) Provision of regulating structures to control the flow depth in the minors, drop or chute structures to prevent erosion, and division boxes and field outlets to properly apportion water to the farmers should be considered.

(2) Farmers should be given help in the proper laying and designing of watercourses, field channels and application systems.

(3) Discipline in the operation and maintenance of the system, both on the farm level and bureaucratic level, needs to be tightened. Rules which are widely accepted by all parties need to be established, and enforced.

(4) Some form of local-level social organization of irrigation needs to be established. Local associations of water users can not only enhance and smooth the flow of information between farmers and officials, but they can also act as a body which regulates the distribution of water below the outlet.

(5) Effective farmer participation should be encouraged. Although the irrigators are not totally excluded from participating in system level decision-making, their involvement is piece-meal. On the outlet level in particular, coordinated farmer participation should be stressed in water distribution procedures and channel maintenance activities.

(6) Further training should be provided for the staff of the irrigation and agriculture department to enhance their technical knowledge and monitoring and evaluation skills.

(7) Effort should be made to further improve the coordination and cooperation between various disciplines and departments.

VII. REFERENCES

Lowdermilk, M.K., W. Clyma, M. Haider, D.Lattimore, J. Layton, D. Lybecker, A. Madsen, L. Nelson, D. Redgrave, F.Santopolo, and D. Sunada. 1981. Diagnostic Analysis of Farm Irrigation Systems: Monitoring and Evaluation Manual, Vol. II. Water Management Synthesis Project, Colorado State University, Fort Collins, CO.

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APPENDIX A

LIST OF WORKSHOP PARTICIPANTS

LIST OF PARTICIPANTS BY DISCIPLINE

Discipline	Team I	Team II	Team III
Agronomy	S.T. Patel	Ashok Chauhan	K.N.S. Kaurwa
Economics	R.J. Patel	D.G. Patel	K.S. Khamesra
Extension	M.C. Patel	D.J. Patel	Amrit Lal Mathur
Irrigation	R.B. Shah G.G. Kaushik	P.C. Patel	R.C. Agarwal
O.F.D.	Anandi Lal Mathur	N.S. Maliya V.K. Patri	D.D. Sharma

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APPENDIX B

WORKSHOP SCHEDULE

TENTATIVE SCHEDULE*

Date	Day	Time	Activity	Staff
1/17	SUN	-	Participants arrive	All
1/18	MON	8:30-9:00	Administration	All
		9:00-10:00	Opening Ceremonies	All
		10:00-10:30	Tea	
		10:30-11:00	Overview of the Workshop	WC
		11:00-12:00	Overview of the Project	K.S. Kang
		12:00-1:00	Lunch	
		1:00-2:00	Soils of the Project	S.P. Tomar
		2:00-3:00	What's in the Bag?	LN
		3:00-3:15	Tea	
		3:15-5:00	Who did it? Team Building	MKL/RL
1/19	TUES	8:30-9:00	Administration	All
		9:00-10:00	Development Model Overview	WC/MKL
		10:00-10:15	Tea	
		10:15-11:15	Crops of the Project	S.P. Tomar
		11:15-12:00	Diagnostic Analysis Overview	WC
		12:00-1:00	Lunch	
		1:00-2:00	Role of Extension/Sociology	MKL/RL
		2:00-3:00	Video Film 1	LN/WC
		3:00-3:15	Tea	
		3:15-4:15	Role of Economics	URM
		4:15-5:00	Professional Attitudes	MKL
1/20	WED	8:30-9:00	Administration	
		9:00-10:00	Role of Agronomy	LN
		10:00-10:15	Tea	
		10:15-11:15	Role of Engineering	WC
		11:15-12:00	Sequence for Diagnostic Analysis	WC/MKL
		12:00-1:00	Lunch	
		1:00-2:00	Professional Attitudes	MKL
		2:00-3:00	Video Film 2	LN
		3:00-3:15	Tea	
		3:15-4:15	Application of Diagnostic Analysis	WC/MKL
		4:15-5:00	Individual Expectations	MKL/RL
1/21	THURS	8:30-9:00	Administration	All
		9:00-10:00	D.A. Applications Gujart	WC/MKL
		10:00-10:15	Tea	
		10:15-11:15	Team Work	WC/MKL
		11:15-12:00	Video Film 3	LN
		12:00-1:00	Lunch	
		1:00-2:00	Planning D.A.	WC/MKL
		2:00-3:00	Reconnaissance Discussion	WC/MKL
		3:00-3:15	Tea	
		3:15-3:45	Team Meeting Format	LN
		3:45-5:00	Discipline Planning for Reconnaissance	All

*Evening sessions may be scheduled during the first two weeks on a need basis. No more than two evening sessions will be held during a week.

Date	Day	Time	Activity	Staff
1/22	FRI	8:00-8:30	Administration	All
		8:30-12:00	Reconnaissance Head of Minor	All
		12:00-1:00	Lunch	
		1:00-5:00	Reconnaissance Tail of Minor	All
1/23	SAT	8:00-8:30	Administration	All
		8:30-9:30	Discipline Meetings to Discuss Reconnaissance	All
		9:30-9:45	Tea	
		9:45-10:30	Staff Report Reconnaissance	WC/All
		10:30-12:00	Discipline Planning for D.A.	
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Selected Outlet by Discipline	All
1/24	SUN	9:00-5:00	Field trip to Namano (optional)	
1/25	MON	8:00-8:30	Administration	All
		8:30-12:00	D.A. of Selected Outlet by Disciplines	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Selected Outlet by Disciplines	All
1/26	TUES	-	Holiday	
1/27	WED	8:30-9:00	Administration	All
		9:00-10:00	Report Presentation by Staff	WC/All
		10:00-10:15	Tea	
		10:15-12:00	Planning for Physical Mapping	WC/MKL
		12:00-1:00	Lunch	
		1:00-2:00	Team Planning for D.A.	All
		2:00-3:00	Review and Discussion of D.A.	RL/All
		3:00-3:15	Tea	
		3:15-5:00	Team Planning for D.A.	All
1/28	THURS	8:00-8:30	Administration	All
		8:30-12:00	D.A. of Head Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Head Outlets	All
1/29	FRI	8:00-8:30	Administation	All
		8:30-12:00	D.A. of Head Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Head Outlets	All
1/30	SAT	8:00-8:30	Administration	All
		8:30-12:00	D.A. of Head Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Head Outlets	All

Date	Day	Time	Activity	Staff
1/31	SUN		Field Trip?	
2/1	MON	8:00-8:30	Administration	All
		8:30-12:00	Lunch	
		12:00-5:00	D.A. of Head Outlets	All
2/2	TUES	8:00-8:30	Administration	All
		8:30-12:00	D.A. of Head Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Head Outlets	All
2/3	WED	8:00-8:30	Administration	All
		8:30-12:00	D.A. of Head Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Head Outlets	All
2/4	THURS	8:00-8:30	Administration	All
		8:30-12:00	Disciplinary Summary Evaluations of Head Outlets	All
		12:00-1:00	Lunch	
		1:00-4:30	Interdisciplinary Summary Evaluations of Head Outlets	All
		4:30-5:00	Self Evaluation	MKL/RL
2/5	FRI	8:00-8:30	Administration	All
		8:30-10:00	Team Presentations on Head Outlets	All
		10:00-10:15	Tea	
		10:15-10:45	Team Presentations on Head Outlets	All
		10:45-12:00	Team Planning D.A. of Tail Outlet	All
		12:00-1:00	Lunch	
		1:00-2:00	Self Evaluations	MKL/RL
		2:00-5:00	Team Planning D.A. of Tail Outlets and/or D.A.	All
2/6	SAT	8:00-8:30	Administration	All
		8:30-12:00	D.A. of Tail Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Tail Outlets	All
2/7	SUN		Field Trip	
2/8	MON	8:00-8:30	Administration	All
		8:30-12:00	D.A. of Tail Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Tail Outlets	All
2/9	TUES	8:00-8:30	Administration	All
		8:30-12:00	D.A. of Tail Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Tail Outlets	All

Date	Day	Time	Activity	Staff
2/10	WED	8:00-8:30	Administration	All
		8:30-12:00	D.A. of Tail Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Tail Outlets	All
2/11	THURS	8:00-8:30	Administration	All
		8:30-12:00	D.A. of Tail Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Tail Outlets	All
2/12	FRI	8:00-8:30	Administration	All
		8:30-12:00	D.A. of Tail Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	D.A. of Tail Outlets	All
2/13	SAT		Field Trip to Udaipur and Jaismand	
2/14	SUN		" "	
2/15	MON*	8:00-8:30	Administration	All
		8:30-12:00	Disciplinary Summary Evaluations of Tail Outlets	All
		12:00-1:00	Lunch	
		1:00-5:00	Interdisciplinary Summary Evaluations of Tail Outlets	All
2/16	TUES	8:00-8:30	Administration	All
		8:30-10:00	Team Presentations on Tail Outlets	All
		10:00-10:15	Tea	
		10:15-10:45	Team Presentations on Tail Outlets	All
		10:45-12:00	Team Final Report Preparation	All
		12:00-1:00	Lunch	
		1:00-2:00	Self Evaluation	MKL/RL
		2:00-5:00	Team Final Report Preparation	All
2/17	WED	8:00-8:30	Administration	All
		8:30-12:00	Team Final Report Preparation	All
		12:00-1:00	Lunch	
		1:00-5:00	Team Final Report Preparation	All
2/18	THURS	8:00-8:30	Administration	All
		8:30-12:00	Team Final Report Preparation	All
		12:00-1:00	Lunch	
		1:00-5:00	Team Final Report Preparation	All

*Video lectures and films will be available during this week as requested by the participants.

Date	Day	Time	Activity	Staff
2/19	FRI	8:00-8:30	Administration	All
		8:30-12:00	Team Final Report Preparation	All
		12:00-1:00	Lunch	
		1:00-3:00	Team Final Report Presentations	All
		3:00-3:15	Tea	
		3:15-5:00	Team Final Report Presentations	All
2/20	SAT	8:30-10:00	Workshop Evaluation	WC/MKL
		10:00-10:30	Tea	
		10:30-12:00	Closing Ceremonies	All
		12:00-1:00	Special Lunch	

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DIAGNOSTIC ANALYSIS OF FARM IRRIGATION SYSTEMS ON THE GAMBHIRI IRRIGATION PROJECT, RAJASTHAN, INDIA

VOLUME II

Agronomy Report

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I. EXECUTIVE SUMMARY

The Gambhiri Irrigation Project is located at the crossing of latitude 24° 42' N and longitude 74° 43' E in Chittorgarh district of Rajasthan. The total command area as per revenue records is 31,617 acres.

The project area falls under the semi-arid climatic zone with hot, dry summers and cool, dry winters. The annual rainfall is 32 inches, with 0 to 6 inches occurring during the Rabi season (November-April). Historically, the Gambhiri Irrigation Project was established in 1956 to increase crop production during the Rabi season and to provide supplemental water during drier periods of the Kharif season (May-October).

The impact that the Gambhiri Irrigation Project has made on the area is demonstrated by the changes in crops and cropping rotations that have occurred on the two minors (Thikaria and Rithola) selected for this study. Prior to the establishment of the irrigation system, only single cropping systems were feasible (Tables 1 and 2). After the establishment of the Gambhiri Project, single cropping systems were replaced by double cropping systems. Such a change has most certainly benefited the farmers in this area.

In addition, the introduction of irrigation to this area stimulated increased crop production, as evidenced from crop cutting surveys conducted by the Indian Department of Agriculture and Statistics. These surveys indicate a substantial improvement in the yields of crops common to the area

Table 1. Common Crop Rotations Before and After the Introduction of Irrigation in the Area Commanded by the Thikaria Minor

Before Irrigation		After Irrigation	
Kharif	*Rabi*	*Kharif*	*Rabi*
maize	fallow	maize	wheat
groundnut	fallow	maize	opium
urd	fallow	groundnut	wheat
sorghum	fallow	sorghum	clover
fallow	wheat	urd	mustard
fallow	gram	sugarcane	ratoon

Table 2. Common Crop Rotations Before and After the Introduction of Irrigation in the Area Commanded by the Rithola Minor

Before Irrigation		After Irrigation	
Kharif	*Rabi*	*Kharif*	*Rabi*
maize	fallow	maize	wheat
groundnut	fallow	maize	barley
urd	fallow	maize	opium
sorghum	fallow	groundnut	wheat
fallow	wheat	sugarcane	ratoon
fallow	grass		

before and after the introduction of irrigation (Table 3). Although new high-yielding varieties, fertilizers, and other improved practices also were responsible for the major improvements in crop yields, the adoption of these improve cropping practices was directly associated with the availability of irrigation water.

Table 3. Average Crop Yields Before the Introduction of Irrigation After 25 Years and on a Government Farm

	Crops	Farmers 1955-56 kg/ha	Farmers 1980-81 kg/ha	Government 1980-81 kg/ha
1.	Maize	670	1350	2500
2.	Sorghum	290	1000	4500
3.	Groundnut	450	800	1500
4.	Urd	320	550	1200
5.	Wheat	690	1850	3500
6.	Gram	250	490	2500

While the Gambhiri Irrigation Project has made a significant contribution to the well-being of the farmers in the area, the operation of the system is below the original design level. Evidence for this is the wide gap between the yields of crops obtained by farmers and those obtained on the Government research farm (Table 3). The Gambhiri Irrigation Project was established without the benefit of a soil survey report. As a result, the base data associated with the physical and chemical properties of the soils of the Gambhiri Project are lacking.

For the above reasons, the Gambhiri Irrigation Project was selected as the site for a Diagnostic Analysis Workshop. The workshop focused on an interdisciplinary approach which recognizes the complexity of irrigated agricultural systems. The purpose of a Diagnostic Analysis itself is to learn how to analyze an irrigation system through field investigation and to understand how that system operates so that suitable suggestions could be given for improvement.

Figure 1 shows the particular areas of the irrigated agricultural environment studied, and discusses those aspects of the biophysical environment of specific interest to the agronomist. Within these areas are a list of the various parameters considered important to the description of the soils, crops, climate, and management practices presently existing on the Gambhiri Irrigation Project. Careful examination of this list suggests that the collection of agronomic data would require a substantial portion of a cropping season. However, within the workshop, agronomic data collection was restricted to a total of 12 days, 6 days on the Thikaria minor and 6 days on the Rithola Minor. As a result, many of the parameters associated with the climate and management practices of the farmer were not included in field investigations. In addition, the shorter time period restricted the sampling procedures. Consequently, this report may only be regarded as indicative.

II. RECONNAISSANCE STUDIES

Prior to the actual Diagnostic Analysis activities, a reconnaissance survey of the two minors was conducted. The purpose of this survey was to gain an overall understanding of the irrigated cropping system and to identify those aspects of the system which would require more detailed investigations. Observations made during the reconnaissance survey are presented for each minor separately.

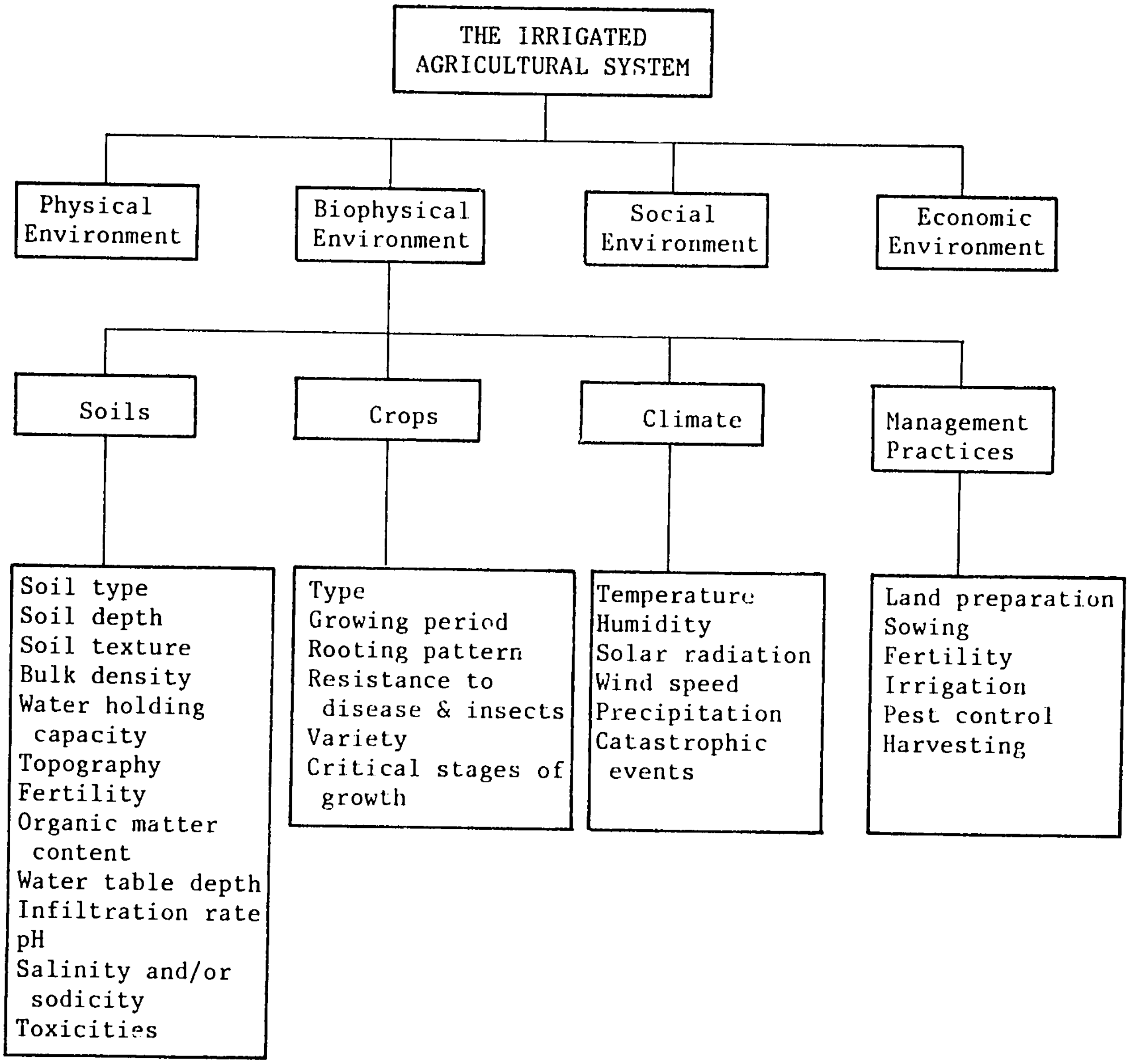

Figure 1. The Major Environments of the Irrigated Agricultural System and the Parameters of Concern in the Biophysical Environment

A. Thikaria Minor

1. Soils

(1) Soil textures varied from clay to clay loams with clay loams found predominantly at the tail outlets.

(2) pH measurements with a soil reaction test kit revealed surface soil pH values around 8.4 at the head outlets to 8.0 at the tail outlets.

(3) General fertility of the soils appeared to be adequate for the crops being grown.

(4) Nitrogen deficiencies were observed in many wheat fields.

(5) Field topographies were quite variable (level, graded, and undulating). However, the majority of fields were characterized as having undulating topographies.

(6) Soil depths appeared to be shallow on the head outlets with greater soil depths occurring at the tail outlets.

(7) The soils have a tendency to develop cracks as the moisture deficiency increases.

2. Irrigation

(1) Observations of the on-farm irrigations suggested that a large percentage of the fields on the Thikaria Minor were irrigated by wild flooding. A few graded borders were observed and a few level basins.

(2) As distance from the main canal increased, the availability of canal water decreased in both time and amount.

(3) The number of wells used to supplement canal irrigation increased from the head reaches to the tail reaches of the Thikaria Minor. Conversations with some farmers indicated that a number of fields were irrigated by wells only.

(4) Conversations with farmers suggested that little knowledge existed about when canal openings and closures occurred.

(5) Symptoms of over irrigation were not exhibited by the crops, although water was standing in some fields for more than one day.

(6) Field channels were poorly designed, constructed, and maintained. Overtopping and seepage through rat burrows were common.

(7) There was an excess number of outlets.

(8) The farmers increased the discharge at the individual outlets by placing stones in the minor.

3. Crops

(1) The major area was sown with an improved variety of wheat (K. Sona). Local varieties of gram and mustard occupied large areas and opium was grown in a few areas.

(2) Stage of Growth:

wheat-tillering to ear emergence
gram-branching to flowering
mustard-flowering
opium-preflowering to flowering

(3) Intercropping observed:

wheat/mustard
opium/garlic/lentil
gram/mustard and lentils
clover/mustard
peas/mustard

(4) Plant populations were not uniform. Some fields had good stands, particularly those near wells and those at the head outlets. Spacing between wheat rows was 25 to 30 cm, rather than the recommended 20 to 22 cm as a result of pora methods of sowing.

(5) Field preparation appeared to be adequate.

(6) Conversations with a few farmers indicated that fertilizer usage consisted primarily of D.A.P. and complete fertilizers. Basal fertilizer applications were low. The farmers tend to apply most of the fertilizer at or near tillering. Uneven application was evident.

(7) Many fields of wheat and gram and mustard were infested with weeds. Species observed were:

Convolvulus arvensis
Cynodon dactylon
Chenopodium sp.
Anagallis arvensis

(8) Pests and disease: aphid infestations on mustard and podborer infestations on gram were observed in a few fields. White rust in mustard was also observed.

(9) Major crop rotations for the Kharif and Rabi seasons were said to be:

maize-opium
maize-wheat
sugarcane-ratoon-wheat
groundnut-wheat
fodder sorghum-gram

(10) General appearances of the wheat crops along the minor indicated that the condition of the crops deteriorated from the head of the minor to the tail of the outlet. However, these observations were variable due to the presence of wells throughout the command area.

B. Rithola Minor

1. Soils

(1) Soil textures were mostly loamy.

(2) pH measurements with a soil reaction kit revealed surface soil pH values of 7.4.

(3) Soils of the Rithola Minor appeared slightly less fertile than those of the Thikaria Minor.

(4) Shallow soil depths were suggested by observations of the soil profiles in wells and deeply cut irrigation channels.

(5) As with the Thikaria Minor, field topography of the Rithola Minor was quite variable.

2. Irrigation

(1) Wild flooding, graded borders, and level basins were observed.

(2) Conversations with a few farmers indicated that only one irrigation from the canal had been provided.

(3) Farmers were not sure when the next rotation would occur.

(4) Irrigation wells were common throughout the command area.

(5) Many of the wheat and barley fields appeared to be under soil moisture stress.

(6) There were a large number of outlets.

(7) Field channels were poorly constructed and maintained.

3. Crops

(1) The major crops on this minor were barley, wheat, opium, sugarcane and gram. All were apparently local varieties.

(2) Stage of growth:

wheat-tillering to flowering
barley-tillering
gram-branching to flowering
mustard-preflowering to flowering

(3) Intercropping observed:

wheat/mustard
barley/gram
opium/garlic
gram/mustard

(4) Plant populations were often very low, possibly as a result of soil moisture stress, low planting rates, and poor nutrition.

(5) General appearances suggested that the lack of water from the head of the Rithola Minor to the tail of the minor had a more negative affect on crops (wheat and barley) than it had on the Thikaria Minor. The condition of wheat was poor throughout most of the Rithola Minor. Similarly, farmers were growing barley on the Rithola Minor and not on the Thikaria Minor. Barley is more resistant to periods of moisture stress than wheat. As observed in the Thikaria Minor, crops irrigated with canal plus well water or well water only were usually in better condition.

III. DETAILED STUDIES

Observations made during the reconnaissance survey suggested that detailed agronomic studies of the Rithola and Thikaria Minors focus on detailed descriptions of the soils, crops, and irrigation practices of the farms in order to determine the production constraints.

A. Methods Used in Diagnostic Analysis

The interdisciplinary teams studied three previously selected outlets located at chain numbers 5, 145, and 158 on the Thikaria Minor and four outlets at chain numbers 6, 21, 75, and 77. Within each outlet, agronomists restricted their data collection to fields of wheat, barley, gram, and mustard. In addition, the agronomist worked with the on-farm engineers in conducting the irrigation evaluations.

A brief description of the methods used for collecting data on the soils and crops follows.

(1) A 1-meter square metal frame was used for plant population counts. The frame was randomly thrown at three places in each field and

the total number of tillers were counted. The average plant population was calculated from these three measurements.

(2) A colorimetric method was used in the field for determining the variations in the pH of the soils with depth. In addition, some soil samples were brought to the laboratory where soil pH was measured electrometrically.

(3) The soil texture was determined by the touch-and-feel method. Soil texture determinations were made throughout the soil profile.

(4) The electrical conductivity of soil and water was determined in the laboratory by conductivity bridge. The soil samples were collected depthwise with the help of tube augers.

(5) The bulk density of the soil was determined with a core sampler. The soil was not disturbed, and samples were taken and weighed in the laboratory.

(6) The soil moisture deficit was determined by gravimetric analysis of soil samples and by the touch-and-feel method.

(7) The weed populations were counted and were put in three grades--low infestation, medium infestation, and high infestation.

(8) Laboratory facilities for soil analysis were not available. Therefore, the nutrient status (N, P, + K) was determined by field observation and tissue testing.

(9) The cropping intensity was determined using the following formula:

$$\text{cropping intensity} = \frac{\text{cropped area}}{\text{land area}} \times 100 \quad .$$

B. Results of Diagnostic Analysis

1. Soils

The soils of the project area are alluvial and colluvial in nature. The colluvial soils were deposited at the bottom of the foothills. The alluvial soils form a part of alluvial plains of the Gambhiri River. The area is undulating and the morphological characteristics, such as color and texture, vary.

The soils at Thikaria Minor were clay to clay loam whereas at Rithola Minor the soils were clay loam to sandy clay loam. Apparently, the soils on both minors were well-drained. The watertable generally fluctuated from 3 to 15 m during the monsoon and winter season. The watertable at the time of the Diagnostic Analysis Workshop was 4 to 9 m below ground level.

The soils of both minors developed over a deep limestone deposit. The soil depth in both minors ranged from 45 cm to over 90 cm, and the typical soil profile (Table 4) described these soils as calcic cambisols (FAO-UNESCO, 1977). Calcic cambisols are recognized as good agricultural soils, but they are susceptible to water erosion and are often subject to inadequate soil moisture regimes during periods of low rainfall. A summary of the soils data for both minors is presented in Tables 5 and 6. Of particular importance are the electrical conductivity measurements made on the irrigation water and soils. The canal water had an electrical conductivity of 600 μmhos/cm, which is considered to be good quality irrigation water. However, water samples from wells on both minors tended to be of poor quality (1700 to 2400 μmhos/cm). Since there are a large number of wells in the project area (5,622 wells), used to supplement canal irrigation to varying degrees, a potential for salinity development exists. However, only one field out of several sampled on both minors had increased salinity. This field was located on the outlet

Table 4. A General Profile Description of the Soils on the Thikaria and Rithola Minors

Horizon	Depth cm	
A_p	0 - 10 cm	Dark greyish brown to dark brown with numerous limestone fragments, crumb structure and frequent roots. The soil pH varied from 7.7 to 8.2 and soil texture ranged from a clay loam to sandy clay loam
B	10 - 35 cm	Greyish brown to dark brown with numerous limestone fragments and a blocky structure. Roots were usually present. The pH ranged from 7.6 to 8.2 and textures ranged from clays to sandy clay loams.
C	35 - 55 cm	Yellowish brown to brown with numerous fine and coarse limestone fragments and a blocky structure. Few roots present. The pH ranged from 7.5 to 8.2 with a clay loam to sandy clay loam texture.
R	55 + cm	Limestone

Table 5. Soils Data Collected from Head, Middle, and Tail of Thikaria Minor

S.N.	Factors	Head	Middle	Tail	Remarks
1.	Texture	clay loam to clay clay % increases with depth	clay loam small gravels	clay loam	
2.	E.C. soil mmhos/cm	2.1 - 2.5	1.5 - 2.2	1.4 - 1.6	
3.	pH lab test	7.0 - 7.4	7.6 - 7.8	8.0 - 8.2	
	pH field test	7.4 - 7.6	7.6 - 8.2	7.5 - 8.2	
4.	Depth of soil (m)	0.6 - 1.0	0.6 - 1.0	0.3 - 1.0	
5.	E.C. of well water (μmhos/cm)	1500	1700 - 1900	2400	well water not safe for irrigation
6.	E.C. of canal water (μmhos/cm)	600	600	-	
7.	Depth of water table (m)	4 - 4.9	6.7 - 8.8	7.0 - 7.9	
8.	Moisture deficit (cm/30 cm)	6.0 - 14.0	2.0 - 5.6	3.8	
9.	Topography (% slope)	< 1.0	0.06 - 0.6	< 1.0	

Table 6. Soils Data Collected from Head, Middle, and Tail of Rithoia Minor

S.N.	Factors	Head	Middle	Tail	Remarks
1	Texture	sandy clay loam to clay loam	clay loam	sandy loam to clay loam	
2	E.C. soil mmhos/cm	1.5 - 5.0	1.4 - 2.2	1.8 - 2.2	E.C. at head is severe
3	pH lab test pH field test	7.6 - 8.2 7.6 - 8.0	7.3 - 8.0 7.8 - 8.0	7.8 - 8.0 -	
4	Depth of soil (m)	0.6 - 1.5	1.5 - 1.8	0.6 - 1.8	
5	E.C. of well water (μmhos/cm)	950 - 2200	2000 - 2200	2200	
6	E.C. of canal water (μmhos/cm)	-	600	-	
7	Depth of water table (m)	5.8 - 7.0	5.5 - 8.5	7.0 - 7.9	
8	Moisture deficit (cm/30 cm)	-	5.8 - 7.4	9.4	
9	Topography (% slope)	-	-	0.5 - 2.0	

at chain 66 on the Rithola Minor and soil samples from this field had electrical conductivities of 5 mmhos/cm. The electrical conductivity values of soil samples from all other fields only ranged from 1.4 to 2.2 mmhos/cm, indicating that most of the area is free from salinity problems.

Similarly, colorimetric pH measurements and electrometrical pH measurements confirmed the calcareous nature of these soils and indicated a lack of problems associated with sodium. The pH of a soil also indicates the relative amount of soil nutrients available to the crop. Within the range of pH values measured, soils are often incapable of supplying iron and zinc in the quantities needed by many field crops. However, iron or zinc deficiency symptoms in the field crops were not observed on either minor.

Surface bulk density measurements ranged from 1.2 to 1.3 for the soils of both minors. Although the soils appeared to be low in organic matter content, soil structure and tilth appeared to be adequate.

Because of the time constraints imposed on the workshop, it was not possible to determine moisture holding capacities of these soils. However, previous research conducted by the Indian Department of Agriculture suggested that field capacity and wilting point values for these soils were approximately 25 to 27 percent and 11 to 12 percent by weight.

With the exception of the shallow depth of soils in some areas of both minors, the chemical and physical properties of the soils on both minors appeared highly favorable for the crops being grown. However, there was reason to believe that salinity problems may develop within those areas of the minors which depend heavily upon the use of well water for irrigation.

2. Crops

The main crop rotations, presented earlier, were similar for both minors. However, water availability obviously influenced the amount of acreage allotted to each crop. This influence was apparent on both minors.

The most important cash crops grown during the *Rabi* season were opium (for medicinal purposes) and sugarcane. The area planted to opium was strictly controlled by the Government. But, both opium and sugarcane were grown only on fields that had an assured supply of water from wells. Both the number of wells and the associated acreage of opium and sugarcane increased from the upper to the lower reaches of the minor. The increased number of wells observed on the lower reaches of the minor was associated with the lack of an assured water supply from the canal.

The next most important cash crop of the area was gram. A similar trend was observed with this crop. Conversely, wheat, which is a secondary cash crop, occupied approximately 80 percent of the acreage at the head of the minor. Apparently, the availability of canal water was sufficient to risk wheat production but not *Rabi* season cash crops. Instead, the farmers on the upper reaches of the Thikaria Minor relied on groundnuts, grown during the *Kharif* season, for their main cash crop (see Appendix A).

Unfortunately, data concerned with the amount of area cultivated with different crops was only collected on outlets located on chain 145 of the Thikaria Minor and chain 75 of the Rithola Minor. However, these data show that 100 percent of the irrigated command area was cropped on the outlet at chain 145, whereas only 61 percent of the irrigated command area was cropped on the outlet at chain 75 of the Rithola Minor (Table 7). Such a difference was obviously due to the inequitable distribution of water along the Rithola Minor. Farmers on this outlet reported that, of the two to three expected irrigations, only one irrigation was received from the canal during the first two months of the Rabi season. Because of the low discharge of their wells, it was not possible to apply supplemental water in sufficient quantities to all of the fields. Consequently, most of the fields planted with wheat and barley were in very poor condition.

Table 7. The Actual Area Planted to the Various Crops and the Percentage of the Irrigated Command Area (ICA) Occupied by the Various Crops

Crop	Area in ha Thikaria (chain 145)	% ICA	Area in ha Rithola (chain 75)	% ICA
Total ICM	12.2		13.8	
Wheat	7.3	60	6.5	47
Barley	-	-	0.8	6
Sugarcane	1.6	13	-	-
Opium	0.4	3	0.4	3
Lucerne	0.8	7	-	-
Methi	0.8	7	0.4	3
Gram	0.8	7	-	-
Others	0.4	3	0.4	3
Total Cropped	12.2	100	8.5	61

3. Irrigation Practices

The Indian Department of Agriculture recommends six irrigations for dwarf wheat at six different crop growth stages. Generally the interval of irrigation was 20 to 15 days in the month of December and January and 12 to 15 days in the month of February and March. But in the command area, most of the farmers at the head of a minor had a tendency to overirrigate the wheat. At some places, the interval of irrigation was 8 to 10 days. Excessive irrigation adversely affects wheat yields and wastes water which is in short supply. The farmers on the lower reaches of the Thikaria Minor and throughout the Rithola Minor received less than two irrigations for wheat. Also, many of the farmers on the lower reaches of the Rithola Minor had not received water for a number of years. Instead, they relied on well water for their crops.

Table 8 shows the average tiller counts for two wheat fields located at chain 145 of the Thikaria and chain 21 of the Rithola Minors. Both fields were irrigated with canal and well water at the proper stages of growth. Tiller counts on these fields were near to or at those recommended for high production and almost two times higher than those observed in wheat fields on either minor irrigated with canal water only. In addition, both of these fields appeared to be in much better condition than those dependent upon canal water alone. The potential yields for these wheat fields were approximately 3,500 to 4,000 kg/ha. The data suggests that farmers who are able to supplement canal water with well water tend to grow better crops. This may be due to the higher costs associated with irrigation by wells which causes them to apply water at the correct growth stages.

Table 8. The Nutrient Status and Tiller Counts for Two Wheat Fields on the Thikaria and Rithola Minors.

Outlet				Tillers/m^2			
Location	N	P	K	Head	Middle	Tail	Average
Chain 21 (Rithola)	M	M	M	348	296	452	365
Chain 145 (Thikaria)	M	M	M	450	465	425	447

Although the use of wells for supplemental irrigation obviously benefited the crop, the low flow rates from these wells limited the extent of their use. This was demonstrated on the Rithola Minor, where farmers relied on well water almost exclusively. They reported that it was impossible to provide adequate water to all of their fields with well water only. As a result, most fields were subjected to soil moisture stress during the growing season. This was reflected in the low tiller counts obtained on wheat fields on the tail of the Rithola Minor (Table 9).

Table 9. The Effect of Topography and Soil Moisture on Tiller Counts for Two Wheat Fields on the Rithola Minor

Outlet Location	Average Percent Moisture in the Root Zone			Average Field Moisture (percent)	Average Number of Tillers/m			
	H	M	T		H	M	T	Average
Chain 21	13.5	13.9	14.9	14.1	288	240	219	249
Chain 75	16.0	17.5	15.0	16.2	210	141	82	144

The cultivation of the barley crop was limited to the areas with unassured irrigation and to saline areas. The Indian Department of Agriculture recommended three irrigations for barley, but farmers on the Rithola Minor only applied one irrigation. This irrigation coincided with the availability of canal water.

The Indian Department of Agriculture recommended only one irrigation during the pod formation stage of gram crops sown in deep clay to clay loam soils. For shallow soils, the recommendation was for two irrigations, the first at branching stage and the second at pod formation stage. However, the farmers generally applied one irrigation at the Thikaria Minor, and the time of application was dependent upon the availability of canal water.

Field topography also was an important factor which influenced the irrigation practices of the farmer on both minors. Within most of the fields observed on either outlet, there were two or more slopes, often complicated with high and low areas. Because of this, most fields were irrigated by wild flooding. Typically, a field was subdivided with bunds into a number of border strips 2 to 6 m wide. The water was applied from a cut in the watercourse at the head of one or more of the borders. As the water advanced down the border, the bunds were cut, allowing the water to flow into the adjacent the border, the bunds were cut, allowing the water to flow into the adjacent border. Cross bunds were often used to insure that water was diverted over high areas of the field. In particularly troublesome fields, water was applied from different sides of the field and/or channels were constructed throughout the length of the field. One farmer located on chain 77, whose field sloped towards the center from both ends, constructed a channel around the border of his field in order to insure that the distal end of the field was irrigated.

The effect of field topography on tiller counts was demonstrated on two fields located on the Rithola Minor. A wheat field located on chain 21 (field no. 94) had slope variations of -.01, +.13, -.43, +.01, and -.09 percent, respectively for 0-30, 30-60, 60-90, 90-120, and 120 - 135 m distances from the head of the field. Average tiller counts at the head, middle, and tail portions of this field were 288, 240, and 219, respectively (Table 9). The variation in tillers obviously resulted from the application of low flow rates against the slope. In another field on the Rithola Minor, the average tiller counts at the head, middle, and tail portions of the field were 210, 141, and 82, respectively. Although the profile of this field was not taken, within-field elevation differences were obviously responsible for this variation in tillers.

Only one field, which had received some land shaping, was irrigated by the more efficient border irrigation method. This field was located on chain 5 of the Thikaria Minor. However, an irrigation evaluation executed on this field indicated that the opportunity time used by the farmer was insufficient for applying the correct amount of water.

A modified basin irrigation method was also observed in fields planted with the high value opium crop. Fields of opium, usually 0.4 ha or less, were subdivided into a number of small basins, the size of which reflected the levelness of the topography. Most of the small basins were 2 to 3 m wide and 6 to 9 m long. Water was either applied from a channel constructed within the field or from basin to basin.

4. Nutrient Status

The recommended fertilizer practices for wheat, barley, gram, maize, and groundnuts are shown in Appendices B and C. Field observations suggested that few farmers followed the recommended fertilizer practices. Farmers who did apply fertilizer, were located in areas which received more than two irrigations from the canal or they obtained supplemental irrigation water from private wells. This was demonstrated by tissue levels of nitrogen, phosphorus, and potassium in wheat. Table 10 summarizes this data according to the general location of wheat fields along the minors and within the outlets. In general, higher levels of fertility were recorded in wheat fields located on the Thikaria Minor than on the Rithola Minor. Higher levels of fertility also were recorded in wheat fields located on the upper reaches of both minors and within the upper reaches of each outlet. The availability of irrigation water followed a similar pattern, suggesting that fertilizer practices on the Gambhiri Irrigation Project, are strongly related to the system's ability to provide the required amount of water at the correct times.

5. Crop Management Practices

The recommended cultural practices for the crops selected in Diagnostic Analysis are shown in Appendices B and C. Field observations of irrigation, nutrient deficiencies, and weed infestations indicated that few farmers on either minor applied all of the practices recommended by the Indian Agricultural Department. However, on some fields irrigated by both canal and well water, the level of management used by the farmer appeared near optimum.

Table 10. The Tissue Levels of Nitrogen, Phosphorus, and Potassium in Wheat at Different Locations Along the Minors and Within Outlets

Location of Outlets and Fields Within Outlets	Thikaria Minor N P K	Rithola Minor N P K
Head Reaches of the Minor		
Head	M M M	M M M
Middle	M M M	M M M
Tail	M L M	L L M
Middle Reaches of the Minor		
Head	M L M	M L M
Middle	M L M	M L L
Tail	M L L	M L L
Tail Reaches of the Minor		
Head	M L L	M L L
Middle	M L L	L L L
Tail	M L L	L L L

Note: H = high, M = medium, L = low
N = nitrogen, P = phosphate, K = potash

The improved levels of management, observed in fields irrigated by both canal and well water, strongly suggested that the farmers' management on both minors was related to the availability of water.

In addition, crop data concerned with the seed source and variety planted indicated that management practices deteriorated as the availability of water decreased. Within all outlets studied on the Thikaria Minor, farmers tended to use improved crop varieties. However, the farmers on the lower outlets, where water availability was less certain, applied less fertilizer, were more careless about weeding fields, and rarely applied insecticides.

The differences in crop management practices were even more apparent between the two minors. Nearly all of the farmers on the Rithola Minor, where the availability of canal water was least assured, used local varieties of gram and barley. In addition, they applied low rates of fertilizer, seldom weeded their fields, and applied no insecticides (Appendix Tables D-R).

Conversations with some farmers revealed an unwillingness to invest in the added labor and input costs associated with improved practices. Their unwillingness to invest in other inputs was due to the unassured and untimely water supply.

6. Constraints

a. Water Distribution

The most serious constraint to crop production was the undependable and inequitable distribution of irrigation water. All of the farmers, regardless of their position on the irrigation system, were unsure of the canal openings and closures. Because of the inequitable distribution of canal water, many farmers on lower reaches of the Thikaria Minor and all farmers on the Rithola Minor received fewer than two irrigations during the Rabi cropping season. As a result, cropping intensities, use of other production inputs, and crop yields substantially decreased as distance from the distributary and outlet increased. Clearly an improvement in the dependability and equity of the water distribution system would increase the effectiveness of a limited supply of water and improve the overall welfare of the farmers in the Gambhiri Irrigation Project area.

b. Field Channel Conveyance System

Field channels throughout the Gambhiri Irrigation Project were constructed by the farmers without the benefit of technical assistance. As a result, water losses from seepage, spillage, and leakage are excessive due to the poor design and improper layout of the field channels. A program intended to improve the dependability and equity of water distribution also should include field channel restoration. The construction of a properly designed field channel system would reduce conveyance losses and thus maximize the use of a limited water supply. Such a program must involve the farmers in order to increase their awareness and commitment to the wise long-term use of water resources.

c. Field Irrigation

Wild flooding was the most common method of irrigation observed. This form of surface irrigation requires constant attention by the irrigator and results in the nonuniform application of water. Other, more effective methods of surface irrigation would improve the within-field distribution of water and increase the effectiveness of labor and other physical inputs. A land shaping program designed to replace the relatively inefficient wild flooding irrigation methods with more precise surface irrigation systems would complement other programs designed to improve the water distribution system. Such a program would benefit all of the farmers if land consolidation were included.

d. Salinity Hazards

Canal irrigation is supplemented with wells on many of the farms in the area, and in a number of instances, wells serve as the major source of irrigation water. However, the quality of the well water, with electrical conductivities from 1100 to 2200 μmhos/cm, is poor. Field data suggested an increase in salinity in fields primarily irrigated with well water. While wells provide an additional and needed source of water, the use of wells as the primary source of irrigation water may result in salinization of the land. Thus, fields primarily irrigated by well water should be monitored for salinity buildup. In addition, farmers should be cautioned about the use of well water.

e. Crops and Cropping Patterns

Research activities of the Agricultural Department should continue to focus on alternative crops and cropping patterns that maximize the use of limited water resources. These activities must be expanded to the farmers' fields where more realistic appraisals can be made.

IV. LITERATURE CITED

FAO-UNESCO. 1977. Soil Map of the World, Volume VII, South Asia. Food and Agriculture Organization, Rome.

APPENDIX A

The Crop Calendar for Selected *Rabi* and *Kharif* Crops,
Gambhiri Irrigation Project, Rajasthan

Table A-1. *Kharif* season

S.M.	Crops	June	July	Aug.	Sept.	Oct.	Nov	. . . .	May
1.	Maize	[—	—	—	—	—	—]		
2.	Groundnut	[—	—	—	—	—]			

Table A-2. *Rabi* Season

S.M.	Crops	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	. . . . .	Sept.
1.	Wheat		[—	—	—	—	—]			
2.	Barley		[—	—	—	—	—]			
3.	Gram	[—	—	—	—	—]				

APPENDIX B

The Recommended Practices for Selected Rabi Crops for Gambhiri Command Area

Wheat:

1. Varieties

   For timely sowing: WH-147, HD2009. Raj 911 and Kalyan Sona

   For rainfed sowing: D134 and Mukta

2. Seed treatment: treat the seed with any mercurial compound at the rate of 2 gms/kg of seed.

3. Soil treatment: broadcast aldrin 5 percent, or B.H.C. 10 percent at the rate of 25 kg/ha before sowing.

4. Fertilizer application:

	Nutrients--kg/ha		
	N	P	K
a. Most economic dose	60	30	0
b. Optimum dose	90	35	0
c. Maximization dose	120	40	30
d. Rainfed crop	30	15	0

5. Time of fertilizer applications

   Rainfed: all N P K drilled at sowing time,

   Irrigated: half dose of N, full P and K drilled, at sowing and top dressing of remaining half dose of nitrogen at first or second irrigation.

6. Seed rate:

   a. Ordinary varieties: 100 kg seed/ha

   b. Bold varieties: 125 kg seed/ha

   Sowing time: 15th to 30th November depending on temperature

   Spacing: line to line--20 to 22 cm

   Weed control: spray after 30 days of sowing with 500-700 litres of water either 0.05 kg a ℓ 2-4-D ester or 0.75 kg a ℓ amine salt/ha

Barley:

1. Varieties:

   Timely sowing: RDB-1, RD103, and RD57

   Late sowing: RS-6

   Rainfed: RD-31, RDB-1

   Saline soils: BL-2

2. Seed treatment: as done in wheat

3. Soil treatment: as done in wheat

4. Fertilizer applications

	Nutrients--kg/ha		
	N	P	K
a. Normal sowing	60	20	0
b. Rainfed crop	25	15	0

5. Time of fertilizer application: as in wheat

6. Seed rate:

   a. Normal sowing: 100 kg seed/ha

   b. Late sowing and saline soils: 125 kg seed/ha

7. Sowing time: middle of October to middle of November, depending on temperature
8. Spacing: line to line spacing--25 cm
9. Weed control: As per wheat crop

Gram:

1. Varieties
   a. Irrigated area: GNG-16, Dahod yellow, H-208, C235, and R.S.-11
   b. Rainfed area: RSG-2 and Dahod yellow
2. Seed treatment: treat the seed with rhizobium culture and after drying treat the seed with fungicide, i.e., Bavistin at the rate of 0.5 gm/kg of seed
3. Soil treatment: as in wheat
4. Fertilizer applications

	Nutrients--kg/ha		
	N	P	K
a. Irrigated crop	20	40	0
b. Rainfed crop	10	25	0

5. Time of fertilizer application: all fertilizer must be drilled before sowing in soil.
6. Seed rate: 80 kg/ha
7. Sowing time: first week of October to middle of November, depending on temperature
8. Spacing line to line: 30 cm
9. Weed control: Hand weeding at branching stage by manual labor

APPENDIX C

The Recommended Practices for Selected Kharif Season Crops

Maize:

1. Varieties: Hybrid Ganga-2, Hybrid Ganga-5, and composite Vijay
2. Seed treatment: any mercurial compound at the rate of 3 gm/kg of seed
3. Soil treatment for termite control: apply 25 kg/ha before sowing either BHC 10 percent or aldrin 5 percent
4. Fertilizer application:

	Nutrients--kg/ha		
	N	P	K
a. Irrigated crop	90	30	0
b. Rainfed crop	45	15	0

5. Time of fertilizer application:
   a. Irrigated crop: 1/3 of nitrogen dose, full dose of P should be drilled at sowing time. Top dress 1/3 nitrogen after 25-30 days of sowing and remaining 1/3 nitrogen at tasseling stage.
   b. Rainfed crop: Apply half dose of nitrogen and full dose of phosphate at sowing by drilling method and topdressing of remaining half nitrogen at tasseling stage with rains.
6. Seed rate: 20 kg/ha
7. Sowing time: 20th June to first week of July
8. Spacing between two rows: 60 cm. The final plant population must be around 60 thousand plants/ha.

9. Irrigation: if needed, apply one irrigation at flowering stage.

10. Weed control: spray 0.5 kg atrazine at preemergence stage.

Groundnut:

1. Varieties: Bunch type--RSB-87 and AK12-24

2. Seed treatment: Treat the seed with Thiram or Captan at the rate of 3 grams/kg of seed and treat with Rhizobium culture just before sowing.

3. Soil treatments:

   for Termite control: Apply Aldrin 5 percent at the Rate of 25 kg/ha before sowing.

   for white grub control: Apply phorate granules 10 percent at the rate of 25 kg/ha.

