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Linking Main and Farm Irrigation Systems in Order to Control Water

Volume 2:
A Case Study of the Niazbeg Distributary in Punjab, Pakistan

Water Management Synthesis Project

WMS Report 69

LINKING MAIN AND FARM IRRIGATION SYSTEMS IN ORDER TO CONTROL WATER

VOLUME 2:

A CASE STUDY OF THE NIAZBEG DISTRIBUTARY IN PUNJAB, PAKISTAN

by

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WMS Report 69

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PREFACE

In recognition of the importance of water management for improving irrigated agricultural production, Water Management Synthesis II Project developed several activities related to irrigation system management. One such activity was the special studies research program initiated by Colorado State University. The program examined formal and informal organizational relationships between main system managers and farmers in their efforts to control water in four irrigation systems in Pakistan, India, Thailand, and Sri Lanka. The information that was obtained is presented in the following five volumes:

Linking Main and Farm Irrigation Systems in Order to Control Water. WMS Report 69. Water Management Synthesis Project, Colorado State University, Fort Collins.

Volume 1: Designing local organizations for reconciling water supply and demand (D.M. Freeman).
Volume 2: A case study of the Niazbeg distributary in Punjab, Pakistan (E. Shinn and D.M. Freeman).
Volume 3: A tank system in Madhya Pradesh, India (V. Bhandarkar and D.M. Freeman).
Volume 4: The case of Lam Chamuak, Thailand (K. Paranakian, W.R. Laitos, D.M. Freeman).
Volume 5: Two tank systems in Polonnaruwa District, Sri Lanka (J. Wilkens-Wells, P. Wilkens-Wells, D.M. Freeman).

The reader is advised that reading Volume 1 will enhance his or her understanding of the significance of the information reported in Volume 2 through Volume 5.

EXECUTIVE SUMMARY

This, the second volume in the Water Management Synthesis II special studies series, reports findings of a study of farmers and main irrigation system management officials on the Niazbeg distributary in Punjab province near Lahore, Pakistan. A purposive sample of 240 farmers, representing six watercourse commands located on the head, middle, and tail sections of the distributary, were studied intensively during fall, 1985. The headmost and tailmost 20 irrigators on each of the six watercourses were selected for study, providing a sample of 40 farmers on each watercourse.

Special attention was paid to the manner in which the main system irrigation bureaucracy was linked to irrigators as farmers and central irrigation managers struggled to control irrigation water. The logic of inquiry was as follows. Adequacy of organizational mechanisms between main system managers and irrigators was viewed as affecting farmer control over irrigation water. Farmer control over water was seen to affect crop yields, cropping intensities, cropping patterns, and farmer willingness to support watercourse-level water users associations. Therefore, the quality of middle-level organization (physical tools appropriately combined with enforceable social rules) between individual farmers and main system management was seen to be critical to irrigation water productivity and farmer willingness to support local organizational development.

What was found? Substantial problems in canal irrigation water supply and control were found at all locations on all sample watercourses. Problems occurred for most sample farmers in most phases of crop growth. However, canal water supply and control did vary -- they became progressively less moving from head to tail of the distributary and as location shifted from head to tail positions within watercourses. The existing _warabandi_ system is in disarray on all watercourses except for watercourse 3, where farmers have informally organized to employ a combination of tubewell and canal water. As expected, data revealed that agricultural production is markedly better on watercourse 3 compared to the other watercourses.

Given the general breakdown in the canal _warabandi_ organization, tubewell water was found to be the primary source of irrigation water for most sample farmers -- especially in _rabi_ (winter). The canal system supplied only 9 percent to 64 percent of the delivered irrigation water, depending on the season and the location of the field in the system. Overall, the canal water delivered across all sample watercourse commands accounted for only 37.9 percent of farmer supplies; tubewells supplied the remaining water available.

Given the lack of adequate canal water, many farmers located toward the tail reaches of the system have withdrawn from the _warabandi_ system. Many who still farm in such reaches have come to depend exclusively upon groundwater. Where canal water is more amply and reliably available

(in the head reaches of the topmost three watercourses), farmers enhance the productivity of their canal water by exchanging turns among themselves. Although technically illegal, water exchange helps farmers to get the right amount of water at the right time to their crops. However, canal water exchange is not attractive where canal water deliveries are insufficient in quantity and timing. Partners to exchange must have assurance of future supply in both quantity and time because no one will give up water currently available for an uncertain promise of water to come. Therefore, canal water exchange and adequacy of supply were positively associated.

Sample farmers who had greater access to canal water supplies and control tended to increase their cropping intensities. In the headmost reaches, these farmers were willing to shift to more water-sensitive and higher yielding crops. However, even in head areas, canal water control was only weakly related to increased yields in rice (kharif) and wheat (rabi). Away from head reaches, canal water control was found to have virtually no relationship to agricultural production as measured by yields or cropping patterns. However, sample farmer control over tubewell water had a strong positive effect on yields and willingness to invest in higher yielding varieties. This was true on all watercourses, but it was especially true on watercourses 4-6.

Water costs per unit of volume increased markedly from head to tail of the system. Under the existing warabandi (rotational) system of canal water shares, farmers obtain whatever volume of water flows during their specified weekly time period. Water volumes lessen with distance from the canal head due to seepage, spillage, and intervening irrigators taking water out of turn. However, water charges remain the same regardless of the amount of water delivered. Therefore, this particular water share system charges the most per unit volume to farmers who receive the poorest water service in terms of supply and timing. Such a system does not earn the enthusiastic allegiance of farmers who are not favored by a head location, where water per unit of volume is cheap.

The cost of tubewell water is substantially higher than the cost of canal water, but there is a direct relationship between amount of payment and amount of water delivered -- a fundamental reality appreciated by farmers. Furthermore, even though it comes at considerably higher cost, tubewell water is more controllable, and therefore more valuable, than is canal water. Water at the right time and in the proper amount is much more productive and is worth its greater price.

Nevertheless, an interdependence exists between canal and tubewell water. For those farmers (especially on watercourse 3) who have access to both water sources, water management is much improved. Canal water is generally of higher quality and can wet the ditches for higher priced tubewell water, thereby stretching the productivity of that relatively expensive resource. Organization that improved the management of canal flows would do much to improve the effectiveness of groundwater use, which would contribute much to greater agricultural production. Main system managers and farmers pay a high price -- calculated in lost production, administrative problems, and deterioration of capital works --

for the absence of effective local organizations that can allocate water, maintain facilities, and resolve local conflicts.

Farmers appreciate the need for improved organization. They indicated a substantial willingness to invest their time and money in such organizations, providing that fundamental conditions were met which would secure their investment. An appropriately designed water users association that could enforce a share system and make it possible to improve control over canal irrigation water was of much interest to sample farmers, especially to those disadvantaged by location in the current system. Furthermore, 70 percent of sample farmers strongly supported the organization of mutually owned tubewells strategically located in their particular watercourse commands. Farmers on watercourse 5, where water control was the lowest of all sample watercourses, were the least willing to support collective organizational efforts. Their history of failure has made for greater atomization and distrust of cooperation -- a pattern found in Sri Lanka (see Volume 5).

Concepts and procedures for the design of local organizations are addressed in Volume 1 of this series of reports: **Linking Main and Farm Irrigation Systems in Order to Control Water: Designing Local Organizations for Reconciling Water Supply and Demand.**

I. THE PROBLEM AND THE ISSUES

A. INTRODUCTION

This study examined the structure and dynamics of the warabandi rotational irrigation system in six command areas of the Niazbeg Subproject Area in Punjab, Pakistan. Specifically, it examined the thesis that the absence of effective local farmer organizations is an important barrier to irrigation development. Without an effective local farmer organization, there is no mechanism that can sufficiently bridge the water management requirements of the main system bureaucracy and the farmers. The result is a loss of water control at both the main system and farm levels, breakdown in the organizational rules of the warabandi system, and reduced agricultural productivity.

While Pakistan is blessed with the natural and human resources necessary to develop a highly productive agriculture, much of that development potential has yet to be realized. Because the majority of Pakistan's people live in rural areas and depend upon irrigated agriculture for their livelihood, the consequences of low agricultural productivity are significant.

Since World War II, irrigation development efforts have focused heavily on structural engineering. Vast amounts of money have been spent on construction and physical rehabilitation in irrigation systems. Bureaucracies created to link rural families with technology, knowledge systems, and essential inputs have often created environments which encourage the concentration of resource control at the main system level (Reuss et al., 1979).

The warabandi system of Pakistan was designed to serve an agriculture which typically had a cropping intensity of 75 percent and emphasized the cultivation of drought-resistant crops (Michel, 1967, pp. 394-395). With the advent of the Green Revolution and the promotion of moisture-sensitive, high-yielding varieties, farmers required increasing control over timing and amounts of water. To increase their water control, farmers have often circumvented warabandi rules or invested in private tubewells.

The cumulative effect of both strategies is a continuing erosion of organizational agreements at the main system and the farm levels. The organizational vacuum at the intermediate level (between main system managers and farmers) leads to an inefficient use of canal water, inequitable distribution, and reduced productivity; all of which further push farmers to behave in ways which are individually rational, but collectively damaging. Recognizing constraints on the system, Pakistan's leaders in water management have launched an ambitious command water management program. It is to this program that our discussion now turns.

B. THE COMMAND WATER MANAGEMENT PROJECT

The Pakistan Command Water Management (CWM) Project incorporates seven subprojects, with at least one subproject in each of Pakistan's four provinces (Figure 1). The CWM Project was initiated to investigate and remedy problems contributing to low agricultural productivity.

Dr. M. Jameel Khan, Director of the Punjab Economic Research Institute in Lahore, has estimated that a yield gap exists between the potential and national average for major crops ranging from 73 percent to 86 percent (Khan, 1985, p. 7). His report also showed that Pakistan's production of major crops was half that of other developing nations, particularly Mexico and Egypt (Table 1). Khan concluded that a four-fold increase in production is possible with strategic improvements in agricultural production.

Table 1. Yield per hectare of major crops in Pakistan and selected countries.

Country	Wheat	Rice (paddy)	Maize	Cotton	Sugarcane
	kg/ha				
Pakistan	1567	2604	1258	338	38,639
India	1602	2050	1207	170	56,844
Bangladesh	-	1950	-	-	-
USA	2394	5462	6898	542	88,802
Turkey	1908	-	1897	634	-
Canada	2123	-	5874	-	-
Egypt	-	5411	-	923	83,575
Mexico	3717	-	1812	892	-
France	5177	-	-	-	-

Source: Khan, 1985.

Policy makers have focused on improving the coordination of delivering critical inputs, particularly water, to close the gap between potential and actual production. The "distributary command area" was selected as the appropriate unit for program action. The area within the CWM subproject commands is presented in Table 2.

The Command Water Management Project is a joint effort of the World Bank, USAID, and the Pakistan Water and Power Development Authority (WAPDA). The World Bank has emphasized bureaucratic reform in order to improve cooperation between agricultural and irrigation agencies, and between these agencies and the private sector within each subproject area. USAID has promoted the development of local water user associations to increase effective organization between the main system and the farm levels, while WAPDA, the agency most involved in pre-project preparation and analysis, has focused on rehabilitation engineering.

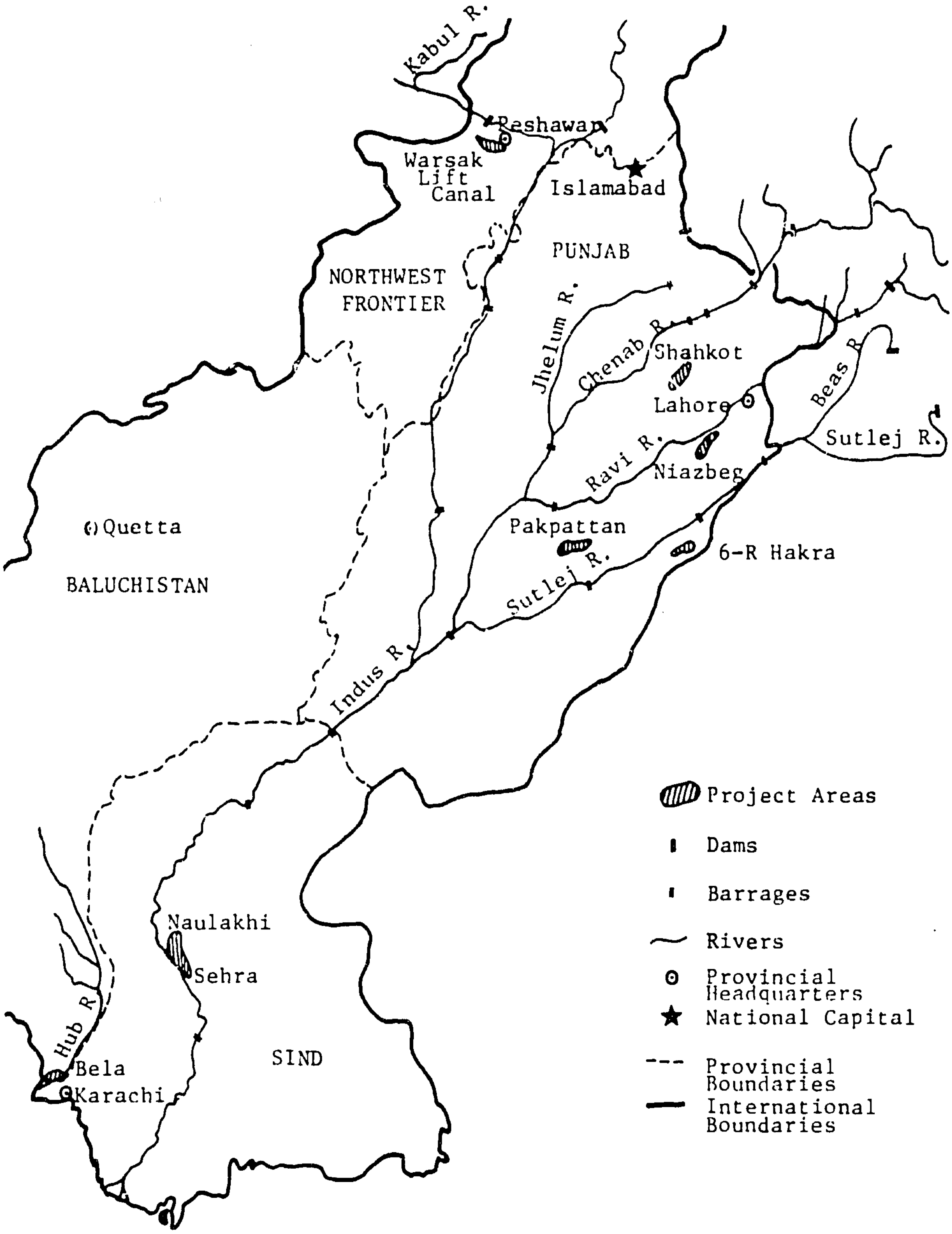

Figure 1. Pakistan Command Water Management Project areas.

Through low-interest, long-term loans, the World Bank provided funding for canal and distributary rehabilitation and USAID provided funding for watercourse rehabilitation. WAPDA also provided funds for rehabilitation. Some funds had been provided for training the new subproject management staff.

Table 2. Command Water Management Project by subproject area unit.

Subproject	Gross Area (1000s acres)	Command Area (CCA) (1000s acres)
PUNJAB		
Pakpattan Canal	119	97
Shahkot Distributary	63	49
6-R Distributary	133	104
Niazbeg Distributary	45	41
Subtotal	360	291
SIND		
Sehra-Naulakhi branches	165	164
NORTHWEST FRONTIER PROVINCE		
Warsak Lift Canal	55	43
BALUCHISTAN		
Las Bela branch	34	17
TOTAL	614	510

Source: Khan, 1985.

C. OBJECTIVE

The objective of this study was to investigate water control, water distribution, and water productivity on six sample watercourses on the Niazbeg Distributary. It was posited that the social organization that links main system management of water supply to farmer demand for water centrally affects water control and, in turn, agricultural water productivity. Without effective organization at the distributary and watercourse level, location heavily determines who will or will not receive adequate and timely amounts of water. The research also investigated how farmers responded to this locational bias.

In spite of the expense of tubewell development and maintenance, farmers in the six command areas of Niazbeg study have cooperated in developing tubewells to gain better water control. The development of groundwater indicates that farmers are willing to invest in cooperative development ventures if they can gain access to an adequate and timely water supply. The study investigated the manner in which Niazbeg farmers were willing to invest in informal cooperative tubewell irrigation organizations to control water.

This report describes the setting and background of the Niazbeg study area and the research design employed. The analysis of the data focuses on the hypothesis that, in the absence of effective local organization, location is an important determinant of water control on the Niazbeg distributary. The relationship between water control and organizational effectiveness at the main system and watercourse levels was analyzed, and the hypothesis that agricultural productivity is a function of organizational effectiveness and farmer water control was tested. Finally, the report explores the relationship between farmer organizational support, water control, and agricultural productivity.

II. THE RESEARCH CONTEXT

A. BACKGROUND AND SETTING

1. Physical and Geological Parameters

The Niazbeg subproject area is located in the Punjab region of the Indus Basin, which includes approximately 200,000 acres. The Himalayan mountains tower over the relatively flat basin, where the slope averages about one foot per mile in its descent to the Arabian Sea. The basin is the result of silt and sand deposition by the following rivers: the Sutlej, the Beas, the Ravi, the Chenab, the Jhelum, the Kabul, and the Indus (Table 3).

Table 3. Catchment areas and runoff of the rivers in the Indus Basin.

River	Catchment Area (miles^2)	Average Annual Runoff, 1922-1961 (million acre-feet)
Sutlej	18,550	14
Beas	6,500	13
Ravi	3,100	7
Chenab	11,400	26
Jhelum	12,900	23
Kabul	26,000	17.4
Indus	102,000	93

Source: Michel, 1967.

The Indus River, the largest of these rivers, winds over 400 miles until it descends to the plains where it is at an elevation of about 1300 ft and is 1100 miles from its mouth. Five of the rivers --the Indus, Jhelum, Chenab, Ravi, and Sutlej -- converge approximately 450 miles from their emergence from the Himalayas. This area has historically been called the Punjab, or "five rivers." The five rivers are patterned like spread fingers of a hand merging into the wrist. The lands lying between the rivers are called doabs, and prior to the 1850s, these areas were largely uninhabited.

When rivers in the Indus Basin flood, water spreads many miles outside the river banks. These alluvial deposits, consisting of clay, silt, sand, and gravel, are roughly estimated to average more than a mile in depth. Michel (1967, p. 30) describes the Indus Basin as "one vast and fairly homogeneous aquifer; a sort of vast sponge, capable of absorbing runoff from the foothills as well as rainfall and seepage from the rivers and canals that cross them, and of transmitting this subterranean flow downslope to the Arabian Sea."

2. Historical and Political Parameters

Prior to 1849, the primary form of irrigation in the Punjab was inundation canals. At the onset of the monsoon in late spring and early summer, rivers would overflow and deposit heavier materials at the bank edges and more refined silts further out from the banks, so that the banks were often higher than the flood plain. As the water receded, farmers would plant crops on the flood plains, irrigating from channels cut in the banks. Irrigated agriculture was thus restricted to areas close to the major rivers.

After 1849, the British undertook a massive irrigation construction program. By the end of the colonial era, British engineers had built the most extensive irrigation system in the world and contributed many of the formulas now used for canal construction and operation. Today, the Indus river network is the largest contiguous irrigation system in the world. Each year, this system irrigates approximately 34.5 million acres. More than 100 million acre-feet of water are distributed through three major storage reservoirs, 19 barrages, 12 link canals, and 43 canal commands to deliver water to about 90,000 watercourses, each of which commands 400 acres on average (Michel, 1967).

The British developed the system of barrages and canals which provided the basis for new flexibility in the distribution of water in the Punjab. Barrages -- a series of concrete bases and steel gates -- could raise the water level for diversion to canals crossing the doabs. They could also control the height, quantity, and velocity of the river flow. Canals could transfer water from rivers having excess supplies to rivers and canals where inadequate supplies restricted further development of agricultural lands.

In 1905, the Triple Canals Project was commissioned to construct the first two link canals. The Jhelum Canal, designed to carry 8,500 cusecs from the Jhelum River to the Chenab River, was completed in 1915. The Upper Chenab Canal, which delivered 15,000 cusecs from the Chenab River to the Ravi River just north of the Niazbeg subproject area, was also completed in 1915. The construction of this canal permitted the construction of the Lower Bari Doab Canal (Michel, 1967, pp. 90-92).

With the construction of such canals, water could be moved about in the irrigation system in a way never before imagined. This leap forward in irrigation technology was designed to serve an agriculture which depended on drought-resistant crops. The goal was to spread water thinly over as large a portion of land as possible. The precise timing and measured quantities of water now required to cultivate high yielding varieties was not of concern. Cropping intensities ranged from 70 percent to 80 percent, and land productivity was restored by allowing it to periodically lie fallow (Michel, 1967, pp. 394-395).

In 1948, when the British granted independence to India, the partition of the Punjab brought profound changes to the social structures and irrigation systems in the new nation of Pakistan. Hindus and Sikhs fled the Pakistan Punjab and Moslem refugees from India took their place.

The partition of the Punjab required the partition of the Indus Basin rivers between India and Pakistan, which resulted in major alterations in the water delivery system. The Niazbeg Canal initially received all its water from the Ravi River, but with partition, India became sole proprietor and manager of the Sutlej, Beas and Ravi rivers. Pakistan responded by commissioning the construction of the Bombanwala-Ravi-Bedian-Dipalpur Link Canal (the BRBD Canal). Completed in 1958, the BRBD Canal had 5,000 cusecs of capacity for conducting water from the Jehlum River (Michel, 1967). The Balloki-Suleimanke (BS Canal), completed in 1954, traverses the southern third of the Niazbeg subproject area, carrying 15,000 to 20,000 cusecs of water through link canals from the Chenab River to the Ravi and Sutlej rivers.

B. THE NIAZBEG SUBPROJECT AREA

1. Physiographic Features

The Niazbeg subproject area lies between the Ravi and Sutlej rivers, approximately 150 miles from where the five rivers of the Punjab meet. The area is less than 50 miles from the India-Pakistan border and is about 30 miles long. It is narrow and flat, with the width of the command area ranging from 1 to 8 miles and elevations ranging from 635 feet to 670 feet above mean sea level (WAPDA, 1983, pp. 1-17). The marketing center, Bhai Pheru, is located about 40 miles southwest of Lahore, and a national highway passes through the center of the subproject area (Figure 2).

On the southeast, the Raiwind drain, originating outside the project boundary, joins the Rohi Nala drain that lies inside the southeastern boundary of the project and empties into the BS Canal. The BS Canal, in combination with the Ravi River and the Rohi Nala drain, effectively remove excess water (Wattenburger et al., 1987).

Ninety percent of the land in the subproject area is classified as old river terrace. The surface of the terrace shows little sign of water erosion and is almost devoid of relief. Three percent of the land is classified as flood plain and 7 percent is urbanized (WAPDA, 1983, pp. 1-15). Silt loams and silty clay loams are by far the most extensive soil textures. Eighty-three percent of the Niazbeg acreage is well-drained and suitable for good irrigated agricultural production.

Average annual precipitation in the Niazbeg subproject area is 15.4 cm; 80 percent of this precipitation comes during the summer monsoon (July and August) (WAPDA, 1983, pp. 1-10). The subproject area is on the periphery of the Punjab plain and therefore catches the edge of the monsoon. Further to the south and east, annual precipitation drops to 6 cm. The temperature is coolest in January with a low averaging 5.2°C (41°F), and hottest in June with a high averaging 40.4°C (104°F). Temperatures often approach 100°F from May through July, increasing evapotranspiration rates for crops during the kharif (summer) agricultural season.

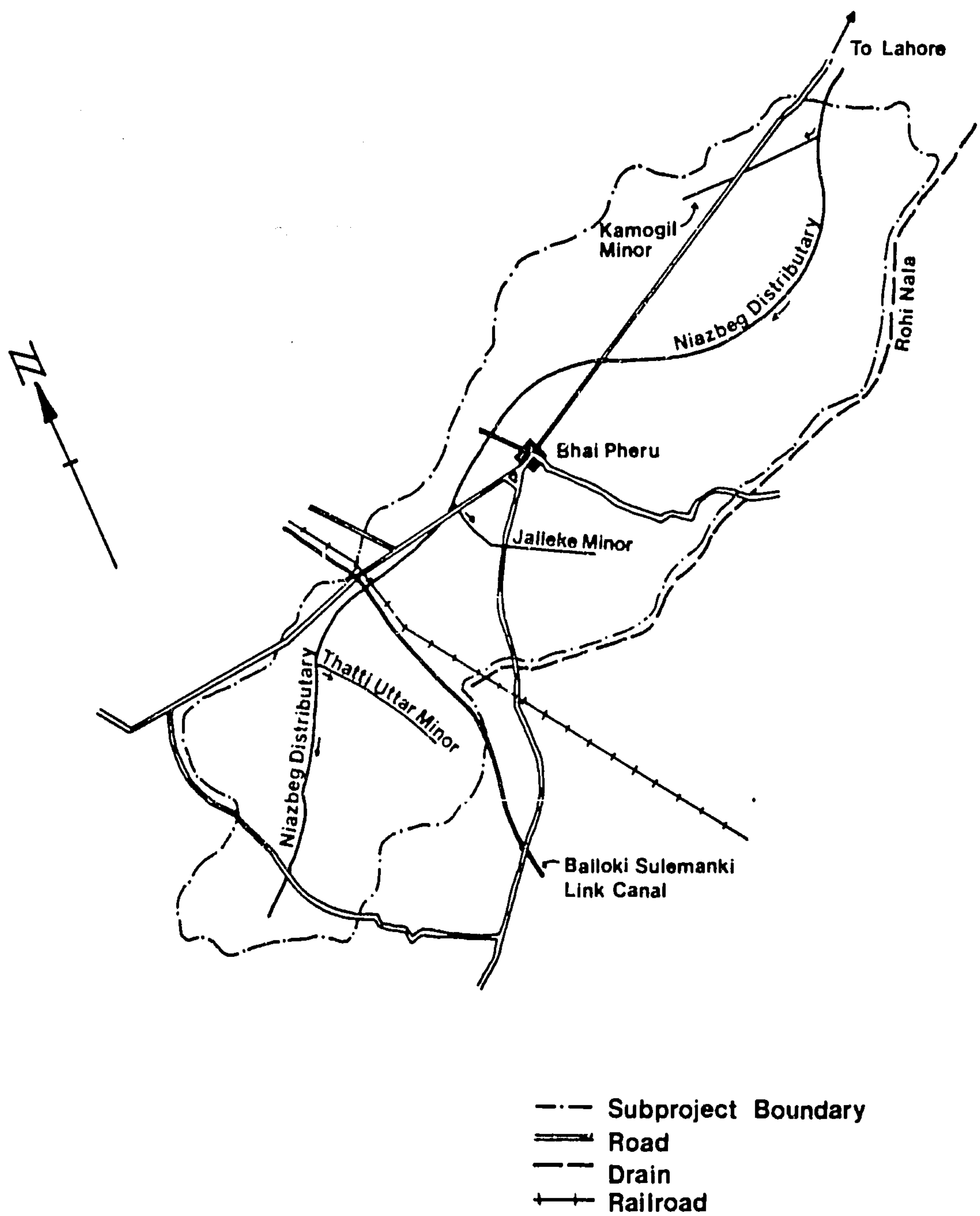

Figure 2. The Niazbeg subproject. (Source: Wattenberger, 1987)

2. Water Supply and Demand

Forty miles from the head of the BRBD Canal, near the site of the Water Management Training Institute at Lahore, a concrete drop structure marks the beginning of the Niazbeg Canal. A structure at this point diverts some flow eastward. The remaining flow passes over the drop structure and travels the upper Niazbeg Canal at a volume of approximately 180 cusecs. The canal continues for approximately 20 miles before its water enters the project site.

The officially sanctioned supply of the Niazbeg distributary at the beginning of the subproject site is 123.5 cusecs. Of the 44,721 acres included in the Niazbeg area, 41,068 acres are considered commandable. The designed water duty of each watercourse head has been set at 330 acres/cusec, or roughly 3 cusecs/1000 acres.

The Niazbeg subproject area is served by three minors: the Kamogil Minor near the head of the subproject area, the Jalleko Minor near the middle; and the Thatti Uttar Minor at the far end of the system (Figure 2). The Niazbeg Canal delivers to 98 watercourses, three-fourths of which are directly on the main canal, while the other one-fourth draw water from one of the three minors.

Private tubewells provide a substantial percentage of the crop water available to Niazbeg area farmers. Table 4 reports the official estimates of private tubewell water pumped as compared to canal and public tubewell water. Estimates of tubewell contribution to the total water supply at Niazbeg are probably low. On the six watercourses studied in this research, 54 private tubewells were installed and operational, each delivering an average of about 250 acre-feet/year, for a total of about 13,500 acre-feet. Thus, the amount of water provided by private tubewells on these six watercourses was one-third of the total amount of tubewell water reported for all 96 watercourses in the Niazbeg system, which suggests that official estimates of tubewell water underestimate its use.

Table 4. Irrigation water supplies and requirements at watercourse head (acre-feet annually (000)).

Subproject	Canal	Public Tubewell	Private Tubewell	Total	Crop Water Required
6-R	250	-	-	250	439
Pakpattan	217	-	54	271	420
Shahkot	80	25	-	105	202
Niazbeg	62	27	39	128	168

Source: World Bank, 1984; WAPDA, 1983.

Table 4 indicates that the overall deficit in water quantity, as estimated by the World Bank, ranges from 25 percent to 75 percent. This is a significant finding, but does not address the even more critical issue of water timing. December and early January represent the only extended period of excess water. Farmers often suffer water shortages at critical periods during the cropping season.

3. Cropping Intensities, Yields, and Patterns

Niazbeg farmers plant a higher proportion of rice than do farmers at other Punjab sites (Table 5). In rabi (winter), Niazbeg farmers lead in the percent of land planted in wheat. Furthermore, in rabi, Niazbeg farmers plant a higher percentage of their acreage in vegetables than do farmers in the other areas. Table 6 indicates that the cropping intensity on arable land in the Niazbeg area increased approximately 113 percent between 1960 and 1982. Between 1976 and 1982, cropping intensities increased 46 percent and Niazbeg farmers generated a 13 percent average increase in yields (Table 7). (Rice yields actually dropped slightly, while wheat, maize, and sugarcane showed the greatest yield increases.) Table 7 also indicates that Niazbeg yields for wheat and sugarcane are better than the average for the Punjab subproject sites, and slightly below average for cotton, maize, and rice.

Table 5. Cropping patterns and average intensities (1979-1982).

	Cultivated Area							
	Pakpattan		6-R		Shahkot		Niazbeg	
	113,171 ac	%	130,615 ac	%	447,615 ac	%	41,592 ac	%
KHARIF								
Rice	2825	2.5	10	0.0	6040	10.4	6533	15.7
Cotton	31155	27.5	30021	23.0	2114	3.6	5275	12.7
Grains	6378	5.6	12841	9.8	4245	7.3	861	2.1
Fodder	9897	8.7	7668	5.9	6360	10.9	17350	41.6
Vegetables	550	0.5	357	0.3	1029	1.8	1460	3.5
Sugarcane	11983	10.6	7943	6.1	6972	12.0	2327	5.6
Orchard	557	0.5	4136	3.2	715	1.2	1852	4.5
Others	559	0.5	1357	1.0	556	1.0	286	0.7
Subtotal	63904	56.4	64336	49.3	28033	48.2	35944	86.4
RABI								
Wheat	47228	41.8	38058	29.1	25375	43.6	26708	64.2
Pulses	151	0.1	1116	0.8	385	0.7	203	0.5
Oilseed	4863	4.3	10725	8.2	1221	2.1	1796	.3
Fodder	8345	7.4	5111	3.9	6894	11.9	5936	14.3
Vegetables	365	0.3	197	0.2	961	1.6	947	2.3
Sugarcane	11983	10.6	7943	6.1	6972	12.0	2327	5.6
Orchard	557	0.5	4136	3.2	715	1.2	1852	4.5
Others	115	0.1	332	0.3	225	0.4	32	-
Subtotal	73647	65.1	67620	51.8	42750	73.5	39801	95.7
Total	137551	121.5	131956	101.1	70783	121.7	75745	182.1

Source: WAPDA, 1983, p. V-7.

Table 6. Cropping intensity of the Niazbeg subproject area (1960-1982).

	Kharif	Rabi	Annual
		%	
1960-61	41.6	38.9	80.5
1965-66	41.6	55.5	97.1
1970-71	41.6	65.5	107.1
1975-76	52.4	63.4	117.8
1979-80	84.5	90.5	175.0
1980-81	81.7	91.6	173.3
1981-82	81.7	89.8	171.5

Source: WAPDA, 1983, p. V-8.

Table 7. Average yields of major crops (maunds/acre).*

Crops	Area	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82
Wheat	Punjab	18.2	16.2	18.2	18.9	19.9	18.0
	Niazbeg	17.1	16.5	21.6	21.5	21.6	-
Cotton	Punjab	2.2	2.9	2.5	2.1	3.4	3.3
	Niazbeg	-	1.99	1.2	1.9	2.2	2.0
Rice	Punjab	23.9	23.7	23.6	21.0	23.3	21.6
	Niazbeg	22.3	23.7	23.4	19.9	20.3	21.3
Sugar-cane	Punjab	413.8	396.8	393.3	421.9	356.1	406.7
	Niazbeg	417.2	430.2	384.0	417.9	464.5	440.1
Maize	Punjab	15.3	15.6	14.9	15.2	15.2	14.8
	Niazbeg		10.8	10.3	14.0	14.0	13.9

*1 maund equals approximately 82 pounds.
Source: WAPDA, 1983, p. V-8.

4. Credit Utilization and Access

Between 1979 and 1982, the number of loans granted by the Niazbeg banks at Bhai Pheru fell from 752 to 228, a 300 percent decline (Table 8). Furthermore, small farmers (those cultivating less than 12 acres) were most effected in this decline, while medium and large farmers suffered no measurable loss of credit access (Table 9). Because small farmers make up the majority of farmers, commercial credit for agricultural improvement is lacking for a large percentage of the farmers in the Niazbeg site (WAPDA, 1983, p. v-33).

Table 8. Number of loans made by ADBP and commercial banks for the Niazbeg subproject area.

Loan Time	1979-1980	1980-1981	1981-1982
Short-term	682	579	190
Medium-term	8	6	7
Long-term	62	49	31
TOTAL	752	634	228

Source: WAPDA, 1983, p. V-33.

Table 9. Distribution of loans to small, medium, and large Niazbeg farmers by the ADBP and commercial banks.

	1979-1980	1980-1981	1981-1982
Small farm loans	562	484	178
Medium farm loans	184	148	178
Large farm loans	6	2	14

Source: WAPDA, 1983, p. V-34.

5. **Demographic Features**

Approximately 63,000 people live in the 34 villages of the Niazbeg subproject area. Farming is the primary occupation of 98 percent of the 240 sample farmers in the Niazbeg study. Of these, 71 percent reported that they depend exclusively on agriculture, and 29 percent reported having secondary occupations. Fifty-four percent of this subset listed their secondary occupation as skilled laborer, 19 percent said they were in business, 16 percent said they were in government service, and 12 percent said they did other miscellaneous jobs.

The majority of sample farmers are small operators (Table 10). Eighty-one percent owned less than 12 acres, and more than 50 percent owned less than 6 acres. However, the sample included 40 landless farmers on watercourse 3 who lease their land from the Pakistan government. Thus, when farmers are classified according to acreage cultivated, the number of small farmers decreases to 74 percent, with 30 percent of these cultivating less than 6 acres. Only 20-25 percent of the sample farmers cultivate more than 12 acres. The median acreage owned among the sample farmers is 5.0 acres while the median acreage operated is 7.25 acres.

Table 10. Land and property owned and operated by sample farmers.

Acres	Acres Owned: No. of Cultivators	Acres Owned: % of Cultivators	Acres Owned: Cum. %	Acres Operated: No. of Cultivators	Acres Operated: % of Cultivators	Acres Operated: Cum. %
0	65*	25.1	25.1	2	0.9	0.9
0- 5.99	65	28.1	53.2	69	30.4	31.3
6-11.99	63	27.7	80.9	97	42.7	74.0
12-24.99	33	14.0	94.9	42	18.5	92.5
25-49.99	6	2.6	97.4	9	4.0	96.5
50-98.00	6	2.6	100.0	8	3.5	100.0

*Includes 40 farmers from watercourse 3 who have no title to their land; it is owned by the Government of Pakistan.

Only 21 percent of the sample farmers have had any formal education (Table 11). Table 12 reports the distribution of quom (caste). All six watercourses are multi-caste, but the Rajputs are the dominant caste group, particularly on watercourses 1 and 5. Jats are the second most numerous caste among the sample farmers. While the Jats have historically been tenant farmers, they have recently become landowners in their own right. Arains, who make up a substantial contingent on watercourse 4, are known for their vegetable farming. Watercourse 3, which has the most diverse caste distribution, consists of refugees who fled India after partition.

Table 11. Years in school for sample farmers on six watercourses (n=231).

Watercourse	(n=)	Years in School: 0	1-4	5	8-10	12-18
1	(40)	31	1	3	5	0
2	(40)	33	1	2	3	1
3	(31)	28	0	2	1	0
4	(40)	31	1	3	5	0
5	(40)	33	1	4	2	0
6	(40)	23	1	4	8	4
Total		179 (78%)	4 (2%)	18 (8%)	23 (10%)	5 (2%)

Table 12. The distribution of caste across watercourses (n=233).*

Watercourse	(n=)	Rajput H	Rajput T	Jat H	Jat T	Arain H	Arain T	Kamboh H	Kamboh T	Gujar H	Gujar T	Malik H	Malik T	Dogar H	Dogar T	Others H	Others T
1	(40)	18	16	0	2	0	0	0	0	0	0	0	0	1	0	1	2
2	(40)	12	3	0	2	4	1	0	2	0	0	1	3	3	8	0	1
3	(33)	6	5	0	4	1	1	3	6	2	0	2	0	0	0	2	1
4	(40)	10	6	4	6	3	4	1	2	0	1	0	1	0	0	2	0
5	(40)	18	11	1	0	0	2	0	0	1	0	0	1	0	5	0	1
6	(40)	2	3	14	16	0	0	2	0	0	0	1	1	0	0	1	0
Totals		110		49		16		16		4		10		17		11	

*H = Head; T = Tail.

III. DESIGN OF THE RESEARCH

A. INTRODUCTION

This chapter describes the research design developed to examine water control, water distribution, and water productivity in the Niazbeg subproject area at three levels of organization: the government-managed main water delivery system, the farmer-managed farm system, and the intermediate or middle-level linkages between the main system and farm levels.

B. VARIABLES AND HYPOTHESES

Four variables and their interrelationships at the three levels of analysis were explored (Figure 3). The dependent, independent, and intervening variables and their measures are listed in Table 13.

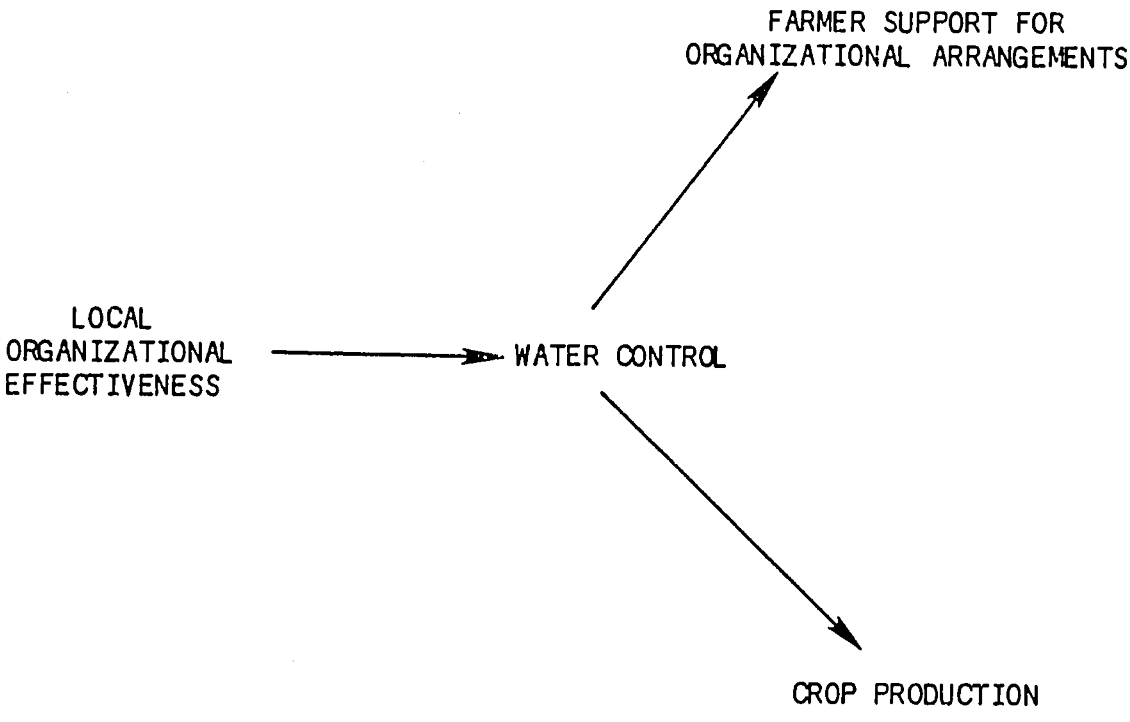

Figure 3. Logic of research.

Table 13. Variables examined in the Niazbeg study and their measures.