4. Fertilizer application:

	Nutrients--kg/ha		
	N	P	K
Rainfed crop	15	60	0

5. Time of fertilizer application: drill full dose of fertilizer before sowing.

6. Seed rate: 100 kg kernels/ha

7. Sowing time: middle of June to 1st week of July

8. Spacing:

   Between two lines--30 cm, and

   Between two plants--10 cm

9. Weed control: one interculture by bullock drawn implement followed by earthing after 30 days of sowing.

APPENDIX D

Soil and Irrigation Water Data for Chain 5 of the Thikaria Minor

Table D-1. E.C. and pH of Soil Saturation Extract

Depth	Ec(m mhos/cm^2)	pH	Remarks
0 - 30 cms	2.4	7.4	Saline sensitive crops like pulses may be affected.
30 - 45 cms	2.1	7.4	
45 - 60 cm	2.5	7.0	

Table D-2. Ec and pH for Canal and Well Water

Source	Ec(μmhos/cm)	Remarks
Canal water	600	safe
Well water	1500	medium quality

Table D-3. Soil pH in Field Test and Texture of Soil

	Depth	pH	Texture
Head	0 - 15	8.0	clay loam
	15 - 30	7.8	clay loam
	30 - 60	7.6	clay
	60 - 90	7.4	clay
Middle	0 - 15	7.8	clay loam
	15 - 30	7.6	-do-
	30 - 60	7.6	-do-
	60 - 90	7.4	clay
Tail	0 - 15	7.6	clay loam
	15 - 30	7.6	-do-
	30 - 60	7.6	-do-
	60 - 90	7.4	clay

APPENDIX E

Table E-1. Crop Data for Chain 5 of the Thikaria Minor

Survey No.	Topography	Crop variety	Av. Tiller or stand per sq.m	Stage of crop	Weeds intensity	Intensity of pests and diseases	Crop condi-tion	Intercrop, if any	Remarks
Head									
28	Sloping	Wheat (K.Sona)	252	Flowering	Nil	Nil	Good	Nil	Average tiller/m^2 208
8	-do-	-do-	197	-d0-	slight	slight (loose smut)	Fair	-do-	
17	-do-	-do-	174	-do-	Nil	Nil	Good	-do-	
Middle									
16	Sloping	Wheat (K.Sona)	111	Flowering	Slight	Nil	Fair	Nil	Average tiller/m^2 = 127
197	-do-	-do-	117	-do-	-do-	Nil	Good	Mustard	
195	-do-	-do-	152	-do-	-do-	Nil	Fair	-do-	
Tail									
217	Sloping	Wheat (K.Sona)	203	Flowering	Nil	Slight smut	Good	Nil	Average tiller/m^2 = 205
226	-do-	-do-	238	-do-	Slight	Nil	Good	Nil	
236/360	-do-	-do-	174	-do-	-do-	Nil	Fair	Nil	
Head									
24	Sloping	Gram local	21	Flowering	slight	Slight root rot & pod borer	Fair	Nil	Average crop stand = 18
26	-do-	-do-	22	-do-	-do-	-do-	-do-	Nil	
20	-do-	-do-	10	-do-	-do-	-do-	Fair	Nil	
Middle									
14	Sloping	Gram	13	pod form-mation	slight	-do-	Good	Nil	Average crop stand = 18
195	-do-	-do-	17	flowering pod	-do-	-do-	Good	Nil	
16	-do-	-do-	17	Flowering	-do-	-do-	Good	Nil	
Tail									
200	Sloping	Gram	20	Flowering pod	-do-	-do-	Fair	Mustard	Average crop stand = 22
203	sloping	-do-	22	-do-	-do-	-do-	Fair	Nil	
210	-do-	Gram	23	-do-	-do-	-do-	Fair	Nil	

APPENDIX F

Table F-1. Nutrient Status of Wheat Fields Located on the Outl·t at Chain 5 of the Thikaria Minor

Survey No. 1	N	P	K	Remarks
28	M	M	M	just enough N, P, K
8	M	L	M	
17	M	M	M	
16	L	L	M	N-Low medium P-low K-enough
197	L	M	M	
195	M	L	M	
217	M	L	M	N, K-just enough P-low
226	M	M	M	
236/360	M	L	M	

Table F-2. Cumulative Moisture Deficit (in cms) at Different Depth in Field 195 (Gram) of the Outlet Located on Chain 5 of the Thikaria Minor

	Border I			Border II			
Depth (cm)	H	M	T	H	M	T	
0 - 15 cms	3.46	2.77	3.13	-	3.29	-	H-Head
15 - 30 cms	6.06	6.99	5.85	6.33	5.97	6.33	M-Middle
30 - 45 cms	6.16	-	-	-	9.45	8.77	T-Tail
45 - 60 cms	-	13.50	11.16	11.07	11.40	10.86	Field capacity, 27%, wilting 12% by weight
				Bulk Density 1.3			

APPENDIX G

Soil and Well Water Data for the Outlets Located at Chain 6 and 21 on the Rithola Minor

Table G-1. The pH by Field Tests

Chak No.	Survey No.	Crop	Depth in cm 0-15	15-30	30-30	60-90	Texture
Chak No. 1	100	Wheat	7.6	7.8	7.8	7.8	
Head	97	"	7.8	7.8	7.8	8.0	
Average			7.7	7.8	7.9	7.9	
	110	Wheat	7.8	7.8	7.8	8.0	
Tail	93	"	7.8	7.8	8.0	8.0	
Average			7.8	7.8	7.9	8.0	
Chak No. 2	110	Wheat	8.0	7.8	7.8	7.6	
	114	"	8.0	7.8	7.8	7.8	
Average			8.0	7.8	7.8	7.7	

Table G-2. Ec and pH of Soil Saturation Extract in Laboratory

	Ec (mmhos)			pH		
Chak No. 1	0-30	30-60	60-90	0-30	30-60	60-90
Head	1.6	1.5	1.5	8.2	8.0	8.0
Middle	1.9	1.5	-	8.2	8.0	-
Tail	4.4	4.8	5.0	7.6	7.6	7.6
Chak No. 2						
Head	1.6	1.3	1.2	7.8	7.8	8.0
Tail	3.2	2.2	1.9	1.6	1.3	1.2

Table G-3. Ec of Well Water (μmhos/cm):

Chak No.	Well No.	Head	Middle	Tail	Remarks
Chak No. 1	1	950	1400	2200	Water Table Varies turn 6.3 m to 7 m
	2	1950	1500	-	
Chak No. 2					
	1	1400	-	1800	

APPENDIX H

Table H-1. Crop Data for the Outlets Located on Chain 6 and 21 of the Rithola Minor

Survey No.	Crop Variety	Tissue Test N P K	Intensity of Weeds	Intensity of Pest Diseases	Crop Condn.	Stage of Crop	Inter Crop	Topography	Tiller Count/M	Texture
Head										
100	Wheat K.S.	M M M	Moderate	Slight Smut	Fair	Flower	Mustard	Sloping Field	99	Sandy Clay Loam
101	"	M M M	"	"	"	"	"	"	144	Clay Loam
Middle										
110	"	M M M	"	Slight Borer	"	"	"	"	213	"
111	"	M M M	Slight	Slight Smut & Borer	"	"	Nil	"	171	"
106	"	M M M	"	"	"	"	"	"	133	"
Tail										
93A	"	M M M	"	Slight Borer	Good	"	Mustard	"	275	"
93B	"	M M M	"	"	"	"	"	"	133	"
94B	"	M M M	Slight	Slight Smut	"	"	Nil	"	204	"
94A	"	M M M	"	"	"	"	"	"	172	"
110	"	L L M	"	Slight Smut Borer Termite	Fair	"	Mustard	"	165	"
110/1	"	L L M	"	"	"	"	"	"	178	"
Tail Chak No. 2										
144	Methi	M M M	"	Nil	"	"	Nil	"	171	"
110/2	Wheat K. S.	L L M	"	Slight Smut & Termite	"	"	"	"	223	"

Table H-1. continued.

Survey No.	Crop Variety	Tissue Test N P K	Intensity of Weeds	Intensity of Pest Diseases	Crop Condn.	Stage of Crop	Inter Crop	Topography	Tiller Count/M	Texture
Chak No.1										
103	Barley Wheat	L L M	Heavy	Slight covered Smut & Pest	Poor	Ear	Nil	Sloping	82	Sandy Clay Loam to Clay Loam
102	"	L L M	Moderate	Slight Covered smut	Fair	Flowering	"	"	77	"
Chak No.2	"	L L M	slight	"	"	"	Nil	"	120	"
101/3	Local Gram	x	"	Slight Pest & Pod Borer	"	Flowering to Pod.	"	"	32	"
102	"	x	Moderate	"	Good	"	"	"	35	"
106/2	"	x	Slight	"	"	"	"	"	30	"
105/2	"	x	"	"	"	"	"	"	35	"

APPENDIX I

Table I-1. Soil Depth and Texture for the Outlet Located at Chain 145 of the Thikaria Minor

S.N.	Depth of Soil 0 - 15	15 - 30	30 - 60	60 - 90
122	Clay loam	Clay Loam	Clay loam	Clay Loam
104	"	"	"	"
84	"	"	"	Clay loam with small gravels
99	"	"	"	"
86	"	"	"	"
98	"	"	"	"
114	"	"	"	Clay loam
91/1	"	"	"	Clay loam with small gravels
99	"	"	"	"

APPENDIX J

Table J-1. Plant Population Counts for the Outlet Located at Chain 145 of the Thikaria Minor

Crop	Particular	Survey No.	Average population per m^2 Head	Middle	Tail	Average
Wheat	Total tillers	122	115	94	88	99
"	"	173	118	168	121	136
Gram	Total plant	-	59	11	35	35

APPENDIX K

Table K-1. Chemical Data for the Soils of the Outlet Located at Chain 145 of the Thikaria Minor

Survey number	Head 122	104	114	Middle 99	84	99	98	86	Tail 91
pH in fields									
0 - 15 cms	8.0	8.2	7.8	8.2	8.2	8.2	8.2	8.2	8.2
15 - 30 cms	8.0	8.0	7.6	8.0	8.0	8.2	8.2	8.2	8.2
30 - 60 cms	8.2	7.8	7.6	8.0	8.0	8.0	8.0	8.0	8.2
60 - 90 cms	8.2	7.8	-	-	-	-	8.0	-	8.0
Average	8.1	7.95	7.67	8.07	8.07	8.13	8.1	8.13	8.15
pH in laboratory									
0 - 15 cms	7.6			7.7					7.6
15 - 30 cms	7.6			7.7					7.7
30 - 60 cms	7.7			7.8					7.7
60 - 90 cms	7.8			-					-
Average	7.67			7.73					7.67
Ec (mmhos/cm)									
0 - 15 cms	2.2			2.0					2.1
15 - 30 cms	2.2			1.5					2.0
30 - 60 cms	2.1			2.1					2.0
60 - 90 cms	2.1			1.9					1.6
Average	2.2			1.9					1.9

APPENDIX L

Table L-1. Nutrient Status of Wheat Fields for the Outlet at Chain 145 of the Thikaria Minor

Survey No.	I 122	II 104	III 84	IV 99	V 86	VI 98	No. of Sample		
							High	Medium	Low
N	M	M	M	M	M	M	-	6	-
P	L	L	L	L	L	L	-	-	6
K	M	L	M	M	L	L	-	3	3

APPENDIX M

Table M-1. The Intensity of Weed Infestations in Fields for the Outlet Located at Chain 145 of the Thikaria Minor

Survey No.	Name of crop	Intensity of Weeds	Name of Weeds
122	Wheat	Medium	Chenopodium spp., Anagallis arvensis, Convolvulus arvensis, Spergula arvensis, Jangli Gobi (forest cauliflower)
104	"	"	
84	"	"	
99	"	Heavy	
86	"	Medium	
98	"	"	
114	gram	medium	
91	"	Very heavy	
99	Methi	Heavy	

APPENDIX N

Table N-1. Summarized Data for the Head, Middle, and Tail for the Outlet Located at Chain 75 on the Rithola Minor

S.N.	Particular		Head	Middle	Tail
1.	Plant population				
	Wheat		210	141	82
	Barley		195	115	151
2.	Tissue test				
	N	medium	M	M	M
	P	low	L	L	L
	K	medium	M	L	L
3.	Soil Texture		Sandy clay loam to clay loam after 60 cm stone	Sandy clay loam to clay loam after 60 cm stone	Sandy clay loam to clay loam after 60 cm stone
4.	pH of soil				
	(a) Field		7.8 to 8.0	7.8 to 8.0	7.8 to 8.0
	(b) Laboratory		7.8 to 8.0	7.9 to 8.0	7.3 to 8.0
5.	E.C. of soil mmhos/cms.		1.7 to 2.2	1.4 to 1.6	1.9 to 2.0
6.	Moisture deficiency cm/30 cm (feel and touch method)		6.6	5.8	7.4
7.	E.C. of well water µmhos/cm		2.1	2.2	2.0 to 2.2
8.	Water level in meters		5.9	7.7	8.6
9.	Variety used				
	Wheat		K. Sona pure seed	K. Sona own seed	K. Sona own seed
	Barley		Local	Local	Local
10.	Stage of crop		Flag leaf to dough	Flag leaf to dough	Flag leaf to dough
11.	Sowing distance		30 cms	30 cms	30 cms
12.	Weed intensity		Low	Medium to heavy	Medium to heavy
13.	Pests				
	Wheat		nil	nil	nil
	Barley		nil	nil	nil
14.	Disease				
	Wheat		nil	nil	nil
	Barley		smut	smut	smut
15.	Moisture deficiency cms/60cms by laboratory at three places in the field		6.44	7.99	6.28

APPENDIX O

Table O-1. The Electrical Conductivity of Well Water and Canal Water for the Outlet at Chain 75 of the Rithola Minor

Source	Electrical conductivity µmhos/cms	Remarks
Well 1	2100	The salinity hazard
Well 2	2200	of well water is high
Well 3	2200	
Well 4	2200	
Canal water	600	The salinity hazard of canal water is low

APPENDIX P

Table P-1. The Average Number of Tillers/m^2 and Productive tillers/m^2 at Various Positions on the Outlet Located at Chain 75 of the Rithola Minor

	Crops			
	Total	Effective	Total	Effective
Head	210	136	195	134
Middle	141	84	115	89
Tail	82	47	151	79
Average	144	89	154	101

APPENDIX Q

Table Q-1. Crop, Soil, and Water Data for Outlet Located at Chain 158 of the Thikaria Minor

Plant populations

	Head			Middle of Minor			Tail Minor		
Name of crop	Survey No.	No. of tillers/ plants	Average per sq m.	Survey No.	No. of tillers/ plants	Average per sq/m.	Survey No.	No. of tillers/ m^2	Average
Wheat, mustard	50	72, 112, 128	104	54	108, 126, 167	133	4	121, 185, 147	151
	52	348, 296, 452	365	4	109, 120, 132	120	3	117, 68, 102,	96
	50	33, 29, 25	30	7	17, 27, 25.	23	3	158, 120, 86	121

Nutrient status of plant

Crop	Survey No.	Status of plant N	P	K	Survey No.	Status of plant N	P	K	Survey No.	Status of plant N	P	K
Wheat, Mustard	50	M	L	L	54	M	L	L	4	M	L	L
		M	L	L		M	L	L		M	L	L
	52	A	A	A	4	M	L	L	3	M	L	L
		A	A	A		M	L	L		M	L	L
		A	A	A		M	L	L		M	L	L

Depth of Soil

Wheat	50	0 - 90 cms	54	0 - 60 cms	4	0 - 60 cms
	50	0 - 75 cms	4	0 - 45 cms	3	0 - 30 cms
	52	0 - 90 cms			3	0 - 45 cms

Soil [illegible]ure Deficiency

Crop	Survey No.	Deficiency	Survey No.	Deficiency	Survey No.	Deficiency
Wheat	50	9.7 cm/90 cm depth	54	2.8 cm/60 cms	4	2.0 cm/60 cms
Gram	50	2.8 cm/90 cms	7	7.4 cm/60 cms	3	2.8 cm/45 cms

	Head		Center		Tail
50	7.8 - 7.5 (gram)	54	7.8 - 7.6 (wheat and mustard)	4	8 - 7.6 (Wheat and Mustard)
50	7.6 - 7.4 (wheat & mustard)	7	7.8 - 7.4 (gram)	3	7.8 - 7.0 "
52	8 - 7.8 "	4	8 - 7.7 (wheat)	3	8 - 7.8 "

Weeds

Head	Center	Tail
Low infection	Low infection	Low infection

Common weeds - Chenopodium album, Anagalis arvensis, Convolvulus arvensis

Soil Analysis

	E.C.	pH	Texture
0 - 15 cms	1.6	8.3	clay loam
15 - 30 cms	1.4	8.2	clay
30 - 45 cms	1.4	8.2	clay

Water Analysis

	E.C.
Well	2400 mhos/cm
River	1200 "

APPENDIX R

Table R-1. Crop, Soil, and Water Data for the Outlet Located at Chain 77 of the Rithola Minor

S. No.	Crop	Plant Pop.	Height	Depth of soil	pH	Touch & feel Moisture def.	Depth of soil	Nutrient status in crop	Weed infestation	Disease	Variety	Irrigation	Depth	pH	Ec Soil mmhos/cm	Ec Well Water µmhos/cm
248	Barley	52 (h)	14"	0-6"	8.2	0.8	Sandy clay	N P K	20%	Smut infestation 15 - 20%	K. Sona local seed	Border method cum wild flooding	0 - 6"	7.8	1.9	1100
		84 (c)	19"	8-12"	8.0	0.8	Sandy clay loam	L L M	Chenopodium				6 - 12"	8.0	1.7	
	Ave.	122 (t) / 83	24"	12-18"	8.0	0.7 / 2.3	clay loam						12 - 18"	8.0	1.8	
187	Wheat	125	18-24"	0-6"	8.2	0.6	Sandy clay	M M L	20%	Kernel bunt smut	K. Sona local seed	Wild flooding	0-6"			
	Mustard	138		6-12"	8.0	0.5	Sandy clay						6-12"			
	Average	108 / 125		12-18"	8.0	0.4 / 1.5	Clay loam									
186	Wheat	168, 209	-	0-6"	8.2	0.7	Sandy clay to clay	M M M	40% Chenopodium	Nil	K. Sona & local	Wild flooding	Remarks: Lots of rat holes in field.			
		280	-	6-12"	8.0	0.6			Krishna need		seed					
	Ave.	252	-	12-18"	7.8	0.4										
				18-24"		1.7"										
Middle																
95	Wheat	158, 209	-	0-6"	8.0	0.3	Clay loam soils	L L M	10%	Covered smut	K. Sona local	Wild flooding				
		78	-	6-12"	8.0	0.2					seed	along borders				
	Ave.	82		12-18"	8.0	0.2 / 0.7"										
131	Gram.	20, 8, 12	-	0-6"	8.0	0.7	Clay loam soils		Few		Local seed	Unirri-gated				
		12	-	6-12"	8.0	0.6						field				
	Ave.	13	-	12-18"	7.8	0.5 / 1.8"										
145	Gram &	20, 24	-	0-6"	7.6	0.8	Clay loam		30%		Local	Only one irrigation by canal				
	wheat	30	-	6-12"	7.4	0.8										
	Ave.	26	-	12-18"	6.8	0.7 / 2.3"										

able R-1. continued.

S. No.	Crop	Plant Pop.	Height	Depth of soil	pH	Touch & feel Moisture def.	Depth of soil	Nutrient status in crop	Weed infestation	Disease	Variety	Irrigation	Depth
Tail													
129	Wheat	238,322	-	0-6"	8.0	0.7	Clay loam	M M M	10%		K. Sona Local seed	Had already given 4 irrigation by well & canal	
	Mustard	285	-	6-12"	7.8	0.6							
		281	-	12-18"	7.8	0.5							
						1.8							
171	Wheat	172,280	-	0-6"	8.0	0.4	Clay loam	M M M	nil		K. Sona and Sona-lika	Had already given 4 irrigation by well and canal	
		265	-	6-12"	8.0	0.5							
		240		12-18"	8.0	0.5							
						1.4"							
46	Wheat	246,256		0-6"	8.2	0.5	Clay loam	M L M	nil		K. Sona	Had already given 4 irrigations by well and canal	
		265		6-12"	8.2	0.4							
		255		12-18"	8.0	0.3							
						1.2"							

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DIAGNOSTIC ANALYSIS OF FARM IRRIGATION SYSTEMS ON THE GAMBHIRI IRRIGATION PROJECT, RAJASTHAN, INDIA

VOLUME III

Irrigation and On-Farm Engineering Report

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I. INTRODUCTION

The Gambhiri Irrigation Project was constructed from 1953-57 to use the monsoon flows of the Gambhiri River, a tributary of Berach about 30 km south of Chittorgarh. Figure 1 shows the location of the project, its command, and canal system. The project, with a live storage of 2,300 million cubic feet (65 million cubic meters) of water, was designed to serve a cultivable command area of 24,196 acres (9,796 ha) with 60 percent intensity of irrigation through its two main canals on either bank. The salient features of the project are given in Table 1.

The reservoir has filled to capacity for the last 25 years (except 1981-82, when it was at 87 percent of capacity), but the targeted irrigated area according to the original design has been achieved only in two years, 1974-75 and 1977-78. Even in these years the _Kharif_ (monsoon) season irrigation boosted the total irrigated area; the irrigation in one _Rabi_ (winter) season was almost equal to the average value. The average cropping pattern over the last five years is presented in Table 2. Figure 2 shows the yearly amount of live storage received and area irrigated. The duty of water achieved is presented in Figure 3 and Table 3.

The left main canal was designed for a discharge of 95 cusecs (2.7 m^3/s) at the head and has a total length of 1,340 chains (40.8 km) to serve a cultivable command area of 15,649 acres (6,338 ha). Besides the direct outlets from the main canals, the following minors take off from the left main canal:

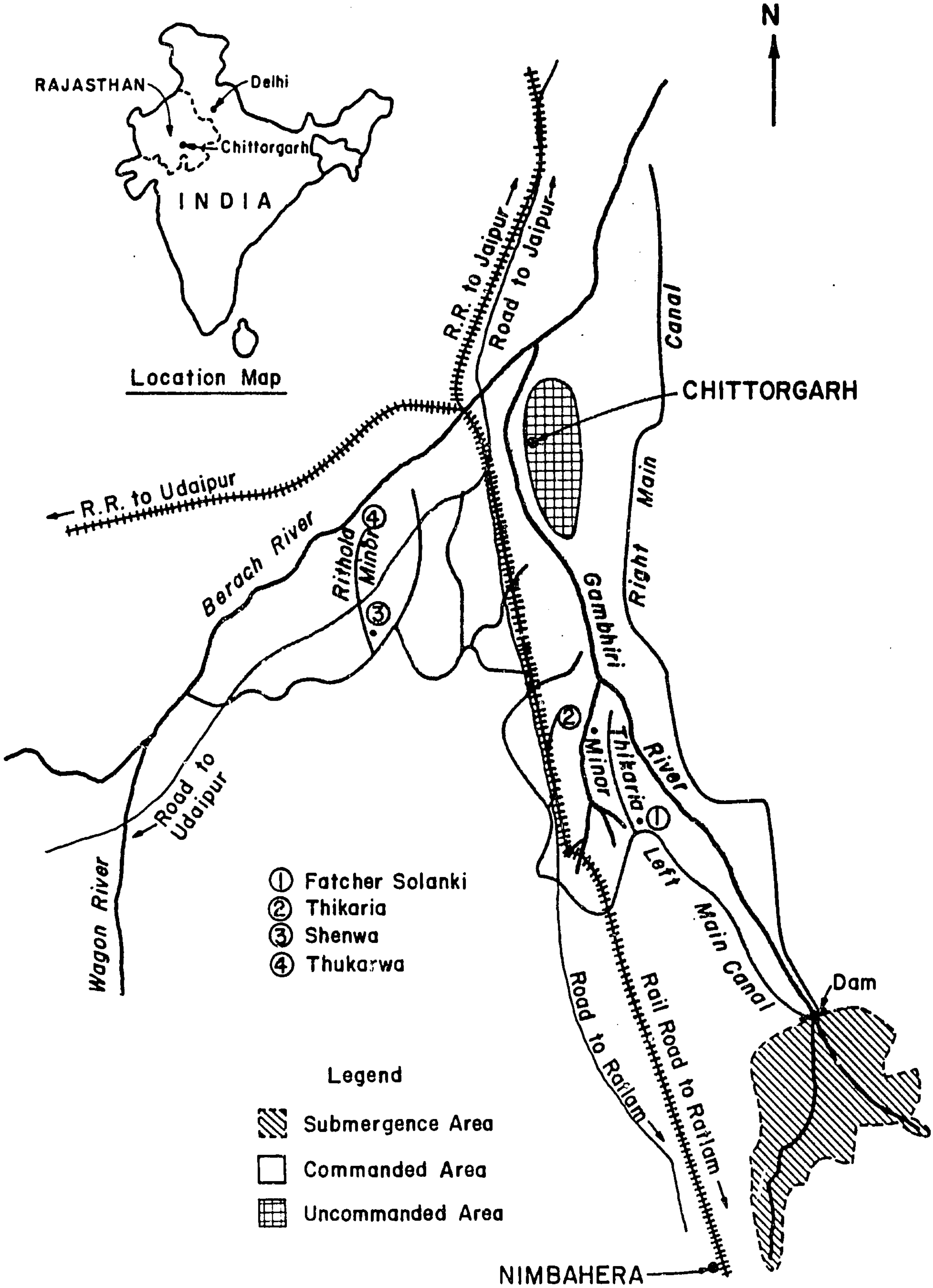


Figure 1. Command area and canals of Gambhiri Irrigation Project

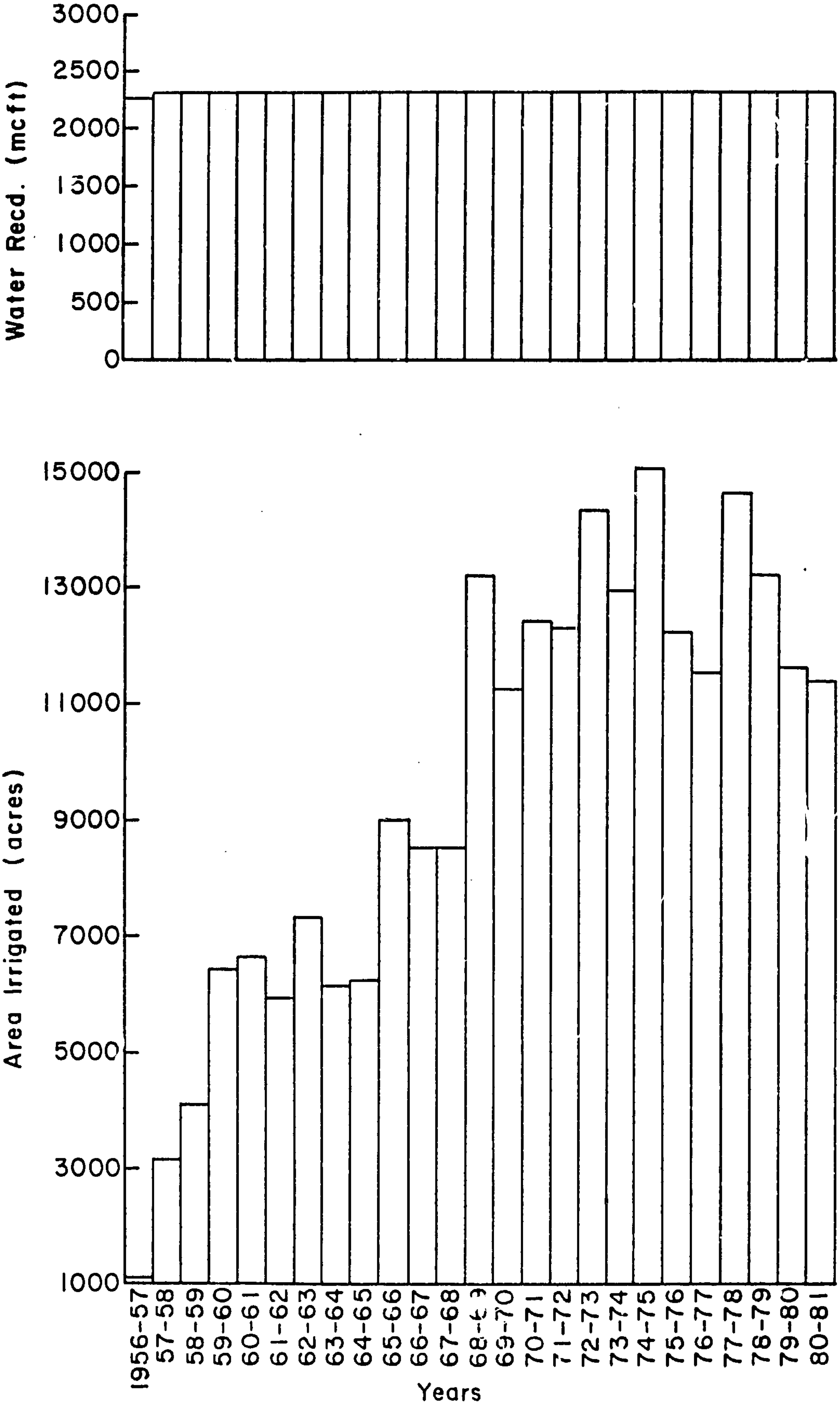


Figure 2. Water Received in Tank and Area Irrigated

Table 1. Salient Features of Gambhiri Irrigation Project

Number	Particulars	Data	
		English Units	S.I. Units
1	Gross catchment area	400 sq miles	1036 sq km
2	Intercepted catchment area	40 sq miles	103.60 sq km
3	Free catchment area	360 sq miles	932.36 sq km
4	Estimated normal yield	3,512 mcft[1]	99.39 mcum[2]
5	Gross capacity of tank at full tank level	2,700 mcft	76.00 mcum
6	Live storage capacity	2,300 mcft	65.00 mcum
7	Total length of earthen dam	10,500 ft	3200.4 metres
8	Length of overflow	2,100 ft	640.08 metres
9	Flood discharge	108,000 cusecs[3]	3056 cumecs[4]
10	Full tank level R.L.	1,477 ft*	431.90 m
11	Maximum water level	1,482 ft	433.40 m
12	Sluice sill level		
	(a) Right Canal R.L.	1,394 ft	424.90 m
	(b) Left Canal R.L.	1,394 ft	424.90 m
13	Discharge of canal at head		
	(a) Right Main Canal	55 cusecs	1.6 cumecs
	(b) Left Main Canal	95 cusecs	2.7 cumecs
14	Duty designed	8 acres/mcft	114.40 ha/mcum
15	Gross commanded area	31,617 acres	12800 ha
16	Cultivable commanded area	24,196 acres	9796 ha
17	Length of left main canal	1,340 chains	40.8 km
18	Length of right main canal	1,160 chains	35.4 km
19	Number of minors		
	(a) Left Main Canal	7	
	(b) Right Main Canal	2	

*Arbitrary Bench Mark
[1] mcft = million cubic feet
[2] mcum = million cubic meters
[3] cusecs = cubic feet per second
[4] cumecs = cubic meters per second

Table 2. Average Cropping Pattern over the Last Five Years on Gambhiri Project

Crop	Average Area Irrigated in the Last 5 years, 1976-77 to 1980-81 (acres)	Percent of Area Irrigated	Percent of C.C.A.**
Rabi:			
1. Wheat	8,242.0	72.13	34.06
2. Barley	422.2	3.67	1.7
3. Gram	791.2	6.92	3.3
4. Wheat & Gram	71.8	0.63	0.30
5. Green fodder	309.0	12.71	1.28
6. Lentil	3.4	0.03	0.01
7. Mustard	75.0	0.66	0.31
8. Vegetables	29.4	0.22	0.12
9. Clover	783.4	6.86	3.24
10. Opium	399.4	3.50	1.65
11. Sugarcane*	285.8	2.50	1.18
12. Barley & Wheat	9.6	0.08	0.04
13. Garden	1.6	0.01	.005
14. Misc. Crops	2.8	0.02	0.01
TOTAL	11,126.0	100.00	47.20
Kharif:			
1. Sugarcane*	290.0	16.56	1.19
2. Cotton	6.3	0.36	-
3. Maize	832.3	47.53	3.40
4. Rice	120.0	6.85	0.49
5. Green fodder	59.7	3.41	0.25
6. Sorghum	16.3	0.93	0.06
7. Groundnut	266.0	15.19	1.09
8. Pulses	5.0	0.29	-
9. Misc. Crops	155.3	8.87	0.06
TOTAL	1,751.0	100.00	6.54
GRAND TOTAL	12,877.0	-	53.74

*Sugarcane is a perennial crop and is, therefore, cultivated in both Rabi and Kharif

**C.C.A. = Cultivable Command Area

Table 3. Yearly Water Received and Area Irrigated with Duty Achieved

Number	Year	Water Received (mcft)	Irrigation (Acres)			Irrigation Intensity(%)			Duty Achieved (acres/mcft)
			Rabi	Kharif	Total	Rabi	Kharif	Total	
1	1956-57	2,268	1,106	-	1,106	4.8	-	4.8	0.49
2	1957-58	2,300	2,680	463	3,143	11.1	1.9	13.0	1.37
3	1958-59	2,300	3,863	246	4,109	15.9	1.0	16.9	1.79
4	1959-60	2,300	4,714	1,768	6,482	19.5	7.3	26.8	2.82
5	1960-61	2,300	4,821	1,845	6,666	19.9	7.6	27.5	2.90
6	1961-62	2,300	4,746	1,191	5,937	19.6	4.9	24.5	2.58
7	1962-63	2,300	4,891	2,476	7,367	20.2	10.2	30.4	3.20
8	1963-64	2,300	4,915	1,243	6,158	20.3	5.1	25.4	2.67
9	1964-65	2,300	4,832	1,497	6,239	19.9	6.2	26.1	2.71
10	1965-66	2,300	5,506	3,518	9,024	22.7	14.5	37.2	3.92
11	1966-67	2,300	6,879	1,647	8,526	28.4	6.8	35.2	3.71
12	1967-68	2,300	6,879	1,647	8,526	28.4	6.8	35.2	3.71
13	1968-69	2,300	8,877	4,329	13,206	36.7	17.9	54.6	5.74
14	1969-70	2,300	10,215	1,055	11,270	42.2	4.4	46.6	4.90
15	1970-71	2,300	11,503	919	12,422	47.5	3.8	51.3	5.40
16	1971-72	2,300	11,740	570	12,310	48.5	2.4	50.9	5.35
17	1972-73	2,300	11,428	2,680	14,108	47.2	11.1	58.3	6.25
18	1973-74	2,300	12,229	717	12,946	50.5	3.0	53.5	5.63
19	1974-75	2,300	11,822	3,241	15,063	48.9	13.4	62.3	6.55
20	1975-76	2,300	12,234	-	12,234	50.6	-	50.6	5.32
21	1976-77	2,300	11,513	-	11,513	47.6	-	47.6	5.01
22	1977-78	2,300	11,042	3,619	14,661	45.6	15.0	60.6	6.37
23	1978-79	2,300	11,890	1,334	13,224	49.1	5.5	54.6	5.75
24	1979-80	2,300	11,318	300	11,618	46.8	1.2	48.0	5.05
25	1980-81	2,300	11,317	-	11,370	46.8	-	46.8	4.94
	Average	2,300	8,118	1,452	9,570	33.5	6.1	39.6	4.16

Live capacity = 2300 mcft.
Designed duty = 8 acres/mcft.

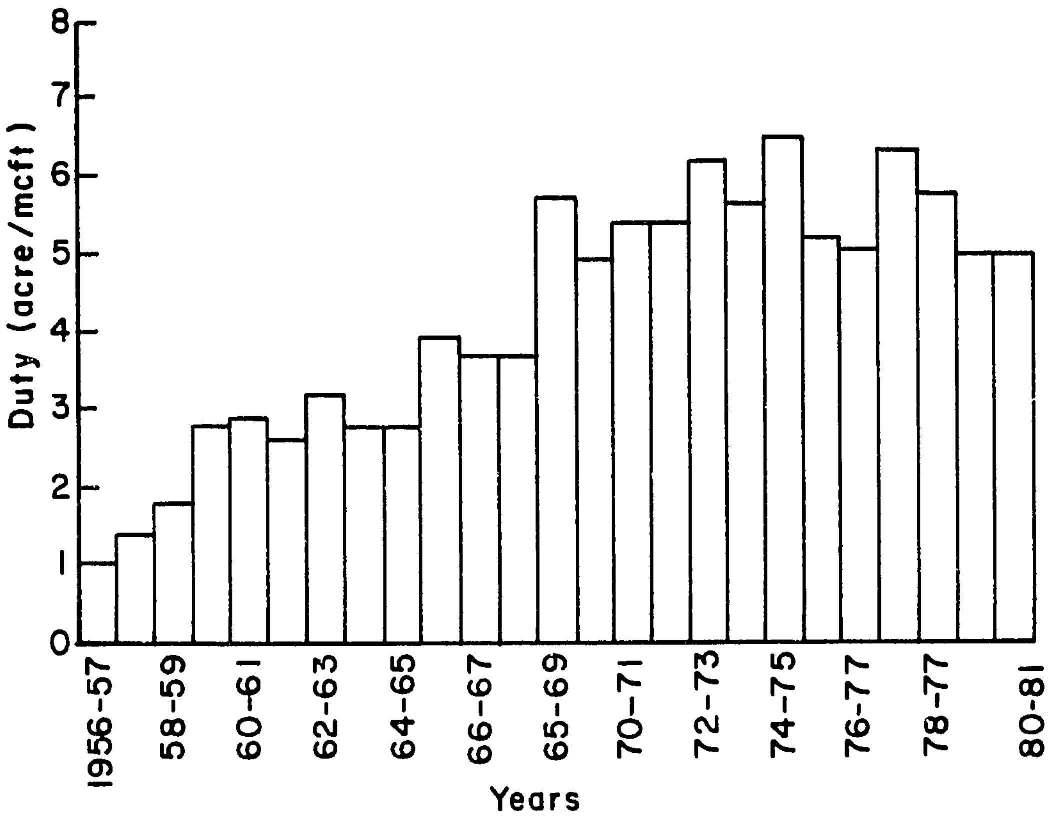


Figure 3. Irrigation Duty Per Million Cubic Feet (mcft) of Water

Number	Name of the Minor	Location of Take Off, chains (km)	Capacity at Head, cusecs (cumecs)
1	Thikaria Minor	326 (9.94)	13.3(0.374)
2	Arnia Minor	662 (20.18)	12.8(0.360)
3	Khor Minor	864 (26.34)	10.6(0.298)
4	Ochari Minor	977 (29.79)	13.7(0.386)
5	Senthi Minor	990 (30.18)	12.7(0.357)
6	Bojunda Minor	1170 (35.67)	7.8(0.220)
7	Rithola Minor	1225 (37.35)	12.5(0.352)

Similarly the right main canal with a capacity at the head of 55 cusecs (1.6 m^3/s) commands a cultivable area of 8,547 acres (3,460 ha) with a total length of 1,160 chains (35.4 km). This canal also serves the land through direct outlets and the following two minors:

Number	Name of the Minor	Location of Take Off, chains (km)	Capacity at Head, cusecs (cumecs)
1	Kalka Minor	813 (24.79)	19.3(0.543)
2	Manura Minor	841 (25.64)	10.7(0.301) .

The project was designed mainly for irrigation facilities in Rabi season, while insurance irrigation also was provided for the Kharif season. More than 47 percent of the cultivable area was irrigated in the Rabi season, while about 7 percent was irrigated in the Kharif season (Table 2), totaling to about 54 percent intensity of irrigation. The main crop in Rabi was wheat, followed by gram and clover; in Kharif the main crop irrigated was maize.

Besides low irrigation intensity, there are other constraints to higher productivity in the command area. To identify constraints, their causes, and their magnitudes, an interdisciplinary workshop for

Diagnostic Analysis of the irrigation project was undertaken from January 18 to February 20, 1982. Agronomists, economists, extension personnel, sociologists, and on-farm and irrigation engineers were involved in the Diagnostic Analysis studies. Irrigation engineers were responsible for defining the original design and the actual operation of the canal system. The on-farm engineers were responsible for understanding the design and the actual operation of the farm water control system. The farm water control system consists of subsystems for water delivery, water application, water use, and water removal. The interaction of the water control system with the agronomic and socioeconomic systems was of importance. At least one irrigation engineer, on-farm engineer, agronomist, economist, sociologist, and extension specialist served with each of the three interdisciplinary teams.

II. RECONNAISSANCE STUDY

The Diagnostic Analysis workshop trained personnel from the various disciplines in an interdisciplinary study of the operation of the project. To facilitate training, two minors, Thikaria Minor at the head of the left canal system which has been lined in a process of modernization of the system, and Rithola Minor at the tail of the left canal which is unlined and unmodernized, were selected for study. Studying these two minors revealed how the system was operating and the value of modernization.

A. Procedures

The reconnaissance study of the two minors consisted of field trips by the engineers to the site. Information was collected by formulating specific questions to be answered by various persons including the project engineers (Lowdermilk et al., 1981). The questions were as follows: How was the system designed to operate originally? What are the present operational procedures? What are the decisions to be made? What are the criteria for the decisions? This strategy was applied to both the operation of the canal system and operation of the on-farm systems, including the watercourses and the application of water to fields.

In a reconnaissance study, questions are asked of officials to determine the original and present operational procedures. Operating personnel are asked to describe operating procedures and the criteria used in making important decisions. The actual operation of the subsystem is observed against criteria for control and regulation of water. For example, the minor must operate to supply a regulated discharge at the appropriate elevation so that the outlets can draw the right amount of water. Further, if water is allocated properly, then measurement or division in the right proportion of flow at each diversion point is essential. Also the variables affecting the flow rates should be determined. Are the discharge, elevation, slope, roughness and losses appropriate? The same procedure is applied while evaluating the on-farm water delivery subsystem. The Diagnostic Analysis of on-farm delivery and application systems is discussed in Lowdermilk et al. (1981), Trout and Kemper (1980), and Gates and Clyma (1980).

Field application of irrigation water can be understood in terms of visual observations of the methods of application of water and the variables involved, including flow rate, field geometry, slope, rate of infiltration, surface roughness, and the management decisions of the farmers. The farmer management decisions for water applicaton are:

when to irrigate (frequency in terms of stress at the time of irrigation and stage of crop) how to irrigate (Are the flow rate and other variables appropriate?); and how much water to apply (Does he apply the right amount of water?). The criteria for each decision help explain the performance. Crop symptoms indicate the performance of the water use subsystem. Waterlogging and salinity or poor surface drainage need to be observed. The water level in wells indicates the location of the water table and waterlogging conditions.

1. The Canal System

The monsoon flows of the river are stored in the reservoir created by construction of the dam across the river for use for irrigation mainly during the Rabi season. After the monsoon each year, the total amount of water available (received) is known. Therefore, this amount of water can be used for irrigation over the command area of the project through the canal system. The total amount of water is the constraint and is known, but this water can be distributed as desired in an extensive or intensive manner, meaning more water over a smaller area or less water over a larger area. The frequency and depth of water distributed is subject to the canal delivery capacities.

For 25 years since the project's construction in 1956-57, the tank has received the full capacity (2,3000 mcft) of the reservoir, but the targeted irrigated area has been achieved only in two years, 1974-75 and 1977-78. With a duty of 8 acres/mcft of water, the area which could have been irrigated every year is 18,400 acres; the maximum area irrigated over the 25 years of operation of the project is only 15,063 acres, in 1974-75, with a duty of 6.55 acres/mcft.

Due to the insufficient capacity of the main canals and excessive seepage and operational loss, all the minors and direct outlets cannot be operated simultaneously. Therefore, the minors are run on a monthly rotational system. The monthly rotational system on the left main canal is as follows:

1. First 10 days after opening the main canal
   - Group A
     - i) Direct outlets from chain 990 to chain 1360 (tail)
     - ii) Bojunda Minor — Run full
     - iii) Rithola Minor
   - Group B
     - i) Direct outlets from 0 chain to 990 chain
     - ii) Thikaria Minor — Run partially
     - iii) Arnia Minor
   - Group C
     - i) Khor Minor
     - ii) Ochari Minor — Remain closed
     - iii) Senti Minor
2. Next 20 days
   - Group A — Remains closed
   - Groups B & C — Run full

Similarly the rotation on the right main canal is as follows:

1. First 7 to 10 days
   - Group A
     - i) Direct outlets from chain 841 to chain 1160 (tail) — Run full
   - Group B
     - i) Direct outlets from chain 0 to chain 612 — Run full
   - Group C
     - i) Direct outlets from chain 612 to chain 841
     - ii) Kalka Minor (off take at chain 813) — Remain closed
     - iii) Manpusa Minor (off take at chain 841)
2. Next 20 days
   - Group A — Remains closed
   - Group B — Runs partially
   - Group C — Runs full

Further, all outlets on a minor do not run for the full period for which the minor runs, but also are run in rotation. The head outlets on a minor are run first, and when the irrigation is completed, they are closed. Then outlets further down are opened. Thus, the water supply is not on-demand but is on a monthly rotational basis, and a farmer on a particular outlet has to take water during the period his minor is running and his outlet is open. Below the outlet farmers of that outlet area receive water on mutually agreed rotation.

Discharge measuring facilities are available neither on the main canals nor on the minors. Running of canals is controlled by maintaining gauges as follows:

Gauge Location	Minimum Gauge Maintained
Left Main Canal	
chain 0	5 feet
chain 90	4 feet
chain 500	3.5 feet
chain 1170	2.75 feet
Right Main Canal	
chain 0	5.5 feet
chain 612	3 feet
chain 813	2.5 feet

Similarly on Thikaria and Rithola Minors, the gauges maintained at the head in the minors are 1.9 feet and 2.5 feet respectively.

Gauges do not reflect a specific discharge because readings are affected by weed growth, which causes resistance to flow in the canal (increase in rugosity) and reduction in cross-sectional area. There are no regulators in the left main canal except in head reaches at chains 54, 80, and 990 . These regulators also are not operated for maintaining the water level in the left main canal, but are used in the monsoon season to keep water from entering the canal. However, the regulator at chain 990 is used to stop water from flowing to the tail reach of the canal.

In compliance with State Government instructions, every irrigation project has a water distribution committee. It consists of the Executive Engineer (Irrigation), the District Agriculture Officer, members of the State Legislative Assembly of the command area, the pradhans and vikas adhikaris of the panchayat samitis falling under the command area, and selected sarpanches and prominent farmers. The water distribution committee draws up the program of the opening of canals, area to be irrigated, and number of waterings.

a. Thikaria Minor

Thikaria Minor is the first minor at chain 326 on the right side of the left main canal (Figure 1). This is a ridge minor and therefore irrigates on both sides. It is 170 chains long, fully lined, with a head design discharge of 13.3 cusecs to command a cultivable area of 1,670 acres. The water is regulated through a 2 x 2 ft sluice gate operated by a screw without any locking arrangements. The minor has steep bed slopes causing high velocity flows and even supercritical flows in certain reaches. There are no falls or regulators within the channel, and therefore, there is insufficient depth of flow for outlets to draw designed discharges. The result is that the canal flow is obstructed by farmers by dumping stones and debris to raise the water level to draw water at a higher flow at each outlet. There are a large number of unauthorized outlets. The minor was opened on the 21st of January, 1982, in the evening.

There are no measuring devices on the minor. However, discharge measured by float on the day of reconnaissance, 22 January, 1982, was 21.6 cusecs at the head against an authorized discharge of 13.3 cusecs. The water in the minor was flowing up to the tail with about 2.5 cusecs discharge. Water for outlets is drawn from the canal by tampering by the farmers and therefore, water fluctuates along the minor considerably. There was no service road all along the minor except in some reaches in which the road was recently constructed.

b. Rithola Minor

Rithola Minor is the last minor taking off from the right bank of left main canal at chain 1225 (Figure 1). This is a contour canal running along the divide of cultivable and uncultivable rocky waste and irrigates only on the left. This minor, as per rotational system of running of minors, receives less water and therefore the irrigated area is very low. It is 77 chains long, fully unlined, with a head discharge of 12.5 cusecs to command a cultivable area of 1,786 acres. The average irrigated area over the last five years has been only 179 acres, or 10 percent intensity. The flow in the minor is regulated through an opening controlled by a 2 x 2 ft steel gate with a screw and without any locking arrangements.

On the day of reconnaissance, the minor was not in operation. The minor has steep bed slopes and has eroded in certain reaches and caused silting in others. There is a large number of outlets, other than the authorized ones, which consist of pipe outlets or cuts in the minor bank. Due to steep bed slopes and unavailability of any regulators, the depth of flow does not seem to be adequate; therefore, the farmers put obstructions to the flow in the minor to draw water in their outlets.

There are no discharge measuring devices or gauges on the minor. Though the minor runs along the contour, there are no cross-drainage works to pass the rain water. Therefore the minor, especially in its tail reaches, acts as a drainage channel. There is no service road along the minor and the condition of the minor is not good.

The flow in both Thikaria and Rithola Minors is regulated by canal chowkidars by opening the screw-type steel gate to a certain opening so as to have a specified depth of water in the minor. The criteria was an instruction from the assistant engineer. The minors, once opened, operate day and night, for 24 hours. To irrigate the area commanded, the minors are designed for 28 days running, but they run, within the rotational system, for a much smaller number of days, i.e., ±20 days for Thikaria Minor and other minors and outlets of head reach, and only 10 days for Rithola Minor, Bojunda Minor, and other outlets in tail reaches below chain 990. This results in drawing higher discharges in Thikaria Minor than designed and less irrigation on Rithola Minor and others in the tail reaches.