Variable	Measure
Dependent	
Organizational effectiveness (main system)	1. Correspondence between *de jure* water allocations and *de facto* water deliveries. 2. Ability of main system management to control or sanction "free riders" who gain benefits without meeting obligations.
Crop productivity	1. Cropping intensity, or percent of land cultivated. 2. Crop yield, or maunds per acre. 3. Cropping pattern, or degree to which moisture sensitive crops are grown.
Intervening	
Water control	1. Capacity to measure and regulate water flowing to the minors, and farmer water control on watercourses. 2. Capacity to maintain canals to design specifications (main system). 3. Correspondence between water delivery and water assessments (main system). 4. Ability of an irrigator to respond to crop water requirements at various stages of plant growth in terms of quantity and timing of water delivery (farm level). 5. Capacity to overcome locational bias in distributing water among and within watercourses (intermediate level).
Independent	
Organizational support (farm level)	1. Farmer reports of willingness to pay assessments for existing and potential water control. 2. Farmer compliance with *warabandi* or tubewell organization rules. 3. Farmer willingness and ability to control "free riders."

The variables listed in Table 13 were combined into the research hypotheses diagrammed in Figure 3. Although many specific hypotheses were examined, the essential logic is straightforward: the effectiveness of collective organizational relationships determine the extent to which water can be controlled in quantity and timing. Water control, in turn, was hypothesized to importantly affect crop production (cropping intensities, yields, and patterns) and farmer propensity to support local organizational arrangements.

C. SAMPLING DESIGN

For each level of analysis -- main system, intermediate level, and farm system -- a different sampling procedure was employed. The procedures are described in the following section.

1. Selection of the Project Site

The Niazbeg subproject area is one of seven project sites in Pakistan chosen to be part of the Command Water Management Project. Because more than half the agricultural activity in Pakistan takes place in the Punjab Province, the Command Water Management Project selected four of the seven sites from Punjab. Although the specific criteria for selecting the sites were not reported to the research team, all four project areas in Punjab had a history of problems with irrigation water supply.

2. Selection of the Six Sample Watercourses

The need to maximize variance in location guided the selection of the sample watercourses. The head and tail watercourses from the Kamogil minor (head), from the Jalleke minor (middle), and from the Thatti Uttar minor (tail) of the Niazbeg distributary were chosen.

3. Selection of Sample Farm Units

To maximize variance within each watercourse, a purposive sample of 40 farmers was drawn from the head and tail each of the six watercourses. A list of all farm units was constructed for each watercourse from head to tail; the headmost 20 farmers and the tail-most 20 farmers were selected so that the total number from each watercourse sample equaled 40. The total sample of farmers from all six watercourses was 240. In the few instances where a selected farmer was unavailable to participate in the research, a replacement sample farmer was selected by incorporating the next farmer on the list.

D. DATA COLLECTION AND ANALYSIS

Engineering and sociological methods of data collection were used in the Niazbeg study, including water delivery and flow measurements, key informant interviews, and structured farmer interviews. Descriptions of the engineering and sociological measurement instruments, procedures, and enumerator training, as well as discussion of general reliability and validity issues can be found in appendices A, B, and C. Discussion of the statistical techniques used in the analysis can be found in Appendix D. The reader is reminded that data were collected as part of a diagnostic analysis exercise (Wattenburger et al., 1987).

E. DISCUSSION OF THE HYPOTHESES

In the absence of sufficient organizational links between main system managers and farmers, water distribution and control is fundamentally conditioned by farmer location in the system: the greater the farmer distance from the water source, the lower the farmer water control. The explanatory power of this locational variable was tested against four rival hypotheses concerning attributes of sample farmers -- land owned, land cultivated, formal education, and caste membership. The analysis examined whether such farmer characteristics offer rival explanations for variability in water access and control.

1. Water Control and Organizational Effectiveness

If officials have the capacity to measure and regulate water flows and to maintain canals to design specifications, they will be able to ensure that irrigation water is delivered to watercourses in the amounts officially allocated by the warabandi. Thus, organizational effectiveness was measured by the degree of correspondence between de jure warabandi water allocations and actual water delivered to the moghas (outlet on a distributary), and by the capacity of officials to sanction "free riders" within the warabandi delivery system.

2. Farmer Water Control and Crop Production

Poor farmer water control, as manifested in locational bias, was predicted to adversely affect crop production in the Niazbeg system. Crop production, as measured in terms of cropping intensity, crop yields, and cropping patterns, was investigated in reference to farm location among and within the watercourses. The analysis of the relationship between water control and crop production focused on the contribution of tubewell technology and tubewell organizations to increased farmer water control and higher crop production.

3. Farmer Water Control and Organizational Support

Farmer organizational support was hypothesized to be the critical variable affected by farmer water control. When farmer water control is improved, organizational effectiveness at the main system level and farmer agricultural production are both enhanced. With increased farmer water control, farmers were hypothesized to be more willing and able to invest in irrigation improvements and to control "free riders."

The relationship between the water distribution arrangements of existing tubewell organizations and farmer agricultural production was also examined. The central hypothesis was as follows: the greater the water control made possible by local organizational distribution arrangements, the greater would be agricultural production. Better agricultural production was to be indicated by greater cultivation of higher yielding, more moisture-sensitive crops.

IV. WATER CONTROL, LOCATION, AND INDIVIDUAL ATTRIBUTES

A. INTRODUCTION

Is canal water control on the six sample watercourses a function of individual farmer attributes, (i.e., caste, formal education, acreage owned, and acreaged cultivated) or is control over canal water a function of farmer location in the command? Significantly different policy implications are generated depending on the answer. If location in the system, given the structure of the *warabandi*, is a major contributor to inadequate water control and lower agricultural productivity, then an organizational solution, such as development of effective water users associations, is needed. On the other hand, if the problem lies in the individual attributes of the farmers themselves, programs must be constructed to alter such attributes for the better (e.g., land ownership).

This chapter examines the explanatory power of the locational and individual farmer attribute arguments. The central hypothesis is that location drives the distribution and use of water in the system. *Warabandi* water share arrangements, which allocate water by time and location, favor farmers nearest the source of supply, while farmers farther from the source suffer a loss of control over water quantity and timing.

B. WATERCOURSE DESCRIPTIONS

Figure 2 (page 9) shows the layout of the Niazbeg subproject area and the location of the three minors from which the sample watercourses were chosen. Watercourses 1 and 2, on the Kamogil Minor, represent the head of the Niazbeg system. Watercourses 3 and 4, on the Jalleke Minor, represent the middle. Watercourses 5 and 6, located on the Thatti Uttar Minor, represent the tail of the Niazbeg system.

1. Watercourse 1

Watercourse 1, headmost watercourse on the Kamogil Minor, lies at the center of a small commercial area and is the most urbanized of the sample watercourses. A national highway bounds the western edge, and there is a prospering brick industry. Some farmers lease their land to brick-makers and other farmers regularly sell tubewell water to them. The 457 acres in the command area of watercourse 1 are divided among approximately 60 farm units, 90 percent of which are farms of less than 12 acres. The watercourse is about 1.25 miles long and serves five spurs (Figure 4). Nauthe Khalsa village is situated near the head of the watercourse, and Dina Nath village is at the tail.

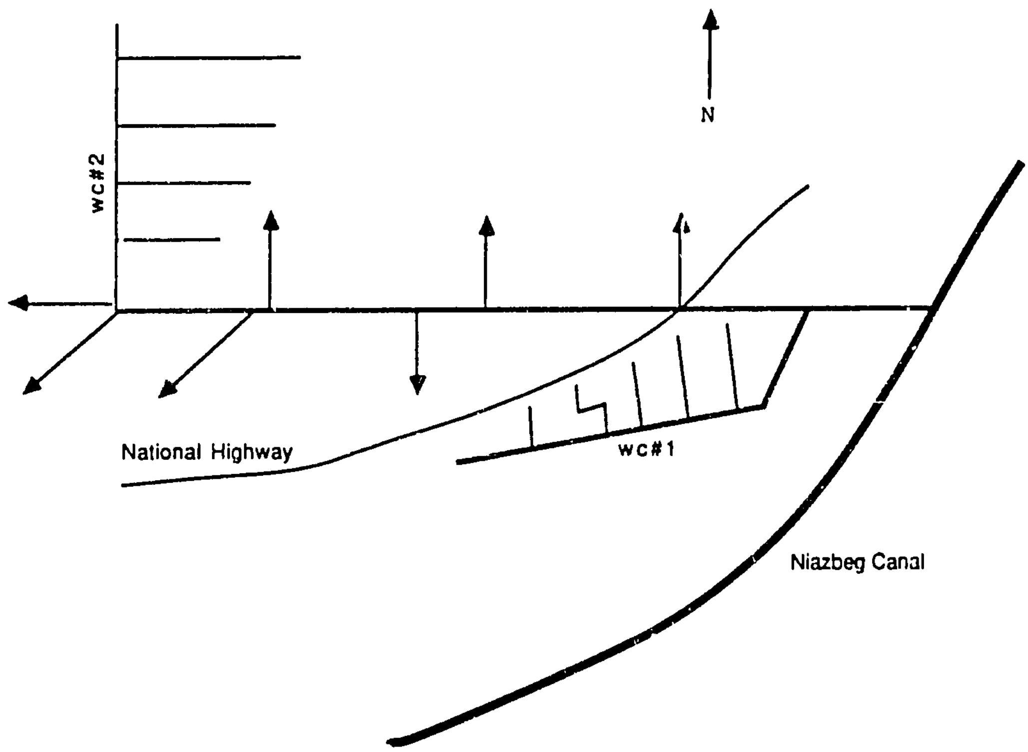

Figure 4. Kamogil minor (head): head and tail watercourses.

The watercourses on the Kamogil Minor receive an excess of water. A key informant reported that the _patwari_ (a local irrigation revenue official) on watercourse 1 collects an unofficial charge of Rs. 3000 every three months from farmers for the excess water delivered to the _mogha_. Farmers have no way to measure the actual amount of water delivered to the _mogha_ and were willing to pay the _patwari_ an addition to their official fees to ensure that the water supply would be maintained at its current rate.

2. Watercourse 2

Watercourse 2 has a channel approximately 6,000 ft long, with four field channels delivering water to the farm _nukkas_ (Figure 4). Watercourse 2 also received an amount of water at the _mogha_ in excess of the officially prescribed quantity. Watercourse 2 commands an area of 650 acres, which is divided into approximately 100 farm units. Of these, 72 percent are farms less than 12 acres. The average acreage shifts upward slightly when farm units are measured in terms of area operated, since small farmers rent land for cultivation. The two villages at watercourse 2 are Nauthe Jagir, located at the northern boundary of the command area, and Takhande, located at the tail end on the western boundary.

3. Watercourse 3

The _mogha_ of watercourse 3 is located .5 miles from the head of the Jalleke minor, which takes off from the Niazbeg Canal approximately 2 miles south of the town, Bhai Peru (Figures 2 and 5). Farmers make allocation arrangements among themselves. Because a national highway passes on the east side of the watercourse command area, watercourse 3 farmers have good access to transportation and commercial markets in the Niazbeg subproject area.

Watercourse 3 farmers all live in Fatehwala village. Most are Moslem refugee families who fled from India after partition. The village appears to be cohesive, with clearly delineated and respected leadership.

Land in watercourse 3 (413 acres) is held by the Government of Pakistan; all attempts by the villagers to secure property rights have been unsuccessful. Because some land is too high in elevation, only 322 acres are actually cultivated. Irrigation is further hampered by the full mile of channel between the _mogha_ and the first _nukka_. The command area is divided into 56 farm units, 90 percent of which incorporate less than 12 acres. The size of the average land-lease from the government is 5.8 acres. No farms of more than 25 acres exist on watercourse 3.

In spite of their tenuous claim to the land, farmers have been willing to invest in irrigation improvement. Two groups of farmers organized among themselves to install two tubewells. Tubewell water is regularly delivered with canal water. The designated leader of the

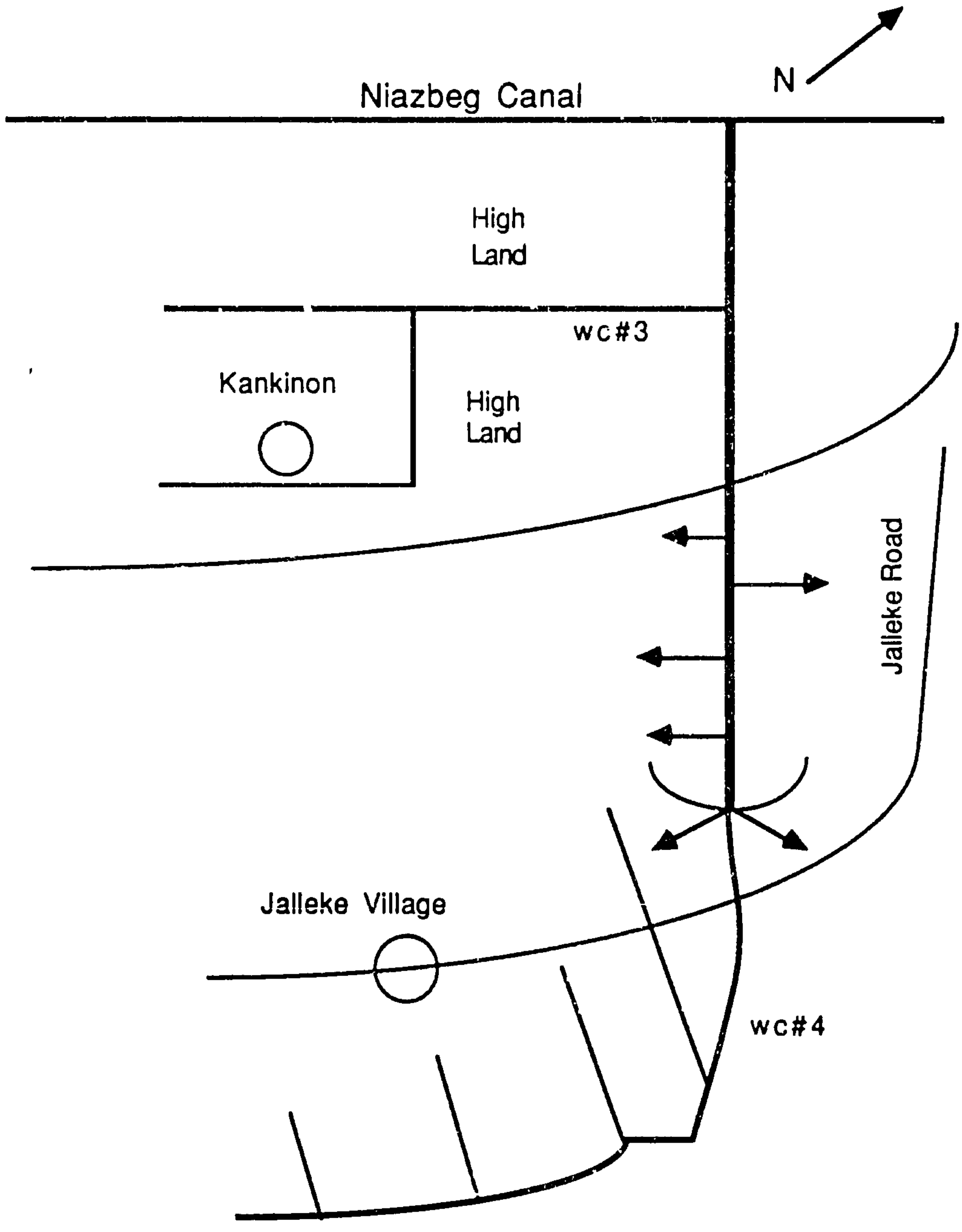

Figure 5. Jalleke minor (middle): head and tail watercourses.

warabandi organization is also the major owner of one of the two tubewells; if *warabandi* rules are not observed, tubewell water can be withheld from the offending party. Thus, an informal, but effective water users association has developed around these tubewells and the conjunctive use of canal and groundwater, which has resulted in greater compliance with *warabandi* rules.

Watercourse 3 is the only sample watercourse where there is extensive vegetable cultivation. On the last farm along the watercourse, the farmer has planted vegetables in furrows, which he irrigates with tubewell and canal water. While proximity to markets has made vegetable production possible, the water control achieved through conjunctive use of canal and tubewell water is also a critical factor.

4. Watercourse 4

Watercourse 4 is the tail watercourse of the Jalleke minor (Figure 5). The *mogha* is approximately 2 miles from the head of the Jalleke minor. After the water flows through the *mogha*, it travels approximately .75 miles before reaching the first *nukka*. The flow of water visibly diminishes between the *mogha* and the first *nukka*. Thick vegetation is noticeable on the bottom and sides of the watercourse and undoubtedly impedes the flow of water. In general the watercourse suffered below average maintenance compared to other sample watercourses.

Four channels branch off of watercourse 4. The first is approximately .5 miles long, and water flows the length of the channel. On the second, third, and fourth channels, barriers have been constructed that prohibit the flow of water. A number of farmers at the tail have abandoned their water rights or have transferred them to farmers closer to the head where the water is more readily available.

Key informants indicated that the inadequacies of the *warabandi* system on watercourse 4 are based on an historical event. In the 1960s, the government installed a public tubewell and reduced the original allocation of canal water from 22 minutes to 11 minutes per acre. The tubewell failed more than two years prior to this research effort, but the Irrigation Department had not adjusted the canal supply. While some tail farmers sold their water rights, others developed groundwater. Today there are ten operational tubewells in the command area, many of which are jointly owned.

Watercourse 4 commands 799 acres. While most farm units include less than 12 acres, a larger percentage of farmers own medium to large size units than on watercourses 1-3. All sample farmers live in Jalleke, which has a population of approximately 1600 people. Bhai Peru, the central town and commercial center of the Niazbeg area, lies about 3.5 miles from Jalleke on a well-paved and well-traveled road. Watercourse 4 also has a prosperous brick-making industry located on the periphery of the canal command area.

5. Watercourse 5

The *mogha* for watercourse 5 is located .5 miles from the head of the Thatti Uttar minor. The main channel of the watercourse is about 2 miles long, and has four branches extending off the main channel (Figure 6). Watercourse 5 is poorly maintained; channel beds are uneven and vegetation is visible on the bottom and the sides of the channel. Water flows down the main channel slowly, and the flow toward the end of the watercourse was usually less than .5 cusecs. Diversion structures leak and are in a general state of disrepair.

All watercourse 5 farmers live in Khanki Mour village, a community with a population of over 3,000 people. The command area of watercourse 5 covers 824 acres, which is divided into approximately 110 farm units. Among the sample farmers, there were no landless farmers, but 75 percent owned less than 12 acres. Almost 25 percent owned farms of 12 to 25 acres. Only one of the sample farmers owned more than 25 acres.

Three private tubewells were found on watercourse 5. One belongs to a single household and was used exclusively on that household's farm. The other two tubewells employed privately constructed channels to carry flow to areas commanded by watercourse 5. These channels, which were well-maintained and clean, were used to transport private tubewell water and were not part of the *warabandi* delivery system.

Three public tubewells on the Thatti Uttar minor are supposed to increase reliability of water delivery, but the tubewells often are shut down without notice and farmers cannot depend on deliveries. However, farmers are charged for public tubewell time regardless of whether or not they actually receive water. According to key informant reports, watercourse 5 farmers had tried to have the public tubewell water deliveries discontinued in order to avoid the additional well water charges. To facilitate this agreement, Rs. 5,000 was collected from the farmers by irrigation officials. More than one year later, farmers were still being charged for tubewell water. In the meantime, farmers who refuse to pay water fees can be jailed.

6. Watercourse 6

Watercourse 6 is approximately 3 miles long, and the first *nukka* is more than 1 mile from the *mogha* (Figure 6). After leaving the outlet, the water travels along the watercourse in a straight line. Heavy groves of bamboo line its course, and the thin banks are subjected to illegal cuts. Consequently, the water flow is greatly reduced by the time it reaches the first officially sanctioned *nukka*.

The majority of farmers on watercourse 6 have responded to the broken *warabandi* system by abandoning it altogether. Approximately .67 miles down from the first *nukka*, the farmers have erected a barrier to prevent the water from flowing further. Approximately, 1.25 miles after the first *nukka*, no canal or tubewell water flows in the channel. The abandoned watercourse has been inoperative for some time because farmers

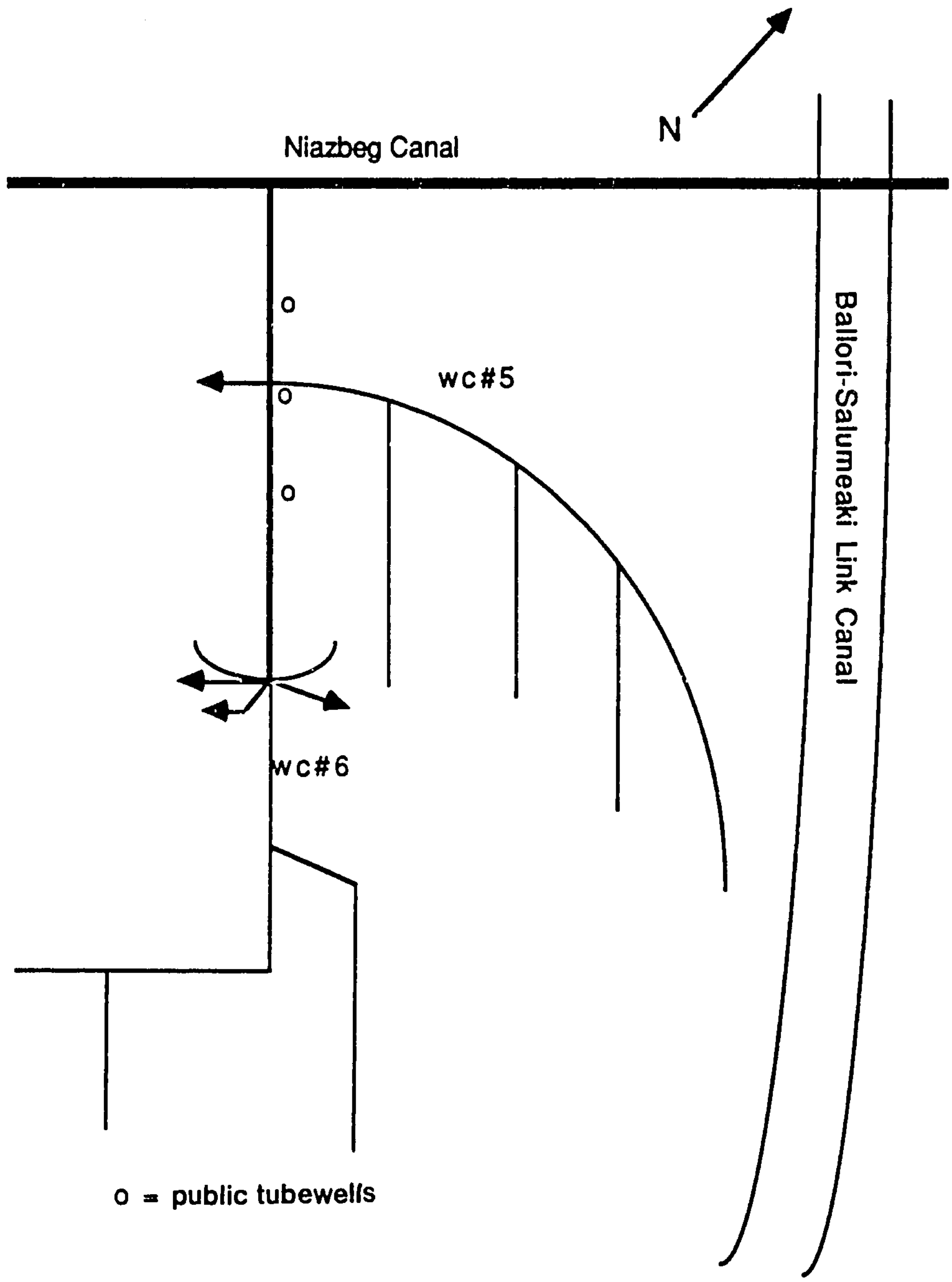

Figure 6. Thatti Uttar minor (tail): head and tail watercourses.

wish to prevent the Irrigation Department from charging them for both canal water and public tubewell water. The farmers have constructed separate channels to deliver private tubewell water.

Watercourse 6 commands 832 acres, the largest area of all sample watercourses. Like other sample watercourses, small farms (less than 12 acres) are in the majority. Of the 40 sample farmers, 3 owned no land and 24 owned less than 6 acres. However, watercourse 6 has a relatively high percentage of farmers with medium and large holdings. Four sample farmers each worked farms of 80 to 100 acres.

Not only did the four large landowners fully cultivate their acreage, but three landless farmers cultivated farms of 25 acres or more. Farms of medium acreage remain the same when comparing land owned and area cultivated. Thus, in terms of area operated, medium and large farmers make up nearly one-third of the sample. Most are located in the head reaches. Farmers of watercourse 6 live in or around Thatti Uttar village, a community of approximately 2,000 inhabitants.

C. WATER CONTROL

Water control on the main distributary of the Niazbeg system and within each sample watercourse was examined. There are two types of warabandi in the Niazbeg system (Table 14). The pukka warabandi of watercourses 1 and 2 is a formal, written set of agreements for water distribution that is adjudicated by the Irrigation Department. The kutcha warabandi of watercourses 3-6 is an informal system by which farmers make water distribution arrangements among themselves. Engineering and sociological measures were used to assess the adequacy of farmer water control. Both quantity and timing of water delivery were considered to be critical and interacting factors in the assessment of water control. The descriptive data presented in the following sections generally support the hypotheses that location is a driving force in determining the adequacy of water control from watercourse to watercourse and farmer to farmer.

1. Engineering Measures of Water Control

Between October 29 and December 5, 1985, 16 measurements were taken of canal water flows entering the moghas of the six sample watercourses. On the same days, measurements were also taken at various outlet (nukka) points along each watercourse. These measurements were used to:

1. Compare the sanctioned water supply with the actual quantities of water delivered to the watercourse moghas.

2. Determine the range of water deliveries to the individual watercourses.

3. Determine the amount of water loss as the water moved from the mogha to the tail (Table 14 and Appendix E).

Table 14. Sanctioned and actual water supply at sample watercourse moghas.

Minor and Watercourse	Sanctioned Supply (cusecs)	Percent Received	Size of CCA* (acres)	Type of Warabandi
Kamogil minor				
Watercourse 1	1.37	156	457	pukka**
Watercourse 2	1.95	171	650	pukka**
Jalleke minor				
Watercourse 3	2.07	66	413	kutcha***
Watercourse 4	4.00	21	799	kutcha***
Thatti Uttar minor				
Watercourse 5	2.47	73	824	kutcha
Watercourse 6	2.50	54	832	kutcha

*Cultural command area.
**Pukka warabandi: water distribution has been formally adjudicated by the Irrigation Department and water share arrangements are written agreements.
***Kutcha warabandi: water share arrangements are worked out informally by the watercourse farmers.

Two factors condition the interpretation of engineering measurements. First, this research was conducted as part of a larger national project, funded and monitored by international agencies (Wattenburger et al., 1987). The staff of the Command Water Management Project insisted that the Irrigation Department push water to the tail of the system before assuming responsibility for the site. Some farmers at the tail of the system stated they had not seen so much water in the system for 20 years. Second, the current sanctioned water supplies are already inadequate to serve demand. The last adjudication for the Niazbeg subproject was in 1931 when the water supply was established at 3 cusecs/1,000 acres. This calculation assumed a cropping intensity of 50 percent during *kharif* and 25 percent during *rabi*, with reliance on crops other than the high-yielding, moisture-sensitive varieties grown today.

The inadequacy of the current adjudication is indicated by the extent of water deficits revealed in Figure 7. Measurements taken between 1977 and 1981 indicate that the amount of water delivered to the Niazbeg system was inadequate to meet the crop demand for at least six months out of the year for most years. Furthermore, Table 14 indicates that the watercourses at the middle and tail of the system suffer greater water shortages compared to those at the head. The two sample watercourses along the Kamogil minor, at the head of the distributary, receive an average of 163 percent of their sanctioned supply, while all of the middle and tail watercourses received substantially less than their sanctioned amount. Note that these discrepancies were measured during a time when an abundance of water was flowing through the system.

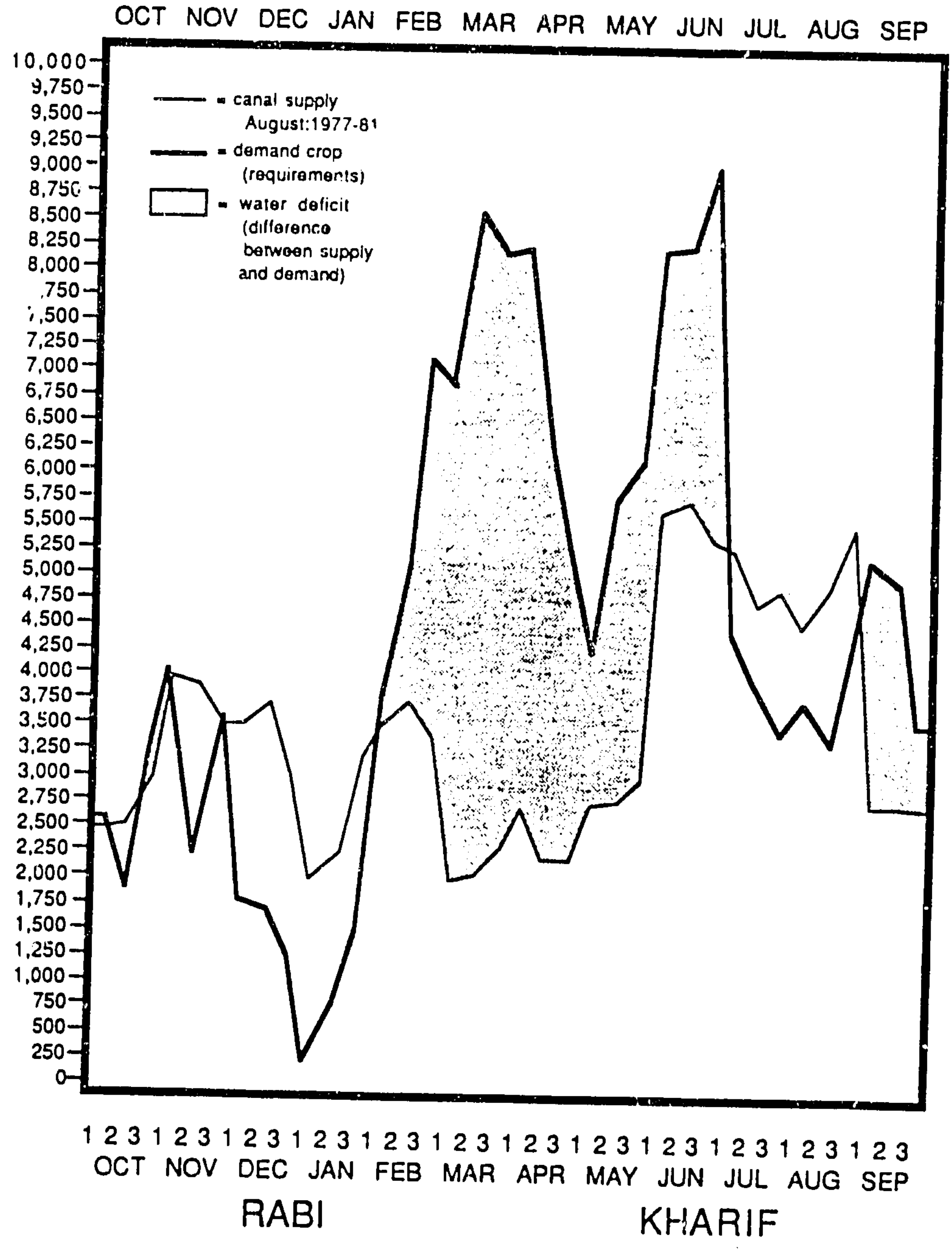

Figure 7. Water supply and demand for Command Water Management Project: the Niazbeg subproject area.

2. Sociological Measures of Water Control

Sociological data were obtained through interviews with sample farmers, who were asked questions designed to ascertain the degree of farmer water control. Questions were asked regarding percentage of canal water used for irrigating crops, whether or not serious water shortages occurred during various crop phases, and how water exchange was used to gain more water control. The sociological data supplements the engineering measures, and the results parallel the engineering analysis. Locational bias was evident in regard to both the amount and timing of water available. Farmers at the head consistently reported that they obtained more water than those at the tail. Furthermore, the data indicate that farmers strive for better water control by circumventing *warabandi* rules by engaging in exchange.

Farmer reports of percent of canal water used for irrigation indicate that the canal *warabandi* system is not meeting farmer crop water demands (Table 15). Furthermore, the majority of sample farmers stated that less than 25 percent of their irrigation water was obtained from the canal *warabandi* system. When analysis focuses on the differences among watercourses, the overall adequacy of the system degrades as one moves toward the tail of the system. The majority of farmers who receive no water from the canal are from watercourse 6 at the end of the system (Table 15).

The data also indicate that the locational bias operates within, as well as among, the watercourses (Table 15). Watercourse 1 and 2 are water-rich relative to the others. Farmers at the head of these channels receive a greater percentage of their irrigation water from the canal than do those at the tail of these channels.

The five farmers from watercourse 1 who received no canal water relied exclusively on private tubewell water, indicating that even farmers on a water-rich watercourse must rely on private tubewell water. Also, these farmers can sell their private tubewell water to the brick-making industry, so that discontinuing association with the *warabandi* is economically advantageous. (Public canal water cannot be sold to brickmakers.)

The seven farmers from watercourse 5 who rely exclusively on canal water are too poor to buy private tubewell water. All reported that their water supply is never adequate to meet their irrigation needs. Farmer reports for percentage of canal water used were virtually identical for *kharif* and *rabi*.

Table 15 also indicates that the locational bias evident from head to tail along the main Niazbeg distributary is reproduced from head to tail along each sample watercourse as water losses increase. Farmers at points most distant from the *mogha* receive diminished supplies relative to their counterparts located closer to the *mogha*. The exceptions are watercourses 4 and 6, where losses are consistently high throughout the watercourse. This departure from the overall pattern is explained by low flows at the *mogha*. All farmers on watercourses 4 and 6 are without adequate water. The relative equality is the result of absolute deprivation.

Table 15. Number of farmers in categories representing percent of canal water used (n=227).*

Watercourse	Percent of Water Used From Canal**														
	None			5-25			26-50			51-75			65-100		
	H	T	Total	H	T	Total	H	T	Total	H	T	Total	H	T	Total
	number of farmers														
1	1	4	5	0	11	11	11	1	12	3	1	4	5	3	8
2	0	0	0	6	13	19	6	6	12	6	1	7	2	0	2
3	0	0	0	16	14	30	0	0	0	0	0	0	0	0	0
4	1	7	8	18	12	30	0	0	0	0	0	0	0	0	0
5	0	4	4	11	16	27	2	0	2	0	0	0	7	0	7
6	12	14	26	6	6	12	1	0	1	0	0	0	0	0	0
Total	14	29	43	57	72	129	20	7	27	9	2	11	14	3	17

*There were 40 sample farmers on each sample watercourse.
**H = Head; T = Tail.

In the warabandi system, timing is perhaps even more critical than absolute quantity. A farmer receives a share of water as a function of a unit of time, regardless of whether or not water is available during that allocated time. Thus, for Niazbeg farmers, reliability of supply is as important as absolute quantity delivered. Figures 8 through 13 indicate that reliability of canal water is low for most of the sample watercourses. During a six-week period, only watercourse 2 had its supply fall within 10 percent of the mean of total water delivered. In addition to problems in the aggregate quantity delivered to watercourses, the water deliveries fluctuated widely, creating additional unreliability.

Table 16 suggests that shortages of irrigation water are widespread among sample farmers on all sample watercourses. While data indicate that sample farmers suffer shortages during different crop phases, reports of shortages occurred for both head and tail farmers within the respective watercourses. Interestingly, farmer reports of serious shortages are much higher for the relatively water-rich watercourses than for those watercourses which have absolutely inadequate supplies. This seeming contradiction may reflect a sense of relative deprivation as distinguished from absolute deprivation. In any case, the system is failing to deliver adequate supplies to many farmers on all watercourses.

Table 16. Number of farmers reporting serious shortages of canal water, by watercourse (n=220).*

Water-	Crop Phases									
	Rauni		Seeding		Growth		Flowering		Maturity	
course	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
1	21	24	13	7	10	6	21	31	1	5
2	24	27	12	2	11	3	22	30	1	3
3	3	2	4	17	26	12	17	9	11	9
4	2	8	6	35	24	9	22	0	5	18
5	18	23	6	6	14	1	5	15	1	2
6	11	8	3	0	8	1	5	10	0	22
Total	79	84	44	67	94	32	92	95	19	59

*There were 40 sample farmers on each sample watercourse, but the "n" is less than 240 because some farmers did not respond to this question.

Legally, exchange of warabandi water turns is strictly prohibited in the pukka warabandi of watercourses 1 and 2. More flexibility among farmers is permitted in the kutcha warabandi of the remaining four watercourses, but exchange is still considered by some as water theft. Table 17 indicates that many farmers, particularly those on the pukka watercourses ignore these prohibitions in order to gain more water control. Because exchange is illegal, farmers were often reluctant to candidly discuss it; therefore, these data may underestimate the extent of water exchange among farmers.

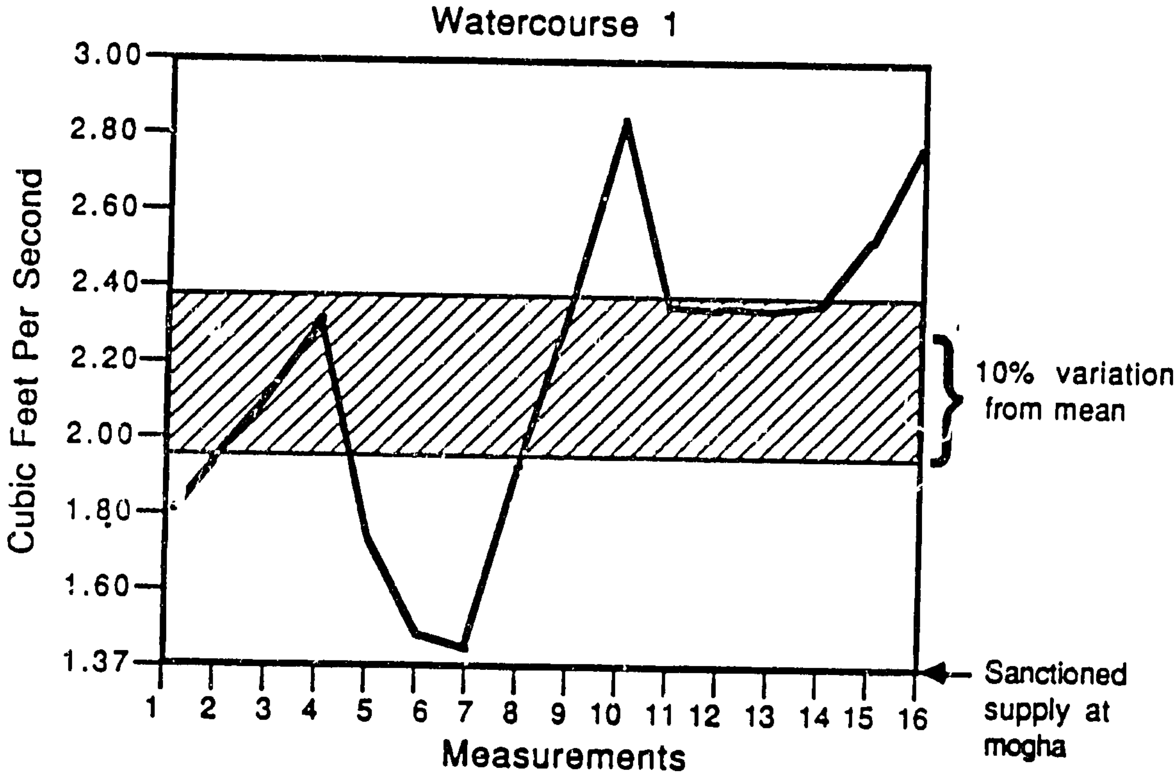

Figure 8. Variation in supply for sample watercourse 1 outlet over a six-week period.

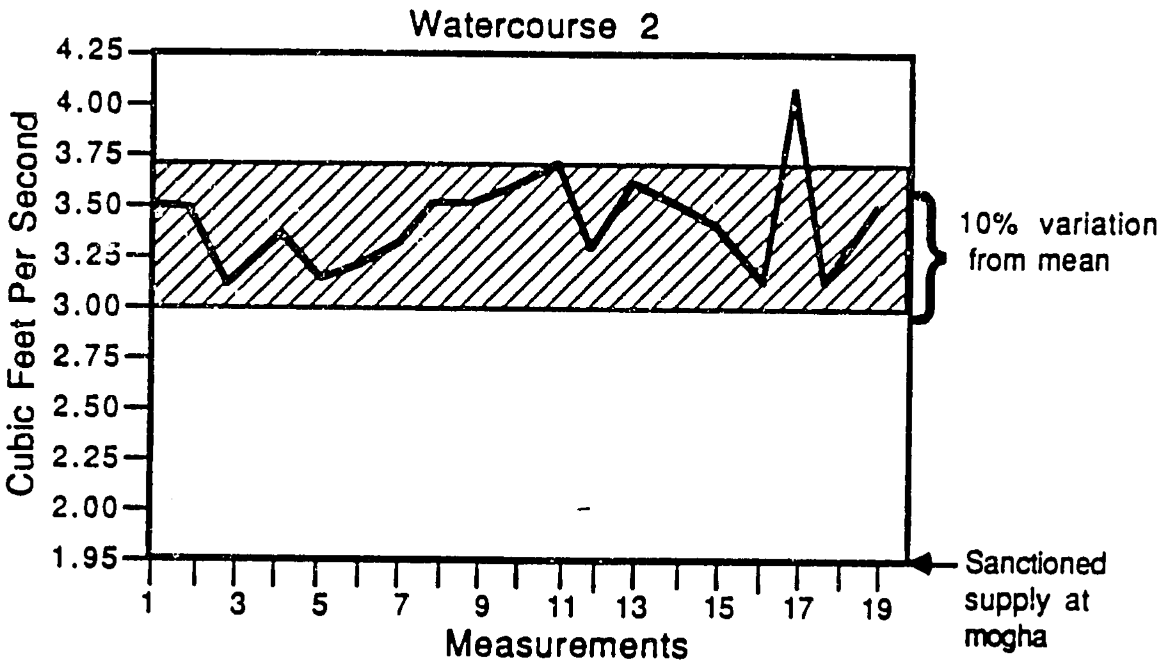

Figure 9. Variation in supply for sample watercourse 2 outlet over a six-week period.