2. The On-Farm System

The sense of responsibility on the part of the engineers about the irrigation was restricted to the delivery of water up to outlet head. The assumption was that design, construction, operation, and maintenance of the watercourses and that of the fields was the sole responsibility of the farmers themselves.

Observations on outlets on Thikaria Minor and on Rithola Minor showed that the watercourses were constructed by farmers from the outlet locations sanctioned by the Irrigation Department, and/or from other locations where the farmers wanted the outlet (resulting in almost double the number of unauthorized outlets). Both authorized and unauthorized watercourses were operated and maintained by the farmers themselves. Sections of the watercourses were not proper and had steep slopes causing erosion which in turn, resulted in fields becoming out of command by the watercourse and thereby necessitating another watercourse for those fields. Watercourse elevations were not tied specifically to the elevations of the fields. Therefore some fields could be irrigated only with difficulty while others remained out of command. There were neither division boxes at each branch of the watercourse nor drop structures to reduce the steep slopes. No nakkas were constructed. The farmer, in directing water to his field, made a cut in the watercourse bank and diverted water by obstructing its flow further down.

The alignment of watercourses was not proper causing longer lengths than necessary. Sometimes there were parallel watercourses to feed nearby fields. In certain chaks, watercourses did not exist for some area under command; therefore, those fields could not be irrigated so far.

The canal outlet was operated in principle by the chowkidar. In practice, farmers would increase the outlet discharge by obstructing the flow in the minor with stones and debris or by partially restricting the watercourse at the head according to their particular need for a flow rate. The actual flow rate in the watercourse also would vary depending on the flow in the minor which, in turn, varied on account of interference and withdrawal of water by farmers upstream.

Observations of flow in watercourses on Thikaria Minor indicated a heavy water conveyance loss. This seems to be the combined effect of improperly aligned, constructed, and maintained watercourses.

Water directed in the watercourse from the outlet in general was not used for the irrigation of only a single field at a time. Rather, several fields, at different locations in the chak, were irrigated by different farmers who divided and subdivided the flow in the watercourse. At some fields, the flow seemed reasonably good up to half a cusec; at other fields, the flow was very small, as if irrigation with well water by charas operation were carried out. At a few places, the entire discharge of the watercourse from the outlet was used for irrigation of one field.

The general method of water application was wild flooding. In wild flooding, water is delivered to a field through a small channel across the field. The water spills from this channel to the total area of the field. The sequence and amount of spilling depend on the topography and the small bunds built at the channel to direct the water.

Besides wild flooding or modified wild flooding, some farmers used graded borders as the system of irrigation. The graded borders received the available flow rate after division and subdivision of the flow in the watercourse. This flow was directed to the first border and traveled to the end of the border. The farmer's criteria for when to stop the water appeared to be when the water reached the end of the border. Frequently, a cut also was made in the ridge separating the first border from the second border, usually in all borders across the field. The water ponded on the lower end of the border and then flowed to the subsequent border as cross-border flow. Thus, the opportunity time to apply the desired amount of water appeared to be approximately the time of advance to reach the end of the border. Since the borders, in general, were not operated as separate hydraulic units and flow was allowed from border to border, the last border, (especially the lower end of the last border) and the lower end of the field itself tended to accumulate water.

The level-basin method was the common method of application used where irrigating mainly from wells, lifting either by charas or pump; however, many charas or pump systems did not use level basins. The same area was also irrigated by canal water when it was available. In level basins, water was applied and stopped when the water filled the basin to a specific depth, as assessed by the farmer. Especially for opium, for which the system is in vogue, the basin size was very small, about 5x6 feet or even 4x5 feet. As with the watercourses, the fields, methods of application of water, and preparation of fields were the sole responsibilities of the farmers. Neither the irrigation engineers nor the agricultural officers perceived that any assistance in regard to application of water was needed by the farmers.

Criteria on when to irrigate a field appeared to be a function of 1) the availability of water in the minor, on a rotational basis, 2) the opening of the outlet, on a rotational system, and 3) the farmer's understanding with other cultivators on his outlet. However, if the farmer had a well, which many of them did have (at least on the tail outlet of Rithola Minor), the farmer irrigated whenever he felt his crop needed irrigation. He had no information about availability of canal water.

The two minors were visited in the forenoon and afternoon. Three outlets on the Thikaria Minor, at chains 5, 148, and 158, and another four outlets on Rithola Minor, at chains 6+49, 21+45, 75 and 77 (tail), were visited. As per the rotational running of the minors, Thikaria Minor was opened on the previous day evening and Rithola Minor was simultaneously closed.

a. Thikaria Minor

The discharge into the water course at 5 chain was estimated to be more than 3 cusecs against the designed capacity of 1.2 cusecs. Stones and debris were dumped in the minor to draw this higher discharge. The watercourse in the head reaches of the minor was eroding and in poor repair. There was heavy seepage with water filling the borrow area. Most of the water was being diverted to a field near the head itself, while some water was going further down. The watercourse further down had a small section and seemed to have steep gradients, causing erosion which resulted in fields adjacent to the watercourse going out of command. This necessitated another watercourse for the same field for irrigation. All the watercourses were earthen without any division boxes, drop structures, or outlets. The alignment of the watercourses also was not proper and had longer lengths than needed.

At chain 168 the canal was fully obstructed, and the flow was diverted to the outlet. Farmers at the tail stated that this was the first time they had received water at the tail simultaneously with the opening of the minor, which was probably because the outlets in upper reaches had not started operating. They suspected that the next day, when the farmers in upper reaches of the minor started operating their outlets, there would be no water. This proved to be true in subsequent days.

b. Rithola Minor

There were very small chaks, and the watercourses even for these were in bad shape. Their alignment did not result in the minimum length to cover the command. They had steep, eroding slopes and could not command the fields properly. At the tail chaks, watercourses existed only for about one-third of the command area; average irrigation over the last five years for the chaks at chain 75 and chain 77 at the tail was 18 and 14 acres, respectively, compared to the cultivable command of 72 and 120 acres.

Crops being grown were mainly wheat and barley. Opium and sugarcane were limited to areas commanded by wells. The large number of wells in the tail chak of the minor were the primary source of irrigation.

The method of application of irrigation water from canals, and also from wells, was wild flooding with a few graded borders. Level basins were limited to opium from well water.

The fields had comparatively acceptable slopes but had very steep slopes near the tail of the chaks. Here also, water distribution among the farmers on a chak was by mutual understanding, forced or otherwise, and there was no system of warabandi.

B. Results of Reconnaissance Study

The purpose of the reconnaissance survey was to identify key benefits and constraints of the operating system. Detailed studies were then designed to collect data that documented the benefits or the constraints of the system. The reconnaissance survey identified the major differences in water supply to minors in the head reaches and to tail reaches of the main canal and of minors. Some difference between farmers on the same outlet at its head and tail was expected.

Besides the major differences in water supply identified, the following specific questions needed to be answered during the detailed studies.

(1) Is the canal system in order technically to support an adequate, equitable, timely, and dependable water supply?

(2) How does the actual operation of a minor compare to the designed operating procedure?

(3) What are the constraints in alignment, sections, grades, <u>pucca</u> structures and nonexistence of watercourses with reference to the application of irrigation water?

(4) What are the losses in the watercourses?

(5) What are the conflicts and constraints imposed on farmers by the existing operating procedure and watercourse conditions?

(6) What are the effects of method of irrigation, unlevel fields, variable slopes, etc. on distribution of irrigation water in a field and consequently on crop production?

(7) What are the factors that influence farmer decisions on how much and which crops to grow?

(8) What is the effect of irrigation on water table?

(9) What is the actual cropping intensity compared to the potential cropping intensity?

III. DETAILED STUDIES

Detailed studies examined two minors, Thikaria Minor in the head reach and Rithola Minor at the tail of the left main canal, specifically looking at three outlets on Thikaria Minor and four outlets on Rithola Minor. These studies answered questions about the operation of this system identified in the reconnaissance studies. The purpose was to collect data to determine quantitatively the benefits of particular aspects of system operation and the constraints to the system.

Major differences in system operation were assumed to exist between the head reaches and the tail reaches of main canals due to various factors besides the supply of water itself in the rotational system of the running of minors. Similarly, due to likely major differences on head and tail reaches of a minor, outlets were selected near the head and near the tail on the two minors. Because additional outlets to those originally sanctioned did exist on both minors, the area commanded by an outlet was small, so that large differences between head and tail on an outlet were not expected. Since most of the farmers were marginal and small, the sampling on an outlet was not structured on the basis of marginal and large farmer. Rather fields that were located on both head and tail of an outlet were selected. However, since it was a Diagnostic Analysis of the existing system, nothing was done to influence the farmer's decision making or way of working. Further, because time was short, the observations concerning application of water, infiltration on the field, and water loss measurements on watercourses were taken where the farmer was applying water on that day.

This section presents the procedure by which the studies were conducted and an analysis and interpretation of data on the canal's physical conditions, its operation, and the farm water control system, including farm delivery, field application, water use, and water removal subsystems.

A. Procedures

To identify the physical conditions of the minors, the longitudinal section and cross-sections of the minors were taken with leveling instruments and other equipment. The existing bed levels, bank levels, and ground levels were taken along the minor at every 30 m (1 chain) together with the bed width and bank width. Discharge in the minors was also estimated using the float method. The location of outlets, their type, and size also were recorded. Operation of the minor was related primarily to operation of the outlets. The irrigation engineers assisted the on-farm engineers in measurement of discharge at an outlet.

The procedures for studying an on-farm delivery system are detailed in the Watercourse Improvement Manual by Trout and Kemper (1980). Discharge at the outlet and discharge at the fields being irrigated were measured with cutthroat flumes to estimate losses in the field channels. Also, measurement of losses in the watercourses was made using the ponding method on Rithola Minor, as the canal was not running. The longitudinal section and cross-sections of watercourses were surveyed. The watercourses and their nakkas were marked on the command area village map to define watercourse locations for all the fields to be irrigated, and lengths were measured to determine the density per acre of cultivable command area.

Field application of water was studied according to the procedures given by Ley and Clyma (1979) for the evaluation of border irrigation systems. The water delivery together with the study of field application systems provided specific data on the performance of the irrigation system.

All trainees and participants worked initially on the same outlet to develop the needed skills and know-how to carry out the work of the discipline concerned. Field studies were then planned by the team, further developed by the disciplines, and executed by various combinations of disciplines. Teams consisting of an irrigation engineer, an on-farm engineer, an agronomist, an economist, and an extension person were assigned to each of the three outlets on Thikaria Minor. Successive detailed studies were executed by the teams on Rithola Minor to gain further experience in skills and an understanding of the procedures for the study.

1. The Canal System

Both Thikaria and Rithola Minors, on which detailed studies were carried out, take off from the left main canal. Due to the inadequate discharging capacity of the main canal, rotational running of the minors has been the operational system. Therefore, to study the system, it was necessary to look into the details of the left main canal. Since much data were collected by visiting the left main canal and from discussions with the project engineers, and as time was a constraint, no survey was taken. Though quantitative data could not be collected, the following aspects of the left main canal appeared to need attention:

(1) The present section of the canal needs redesigning in many reaches. The canal bed is higher by 1 to 2 feet than designed in many reaches. This has reduced the carrying capacity of the canal substantially and needs priority attention.

(2) A considerable length of the head reaches of the canal pass in fissured rock strata, and there is heavy seepage.

(3) In some reaches only one bank was constructed. Therefore water spreads over a large area, resulting in excessive seepage losses.

(4) There are no effective cross-regulators on the canal; also, there are many direct outlets from it with a small command area.

(5) The direct outlets from the main canal are pipe outlets with higher discharging capacity than required. They are easily tampered with by farmers and result in excessive discharge and waste.

(6) Discharge measuring devices do not exist at all on the canal and are essential for the proper allocation and use of water.

The Thikaria Minor runs with steep slopes for most of the reaches, causing very high flow velocities and even supercritical flows in some reaches. Because the minor is lined throughout, the excessive velocity does not cause erosion, but creates the problem of insufficient flow depth. The maximum slope is 1 in 200 and varies to an almost horizontal bed slope (Figure 4). The cross sections of the minor are presented in Figure 5.

Rithola Minor is unlined throughout its length. The minor also has very steep slopes. The slope varies from 1 in 150 to horizontal in some reaches with steeper slopes in general (Figure 6). The cross sections of the minor are presented in Figure 7. The minor also has no regulating or drop structures. These steep slopes coupled with the absence of any regulating or drop structures on both the minors cause insufficient depth of flow at the outlet locations. As a result, the farmers draw water in their outlets by dumping stones and debris, and they interfere with the flow in the minors. This causes variable flow in the minors. The discharge at an outlet of Thikaria Minor was measured with stones dumped by farmers across the minor and with the stones removed; the discharge varied from 3.6 cusecs, with stones, to 1.1 cusecs, without stones, compared to the design discharge of 1.53 cusecs from the outlet.

There are many unauthorized outlets on the Thikaria Minor. Coupled with the 18 authorized outlets are 32 unauthorized outlets, totaling 50 outlets in all. There are only nine outlets with regulation arrangements with a steel gate and 1 x 1 foot-size opening. The

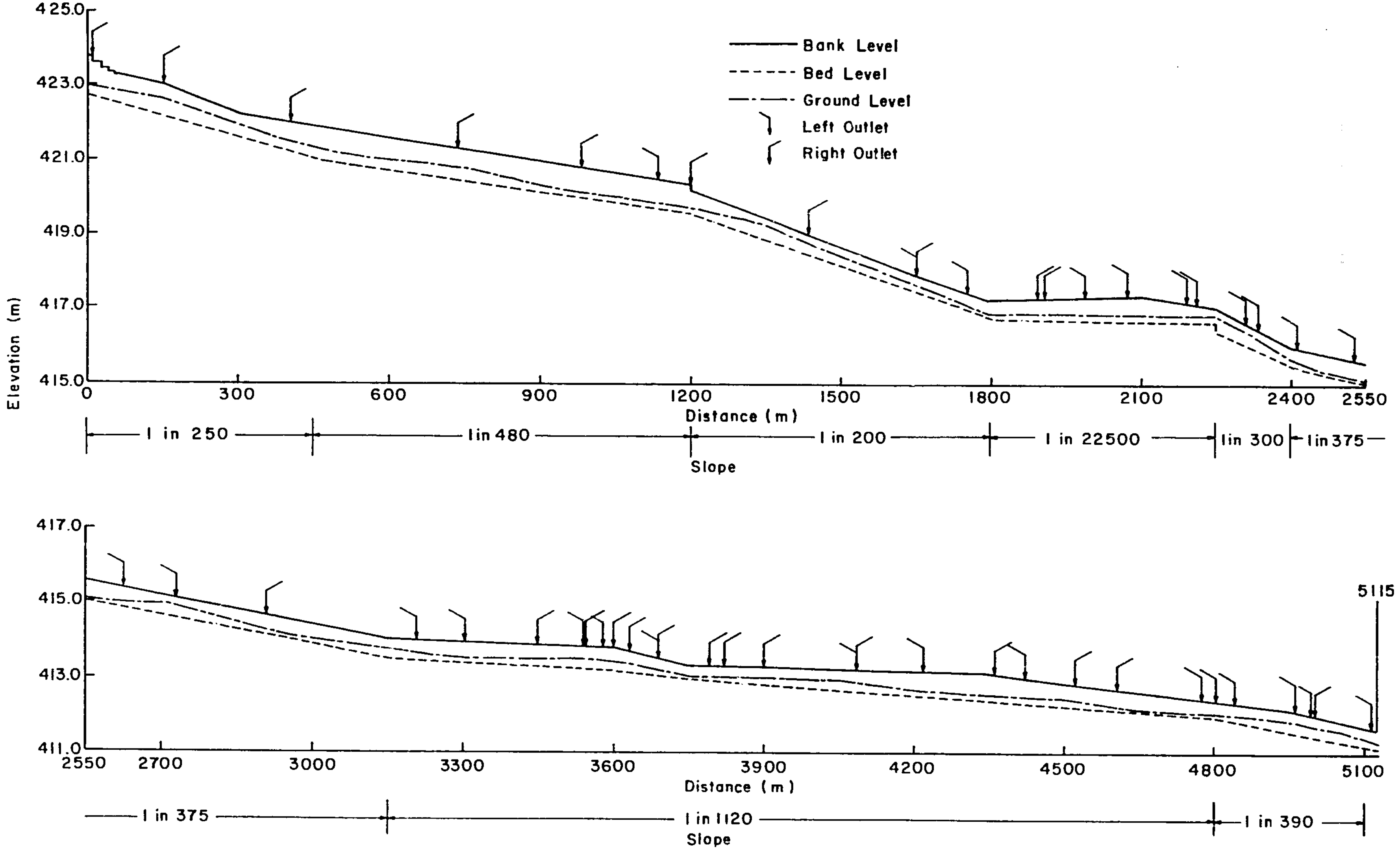


Figure 4. Longitudinal Section of Thikaria Minor

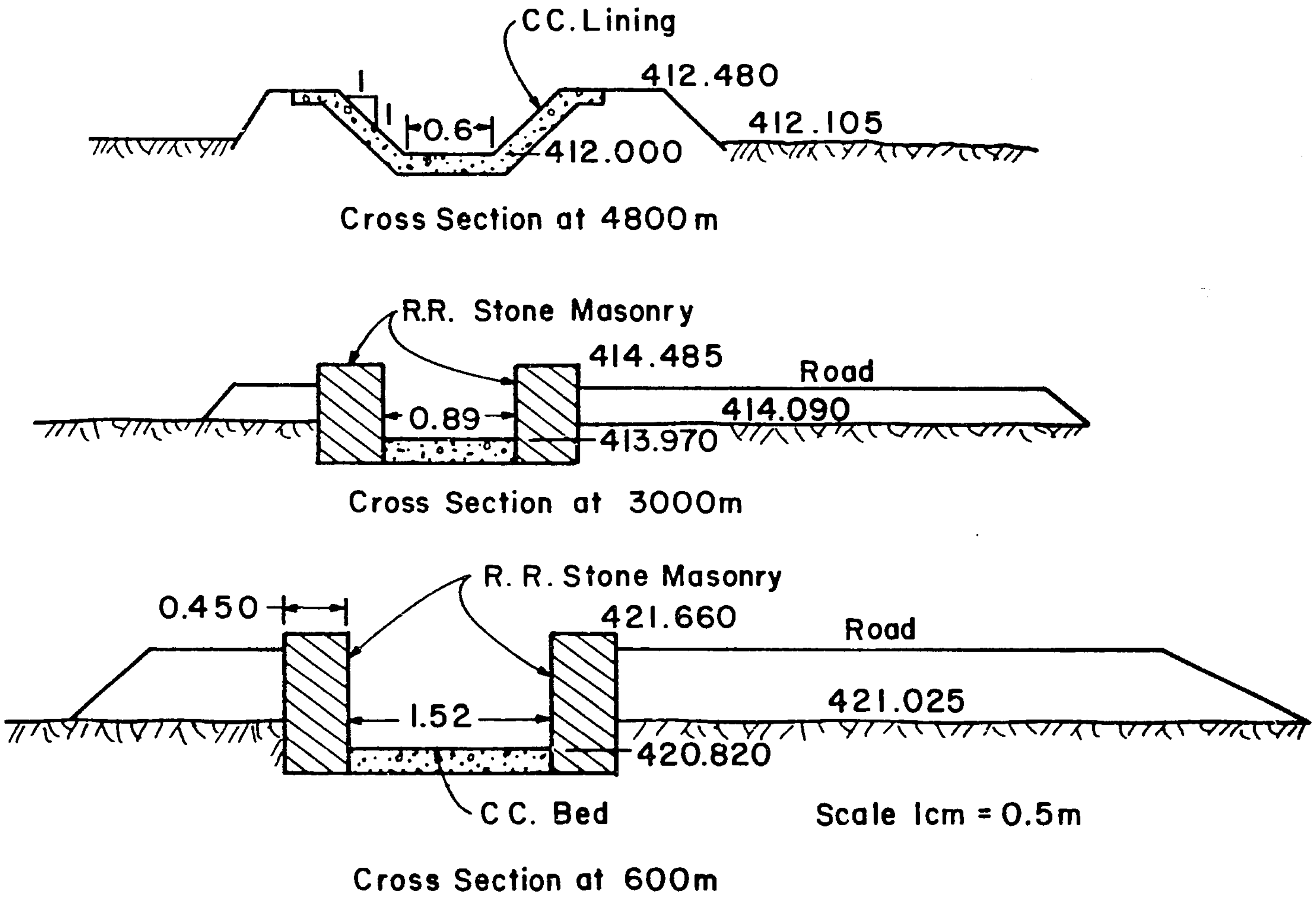


Figure 5. Cross Sections of Thikaria Minor

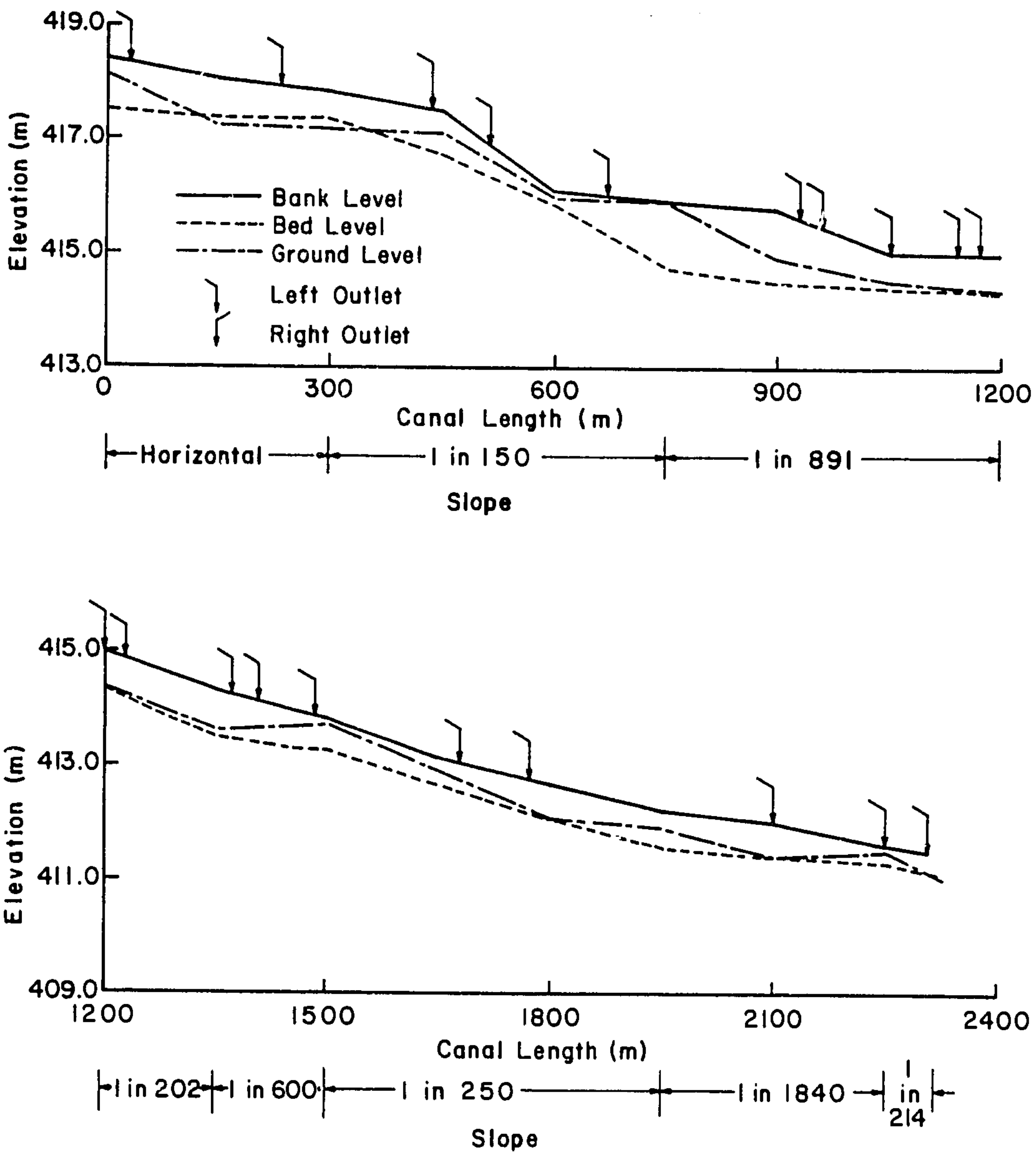
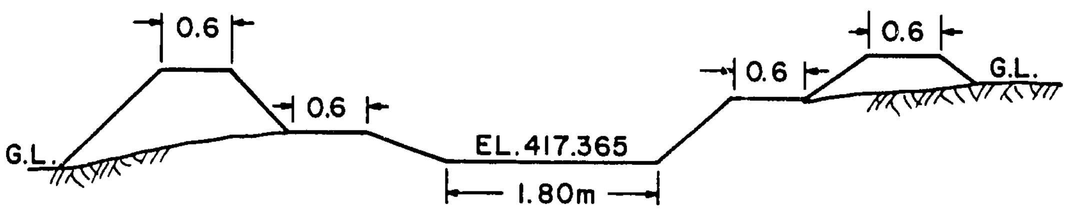
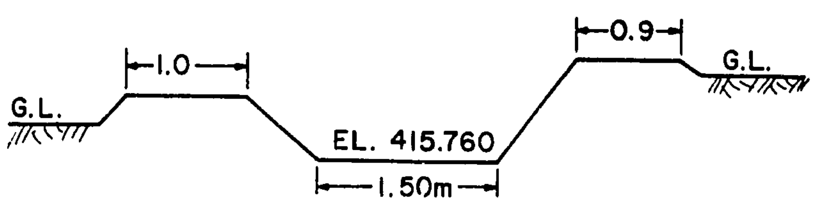


Figure 6. Longitudinal Section of Rithola Minor



Cross Section at 194.7m



Cross Section at 634.5m

Figure 7. Cross-Sections of Rithola Minor

remainder are either embedded pipes or holes or cuts in the masonry walls of the minor. Similarly, there are 19 outlets on Rithola Minor which are either cuts in the banks or consist of a pipe or pipes embedded in the minor bank. Thus, the discharge of the outlet depends on the obstruction put by the farmers in the minor, the outlets in question, and outlets downstream. No tail cluster exists on the minor. Figure 8 classifies the outlets of Thikaria Minor as authorized and unauthorized, with and without control, and their distribution on left and right sides of the minor.

In view of the large number of unauthorized outlets and interference by farmers in their running (partly due to insufficient depth and absence of control structures in minor), the flow in the minor fluctuated considerably. A few of the observations taken on various dates on Thikaria Minor indicate the same (Table 4.)

Table 4. Fluctuation in Discharge on Thikaria Minor

Date	Head Reach		Tail Reach	
	Discharge (cusecs)	Location	Discharge (cusecs)	Location
Jan 22, 1982	21.6	chain 4	2.30	chain 170
Jan 25, 1982	21.6	chain 4	4.45	chain 106
	12.25	chain 35	no water	chain 145
Jan 27, 1982	21.6	chain 4	2.37	chain 113
			no water	chain 158

Major constraints for management of the minors are as follows:

(1) Lack of measurement and monitored flow and operation time at the inlet of each minor.

(2) Lack of regulation of the flow at each outlet and use of unauthorized outlets.

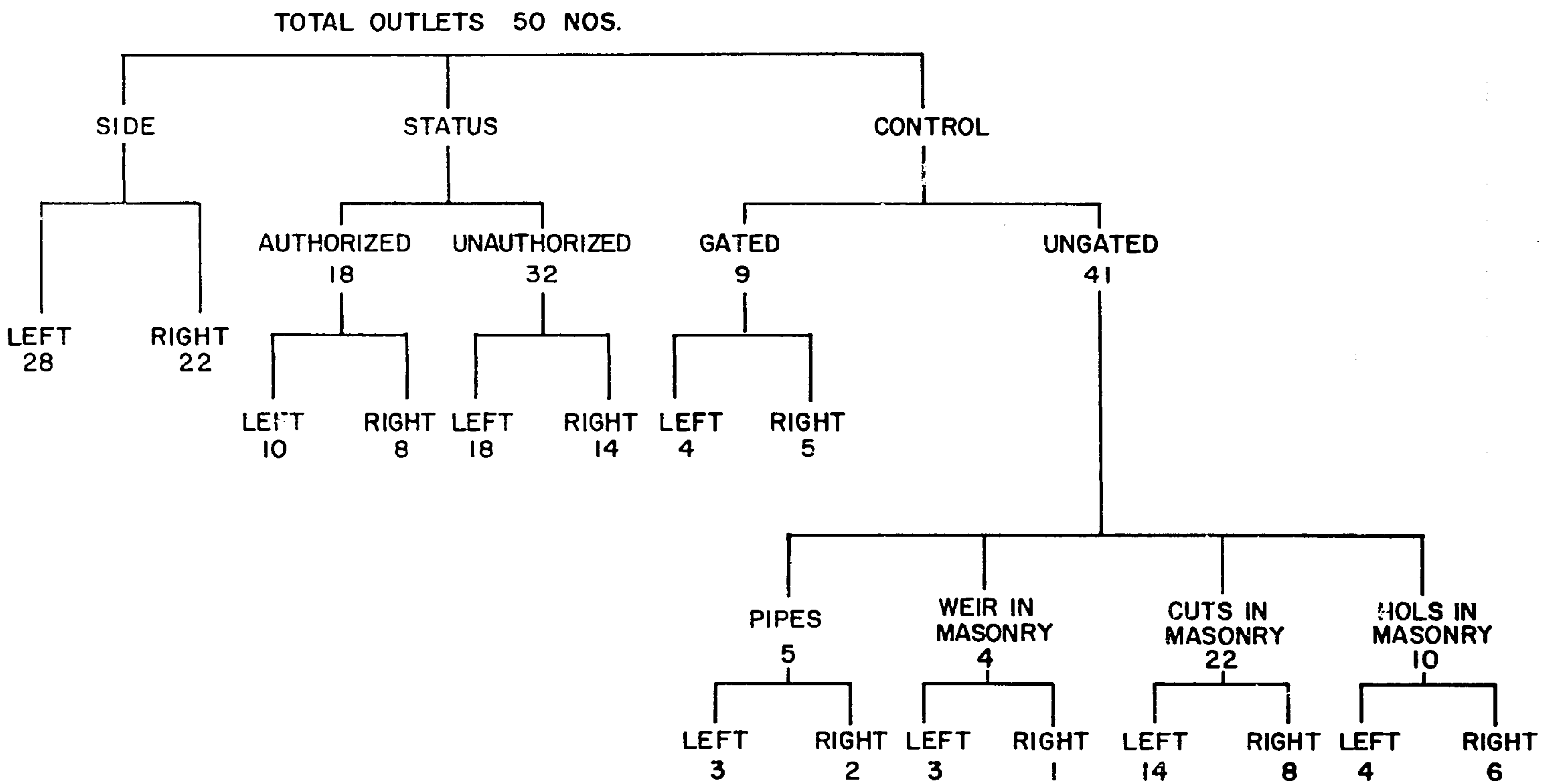


Figure 8. Classifications of Outlets on Thikaria Minor

(3) Steep slopes causing insufficient depth of flow, and lack of control structures along the minors to regulate flow and depth.

(4) Lack of a proper irrigation schedule and equitable and dependable delivery of water; lack of knowledge of the schedule by the farmers.

(5) Lack of a management plan and following of that plan for an effective explanation for the canal, minor, and on-farm delivery systems.

(6) Lack of an effective organization of farmers for participation in the management of the system.

2. The On-Farm System

The farm water control system refers to the water delivery subsystem, water application subsystem, water use subsystem, and water removal subsystem. The head (Thikaria) minor had a higher percentage of irrigation in comparison to the tail (Rithola) minor due to the greater amount of water being made available (Table 5). Table 5 also indicates that the irrigation water is reduced from head to tail on the minor. A detailed study on seven outlets was undertaken. The chak plans showing the minor with outlets, fields, watercourses along with nakkas are presented in Appendix C.

a. Water Delivery Subsystem

As mentioned earlier, a large number of unauthorized outlets and their operation by the farmers resulted in discharge variation on the outlet in question as well as on outlets further downstream. Due to the nonexistence of any regulators either in the minor itself or at the outlet, the fluctuations in discharge in the minor resulted in fluctuations in the discharge of the outlets.

Table 5. Area Commanded and Area Irrigated on Selected Outlets

Minor	Chak	G.C.A.*, Acres	C.C.A.**, Acres	Average Area Irrigated, Acres	Percent of Area Irrigated
Thikaria Chain	5	129	128	98	76
Thikaria Chain	145	48	47	25	53
Thikaria Chain	158	34	33	19	57
Rithola Chain	6+49	19	18	11	61
Rithola Chain	21+15	9	9	6	67
Rithola Chain	75	75	72	18	25
Rithola Chain	77	126	120	15	12

*Gross Command Area
**Cultivable Command Area

Discharge measurements on outlets at chain 145 of Thikaria Minor were carried out on January 29, January 30, and February 1 (1982), and the fluctuations in discharge are shown in Figure 9. Wide fluctuation in flow rate was observed (Table 6). This shows that the discharge varied on a given day as well as over the days. On January 30, the discharge was higher than 27.8 liters per second prior to 2:00 p.m., but the flume could not be fixed due to spillage from the watercourse.

Table 6. Discharge Variation on Outlet at Chain 145 of Thikaria Minor

Date (1982)	Time	Discharge in liters per second	
January 29	3:00 p.m.	15.0	Ave. 11.8
	3:50 p.m.	12.2	
	4:20 p.m.	8.2	
January 30	2:00 p.m.	27.8	Ave. 25.16
	2:20 p.m.	20.1	
	2:40 p.m.	26.3	
	2:50 p.m.	27.2	
	3:00 p.m.	24.4	
February 1	10:25 a.m.	10.2	Ave. 6.63
	10:35 a.m.	9.1	
	10:50 a.m.	0.6	

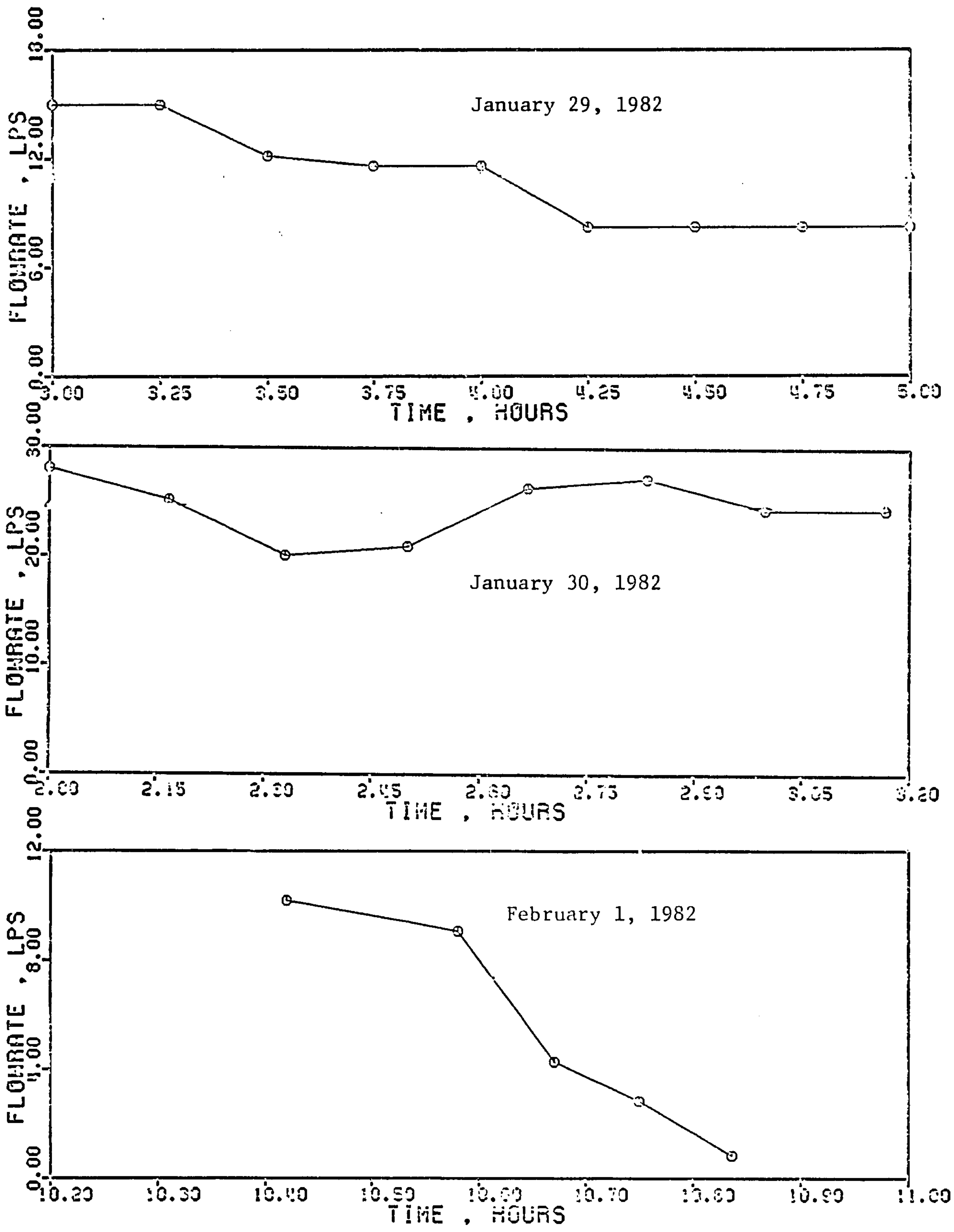


Figure 9. Fluctuation in Discharge of Outlet at Chain 145 of Thikaria Minor

Discharge at chain 5 on Thikaria Minor was altered by the farmers and ranged from 101.9 to 144.3 liters per second. Similarly, the discharge from chain 145 outlet of Thikaria Minor on January 29 was altered by the farmers and the discharge was as follows:

Time	Discharge in liters per second
12:40 p.m.	24.4
12:55 p.m.	20.1
1:10 p.m.	21.8
1:25 p.m.	22.7
1:40 p.m.	19.3
1:55 p.m.	19.3

The discharge variation at the head of the minor, or chain 5, was mainly caused by the regulation of the outlet by the farmers. The variation in the outlet discharge at chains 145 and 158, further down in the minor, was due to the unregulated variation of the minor discharge which, was also the result of the regulation of outlets upstream by the farmers.

Outlet discharges on Rithola Minor could not be taken as the minor was not running during the period of study.

Discharge measurements at chain 158 outlet of Thikaria Minor were taken with a 8-inch x 3-foot cutthroat flume at an interval of 10 minutes. The effect of variability in flow rate on the depth of water applied to different borders is presented in Table 7. The average depth of water applied over the borders varied from 6 cm to 10.3 cm. The average depth applied over the field was 8.41 cm with a range of 4.33 cm, which is ±29 percent over the average of the field.

The longitudinal section and cross-sections of the watercourses were also taken (Appendix C). The grade of the bed of the watercourses was variable but the average slope was very steep (Table 8).

Table 7. Irrigation of Borders

Border No.	Border Parameters			Irrigation Timing		Irrigation Time (minutes)	Quantity of Water Applied (m^3)	Average Depth of Water Applied (cm)
	Length (m)	Width (m)	Area (sq m)	Start	Closing			
4	34	6	204	2.03	2.14	11	16.6	8.1
5	34	8	272	2.14	2.27	13	16.4	6.0
6	34	6	204	2.27	2.37	10	13.3	6.5
7	34	5	170	2.37	2.48	11	17.4	10.2
8	34	5	170	2.48	2.58	10	15.8	9.3
9	34	5	170	2.58	3.10	12	17.6	10.3

Table 8. Average Slope of Watercourses

No.	Name of Watercourse	Average Slope
1	Chain 5 Thikaria Minor	1 in 200
2	Chain 145 Thikaria Minor	1 in 540
3	Chain 158 Thikaria Minor	1 in 630
4	Chain 6+49 Rithola Minor	1 in 214
5	Chain 75 Rithola Minor	1 in 280
6	Chain 77 Rithola Minor	
a.	Branch AB	1 in 110
b.	Branch CD	1 in 180
c.	Branch EF	1 in 270
d.	Branch AG	1 in 188

Because of the absence of any drop structures, or control structures to maintain a non-erosive slope, the watercourses have eroded below the fields to be commanded. Thus, the fields could not be irrigated by the canal water, and some other watercourse had to be dug and brought to the fields from a higher elevation.

The watercourses had no control structures, division boxes, <u>pucca nakka</u> points, or even crossing of village roads.

Thus, the alignment of the watercourses was not proper and resulted in excessive lengths (Table 9), causing excessive seepage losses in transit, uncommanding certain fields, and erosion.

Table 9. Length of Watercourses

Outlet	Length in m/acre of C.C.A.
Chain 5 Thikaria Minor	26
Chain 145 Thikaria Minor	26
Chain 158 Thikaria Minor	21
Chain 6+45 Rithola Minor	17
Chain 21+45 Rithola Minor	22
Chain 75 Rithola Minor	52
Chain 77 Rithola Minor	35

Water loss in the watercourses for outlets at chain 5 and at chain 145 on Thikaria Minor was also studied (Table 10).

Table 10. Loss Rate in Watercourses

Minor and Outlet Number	Loss rate (lps/100 m)	Percent Loss Per 100 m
Chain 5 Thikaria Minor	0.20	4
Chain 145 Thikaria Minor	2.23	13.8
Chain 21+49 Rithola Minor	0.41 0.73	-

Because Rithola Minor was not running, water loss measurements in the watercourse were carried out using the ponding method. These loss rates were considerably high and represented a loss of 29.8 percent on watercourse at chain 145 Thikaria Minor, in a length of only 216 m; it was 44.4 percent at chain 5 Thikaria Minor, in a length of 1109 m (Table 10). These loss rates, however, do not represent the average delivery efficiency for a significant number of fields. Loss rate from watercourses where the fields are high and the water level in the watercourses is at a greater depth results in significantly greater losses. The ponding loss measurement carried out on the Rithola Minor outlet indicates that the losses are twice as much when the water level is only 4 cm higher (Table 11). The loss rate is reduced at lower water level (Appendix A).

Table 11. Variations in Losses in Watercourses at Different Depths of Ponding

	Losses in lps/100 m		
	At 4 cm below	At operational	At 4 cm above
Reach I	0.26	0.41	0.88
Reach II	0.42	0.73	1.58

The variation in the two reaches is due to the condition of the watercourse. This study indicates that there will be a high loss rate when irrigating fields marginally commanded by the watercourse due to seepage, overtopping, and breaching of the watercourse banks.

Another study examined the elevation control of the watercourses. Figure 10 shows the bed levels of the watercourse and the levels of fields at chain 158 of Thikaria Minor. Field survey numbers 60 to 70 were out of command (see the elevation of the watercourse bed and the elevation of the fields), which is about 18 percent of the cultivable area commanded by the outlet.

Further, the chaks commanded by outlets at chains 75 and 77 of Rithola Minor did not have watercourses to serve all the cultivable command area. The watercourses existed only for 23 and 50 acres of cultivable area in chaks commanded by outlets at chains 75 and 77, respectively, compared to the total cultivable command area of 72 and 120 acres, respectively, on these outlets.

In summary, the alignment, grade, and sections of the watercourses either were not proper, did not command the fields properly, or did not exist for all the cultivable area in the chak. The maintenance of the channels was poor. Thus, the construction and maintenance of watercourses resulted in excessive operational water losses, and the water which should have been used for growing crops was wasted.

b. Water Application Subsystem

The water application subsystem was studied from the following viewpoints:

(1) The engineers and agronomists related crop stands and crop conditions to elevation of the field surface.

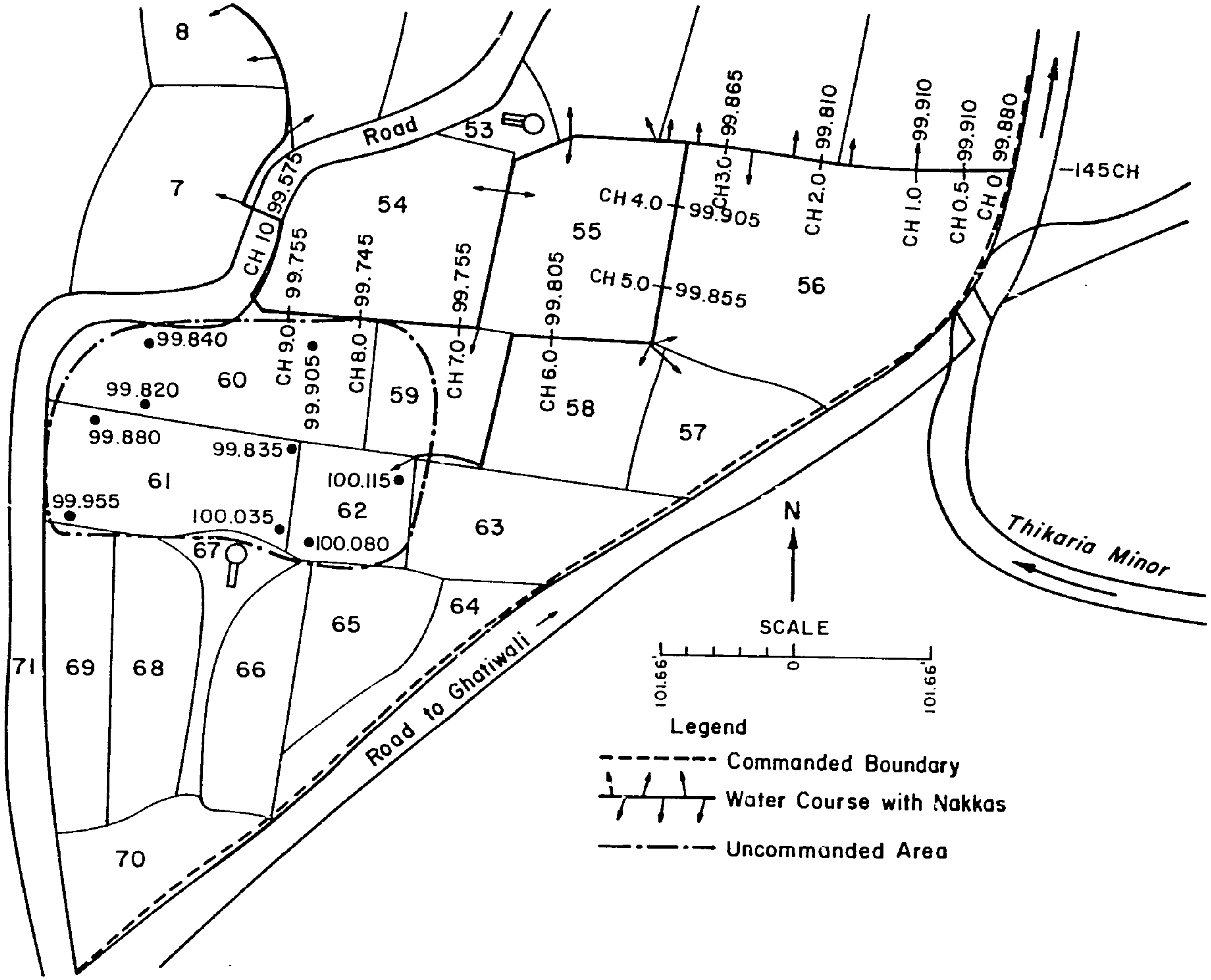


Figure 10. Chain 158 Chak of Thikaria Minor Showing Out of Command Area

(2) Graded border systems of irrigation were evaluated with reference to water application and water availability for crop growth along the border.

General observations of the engineers and agronomists and physical mapping of the graded borders showed that major problems existed in levelness of the fields. In particular, the fields close to the boundary of the <u>chak</u> near the natural drainage had steep slopes. According to the United States Department of Agriculture's (USDA) standards for land leveling, graded borders should have a uniform grade with deviations not to exceed ±3 cm with no reverse grades. When compared with the maximum allowable deviation of 6 cm, the ranges in Table 12 show that all ranges are exceeding by many times. Even reverse grades existed on the border at chain 158 of Thikaria Minor. A few fields were surveyed, and the field slopes are shown in Figure 11. Fields were not level and even had reverse slopes.

Repeatedly, agronomists and engineers observed the relationship between the poor crop stand, no crop or poor crop conditions, and low and high areas in the fields. The extension personnel determined that the farmers thought that their fields were level.

Irrigation engineers thought that delivery of water up to outlet was their responsibility and that what happened to it after was not. Similarly, the agriculture personnel thought that their buisiness was in regard to supply of seeds, fertilizers, plant protection activities, and guidance about cropping practices. Thus, irrigated agriculture in the field was no organization's responsibility. Farmers had to learn by experience without guidance from any source.