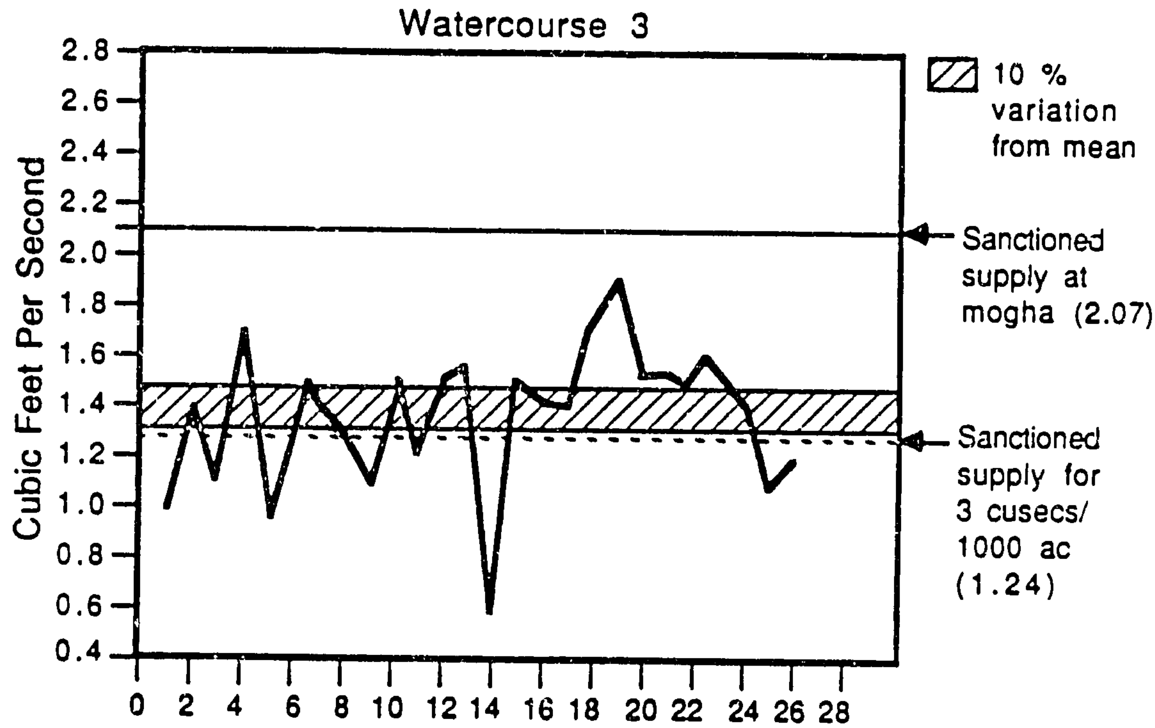

Figure 10. Variation in supply for sample watercourse 3 outlet over a six-week period.

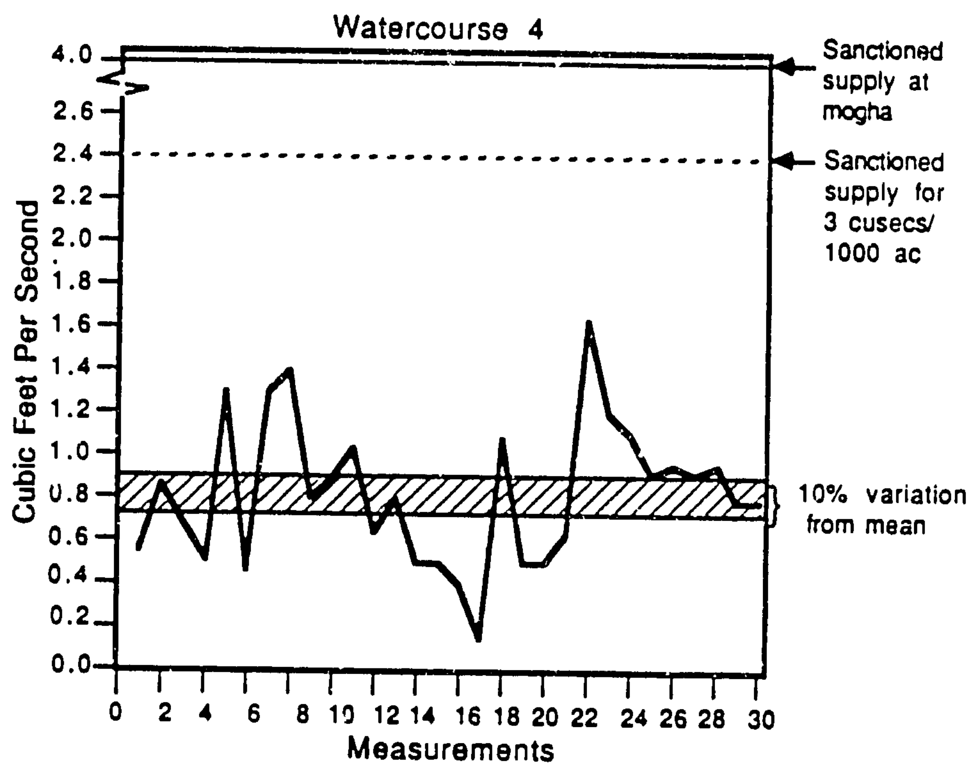

Figure 11. Variation in supply for sample watercourse 4 outlet over a six-week period.

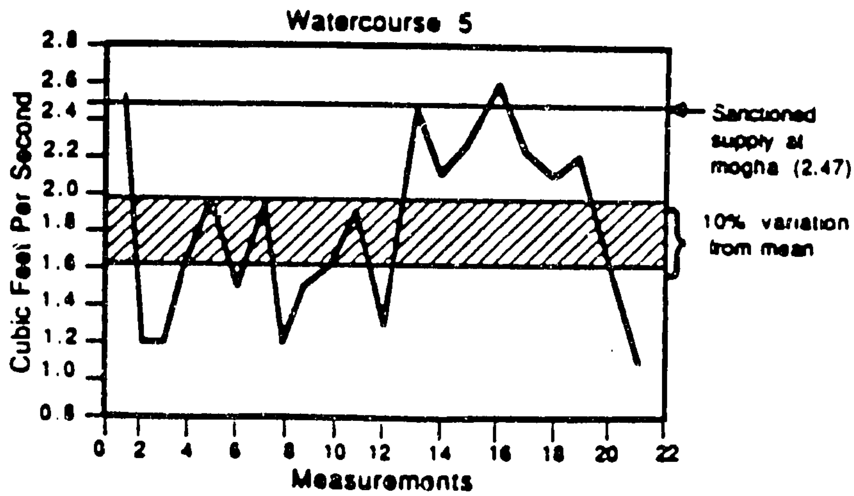

Figure 12. Variation in supply for sample watercourse 5 outlet over a six-week period.

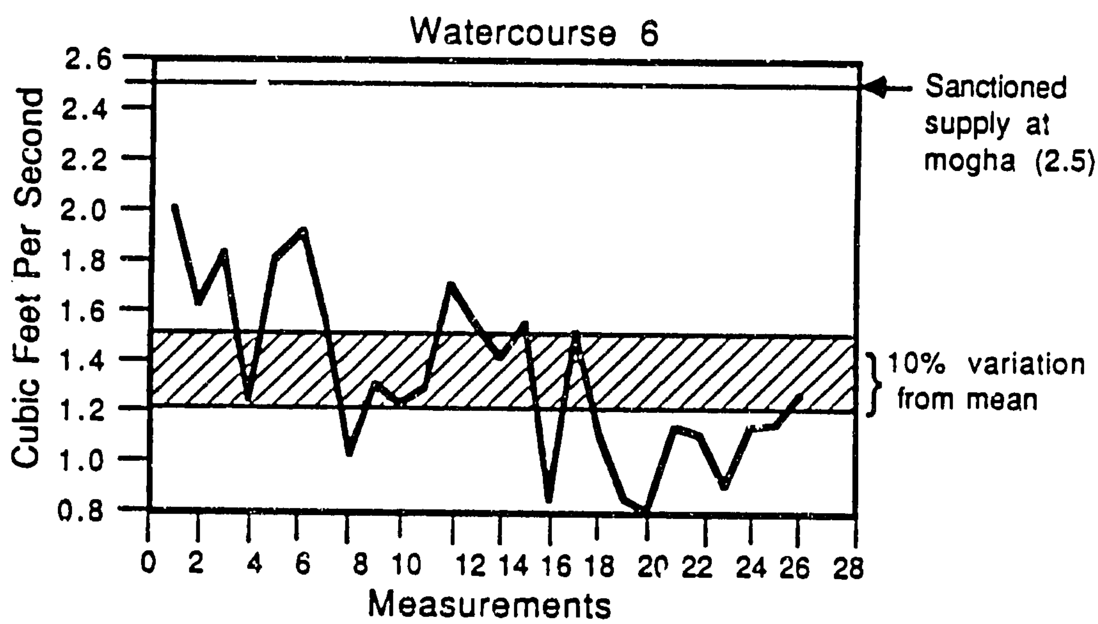

Figure 13. Variation in supply for sample watercourse 6 outlet over a six-week period.

Table 17. Sample farmer reports of water exchange on most important field (n=211).

Water-course	(n=)	Average Frequency of Exchange*								
		No Exchange			Some Exchange			Often Exchange		
		H	T	Total	H	T	Total	H	T	Total
1	(38)	6	13	19	7	5	12	5	2	7
2	(40)	5	14	19	15	6	21	0	0	0
3	(27)	13	9	22	1	4	5	0	0	0
4	(29)	11	12	23	3	2	5	1	0	1
5	(40)	12	11	23	6	7	13	2	2	4
6	(37)	13	18	31	2	0	2	3	1	4
Total		60	77	137	34	24	58	11	5	16

*H = Head; T = Tail.

Table 17 indicates that sample farmers at the head of the system practiced exchange more than their counterparts on tail watercourses, and farmers on the head reaches of the individual sample watercourses were more likely to practice exchange than those toward the tail. Only farmers with relative abundance of water have the flexibility necessary for water exchange. The flows at the tail reaches of the watercourses tend to be too small and unreliable to allow water exchange. Exchange partners require water predictability in both timing and quantity. There is no greater disincentive to water exchange between partners than uncertainty about quantity and timing of water flows. Farmer "X" is unlikely to exchange water with farmer "Y" if farmer "Y's" supply is uncertain.

By combining sample farmer responses to questions measuring both quantity and timing, an overall measure of water control was constructed. Table 18 indicates that a majority of farmers have poor canal water control. Consistent with the locational bias hypotheses, the number of farmers with poor water control increases as one moves from watercourse 1 to watercourse 6. Within the two head watercourses, greater numbers of farmers have moderate to good water control than have poor water control, while the reverse is true for farmers located on watercourses 3 through 6. While water control is relatively better at the head of the system, the data in Table 18 suggest that farmers throughout the system have substantial problems with water quantity and timing. the number of farmers on the head watercourses with poor water control indicates that the _warabandi_ is inadequate for a substantial minority of those located in relatively favorable positions.

Table 18. Degree of water control on sample farmers' most important field, using measures of water quantity and timing (n=206).

		Degree of Reported Water Control								
Water-		Poor			Moderate			Good		
course	(n=)	Head	Tail	Total	Head	Tail	Total	Head	Tail	Total
1	(39)	2	10	12	12	9	21	4	2	6
2	(40)	3	12	15	12	8	20	5	0	5
3	(27)	9	7	16	5	6	11	0	0	0
4	(30)	8	8	16	8	6	14	0	0	0
5	(36)	10	10	20	8	8	16	0	0	0
6	(35)	14	16	30	2	3	5	0	0	0
TOTAL		46	63	109	47	40	87	9	2	11

D. LOCATION, INDIVIDUAL ATTRIBUTES, AND WATER CONTROL

The analysis of water control among and within watercourses suggests that location is a dominant factor in determining which farmers have the greatest degree of water control. The analysis also suggests that the entire warabandi system with Niazbeg is problematic. While this analysis provides strong evidence supporting the relationship between location and water control, a statistical analysis which permits controlling the effect of other variables lends further support to the location argument.

Tables 19, 20, and 21 report the distributions of farm size, actual acreage cultivated, and year of education of sample farmers, respectively, by watercourse location. Table 22 summarizes the relationships among these variables by location and water control. Table 22 indicates that distance of the field outlets from the mogha is generally the dominant factor in determining farmer water control. In the cases of watercourses 1, 2, 4 and 5, the analysis indicates that location has a strong influence over water control when controlling for the effect of land owned, land cultivated, and years in school. On the other hand, the explanatory power of location is not strong for watercourses 3 and 6.

In watercourses 1 and 2, the strength of the locational variable is reduced by the relatively favorable positions of these watercourses. Thus, aggregate quantity of water is not as much a problem as timing. Furthermore, because the two head watercourses receive more water, they also have relatively high loss rates along the watercourse (Appendix E). Finally, the extensive use of exchange by farmers at the head of the watercourses (Table 17) reduces the effect of location on water supply.

For watercourse 4, Table 19 suggests that location, while moderately associated with water control, is also associated with the size of the area cultivated. The larger the area operated, the less the degree of water control. This reflects the fact that there is a clustering of larger farmers toward the tail. Furthermore, there is wholesale malfunctioning of the warabandi along watercourse 4. Watercourse 4 receives only 21 percent of its sanctioned supply (Table 14). Water deliveries are erratic, compounding chronic shortage with unpredictability.

Table 19. Land ownership among sample farmers (n=238).*

Water-course	Acres Owned**														
	None***			0.1-5.9			6-11.9			12-24.9			25+		
	H	T	TL	H	T	TL	H	T	TL	H	T	TL	H	T	TL
1	1	4	5	12	4	16	7	8	15	0	2	2	0	2	2
2	3	4	7	6	3	9	5	7	12	5	4	9	1	1	2
3	20	20	40	0	0	0	0	0	0	0	0	0	0	0	0
4	2	8	10	2	0	2	9	7	16	5	3	8	1	2	3
5	0	0	0	7	10	17	8	5	13	4	5	9	1	0	1
6	3	0	3	10	11	21	1	6	7	4	1	5	2	2	4
Total	29	36	65	37	28	65	30	33	63	18	15	33	5	7	12

*There were 40 sample farmers on each sample watercourse.
**H = Head; T = Tail; TL = Total.
***The category of landless farmers included 40 farmers from watercourse 3, where the land is owned by the Government of Pakistan and leased to farmers.

Table 20. Area cultivated by sample farmers (n=238).*

Water-course	Acres Cultivated**														
	None			0.1-5.9			6-11.9			12-24.9			25+		
	H	T	TL	H	T	TL	H	T	TL	H	T	TL	H	T	TL
1	0	0	0	9	6	15	9	9	18	1	4	5	1	1	2
2	1	0	1	6	2	8	7	10	17	4	6	10	2	2	4
3	0	0	0	7	8	15	8	4	12	0	1	1	0	0	0
4	1	0	1	3	1	4	8	12	20	7	4	11	0	3	3
5	0	0	0	5	9	14	10	6	16	4	5	9	1	0	1
6	0	0	0	5	8	13	6	8	14	4	2	6	5	2	7
Total	2	0	2	35	34	69	48	49	97	20	22	42	9	8	17

*There were 40 sample farmers on each sample watercourse.
**H = Head; T = Tail; TL = Total.

In response to this inadequate and untimely water supply, many farmers on watercourse 4, especially those located toward the tail, have sold their canal water rights or have developed tubewells. Generally, tail farmers have sold their water rights to head farmers and have dropped out of the warabandi altogether. That so many tail farmers have dropped out of the system for lack of canal water control testifies to the significance of location, in spite of its somewhat diminished importance in the statistical analysis.

Table 21. Formal education of sample farmers (n=231).*

Watercourse	None H	None T	None TL	1-4 H	1-4 T	1-4 TL	5-7 H	5-7 T	5-7 TL	8-10 H	8-10 T	8-10 TL	11-18 H	11-18 T	11-18 TL
1	17	14	31	1	0	1	1	2	3	1	4	5	0	0	0
2	16	17	33	1	0	1	1	1	2	2	1	3	0	1	1
3	14	14	28	0	0	0	1	1	2	1	0	1	0	0	0
4	16	15	31	0	1	1	1	2	3	3	2	5	0	0	0
5	17	16	33	1	0	1	2	2	4	0	2	2	0	0	0
6	9	13	22	1	0	1	3	1	4	5	4	9	2	2	4
Total	89	89	178	4	1	5	9	9	18	12	13	25	2	3	5

Years in School**

*There were 40 sample farmers on each sample watercourse.
**H = Head; T = Tail; TL = Total.

Table 22 indicates that the relationship between location and water control is strongest on watercourse 5. Several factors have combined to create this strong relationship. Watercourse 5 is populated by the poorest farmers of the six watercourses, and the channel is badly in need of repair. It receives only 73 percent of its sanctioned supply of 2.47 cusecs, an amount of water that is insufficient to meet the needs of the more than 800 acres in the command area (Table 14). Furthermore, as Appendix E indicates, the water loss rates increase dramatically as one moves down the watercourse.

Table 22 indicates there is no strong relationship between water control and location within watercourse 3. The analysis reveals the unique circumstances of watercourse 3, where farmers have installed jointly owned, privately managed, cooperative tubewells. These farmers have local organizations to distribute water and control "free riders" within the tubewell organizations. Through conjunctive use of canal and tubewell water, the farmers on watercourse 3 have managed to overcome the generally poor water control provided by the canal system alone (Table 18). In circumventing the _warabandi_, they have substantially overcome locational bias.

The conditions on watercourse 6 (at the tail of the system) are similar to those of watercourse 5, but are more severe. Of 39 farmers asked about use of canal water, 26 reported they had dropped out of the _warabandi_ altogether (Table 16). Furthermore, 12 of these 26 farmers are located at the head of the watercourse. In short, the _warabandi_ water deliveries in watercourse 6 are so inadequate that the importance of location within the watercourse is diminished.

Because caste is a nominal categorical variable, it was not included in the statistical analysis. However, caste was considered one of the potentially important variables which might influence water control. Table 23 reports the distribution of caste among and within watercourses. The Rajput caste dominates within the system as a whole, except on watercourse 6, which is dominated by Jats.

Table 22. Water control, location, and personal attributes.

Watercourse	Correlations	Variables: Land Owned	Area Cultivated	Years in School	Distance from Mogha
1		(40)[3]	(40)	(40)	(39)
	Zero-order[1]	-.03	.01	-.12	-.38
	Partial[2]	-.02	.02	.00	-.36
2		(39)	(40)	(40)	(38)
	Zero-order	-.05	-.14	-.10	-.48
	Partial	-.04	-.10	-.10	-.48
3		(0)	(28)	(31)	(39)
	Zero-order	*	-.25	-.36	.16
	Partial	*	.16	-.32	.12
4		(39)	(39)	(40)	(33)
	Zero-order	.05	-.45	.15	-.42
	Partial	.11	-.47	.02	-.41
5		(40)	(40)	(40)	(37)
	Zero-order	-.31	-.19	.02	-.68
	Partial	-.29	-.16	-.16	-.77
6		(40)	(40)	(40)	(38)
	Zero-order	-.24	-.17	-.09	-.10
	Partial	-.17	-.08	-.05	-.13

*The land on watercourse 3 is owned by the Government of Pakistan and leased to the farmers.

[1]Zero-order correlation: The correlation between water control and the indicated variable without removing the effects of the other variables in the table.

[2]Partial correlation: The correlation between water control and the indicated variable with the effect of all other variables in the table removed.

[3]() indicate the number of farmers.

An examination of caste distribution across watercourses reveals that the Rajputs are particularly dominant on watercourses 1 and 5, where they outnumber all the other castes combined. However, given the contrasts between watercourses 1 and 5, the observed dominance of Rajputs does not appear to be associated with improved water control. Watercourse 1 is water-rich and 27 farmers reported having moderate to good water control. Watercourse 5 is water-poor; none of the farmers reported having good water control and only 16 reported having moderate control. Caste cannot meaningfully be advanced as a rival hypothesis to location in explaining water control differences among watercourses.

Table 23. Distribution of caste across watercourses (n=233).