Table 12. Range of Elevation in Selected Fields

Name of minor	Outlet at Chain	Field no.	Elevation					
			Maximum (ft)	Minimum (ft)	Max. Dev. from Ave. Slope (in.)	Slope (%)	Border/Basin	Remarks
Thikaria	5	195	418.41	416.83	3.03	0.95	Border No. 1	--
Thikaria	5	195	418.46	416.88	1.57	0.96	Border No. 2	--
Thikaria	5	195	418.49	416.92	3.23	0.92	Border No. 3	--
Thikaria	158	4	414.175	414.020	1.93	0.48	Border No. 8	Reverse slope
Rithola	6+49	100	416.401	416.128	0.83	0.33%		--
Rithola	6+49	110	415.85	415.06	4.0	0.73		Reverse slope
Rithola	6+49	94	99.80*	99.56	2.76	0.14		Reverse slope
Rithola	75	251	99.76*	99.30	9.84	-	Level-Basin	--
Rithola	75	157	95.84*	95.60	4.00	-	Level-Basin	--

*These are arbitrary levels without connecting with bench mark.

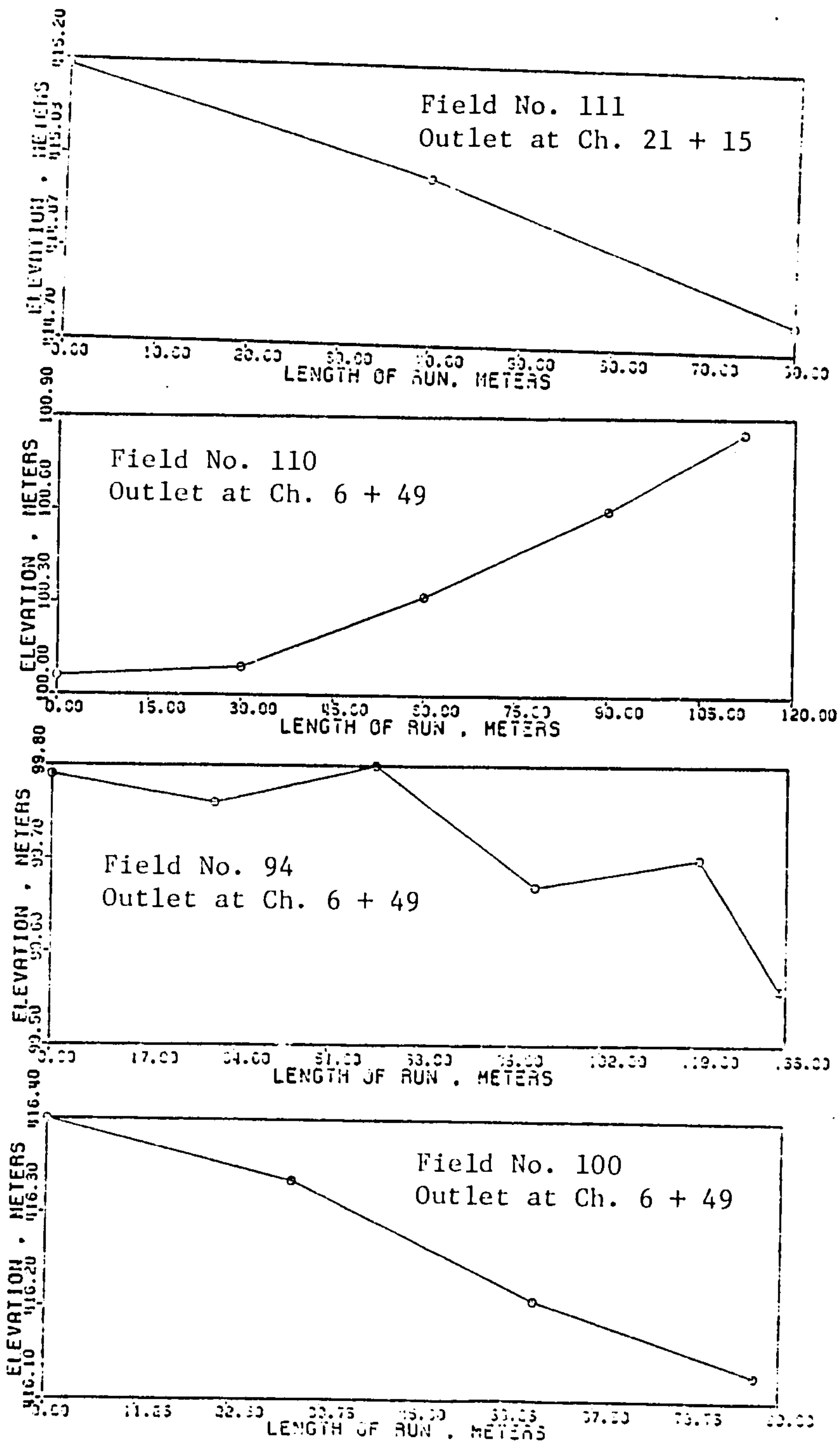


Figure 11. Slopes in Field on Rithola Minor.

General observations of irrigation revealed several general problems: (1) unlevelness of the land, (2) the fluctuating discharge, and (3) low flow rates from division and subdivision of flow due to the large number of fields being irrigated at one time.

The most common method of water application to crops was wild flooding. In this method water from a watercourse is delivered through a small channel constructed across the field. The water spills from this channel to areas of the field, and the water is guided to various parts of the field by small bunds. The sequence of spilling and the amount of water delivered to a particular part of the field depends upon the topography, the small bunds built at the channel to direct the water, and the guiding bunds. The application of water depends significantly on the farmers' efforts to unsystematically distribute water over the field. Thus, some parts of the field receive excess water while the higher parts receive little or no water. Large amounts of over-irrigation and large amounts of under-irrigation result.

Besides the general practice of wild flooding, some farmers on the project have been using graded borders. Especially at chain 158 of Thikaria Minor, the farmers used it not only for cash crops like ladiesfinger (okra) but also on the wheat crop. Borders were 7 to 13 m wide and 34 to 165 m long. A layout of borders at chain 158 is shown in Figure 12.

The criteria for the amount of water needed was to apply water until it reached the end of the field. This was repeatedly observed during the detailed study, both at chain 5 outlet and chain 158 of Thikaria Minor for gram and wheat, respectively. Advance and recession data observed at Border No. 1 and 2 at chain 5 and another at chain 158

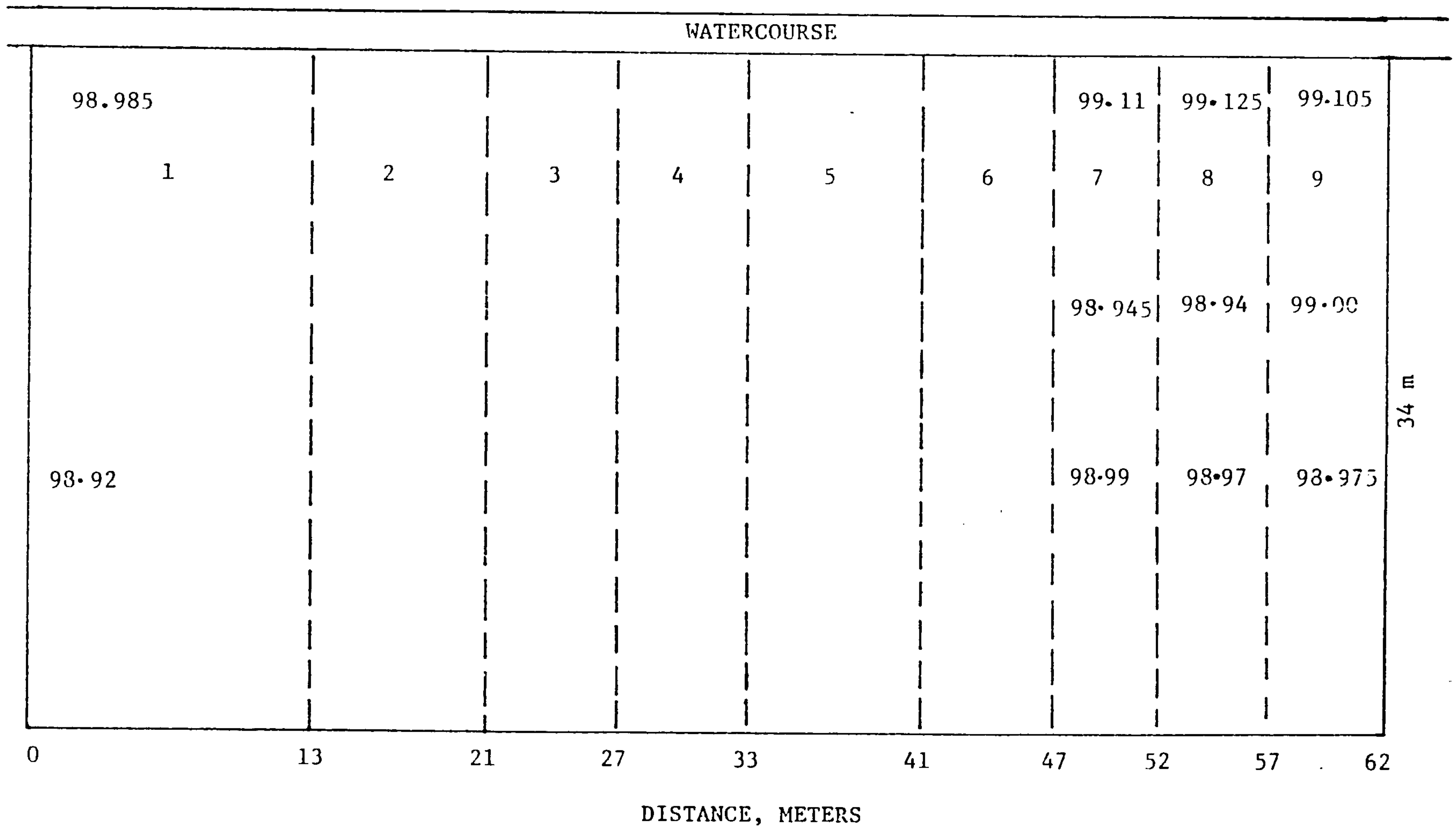


Figure 12. Layout of Borders at the Chain 158 Outlet of Thikaria Minor

were plotted. Studies were also carried out with infiltrometers on these borders to find the rate of infiltration. With the advance and recession curves, and knowing infiltration opportunity time and the rate of infiltration, the total amount of water infiltrated at a location in the border was determined. The ground profile, advance and recession curves, and the depth of water infiltrated are plotted together to give a visual idea of the combined effect on total infiltration (Appendix B). The values of uniformity coefficients and the application efficiency for the three borders appear in Table 13.

Table 13. Uniformity Coefficient and Application Efficiency of Borders

Outlet No.	Border No.	Uniformity Coefficient	Application Efficiency	Remarks
5 Chain Thikaria Minor	1	0.95	100	Underirrigation
	2	0.89	100	Underirrigation
Chain 158 Thikaria Minor	1	0.90	100	Underirrigation

These two detailed irrigation observations do not provide sufficient data to reach conclusions; therefore, a more detailed study of performance of graded borders is necessary. Based on experience with this type of irrigation system and general observations, a number of problems with graded border irrigation exist.

One problem is that the reverse grades on the borders are considered unacceptable. A second problem relates to the inadequate opportunity time at the upper and lower portion of the border when the farmer uses the criteria of irrigating until the water reaches the end of the border. A third problem relates to the ponding of water and the selection of proper flow rate over which the farmer has little control.

To irrigate graded borders uniformly, the farmers should select an oppropriate flow rate for the particular slope (grade) such that advance and recession times result in a distribution of water uniform with the infiltration rates of the soil. A wide variation in flow rate would make it essentially impossible for farmers to control the application of irrigation water to a graded border. This results in over-irrigation for some part of the field and under-irrigation for the other due to combination of intake, slope, and flow rates. Because of wide fluctuation in flow rates, the result of irrigation at a given place in the field varies depending on the flow rate of water that actually arrives at the field. Good water management in these conditions is extremely difficult.

For opium production, level basin irrigation was practiced in all parts of the project command with well water irrigation, either using a charas or a pump driven by electric or a diesel motor. The size of level basins was as small as 4 x 5 feet. Farmers applied water to level basins by observing when a certain depth in the basin was achieved. This method needed more labor. The farmer understands the benefits of proper distribution of irrigation water when the crop is valuable and the water supply is scarce. No detailed study of level basins was conducted because well irrigation was not in progress during the time of study.

c. Water Use Subsystem

Generally farmers irrigated when water was available in their minor and outlet. On Thikaria Minor farmers had two to three irrigations, while at Rithola Minor the number of irrigations varied from one to two, depending on the location, (head or tail outlet) of the minor. A farmer at chain 158 of Thikaria Minor, irrigated his field from a well three days before the canal supplies were available as he did not know the availability of water from the canal; he again irrigated when canal water was made available since he was uncertain about the next watering from canal. Because well water, obtained either with charas or pumps, is considerably costlier than canal water, a farmer applies well water to canal-irrigated fields only when he feels greater loss to a crop in the absence of water. The result was that some fields were overstressed with yield reductions, while others were over-irrigated because of frequent applications. Within a field over-irrigation and under-irrigation are expected to be widely variable because of the nonuniformity of surface level, the system of irrigation, and the farmer's criteria for application of water. A more careful determination of frequency of watering for the type of system, the crop, and the soil needs to be determined for the project area. Farmers should be made aware of the general recommendations. Operation of the canal system should then be synchronized.

d. Water Removal Subsystem

The surface drainage throughout the project area appears to be good. This is because of more than adequate grades on fields. However, there may be erosion problems during the monsoon season due to rainfall and rainfall runoff from the fields.

Subsurface drainage throughout the command seems to be adequate. Wells appeared throughout the command. For example, there were 3 and 4 wells in the command of chains 145 and 158 of Thikaria Minor, respectively, and there were 4 and 21 wells in the command of chains 75 and 77 outlets of Rithola Minor, respectively. Table 14 indicates that the water table was about 7 to 8 m below ground. Similarly, the water level in wells in the command of chain 75, Rithola, varied from 5.9 to 8.6 m.

Table 14. Waterlevel in Wells at Chain 158 of Thikaria Minor

No.	Location of well (Field survey no.)	Water level in well (m)*	Average Ground Level (m)	Remarks
1	67	92.26	100.00	Lift irrigation by electric pump
2	53	93.21	100.00	Lift irrigation by charsa
3	11	92.33	99.50	Not used for irrigation
4	5	92.37	99.50	Not used for irrigation

*With reference to arbitrary bench mark.

The farmers at the tail of Rithola Minor, at the chain 75 and 77 outlets, said that the yield of water from the wells was good when the minor was running and was less when the minor was not running. The wells in command of chains 145 and 158 of Thikaria Minor were used as sources of supplemental irrigation; most of the wells in command of chains 75 and 77 of Rithola Minor were the main sources of irrigation since the amount of water available in the minor was inadequate and undependable.

If the conditions for irrigation water availability were improved and the wells were seldom or never used for irrigation, the water table might rise and careful observation of the water table would be needed. Even at that time, some system of conjunctive use of well waters would need to be devised which, on one hand, would provide more water for irrigation and, on the other, keep the water table under control. This is especially needed at the tail chaks of Thikaria and Rithola Minors as the quality of well water is comparatively poor. The EC is of the order of 2000-2400 mmhos/cm and the pH about 8.2.

B. Legal Status

The "Rajasthan Irrigation and Drainage Act, 1954" and the related "Rajasthan Irrigation and Drainage Rules, 1955" govern the irrigation and drainage in Rajasthan. Section 31 and 32 of the Act together with Rules 10 and 11 of the "Rajasthan Irrigation and Drainage Rules, 1955" deal fully with regard to supply of water, i.e., grounds of refusal to grant water, fields liable to be debarred from canal irrigation, and distribution of water. Subsections 1 to 3 under Rule 11 give adequate powers to deal with unauthorized outlets while subsection 4 of Rule 11 together with subsections (f) and (h) of Rule 10 deal with enforcement of warabandi-distribution of water among the farmers of a chak. Under Rule 9(b) action can be initiated for the conjunctive use of ground water with canal water.

Fields can be debarred from canal irrigation for nonmaintenance of watercourses under subsection (g) of Rule 10, while subsection (d) deals with the preparation of fields in kyaris (subparts) for application of water. Section 18 deals with the construction of watercourses while Section 18A provides for governmental construction and maintenance of watercourses at the expense of the farmers in case of default. Section 55 of the Act deals with imposition of penalty and imprisonment for violation of any rules.

The provisions of the Act and Rules are not fully understood by the irrigation officials at the various levels, and there seems to be general lack of initiative to enforce them. However, for effective enforcement, some general simplification of rules is needed along with increased knowledge and understanding of the same. The following needs attention:

(1) For more effective enforcement of the provisions of the Act and Rules; magisterial authority should be vested with Executive Engineers on medium irrigation projects as has been done on major projects such as Chambal. The present procedure of taking such matters to a magistrate is not only time consuming, but ineffective.

(2) Officials at various levels need to be trained in the proper understanding of the provisions of the Act and Rules, their dissemination, and enforcement.

While the above could provide a means of better enforcement, a more effective approach would be one of mutual cooperation involving farmers' organizations in the management of the system.

C. Positive Aspects of System Operation

In any Diagnostic Analysis a major focus is the operation of the system and constraints to improvement. In the process of studying a system, the focus tends to be on the deficiencies of operation. However, there are always some positive aspects of operation. The following positive aspects of system operation in the Gambhiri Project, though not quantified, represent major benefits.

(1) The cooperation of the farmers, *sarpanches* of the *panchayats*, irrigation officials such as *patwaris*, junior engineers, assistant engineers, and the executive engineer was indicative of the high level of interest shown in improving the

operation of the system. Their assistance was essential in understanding the system and how it works.

(2) Preparation and submission of a "modernization estimate" of the project for sanction further indicated the interest and mood of the irrigation officers. They were aware of the deficiencies in the system and wish to improve the same.

(3) The rotational running system of minors was an adjustment of the Irrigation Department and of the farmers for the insufficient discharging capacity of the main canal systems.

(4) Farmers dug wells, operated labor intensive and costly charas, or installed diesel or electric pumps to provide more adequate and dependable water supply.

(5) Good surface and subsurface drainage existed in the project command.

The farm water control system constraints were as follows:

(1) The supply of water was inadequate, inequitable, and untimely. The water supply was more on head minors than at tail minor, and on head outlets than on tail outlets of the same minor. The discharge in an outlet fluctuated also with time.

(2) There was no system for equitable distribution of water below the canal outlet.

(3) No assistance was provided to the farmers for the design, construction, and management of the watercourses. Therefore, watercourses were improperly designed and constructed, resulting in watercourses with steep slopes and nonexistence of drop structures, nakkas, etc. This resulted in unnecessary lengths, overtopping, and excessive water losses.

(4) Wild flooding, the prevalent method of applying water to fields, was ineffective and inefficient. No assistance was provided to the farmer for field water application. Some graded borders and level basins were used, but fluctuations in flow rate and unlevelness of fields were still major constraints.

(5) Erosion in the fields seemed to be a problem during the monsoon season.

IV. SUMMARY

This study examined the left main canal of the Gambhiri Irrigation Project and two minors, Thikaria and Rithola, in the head and tail reaches. Observations indicated that the left main canal needs to be redesigned in various reaches. The bed level was higher than designed in certain reaches, and thus its discharging capacity was substantially low and was not sufficient to feed all the minors and outlets simultaneously. The rotational system of running minors was grossly inequitable in favor of head reaches.

The two minors had steep, slopes causing erosion in the unlined Rithola Minor and insufficient depth of flow to feed outlets in both the minors. As there were no regulators on the minors, farmers interfered in operating and running the minors. This resulted in discharge fluctuations in outlets downstream and inequity in distribution of supplies.

A large number of unauthorized outlets existed on the two minors. Even with higher discharge than the designed capacity of the minors, all the outlets on each minor could not be fed simultaneously, and the tail reaches did not receive any water. The rotational running of outlets on a minor was impossible.

The four subsystems of farm water control system studied on seven outlets had several problems. Fluctuations in flow rate at the outlet and at the field were significant because of fluctuations in flow rate in the minor and operation of outlet discharge by the farmer.

The alignment, grade, and sections of the watercourses were not proper. The lack of control and drop structures, division boxes, and *pucca nakkas* caused erosion of the channel bed and inability to command fields. Consequently, another watercourse had to be brought in to command the fields. Improper alignment of the watercourses left many fields uncommanded and resulted in longer than necessary watercourses. In tail *chaks* of Rithola Minor, watercourses commanding the full cultivable area did not exist. The maintenance of the watercourses was poor. All this resulted in heavy losses in conveyance which, with the limited data available, was estimated at more than 40 percent.

Wild flooding was the general method of application of irrigation water. Even with the graded border system in use, water application was far from satisfactory because the fields had unlevel topography. The division and subdivision of flow rate, simultaneous irrigation of several fields, low and variable rates of discharge, and improper design resulted in variable water application depths. The limited data available showed that the fields were under-irrigated after highly stressed conditions, contrary to the general concept of over-irrigation. Under-irrigation and over-irrigation in parts of the field were the result of uneven topography. This was evidenced by poor crop stands and yields in the area. However, the farmers perceived their fields to be level.

The farmers did not know about the time of canal water availability. There was no system of water distribution among the fields under an outlet. At tail chaks of Thikaria Minor wells were the source of supplemental irrigation, while at the tail chaks of Rithola Minor wells were the primary source of irrigation and canal water was the supplemental source.

Surface drainage seemed to be very good due to sufficient grades of fields. Subsurface drainage for the time being also seemed to be good. The groundwater table varied from 5 to 9 meters. However, more supplies that may be made available with improvement of the system could result in nonuse of wells for irrigation.

The provisions of the Irrigation and Drainage Act and Rules concerning supply and distribution of water were not being enforced. The knowledge in regard to the provisions of the Act and Rules was not fully understood by the irrigation officials at the various levels, and there seemed to be a general lack of initiative to enforce them. For effective enforcement, proper understanding of the provisions of the Act and Rules by the officials at the various levels is needed. Magisterial authority may be vested with the executive engineers since the present procedure to take the matter to a magistrate is time consuming. In addition, effective farmer participation in water allocation and distribution and related activities must be started.

Surface drainage seems to be very good due to sufficient grades of the fields. Subsurface drainage also seems to be good at present. The ground water table varies from 5 to 9 meters. However, the effect of making more water available with improvement of the system and nonuse of wells for irrigation must be kept in mind.

The provisions of the Irrigation and Drainage Act and Rules concerning supply and distribution of water are not being enforced. In addition, these provisions are not fully understood by the irrigation officials at the various levels, and there seems to be general lack of initiative to enforce them. For effective enforcement, proper understanding of the provisions of the Act and Rules by these officials is needed. Magisterial authority could be vested with the executive engineers since the present procedure to take the matter to a magistrate is time consuming and ineffective. In addition, effective farmer participation in water allocation and distribution and related activities must be started.

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APPENDIX A

Measurement of Losses in Watercourse by the Ponding Test

Rithola Minor was closed during the period of study; hence the seepage losses in the watercourse were estimated by ponding in a watercourse on Rithola Minor by taking water from well. The top width of the watercourse at the operational level was 27.5 cm and 49.4 cm, respectively, in reach 1 and reach 2. The operational level of the watercourse was 13 cm (depth of flow). The gauge readings at the two reaches at various time intervals were recorded and appear in Figure A-1. Using the method presented by Trout and Kemper (1980), the loss rates at the operational level (operational depth of the watercourse) were 0.700 lps/100 m and 0.43 lps/100, respectively, at reaches 1 and 2. The relationship between time and gauge reading, and gauge reading and top width for the two reaches (tests) are presented in Figure A-2. Based upon this data, the relationship between loss rate and the depth of water in the minor are presented in Figure A-3. From the data it is clear that the loss rates almost doubled when the water level in the watercourse was higher than the operational level by only 4 cm, and also was reduced to half of the operational level at 4 cm below operational depth.

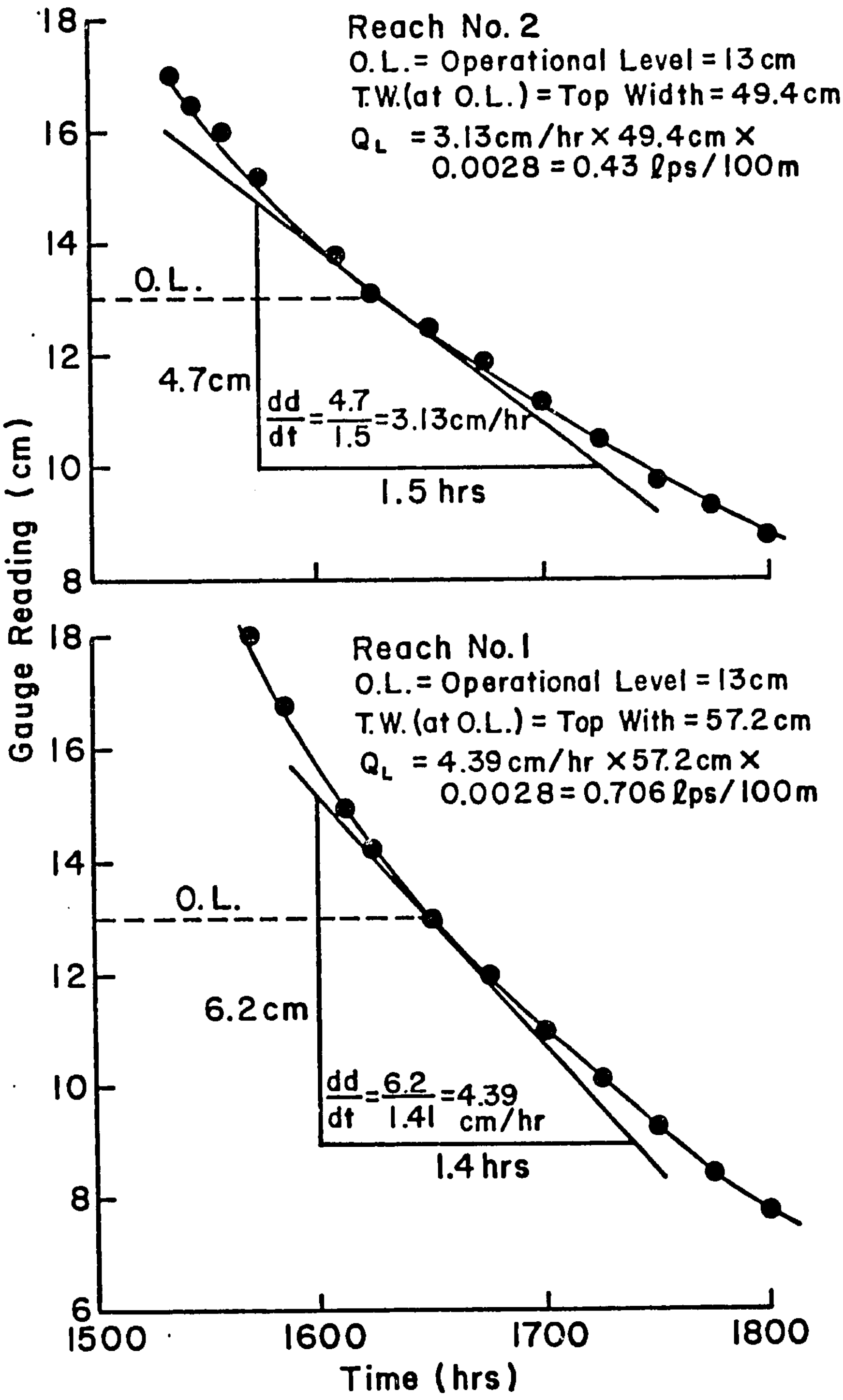

Figure A-1. Gauge Versus Time for Reaches 1 and 2 of Rithola Minor

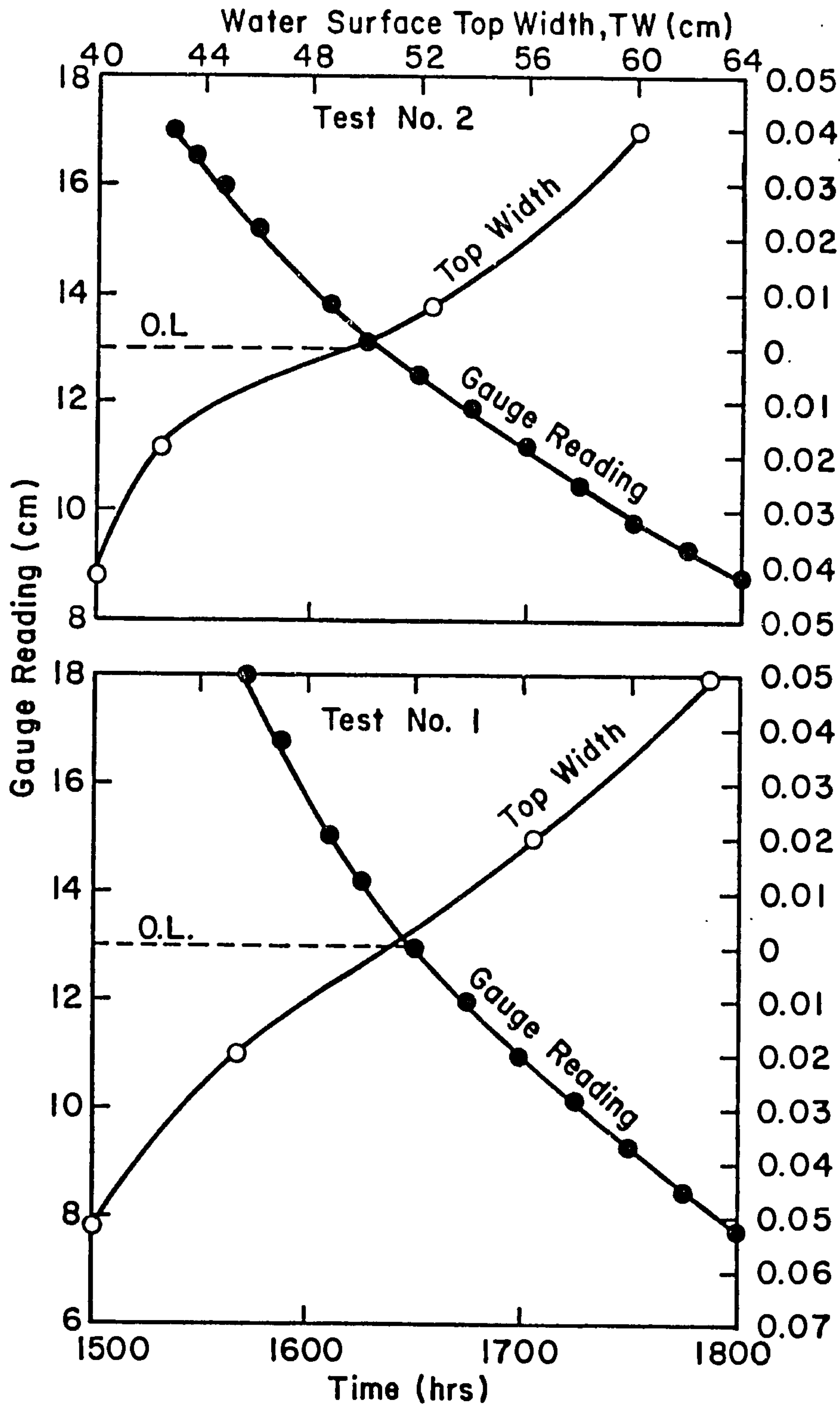

Figure A-2. Gauge Versus Topwidth and Gauge Versus Time for Reaches 1 and 2 of Rithola Minor

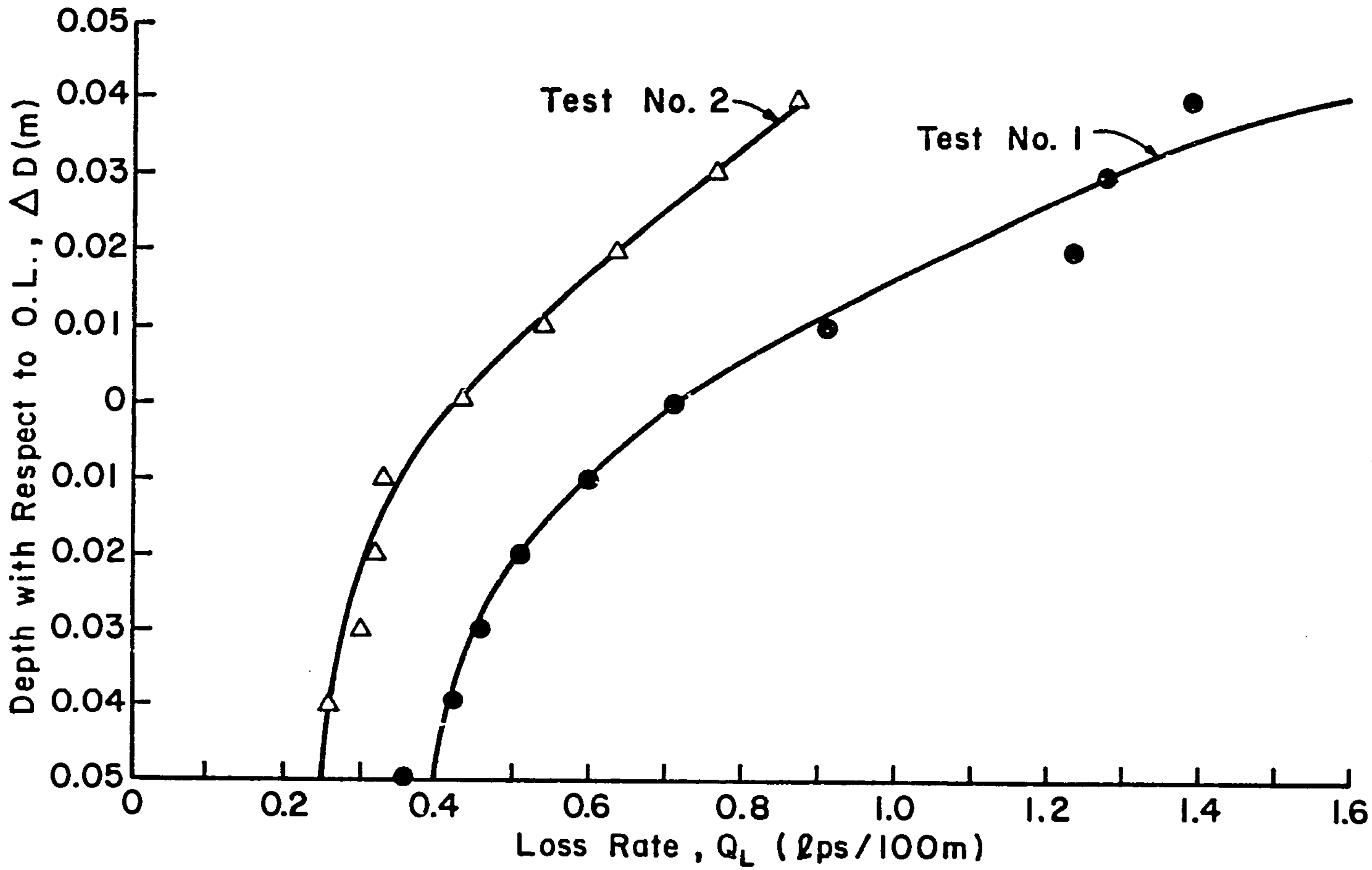

Figure A-3. Water Losses in Watercourses at Different Depths of Flow

APPENDIX B

Evaluation of Graded Borders

In the Diagnostic Analysis of the field application system, three graded borders were evaluated: two borders at chain 5 and one border at chain 158 of Thikaria Minor. The nos. 1 and 2 of the chain 5 outlet were 5.4 m wide, whereas the border of the chain 158 outlet was 5.0 m wide. The infiltration measurements were made using cylinder infiltrometers. The data for individual borders are presented in Figures B-1, B-2 and B-3. The field slopes, the soil-moisture deficiency before irrigation, and advance and recession were also measured (Figures B-4, B-5, and B-6), and the average slope of the borders and infiltration equations are given below:

Outlet Location	Border	Slope	Infiltration Function Original	Infiltration Function Adjusted
Chain 5	1	0.0097	$36.0\ t^{0.171}$	$36.0\ t^{0.171}$
	2	0.0097	$11.5\ t^{0.395}$	$16.8t^{0.395}$
Chain 158	1	0.0046	$22.0\ t^{0.150}$	$22.0\ t^{0.150}$

The inflow rates were 0.282 cfs and 0.54 cfs, respectively, into Border 1 and Border 2. Therefore, the unit inflow rates were 0.0159 cfs/ft and 0.0283 cfs/ft into Border 1 and Border 2. The average depth infiltrated into Border 1 was 77 mm and Border 2 was 86 mm. Since the outflow from the borders was insignificant, all the water applied infiltrated into the borders. The infiltration functions were adjusted accordingly (Ley and Clyma, 1980) and are as mentioned earlier. The water deficiency and the total water applied are as given below:

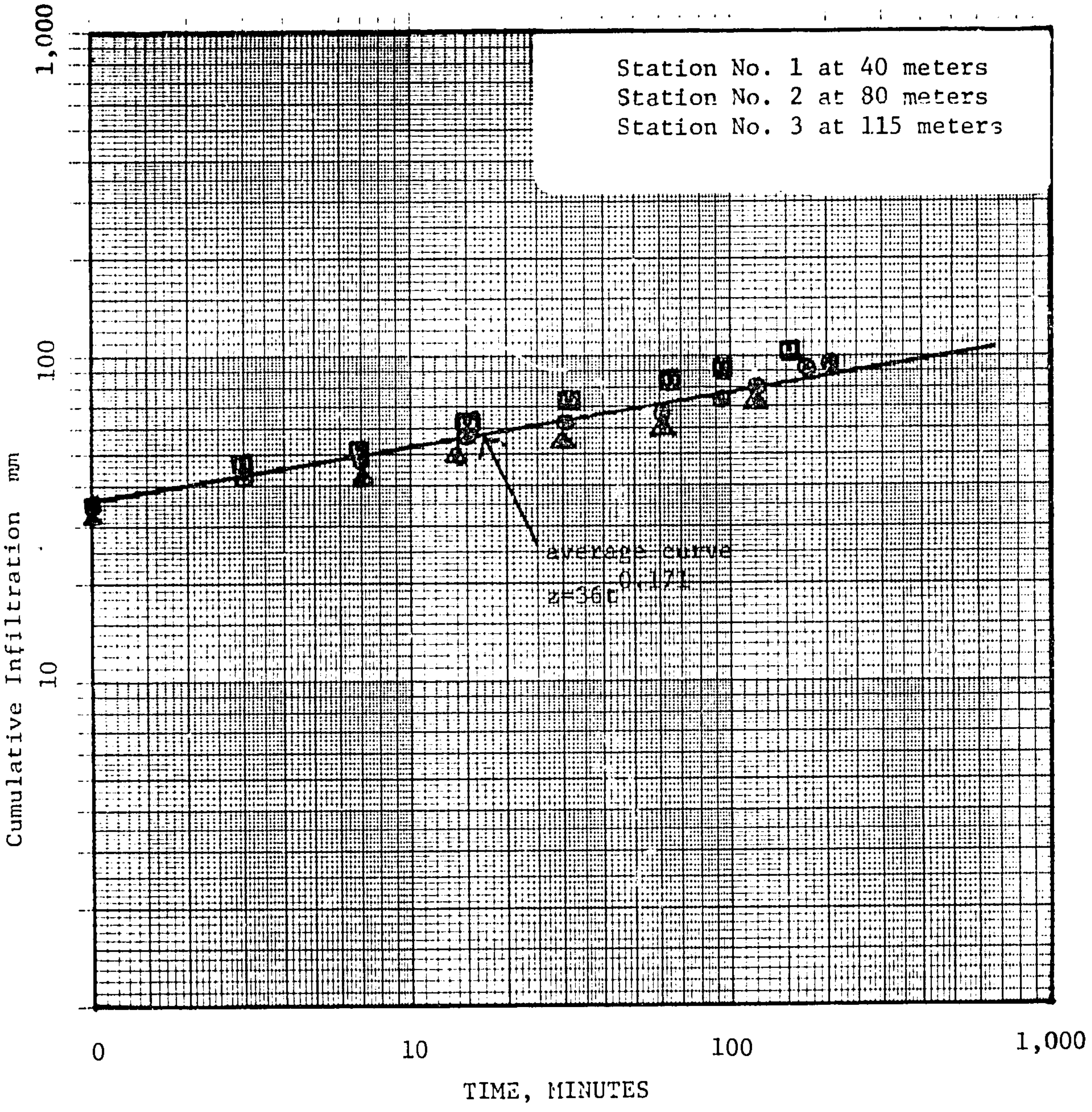

Figure B-1. Cylinder Infiltrometer Data for Border 1

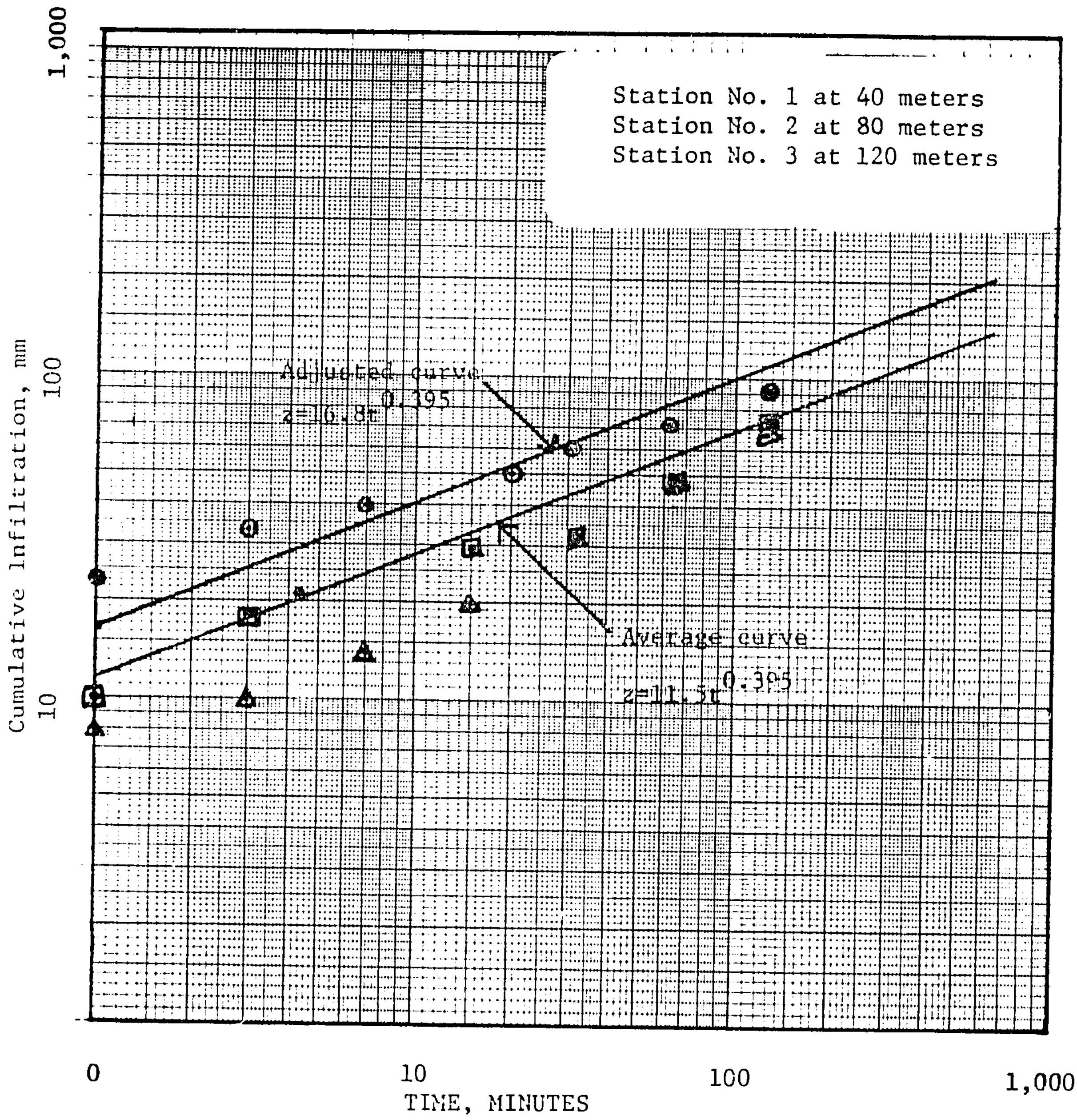

Figure B-2. Cylinder Infiltrometer Data for Border 2

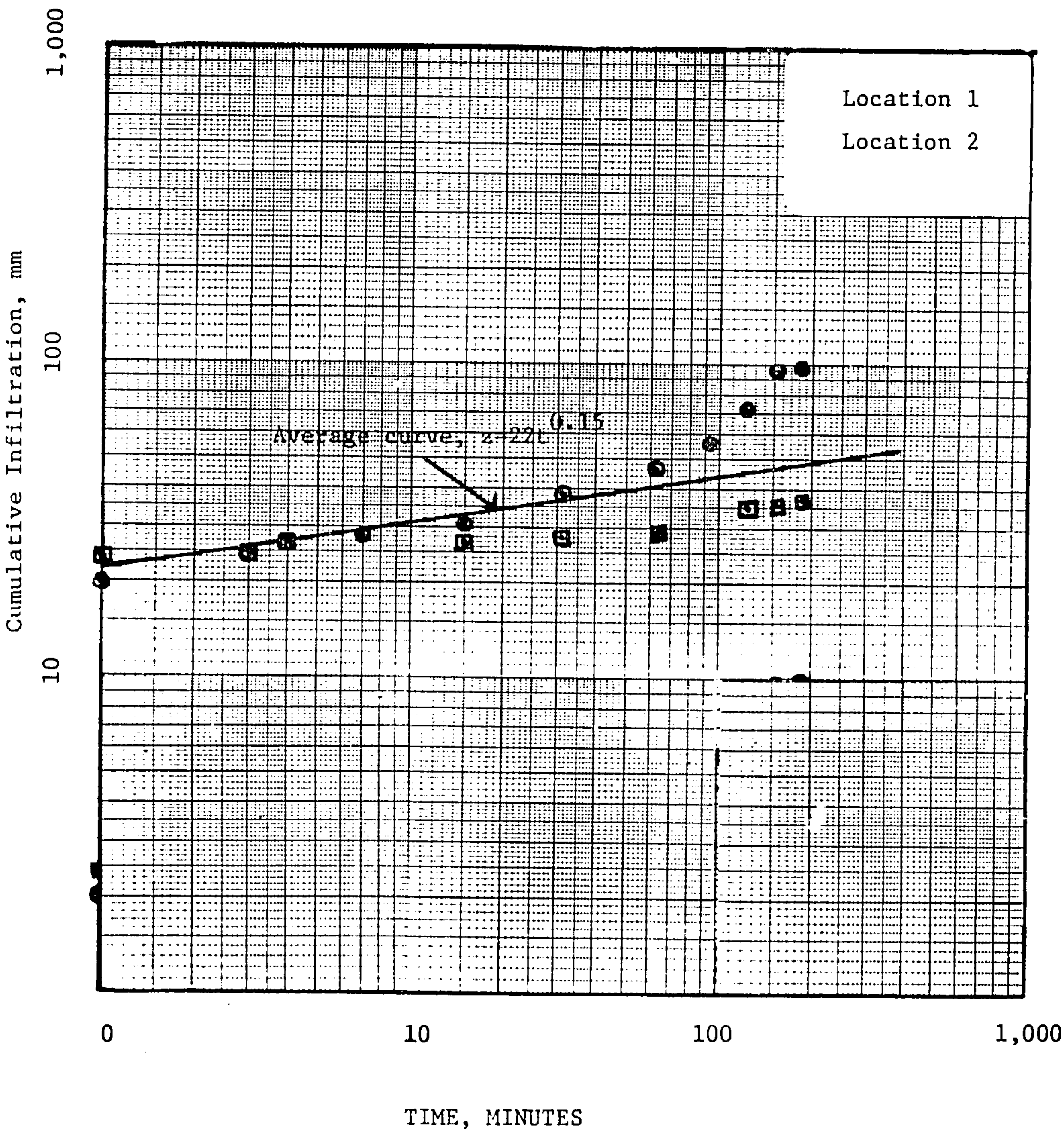

Figure B-3. Cylinder Infiltrometer Data for Border 1 at the Chain 158 Outlet of Thikaria

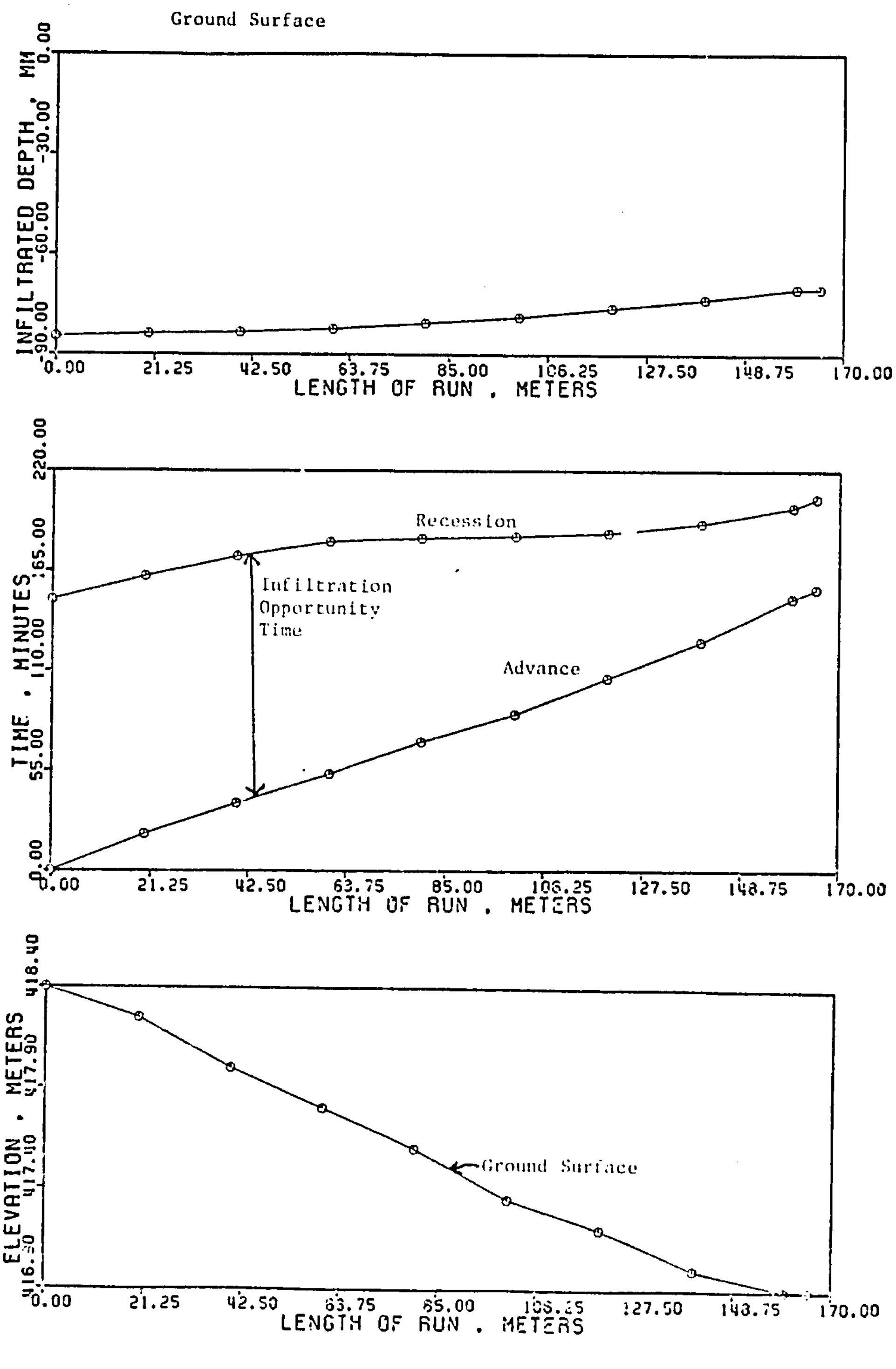

Figure B-4. Field Slope, Advance and Recession, and Infiltrated Depth for Border 1

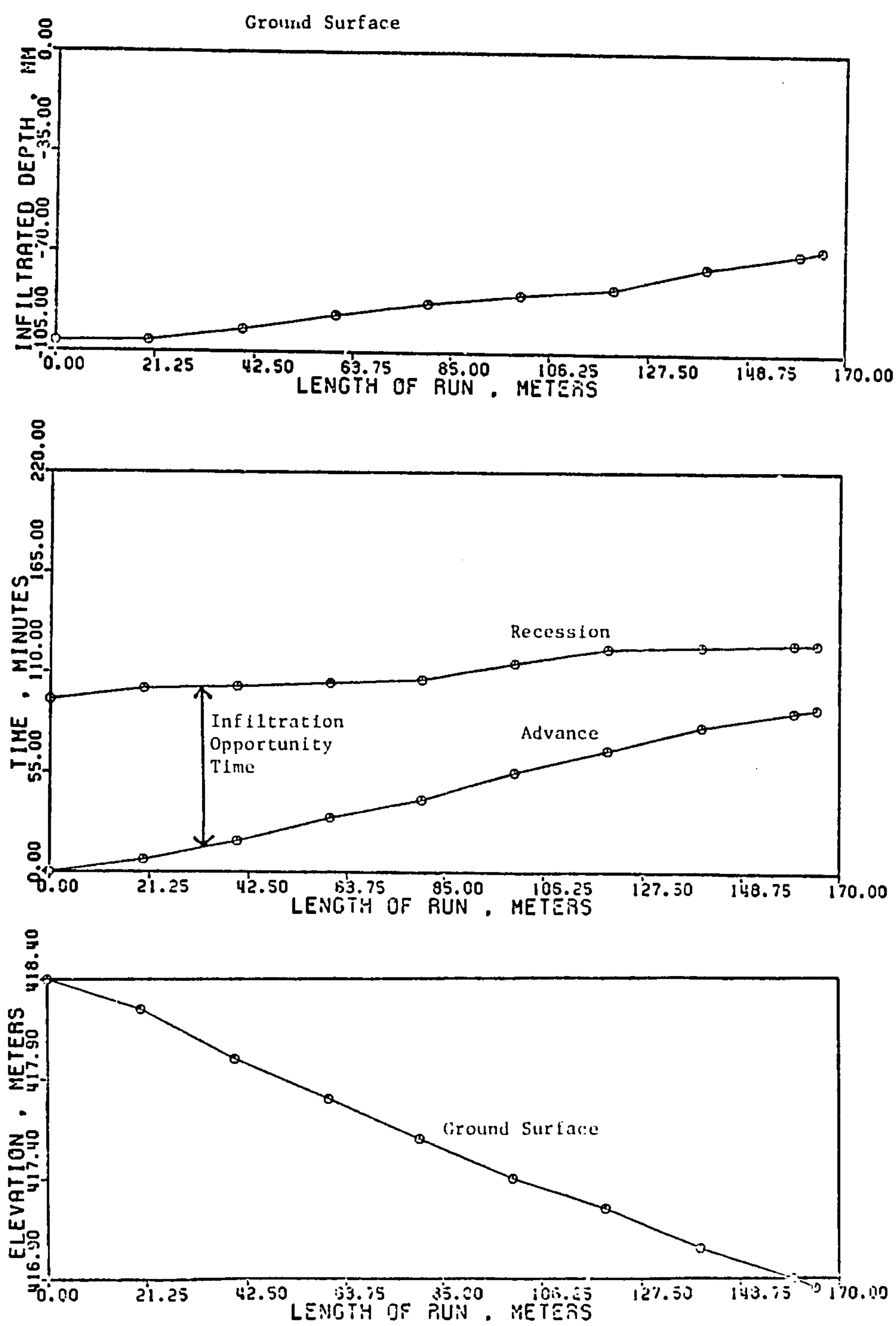

Figure B-5. Field Slope, Advance and Recession, and Infiltrated Depth for Border 2

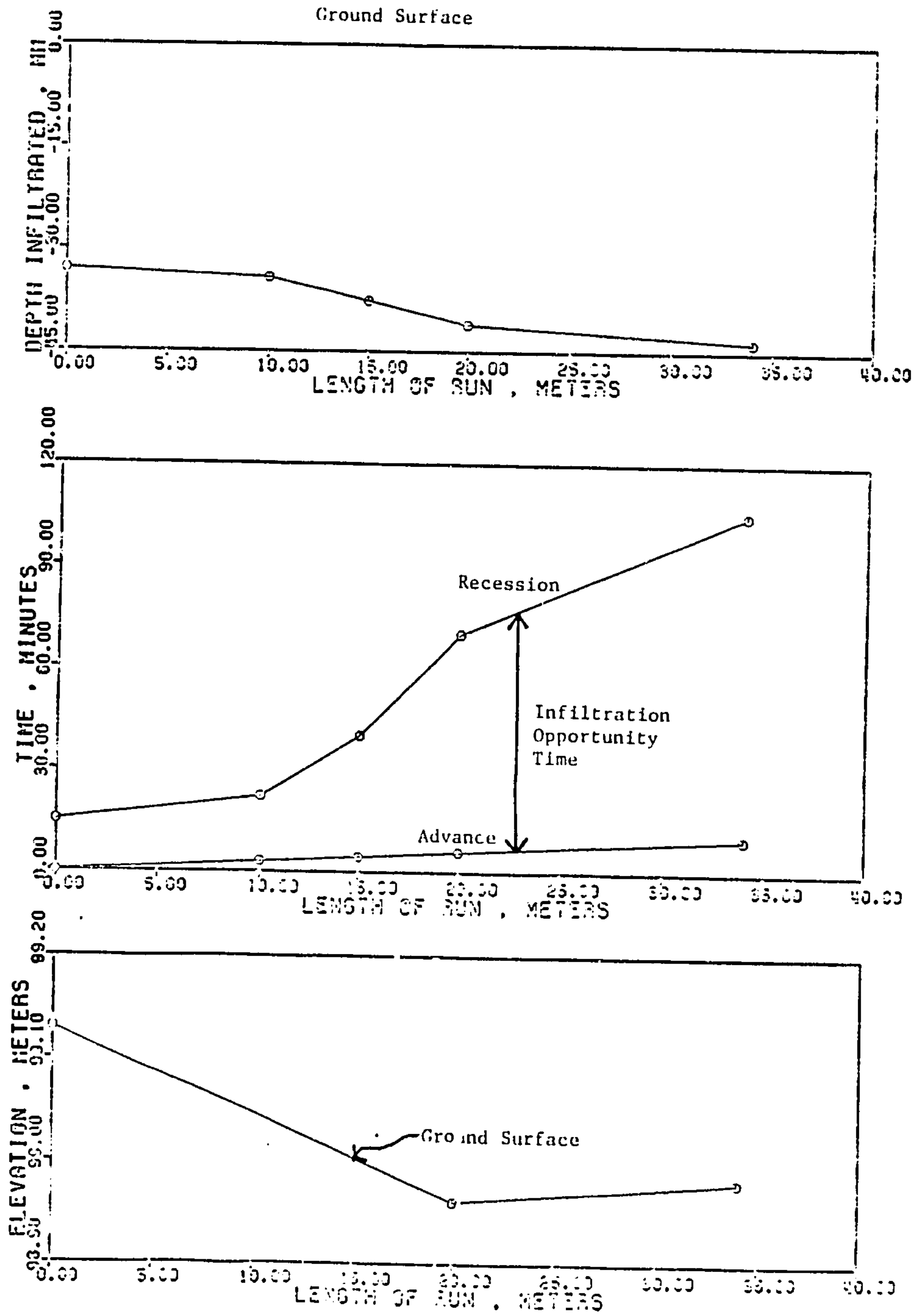

Figure B-6. Field Slope, Advance and Recession, and Infiltrated Depth for Border 1 at Chain 158 Outlet of Thikaria

Outlet Location	Border	Deficiency	Depth Applied	E_a*	UC**
Chain 5	1	106 mm	77 mm	100	0.95
	2	112 mm	86 mm	100	0.89
Chain 158	1	70 mm	-	-	0.90

The application efficiency and the uniformity coefficient (Christiansen, 1942) for the borders also are given above. Both the borders were under-irrigated, as is clear from above. According to the analysis, the performance of the borders was not adequate. In order to see whether the design satisfies the SCS design standard, a design is presented next for Border 1.

A design depth of 3.5 inches (89 mm) was taken. Based on the infiltration characteristics of Border 1, intake family No. 1 (USDA, 1974) was chosen ($z = 0.0701t^{0.785} + 0.275$ inches). The time to infiltrate (t_u) 89 mm was:

$$t_u = \left(\frac{3.5 - 0.275}{0.0701}\right)^{\frac{1}{.785}} = 144 \text{ min} \quad .$$

The average slope of the border (S_o) was 0.0097. The roughness (n) was supposed to be 0.15. For the given slope, recommended width is 50 ft (15 m), and the application efficiency is 65 percent. The unit flow rate per 100 ft length of border (q_u) is given as:

$$q_u = \frac{3.5}{7.2*144.26} = 0.00337 \text{ cfs/ft}$$

and the unit flow rate for the full length of the border (Q_u) is

$$Q_u = 0.00337 * \frac{(165*3.28)}{100} \frac{100}{65} = 0.02806 \text{ cfs/ft}$$

---

*E_a = Application efficiency. The ratio of the amount of water stored in the root zone to the amount of water applied to the field, expressed in percent.

**UC = Coefficient of uniformity (see Christiansen, 1942).

The maximum nonerosive stream size ($Q_{u)erosion}$) for the field is:

$$Q_{u)erosion} = 0.0019\ \bar{S}_o^{.75} = 0.0019(.0097)^{-0.75}$$

$$= 0.0615 \text{ cfs/ft}$$

The constraint on flow for minimum depth ($Q_{u,min,depth}$) is

$$Q_{u,min,depth} = (0.000064)L\ S_o^{1/2}/n$$

$$= 0.00064(165*3.28)(.0097)^{0.5}/0.15$$

$$= 0.0227 \text{ cfs/ft}$$

The maximum depth of flow was

$$\left(\frac{Q_u \cdot n}{C_u\sqrt{S_o}}\right)^{0.6} = \left(\frac{0.02806 * 0.15}{1.486\sqrt{.0097}}\right)^{0.6} \begin{array}{l} = 0.12' \\ = 1.43'' \end{array}$$

(where n is Mannings rugosity, and C_u = 1.486 in Mannings formula for velocity in the English system) which is reasonable. Therefore, the design specifications based upon the SCS design procedure are:

SCS	Existing
Q_u = 0.02806 cfs/ft	Q_u = 0.01593 cfs/ft
t_a = 144 min	t_a = 143 min
E_a = 65 percent	E_a = 100 percent (due to under-irrigation)
	L = 541.20 ft (165 m)

Comparing with the Soil Conservation Service border irrigation design procedure (USDA, 1974), the existing flow rate is much smaller than the minimum recommended under the given set of field conditions. Therefore, the existing design is not satisfactory.

The required minimum flow rate for the given set of conditions is 0.0227 cfs/ft, which guarantees sufficient spread of water across the field. The actual flow rate found in the field was 0.0159 cfs/ft. Hence the advance rate was very slow even on this steep slope (0.0097), and the difference in infiltration opportunity time between the upstream end and the downstream end is significant. The calculated uniformity is still very high due to the infiltration characteristics of the soil.

Similarly, the permissible width for the given slope is 50 ft. The actual width of the border is 17.50 ft. Using the maximum permissible width minimizes the number of borders (and bunds) in the field, and takes minimum land out of cultivation. Since the width of the border is much less than recommended and the field is unlevel, the field levelness could be the constraint on border width. Conversely, since the flow rate was much smaller than the minimum required and the dependability of water supply was low, flow rate seems to be the constraint for the given situation.

The operation of the system also plays an important role on the performance of the system, which is obvious under the present situation. The criteria used by the farmer for cutting off the flow rate into border is when the flow rate reaches the downstream end of the field. The soil infiltration rates are very low. The criteria of cutting off the flow rate when the water reaches the downstream end of the field did not leave enough opportunity time to infiltrate the required amount of water into the root zone. The result was under-irrigation Figures B-4 and B-5.

Reverse field slopes are also present. In Border 1 of outlet at chain 158, the field has a steep slope at the upstream end of the field, and towards the downstream end the field has negative slope. The water advanced and receded in the initial section very fast, and the water receded very slowly towards the downstream end of the field (Figure B-6). The difference in the infiltration opportunity was great between the upstream and downstream end of the field. The uniformity coefficient for Border 1 at chain 158 is 0.90.

APPENDIX C

Chak Plans, Longitudinal Profiles, and Cross Sections of Watercourses under Thikaria and Rithola Minors

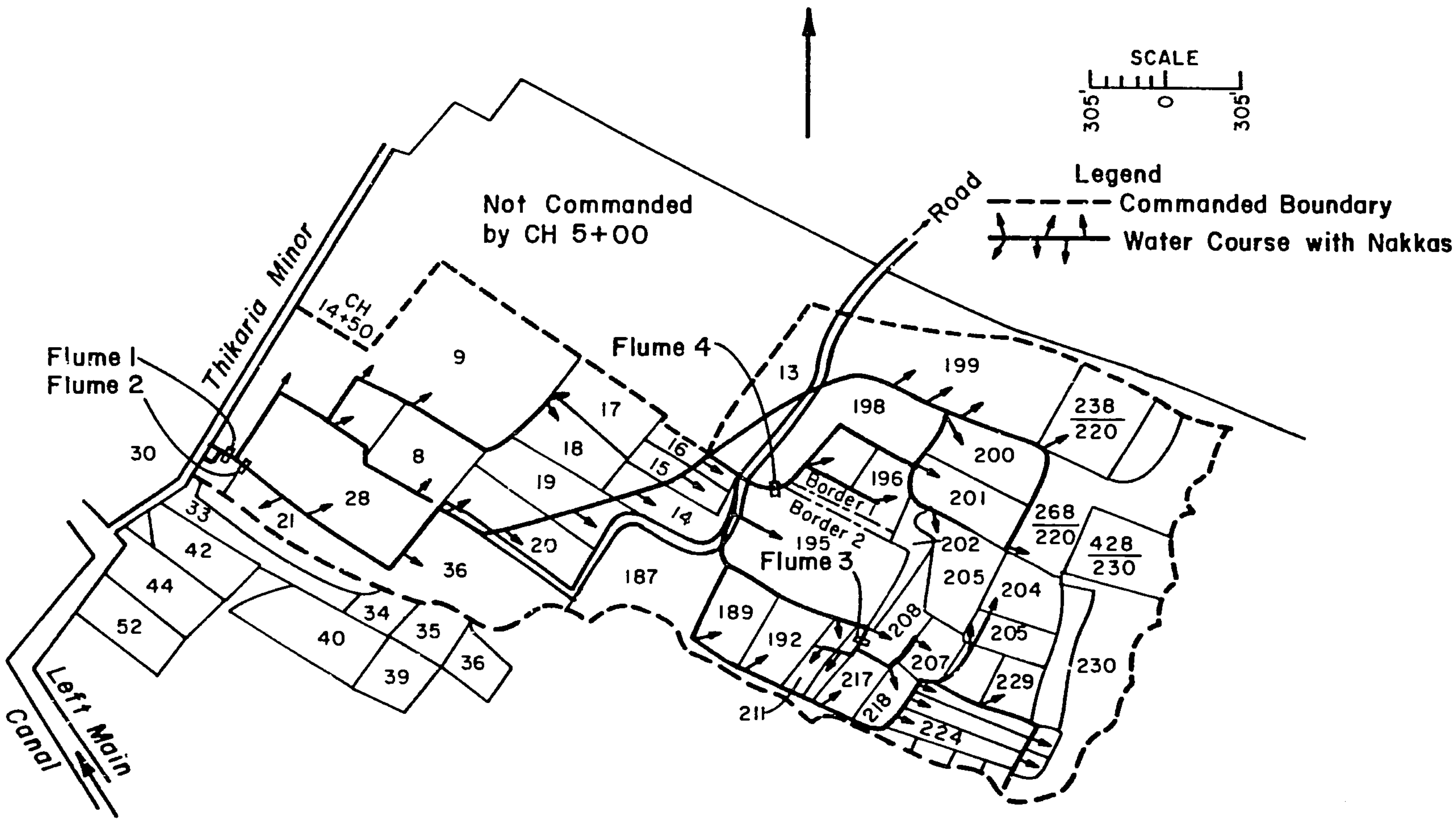

Figure C-1. Chak Plan of Outlet at Chain 5 Thikaria Minor

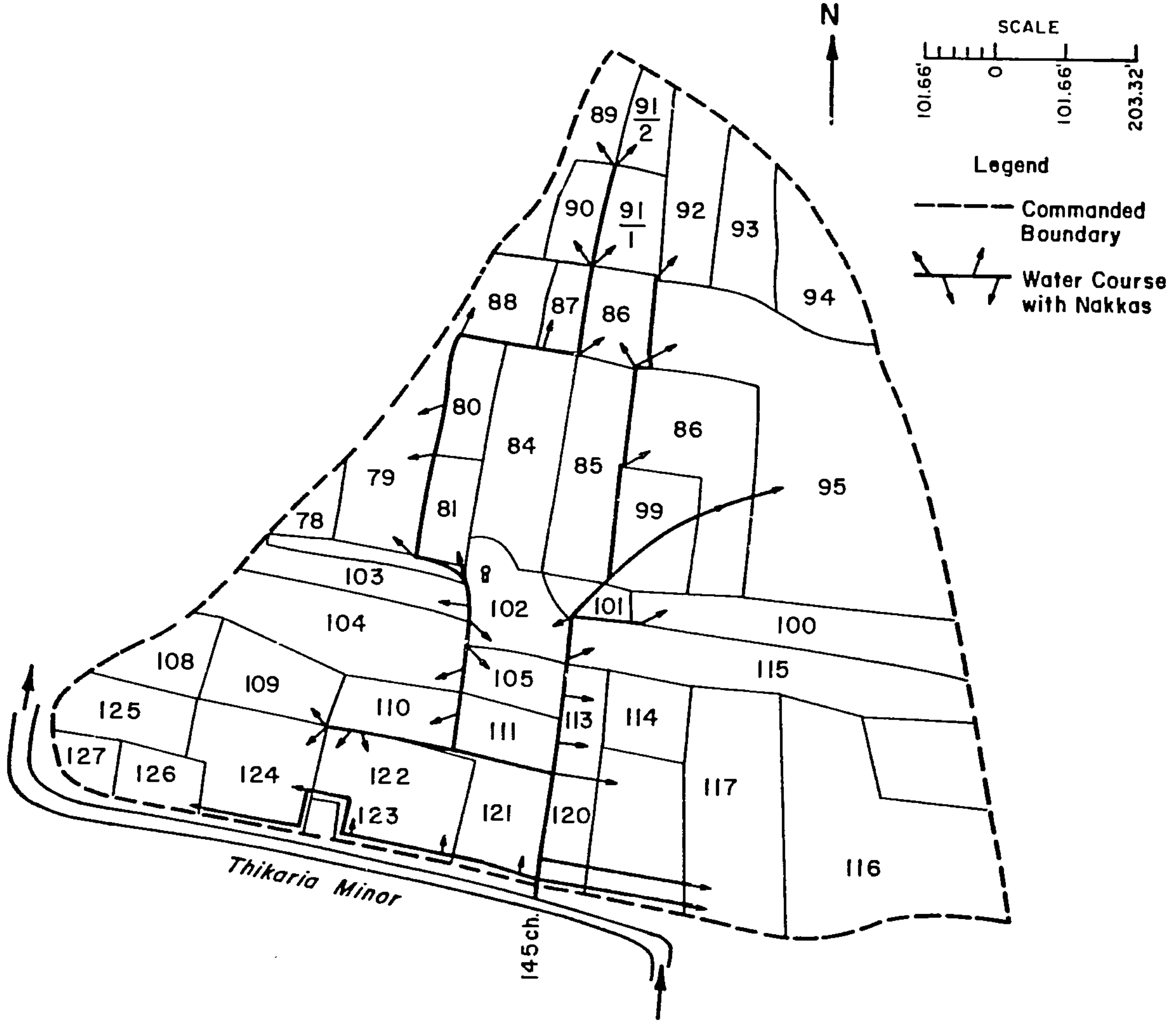

Figure C-2. Chak Plan of Outlet at Chain 145 of Thikaria Minor

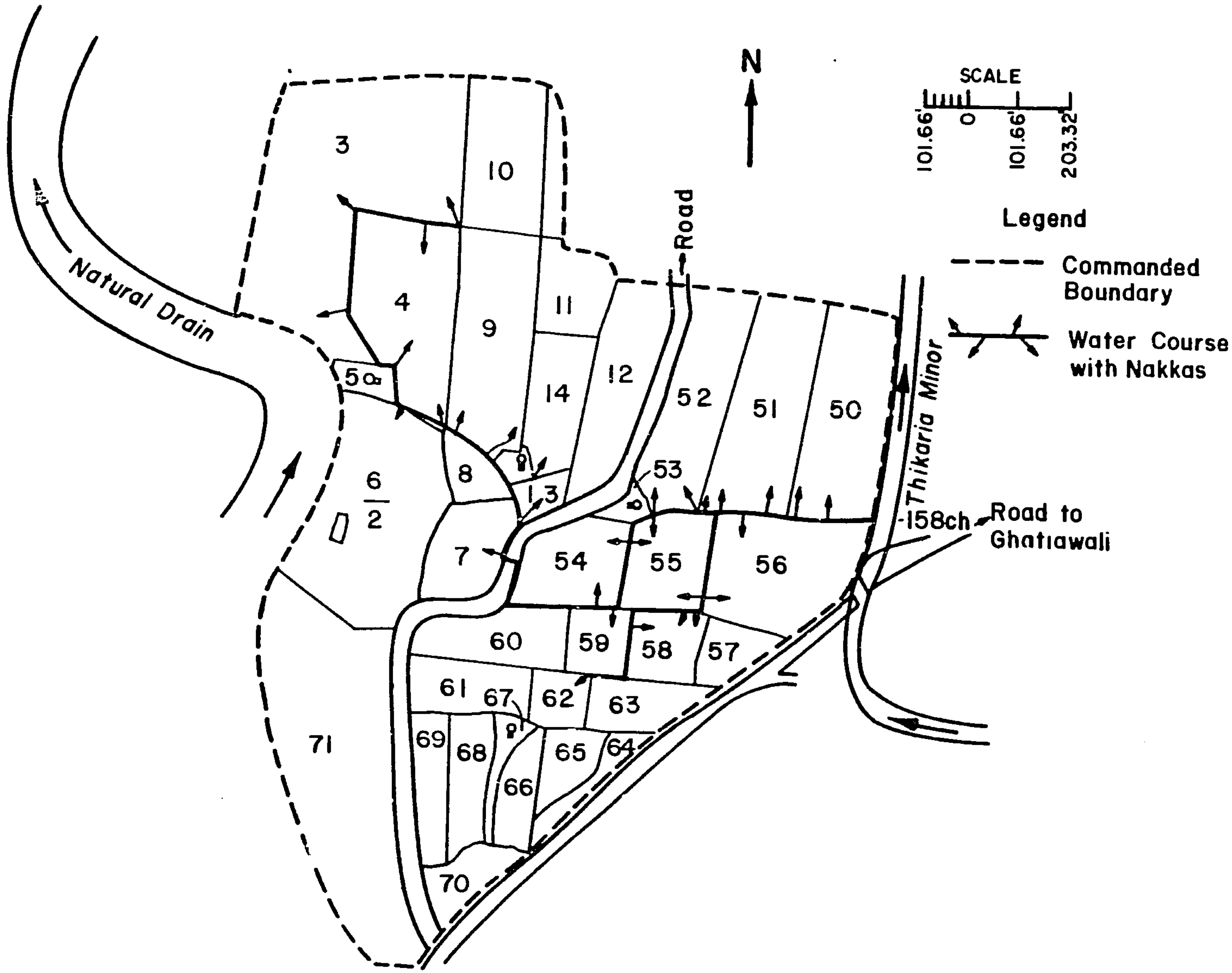

Figure C-3. Chak Plan of Outlet at Chain 158 of Thikaria Minor

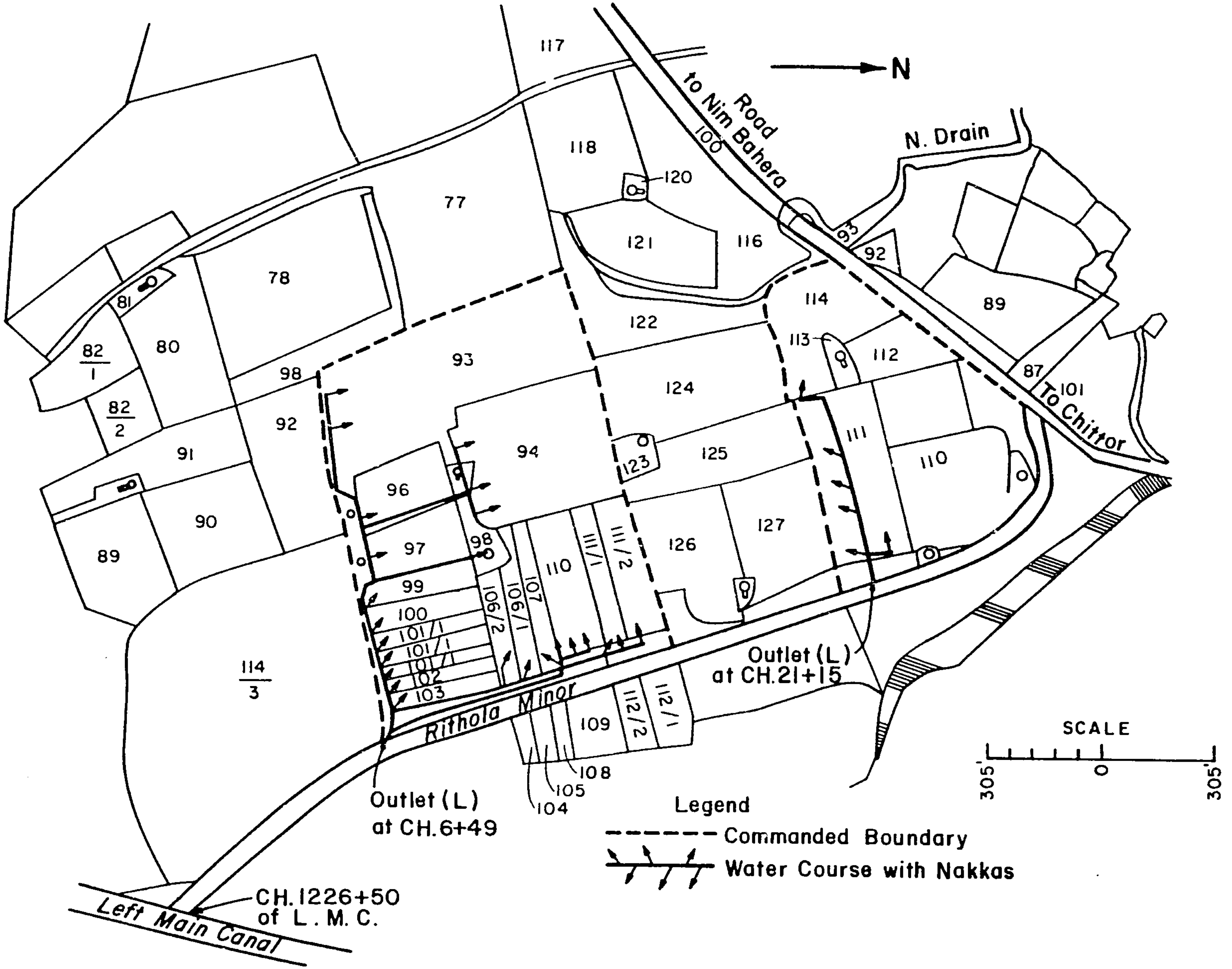

Figure C-4. Chak Plan of Outlets at Chains 6+49 and 21+15 of Rithola Minor

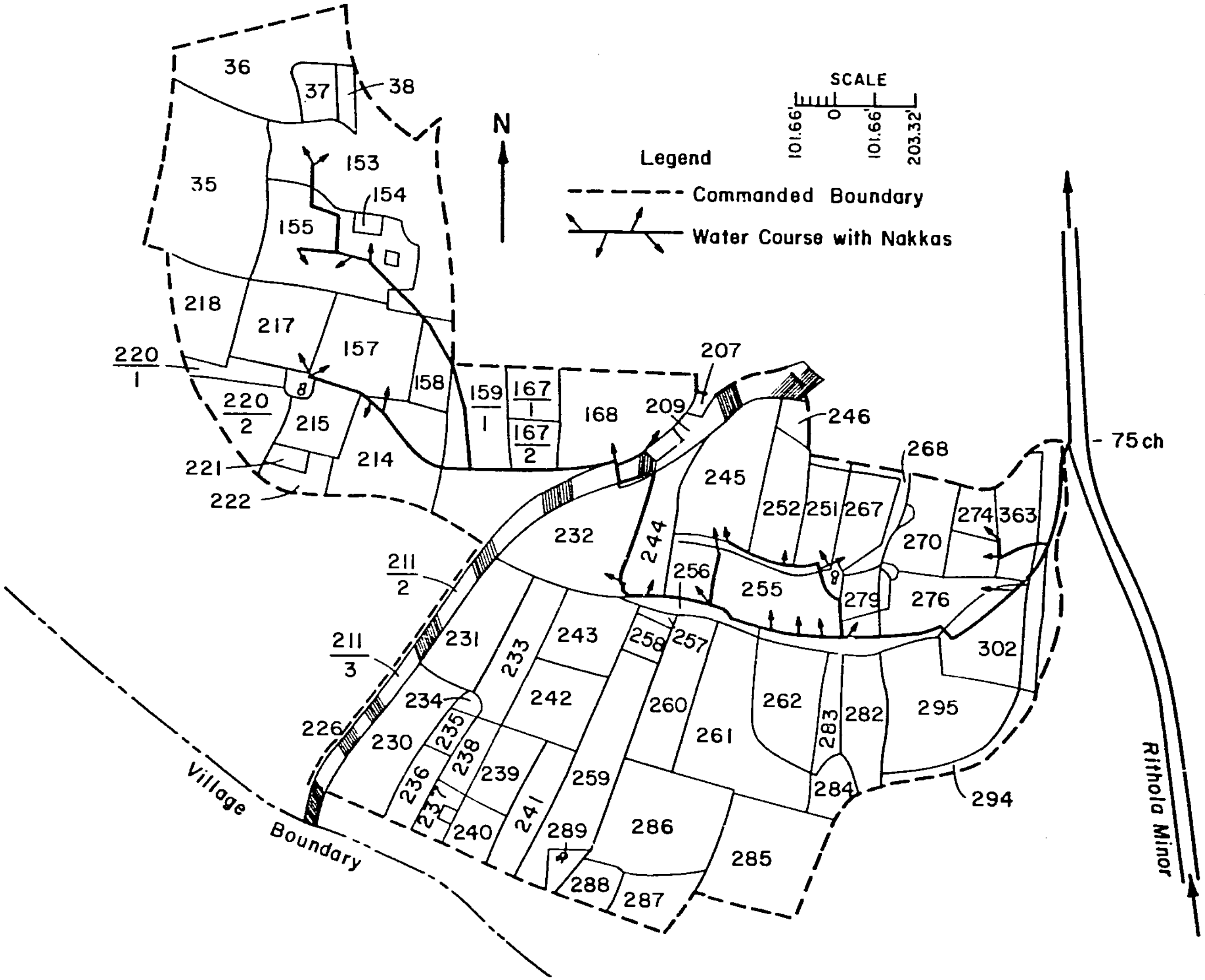

Figure C-5. Chak Plan of Outlet of Chain 75 of Rithola Minor

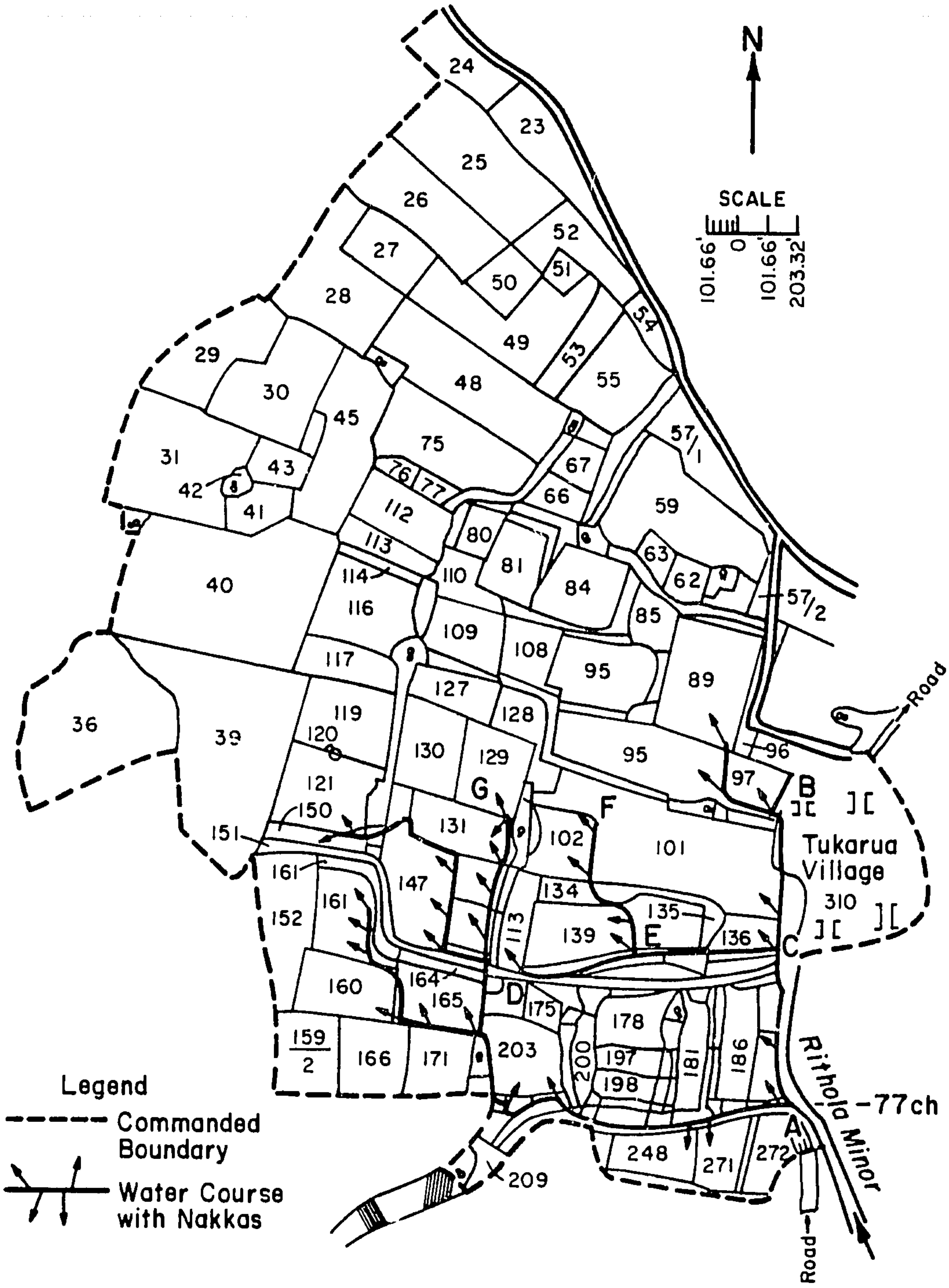

Figure C-6. Chak Plan of Outlet at Chain 77 of Rithola Minor

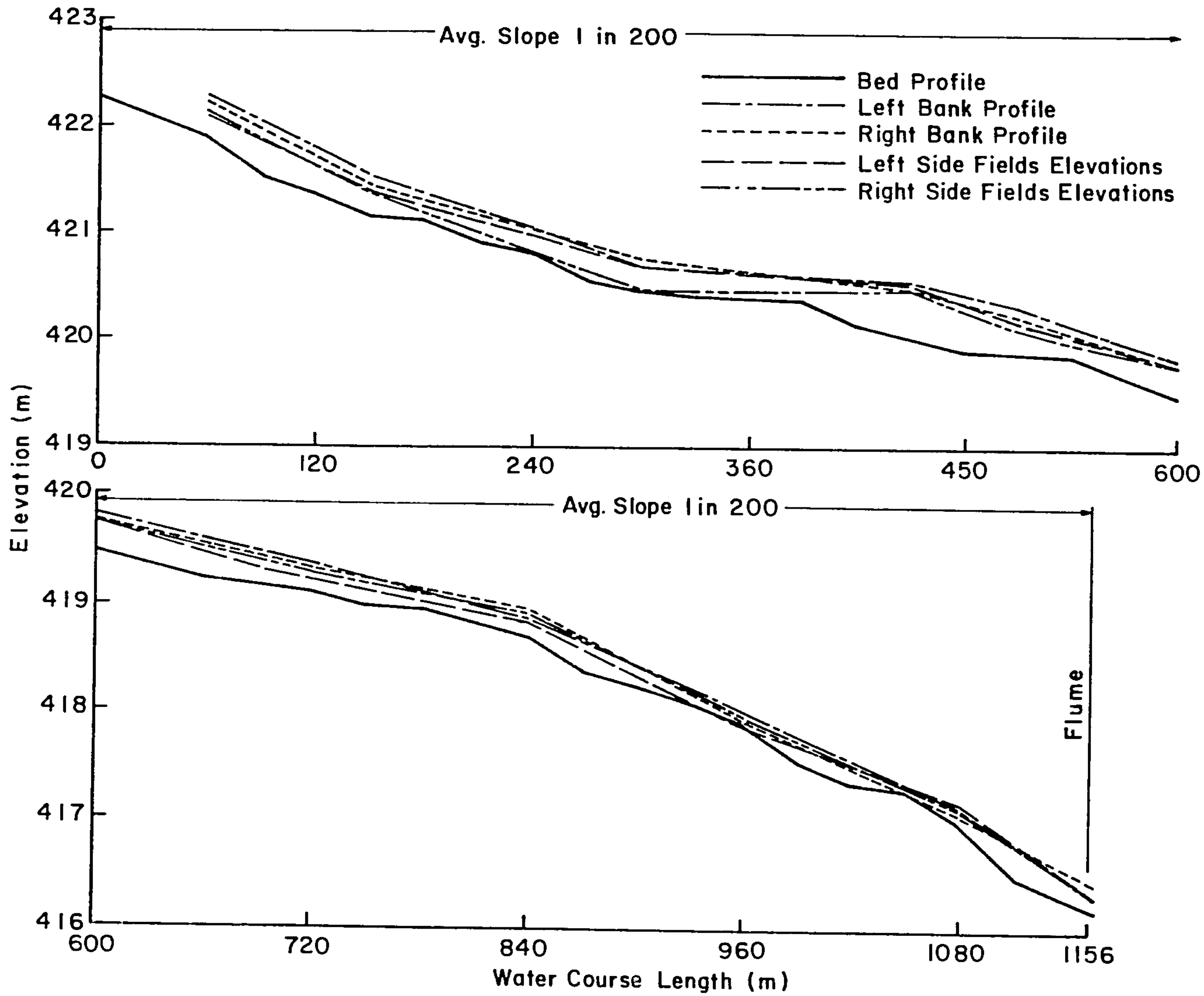

Figure C-7. Longitudinal Section of Watercourse at Chain 5 Outlet of Thikaria Minor

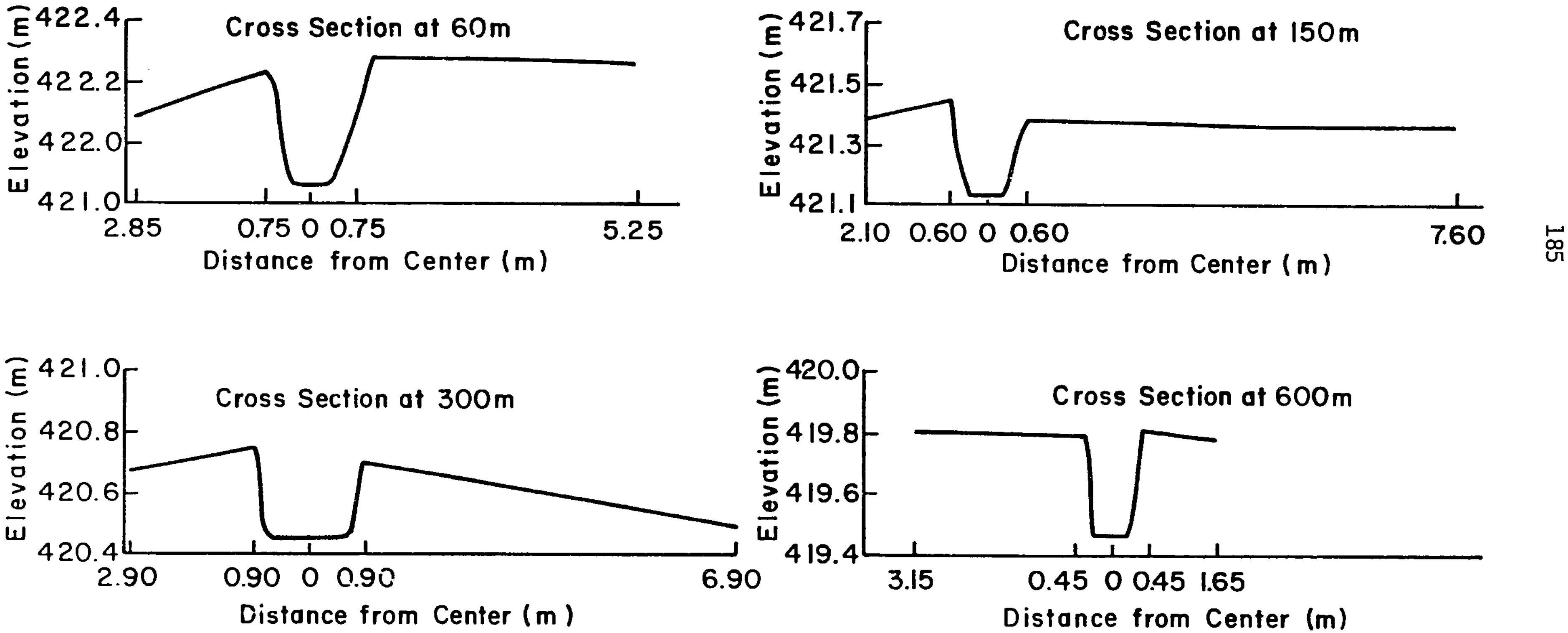

Figure C-8. Cross Sections of Watercourse at Chain 5 Outlet of Thikaria Minor

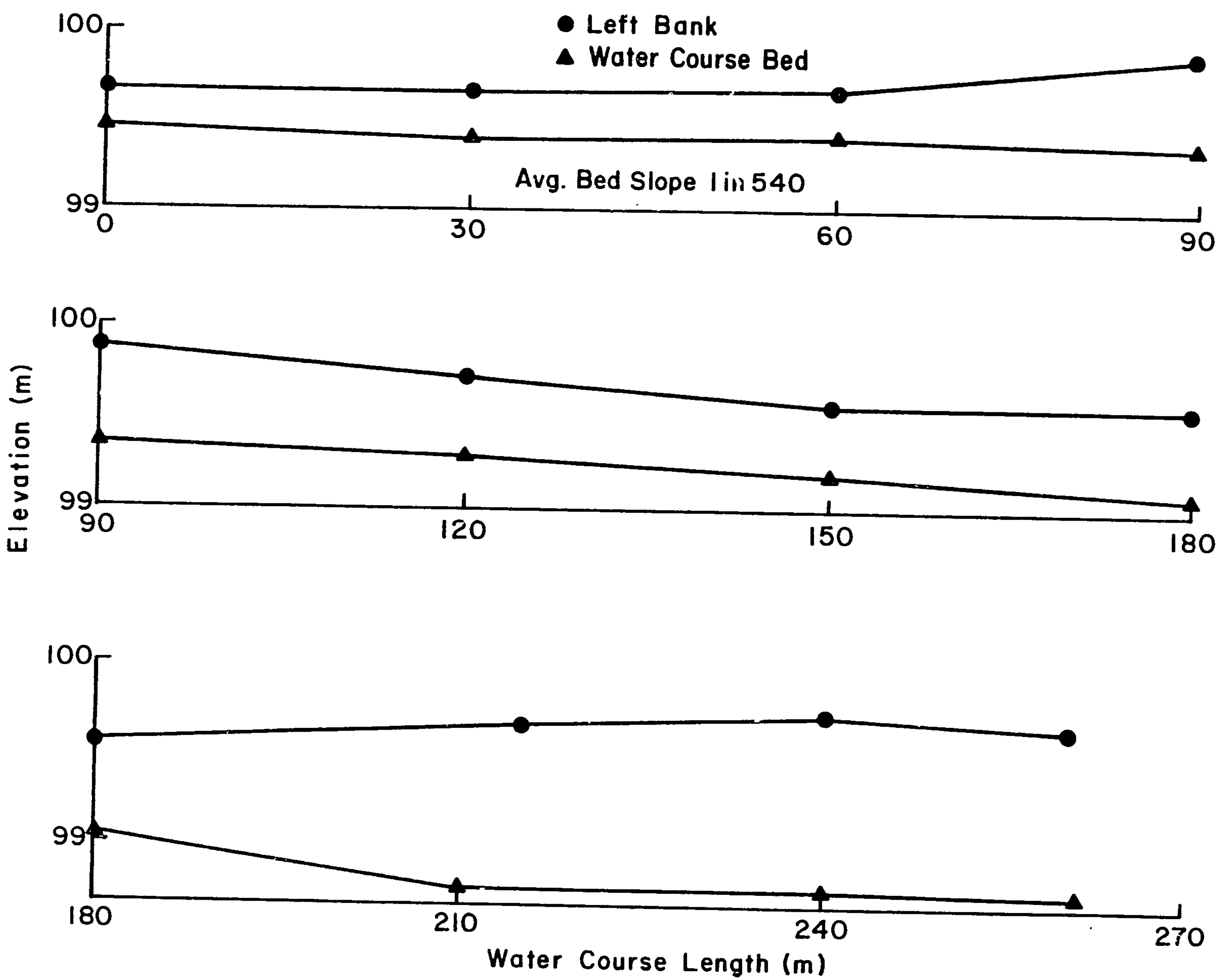

Figure C-9. Longitudinal Section of Watercourse at Chain 145 Outlet of Thikaria Minor