Water-		Caste*																	
		Rajput			Jat			Dogar			Arain			Kamboh			Other		
course	(n=)	H	T	TL	H	T	TL	H	T	TL	H	T	TL	H	T	TL	H	T	TL
1	(40)	18	16	34	0	2	2	1	0	1	0	0	0	0	0	0	1	2	3
2	(40)	12	3	15	0	2	2	3	8	11	4	1	5	0	2	2	1	4	5
3	(33)	6	5	11	0	4	4	0	0	0	1	1	2	3	6	9	6	1	7
4	(40)	10	6	16	4	6	10	0	0	0	3	4	7	1	2	3	2	2	4
5	(40)	18	11	29	1	0	1	0	5	5	0	2	2	0	0	0	2	1	3
6	(40)	2	3	5	14	16	30	0	0	0	0	0	0	2	0	2	2	1	3
Total		66	44	110	19	30	49	4	13	17	8	8	15	6	10	16	14	11	25

*H = Head, T = Tail, TL = Total.

Watercourse 2 is the one watercourse where a caste group clearly clusters in one location: Rajputs dominate the head of this watercourse, which has relatively good water control. However, this tendency to cluster at the head position does not occur on other watercourses. Thus, there is nothing in the caste distribution within watercourses to suggest that caste membership might explain access to, and control over, water.

Any posited relationship between caste and water control is further weakened by the example of watercourse 3. On this watercourse, a relatively wide range of caste are represented. Yet, the farmers on this watercourse have been able to organize around conjunctive use of tubewell and canal water to eliminate locational bias and achieve greater water control. Furthermore, this watercourse appears to have maintained a great deal of social cohesion. Differences in caste do not appear to have been a significant barrier to collective efforts to improved water control.

E. CONCLUSIONS

The analysis of water control among and within the six sample watercourses suggests that farmer location is the most important influence on the degree to which water control is available to farmers within the Niazbeg system. Other variables advanced as rival hypotheses to location do not emerge as alternative explanations for variation in sample farmer water control. Furthermore, the locational bias maintains explanatory power in the analysis of water control throughout the system. The watercourses in which the statistical analysis failed to reveal the locational bias in sharp relief were those in which the warabandi system had broken down to such an extent that farmers at the head had lost their relatively favorable position or farmers had informally organized to allocate water to overcome the effects of distance from the mogha.

The analysis points to the need for organizational policy that will reduce or eliminate the influence of location. Development of water users associations within watercourses which are capable of over-coming the effects of distance from the mogha is the most plausible remedial action. The farmers along watercourse 3 have already demonstrated how successful such an organization can be if it can provide better water control for individual farmers and if it can control the "free riders" within the system.

Individual farmers on watercourse 3 have been willing to invest in the relatively expensive development of groundwater. Furthermore, because the tubewell organizations safeguard their collective interests against individuals who threaten the organizational agenda, farmers on watercourse 3 have been willing to subordinate themselves to the rules and guidelines of such organizations. In short, the individual and collective interests were made to coincide to provide better water control to the farmers. If farmers are given the incentive and support for developing such organizations around the canal system, the potential for equitably distributing water and improving agricultural production will be greatly enhanced.

V. ORGANIZATIONAL EFFECTIVENESS AND WATER CONTROL IN THE MAIN SYSTEM

A. INTRODUCTION

The main system delivers large volumes of water to the distributaries for further distribution to the watercourses. Public management of the main system has a major influence on the degree of water control achieved at the watercourse and farm levels, where flexibility and timing are of primary importance in meeting crop water demands.

The first indicator of organizational effectiveness is the capacity of the main system to deliver officially sanctioned shares of water to watercourse outlets. In Pakistan, this share is based on several factors, including the size of the command area. One measure of organizational effectiveness is the degree of correspondence between the de jure (officially prescribed) allocations and de facto (observed) water deliveries. High correspondence indicates strong organizational effectiveness, while low correspondence indicates low organizational effectiveness.

A second indicator of organizational effectiveness is the capacity of the main system to control "free riders." If the main system monitors water distribution so that it can sanction water users who attempt to take advantage of other water users and violate prescribed rules for irrigation, then organizational effectiveness is high.

In Chapter IV, it was demonstrated that location dominated water distribution in the Niazbeg system. In the absence of a network of effective local water management organizations to correct locational bias on the distributary and watercourses, it was hypothesized that an organizational void would be filled by social forces that lead to problematic water allocation and maintenance. A hidden, unofficial organization would develop as water control was gained by those who could make unofficial arrangements with main system managers -- arrangements which might serve specific interests at the expense of the larger irrigation system. This unofficial, hidden organization would undermine warabandi allocation rules and undercut legally sanctioned allocations.

Data collected for Chapter V came largely from key informant interviews. Information was gathered from 8 to 10 key informants in the Irrigation Department and key informants (farmers) working on the sample watercourses. Measurements of canal water flows were obtained at strategic points on the Niazbeg Canal, and from the heads of the three minor distributaries and the six sample watercourses. The sections of the analysis using the information communicated by key informants is largely qualitative.

B. ORGANIZATIONAL EFFECTIVENESS AND CANAL WATER CONTROL

It was hypothesized that the greater the organizational effectiveness of the main system management, the greater the canal water control. Water control at the main system level of organization was measured by comparing officially prescribed and observed flows. A delineation of the allocation rules at the distributary level and a description of the positions and roles of the canal managers provide the context for discussing effectiveness of the main system organization.

1. Main System Canal Managers and Roles

Canal water control is the capacity of the main system management to measure and regulate water flows throughout the distributary command area and to maintain the canals in such a way that water can be delivered according to plan.

Engineers, employed as civil service managers, are responsible for managing main system canals so that they deliver sanctioned supplies throughout the command areas under their jurisdiction. The staff employed under their supervision are commissioned to fulfill this mandate. The role set of the Irrigation Department on the Niazbeg Canal includes the chief operations officer or subdivisional officer (SDO) and one sub-engineer or overseer who is responsible for administering the canal from the 45,000' mark (about 8.5 miles from the beginning of Niazbeg Canal) to the end of the Niazbeg Canal. The sub-engineer supervises three to four canal overseers.

These overseers are responsible for canal maintenance, and they regulate canal water flows. They are also responsible for checking watercourse outlets for signs of illegal tampering. Several <u>belldars</u> (laborers) are assigned throughout the system to do the required maintenance work at the direction of the sub-engineer and overseers. There is also one gauge reader sanctioned near the end of the Niazbeg Canal whose responsibility is to daily check the height of the canal flow and communicate these readings to the signaler, who telegraphs them to the sub-engineer in charge and to the SDO's office in Lahore. Changes in the canal water level are made by increasing or decreasing water flows at the distributary outlet. Typically it takes three days for the results of any corrective action to reach the tail of the system.

While the Niazbeg system is staffed to manage water flows, adequate physical structures do not exist with which to control, measure, or monitor water. Although the sanctioned supplies for minors and watercourse command areas are specified, neither main system managers nor farmers have a way to check the actual supply. Field personnel cannot measure the water flow without installing a measuring device, and they rarely do so.

Few engineers or farmers are aware of the exact sanctioned supply. At one point during the research, records dating back to 1931 had to be opened to resolve differences of opinion among engineers about prescribed flows. Farmer informants generally did not know how much water they were supposed to receive, much less how much they were receiving.

When there is so little knowledge of the formally sanctioned allocations and inadequate means to measure and monitor water flow, prescribed flows are likely to differ from water delivered. Because the value of canal water to farmers heavily depends on its adequacy and timeliness to fulfill shifting crop demand, farmers are likely to turn to extra-legal means to gain water control. (Appendix F describes assessment and revenue collection rules currently in force.)

2. Allocation and Distribution Rules

Three rules apply to water allocation at the main system level: 1) a rule for determining the sanctioned supply; 2) a rule for delivering the sanctioned supply; and 3) procedural rules for resolving conflict due to violations of allocation rules. This section explores the correspondence between de jure rules and de facto behavior at the main system level.

Determining the Sanctioned Supply. Table 24 reports the sanctioned and actual supplies at various points in the Niazbeg subproject. Several criteria determine the officially sanctioned supply for the Niazbeg system. First, the Indus rivers system must be able to supply water to the Niazbeg command area without interfering with or reducing water delivery to other command areas. Once this condition is met, then the total cultivable area is established and the amount of irrigation water needed to supply the command area is calculated. A distributary is then designed to command this area; the design typically places maximum delivery capacity at or near the originally calculated de jure requirement.

Table 24. Sanctioned and actual water discharges on the Niazbeg Canal.

	Location (miles)	Sanctioned Supply (cusecs)	Actual Supply* (cusecs)	Percent of Sanctioned Supply Received
Niazbeg head	00.00	213.00	256.90	121
Project head	14.55	123.50	159.00	129
Kamogil minor	18.93	15.97	23.00	145
Watercourse 1	19.40	1.37	2.14	156
Watercourse 2	22.10	1.95	3.33	171
Jalleke minor	29.56	15.62	5.40	35
Watercourse 3	30.23	2.07	1.37	66
Watercourse 4	31.59	4.00	0.82	21
Thatti Uttar minor	33.25	12.99	4.90	38
Watercourse 5	33.80	2.47	1.80	73*
Watercourse 6	35.08	2.50	1.34	54*

*"Actual Supply" is an average of 5-29 measures taken over six weeks at each of the designated locations.

**Three public tubewells pump water into the tail minor.

Allocations for the Niazbeg system were last adjudicated in 1931, when a flow of 3.0 cusecs per 1,000 acres was deemed adequate for the Niazbeg Canal command. The allocation was based on an assumed annual cropping intensity of 75 percent (25 percent of the land was to be irrigated in *kharif* and 50 percent was to be irrigated in *rabi*). The city of Lahore was allocated 195 cusecs of the total distributary flow. Thus, the canal was designed to carry a total allocation of 402.5 cusecs, to be discharged at the Lahore-Niazbeg distributary outlet. According to engineers managing the system, the canal structure could accommodate no more than a 10 percent increase in water level.

Delivering the Sanctioned Supply. The primary responsibility of the main system is the delivery of the sanctioned supply to the watercourse outlets. Table 24 indicates that the main system has not been able to fulfill its obligation to supply the sanctioned water supply to any measured point in the system. The low correspondence between sanctioned and actual deliveries, with oversupply at the head and serious undersupply at the tail, indicates the system is not organizationally effective.

Controlling "Free Riders." Conflict occurs within large-scale irrigation systems when farmers do not obtain their share of sanctioned water or when some farmers obtain more than their share by water theft or by installing unauthorized outlets. In the Niazbeg system, main system managers only become involved in these conflicts if they occur on a watercourse with an official (*pukka*) *warabandi* schedule or if the issues of conflict concern the sanctioned supply at the watercourse outlet. On unofficial (*kutcha*) *warabandi* watercourses, all conflicts must be settled internally without the assistance of the Irrigation Department.

The procedure for gaining main system intervention in conflict resolution can be costly. The aggrieved party must travel to the office of the subdivisional officer in Lahore to make a formal application. If the application is accepted after review by the SDO, it is sent to the Office of the Assessor (*zilladar*). This office, through the local canal supervisors (*patwaris*), investigates the claim and makes recommendations. These recommendations are sent to the SDO office in Lahore for final judgment, which is communicated back to the *zilladar*. The *zilladar* informs the complainant of the decision. If the latter is not satisfied, an appeal can be made to the executive engineer, and then to the superintending engineer. If the decision is still disputed, the case is sent to the civil courts.

Use of the formal grievance procedure, as reported by key informants, indicates that organizational effectiveness for conflict resolution at the main system is low. During 1985 *kharif*, 35 complaints were filed. However, none were filed by farmers; rather, they were filed by laborers who were reporting illegal activities of farmers. None had been followed through to completion, although some cases were in various stages of consideration.

Key informants on the watercourse reported that the biggest problem encountered in water distribution is controlling behavior of influential landlords, who are rarely prosecuted for their breaches of conduct. Some informants noted that the fine is not large enough to deter wealthy farmers from water theft and that influential farmers can pursue appeals for years. Furthermore, small farmers are reluctant to file complaints against larger and more influential operators. Small farmers are not the only ones who are intimidated. One official who had apprehended an influential landlord reported that the violator had warned him that he would lose his position if he pursued the case. According to this informant, influential water users are often successful in obtaining extra-legal supplies of water simply by requesting it from the Irrigation Department.

Such reports suggest that influential "free riders" have more immunity from main system sanctions than do less powerful farmers. Thus, power and wealth appear to undermine organizational effectiveness at the main system level. In short, the main system can neither fulfill its professional mandate to deliver sanctioned water supplies nor can it systematically control "free riders" who pursue their private benefits by violating prescribed allocation rules.

C. CONCLUSIONS

Water control in the main system was measured in terms of the capacity to measure the flow of canal water through the system, the capacity to regulate the flow of canal water to deliver sanctioned water supplies throughout the system, and the ability to maintain the canals to design specifications. The description of the operations of the Niazbeg system indicates that at the main system level, water control is problematic. Officially prescribed supplies did not correspond to water supplies delivered to the six sample watercourses. Furthermore, there is generally a low correspondence between <u>de jure</u> rules for allocating water or resolving conflict and the actual enforcement of the rules. No appropriately designed organization exists to manage water on the distributary.

VI. THE EFFECT OF WATER CONTROL ON AGRICULTURAL PRODUCTION

A. INTRODUCTION

This chapter explores the relationship between water control and three measures of agricultural production: cropping intensity, crop yields, and cropping patterns. It was hypothesized that increased water control is positively related to increased cropping intensities and yields, and choice of more water sensitive crops (compared to drought-resistant crops).

In the face of the locational bias operating within the canal delivery system, Niazbeg farmers have attempted to improve water control by gaining greater access to groundwater through the development of tubewells. Furthermore, farmers have organized around these tubewells, establishing working agreements for cooperatively maintaining tubewell technology and distributing tubewell water. Not only have these farmers improved their individual water control, but they also have created an organizational mechanism for water allocation, channel maintenance, and control of "free riders."

In the Niazbeg system, tubewells are a significant source of irrigation water. Therefore, this report examines the impact of canal water control and tubewell water control on agricultural production.

B. TUBEWELL WATER

Because reduced water control adversely affects agricultural production, farmers can be expected to initiate and support measures that increase water control. One of the primary ways that Niazbeg farmers increase water control is to increase access to groundwater through tubewell development. Moreover, individual farmers organize collectively to purchase and maintain tubewells. They create roles, rules, and tools to manage tubewell technology and to allocate and distribute tubewell water. Tubewells are especially essential to farmers located at the tail of the system where the canal water supply is particularly inadequate and unreliable.

1. Public Tubewell Operation

In the Niazbeg system, public and private tubewells are employed. Public tubewells are operated under control of the Water and Power Development Authority, whereas private tubewells are owned and operated by local farmers -- individual and jointly. Public tubewells were initially installed in the late '60s to lower water tables and to supplement _warabandi_ canal supplies. Water from these tubewells is pumped directly into original watercourses or minor canals.

Officially, public tubewells are supposed to operate 20 hours/day. A tubewell operator is assigned to each government tubewell. His responsibility is to operate the tubewell according to the established schedule or as the tubewell subdivisional officer otherwise dictates. The tubewell operator keeps a daily log of the tubewell operations and records when the tubewell is inoperative because of mechanical or electrical problems, watercourse repairs, or lack of demand for the water. Tubewell operations are not adjusted to make up for times when the tubewell is not operating as scheduled. Operation of the government tubewells is relatively inflexible, and the operators do not regularly adjust pumpage to compensate for variation in canal flows.

De facto public tubewell operations are considerably different from the de jure rules. A review of the 1984 government logs for the 39 active public tubewells in the Niazbeg command disclosed that the tubewells operated on average of 12 hours/day, well below the required 20 hours. On average, public tubewells were inoperative nearly 40 percent of the time; only 17 percent of down time was for the officially scheduled, 4-hour/day rest time.

Because public tubewells are part of the water distribution system controlled at the main system level, they are essentially part of the watercourse warabandi. For purposes of this study, they were considered part of the warabandi and distinct from private tubewells.

2. Private Tubewell Operation

Private tubewells are operated with a great deal more flexibility than public tubewells. If electrical power or diesel fuel is available, water can be applied at any time to meet farmers' demand. Furthermore, because most farmers are within 2,000 ft of their tubewell source, they have considerably less problem with channel water loss. In short, the private tubewells essentially operate on farmer demand.

As expected, the number of private tubewells is greater at the tails than at the heads of the system. The three watercourses at the head of the Niazbeg distributary are served by 17 tubewells, while the tail three watercourses have 36. Private tubewells are major water suppliers, each providing irrigation for 2 to 20 farm units.

Within the sample watercourses, 16 tubewells are located at the heads of the six watercourses, while 37 are located at the tails. Thus, as access to canal water has diminished, the reliance on tubewells has increased.

Three measures were used to compare the contributions of tubewell and canal water to irrigation supplies. First, farmers were asked to estimate the percentages of tubewell and canal water applied to their crops. Second, engineering measurements were made: tubewell discharge, yearly electrical consumption, and acre-feet of water pumped during 1985. Third, farmers were asked to identify acreage irrigated by canal and that irrigated by tubewell.

Taken alone, each of the measures is problematic. Farmer estimates are subject to inaccuracies and engineering measures are unable to reveal the dependency of farmers on tubewell water versus canal water. Together, though, they provide a pattern of evidence not obtained using only one approach.

Farmer estimates (Table 25) reveal a heavy reliance on tubewell water. On the average, sample farmers reported that 73 percent of the irrigation water used by sample farmers comes from tubewells, leaving only 27 percent to come from the *warabandi* surface canal flows. Furthermore, the locational factor is extremely important in determining reliance on tubewell water compared to canal water (Table 25). Farmers at the tails of all six watercourses depend more on tubewells than their counterparts at the watercourse heads -- the average tubewell water supply for all six watercourse head sections was 66 percent, while the tail sections average 81 percent (Table 25). The average amount of tubewell water supplied to the head sections of the first three watercourses was 56 percent, while tubewell water supplied to the tail sections of the last three watercourses was almost 92 percent. Only on the heads of watercourses 1 and 2 do surface canal water supplies exceed tubewell water supplies.

Table 25. Sample farmer estimates of percent of tubewell and canal water applied to *kharif* and *rabi* crops (n=227).

Watercourse	% of Tubewell Water			% of Canal Water		
	Head	Tail	Watercourse	Head	Tail	Watercourse
1	42	66	54	58	34	46
2	49	67	58	51	33	42
3	78	77	78	22	23	22
4	83	93	88	17	07	12
5	52	87	69	48	13	12
6	91	95	93	09	05	07

Engineering measures support farmer estimates. During a one-year period (1985), the water pumped from private tubewells (Table 26) was much higher than generally assumed by key informants in the Irrigation Department. The equivalent continuous discharge from tubewells was found to equal an average of 2.95 cusecs in each watercourse, compared to the average *mogha* discharge of 1.84 (Table 26).

Table 27 summarizes private tubewell pumpage across the six sample watercourses, while disaggregating the data by number of tubewells on each watercourse. The relatively greater reliance of farmers at tail locations stands out. Farmers on the three head watercourses pumped an average of 1,691 acre-feet of tubewell water, while those on the three tail watercourses delivered an average of 2,572 acre-feet to each watercourse.

Table 26. Distribution of surface and groundwater supply (1985).

Watercourse	CCA* (acres)	Avg. Mogha Discharge (cusecs)	Tubewell** Pumpage (cusecs)	Total Supply (cusecs)	Percent Tubewell	Percent Canal
1	457	2.13	1.33	3.46	38.4	61.6
2	650	3.55	4.41	7.76	56.5	44.6
3	413	1.37	1.27	2.64	48.1	51.7
4	799	0.82	5.51	6.33	87.5	13.5
5	824	1.80	2.85	4.65	61.4	38.6
6	832	1.34	2.30	3.64	63.2	36.8
Weighted Average	663	1.84	2.95	4.75	62.1	37.9

*Cultural commanded area.
**Tubewell pumpage expressed as continuous rate of discharge.
Source: Wattenburger et al., 1987, p. 128.

Table 27. Summary of private tubewell pumpage.

Water-course	Number of Private Tubewells	Average Pumping Capacity (cusecs)	Average Yearly Operation (hrs)	Average Daily Usage (hrs)	Total Yearly Pumped (ac-ft)	Equivalent Continuous Discharge (cusecs)
1	3*	0.88	4,584	12.8	961	1.33
2	16**	1.06	2,283	7.1	3,192	4.41
3	2	1.29	4,303	13.5	920	1.27
4	11	1.43	3,389	11.8	3,992	5.51
5	9***	1.30	2,280	7.1	2,061	2.85
6	8****	1.38	1,999	6.3	1,664	2.30
Average		1.22	3,141	9.8	2,132	2.95

*Three tubewells that deliver water to owners only and provide tubewell water to brick factories were not measured and were not included in the calculations.
**Eight tubewells at the tail of watercourse 2 are not included in the <u>warabandi</u> schedule and serve areas not receiving canal water.
***Seven of the nine tubewells which deliver water to watercourse 5 are located outside the command area of watercourse 5. These tubewells primarily provide water to other watercourses. Appropriate adjustments have been made.
****Two tubewells that serve watercourse 6 were not measured; therefore, the contribution of tubewells to irrigation water is underestimated in this table.
Source: Wattenburger et al. 1978, p. 127.

Table 27 indicates that farmers on watercourses with fewer tubewells used each tubewell more hours than farmers on channels with more tubewells. Tubewells on the three head watercourses were used an average of 11.1 hours/day, while the 35 tubewells located on tail watercourses were run an average of 8.4 hours/day. The two tubewells on watercourse 3 were run an average of 13.5 hours/day. Private tubewell water is a primary source of irrigation water for Niazbeg farmers.

Acres irrigated by tubewell and canal water were identified only in watercourses 1, 2, 5 and 6 -- the extreme head and tail watercourse commands. Significant seasonal differences existed in the use of tubewell water compared to canal water (Table 28). While the ratio of tubewell water to canal water used was about 2:1 in _kharif_, it was 3:1 in _rabi_. Furthermore, the data in Table 28 consistently indicate that farmer reliance on tubewell water is greater at the tail locations than at the head in both seasons.

Tubewell water is the primary source of irrigation water for most Niazbeg farmers, particularly in _rabi_. The canal system supplied 9 percent to 64 percent of irrigation water, depending on the season and location in the system; conversely, tubewell water supplied 36 percent to 91 percent of irrigation water.

Table 28. Percent of acreage served by tubewell and canal water supplies (n=126).

Watercourse and Distributary Position	Percent of Acreage Served					
	Head		Tail		Combined	
	Canal	Tubewell	Canal	Tubewell	Canal	Tubewell
Kharif						
Head (1,2)	64	36	43	57	51	49
Tail (5,6)	14	86	13	87	14	86
Total (1,2,5,6)	32	68	32	68	31	69
Rabi						
Head (1,2)	55	45	35	65	44	56
Tail (5,6)	13	87	09	91	11	89
Total (1,2,5,6)	25	75	24	76	25	75

The dependence of Niazbeg farmers on private tubewell water has important policy implications. First, private tubewell water needs to be recognized as the primary water source that it is. Second, if the primacy of tubewell water is recognized, approaches to improving agricultural production through canal _warabandi_ organizational improvements need to be carefully examined. Physical repair of the watercourses will not, by itself, significantly increase farmer water control.

Policy makers also need to seriously consider the organizational implications of the development of private tubewells. Through their cooperative construction, maintenance, and operation of expensive technologies, Niazbeg farmers have demonstrated that they are willing to invest in improved water control and to informally organize to sustain it. They have demonstrated a capacity for entering into long-term mutual agreements through which they allocate and monitor water distribution and control "free riders." This indicates that farmers will create, maintain, and support viable organizations if these organizations can deliver something otherwise unavailable -- in this case, water control. The challenge to policy makers is to recognize farmer capacity for organizational effort in order to improve farmer water control in the warabandi canal system.

A most significant factor limiting farmer control of canal water is lack of appropriately designed organizations for the task. Local farmer organizations could provide a mechanism to remove the locational bias in canal distribution and generate support for canal operations and maintenance from farmers on all locations. Warabandi water is cheaper and generally of better quality than groundwater. If farmers can gain main system support for building the organizational "security zones" that local organizations can provide, they will be able to improve control over canal warabandi water, and improve their capacity for agricultural production. (See Volume 1 for a discussion of design of local organizations.)

C. AGRICULTURAL PRODUCTION AND WATER CONTROL

A central hypothesis is that farmer water control is a primary factor influencing agricultural production and farmers will invest in collective organizational ' 'igation improvements if it benefits them to do so. This section of Chapter VI describes the analysis of the relationship between variation in water control (tubewell and canal) and agricultural production.

1. Agricultural Production Measures

A brief review of the three measures of agricultural productivity (cropping intensity, crop yields, and cropping patterns) follows.

Cropping Intensity. Cropping intensity is defined as the percent of land under cultivation during a particular cropping season or year. If a farmer plants crops on all possible cultivable acreage, the cropping intensity of the farm is 100 percent for the specific season and 200 percent for the year. Researchers investigated the cropping intensity for both kharif and rabi.

Crop Yield. Yields were measured in maunds per acre. A maund equals 37.32 kg, or approximately 82 pounds. The two crops measured for yield were rice (kharif) and wheat (rabi); these measures relied on farmer estimates of yield. Although 97 (42%) of the sample farmers planted rice in kharif, only 79 of these reported yield estimates. Of the 240 sample farmers, 227 (97%) planted wheat in rabi. Information on yields was available for 191 of these farms.

Cropping Pattern. It was hypothesized that the greater the water control, the more a farmer would be likely to invest in high-yielding, more moisture-sensitive crops and varieties. Two measures were devised to test this hypothesis (Appendices G and H). The first is a measure of drought resistance, and the second is a measure of the average seasonal evapotranspiration (ETA) of a particular crop. Drought resistance was based on crop yield reduction in response to a missed irrigation at four cropping phases: growth, flowering, grain formation, and maturity. The average daily evapotranspiration rate differs from the drought resistance measure in that it does not consider plant stress at various growth stages. These two measures were employed in both *kharif* and *rabi* for the respective crop, rice or wheat.

2. Water Control Measures

A scale measuring water control was constructed for tubewell water (Appendix I). The canal water control scale and the tubewell water control scale are described below. Each used somewhat different methods. However, for both canal and tubewell water, water control was defined as the capacity of the individual farmer to apply sufficient quantities of water to crops before crops reached the wilting point.

Canal Water Control Measures. A canal water control scale was designed to measure the quantity, timing, reliability, and adequacy of the water supply. The reliability of the water delivery system indicates the extent to which a farmer can depend on it. While some might contend that reliability as a measure is included in the measures of quantity and timing, note that reliability of supply can be very high when quantity is very low. That is, the farmer can rely on the water never arriving, which is the case for more than 10 percent of the Niazbeg sample farmers. Adequacy of water was measured by obtaining sample farmer estimates of how often they received water sufficient to fill their particular crop's consumptive demand.

Data were obtained by asking farmers questions regarding adequacy of the canal supply. The selection for farmer responses were as follows: "do not receive canal water" (0), "not at all" at a particular stage (1), "little" (2), "moderate" (3), "good" (4), "excellent" (5).

The scale was constructed by summing reported values (0-5) for the quantity, timing, and reliability indicators. The value for canal water sufficiency was squared. It was judged that sufficiency should be given additional weight. The scale was transformed into a "percent of potential," with the resulting coefficients reflecting the percent of total points possible -- ranging from zero to a maximum score of 100 percent.

Table 29 reports that the four variables composing the canal water control scale correlate highly with one another. The component variables are also highly associated with the composite measure, ranging from .69 (reliability) to .88 (sufficiency). Finally, the raw scale composite measure and its transformation into a percent of potential measure show the same high association.

Table 29. Correlation matrix: scale components for canal water control.

	Sufficiency of Supply (n=230)	Satisfaction: Quantity (n=229)	Satisfaction: Timing (n=227)	Satisfaction: Reliability (n=229)	Raw Scale (n=225)	Percent Potential Scale (n=225)
Sufficiency of supply	-	.50	.35	.33	.88	.88
Quantity satisfaction	.50	-	.78	.73	.80	.80
Timing satisfaction	.35	.78	-	.80	.72	.72
Reliability satisfaction	.33	.73	.80	-	.69	.69
Raw scale	.88	.80	.71	.69	-	1.00
Percent potential scale	.88	.80	.71	.69	1.00	-

Tubewell Water Control Measure. In constructing a scale for tubewell water control, somewhat different measures were used than those employed for canal water control. Two timing measures were used. The first was the time required for water to be delivered after being requested. the second measure used was the sample farmer estimate of number of times water was not available when requested. The values for this measure ranged from 0 to 10. If a farmer requested water five times and received it five times, the score was 10; if water was requested five times and was not available one time, the score was 8; and so on. Farmers were also asked to estimate the sufficiency of their tubewell water supplies. Sufficiency values ranged from zero to five (0 = no sufficiency and 5 = totally sufficient). Like the canal water control scale, the values were squared, providing a maximum of 25 points.

Finally, the indicator of reliability was employed on a straight 0-5 scale, ranging from "no tubewell water received" to "always received." Reliability is a genuine issue for tubewell water control since problems with power, mechanical breakdown, and tenuous agreements with the supplier may negatively affect water delivery. A maximum of 56 points was possible, and points were transformed into a percent of potential scale ranging from zero to a maximum of 100 percent of potential tubewell water control.

Table 30 reports strong intercorrelations among the four tubewell water control measures. Coefficients range from .38 to .75. All four measures were highly correlated with the composite tubewell water scale, ranging from .66 (reliability) to .90 (sufficiency).

Table 30. Correlation matrix: scale components for tubewell water control.

	Sufficiency of Supply (n=219)	Timing: Measure 1 (n=219)	Timing: Measure 2 (n=218)	Reliability of Supply (n=220)	Percent of Potential Scale (n=213)
Sufficiency of supply	-	.54	.46	.75	.90
Timing: Measure 1	.54	-	.38	.51	.80
Timing: Measure 2	.46	.38	-	.51	.66
Reliability of supply	.75	.51	.51	-	.79
Percent of potential scale	.90	.80	.66	.79	-

There is almost no correlation between components of the two sets of measures for canal water control and tubewell water control (Table 31). The two types of water control are largely independent of each other among sample farmers.

3. Analysis of Water Control and Agricultural Production

Tables 32 and 33 report results of the analysis of water control and agricultural production for _kharif_ and _rabi_. The six sample watercourses are ranked according to the degree of water control achieved. Rankings disclose the significant difference in water control achieved by farmers on watercourse 3, the highest ranked watercourse, and watercourse 5, the lowest ranked.

Tables 32 and 33 also reveal the important contribution of tubewell water to farmer water control. While the three head watercourses continue to have superior water control compared to the tail watercourses, the locational bias of the canal _warabandi_ is somewhat alleviated by the access to tubewell water within the head and tail sections. Hence, watercourse 3 enjoys the number one rank for combined water control, even though it is ranked third in canal water control. Also, watercourse 6, with an abysmally low degree of canal water control, owes its fifth place ranking almost totally to tubewell water. Without tubewell water, watercourse 6 farmers would be out of business.

Table 31. Correlation matrix: canal and tubewell water control components.

	Tubewell Sufficiency of Supply (n=219)	Tubewell Timing: Measure 1 (n=219)	Tubewell Timing: Measure 2 (n=218)	Tubewell Reliability of Supply (n=220)	Tubewell Percentage Scale (n=213)
Canal sufficiency of supply	-.06	.02	-.19	-.18	-.08
Canal quantity satisfaction	-.22	-.04	-.05	-.21	-.16
Canal timing satisfaction	-.01	.16	.00	-.11	.05
Canal reliability satisfaction	-.01	.14	-.08	.00	.03
Canal percentage scale	-.08	.07	-.15	-.18	-.06

Table 32. Water control and agricultural production: watercourse rankings in *kharif*.

	Water Control Scores			Agricultural Production Scores			
	Combined Water Control (n=207)	Tubewell Water Control (n=213)	Canal Water Control (n=225)	Cropping Intensity Scale (n=234)	Drought Resistance Scale (n=234)	ETA* (n=234)	Rice Yield Maunds/ Acre) (n=89)
Watercourse Rank Order							
3	98.6	74.0	24.6	82.3	288	378	21.4
2	88.5	55.0	33.5	76.2	168**	330	20.4
1	75.6	48.0	27.6	73.9	182**	319	19.5
4	74.8	57.0	17.8	61.8	218	299	16.4**
6	71.3	65.5	5.8	62.6**	153	277	19.4
5	52.1	33.7	18.4	59.5	125	237	19.3
Average	(76.8)	54.5	21.2	69.4	187	306	19.0

*Average evapotranspiration per day.
**Out of expected descending order.

Table 33. Water control and agricultural production: watercourse rankings in *rabi*.

	Water Control Scores			Agricultural Production Scores			
	Combined Water Control (n=204)	Tubewell Water Control (n=210)	Canal Water Control (n=225)	Cropping Intensity Scale (n=234)	Drought Resistance Scale (n=234)	ETA* (n=234)	Wheat Yield Maunds/ Acre) (n=222)
Watercourse rank order							
3	98.7	74.1	24.6	94.5**	206	304	27.5
2	92.2	58.7	33.5	95.5	158	293	27.3
1	80.8	53.2	27.6	91.5	142**	265	25.0
4	75.6	57.8	17.8	81.4**	149	239**	24.2
6	74.2	68.4	5.8	87.5**	146**	262	24.9**
5	54.9	36.5	18.4	87.6	147	257	20.6
Average	(77.3)	57.1	21.2	89.7	158	270	24.9

*Average evapotranspiration.
**Out of expected descending order.

The relationship between enhanced water control and improved agricultural production is also indicated (Tables 32 and 33). While there are exceptions to the expected descending order, substantial differences stand out in the agricultural productivity of watercourse 3 and watercourse 5. In both *kharif* and *rabi*, the differences in cropping patterns is marked. In *kharif*, the difference in cropping intensity is substantial, and in *rabi*, the relationship between water control and yield is even more dramatic than in *kharif*.

Table 33 reveals some other important seasonal differences. For instance, cropping intensity in *rabi* increased by more than 20 percent. This increase was most marked in the tail watercourses. The drop in values in *rabi* is explained by the relative dominance of wheat, a more drought-resistant crop. Because wheat requires less water, the average evapotranspiration is also lower.

Table 34 aggregates the values for the six watercourses to reveal the overall pattern between water control and agricultural production. Water control drops an average of 22.5 points from head to tail for both seasons. The effect on agricultural production is definitive in both seasons: cropping intensities drop, cropping patterns shift from more to less moisture sensitivity, average evapotranspiration drops 12 to 21 percent, and yields are noticeably reduced.

Table 34. Water control and agricultural production by system head and tail, *kharif* and *rabi*.

System Scores by Season	Water Control Scores: Combined Water Control	Tubewell Water Control	Canal Water Control	Agricultural Production Scores: Cropping Intensity	Drought Resis-tance	ETA*	Rice/ Wheat Yield** (Maunds/ Acre)
Kharif (n=207)							
Head (1-3)	88	59	29	78	210	342	20.6
Tail (4-6)	66	52	14	62	165	271	17.6
Rabi (n=204)							
Head (1-3)	91	62	29	94	169	287	26.6
Tail (4-6)	68	54	14	86	147	253	23.2

*Average evapotranspiration.
**Rice yield (n=84); wheat yield (n=202).

Table 35 reports system-level, zero-order correlations of the water control and agricultural variables for *kharif* and *rabi*. (Appendix D clarifies the uses and limitations of the statistics for eta and Pearson's "r"). In the system-level analysis, sample farmer data from all six sample watercourses was aggregated. Location varied from the head-head portion of watercourse 1 to the tail-tail portion of watercourse 6. Such an aggregated approach loses much information compared to the preceding watercourse-by-watercourse analysis. Therefore, statistical coefficients are modest. Nevertheless, certain relationships stand out.

First, at the distributary level, all relationships between water control and agricultural production variables are positive. However, Table 35 indicates that cropping intensity is more affected by canal water control than by tubewell water control. That is, the greater the canal water control, the greater is the cropping intensity. On the other hand, tubewell water control has a greater influence on cropping patterns and yields than does canal water control. Farmers with greater tubewell water control will be more likely to grow moisture-sensitive, high-yielding crops. Furthermore, farmers with greater tubewell water control are more likely to have higher yields.

While these initial findings strongly support the argument that water control is the critical factor determining the limits and potential of agricultural productivity on the Niazbeg distributary, the explanatory potential of other variables needs to be examined. The following analysis examines the impact of water control when controlling for the influences of location and size of landholding.

Table 35. Water control and agricultural production: system-level, zero-order correlations.*

	Kharif				Rabi			
	Canal Water Control (n=220)		Tubewell Water Control (n=208)		Canal Water Control (n=220)		Tubewell Water Control (n=207)	
	(eta)	(r)	(eta)	(r)	(eta)	(r)	(eta)	(r)
Cropping intensity	.38	.35	.23	.13	.18	.24	.20	.13
Rice/wheat yield**	.28	.10	.39	.25	.32	.16	.30	.27
Drought resistance	.20	.15	.36	.29	.24	.18	.26	.20
ETA	.36	.31	.30	.21	.26	.22	.22	.18

*ETA = average evapotranspiration; r = Pearson's "r"; eta = statistical procedure

**Rice yield: Canal water (n=88); Tubewell water (n=85).
Wheat yield: Canal water (n=216); Tubewell water (n=203).

4. Partialing Out Effects of Rival Hypotheses

Tables 36 and 37 report results of a partial correlation analysis of four explanatory variables (canal water control, tubewell water control, location, and size of landholding) on the dependent variables (cropping intensity, yield, and cropping patterns as measured by crop ETA and crop drought resistance).

The partial analysis was performed on the aggregate of all sample farmers representing all positions on all six sample watercourses. Eta and the zero-order Pearson's "r" value express the strength of bivariate relationships between each independent and dependent variables. The partial correlation coefficient expresses the relationship between each independent variable and each dependent variable when effects of all other variables in the tables have been statistically removed.

A review of Tables 36 and 37 indicates that when the effects of location, landholding size, and tubewell water control are removed (Table 36), canal water control in <u>kharif</u> maintains its positive relationship with cropping intensity, loses any relationship with rice yield, and is only slightly related to the two measures of cropping patterns. When the effects of location, landholding size, and canal water control are statistically controlled, tubewell water control is related only weakly to cropping intensity, but is related to an increased degree with rice yield in <u>kharif</u> and farmer cropping choices (i.e., propensity to shift to more water-demanding varieties). This indicates the importance of tubewell organization to the functioning of the irrigation system.

Table 36. System-level, partial correlation analysis of competing explanations for agricultural productivity (kharif).

Independent Variables	Cropping Intensity (n=234)	Rice Yield (n=89)	Cropping Pattern: Drought Resistance (n=234)	Cropping Pattern: ETA/day (n=234)
Canal Water Control				
Eta*	.38	.28	.20	.36
Zero r**	.35	.10	.15	.31
Partial***	.27	.00	.12	.26
Location	.00	.00	.00	.00
Landholding size	.00	.00	.11	.12
Tubewell water control				
Eta*	.23	.39	.36	.30
Zero r**	.13	.25	.29	.21
Partial***	.16	.24	.27	.23
Location	.00	.00	.00	.00
Landholding size	.00	.00	.11	.12

*Eta = the eta statistic (see Appendix D)
**Zero r = zero-order correlation.
***Partial = partial correlation with above four independent variables of canal water control, tubewell water control, location, and size.

When effects of the same potentially rival hypotheses are statistically controlled in rabi (Table 37), canal water control maintains a lower relationship with the three agricultural production variables than was observed during kharif. However low, canal water control maintained a slightly stronger relationship with cropping intensity than did tubewell water control. However, tubewell water control maintained a stronger relationship with wheat yield and the two measures of cropping pattern than did canal water control.

Note that landholding size sustains no relationship with kharif cropping intensity or yields, and only a very weak relationship with cropping pattern. In rabi, a low, but positive, relationship is found between landholding size and wheat yield; whereas larger operators tend to have slightly lower cropping intensities. However, this negative relationship is small and should not be considered significant.

The partial correlation analysis suggests that the original relationships found between water control and agricultural productivity are not significantly altered when controlling for location and size of landholding. Tubewell water continues to have a significant effect on cropping patterns and crop yields, while canal water control is more likely to affect cropping intensities. The influence of both canal water control and tubewell water control on evapotranspiration rates remain roughly equal, although canal water control has more effect in *kharif* and tubewell water control is more significant in *rabi*.

Table 37. Partial correlation analysis of competing explanations for agricultural productivity (*rabi*).

			Cropping Pattern	
Independent Variables	Cropping Intensity (n=234)	Wheat Yield (n=222)	Drought Resistance (n=234)	ETA/ day (n=234)
Canal Water Control				
Eta*	.28	.32	.24	.26
Zero r**	.24	.16	.18	.24
Partial***	.18	.10	.20	.22
Location	.00	.00	.00	.00
Landholding size	.12	.18	-.11	-.19
Tubewell Water Control				
Eta*	.20	.30	.26	.22
Zero r**	.13	.27	.20	.18
Partial***	.17	.27	.24	.24
Location	.00	.00	.00	.00
Landholding size	-.12	.18	-.11	-.19

*Eta = the eta statistic (see Appendix D)
**Zero r = zero-order correlation.
***Partial = partial correlation with above four independent variables of canal water control, tubewell water control, location, and size.

5. Analysis of Water Control and Agricultural Production by Quadrant

The Niazbeg system was subdivided into quadrants. Quadrant 1 included the first 20 sample farmers on watercourses 1 through 3 (head of the head of the system); quadrant 2 included the tail 20 sample farmers on watercourses 1 through 3 (tail of the head); quadrant 3 was composed of the first 200 sample farmers at the head of each of watercourses 4 through 6 (head of the tail); and quadrant 4 consisted of the tail 20 sample farmers at each of the tail positions of watercourses 4 through 6 (tail of the tail). The quadrant groups were intended to disaggregate the sample farmers into units sufficiently large to permit multi-variate analysis, but leave the sample sufficiently disaggregated to perceive rough distributions by location (Tables 38 and 39) -- something not possible in the system-level analysis.