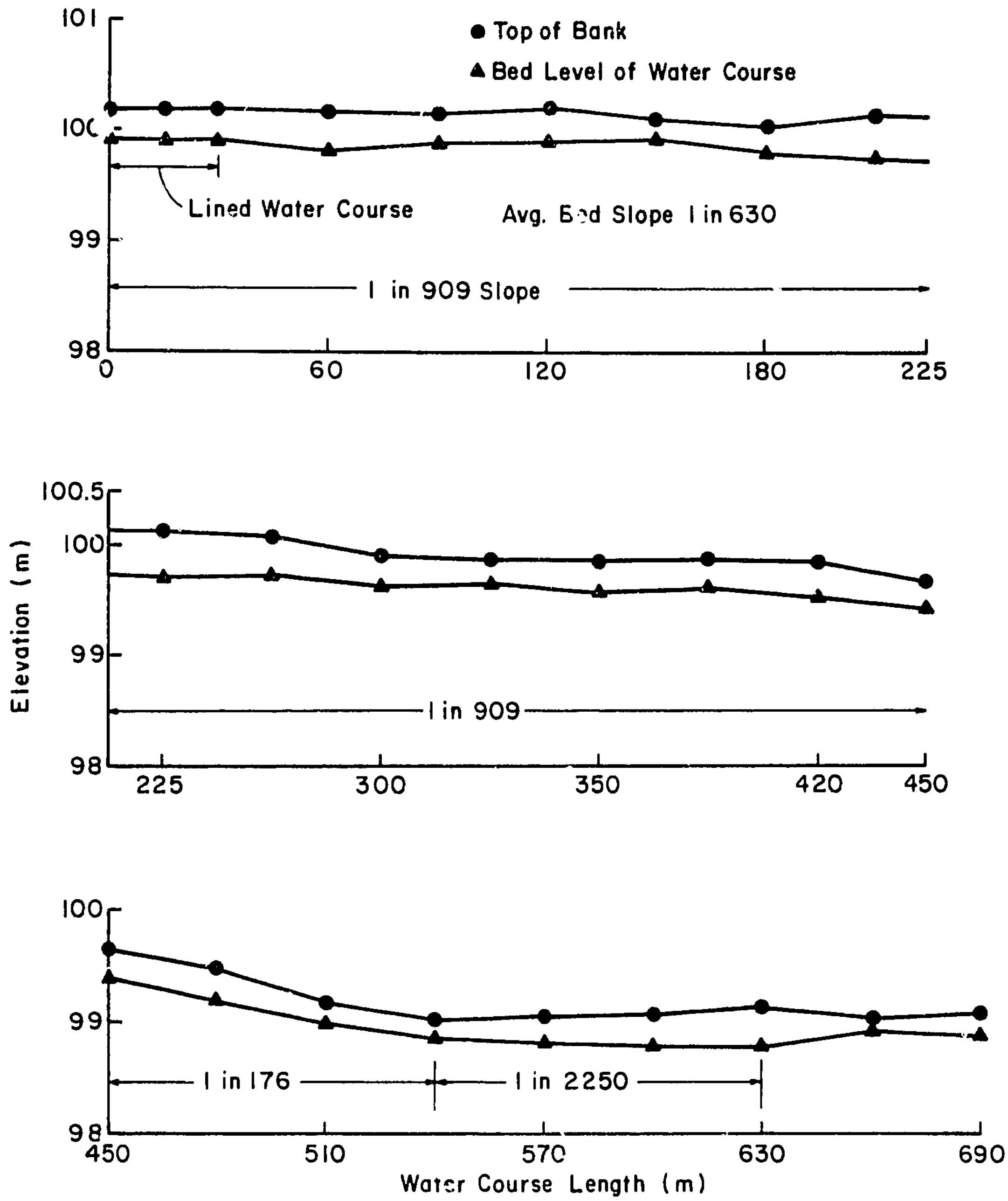

Figure C-10. Longitudinal Section of Watercourse at Chain 158 Outlet of Thikaria Minor

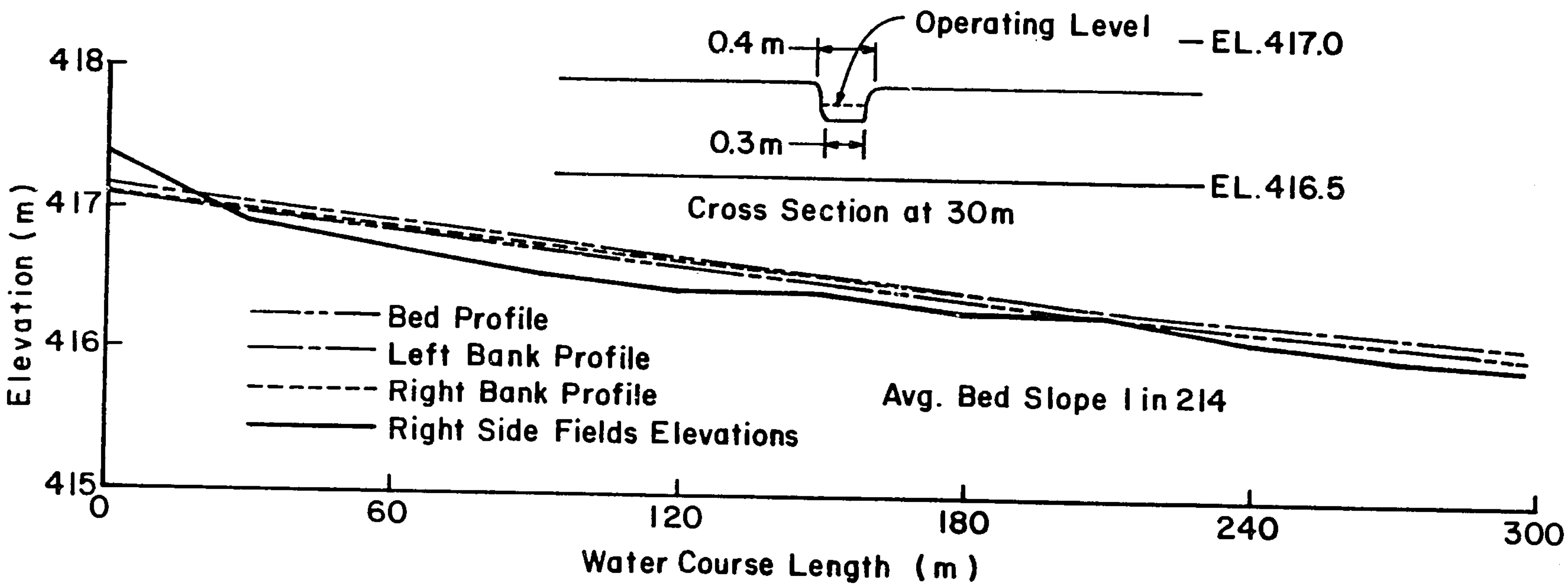

Figure C-11. Longitudinal Section and Cross Section of Watercourse at Chain 6 + 49 Outlet of Rithola Minor

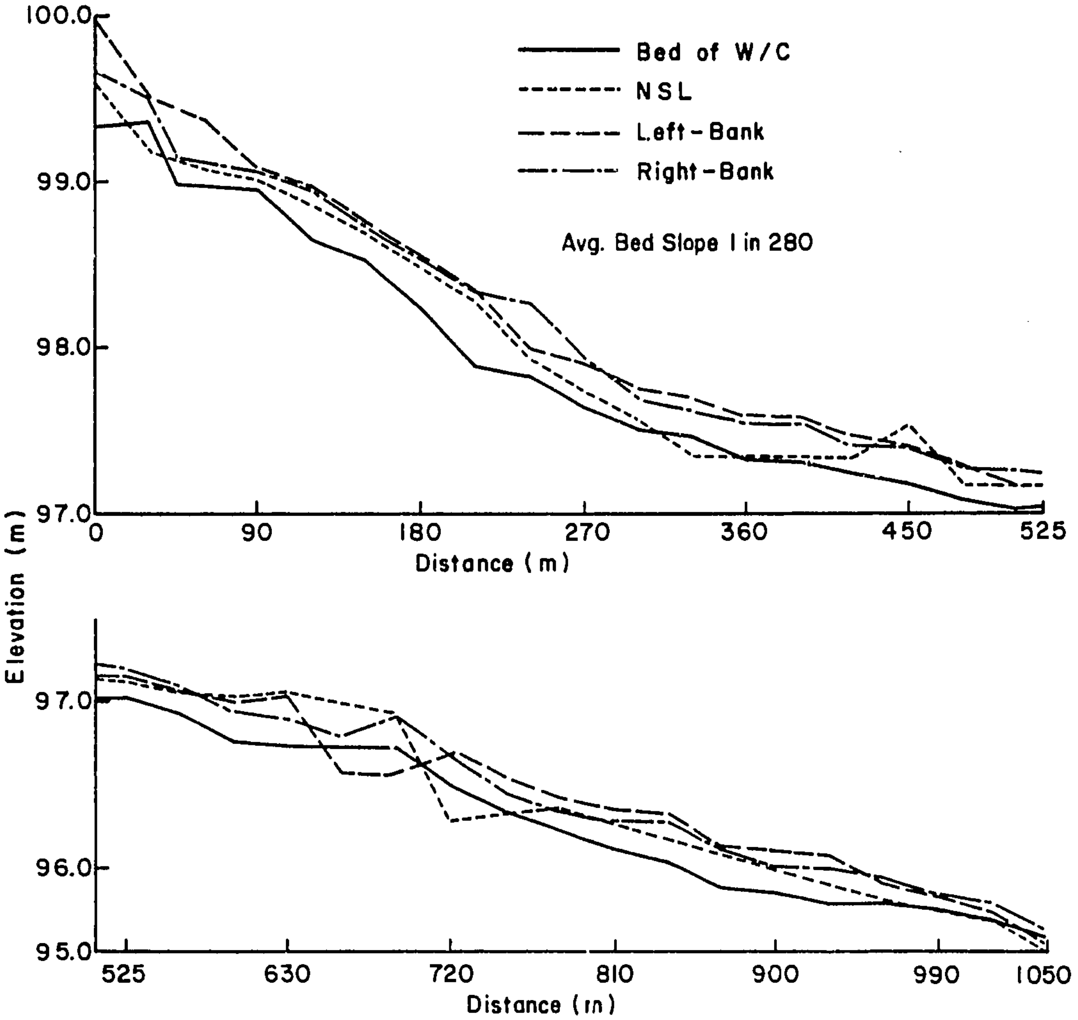

Figure C-12. Longitudinal Section of Watercourse at Chain 75 Outlet of Rithola Minor

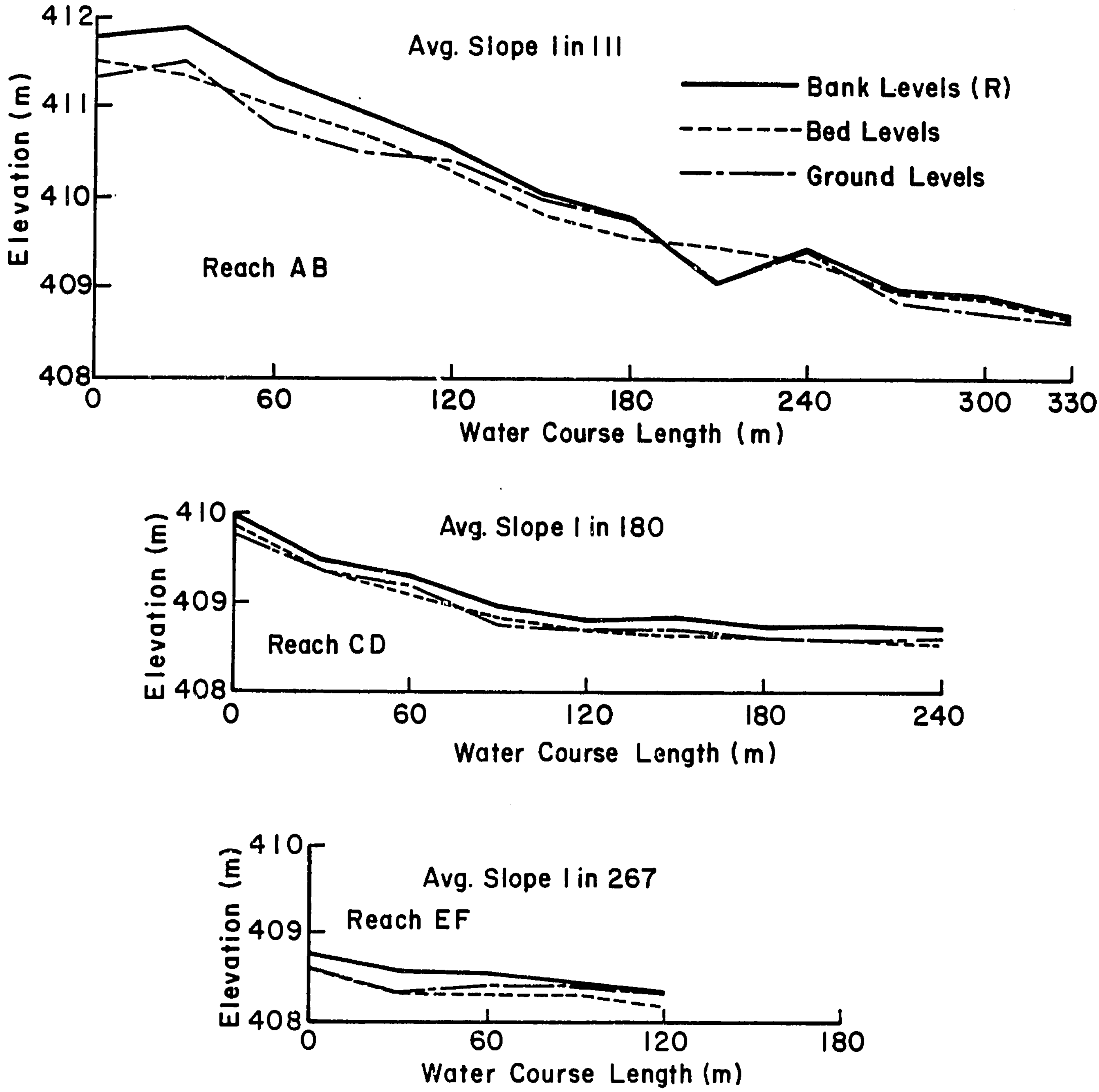

Figure C-13. Longitudinal Section of Watercourse at Chain 77 Outlet Rithola Minor Branch AB, CD, EF

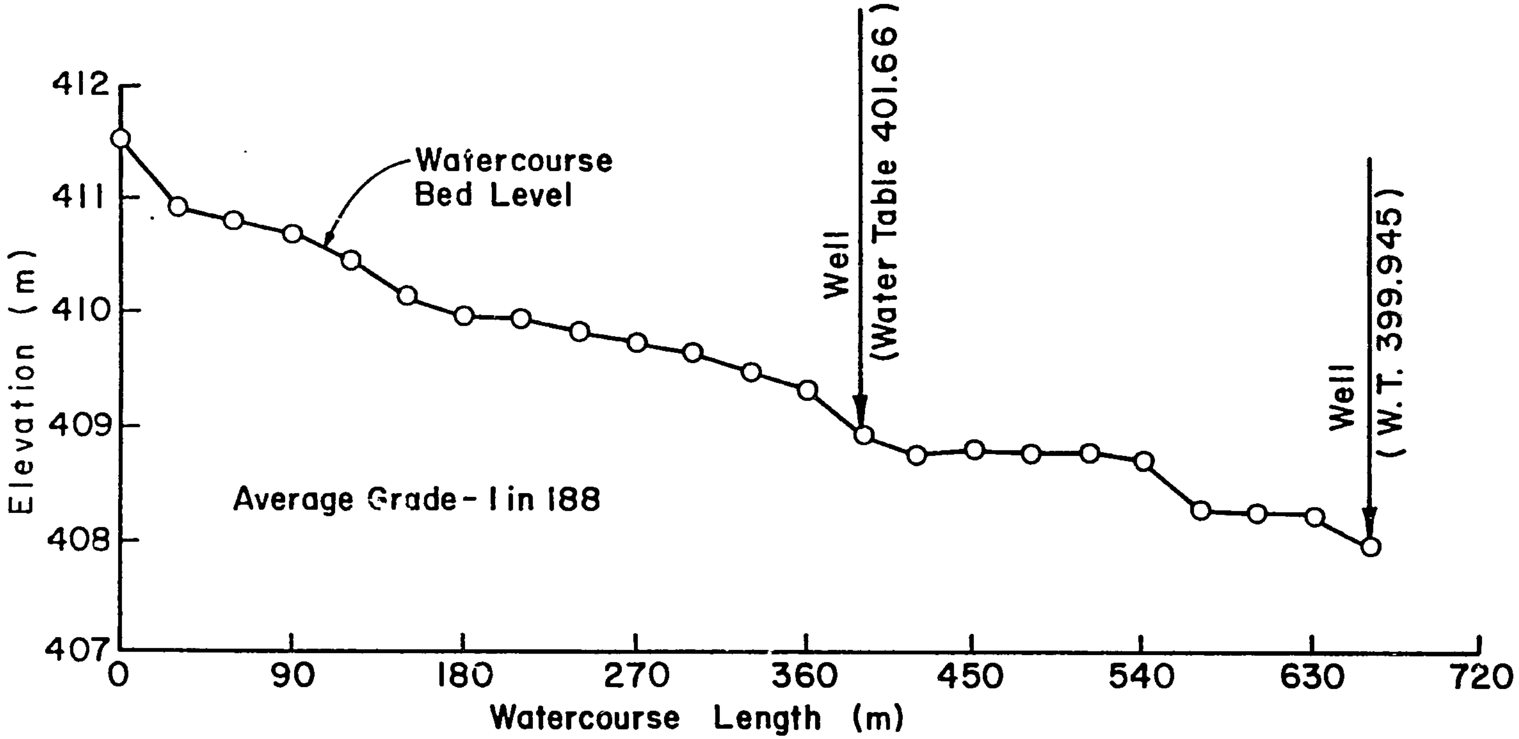

Figure C-14. Longitudinal Section of Watercourse at Chain 77 Outlet Rithola Minor Branch AG

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DIAGNOSTIC ANALYSIS OF FARM IRRIGATION SYSTEMS ON THE GAMBHIRI IRRIGATION PROJECT, RAJASTHAN, INDIA

VOLUME IV

Economics Report

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I. INTRODUCTION

At the Diagnostic Analysis Workshop held in Rajasthan, India from January 18 to February 20, 1982, the objectives of the economists were 1) to study and assess the economic condition of different farms in relation to their access to irrigation water; and 2) to study the impact of various economic constraints on the overall output and income of these farms.

The study sites for the workshop were selected within the Gambhiri Irrigation Project. This project was established in 1965 to increase crop production area in the Rabi season, and to provide supplemental water during dry periods of the Kharif season. An overall increase in crop yield and cropping intensity has been achieved as a result of this undertaking.

The improvements made in productivity and farm income are, however, below projections made for the project. A rather large gap exists between the yield obtained by the farmers and those obtained by the project's experiment station. Research conducted by the Department of Agriculture suggests a number of constraints that might be responsible for inhibiting these farms from achieving their potential output and subsequent income.

II. PROCEDURE

To establish the criteria for the detailed studies, part of Diagnostic Analysis, a reconnaissance study was done first for both the minors. The observations were noted as were the various points emerging from the preliminary discussions with the farmers and among team experts. A comprehensive questionnaire for the collection of information/ data was developed (e.g., production cost, economic conditions of the farmers, cropping pattern, size of holdings, etc.).

Detailed studies were carried out on the three previously selected outlets, at chain number 6, 145 and 154 of Thikaria Minor and 7-22, 75 and 77 of Rithola Minor. The villages within the command area of each outlet were Fatcher Solanik (chain no. 6), Thikaria (chain no. 145 and 154), Shenwa (chain no. 7-22), and Thukarwa (chain no. 75 and 77). Because these areas are very large, only three outlets along each minor canal were selected for training and study purposes. The outlets selected were located at the head, middle, and tail end of the minor.

On the basis of the revenue record for the crops grown in the command area, five crops were identified for the Diagnostic Analysis study. The crops were wheat, gram, barley, maize, and groundnut.

III. RECONNAISSANCE OBSERVATIONS

A. Farm Size

The majority (84 percent) of the farmers in both Thikaria and Rithola Minors belong to the categories referred to as small and marginal farmers.* The average size of farm holding for Thikaria and Rithola Minors was 2.02 ha and 1.35 ha, respectively, with an average irrigated area of 1.3 ha and 0.61 ha. The farm size at Thikaria Minor was significantly greater than at Rithola minor.

B. Location and Access to Irrigation Water

At the head reaches (chain no. 6 and 7-22) of both minors, the canal is the primary source of irrigation. At both the other two outlets (chain no. 145 and 158; 75 and 77), the wells are the primary source of irrigation water and the canal is used as a secondary source.

*Farms under 2.49 hectares are classified as marginal, and farms in the size range of 2.5 to 4.99 hectares as small.

Most of the farmers in the latter outlets of both minors complained about theinadequate and untimely supply of canal water. The head reach farmers use more water and they also get one or two additional irrigations compared to farmers at the tail end. The tailenders are never given canal water first.

At Thikaria Minor most of the farmers use diesel and electric pumps for lifting water from the wells; at Rithola Minor most of the farmers use charas, a costly and time consuming procedure. Most of the farmers practice wild flooding, which not only wastes the irrigation water, but also develops irregular patches of non-irrigated areas resulting in lower yields.

Farmers indicated dissatisfaction with rotation of canal water. The influential and big farmers were viewed as getting a disproportionately larger share of the water.

C. Cropping Pattern

At both Thikaria and Rithola Minors the following major cropping patterns are followed:

maize - wheat,

maize - gram,

groundnut - wheat,

maize - barley,

maize - opium,

maize - methi.

The major crops are maize and groundnut in the Kharif season and wheat, gram, and barley in the Rabi season. Of these crops, wheat covers more than 60 percent of the area in Rabi, while maize crop covers a similar percentage in Kharif. Both of these cereal crops provide fodder for the animals. The farmers, who have access to a supplemental source of irrigation water (i.e., wells), produce cash crops of sugarcane. The farmers with larger holdings produce groundnuts during the Kharif season. The small and marginal farmers produce fewer crops, but most raise more than one crop during the year. However, the cropping intensity at Rithola Minor is less than at Thikaria Minor. On an average, the cropping intensity was 160 percent.

D. Seed and Fertilizer Application

The majority of the farmers use their own seed for the next crop. A small percentage of the farmers obtain certified seed on credit. The use of fertilizers varies according to the economic conditions of the farmers and the availability of irrigation water. During the Kharif season phosphatic fertilizers are applied mostly to the groundnut crop (cash crop). In the case of maize and wheat most of the farmers apply topdressing of nitrogenous fertilizers. The farmers know the importance of manures and fertilizers; however, due to economic conditions, they are unable to use the recommended doses.

All the farmers apply farmyard manure to their fields in rotation (5-10 cartloads/ha). The quantity of manure applied is limited by its availability at the farm level. Manure is never purchased from fellow cultivators. The application is done once every two or three years, usually during the low farming activity period of May and June. Some farmers, however, do apply manure during October and November.

No farmer has used plant protection measures for controlling the damage caused by insects and diseases. At Rithola Minor where severe damage was observed, farmers did not know the control measure for rats and termites.

The availability of inputs is also a limitation. The farmers of Rithola Minor purchase their fertilizer and insecticide from Chittorgarh. In Thikaria Minor there is a cooperative society, but it does not supply inputs in adequate quantities or at appropriate times.

E. Labor/Bullock Power

As mentioned previously, a majority of the farmers have small holdings. They rely totally on family members for all the agricultural operations. The head reach farmers in Thikaria Minor employ labor for weeding and the harvesting of the crops. Threshing is done mostly in the village by their own family members. The hired laborers are generally the family members of other small and marginal farmers within that village.

Most of the farmers use their own bullock power for agricultural operations. Others engage in barter for the use of bullocks. They help each other in providing bullock power for field preparation and for the transport of the produce to the village.

F. Crop Production and Disposition

If all the inputs are provided at optimum level along with the ample and timely supply of water, institutional finance, etc., the farmers can harvest 25-30 quintal of wheat and 20-25 quintal of hybrid maize per hectare. However, due to various constraints, the farmers of both areas are not able t achieve this level. Yield comparisons indicate that Thikaria Minor farmers have achieved a higher level of output than the Rithola Minor farmers.

The farmers of the Thikaria Minor head reaches (chain no. 6) have larger holdings in comparison to the rest of the farmers in all other areas of the two minors. These farmers with larger holdings have allocated a comparatively greater land area to the production of groundnut, a cash crop, and have produced a surplus of cereal crops for market. The majority of small and marginal farmers do, however, produce the cereal crops needed for their own household consumption. The farmers, having assured supply of irrigation in hand (i.e., wells) have raised sugarcane and alfalfa. Except for alfalfa, the crops are produced for market.

G. Institutional Support

Various agencies exist for the benefit of the farmers. The function and performance of a number of institutions designed for assisting farmers are described below.

1. Village Cooperative Societies

The primary aim of the village cooperative societies is to supply farmers with certified seed, fertilizers, insecticides, and pesticides. They usually stock such inputs well in advance. The stocked quantity of inputs is based on their use the previous year. These inputs are sold for cash and on credit by advancing short-term loans through banks. Only one cooperative society is located at Thikaria village, and it does not function properly. The villagers of Thikaria and Fatcher Solanki, therefore, purchase their inputs from Nimbahera. No village cooperative is functioning in Rithola Minor so the villagers obtain their inputs from Chittorgarh.

2. Institutional Finance

Under the various schemes of the state government, short term loans are advanced to the farmers through cooperatives or cooperative banks. But the small and marginal farmers, who have not been able to repay old loans (so-called defaulters) are not advanced more loans for purchase of necessary inputs. Limited financial capital and inability to borrow restrict the amount of improved seed and fertilizer application for such farmers. Some of the farmers obtain their seed on loan from fellow cultivators and pay back, in kind, twice the quantity borrowed.

3. Training and Visit System

Under the new "Training and Visit System," the Agriculture Department has posted village extension workers in the circles. The villages coming under Thikaria Minor (namely Fatcher Solanki and Thikaria) and Rithola Minor (Thukarwa and Shenwa) have been covered under this system. The aim of the "Training and Visit System" is to provide the latest technology to the farmers by working with a group of contact farmers.

In these villages except for the few large farmers, nobody knows about this program which in turn explains why most farmers are ignorant about the latest available technology. The farmers know the value of fertilizers and good quality seed but a large number of them are ignorant about plant protection measures. No training is provided at present for improving irrigation practices. This may have resulted in the waste of water, a scarce input.

4. Irrigation Department

For the maintenance and operation of canals, the Irrigation Department has provided patwaris on the major minors. The farmer knows the irrigation patwari, but he is unable to help in equitable distribution of water. The farmers do not know the exact dates for the opening and closing of canals. The existing water distribution system is not providing an equitable distribution of water to farms located on different points along the minors.

IV. SUGGESTIONS FOR THE DETAILED STUDIES

Nine questions were developed as a result of the reconnaissance survey. These questions, which follow form the basis for the Diagnostic Analysis' detailed studies, as approached from a socio-economic perspective.

(1) What are the sizes of holdings at all outlets, both non-irrigated and irrigated, and are they sufficient to sustain the farm families?

(2) Does the availability of canal water affect the economic conditions of the farmers?

(3) Does the number of irrigations from the canal play an important role in the selection of crops?

(4) Does the size of holding affect the crop selection?

(5) What is the impact of well irrigation on cost of production?

(6) What are the major economic constraints in getting higher yield of wheat, maize, groundnut, gram, and barley?

(7) What factors, other than availability of canal water and farm size, affect the selection of crops?

(8) How has the institutional support affected the economic conditions of the farmers in both minors?

(9) What are the reasons for high fragmentation of the holdings?

In order to provide answer to the above questions, a questionnaire was developed to collect relevant data from several farms in the designated areas.

V. DETAILED STUDIES AND FINDINGS

A. Characteristics of Minors by Outlet

Based on secondary data, the total number of farm families, the cultural command area, the irrigated command area, and size of holding, appear in Table 1. The same data also appear in histograms (Figure 1).

As Table 2 shows, average farm holding and irrigated command area were larger at Thikaria Minor than Rithola Minor by 50 percent and 200 percent, respectively. At outlet 6 on Thikaria Minor, the average farm holding was 2.45 ha and the average size of an irrigated command area was 1.94 ha. On Rithola Minor, on the other hand, the average farm holding was 0.98 ha (outlets 7-22) and the average irrigated command area was 0.20 ha (outlet 6) (Table 2).

Table 1. Cultural and Irrigated Command Areas by Outlet

Items	Thikaria Outlet Number				Rithola Outlet Number			
	6	145	158	Total	7-22	75	77	Total
Cultural command area (ha)	61.2	18.8	13.2	93.2	10.8	28.8	48.0	87.6
Designed irrigated command area by canal (ha)	48.4	12.0	8.0	68.4	8.0	14.0	7.2	29.2
Number of farmers	25	11	8	44	11	15	36	62
Total number of chaks	244	51	31	326	30	85	167	282
Number* of small and marginal farmers (on the basis of area)	17	9	6	32	9	11	31	51

*The latest system for the classification of marginal/small, medium, and large farmers is based on the annual income. At present the data for income are not available, hence the old classification system has been adopted.

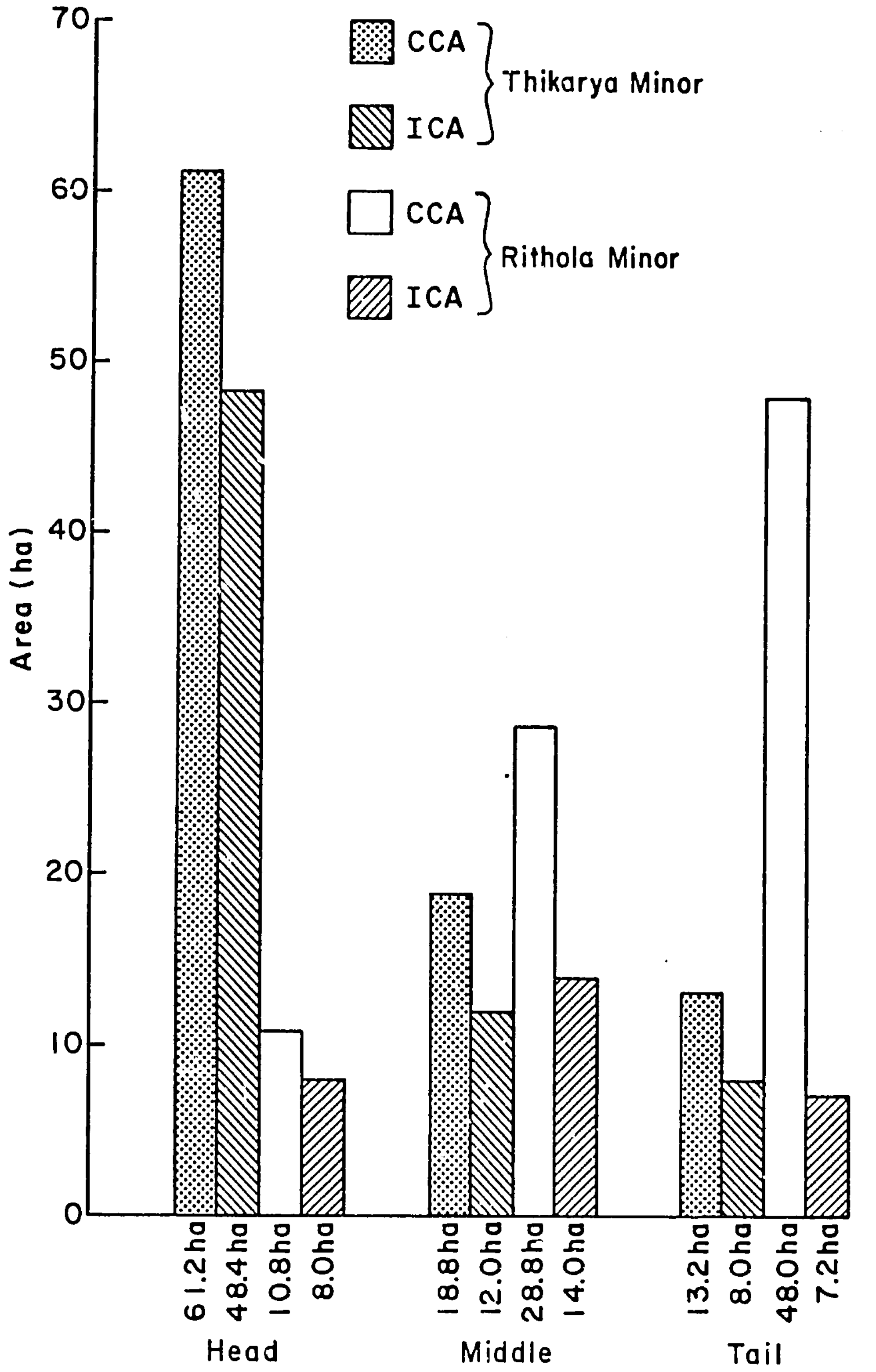

Figure 1. Total Cultural and Irrigated Command Area at Selected Outlets at Thikaria and Rithola Minors

On the basis of the total number of farmers in both minors, the majority consisted of the small and marginal classes (78 percent). Eighty-three percent of the Rithola Minor and 73 percent of the Thikaria Minor farmers can be classified as such. If the comparison is made among the outlets, the largest percentage of small and marginal families (86 percent) was located at outlet 77 of Rithola Minor, while the lowest number of families (68 percent) was located at outlet 6 of Thikaria Minor. The size of the holdings directly relates to the economic status of the farmers, their annual income, and the selection of crops.

Table 2. Average Farmer's Holding at Outlets Studied

	Thikaria Outlet Number				Rithola Outlet Number			
Items	6	145	158	Average	7-22	75	77	Average
C.C.A./farmer (ha)	2.45	1.70	1.65	2.12	0.98	1.92	1.33	1.41
I.C.A./farmer (ha)	1.94	1.09	1.00	1.55	0.72	0.93	0.20	0.47
Marginal and small farmers (percent)	68	82	75	73	83	73	86	82
Others (percent)	32	18	25	27	18	27	14	18

*To make whole number more than 0.5 has been read as 1.
C.C.A. - Cultural Command Area.
I.C.A. - Irrigated Command Area.

B. Cropping Pattern and Farm Size

Table 3 reports the percentages of different crops in Thikaria Minor and Rithola Minor over the last five seasons, from 1976-77 to 1980-81. The largest area during the time period under study was covered by wheat crop in Rabi season. A comparison of cropping pattern for farms, with and without supplemental irrigation water (i.e., wells), indicated a greater area given over to cash crops in farms with supplemental sources of irrigation water.

Table 3. Cropping Pattern under Canal Irrigation (Percentage)

	76-77		77-78		78-79		79-80		80-81		Average		Overall average for both Minors
Crop	T*	R**	T	R	T	R	T	R	T	R	T	R	
Wheat	64	75	63	42	56	63	51	79	64	88	60	69	65
Opium	1	2	5	2	8	9	7	3	7	8	6	7	7
Sugarcane	6	2	13	5	11	7	4	1	4	-	6	4	4
G. fodder	2	1	2	-	5	-	7	1	2	4	5	3	4
Gram/barley	19	18	2	47	1	-	3	8	-	-	4	13	9
Misc.	8	2	15	4	19	21	28	8	23	-	19	4	11
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

*T-Thikaria Minor
**R-Rithola Minor
Note: Data were made available courtesy of the Irrigation Department, Government of Rajasthan, Chittorgarh.

The small and marginal farmers produced fewer crops, with a greater portion of their land involved in wheat production. The reasons for selection of the wheat crop were: 1) it provides grain for human consumption and fodder for animals; 2) it is a comparatively hardy crop; 3) it will give some production in adverse weather conditions; 4) it needs less care compared to cash crops; and 5) it needs less initial investment.

Farms with the larger size and a supplemental source of irrigation have been allocated a greater area for miscellaneous crops such as *methi*, mustard, and other crops. However, at Rithola Minor the area allotted to miscellaneous crops was small in most years. More area has been allotted for green fodder crops in Thikaria. As far as opium is concerned, its cultivation for medicinal purposes is controlled by the Narcotics Department so that its area remains more or less the same.

Within the available irrigated and non-irrigated command areas, more gram has been produced at Thikaria Minor where the canal is the major source of irrigation water, compared to Rithola Minor where all the command is supplemented by well irrigation. Because of salinity in the soil and well water, and canal water being less available at Rithola Minor, more area (overall average for last 5 years--13 percent) was planted in barley. With these conditions barley is the best choice for the farmers.

During the rainy season of *Rabi*, maize is the major crop in both minors. In this season some area was also allocated for production of groundnuts, mostly by large holding farmers. The area allocated by small farmers for production of groundnut is limited because of the initial high cash requirement for purchase of seed and large amounts of fertilizer.

C. Use of Various Inputs and Their Management

The high cost of certified high yielding varieties of seed, given the poor economic conditions of the farmers, limits its use. There is also a direct relationship between an assured supply of water and use of high-yielding varieties. In the case of this canal irrigation system, the supply of water is not certain for farmers within tail-end reaches. Therefore, they do not take the risk of using high-yielding varieties and optimum doses of fertilizers.

As stated previously, most of the small and marginal farmers use their own seed. In the case of wheat, almost all the farmers are using Kalyan Sona, but they have not changed the seed for the last 5 to 10 years. This continued usage of the seed results in seed degradation; consequently, the seed should be renewed every two or three years.

Farmers also know the high-yielding capacity of hybrid maize, but again, most of them cannot afford the initial cost of the seed nor the high nutrient requirements.

The village cooperatives are not making seed available at the time needed or on credit. This has made it difficult for the marginal and small farmers to switch over to high-yielding varieties or cash crops. The large farmers have allocated a large area to cash crops and high-yielding varieties because they can obtain the required fertilizers on cash or credit basis from marketing societies at Nimbahera or Chittorgarh.

If the required agricultural inputs and credit were readily available, the small and marginal farmers might also be able to increase their farm output and income. The required inputs should be stocked on the basis of the previous year's consumption. However, these Cooperative Societies are not functioning appropriately. Even when they do function, it is only the affluent, influential farmers of the village, who can take advantage of them.

Due to the limitation of funds, the small and marginal farmers who have good access to irrigation water continue to apply only minimum doses of fertilizer to wheat and maize crops. The affluent, large-holding farmers, on the other hand, not only apply a higher top dressing, but also a basal dose of fertilizer to wheat and groundnut crops as well.

The rates for various seed varieties and fertilizers are given in Appendix B. Mostly farmers applied top dressing. The affluent and large holding farmers applied a higher top dressing as well as basal dose in wheat and groundnut crops. The small farmers' risk-bearing capacity is limited, hence they applied fertilizers only when they were more or less certain of a good harvest. This was especially the case in Kharif season because most Kharif crops depend on the vagaries of the monsoon.

The survey showed none of the cultivators had utilized plant protection measures, even the cultivators who observed severe damage of rats and termites in the wheat crop and aphid damage in alfalfa.

Almost all the cultivators applied farmyard manure to their fields, but the amount depended on the number of animals they maintained. Some of the farmers helped each other transporting manure from the village to the fields through a barter system. They never hired labor for this activity. The number of cartloads per hectare varied from 5 to 10. Farmers applied manure mostly during the labor slack period, or the months of May and June. The application of manure to each field was on a rotation basis once in every two or three years, depending on its availability. Compared to large farmers, the small and marginal farmers depended more on farmyard manure as they could not obtain sufficient quantities of chemical fertilizer.

D. Institutional Finance

There are provisions for short-term loans through the cooperative banks, but because of a number of adminstrative problems the small farmers have not been able to obtain the credit they need. Mostly the affluent farmers have taken advantage of the loans. According to the interviews, the majority of the small and marginal farmers have not repaid the old loans. This is the major reason why no further loans can be advanced to such defaulters. Provision of easy, short-term loans may enable small and marginal farmers to allocate a larger area to production of profitable cash crops. Credit is needed to purchase high-yielding seed varieties and more chemical fertilizer for cash and cereal crops, and to achieve higher production per unit.

E. Irrigation Water, Use of Inputs, and Cropping Pattern

Water is a very important input in the selection of crops. Farmers indicated that there was a difference in the number of irrigations and quantity of water supplied within the various outlets of a particular minor, and among the minors. The farmers at the head reaches got the highest quantity as well as number of irrigations in comparison to farmers at the tail. For the tail-end farmers with no supplemental source of irrigation, their crops were poor in comparison to head-reach farmers. They could not take a large risk due to unavailability of water. Those farmers who depended on wells incurred more expenditure per irrigation compared to those who used canal water. Canal water was the cheapest source of irrigation. Using charas to lift water was the costliest and most inefficient irrigation method.

A comparison of yield, production expenses, and net income of major crops between the minors' head and tail reaches and farms along a particular minor follows. For a uniform comparison between the minors, the average input prices quoted by farmers were used (e.g., cost of farmyard manure, cost of well irrigation, and labor). The cost of fertilizers was based on last year's prices.

For the convenience of the farmers, the data were collected for one bigha. After compilation, the gross and net income were converted to a hectare basis (Appendices C and D). Those crops with a significant difference in application of input, production costs, and income in relation to their location along the canal are discussed here in detail. The crops for which this relationship was not found, are briefly described. The net income per hectare for all major crops, except barley, for the Thikaria and Rithola Minors is illustrated in Figures 2 to 4.

1. Wheat

Wheat was the only crop raised by almost all the farmers on large areas of their holdings. This was the case in both minors whether based on canal irrigation alone, or canal water supplemented by well irrigation. The net income trends for the two minors, and for various outlets within the minors, appear in Figure 3. The details of expenditure on various items and income is in Appendix C.

A direct visible relationship existed between the availability of canal irrigation and use of chemical fertilizers. Similar relationships were observed between the size of holding and fertilizer application. At Thikaria Minor's head reaches the farmers had, on an average, applied 93 percent more chemical fertilizers to the wheat crop than the cultivators of Rithola Minor's head reaches. There was a difference of two to three irrigations between the Rithola Minor and Thikaria Minor. The head reach farmers in Thikaria and Rithola Minors were totally dependent on canal water, except for the tail ends of head outlets. At the head reaches the farmers had taken two irrigations--one at the opening of the canal and another at the closing time. There

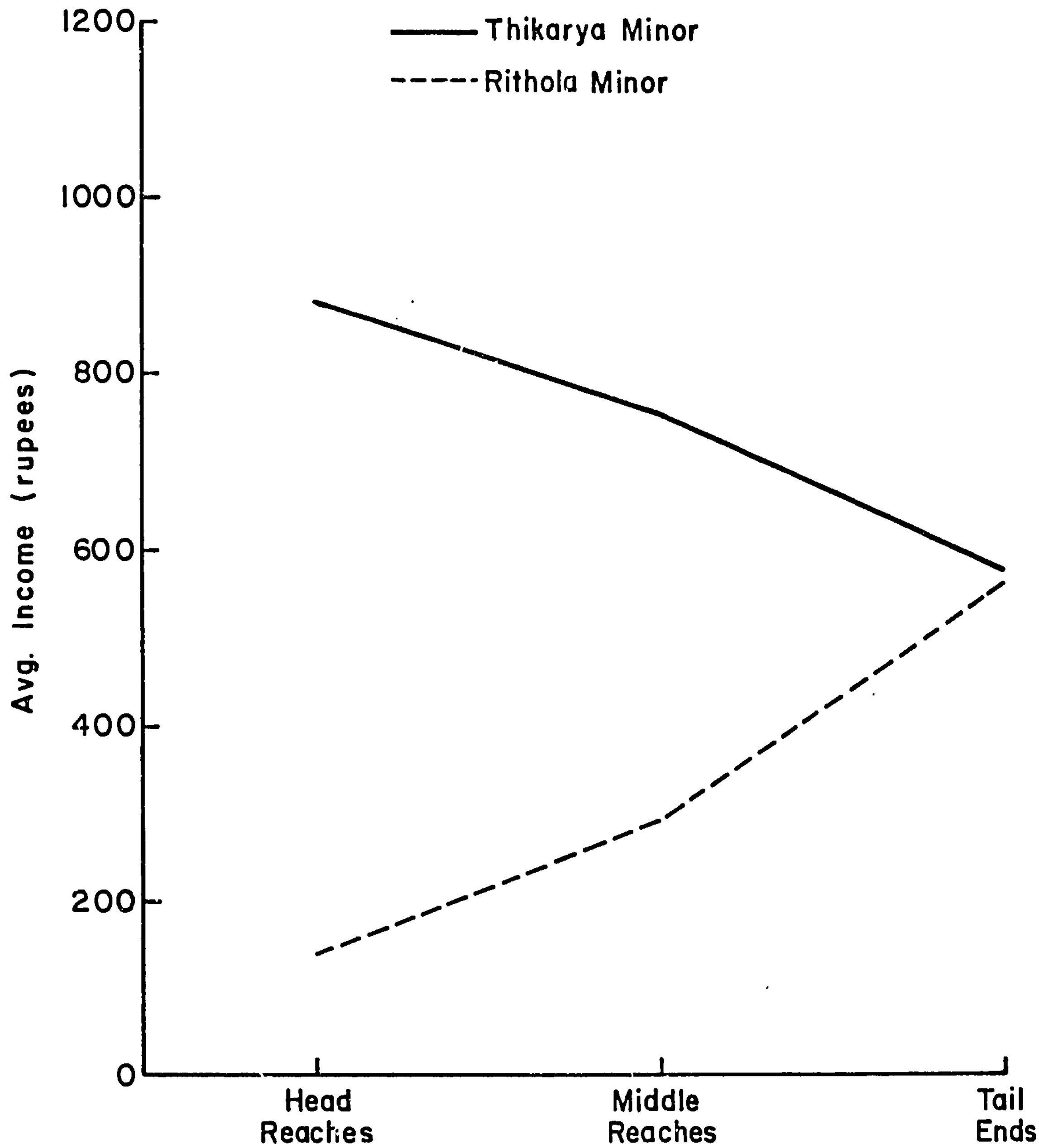

Figure 2. Average Trend of Income from Wheat Crop per Hectare of Both Minors at Head, Middle, and Tail Reaches

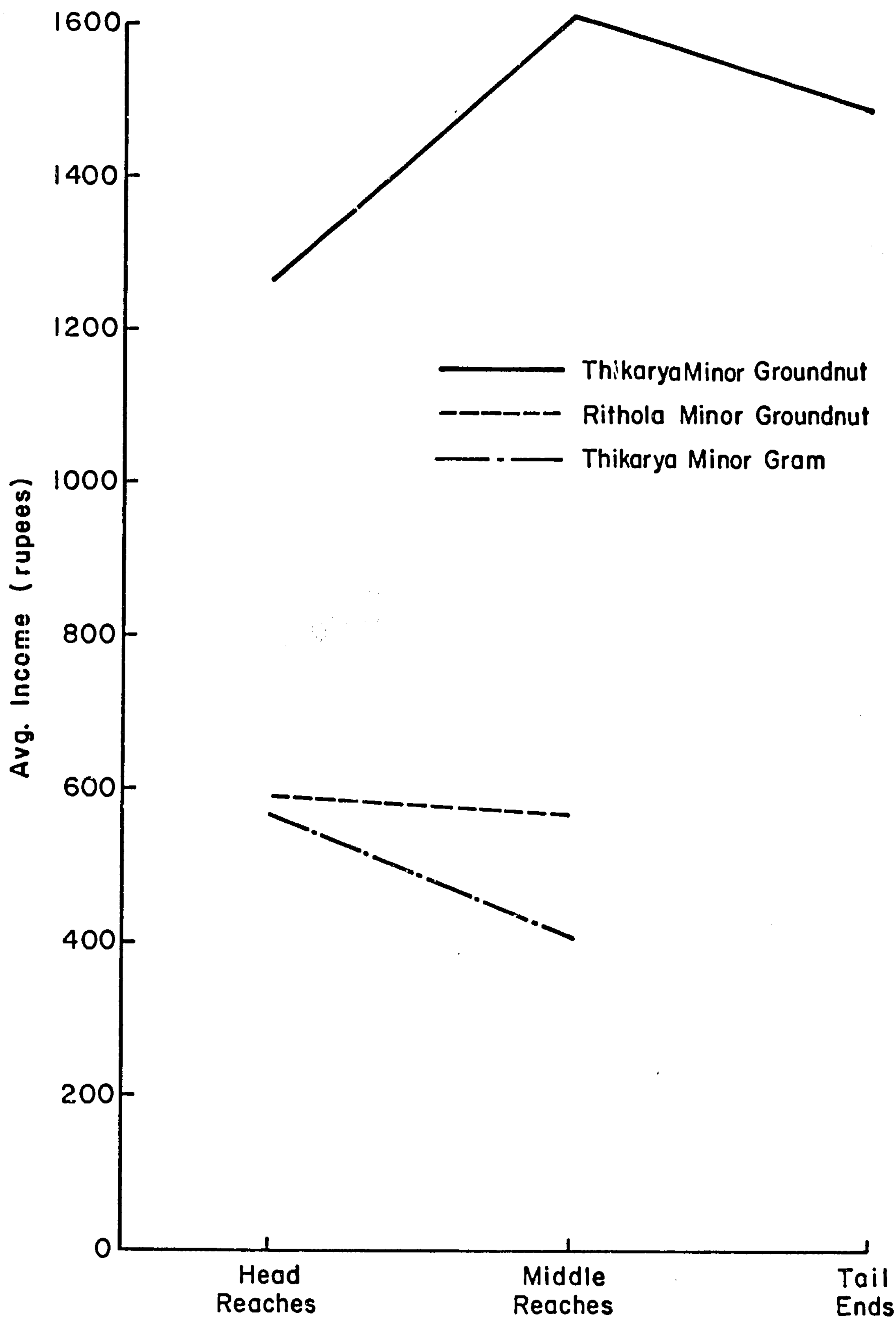

Figure 3. Income from Gram and Groundnut Crop (per ha) at Thikaria Minor

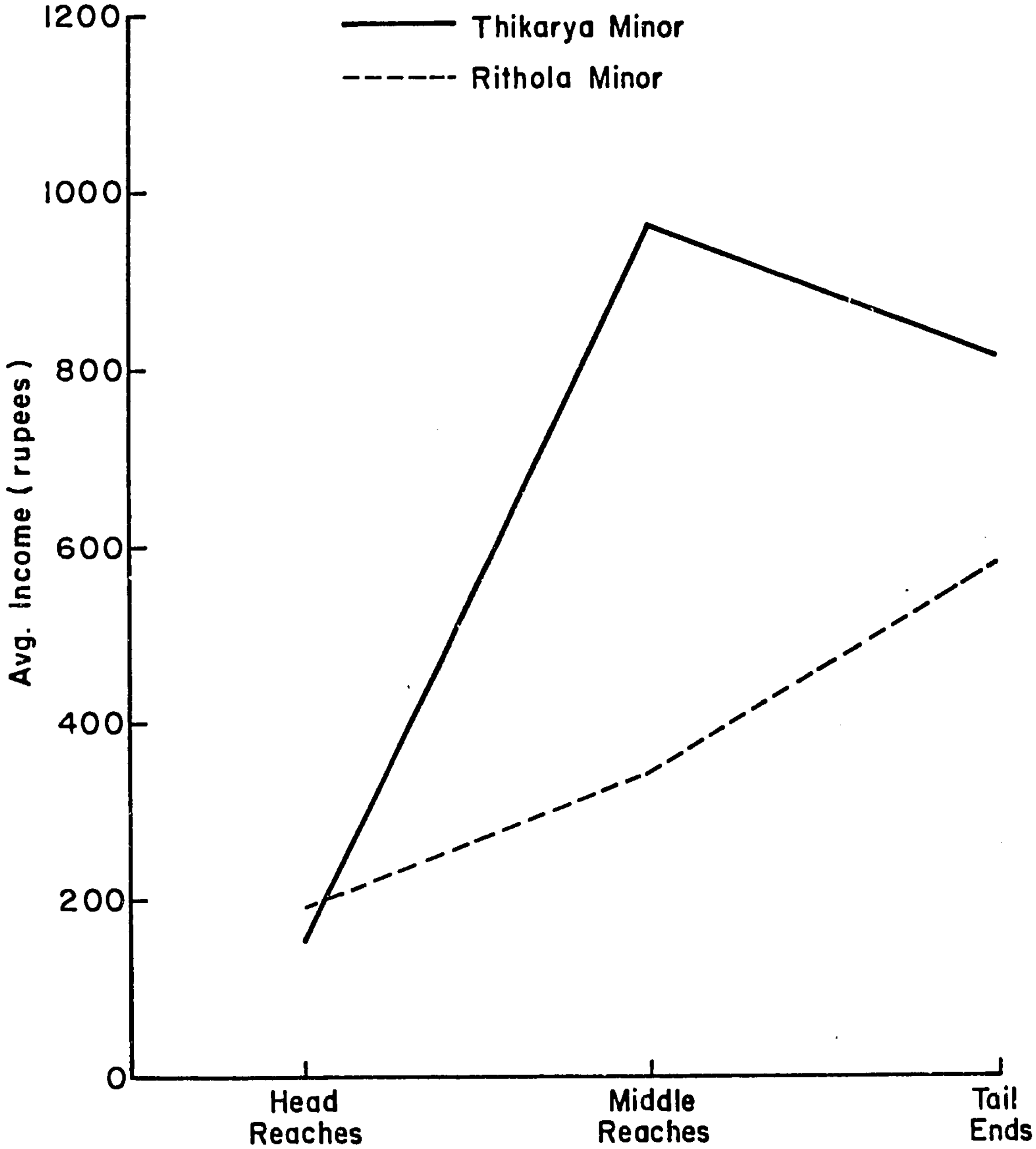

Figure 4. Comparative Income of Maize Crop at Both Minors at Head, Middle, and Tail Reaches

was no financial risk to the farmers in the application of high doses of fertilizers at head reaches of Thikaria Minor. The farmers of tail reaches, however, could not take such a risk because of the lack of adequate and timely supply of water from the canal.

When the average net income of the wheat crop between the head and tail reaches of head outlet of Thikaria Minor were compared, the cost incurred on irrigation (for lifting of water by charas) was Rs 161 per hectare by tail-end farm compared to Rs 15 per hectare for canal water by head end farms. Clearly the tail-end farmers, who used a supplementary water source (i.e., well) in the absence of adequate canal irrigation, would incur more expenditure lifting water from wells, especially by charas. The availability of water directly affected the yields achieved. When the application of fertilizers is compared between the head and tail outlets farms, the farmers of head-end farms spent 50 percent more on fertilizer than the tail-end farms, even though these tail-end farmers have a supplementary source of irrigation.

When the average incomes of farmers of head outlets of Thikaria and Rithola Minors were compared, the income of head minor was more than six times that of the tail minor (Rithola) farmers.

Net income from wheat increased along the watercourse at Rithola Minor where the canal water was supplemented by well, and decreased at Thikaria Minor where canal water was the primary source of water (Figure 2). The overall average net income was lower for Rithola Minor farmers than Thikaria Minor farmers.

2. Gram

Gram is a crop which is primarily grown using canal irrigation. The net income per hectare for the two outlets in the Thikaria head minors were compared by outlet (Figure 3). With the increase in the distance from the head of the minor, the net income decreased. This can be directly related to the supply of irrigation water. Net income from production of gram was Rs 572 per hectare for the farm located at the head, and Rs 412 per hectare for the farm located at the tail of the canal (see Appendix D).

3. Maize and Groundnut

Maize is an important cereal crop raised by almost all the cultivators, whereas groundnut was produced mostly by the larger farmers. Farmers who had access to a supplemental source of irrigation water achieved higher yield and income from maize production. This relationship was found for groundnuts only in the Thikaria Minor. The impact of supplementary irrigation on yield and income of these two crops becomes particularly evident when there is a monsoon failure and/or when there is a large interval between the rains (Figures 3 and 4).

4. Barley

Because of the salinity in soils and water, the farmers produced barley instead of gram at Rithola Minor. Due to limited data, this crop was not studied.

VI. SUMMARY

(1) The choice of crop is affected by the size of holding. The smaller the size, the fewer the number of crops produced. Smaller

farmers have allocated a greater portion of their farm for production of cereals for family consumption. This basically has eliminated the production of profitable cash crops as a possible choice.

(2) Uneven distribution and supply of canal water increases the risk for using the costly inputs of fertilizer and hybrid seeds.

(3) The choice of crops is affected by the supply of irrigation water.

(4) Using <u>charas</u> is the most costly method of lifting water. Because of their high initial investment cost, the small farmers are unable to purchase electric or diesel pumps, a more efficient alternative.

(5) The absence of effective village Cooperative Societies, supported by a financial institution for advancing loans, has restricted the small and marginal farmers to a low application level of various production-improving inputs.

VII. RECOMMENDATIONS

(1) The water distribution system needs to be reorganized, so that all the farms located along the minors can have equitable access to irrigation water.

(2) Village Cooperative Societies should take a more active role in provision of all inputs in order to make them available to the farmers at the right time and in adequate quantities.

(3) Short-term loans need to be provided in order to enable the small and marginal farmers to acquire improved varieties of seed and more fertilizers.

(4) Training should be provided to the officials of the Agriculture and Irrigation Departments. Farmers need to be educated in water management, crop selection, pest control, and the use of other inputs.

APPENDIX A

Table A-1. Number of Wells with Source of Lifting Water

Thikaria Minor					Rithola Minor				
Outlet Number	C	EP	DP	Total	Outlet Number	C	EP	DP	Total
6*	-	-	-	-	7-22	-	-	-	-
145	-	2	-	2+1*	75	3	-	1	4
158	2	1	-	3+1*	77	18	-	3	21
Total	2	3	-	5+2*		21	-	4	25

*Data not available
C = *Charas* (local method of lifting)
EP = Electric Motor
DP = Diesel Pump

Table A-2. Means of Lifting Water and Cost per Bigha per Season

Source/Means	Rs
Canal Water	12.50
Electric Pump	7.00
Diesel Pump	21.00
Charas	58.00

Table A-3. Irrigated Area by Canal

Name of the Minor Without Number	Total Designed Area of All the Outlets under Study (ha)	Area Irrigated by Canal (ha)					Average for Last 5 Years (ha)	% of Aver. Irr. Area Against Designed	Actual Irrigation Intensity
		76-77	77-78	78-79	79-80	80-81			
Thikaria	(6)48.4*	-	-	-	-	-	-	-	-
	(145)12.0	11.57	8.90	11.13	12.67	6.91	10.24	85	54
	(158) 8.0	7.13	6.9	8.47	8.69	6.90	7.62	95	58
Rithola	(722) 8.0	6.76	6.82	7.78	5.90 (3.25)**	6.83	6.82	85	63
	(75)14.0	13.37	3.78	5.59	6.70	7.14	7.32	52	25
	(77) 7.2	7.20	4.26	6.48	7.12	4.46	5.90	82	12

*Data not available
**Irrigation given to *Kharif* crops
SOURCE OF DATA - Executive Engineer Irrigation Department for Chittorgarh

APPENDIX B

Table B-1. High-Yielding Varieties and the Selling Rate

Serial Number	Crop	Varieties	Rate/Kg.
1	Maize	G2, G5	Rs 6/-
2	Wheat	Kalyansona,Raj911, Sonalika	Rs 5.40/-
3	Gram	Do had yellow C 235	Rs 5.40/-
4	Barley	RDB 1, RD 57	Rs 2.90/-
5	Opium	Ghatia	Rs 15/- to 20/-
6	Sugarcane	CO 419	Rs 0.30/-
7	Eggplant	Deploid	Rs 15/-
8	Groundnut	M 13	Rs 6/-

Table B-2. Price List of Fertilizers (retail prices)

Serial Number	Name of Fertilizer	Rate @ 50 kggs bag.	Remark
1	Urea 46%	Rs 117.50	Octroi extra
2	D.A.P. 18:46	Rs 180.00	" "
3	N.P.K. 12:32:16	Rs 162.50	" "
4	Super Phosphate (Triple) 46% (powder)	Rs 120.00	" "
5	Super Phosphate (16%)	Rs 48.00	" "

Table B-3. Rates of Diesel Pumps/Electric/Persian Wheel

Serial Number	Type of System	#	Rate
1	Diesel pump	5HP	Rs 6000/-7000/-
2	Electric Motor	5HP	Rs 7000/-
3	Electric Motor	3HP	Rs 6000/-
4	Cost of Persian wheel		Rs 2000 to 3000/-
5	Cost of Charas		Rs 800-1000/-
6	Rate of Diesel		Rs 3.22/lit
7	Rate of Electricity		Rs 0.23/unit

APPENDIX C

Table C-1. Bifurcation of Various Inputs and Outputs for Wheat Crop

	Cost of Seed (1)	Cost of FYM (2)	Cost of Fertilizer (3)	Cost of Irrigation (4)	Cost of Labor (5)	Cost of Bullock Power (6)
Thikaria (head outlet 6)						
Head	33	125	267	15	184	175
Middle	32	150	172	15	186	184
Tail	51	-	100	161	190	157
Rithola (head outlets 7-22)						
Head	38	-	161	15	75	162
Tail	40	-	173	15	133	244

	Land Rev.* (7)	Total Exp. (8)	Exp./Hectare (9)
Thikaria			
Head	1.00	800	3600
Middle	1.00	740	3300
Tail	1.00	660	2970
Rithola			
Head	1.00	452	2034
Tail	1.00	604	2718

*Land revenue is less but it has been given in whole number.

INCOME

	Cost of** Produce (10)	Yield per Bigha in Quintal* (11)	Gross Income (12)	Net Income Per Ha. (13)
Thikaria (w147/-)				
Head	1002	7.16	4509	909
Middle	1029	7.00	4630	1330
Tail	750	5.10	3375	405
Rithola (w150/-)				
Head	480	3.00	2160	126
Tail	640	4.00	2880	162

NOTE: (i) details of cost bifurcation per bigha (4.5 bigha = 1.0 hectare)
(ii) gross expenditure, income and net inome converted in hectares
**cost of produce, includes cost of grain and straw both

APPENDIX D

Table D-1. Average Expenditure, Gross and Net Income of Various Crops Minor and Outlet Wise (rupees/hectare)

A. Crop: WHEAT

THIKARIA MINOR	G.E.	G.I.	N.I.	RITHOLA MINOR	G.E.	G.I.	N.I.
O.No.6				O.No.7-22			
H	3600	4509	909		2034	2160	126
M*	3300	4630	1330		-	-	-
T*	2970	33375	405		2718	2880	162
Average	3289	4171	881		2378	2520	142
Per Rs/Return		1:1.33				1:1.05	
O.No.145				O.No.75			
H	3038	3870	832		3177	3375	198
M*	2460	3262	801		2900	3100	200
T*	2585	3217	632		3170	3645	475
Average	2694	3449	755		3082	3373	291
Per Rs/Return		1:1.28				1:1.09	
O.No.148				O.No.77			
H	1492	2362	870		2180	2700	520
M*	-	-	-		2461	3000	539
T*	1743	2025	282		2341	2800	459
Average	1617	2193	576		2327	2833	506
Per Rs/Return		1:1.35				1:1.21	

B. Crop: MAIZE

THIKARIA MINOR	G.E.	G.I.	N.I.	RITHOLA MINOR	G.E.	G.I.	N.I.
O.No.6				O.No.7-22			
H	2814	2970	156		2012	2115	103
M	2745	2970	225		2088	2371	283
T	2767	2880	113		-	-	-
Average	2775	2940	165		2050	2243	193
Per Rs/Return		1:1.05				1:1.09	
O.No.145				O.No.75			
H	2102	3985	1183*		2195	2628	433
M	1912	3138	1226*		2392	2646	254
T	2132	2698	496		-	-	-
Average	2048	3017	969		2293	2637	344
Per Rs/Return		1:1.47				1:1.15	
O.No.158				O.No.77			
H	2117	2916	799		2599	2916	317
M	2282	3111	829		2641	3645	1004
T	-	-	-		2501	2995	424
Average	2199	3013	814		2580	3162	582
Per Rs/Return		1:1.37				1:1.22	

Table D-1. Continued.

C. Crop: <u>GRAM</u>

THIKARIA MINOR

	G.E.	G.I.	N.I.
<u>O.No.6</u>			
Average	1278	1850	572
Per Rs/Return		1:1.44	
<u>O.No.145</u>			
Average	1809	2221	412
Per Rs/Return		1:1.22	

D. Crop: <u>BARLEY</u>

RITHOLA MINOR

	G.E.	G.I.	N.I.
<u>O.No.75</u>			
	2202	2981	779
		1:1.35	

E. Crop: <u>GROUNDNUT</u>

	G.E.	G.I.	N.I.
<u>O.No.6</u>			
Average	2869	4140	1271
Per Rs/Return		1:1.44	
<u>O.No.145</u>			
Average	3708	5319	1611
Per Rs/Report		1:1.43	
<u>O.No.147</u>			
Average	3339	4838	1499
Per Rs/Report		1:1.44	

	G.E.	G.I.	N.I.
	2835	3415	580
		1:1.20	

O.No. = outlet number (number of chains from head of minor);
H = head reaches; M = middle reaches; T = tail ends;
* = supplemental irrigation by well.

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DIAGNOSTIC ANALYSIS OF FARM IRRIGATION SYSTEMS ON GAMBHIRI IRRIGATION PROJECT, RAJASTHAN, INDIA

VOLUME V

Sociology/Extension Report

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I. INTRODUCTION

The Diagnostic Analysis Training Workshop on the Gambhiri Irrigation Project was held at Chittorgarh, Rajasthan, from January 18 to February 20, 1982. The participants were divided into three interdisciplinary teams, which included extension and sociology personnel in each of these teams. These team members were to gather information on how the system actually operates, in addition to identifying the social and organizational constraints which hinder the efficient and effective operation of the Gambhiri Irrigation Project. Data were collected on the quality and quantity of institutional services provided to the farmers, as well as on the irrigation behavior of the farmers. By interviewing a sample of farmers and selected influential people in the area, the sociology and extension team members gained an understanding of the determinants, characteristics, and consequences of farmer irrigation behavior.

The remainder of this technical report describes how Diagnostic Analysis of the Gambhiri Irrigation Project was carried out by the extension and sociology personnel and includes the results of their studies. A brief description of the methods used to obtain the data and the results of the preliminary reconnaissance carried out in the project area are included. The major part of this report presents the overall findings of diagnostic analysis. The final section consists of a summary outlining the key social and organizational constraints of the Gambhiri Irrigation Project, and some recommendations.

II. METHODS

Before the actual start of the Diagnostic Analysis Workshop, officials from the Rajasthan Irrigation Department, USAID, and the

Water Management Synthesis Project selected the Gambhiri Irrigation Project in Rajasthan as the site for the workshop. These same officials selected four basic study sites within the project area to conduct a detailed study. As the officials wished to compare conditions at the extreme head and tail of the irrigation system, these four study sites were located along the head and tail minors. Two of the study sites were located on the head minor canal, Thikaria, with one at the extreme head of the minor canal and one at the extreme tail. The other two sites were located on the tail minor canal, Rithola, with one site at the head of the minor and another site at the extreme tail of the minor. While studying both head and tail sites on both the head minor and tail minors, a four-cell table of analysis was constructed. Thus, data could be collected, analyzed, and compared across the four study sites.

		Outlets	
		Head	Minor
Minors	Head	1	2
	Tail	3	4

Each of the four sites was located near a village and all of the sample farmers lived in the villages of 1) Fatcher Solanki, 2) Thikaria, 3) Shenwa, or 4) Thukarwa. From the Irrigation Department a list of all the farmers on the four selected sites was obtained. This consisted of 73 cultivators, and of these, 64 were contacted and interviewed. Nine of the farmers could not be interviewed during the workshop because they were out of the area.

Before the actual interviews took place, all the participants travelled to the four study sites for a preliminary reconnaissance.

During this trip, the participants observed the conditions in the fields and were able to talk informally with some of the farmers. These observations and conversations were subsequently included in the construction of the questionnaire.

Based on this preliminary reconnaissance and on Volumes I and II of the Water Management Synthesis Project's Monitoring and Evaluation Manuals: Diagnostic Analysis of Farm Irrigation Systems (Lowdermilk et al., 1981), the participants discussed among themselves questionnaire construction and the concepts which needed to be examined. Sampling procedures, field data collection, and field interview techniques were reviewed by the participants. From these studies and discussions, a questionnaire was developed and administered to the 64 farmers regarding their irrigation behavior. The questionnaire took into consideration the factors which might constrain full agricultural productivity of the project area. The questionnaire also asked the farmers themselves to outline what they perceived to be the significant constraints confronting them in their irrigation system.

The goal of the field survey was to understand how farmers regarded the selected constraints while managing irrigation water for their crop production. The engineers, economists, and agronomists of the interdisciplinary teams also reviewed the farmer interview schedules to ensure that useful data would be collected to supplement and complement the engineering and agronomy data.

In addition to these 64 sample farmers, 13 "key informants" were interviewed. These were influential or respected members of the four villages. These key informants were particularly helpful in providing information regarding irrigation disputes and conflicts in the project area. Eight minor-level irrigation officials were also contacted and interviewed concerning the problems and pressures which they face in their positions. These minor level officials are irrigation authorities who live at the project site and are responsible for the day-to-day operation of the system. Finally, three major irrigation officials (Executive Engineers, Superintending Engineer) were contacted and interviewed regarding the system's constraints.

The object of these field interviews was to obtain information which would reliably and validly reflect the farmers' and officials' actual socio-economic conditions and elicit data about irrigation behavior, maintenance procedures, the social organization of water users, and many other factors.

III. RECONNAISSANCE SURVEY

The reconnaissance is the first phase of diagnostic analysis and aids in understanding the irrigation practices of the farmers. Unlike the detailed study, the reconnaissance survey is general in nature as it tries to isolate the major constraints on the irrigation system. Rather than using detailed interview schedules and strict sampling procedures, the sociology and extension personnel in a reconnaissance survey visually inspect the condition of fields, canals, channels, houses, and talk with farmers and officials who are in the area. Informal observation and discussions with the farmers often uncover major problems.

The reconnaissance survey on the Gambhiri Irrigation Project was actually begun in the classroom, where members of the Irrigation Department staff provided the participants with background information about the project area. From these materials, some salient points emerged. With the construction of the Gambhiri Project, 9,678 hectares (ha) acres of land have come under command in 80 villages, primarily composed of Jat, Rajput, Kumawat, Bhils, Brahmins, and Vaishys. Out of the total number of farmers in the entire project site, 84 percent own less than 2 ha of land. About 13 percent of the farmers have larger holdings of between 2 to 4 ha. Among the small farmers, a majority consist of tribes.

Holding classification is as follows:

1.	0-1.6 hectares	2,045 household families
2.	1.6-2.0 hectares	102 household families
3.	2.0-4.0 hectares	345 household families
4.	4.0-6.0 hectares	50 household families
5.	6.0-8.0 hectares	6 household families
6.	8.0-10.0 hectares	5 household families
7.	10.0-12.0 hectares	3 household families
8.	12.0 and above	2 household families

As these figures indicate, most of the farmers in the project area are owners of very small plots of land.

Prior to the completion of the Gambhiri Irrigation Project, the area was single-cropped. Since the project has become operational, it has turned to a double- and triple-cropped area, with cultivation in both the Rabi and Kharif seasons.

Next, the three interdisiciplinary teams travelled to the four study sites, and the extension and sociology team members observed the condition of the area and talked with a number of farmers. On the basis of this reconnaissance, some major symptoms of a basically ineffective and inefficient irrigation system were discovered. These included:

1. Timely irrigation water is not supplied with the desired quantity to the fields because of the partial opening of the canal.
2. Sometimes farmers at the head minor (Thikaria) take more water than their allotment permits. As a result, farmers at the tail minor (Rithola) suffer.
3. Various types of disputes on the canal exist, which hamper the timely supply of irrigation water to the farmers. Some court cases in this regard were also reported and have been pending for the last two years.
4. The maintenance of the minor canals is not done in a timely way and properly by the Irrigation Department.
5. The field channels are cleaned jointly once a year by farmers, but sometimes a few of the farmers do not join in the cleaning. In that case, no action is taken or proposed except to persuade the non-cleaners to participate. This insufficient cleaning results in a poor water flow.
6. Irrigation officials have little contact with the farmers.
7. The farmers generally know the office location of the local level irrigation and agricultural officials, but often do not know their names.
8. Low doses of fertilizer are used in crop production, and higher than recommended seed rates are used for some crops, particularly maize.
9. Except for gram, most of the farmers are using improved seeds. In the case of wheat, however, for the last six to eight years farmers have used seed produced from their own fields.

The overall conclusion of the sociology and extension reconnaissance survey confirmed what many irrigation officials had told the participants - the Gambhiri Irrigation Project was a "sick system," and much in need of improvement. A kind of water anarchy prevails in the four study areas, where the tail areas receive little if any water, while the head sites receive untimely amounts of water which are often used to overirrigate their crops. The farmers seem to have little water control, or the ability to predict accurately that a certain amount of water will be delivered to them at a certain time.

On the basis of this preliminary reconnaissance survey, some key observations of the system were made. These may help explain the subsequent irrigation behavior of the farmers and officials. These observations included:

1. Many private wells operate throughout the area. These wells provide a more dependable water supply to the farmers, in addition to increasing the farmers' water control.
2. The farmers are quite vocal in their desire to improve the operation of the irrigation system. They are not satisfied with the present operation of the system and clearly want improvements. The farmers want direct government assistance in reforming and reorganizing the Gambhiri Irrigation Project.
3. The Irrigation Department is attempting to improve the project through a modernization program. Most of the activities of this modernization program, however, involve only the physical environment of irrigation; little effort is being made in the institutional environment.

4. The Irrigation Department does not become involved in activities below the outlet. Irrigation below the outlet is entirely in the hands of the farmers.

These observations indicate that the farmers need help, both physically and institutionally, and the Irrigation Department is making an attempt to improve at least the physical environment of the irrigation system. Both farmers and officials, seem to have the similar goals, but the system still delivers inadequate and untimely water supplies.

Based only on preliminary results, the sociology and extension personnel concluded that the key constraints on this system were the undependable, inequitable, untimely, and inadequate supply of water and the lack of effective communication between the farmers and the irrigation officials. Because of physical and institutional problems, the water supply is highly unreliable, and water management throughout the system is relatively poor. Both officials and farmers are aware of these problems, but neither party has opened adequate lines of communication. Without any local organization of water users, discipline, or effective participation, the results at the project site were an inadequate supply of water and poor communication between farmers and officials.

These conclusions were based on only a reconnaissance survey, and a detailed study needed to be conducted to determine the nature and extent of the key constraints identified above. This detailed study needed to answer the following questions: What are the general socio-economic conditions at the four study sites? What are the farm conditions and the quantity/quality of the institutional agricultural services provided to the farmers? What is the quantity/quality of the institutional irrigation services provided to the farmers? And finally, what are the irrigation conditions and irrigation behavior of the farmers?

IV. RESULTS OF THE DETAILED STUDIES

Most of the findings concerning constraints operating at the Gambhiri Irrigation Project are based on the interviews conducted with 64 farmers in the four study areas. The results are broken down for each individual village study site, separately for the Thikaria Minor and Rhitola Minor, and summarized for all 64 farmers.

A. Socio-Economic Conditions at Four Study Sites

The total farm size in the four study sites, both in villages and minor canals is relatively similar, though the head minor farms appear to contain a greater proportion of large farms (Table 1). About one-third of the head minor farms are classified as large, though on a village basis, the two head villages on the two minors contain the greatest proportion of large farms.

As item 3 in Table 1 indicates, the farm sizes on the outlets are significantly different from one another. The head minor farms on the study outlets average almost 1 ha larger than the tail minor farms on the outlets. Also, clearly the head village, Fatcher Solanki, has the largest average farm size on the outlets, 2.5 ha. The head village, Fatcher Solanki, and the head minor also have the largest proportion of holdings on the outlets classified as large. All 64 of the farmers interviewed were owners-operators.

The vast majority of the farmers at these study sites were either marginal or small landholders. There was a great range in total farm

Table 1. Socio-economic Conditions at Four Study Sites

Number	Items	Name of Villages: Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikariya)	Tail Minor (Rhitola)	Summary Figures
1.	Total Farm Size (mean) (ha)	3.7	2.7	3.6	3.5	3.3	3.5	3.4
2.	Total Farm Size Catagories (Ha.)							
	Marginal (<2.5)	10 (42%)	9 (60%)	3 (43%)	9 (50%)	19 (49%)	12 (48%)	31 (48%)
	Small (2.5-5.0)	4 (16%)	4 (27%)	2 (29%)	7 (31%)	8 (21%)	9 (36%)	17 (27%)
	Large (> 5.0)	10 (42%)	2 (13%)	2 (29%)	2 (11%)	12 (31%)	4 (16%)	16 (25%)
3.	Farm Size on Outlet (mean) (ha)	2.5	1.3	1.3	1.2	2.0	1.3	1.7
4.	Farm Size Catagories on Outlet (ha)							
	Marginal (<2.5)	15 (63%)	13 (87%)	6 (86%)	17 (94%)	28 (72%)	23 (29%)	51 (80%)
	Small (2.5-5.0)	5 (21%)	2 (13%)	1 (14%)	0	7 (18%)	1 (4%)	8 (15%)
	Large (>5.0)	4 (17%)	0	0	1 (6%)	4 (10%)	1 (4%)	5 (8%)
5.	Owner Operation	All	All	All	All	All	All	All
6.	No. of Farmers interviewed (64)	24	15	7	18	39	25	64

size, from 0.5 ha to 19.3 ha, in this area, but clearly the average size tended to be small, Though there are differences between the sizes at the various sites, the overall picture is one of marginal and small landholding.

B. Institutional Agricultural Services and Conditions

Table 2 examines the effectiveness of local agricultural institutions and agents such as the gram sevak (village extension worker), contact farmer, Assistant Agricultural Officer, cooperative manager, and the fertilizer agent. The farmers were asked if they knew the office location and names of these people, and then they were asked to evaluate their helpfulness.

Gram Sevak: Most of the people at all locations knew the office location of the gram sevak and over half knew his name. In Fatcher Solanki, however, two-thirds of the farmers did not know his name. About half of the head and tail minor farmers found the gram sevak of some help, while one-quarter said that he was of no help.

Contact Farmer: The vast majority (86 percent) of all farmers at all locations knew neither the location nor the name of the contact farmer in this area, and the cultivators felt he was of no help. This low recognition factor and rating may be because the contact farmer did not make an effort to meet with other farmers.

Assistant Agriculture Officer: Most (79 percent) of the farmers on the head minor did not know his office location, but most (60 percent) of the tail farmers did. Few of the farmers at any location knew his name, but curiously, those few that did know his name were in the tail villages of each minor. The farmers at all locations felt that he was of little help, but his effectiveness was rated somewhat higher along the tail minor.

Table 2. Institutional Agricultural Services and Farm Conditions

Number	Items	Name of Villages: Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
1.	Gram Sevak Office Location Known							
	No	4 (17%)	0	0	3 (17%)	4 (10%)	3 (12%)	7 (11%)
	Yes	20 (83%)	15 (100%)	7 (100%)	15 (83%)	35 (90%)	22 (88%)	57 (89%)
2.	Name of Gram Sevak Known							
	No	15 (63%)	3 (20%)	3 (45%)	5 (28%)	18 (46%)	8 (32%)	26 (41%)
	Yes	9 (38%)	12 (80%)	4 (57%)	13 (72%)	21 (54%)	17 (68%)	38 (59%)
3.	Helpfulness of Gram Sevak							
	No help	10 (92%)	1 (7%)	0	3 (17%)	11 (29%)	3 (12%)	14 (22%)
	Some help	8 (33%)	11 (79%)	4 (57%)	11 (61%)	19 (50%)	15 (60%)	34 (54%)
	Highly helpful	6 (25%)	2 (14%)	3 (43%)	4 (22%)	8 (21%)	7 (28%)	15 (24%)
	Missing data	0	1	0	0	1	0	1
4.	Contact Farmer Location Known							
	No	22 (92%)	12 (80%)	5 (71%)	16 (89%)	34 (87%)	21 (84%)	55 (86%)
	Yes	2 (8%)	3 (20%)	2 (29%)	2 (11%)	5 (13%)	4 (16%)	9 (14%)
5.	Name of Contact Farmer Known							
	No	23 (96%)	12 (80%)	5 (71%)	16 (89%)	35 (90%)	21 (84%)	56 (87%)
	Yes	1 (4%)	3 (20%)	2 (29%)	2 (11%)	4 (10%)	4 (16%)	8 (15%)
6.	Helpfulness of Contact Farmer							
	No help	23 (100%)	13 (93%)	5 (83%)	17 (100%)	36 (97%)	22 (96%)	58 (97%)
	Some help	0	1 (7%)	1 (17%)	0	1 (3%)	1 (4%)	2 (3%)
	Highly helpful	0	0	0	0	0	0	
	Self	1	1	1	1	2	2	4

Table 2. Institutional Agricultural Services and Farm Conditions (continued)

		Name of Villages						
Number	Items	Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
7.	Asst. Ag. Officer Office Location Known							
	No	21 (88%)	10 (67%)	3 (43%)	7 (39%)	31 (79%)	10 (40%)	41 (64%)
	Yes	3 (12%)	5 (33%)	4 (57%)	11 (61%)	8 (21%)	15 (60%)	23 (36%)
8.	Name of Asst. Ag. Officer Known							
	No	24 (100%)	11 (73%)	7 (100%)	11 (61%)	35 (98%)	18 (72%)	53 (83%)
	Yes	0	4 (27%)	0	7 (39%)	4 (10%)	7 (28%)	11 (17%)
9.	Helpfulness of Asst. Ag. Officer							
	No help	24 (100%)	12 (80%)	3 (43%)	11 (61%)	36 (92%)	14 (56%)	50 (78%)
	Some help	0	3 (20%)	2 (29%)	7 (39%)	3 (8%)	9 (36%)	12 (19%)
	Highly helpful	0	0	2 (29%)	0	0	2 (8%)	2 (3%)
10.	Co-op Manager Office Location Known							
	No	5 (21%)	3 (20%)	0	4 (22%)	8 (21%)	4 (16%)	12 (19%)
	Yes	19 (79%)	12 (80%)	7 (100%)	14 (78%)	31 (79%)	21 (84%)	52 (82%)
11.	Name of Co-op Manager Known							
	No	16 (67%)	4 (27%)	1 (14%)	12 (67%)	20 (51%)	13 (52%)	33 (52%)
	Yes	8 (33%)	11 (73%)	6 (86%)	6 (33%)	19 (49%)	12 (48%)	31 (48%)
12.	Helpfulness of Co-op Manager							
	No help	8 (33%)	8 (53%)	0	9 (50%)	16 (41%)	9 (36%)	25 (40%)
	Some help	10 (42%)	6 (40%)	1 (14%)	9 (50%)	16 (41%)	10 (40%)	26 (41%)
	Highly helpful	6 (25%)	1 (7%)	6 (86%)	0	7 (18%)	6 (24%)	13 (20%)
13.	Fertilizer Agent Office Location Known							
	No	20 (83%)	9 (60%)	7 (100%)	9 (50%)	29 (74%)	16 (64%)	45 (70%)
	Yes	4 (17%)	6 (40%)	0	9 (50%)	10 (26%)	9 (36%)	19 (30%)
14.	Name of Fertilizer Agent Known							
	No	21 (88%)	11 (73%)	7 (100%)	9 (50%)	32 (82%)	16 (64%)	48 (75%)
	Yes	3 (12%)	4 (27%)	0	9 (50%)	7 (18%)	9 (36%)	16 (25%)
15.	Helpfulness of Fertilizer Agent							
	No help	22 (92%)	12 (80%)	7 (100%)	15 (83%)	34 (87%)	22 (88%)	56 (87%)
	Some help	0	2 (13%)	0	3 (17%)	2 (5%)	3 (12%)	5 (8%)
	Highly helpful	2 (8%)	1 (7%)	0	0	3 (8%)	0	3 (5%)

Cooperative Manager: Most (82 percent) of the farmers at all locations knew his office location, and half on each minor knew his name. On a village-comparison, however, the cooperative manager was well-known in Thikaria and Shenwa, but not well known in Fatcher Solanki and Thukarwa, the two villages on the extreme head and extreme tail of the system. At least 60 percent of the farmers on both minors felt that he was of some help or highly helpful. On a village basis, the two head villages on each minor think most highly of him.

Fertilizer Agent: Very few (25-30 percent) farmers knew a fertilizer agent or his office location, and the farmers felt he was of little help.

The data in Table 2 suggest that the gram sevak and cooperative manager are relatively well-known to the farmers and are of some help. The contact farmer, Assistant Agriculture Officer and the fertilizer agent, however, are not well known and the farmers perceive them as not providing much help. With regard to these agricultural personnel, then, their effectiveness seems somewhat limited, though the farmers do have a fair amount of contact with them.

1. Agricultural Information

Table 3 examines the adequacy and frequency of various pieces of agricultural information.

Price of Inputs: Information concerning price of inputs was received by farmers through markets known as "Krishi Upaj Mandi," and also from local businessmen and fellow farmers. All farmers at all locations seemed to be getting this informaton fairly regularly, though the two head villages on each minor had more reliable information.

Table 3. Frequency of Agricultural Information Received by Sample Farmers

Number	Items	Name of Villages: Fatcher Solanki (Head of Head Minor)	Name of Villages: Thikaria (Tail of Head Minor)	Name of Villages: Shenwa (Head of Tail Minor)	Name of Villages: Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
1.	Price of Inputs							
	Never	0	0	0	0	0	0	0
	Sometimes	11 (46%)	13 (93%)	2 (29%)	18 (100%)	24 (63%)	20 (80%)	44 (70%)
	Usually	13 (54%)	1 (7%)	5 (71%)	0	14 (37%)	5 (20%)	19 (30%)
	Missing data	0	1	0	0	1	0	1
2.	Market Places							
	Never	0	0	0	0	0	0	0
	Sometimes	18 (75%)	14 (100%)	3 (43%)	16 (94%)	32 (84%)	19 (79%)	57 (82%)
	Usually	6 (25%)	0	4 (57%)	1 (6%)	6 (16%)	5 (21%)	11 (18%)
	Missing data	0	1	0	1	1	1	2
3.	New Crop Varieties							
	Never	3 (13%)	0	0	0	3 (8%)	0	3 (5%)
	Sometimes	15 (63%)	12 (86%)	3 (43%)	16 (89%)	27 (71%)	19 (76%)	46 (73%)
	Usually	6 (25%)	2 (14%)	4 (57%)	2 (11%)	8 (21%)	6 (24%)	14 (22%)
	Missing data	0	1	0	0	1	0	1
4.	Fertilizer Use							
	Never	2 (8%)	2 (13%)	0	0	4 (10%)	0	4 (6%)
	Sometimes	14 (58%)	10 (67%)	0	17 (94%)	24 (62%)	17 (68%)	41 (64%)
	Usually	8 (33%)	3 (20%)	7 (100%)	1 (6%)	11 (28%)	8 (32%)	19 (30%)
	Missing data	0	0	0	0	0	0	
5.	Insecticide Use							
	Never	13 (54%)	7 (47%)	1 (14%)	5 (28%)	20 (51%)	6 (24%)	26 (41%)
	Sometimes	7 (29%)	8 (53%)	1 (14%)	12 (67%)	15 (38%)	13 (52%)	28 (44%)
	Usually	4 (17%)	0	5 (71%)	1 (6%)	4 (10%)	6 (24%)	10 (16%)
	Missing data	0	0	0	0	0	0	

Market Places: Similarly, most farmers (82 percent) in all villages and on both minors seemed to be receiving this information, perhaps because they knew that there is a regulated market yard near to their village. Once again, Fatcher Solanki and Shenwa, the two head villages on the minors, seemed to have a more regular flow of this information.

New Crop Varieties: Again, the vast majority (95 percent) of farmers were receiving this information either sometimes or usually, primarily through the extension system.

Fertilizer Use: Approximately 60 to 70 percent of all the farmers were getting fertilizer information "sometimes," primarily from extension and cooperative services. However, the two head villages were getting a more reliable flow of fertilizer use information.

Insecticide Use: On the head minor, over half the farmers never received information on the use of insecticides, while at the tail minor three-fourths of the farmers received the information either sometimes or usually. Perhaps the *gram sevak* was better informed at the tail minor.

With the possible exception of information on insecticide use, it appeared that *agricultural* information was received fairly regularly at all locations. This information, though not directly related to the irrigation system, has an effect on farm management practices.

2. Use and Ownership of Implements

Table 4 deals with the farmers' use and ownership of improved agricultural implements.

Tractor for Plowing: Only three out of 64 farmers owned a tractor for plowing, and those three lived in the head village of the head

Table 4. Use of Improved Implements

Number	Items	Name of Villages: Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
1.	Tractor for Plowing							
	Does not use	11 (46%)	11 (73%)	4 (57%)	9 (50%)	22 (56%)	13 (52%)	35 (55%)
	Owns	3 (13%)	0	0	0	3 (8%)	0	3 (5%)
	Rents	10 (42%)	4 (27%)	3 (43%)	7 (39%)	14 (36%)	10 (40%)	24 (38%)
	Barter	0	0	0	2 (11%)	0	2 (8%)	2 (3%)
2.	Thresher							
	Does not use	4 (17%)	2 (13%)	1 (14%)	5 (28%)	6 (15%)	6 (24%)	12 (19%)
	Owns	4 (17%)	0	0	1 (6%)	4 (10%)	1 (4%)	5 (8%)
	Rents	16 (67%)	13 (87%)	6 (86%)	10 (56%)	29 (75%)	16 (64%)	45 (71%)
	Barter	0	0	0	2 (11%)	0	2 (8%)	2 (3%)

minor. Over one-third of all the farmers rented tractors, but over one-half of all farmers did not use a tractor at all.

Thresher: Only five farmers owned threshers, four at the extreme head village, and one at the extreme tail. About three-fourths of head and tail minor farmers rented threshers.

Although not shown in tabular form, farmer interviews provided other useful information regarding the use and ownership of improved agricultural implements. Most (66 percent) head minor farmers owned a bullock-drawn improved tiller, but at the tail minor, ownership was slightly less than one-half of the farmers. Very few (18 percent) farmers used a bullock-drawn mouldboard plow or rubber tire bullock cart, but most farmers (86 percent) owned a bullock-drawn seed drill. There was little (8 percent), if any, use of tractors for land leveling at any location, but almost half of head and tail minor farmers used a bullock for land leveling. At the head minor, half the farmers rented a tractor trolley, but at the tail minor, no one used one.

The farmers' use of improved agricultural implements, seemed to reflect the overall socio-economic conditions of the area. Most of the farmers used their own bullock-drawn implements, compared to only three or four farmers who owned tractor drawn implements. Few farmers did land leveling operations. Some rudimentary improved implements using gasoline, diesel, or electricity were owned by only a few, primarily those on the head minor.

3. Recommended Crop Practices

Table 5 deals with the farmers' use of recommended crop practices. They seemed to have the full knowledge of recommended crop practices, but they followed only partial recommendations.

Table 5. Use of Recommended Crop Practices

Number	Items	Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
		Name of Villages						
1.	Improved Variety of Maize							
	No	0	2 (13%)	4 (57%)	12 (80%)	2 (5%)	16 (73%)	18 (30%)
	Yes	24 (100%)	13 (87%)	3 (43%)	3 (20%)	37 (95%)	6 (27%)	43 (70%)
	Missing data	0	0	0	3	0	3	3
2.	Improved Variety of Wheat							
	No	0	1 (7%)	0	0	1 (3%)	0	1 (2%)
	Yes	23 (100%)	14 (93%)	7 (100%)	17 (100%)	37 (97%)	24 (100%)	61 (98%)
	Missing data	1	0	0	1	1	1	2
3.	Improved Variety of Gram							
	No	15 (65%)	12 (92%)	4 (100%)	2 (67%)	27 (75%)	6 (86%)	33 (77%)
	Yes	8 (35%)	1 (8%)	0	1 (33%)	9 (25%)	1 (14%)	10 (23%)
	Missing data	1	2	3	15	3	18	21
4.	Seed Rate: Kg/Ha (mean)							
	Maize (recommended: 20)	26	27	29	28	27	28	27
	Wheat (recommended: 100-125)	95	101	118	105	97	108	102
	Gram (recommended: 80)	45	56	59	83	49	69	53
5.	Cropping Intensity	172	156	122	130	166	128	152

Improved Varieties of Maize, Wheat, and Gram: With maize, 95 percent of the head minor farmers used an improved variety, but only one-fourth of the tail minor farmers planted the improved varieties. Almost all used improved wheat, but very few (23 percent) farmers at any location planted improved gram.

Seed Rate: Maize, Wheat, and Gram: The maize seed rate differed little among locations, but a higher than recommended rate was used. This may have been to keep a proper plant population, because maize is not irrigated by canals or wells unless that crop fails at the last stage. The seed rate for wheat followed the recommended rate, but there was a significant difference in the wheat seed rate in the four locations. The farmers used a lower than recommended seed rate for gram, with significantly different rates among locations.

The interviews also revealed that farmyard manure used for maize was 80 percent of the recommended dose, but for wheat was only 50 percent. Soil treatment was not being done by farmers, and seed treatment also was not done. The improved seed the farmers own may already be treated but it may not be certified. Certified seed is treated, but only 5 percent of Gambhiri farmers used certified seed for wheat. For all crops, the sowing method and number of plowings were followed fully, while interculture operations and plant protection measures were taken when needed.

With fertilizer, the maize crop did not receive a basal dosage, but top dressing was used. In the case of groundnuts, 50 percent of the recommended D.A.P. fertilizer dosage was used as a basal dose. For wheat, D.A.P. fertilizer was used as a basal dose and was supplemented by urea fertilizer applied as top dressing. Overall, low doses of fertilizer were used. Because of the uncertainty of the water supply, perhaps the farmers did not apply the full doses. Finally, Table 5 demonstrates large differences in cropping intensity among all the study sites.

This data concerning farm conditions and institutional agricultural services paint a mixed picture. Though the farmers received fairly consistent information on certain agricultural practices (i.e., price of inputs, new crop varieties, fertilizer use), the actual on-farm agricultural conditions remained less than ideal. Some agricultural personnel were well-known to the farmers (e.g., gram sevak, cooperative manager), but others (e.g., fertilizer agents) were virtual strangers throughout the project area. The majority of farmers used improved seed for wheat and maize, but generally employed low doses of chemical fertilizer.

The agriculture of this area, therefore, is typical of rural Asia: small farmers, few improved implements, and scattered institutional services provided. Though the agriculture in the project area was not as productive as it could be, the farmers grew two crops a year and some agricultural services reached the farmers. The major constraint in their agricultural practices seems to be directly related to the irrigation services and conditions in the area. The following section of this report details these services and conditions.

C. Institutional Services for Irrigation

Table 6 describes the effectiveness of irrigation institutional services in the study area.

Chowkidar: Most of the farmers on the tail minor knew the name and location of the chowkidar (gatekeeper), but in the head village of

Table 6. Institutional Services for Irrigation

Number	Items	Name of Villages: Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
1.	Canal Chowkidar Office Location Known							
	No	15 (63%)	0	0	4 (22%)	15 (39%)	4 (16%)	19 (30%)
	Yes	9 (38%)	15 (100%)	7 (100%)	14 (78%)	24 (62%)	21 (84%)	45 (70%)
2.	Canal Chowkidar Name Known							
	No	21 (88%)	0	0	6 (33%)	21 (54%)	6 (24%)	27 (42%)
	Yes	3 (13%)	15 (100%)	7 (100%)	12 (67%)	18 (46%)	19 (76%)	37 (58%)
3.	Helpfulness of Canal Chowkidar							
	No help	18 (75%)	5 (33%)	0	11 (61%)	23 (59%)	11 (44%)	34 (53%)
	Some help	6 (25%)	10 (67%)	3 (43%)	7 (39%)	16 (41%)	10 (40%)	26 (47%)
	Highly helpful	0	0	4 (57%)	0	0	4 (16%)	4 (6%)
4.	Canal Patwari Office Location Known							
	No	0	0	0	1 (6%)	0	1 (4%)	9 (2%)
	Yes	24 (100%)	15 (100%)	7 (100%)	17 (94%)	39 (100%)	24 (96%)	63 (98%)
5.	Canal Patwari Name Known							
	No	2 (8%)	2 (13%)	2 (29%)	7 (39%)	4 (10%)	9 (36%)	13 (20%)
	Yes	22 (92%)	13 (87%)	5 (71%)	11 (61%)	35 (90%)	16 (64%)	51 (80%)
6.	Helpfulness of Canal Patwari							
	No help	2 (8%)	10 (67%)	0	8 (44%)	12 (31%)	8 (32%)	20 (31%)
	Some help	12 (50%)	5 (33%)	3 (43%)	10 (56%)	17 (44%)	13 (52%)	30 (47%)
	Highly helpful	10 (42%)	0	4 (57%)	0	10 (26%)	4 (16%)	14 (22%)
7.	Water Distribution Committee Location Known							
	No	12 (50%)	7 (47%)	0	12 (67%)	19 (49%)	12 (48%)	31 (48%)
	Yes	12 (50%)	8 (53%)	7 (100%)	6 (33%)	20 (51%)	13 (52%)	33 (51%)
8.	Water Distribution Committee Member Name Known							
	No	24 (100%)	11 (73%)	7 (100%)	16 (89%)	35 (90%)	23 (92%)	58 (91%)
	Yes	0	4 (27%)	0	2 (11%)	4 (10%)	2 (8%)	6 (9%)
9.	Helpfulness of Water Distribution Committee							
	No help	17 (71%)	13 (87%)	2 (29%)	15 (88%)	30 (77%)	17 (71%)	47 (75%)
	Some help	7 (29%)	2 (15%)	5 (71%)	2 (12%)	9 (23%)	7 (29%)	16 (25%)
	Highly helpful	0	0	0	0	0	0	0
	Self	0	0	0	1	0	1	1

the head minor, very few of the farmers knew his name and location. This may be because the tail farmers are having more problems and are forced to contact the chowkidar more often. Approximately half of all the farmers at all locations felt that he was of no help.

Patwari: Almost all the farmers on both the head and tail minor knew the office location and name of the canal patwari (revenue official). The helpfulness of the patwari was perceived to be fairly effective at the head and tail minors. However, the two tail villages on each minor thought that his effectiveness was very low, while the two head villges on each minor considered his effectiveness to be high.

Water Distribution Committee: (The group in Chittorgarh that decides the number and timings of irrigation along the minors.) Half the interviewed farmers on the minors knew the location of the committee in Chittorgarh, but in the extreme tail village, where this committee is of vital importance, two-thirds of the farmers did not know its location. Few, if any of the farmers knew the name of a member, and approximately three-fourths of all farmers felt that it was of no help.

This patwari and chowkidar seemed to be relatively well-known by the farmers, but their helpfulness was ranked as relatively low. The Water Distribution Committee was neither well known nor perceived as being very helpful.

1. Adequacy and Frequency of Irrigation Information

Table 7 deals with the adequacy and frequency of information received by the farmers regarding irrigation matters.

Revenue Payment Dates: All farmers seemed to be getting this information at least "sometimes," but the reliability of receiving the information was much higher at the two head villages of the two minors.

Table 7. Frequency of Irrigation Information Received by Sample Farmers

Number	Items	Name of Villages: Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
1.	Revenue Payments Dates							
	Never	1 (4%)	0	0	0	1 (3%)	0	1 (2%)
	Sometimes	3 (13%)	14 (100%)	1 (14%)	11 (92%)	17 (45%)	12 (63%)	29 (51%)
	Usually	20 (83%)	0	6 (86%)	1 (8%)	20 (53%)	7 (37%)	27 (47%)
	Missing data	0	1	0	6	1	6	7
2.	Canal closure Dates							
	Never	7 (29%)	7 (54%)	0	5 (50%)	14 (38%)	5 (29%)	19 (35%)
	Sometimes	11 (46%)	6 (46%)	1 (14%)	5 (50%)	17 (46%)	6 (35%)	23 (43%)
	Usually	6 (25%)	0	6 (86%)	0	6 (16%)	6 (35%)	12 (22%)
	Missing data	0	2	0	8	2	8	10
3.	Water Use Practices On-Farm							
	Never	22 (92%)	4 (27%)	6 (86%)	9 (64%)	26 (67%)	15 (71%)	41 (68%)
	Sometimes	1 (4%)	9 (60%)	1 (14%)	5 (36%)	10 (26%)	6 (29%)	16 (27%)
	Usually	1 (4%)	2 (13%)	0	0	3 (8%)	0	3 (5%)
	Missing data	0	0	0	4	0	4	4
4.	Seasonal Water Supply Information							
	Never	17 (71%)	5 (36%)	5 (71%)	10 (71%)	22 (58%)	15 (71%)	37 (63%)
	Sometimes	2 (8%)	9 (64%)	1 (14%)	4 (29%)	11 (29%)	5 (24%)	16 (27%)
	Usually	5 (21%)	0	1 (14%)	0	5 (13%)	1 (5%)	6 (10%)
	Missing data	0	1	0	4	1	4	5

Canal Closure Dates: About one-third of the farmers on both minors received no information regarding canal closure dates, and what information was received went to the two head villages on each minor more often.

Water-Use Practices On-Farm: Two-thirds of head and tail minor farms never received this information. Here, however, what little information was received more often went to the two tail villages on each minor.

Seasonal Water Supply Information: From one-half to three-fourths of all farmers on both minors never got this vital information. Little information was received by the farmers, particularly at the tail villages of each minor. In fact, many of the villagers in the extreme tail village of Thukarwa said that they never received canal water and thus the information was not important for them.

2. Information Sources

Table 8 examines the sources and frequency of information received by the farmer on when, how, and how much to irrigate their crops.

Gram Sevak: One-half to two-thirds of the farmers on both minors never received information as to when, how, or how much to irrigate their crops from the gram sevak. When studying the village frequency, however, the two tail villages on each minor (Thikaria, Thukarwa) received this on-farm irrigation information much more frequently than the two head villages on each minor (Fatcher Solanki, Shenwa).

Contact Farmer: Virtually no on-farm irrigation information was received anywhere from the contact farmer.

Chowkidar: Most farmers on both minors did not get on-farm irrigation information from the chowkidar, but as in the case of the

Table 8. Irrigation Information Sources

Number	Items	Fatcher Sclanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
		Percent Receiving Information From Sources as to When, How, How Much to Irrigate Crops						
		Name of Villages						
1.	Gram Sevak							
	Never	23 (96%)	4 (27%)	6 (86%)	7 (41%)	27 (69%)	13 (52%)	40 (64%)
	Sometimes	1 (4%)	10 (67%)	0	10 (59%)	11 (28%)	10 (42%)	21 (33%)
	Usually	0	1 (7%)	1 (14%)	0	1 (3%)	1 (4%)	2 (3%)
	Missing data	0	0	0	1	0	1	1
2.	Contact Farmer							
	Never	23 (100%)	11 (79%)	6 (100%)	17 (100%)	34 (92%)	23 (100%)	57 (95%)
	Sometimes	0	3 (21%)	0	0	3 (8%)	0	3 (5%)
	Usually	0	0	0	0	0	0	0
	Self	1	1	1	1	2	2	4
3.	Chowkidar							
	Never	22 (92%)	7 (47%)	6 (86%)	10 (56%)	29 (74%)	16 (62%)	45 (70%)
	Sometimes	2 (8%)	8 (53%)	0	8 (44%)	10 (26%)	8 (34%)	18 (28%)
	Usually	0	0	1 (14%)	0	0	1 (4%)	1 (2%)
4.	Radio							
	Never	23 (96%)	8 (57%)	7 (100%)	16 (89%)	31 (82%)	23 (92%)	54 (86%)
	Sometimes	1 (4%)	6 (43%)	0	2 (11%)	7 (18%)	2 (8%)	9 (14%)
	Usually	0	0	0	0	0	0	0
	Missing data	0	1	0	0	1	0	1
5.	Seed/Fertilizer Agents							
	Never	24 (100%)	7 (47%)	7 (100%)	16 (94%)	31 (80%)	23 (96%)	54 (86%)
	Sometimes	0	7 (47%)	0	1 (6%)	7 (18%)	1 (4%)	8 (13%)
	Usually	0	1 (7%)	0	0	1 (3%)	0	1 (2%)
	Missing data	0	0	0	1	0	1	1
6.	Farmer Friends							
	Never	21 (88%)	4 (27%)	6 (86%)	5 (28%)	25 (64%)	11 (44%)	36 (56%)
	Sometimes	3 (12%)	9 (60%)	0	13 (72%)	12 (31%)	13 (52%)	25 (39%)
	Usually	0	2 (13%)	1 (14%)	0	2 (5%)	1 (4%)	3 (5%)
7.	Patwari							
	Never	23 (96%)	14 (93%)	7 (100%)	18 (100%)	37 (95%)	25 (100%)	61 (95%)
	Sometimes	0	1 (7%)	0	0	1 (3%)	0	1 (2%)
	Usually	1 (4%)	0	0	0	1 (3%)	0	1 (2%)

Gram Sevak, almost half of the farmers in the two tail villages of Thikaria and Thukarwa received information from the chowkidar at least sometimes.

Radio: Except for the tail village on the head minor, virtually no one received information from the radio.

Seed/Fertilizer Agents: Again, very little consistent information was received on either minor, but the village of Thikaria, the tail village on the head minor, did seem to get a relatively reliable flow of information.

Farmer Friends: Over half of the farmers on the tail minor received on-farm irrigation information from farmer friends at least sometimes, while the head minor farmers displayed the opposite pattern - over half of the farmers never got information. Village comparison, showed quite striking results. The two head villages on each minor rarely received this information from farmer friends, while the two tail villages on each minor had a consistent flow of this information.

Patwari: Almost all farmers (95 percent) at all locations never received on-farm irrigation information from the patwari.

Overall, this last set of items reveals a picture of the selected farmers rarely, if ever, receiving information concerning when, how, and how much to irrigate their crops. What little information was received came from farmer friends and the gram sevak. An interesting pattern emerges where the tail villages of each minor appeared to have a more consistent flow of this information when compared to the head villages of each minor. This entire section dealing with the institutional services for irrigation paints a rather gloomy picture. In terms of effectiveness of irrigation agents and institutions, the farmers had a low impression of the frequency and accuracy of irrigation information. Institutionally, therefore, few irrigation services reached the farmers.

D. Irrigation Conditions and Behavior of Farmers

Data in Tables 9 through 13 describe the actual irrigation conditions reported by the farmers. They show what the farmers perceived to be their major constraints and how they respond to these perceived constraints.

1. Irrigation Conditions

Table 9 examines irrigation conditions and farmer irrigation behavior.

Source of Irrigation Water: On the tail minor, one-third of the farmers used only well water because of non-availability of canal water, particularly in the extreme tail village of Thukarwa. But at the head minor, one-third of the farmers used only canal water. Farmers at the head received much more canal water than farmers at the tail.

Perceived Problems: When asked to identify their single most important problem in increasing crop production, almost all farmers (97 percent) on the head minor replied "water." At the tail minor, however, 60 percent replied "water" and 40 percent said "credit." All of the farmers who replied "credit" were in the tail village of the tail minor, which receives a very unreliable supply of water. Such a response from a village where the water supply is so uncertain is quite surprising. Where water is so scarce, it was thought that the farmers would perceive water constraints as their most serious agricultural

Table 9. Irrigation Conditions and Behavior of Farmers

Number	Items	Name of Villages: Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
1.	Source of Irrigation Water							
	Canal water only	12 (50%)	2 (13%)	1 (14%)	0	14 (36%)	1 (4%)	15 (23%)
	Well water only	0	0	0	8 (44%)	0	8 (32%)	8 (13%)
	Canal and well water	11 (46%)	11 (73%)	6 (86%)	10 (56%)	22 (56%)	16 (64%)	38 (54%)
	Canal, well, stream water	0	2 (13%)	0	0	2 (5%)	0	2 (3%)
	Canal and stream water	1 (4%)	0	0	0	1 (3%)	0	1 (2%)
2.	Most Important Perceived Problem of Farmers in Increasing Crop Production?							
	Credit	0	0	0	10 (56%)	0	10 (90%)	10 (16%)
	Land	0	0	0	0	0	0	0
	Water	24 (100%)	14 (93%)	7 (100%)	8 (44%)	38 (97%)	15 (60%)	53 (83%)
	Seed	0	0	0	0	0	0	0
	Fertilizer	0	1 (7%)	0	0	1 (3%)	0	1 (2%)
	Pesticides	0	0	0	0	0	0	0
	Electric Power	0	0	0	0	0	0	0
	Marketing	0	0	0	0	0	0	0
3.	If Water is Main Problem is it:							
	Quantity	6 (25%)	6 (43%)	0	5 (63%)	12 (34%)	5 (33%)	17 (32%)
	Maintenance	0	0	1 (14%)	0	0	1 (7%)	1 (2%)
	Frequency	0	4 (29%)	1 (14%)	0	4 (10%)	1 (7%)	5 (9%)
	Disputes	0	0	0	0	0	0	0
	Timing	18 (75%)	4 (29%)	5 (72%)	3 (37%)	22 (56%)	8 (53%)	30 (57%)
4.	Number of Irrigations/ Season (mean)							
	WHEAT							
	Canal	3.9	2.3	2.0	0.9	3.3	1.2	2.5
	Well	0.9	2.6	1.4	2.8	1.6	2.4	1.9
	Total	4.9	4.9	3.4	3.6	4.9	3.6	4.4
	GRAM							
	Canal	1.7	1.1	2.0	0.7	1.5	1.4	1.5
	Well	0.2	0.4	0.0	0.7	0.3	0.3	0.3
	Total	1.8	1.6	2.0	1.3	1.7	1.7	1.7

Table 9. Continued.

Number	Items	Name of Villages						
		Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
5.	Farmers Perception of Optimum Number of Irrigations/Season (mean)							
	Wheat	6.1	5.4	5.3	5.9	5.8	5.7	5.8
	Gram	1.9	2.0	2.0	2.7	2.0	2.3	2.0
6.	Number of Days Outlet On (mean)	23	12	20	7	19	12	17
7.	Number of Days Outlet Off (mean)	16	31	19	32	22	27	24
8.	Does the Minor Usually Run at:							
	Full capacity	22 (92%)	0	5 (71%)	0	22 (56%)	5 (20%)	27 (47%)
	Partial capacity	2 (8%)	15 (100%)	2 (29%)	11 (61%)	17 (44%)	13 (52%)	30 (53%)
	Don't know	0	0	0	7 (39%)	0	7 (28%)	7
9.	Own Dug Well							
	No	8 (33%)	0	1 (14%)	0	8 (21%)	1 (4%)	9 (14%)
	Yes	16 (67%)	15 (100%)	6 (86%)	18 (100%)	31 (80%)	24 (96%)	55 (86%)
10.	If Own Dug Well, is it:							
	Bullock lift	7 (41%)	7 (37%)	1 (17%)	15 (75%)	14 (39%)	16 (62%)	30 (48%)
	Diesel lift	1 (6%)	2 (11%)	1 (17%)	5 (25%)	3 (8%)	6 (23%)	9 (15%)
	Electric Lift	9 (53%)	10 (53%)	4 (67%)	0	19 (53%)	4 (15%)	23 (37%)
11.	Time to Irrigate Average Bigha (mean hours)	8.3	11.1	6.4	28.5	10.7	19.9	13.6
12.	Percent of Total Area Irrigated (mean)	79.9	74.9	61.4	53.2	77.9	55.5	69.2

problem. Further informal conversations with the farmers at this location revealed that most of the farmers needed credit to buy improved implements for their wells. As well water is a prime source of irrigation water, listing "credit" as a problem in this instance, bears a direct relation to water problems. Additionally, we can hypothesize that these farmers have simply given up the hope of ever receiving a reliable and predictable supply of water, and thus it is simply not a perceived problem for them.

When the farmers who perceived water to be the major problem were asked what aspect of water was the biggest constraint, half of the farmers on both minors said timing. Among the villages, three-fourths of the farmers in the head villages on each minor replied timing, while many of the farmers (43 percent and 63 percent) in the tail villages on each minor said quantity. One would expect the head villages on each minor to receive a greater quantity of water, thus making the timing of the water delivery more important to them. On the other hand, the two tail villages would be expected to receive less water, so that water quantity would be more important for them.

Number of Irrigations: In the case of wheat, the number of canal irrigations per season and total irrigations per season was much higher along the head minor than the tail minor. Conversely, the farmers along the tail minor applied more well water irrigations to wheat than the head farmers. The figures presented in item 4 for wheat indicate that in any given season, the head minor farmers were able to apply significantly more irrigations than the tail minor farmers. As the recommended annual total waterings for wheat is four to six, the tail minor farmers were not applying sufficient water to their wheat.

In the case of gram, farmers in both the head and tail minors applied virtually the same number of irrigations. The recommended number of irrigations for gram is two, and neither the head nor tail minor farmers applied that number.

If a sufficient quantity of water were made available to the farmers at all locations, they would follow the official recommendations and increase their number of irrigations for both wheat and gram. Most of the farmers reported that they would give two additional irrigations to wheat if optimum water was made available. Similarly, the farmers reported that they would give one additional irrigation to gram if more canal water was made available.

Canal Operation: The farmers reported that the days the outlet is open are more at the head minor than the tail, while days it is closed are more at the tail minor than the head. For outlet days on, the villages at the head of each minor, Fatcher Solanki and Shenwa, reported far more days on than the tail villages on each minor. Conversely, the tail villages on each minor, Thikaria and Thukarwa, reported far more days that the outlet was closed than the two head villages. The same village relationship holds for the capacity of the canal when it is running: the head villages on each minor reported full capacity, while the tail villages on each minor reported partial capacity. In other words, the relationship here is between the head villages on each minor versus the tail villages on each minor, rather than the head minor villages versus the tail minor villages.

Wells: Most of the farmers owned wells at all locations, though one-third of the farmers at Fatcher Solanki, the extreme head village, did not own wells. In this village, and possibly at Shenwa, the well water for irrigation was perhaps simply used to supplement the primary source of water, the canal. In the other villages, however, well water was the primary source of irrigation and was merely supplemented by canal water. Of those owning wells, there was a greater proportion of diesel and electric lifts along the head minor, and a greater proportion of the costly and inefficient bullock lifts along the tail minor.

Time to Irrigate Average Bigha: Although irrigation time depends on a variety of factors, including soil type, slope of the land, and farmer efficiency, the actual time involved in this operation is still an indicator of overall irrigation conditions. It took the tail minor farmers almost twice as long to irrigate as the head minor farmers, and the extreme tail village took more than three times as long to irrigate a *bigha*, when compared to the extreme head village. This may be because of the low flow rate of water at the tail.

Percent of Total Area Irrigated (Rabi): A far greater percentage of land was irrigated in the *Rabi* season on the head minor compared to the tail. This probably reflects the poor irrigation conditions along the tail minor.

2. Exchange and Purchase of Water

Table 10 examines the exchange and purchase of water at the four study sites. These processes of exchange and purchase are at least two potential methods which the farmers could use to increase their water control.

Exchange of Water: Over two-thirds of the head minor farmers exchanged their informal turns for using canal water, while only one-third of the tail minor farmers did. On a village basis, the extreme tail village did the least amount of water trading, perhaps because

Table 10. Exchange of Water

Number	Items	Name of Villages						
		Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
1.	Do You Ever Exchange Your Informal Turn for Using Canal Water with Another Farmer?							
	No	6 (25%)	5 (33%)	2 (29%)	10 (56%)	11 (28%)	12 (48%)	23 (36%)
	Yes	18 (75%)	10 (67%)	5 (71%)	3 (17%)	28 (72%)	8 (32%)	36 (56%)
	Never getting canal water	0	0	0	5 (28%)	0	5 (20%)	5 (8%)
2.	Do You Ever Exchange Canal Water for Well Water?							
	No	24 (100%)	15 (100%)	7 (100%)	10 (56%)	39 (100%)	17 (68%)	56 (88%)
	Yes	0	0	0	1 (6%)	0	1 (4%)	1 (2%)
	Never getting canal water	0	0	0	7 (39%)	0	7 (28%)	7 (11%)
3.	Have You Ever Bought Canal Water from Another Farmer?							
	No	24 (100%)	15 (100%)	7 (100%)	14 (100%)	39 (100%)	21 (100%)	60 (100%)
	Yes	0	0	0	0	0	0	0
	Missing data	0	0	0	4	0	4	4
4.	Have You Ever Bought Well Water from Another Farmer?							
	No	23 (96%)	11 (73%)	7 (100%)	14 (93%)	34 (87%)	21 (95%)	55 (86%)
	Yes	1 (4%)	4 (27%)	0	1 (7%)	5 (13%)	1 (5%)	6 (9%)
	Missing data	0	0	0	3	0	3	3 (5%)

there was such limited time to exchange because of the small and unpredictable flow of water. Also, these farmers along the tail undoubtedly lacked the water control to exchange water turns consistently.

Additionally, few if any farmers exchanged canal for well water, and no farmers bought canal water from another farmer. A few farmers, however, had bought well water from other farmers.

3. Maintenance

Table 11 looks at the maintenance activities at the four sites.

Maintenance: Although number of cleanings cannot be used as a substitute for quality of maintenance, it does provide some insight into the effectiveness of farmers' maintenance work. While there was little difference in the number of yearly cleanings between the head and tail minors, there was a slightly larger variation by village. What is interesting is the relatively low number of cleanings (1.4) at the extreme tail village. One would expect the farmers at this location to be especially careful with cleanings, to maximize every drop of water. Perhaps at the extreme tail location the farmers receive such an unreliable supply of water that they feel they do not want to make the effort to emphasize field channel cleaning. Their costs of maintenance may simply exceed whatever benefits they would receive from more frequent cleanings.

Overall, the farmers were satisfied with the frequency and quality of field channel cleaning, though there was less satisfaction on the tail minor. On a village basis, 100 percent of the farmers at the head villages on each minor were satisfied, while only slightly more than half of the tail village farmers on each minor were satisfied with the frequency and quality of field channel cleaning.

Table 11. Maintenance

Number	Items	Name of Villages: Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
1.	Number of Times Field Channel Cleaned/Year (mean)	1.2	1.6	1.7	1.4	1.3	1.5	1.4
2.	Satisfied with Field Channel Clearing Frequency?							
	No	0	4 (27%)	0	8 (53%)	4 (10%)	8 (36%)	12 (20%)
	Yes	24 (100%)	11 (73%)	7 (100%)	7 (47%)	35 (90%)	14 (64%)	49 (80%)
	Missing data	0	0	0	3	0	3	3
3.	Satisfied with Field Channel Clearing Quality?							
	No	0	6 (43%)	0	7 (47%)	6 (16%)	7 (32%)	13 (22%)
	Yes	24 (100%)	8 (57%)	7 (100%)	8 (53%)	32 (84%)	15 (68%)	47 (78%)
	Missing data	0	1	0	3	1	3	4
4.	Major Problems for Organizing Activities for Maintenance							
	Nonparticipation	3 (13%)	5 (36%)	1 (14%)	6 (50%)	8 (21%)	7 (37%)	15 (26%)
	Timeliness	12 (50%)	8 (57%)	2 (28%)	5 (42%)	20 (53%)	7 (37%)	27 (47%)
	Quality of work	1 (4%)	1 (7%)	0	1 (6%)	2 (5%)	1 (5%)	3 (5%)
	No problem	8 (33%)	0	4 (57%)	0	8 (21%)	4 (21%)	12 (21%)
	Missing data	0	1	0	6	1	6	7

For organizing maintenance activities, timeliness seemed to be the most prevalent constraint among both the head and tail minor farmers, though tail minor farmers also reported non-participation as a major problem. On a village basis, only at the head villages of each minor was "no problem" reported. Thus, a significant proportion of farmers at these villages felt that no problem existed at all regarding organizing maintenance activities. No farmer at the tail villages on each minor felt that there was "no problem."

4. Extralegal Practices

Deviant or Extralegal Practices: Table 12 examines the prevalence of various illegal irrigation practices in the area. As the constraints to increased crop production become more serious, more deviant or illegal irrigation behavior is likely to be observed.

One-half to three-fourths of all farmers at all locations reported that farmers take water on another's turn without permission. Breaking or cutting the field channel to get extra water was slightly more prevalent at the head minor, though on a village basis, the extreme tail village of Thukarwa seemed most plagued by this practice.

About one-half of the head and tail minor farmers reported that farmers open outlets or influence the chowkidar to open outlets to gain additional water. On a village basis, this practice clearly seemed more prevalent in the tail villages of each minor. Over three-quarters of the tail minor farmers, but only one-third of the head minor farmers, reported the existence of illegal outlets in the minor or breaking the banks of the minor either sometimes or usually. Between one-half and two-thirds of all the farmers on both minors also claimed that farmers take more water than their regular turn allows either sometimes or usually.

Table 12. Extralegal Practices

Number	Items	Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
		Name of Villages						
1.	Taking Water on Another Turn without Permission							
	Never	5 (21%)	4 (27%)	6 (86%)	4 (31%)	9 (23%)	10 (50%)	19 (37%)
	Sometimes	16 (67%)	11 (73%)	0	4 (31%)	27 (69%)	4 (20%)	31 (53%)
	Usually	3 (13%)	0	1 (14%)	5 (39%)	3 (8%)	6 (30%)	9 (15%)
	Not getting canal water	0	0	0	5	0	5	
2.	Breaking or Cutting Field Channel While Other Farmer is Using Water							
	Never	7 (29%)	7 (47%)	6 (86%)	4 (31%)	14 (36%)	10 (50%)	24 (41%)
	Sometimes	14 (58%)	8 (53%)	1 (14%)	6 (46%)	22 (56%)	7 (35%)	29 (49%)
	Usually	3 (13%)	0	0	3 (23%)	3 (8%)	3 (15%)	6 (10%)
	Not getting canal water	0	0	0	5	0	5	5
3.	Farmers Opening Outlets or Influencing Chowkidar to Open Outlets for Extra Water							
	Never	20 (83%)	2 (13%)	6 (86%)	2 (17%)	22 (56%)	8 (42%)	30 (52%)
	Sometimes	2 (8%)	13 (87%)	0	8 (67%)	15 (39%)	8 (42%)	23 (40%)
	Usually	2 (8%)	0	1 (14%)	2 (17%)	2 (5%)	3 (16%)	5 (9%)
	Not getting canal water	0	0	0	6	0	6	6
4.	Illegal Outlets in Minor or Breaking Banks							
	Never	22 (92%)	3 (20%)	1 (14%)	3 (25%)	25 (64%)	4 (21%)	29 (49%)
	Sometimes	0	7 (47%)	5 (71%)	5 (42%)	7 (18%)	10 (53%)	17 (29%)
	Usually	2 (8%)	5 (33%)	1 (14%)	4 (33%)	7 (18%)	5 (26%)	12 (20%)
	Not getting canal water	0	0	0	6	0	6	6
5.	Farmers Taking More Water than Their Regular Turn Allows							
	Never	10 (42%)	5 (33%)	6 (86%)	3 (23%)	15 (38%)	9 (45%)	24 (41%)
	Sometimes	11 (46%)	8 (53%)	1 (14%)	9 (69%)	19 (49%)	10 (50%)	29 (49%)
	Usually	3 (13%)	2 (13%)	0	1 (8%)	5 (13%)	1 (5%)	6 (10%)
	Not getting canal water	0	0	0	5	0	5	5

Table 12. Extralegal Practices (co

Number	Items	Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
		Name of Villages						
6.	Destruction or Damage to Field Channels by Animals							
	Never	16 (67%)	3 (20%)	6 (86%)	1 (7%)	19 (49%)	7 (33%)	26 (43%)
	Sometimes	7 (29%)	11 (73%)	0	13 (93%)	18 (46%)	13 (62%)	31 (52%)
	Usually	1 (4%)	1 (7%)	1 (14%)	0	2 (5%)	1 (5%)	3 (5%)
	Not getting canal water	0	0	0	4	0	4	4
7.	Destruction or Damage to Field Channels by Farmers							
	Never	23 (96%)	2 (13%)	6 (86%)	2 (14%)	25 (64%)	8 (38%)	23 (55%)
	Sometimes	0	11 (73%)	1 (14%)	12 (86%)	11 (28%)	13 (62%)	24 (40%)
	Usually	1 (4%)	2 (13%)	0	0	3 (8%)	0	3 (5%)
	Not getting canal water	0	0	0	4	0	4	4
8.	Obstructions Placed in Minor to Increase Water Level in Minor							
	Never	9 (34%)	2 (13%)	6 (86%)	4 (31%)	11 (28%)	10 (50%)	21 (36%)
	Sometimes	13 (54%)	7 (47%)	1 (14%)	1 (8%)	20 (51%)	2 (10%)	22 (37%)
	Usually	2 (8%)	6 (40%)	0	8 (62%)	8 (21%)	8 (40%)	16 (27%)
	Not getting canal water	0	0	0	5	0	5	5
9.	Destruction or Damage to Structures on Minor							
	Never	20 (87%)	8 (53%)	7 (100%)	6 (55%)	28 (74%)	13 (72%)	41 (73%)
	Sometimes	1 (4%)	7 (47%)	0	5 (45%)	8 (21%)	5 (28%)	13 (23%)
	Usually	2 (9%)	0	0	0	2 (5%)	0	2 (4%)
	Not getting canal water	1	0	0	7	1	7	8
10.	Disputes over Irrigation Turns							
	Never	14 (58%)	4 (27%)	6 (86%)	4 (31%)	18 (46%)	10 (50%)	28 (48%)
	Sometimes	8 (33%)	10 (67%)	1 (14%)	9 (69%)	18 (46%)	10 (50%)	28 (48%)
	Usually	2 (8%)	1 (7%)	0	0	3 (8%)	0	3 (5%)
	Not getting canal water	0	0	0	5	0	5	5
11.	Court Cases or Disputes Over Land or Water Rights							
	Never	21 (88%)	11 (79%)	6 (86%)	8 (89%)	32 (84%)	14 (88%)	46 (85%)
	Sometimes	1 (4%)	3 (21%)	1 (14%)	1 (11%)	4 (11%)	2 (12%)	6 (11%)
	Usually	2 (8%)	0	0	0	2 (5%)	0	2 (4%)
	Not getting canal water	0	1	0	9	1	9	10

Destruction or damage to field channels by animals or farmers seemed more prevalent at the tail minor. When considering villages, however, practice was much more prevalent at the tail villages on each minor and almost non-existant at the head villages of the two minors.

Obstructions placed in the minor to increase the water level were reported by one-half to three-fourths of all the farmers, but the practice appeared to be much more widespread at the tail villages on each minor. At all locations, little destruction or damage to structures on the minor was reported. Disputes over irrigation turns were reported by half the farmers on both minors, though they appeared to be more prevalent at the two tail villages. Finally, court cases or disputes did not appear to be a major problem or occurrence at any location.

Overall, the data presented in Table 12 show a significant amount of deviant or illegal irrigation behavior on the part of the farmers, as they attempt to gain some measure of water control. The overall pattern of these practices seems to show a greater frequency at the tail villages of each minor, where individual water control is likely the poorest. The degree of discipline among the farmers is quite low. These unauthorized and illegal practices contribute to inefficient and inequitable water use in the long run, though in the short run, they undoubtedly are one of the few ways in which the farmers can increase their water control.

5. Farmer Satisfaction

Table 13 examines the extent of farmer satisfaction with the irrigation project.

Farmer satisfaction with maintenance and cleaning was rated as fair by most of the farmers (59 percent and 55 percent) on both minors,

Table 13. Farmer Satisfaction

Number	Items	Fatcher Solanki (Head of Head Minor)	Thikaria (Tail of Head Minor)	Shenwa (Head of Tail Minor)	Thukarwa (Tail of Tail Minor)	Head Minor (Thikaria)	Tail Minor (Rithola)	Summary Figures
		Name of Villages						
1.	Maintenance and Cleaning							
	Low	0	3 (20%)	0	5 (39%)	3 (8%)	5 (25%)	8 (14%)
	Fair	12 (50%)	11 (73%)	4 (57%)	7 (54%)	23 (59%)	11 (55%)	34 (58%)
	High	12 (50%)	1 (7%)	3 (43%)	1 (8%)	13 (33%)	4 (20%)	17 (29%)
	Missing data	0	0	0	5	0	5	5
2.	Water Distribution Along the Minor							
	Low	8 (33%)	9 (60%)	0	9 (82%)	17 (44%)	9 (50%)	26 (46%)
	Fair	15 (63%)	6 (40%)	6 (86%)	2 (18%)	21 (54%)	8 (44%)	29 (51%)
	High	1 (4%)	0	1 (14%)	0	1 (3%)	1 (6%)	2 (4%)
	Missing data	0	0	0	7	0	7	7
3.	Water Distribution Along the Field Channel							
	Low	8 (33%)	9 (60%)	2 (29%)	8 (73%)	17 (44%)	10 (56%)	27 (47%)
	Fair	15 (63%)	6 (40%)	4 (57%)	2 (18%)	21 (54%)	6 (33%)	27 (47%)
	High	1 (4%)	0	1 (14%)	1 (9%)	1 (3%)	2 (11%)	3 (5%)
	Missing data	0	0	0	7	0	7	7
4.	Discipline of Farmers Who do Not Cooperate in Distribution of Water and Maintenance of Field Channels							
	Low	8 (33%)	4 (29%)	0	1 (9%)	12 (32%)	1 (6%)	13 (23%)
	Fair	14 (53%)	9 (64%)	7 (100%)	10 (91%)	23 (61%)	17 (94%)	40 (71%)
	High	2 (8%)	1 (7%)	0	0	3 (8%)	0	3 (5%)
	Missing data	0	1	0	7	1	7	8
5.	Settling of Disputes							
	Low	3 (13%)	3 (20%)	0	1 (9%)	6 (16%)	1 (6%)	7 (13%)
	Fair	18 (78%)	11 (73%)	7 (100%)	9 (82%)	29 (76%)	16 (89%)	45 (80%)
	High	2 (9%)	1 (7%)	0	1 (9%)	3 (8%)	1 (6%)	4 (7%)
	Missing data	1	0	0	7	1	7	8
6.	Water Distribution Committee in Chittorgarh							
	Low	7 (32%)	7 (47%)	0	10 (77%)	14 (38%)	10 (50%)	24 (42%)
	Fair	11 (50%)	7 (47%)	5 (71%)	2 (15%)	18 (49%)	7 (35%)	25 (44%)
	High	4 (18%)	1 (7%)	2 (29%)	1 (8%)	5 (13%)	3 (15%)	8 (14%)
	Missing data	2	0	0	5	2	5	7
7.	Pucca lining of Minor							
	Low	5 (21%)	1 (7%)			6 (15%)		
	Fair	9 (33%)	7 (47%)	NA	NA	16 (41%)	NA	
	High	10 (42%)	7 (47%)			17 (44%)		
	Missing data	0	0			0		
8.	New Outlet Gates on Minor							
	Low	9 (38%)	6 (46%)	0	7 (88%)	15 (41%)	7 (47%)	22 (42%)
	Fair	10 (42%)	6 (39%)	6 (86%)	1 (12%)	15 (41%)	7 (47%)	22 (42%)
	High	6 (21%)	2 (15%)	1 (14%)	0	7 (19%)	1 (7%)	8 (15%)
	Missing data	0	2	0	10	[illegible]	10	12

though the tail villages on the minors each had a significant number of farmers rate their satisfaction as low. Water distribution along the minor and field channels rated a ranking of low satisfaction from approximately half the head and tail minor farmers. Once again, the tail villages on the minor had significantly lower satisfaction ratings than the two head villages.

The vast majority (71 percent) of farmers, particularly on the tail minor, were fairly satisfied with the discipline of non-cooperating farmers. Here the village breakdown was relatively evenly distributed. The same relationship held true for the fair degree of satisfaction farmers had with the settling of disputes.

The farmers' satisfaction with the Water Distribution Committee in Chittorgarh was slightly higher along the head minor, though the prevalent feeling at both locations was either low or fair. The head villages on each minor had a significantly higher satisfaction rating. The pucca lining along the minor only applied to the head minor; the satisfaction rating of new outlet gates on the minor was primarily low or fair along each minor, but was sufficiently higher at the head villages of each minor.

In summary, very few farmers throughout the system reported a "high" degree of satisfaction with the irrigation project. In this area of Rajasthan, where irrigation is so critical to the success of agriculture, "fair" or "low" degrees of satisfaction do not reflect an efficient irrigation system.

The irrigation behavior of the sample farmers and the conditions at the project site appear rather bleak. The farmers reported their major constraint to increased agricultural production was the poor timing and low quantity of water supplied. This unpredictable water supply was somewhat controlled by the existence of wells, but many of these wells only operated with a labor-intensive bullock lift. The farmers cleaned field channels and exchange water only when they felt it would be worthwhile, which was not often. Their overall response to these water conditions was to engage in a variety of unauthorized irrigation practices and to possess a relatively low degree of satisfaction concerning the project.

E. Disputes and Conflicts Regarding Water

Wherever water is used for irrigation, disputes and conflicts are bound to occur. It is helpful to understand where the conflict is taking place, what patterns the conflict takes, its intensity, and who are the participants involved in the disputes over the water. With this information, conflict and disputes can be managed constructively.

To study the water disputes on the Thikaria and Rithola Minors, 13 "key informants" were identified and then interviewed concerning the water disputes in the Gambhiri Project area. These "key informants" were all influential farmers in the area, and included contact farmers, members in cooperative societies, elected village leaders, and farmers who regularly attended the Water Distribution Committee meetings in Chittorgarh.

1. Issues and Patterns of Water Disputes

On the Thikaria and Rithola Minors, the major water conflicts identified included disputes between head and tail farmers on the minor; disputes between head and tail farmers on the outlet; disputes over the allocation system of water; and disputes covering large and influential farmers taking too much water. Different types of disputes existed on the Thikaria (head) and Rithola (tail) minors (Tables 14 and 15).

The most important disputes on the Thikaria minor involve the allocation system of water, and conflicts between head and tail farmers on the minor and outlets. At Rithola minor, the pattern of disputes was somewhat different. There, the most important dispute concerned head and tail farmers on outlets, and large and inf. .ential farmers taking too much water. Thus, on both Thikaria and Rithola Minors disputes between head and tail farmers on outlets were important. At the head (Thikaria) Minor, allocation disputes were important, and at the tail (Rithola) Minor, large and influential farmers were involved in more disputes.

At the head minor, two of the seven key informants identified cleaning and maintenance disputes as important, while no one at the tail minor identified these. Also, two key informants out of six on the tail minor said that disputes between castes over water was important, while no one at the head minor felt this way.

2. Participants in the Water Disputes

Once the patterns and issues of the water disputes were identified, it was necessary to identify the groups involved in the disputes. For both Thikaria and Rithola Minors, the participants involved in the conflict were farmers at various specific locations along the minors and outlets, irrigation officials, castes, political organizations, those who participated in the cleaning versus those who did not, and larger farmers versus smaller farmers (Tables 16 and 17).

Table 14. Water Disputes at Head Minor (Thikaria)

Number of Times Dispute was Listed As Most Important	Number of Farmers Who Said Dispute Existed in Area (N = 7 each key informant was asked to list and rank 3 disputes in his area.)	Description of Dispute
3	4	Disputes over allocation system of water
1	5	Disputes between head and tail farmers on minor
1	5	Disputes between head and tail farmers on outlet
1	3	Disputes over large and influential farmers taking too much water
1	2	Disputes over non-cooperation of cleaning and maintenance of field channels
0	1	Not giving water

Table 15. Water Disputes at Tail Minor (Rithola)

Number of Times Dispute was Listed As Most Important	Number of Farmers Who Said Dispute Existed in Area (N = 6; each key informant was asked to list and rank 3 disputes in his area.)	Description of Dispute
3	5	Disputes between head and tail farmers on outlet
1	3	Disputes over large and influential farmers taking too much water
1	2	Disputes over allocation system of water
1	2	Disputes between head and tail farmers on minor
0	2	Disputes over farmers taking water too long
0	2	Disputes between castes over water

Table 16. Participants in Water Disputes on Head Minor (Thikaria)

Number of Times Group is Mentioned in Dispute (N = 7; each key informant was asked to list the groups in 3 disputes.)	Intensity of Dispute	Participants
6	Arguing	All farmers versus irrigation officials
4	Fighting, Courts involved	Head versus tail farmers on outlet
4	Fighting	Head versus tail farmers on minor
3	Fighting	Powerful versus small farmers; political organization versus political organization
2	Arguing	Those who clean channels versus those who do not

Table 17. Participants in Water Disputes on Tail Minor (Rithola)

Number of Times Group is Mentioned in Dispute (N = 6; each key informant was asked to list the groups in 3 disputes.)	Intensity of Dispute	Participants
5	Fighting	Head versus tail farmers on outlet
4	Fighting, Murder	Large farmers versus poor farmers
2	Arguing	Caste versus caste
1	Fighting	Those who take water too long versus others
1	Panchayat Involved	Head versus tail farmers on minor
1	Arguing	Head farmers versus irrigation officials
1	Arguing	Head farmers and irrigation officials versus tail farmers
1	Arguing	One farmer versus another farmer

The water disputes at Thikaria Minor appeared broad and general in nature. The most important dispute at the head minor involved the farmers arguing with irrigation officials about the water situation. Here, the groups involved in the disputes went beyond the minor itself and involved government irrigation officials. Political organizations also were involved in the disputes on this minor. The conflicts between head and tail farmers on the minor and outlets also were relatively intense; fighting often was the result and the courts became involved.

The water disputes at Rithola Minor were more localized, and did not involve outside officials and political organizations much. The major disputes involved head versus tail farmers on the outlet, and large versus poor farmers. The intensity of these disputes, was very high, involving fighting, and in one case, a murder over a water dispute. In another instance, the panchayat was involved in the conflict.

In summary, the conflict here involved the location of the farmers, the power of the farmers, and the various officials who make and implement water policy. The farmers along the head minor wanted not only to maintain the water status quo, but to increase and upgrade the quantity and timeliness of water delivery to their fields. They felt that various irrigation officials were obstructing them in their efforts. The farmers on the tail minor had more infighting among themselves, but still desired more quantity and timeliness of water supply. They were unsure as to who or what organization to approach in order to accomplish these goals.

F. Report from Minor Irrigation Officials

The minor-level officials (patwari, chowkidar) have their own set of constraints in working with the project at the field level on a day-to-day basis. To analyze their constraints, eight minor-level irrigation officials working on the Gambhiri Project were contacted and interviewed using a separate questionnaire. Included were two patwaris, two chowkidars, one overseer, one MATE (maintenance and modernization), one munshi (field clerk), and one laborer.

1. Problems and Pressures from the Department

The minor officials reported that often they received their salary very late and rarely receive timely a travel allowance and daily allowance which they feel they deserve. There was little surety of promotion, and they often were expected to work 20 - 24 hours per day without any incentive. The facilities provided to them were usually inadequate. When conflicts with farmers arose, they received little support from the department.

2. Local Politics

The minor officials told the interviewers that there were many pressures applied to them from local politicians and political factions. They stated that in the performance of their official duties, they often must adjust to the wishes of local politicians. Political pressure was applied to them to supply more water or water out of turn, and threats were made to have the minor official fired if he did not follow the local politician's request. More than once a minor official claimed that a politician would complain to the Irrigation Department in Chittorgarh about a minor official and would force the minor official to change the local water policy. If the *sarpanch* of a village orders the official to do something contrary to the official water policy, the minor level irrigation official has no choice but to obey. As a result, some minor officials complained that they were unable to collect fines for wastage of water.

3. Local Farmers

The minor officials also reported that the farmers themselves contributed to problems when the officials were carrying out their departmental duties. The officials were often drawn into the conflicts and disputes between farmers. Farmers often pressured them to supply more water than their turn allows. If more water were not supplied, the more powerful farmers often threatened to have the minor officals transferred to another post. Farmers often illegally opened gates, broke gates, used water over their turn, and did not share the water equitably. The minor officials felt hampered by the farmers themselves.

4. Farmer Methods of Getting Water

When asked about the various methods used by farmers to obtain water by extralegal means, at least 50 percent of the eight minor officials reported that these methods are used by farmers either sometimes or often (Table 18). According to them, farmers were stealing water from the minor, taking water beyond their allotted time, placing obstructions in the minor, and allowing water to run to waste. These extralegal practices by the farmers might be a result of the constraints, problems, and pressures which the minor officals must face in their jobs.

5. Damages

The officials also were asked to provide information about damages to minor head gates, minor banks, and outlet gates (Table 19).

Table 18. Farmer Methods of Getting Water

Method	Frequency (N=8)		
	Much	Sometimes	Never
1. Farmers open gates at night.	1 (12%)	6 (75%)	1 (12%)
2. Farmers open gates by day.	1 (13%)	3 (38%)	4 (50%)
3. Farmers steal water from the minors.	1 (12%)	6 (75%)	1 (12%)
4. Farmers take water beyond their allotted time.	2 (29%)	4 (57%)	1 (14%)
5. Farmers pay for lower-priced crops, but irrigate higher-priced crops.	2 (25%)	1 (13%)	5 (63%)
6. Farmers put obstructions in minors to increase minor level.	2 (25%)	6 (75%)	0
7. Water flows from outlet but runs to waste.	1 (13%)	5 (63%)	2 (25%)

Table 19. Damages to Structures

Damaged Structure	Type of Problem (N=8)		
	Major	Minor	No Problem
1. Minor head gates	0	4 (50%)	4 (50%)
2. Minor banks	1 (13%)	5 (63%)	2 (25%)
3. Outlet gates	1 (13%)	5 (63%)	2 (25%)

A significant amount of damage to these structures would contribute to the less than optimum performance of the Gambhiri Project.

The eight minor officials believed that damages to minor banks and outlet gates were the most severe problems. Reporting and repairing these damages might be difficult at times because of the pressures placed upon minor officals.

In general, the constraints on the project were not exculsively with the farmers. For minor irrigation officials, many problems existed including low pay, dissatisfaction with working conditions, political and social pressure, extralegal activities, and damage to irrigation structues. If the problems are to be solved, various minor officials need to be consulted regarding their views of the water situation. Any solution must involve the farmers themselves, but various levels of irrigation officials also need to be included in searching for proper solutions.

V. SUMMARY AND RECOMMENDATIONS

At the conclusion of the preliminary reconnaissance survey, some major questions which were posed included the general socio-economic conditions at the four study sites, the farm conditions and the quantity and quality of the institutional agricultural services in the area, the quantity and quality of the institutional irrigation services in the area, and the irrigation conditions and irrigation behavior of the farmers. The data presented in the detailed study confirmed the description of the Gambhiri Irrigation Project as a "sick system."

The project area was populated by small and marginal farmers who depend on a reliable and predictable supply of water for maximum agricultural production. Agricultural institutions, services, and agents were somewhat known to farmers, and some agricultural information was provided to them by the extension service. Low numbers of agricultural implements were used on-farm. Overall, the farmers did not give high ratings to the effectiveness of all these agricultural services, though they seemed to receive at least adequate information from the Agriculture Department.

The farmers did not receive adequate information concerning irrigation matters. Extension personnel might consider how to include water management as an integral impact point for improved crop production. The poor predictability of the water supply lead the farmer into extralegal behavior and to the use of less than optimal levels of agricultural inputs. Disputes were prevalent along both minors, and minor level officials reported vast pressures on them to alter the officially sanctioned rules.

The result of all these factors was a system of water anarchy, where rules were either nonexistent or disobeyed, and where individual water control was based purely on location, with those in the head villages of each minor having a far greater degree of water control than those at the tail villages of each minor. Both the farmers and the water authorities were dissatisfied with the operation of the Gambhiri Irrigation Project.

The key constraints of the system were the unpredictable and inadequate supply of water delivered to the farmers, and the poor communication between farmers and irrigation officials which often results in misunderstandings and antagonism. Rotation of water along the minors and outlets was very unpredictable and undependable causing farmers not to improve on-farm water management. This same unpredictability also related to farmer decisions not to use improved inputs or services. At the same time, the lack of two-way communication between farmers and officials resulted in undisciplined operation of the system.

The cause of these constraints is at least three-fold: lack of local social organization by the farmers, lack of discipline among the farmers and the officials, and lack of effective participation of the farmers in the water decisions of the higher authorities. Each of these three factors is related to one another, and each depends on the others for effective implementation.

Without some form of local, outlet-based, social organization of farmers, the scarce water resources at the village level will continue to be fought over. There is no formal, organizational set-up by the farmers to equitably allocate the water along the outlet, maintain and clean the outlets periodically, and manage the disputes which will always arise when water is involved. At the Gambhiri Irrigation project, lack of local organization coupled with a scarce resource has produced chaos.

The lack of an organization is not surprising considering the lack of discipline at all levels of the system. The farmers took any water that was available to them, often illegally, and the water authorities in Chittorgarh were often forced to change the water delivery schedule due to political and social pressures. Both the farmers and the water authorities would welcome more discipline in the system, if only to increase the predictability of the water quantity and timing. Both parties have a single goal, but poor communication results in a perception that the farmers and officials have contradictory goals.

Proper discipline is nonexistent because of the lack of effective participation by the farmers. Participation does exist, particularly at Water Distribution Committee meetings, which any farmer can attend, and many do. Yet these affairs often turn out to be raucous, with many voices speaking independently with no common purpose in mind. Effective participation would include some form of consensus among the farmers, where a few voices could genuinely speak for the interests of many.

These three key elements of the water management system -- organization, discipline, participation -- are lacking at the Gambhiri Irrigation Project. Without these three elements, the system crumbles and becomes a sick system characterized by water anarchy. One farmer told interviewers, "If the system is alive, I am alive; if the irrigation is dead, I am dead."

A few recommendations to implement improvements can be suggested. First, the modernization program should continue, but a greater emphasis should be placed on the organizational aspects of irrigation: information flows to and from the farmers, the organization of water-users, and the discipline of farmers and officials alike who do not abide by generally accepted rules. Second, a cadre of water management specialists from the Irrigation and Agriculture Departments, trained in Diagnostic Analysis, should be assigned to the project area. Third, a training center should be established to teach dedicated professionals new improvement technologies. All of these actions would greatly benefit the operation and maintenance of the Gambhiri Irrigation Project and produce an irrigation system composed of concerned officials and more prosperous farmers.

VI. REFERENCES

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