Table 38. Canal and tubewell water control, and agricultural production by quadrant for kharif (Pearson's r).

	Cropping Intensity (n=234)		Cropping Pattern: Drought Resistance (n=234)		Cropping Pattern: ETA/day (n=234)		Crop Yields (n=89)	
Quadrant*	Canal	TW**	Canal	TW	Canal	TW	Canal	TW
1 (head/head)	.38	.07	.07	.38	.34	.22	-.48	.60
2 (tail/head)	.45	.12	.13	.12	.41	.17	.22	.49
3 (head/tail)	.07	.13	.01	.34	.00	.23	.00	.14
4	14	.31	.16	.14	.13	.29	***	***

*Head/head = head of distributary, head of watercourse; tail/tail = tail of distributary, tail of watercourse.
**TW = Tubewell.
***Quadrant 4 farmers did not grow rice due to lack of water supply and control.

Table 39. Canal and tubewell water control, and agricultural production by quadrant for rabi (Pearson's r).

	Cropping Intensity (n=234)		Cropping Pattern: Drought Resistance (n=234)		Cropping Pattern: ETA/day (n=234)		Wheat Yields Maunds/Acre (n=222)	
Quadrant*	Canal	TW**	Canal	TW	Canal	TW	Canal	TW
1 (head/head)	.17	.12	.00	.38	.19	.27	.00	.28
2 (tail/head)	.40	.12	.64	.21	.46	.11	.11	.36
3 (head/tail)	.00	.30	.05	.25	-.13	.29	.00	.40
4 (tail/tail)	.05	.08	.00	.13	.00	.23	.26	.04

*Head/head = head of distributary, head of watercourse; tail/tail = tail of distributary, tail of watercourse.
**TW = Tubewell.

Canal water control sustained a substantial and positive relationship with increased cropping intensities throughout the head of the system during both kharif and rabi. Farmers in quadrant 1 at the head of the system employed their greater canal water control to increase cropping intensity. Tubewell water control had almost no effect on cropping intensities at the head of the system. Rather, tubewell water control appeared to be strongly related to improving yields and to moving to higher-yielding, less drought-resistant crops. This tendency holds for both seasons, but the relationship is stronger in kharif.

In quadrants 3 and 4, the situation is reversed. Tubewell water supplies made irrigation possible over substantial reaches of the tail of the system. Farmers located on these watercourses use tubewell water to increase the amount of land cropped. Apparently, in rabi at least, the access to tubewell water provides enough security to increase cultivated acreage in quadrant 3, but is insufficient in quadrant 4 to induce change in cropping patterns to more moisture-sensitive, but higher-yielding crops.

Table 38 reports that during kharif, canal water control had a negative relationship to yields at the head of the system (quadrant 1) -- tubewell water control made up the difference even in this relatively favored sector of the system. However, except for farmers at the tail of the tail watercourses (quadrant 4), tubewell water control was strongly and positively related to increases in both rice (kharif) and wheat (rabi) yields.

The relationship between canal water control and cropping patterns is substantial for farmers at the tails of the head watercourses (quadrant 2). Here, canal water control appeared to be associated with the cultivation of moisture-sensitive crops. Among all sample farmers in the other three quadrants, canal water control is only weakly associated with cropping patterns. On the other hand, tubewell water appeared to have an important positive relationship with cropping patterns among farmers in quadrant 1 and quadrant 3.

D. CONCLUSIONS

The importance of enhancing farmer irrigation water control in order to improve agricultural productivity is supported by the information presented in this chapter. Furthermore, the significant contribution of tubewell water to enhanced farmer water control is clearly indicated at all locations, and is especially apparent for Niazbeg farmers located at the tail of the system. Clearly, tubewell water is a strategic component of Niazbeg irrigation on the sample watercourses bocause it makes irrigation possible in reaches not well served by canal water and it improved production substantially, even in areas relatively well served by canal water. It is also clear that improvements in canal functioning, by way of improved organizational rules and tools for management of canal water, would do much to improve the conditions of irrigated agriculture.

The hypotheses regarding water control and the three agricultural production variables were supported by this analysis, but with particular qualifications. Canal water control consistently contributed to increased cropping intensities and more water-sensitive cropping patterns at the head of the Niazbeg system, while it had, at best, a weak relationship to crop yields. On watercourses 4 through 6, canal water control had little relationship to agricultural production, while tubewell water control had a strong positive effect on all agricultural production measures.

The contrast between the water control provided by canal and tubewell water delivery systems is extremely important for policy makers and others seeking to improve agricultural productivity. The tubewell delivery system is able to provide increased water control and, hence, increased agricultural productivity because it is locally controlled and managed by the water users themselves. Thus, the degree of flexibility necessary for farmers to apply water in sufficient quantity and in a timely manner is built into the tubewell system. Because of the enhanced water control provided by tubewells, farmers are willing to invest in tubewell construction and maintenance and to provide organizational support to control "free riders." In short, where farmers are guaranteed greater water control, they are willing to submit to organizational rules that enhance collective productivity and well-being.

If organizations adapted to the requirements of managing surface water flows can be built, a vastly improved irrigated agriculture is possible. Pakistani farmers on sample watercourses have already organized in the realm of groundwater.

VII. WATER CONTROL AND CROPPING PATTERNS

A. INTRODUCTION

This chapter further examines relationships between water control and farmer's choice of cropping pattern. When farmers have adequate water control, they are able to cultivate higher-yielding, more moisture-sensitive crops. Without adequate water control, farmers are forced to rely on more drought-resistant, lower-yielding varieties. Yields are, in part, a function of farmers' chosen cropping patterns.

This chapter is divided into three sections. The first examines the relationship between water control and existing cropping patterns. The second examines the shifts in cropping patterns that sample farmers reported would occur if they were to obtain "adequate" water. The third presents an analyses of the relationship between crop water demand and water supply.

B. WATER CONTROL AND CROPPING PATTERNS

Analysis of cropping patterns provides insight into the relationship between water supply and agricultural production. Cropping choices are especially significant to small farmers who need to maximize production on limited acreage. Water-sensitive, higher-yielding varieties promise greater productivity per acre. The capacity to grow more water-sensitive, high-yielding varieties can dramatically improve the wellbeing of all farm families. However, such crop varieties require good water control, which is denied to many Niazbeg farmers by lack of effective local organizations between main and farm systems.

Farmers were asked to identify their existing cropping patterns in kharif and rabi, including the amount of land they left fallow. Existing cropping patterns have been found to differ little from head to tail positions of individual watercourses, suggesting that tail farmers have adjusted to low canal water supplies by developing tubewell organizations to construct and pay for tubewell technology. However, no group of farmers has a completely desirable water situation, and farmers along the tail watercourses are especially vulnerable to lack of water, particularly canal water.

Table 40 reports water control scores for the six sample watercourses. (Measures of water control were delineated in Chapter III, IV, and V). Farmers on watercourses 1, 2, and 3 have relatively high water control, with an average combined score of 87.6 out of a potential score of 200. Farmers on watercourses 4 through 6 were found to have relatively lower water control, with an average score of 67.

Table 40. Ranking of Niazbeg sample watercourses by water control.

Water-course	Tubewell Control (High Score = 100) (n=213)			Canal Control (High Score = 100) (n=225)			Combined Control (High Score = 200) (n=207)		
	Head	Tail	WC*	Head	Tail	WC*	Head	Tail	WC*
3	75	73	74.0	25	24	24.6	100	97	98.6
2	48	62	55.0	36	31	33.5	84	93	88.5
1	45	51	48.0	31	24	27.6	76	75	75.6
Average for 1-3	56	62	59.0	31	26	28.6	87	88	87.6
4	62	50	57.0	21	14	17.8	83	64	74.8
6	70	61	65.5	8	4	5.8	77	66	74.2
5	25	41	33.7	20	17	18.4	45	58	51.5
Average for 4-6	52	51	52.1	16	11	14.0	68	63	66.8
Average for 1-6	54	57	55.5	24	19	21.0	78	76	76.5

*WC = watercourse.

Tubewell control scores are greater than 50 for all watercourses, except watercourses 1 and 5. Tail watercourses 5 and 6 generated higher scores for tubewell water control than watercourses 1 and 2, indicating their relatively higher dependence on tubewell water. Canal water control scores are low for all watercourses. However, canal water control scores at the head of the system are much higher than those at the tail. Thus, the differences in water control scores from head to tail are much greater for canal water control than for tubewell water control. Table 40 also reveals the importance of tubewell water control to tail watercourses, particularly watercourse 6. Tubewell water is essential to irrigated agriculture in all commands, but it is especially the case in the tail watercourses.

1. Water Control and Existing *Kharif* Cropping Patterns

Kharif is a time of high water stress. The Niazbeg subproject area is located on the edge of the desert, where precipitation is low and the monsoon is unreliable. Average maximum temperatures range between 90°F and 105°F. These factors make water control in *kharif* especially critical.

In Table 41, *kharif* crops characterized by higher moisture sensitivity are ranked from left to right in descending order of water demand. Table 42 ranks less moisture sensitive crops. (See Appendix G for the methodology of measuring moisture sensitivity). In other words, the further one proceeds to the right on Tables 41 and 42, the greater is the drought resistance. Each crop in each watercourse was assigned a score representing moisture sensitivity. These crop scores were then summed to a watercourse drought resistance score. The higher the score, the more sample farmers were growing moisture-sensitive (and potentially higher-yielding) crops (Tables 43 and 44).

Table 41. Water control (tubewell and canal) and percent of sample farmer watercourse command area in more moisture-sensitive crops (*kharif*) (n=234).

Water-course	Crop and Moisture Sensitivity Score*								Total % of Crop Acreage**	
	Rice (7.79)		Maize (6.55)		Veg. (5.03)		S/Cane (2.70)			
	H	T	H	T	H	T	H	T	H	T
3	12	10	3	13	19	18	6	2	40	41
2	12	8	4	4	0	2	3	7	19	21
1	11	13	10	7	6	4	0	1	27	25
4	13	20	2	3	4	8	3	5	22	36
6	13	4	7	2	1	21***	14	5	35	32
5	1	1	5	8	0	0	4	6	10	15
Averages										
1-3	12	10	6	8	8	8	3	3	29	29
Head & Tail	11		7		8		3		29	
4-6	9	8	5	4	2	10	7	5	22	28
Head & Tail	8.5		4.5		6		6		25	
1-6	11	9	6	6	5	9	5	4	25.5	28.5

*() indicate moisture sensitivity score for crop; H = Head, T = Tail; veg. = vegetables, s/cane = sugarcane.
**Values do not sum to 100% because some land was in crops reported on Table 42.
***Includes orchard.

The six sample watercourses (Tables 41, 42) were ranked by degree of water control from highest (watercourse 3) to lowest (watercourse 5), and cropping patterns are reported for the head and tail sample farmers on each watercourse.

Results reported in Tables 41-44 support the hypothesis that the greater the water control, the greater is the propensity of sample farmers to select higher-yielding crops. The relationship is most apparent when one compares the pattern of watercourse 3 with watercourse 5. The sums of the crop moisture sensitivity scores (Table 43 and 44) for watercourses 3 and 5 are, respectively, 289 and 120 -- a 2.4:1 ratio expressing the most substantial drop in sample farmer willingness to grow moisture-sensitive crops. Overall, 40 percent of the land in watercourse 3 at the head and 43 percent at the tail was planted in highly water-sensitive crops, while only 10 percent of the land in watercourse 5 at the head and 5 percent at the tail was planted in such crops (Table 41).

Table 42. Water control (tubewell and canal) and percent of sample farmer watercourse command area in less moisture-sensitive crops (kharif) (n=234).

	Crop and Moisture Sensitivity Score*									
	Cotton (1.91)		Sorghum (1.10)		Fodder (1.09)		Fallow (0.00)		Total % of Crop Acreage**	
Water-course	H	T	H	T	H	T	H	T	H	T
3	5	1	10	9	27	29	18	18	60	57
2	7	6	6	5	44	44	24	24	81	79
1	11	5	16	14	34	27	12	30	73	76
4	6	4	6	4	29	15	37	42	78	64
6	1	7	2	6	23	21	39	34	65	68
5	8	11	5	7	23	33	53	34	90	85
Averages										
1-3	8	4	11	9	35	33	18	24	71	71
Head & tail	6		10		34		21		71	
4-6	5	7	5	5	25	23	43	37	78	72
Head & tail	6		5		24		40		75	
1-6	7	6	8	7	30	28	31	31	75	72

*() indicate moisture sensitivity score for crop; H = Head; T = Tail.
**Values do not sum to 100% because some land was in crops reported on Table 41.

Table 43. Water control and cropping pattern as measured by water sensitivity scores: more sensitive crops (kharif) (n=234).

	Sums of Canal Command Crop Scores		
Watercourse	Head	Tail	Average
3	225	259	242
2	128	118	123
1	181	170	176
4	143	229	186
5	190	229	186
6	51	76	64
Averages			
1-3	178	182	180
4-6	128	156	142
1-6	153	169	161

Table 44. Water control and cropping pattern as measured by water sensitivity scores: less sensitive crops (kharif) (n=234).

Watercourse	Sums of Canal Command Crop Scores Head	Tail	Average
3	50	43	47
2	68	65	67
1	76	54	60
4	50	27	39
5	29	43	36
6	47	65	56
Averages			
1-3	65	54	60
4-6	42	45	44
1-6	54	50	52

When one compares cultivable land left fallow in watercourses 3 and 5, one observes (Table 42) that watercourse 3 sample farmers left less than one-fifth of their land fallow (head = 18%, tail = 18%), whereas watercourse 5 sample farmers left 53 percent of their land fallow at the head and 34 percent fallow at the tail reaches.

The distributions horizontally across Tables 41 and 42 show that acreages planted in the more and less moisture sensitive crops do not vary greatly between head and tail reaches of the watercourses. Farmers, with tubewell technology, have reduced the impact of head and tail location on cropping pattern. However, the proportions of cropped acreages (reading down the columns in Tables 41 and 42) reveal that watercourse location on the Niazbeg distributary produces pronounced effects on sample farmer shift to less moisture-sensitive crops (cotton, sorghum, fodder) and to leaving cultivable land fallow. The difference in average moisture score between the three head watercourses and the tail watercourses (180 versus 142) is much less dramatic than the difference between watercourses 3 and 5, but it reveals the general association between loss of water control due to distributary location and cropping pattern shift to less moisture demanding crops (Tables 43 and 44). This suggests a need to improve water control on the distributary in order to organize farmers along the watercourse.

2. Water Control and Existing Rabi Cropping Patterns

A time of cool weather and low evapotranspiration, rabi is the main crop producing season in the Niazbeg subproject area. During rabi, wheat is grown on 57 percent of all the cultivated land. However, more moisture-sensitive crops are also grown, and it is predicted that in rabi, as in kharif, the greater the water control, the greater is the likelihood of increased planting of more moisture demanding crops.

Table 45 supports the anticipated relationship. However, the relationship between water control and the cultivation of moisture-sensitive crops is not as strong in _rabi_ as it is in _kharif_. In _rabi_, watercourses 1 through 3 had a moisture sensitivity score of 177, and watercourses 4 through 6 had a score of 143. (_Kharif_ scores were 289 and 120, respectively.) Thus, the ratio for _rabi_ is 1.24:1 compared to the _kharif_ ratio of 2.4:1.

The water sensitivity scores reported in Table 45 also indicate that the farmers at the tail sections of the head watercourses have benefited from tubewell water development. These farmers have a slightly higher water sensitivity score than their counterparts at the heads -- 178 to 176, respectively. Farmers at the tails of the tail watercourses have a somewhat lower score than those at the heads of the tail watercourses -- 139 to 146, respectively.

Table 45. Water control and percent of watercourse command area in _rabi_ crops, and head-tail moisture sensitivity scores (n=234).

	Crop and Moisture Sensitivity Score*															
	Veg. (6.55)		S/Cane (2.70)		Oilseed (2.27)		Berseem (1.98)		Wheat (1.42)		Oats (1.00)		Fallow (0.00)		Total Score	
Water-course	H	T	H	T	H	T	H	T	H	T	H	T	H	T	H	T
	%															
1-3	6	7	1	1	1	1	20	19	60	57	6	8	6	9	176	178
4-6	1	2	1	1	14	12	10	12	57	50	3	1	14	23	146	139
1-6	4	4	1	1	7.5	6.5	15	15	59	54	5	5	10	16	161	159
Averages																
1-3 (head & tail)	6.5		1		1		19.5		58 5		7		7.5		177	
4-6 (head & tail)	1.5		1		13		11		53.5		2		18.5		143	
Total	4		1		7		15		56		5		13		160	

*() indicate moisture sensitivity score for crop; H = Head, T = Tail, veg. = vegetables, s/cane = sugarcane.

C. WATER CONTROL AND PROJECTED CROPPING PATTERNS FOR _KHARIF_ AND _RABI_

The following analysis, reported in Tables 46 and 47, is based on farmer estimates of cropping changes they would make if they had "adequate" water.

1. Water Control and Potential Cropping Patterns in *Kharif*

Table 46 depicts the potential changes in cropping patterns in *kharif* if sample farmers were to obtain "adequate" water. Data were collapsed for head watercourses 1-3 and tail watercourses 4-6. Crops are listed horizontally by degree of drought-resistance, from more to less moisture demanding. The cropping pattern moisture scores for each watercourse were aggregated to system head (watercourses 1-3) and system tail (watercourses 4-6). Table 46 also indicates the percent of change between the existing cropping patterns and the potential cropping pattern that would result from a hypothetical increase in water availability to a farmer-defined level of "adequacy."

Table 46 indicates that a dramatic shift toward cultivation of more moisture-sensitive crops would occur in *kharif* if sample farmers had "adequate" water. At the time of data gathering, Niazbeg farmers planted approximately 27 percent of their land in moisture sensitive crops. Table 46 reveals that with improved water control, sample farmers would plant approximately 62 percent of their land in water sensitive crops. The largest projected increase would be in production of rice, while the largest decrease would be in production of fodder. Furthermore, cropping intensities could be projected to increase, with the percentage of fallow land dropping from 63 percent to 22 percent.

According to sample farmer reports summarized in Table 46, if Niazbeg farmers were to have "adequate" water supply, the greatest change in cropping patterns and cropping intensity would occur on tail watercourses. The farmers on the tail watercourses would increase their cultivation of water sensitive crops by 258 percent compared to the 210 percent increase among farmers on head watercourses. However, it should be noted that farmers on head watercourses indicate nearly as great as willingness as farmers on tail watercourses to shift from drought resistant to water sensitive crops and to increase cropping intensity. This willingness suggests that all farmers are producing below their desired capacity and would welcome the opportunity to increase cultivation of water sensitive crops and to increase cropping intensity.

Table 47 compares cropping patterns and cropping intensities of watercourse 3 (where farmer water supplies and control is greatest) to watercourse 5 (where farmer water supplies are least favorable). The differences between the two watercourses underscore the significance of the relationship between water control and agricultural productivity.

Table 47 indicates that improved water control would have the most dramatic positive effect on the least advantaged groups of farmers in the Niazbeg area. Given the scenario of "adequate" water, farmers on watercourse 5 projected a 700 percent increase in cultivation of water sensitive crops and a 96 percent reduction in fallow land. In short, with improved water control, the greatest degree of change in cropping patterns and cropping intensity could take place where it is most needed -- at the tail of the system. That watercourse 5 farmers now leave about half of their land fallow during *kharif* testifies to the desperate

Table 46. Water availability and potential cropping patterns for *kharif* (n=233).

Position	Rice (7.19)	Maize (6.55)	Veg (5.03)	S/cane (2.70)	Cotton (1.91)	Sorghum (1.10)	Fodder (1.09)	Fallow (0.00)	CMS Avg.**	% of Change
	Crop Water Sensitivity/Demand*									
	-% of cultivable area-									
Head										
Existing	11	7	8	3	6	10	33	22	2.31	
With "adequate" supply	29	12	10	10	6	8	17	8	4.04	
% change	264	171	125	333	0	-20	-54	-64	175	57
Average										
Existing		29				71				
With "adequate" supply		61				39				
% change		210				-45				
Tail										
Existing	9	5	4	6	6	5	24	41	1.77	
With "adequate" supply	30	10	8	14	4	5	15	14	3.78	
% change	333	200	200	233	-33	0	-37	-65	214	47
Average										
Existing		24				76				
With "adequate" supply		62				38				
% change		258				-50				
Total										
Existing	20	12	12	9	12	15	57	63		
With "adequate" supply	59	22	18	24	10	13	32	22		
% change	295	183	150	266	-17	-13	-44	-65		
Average										
Existing		27				73				
With "adequate" supply		62				38				
% change		230				-48				

*( ) indicate moisture sensitivity score for crop. High moisture sensitivity scores indicate crops that are high in response to a missed irrigation and are, therefore, more sensitive to water stress. Low values indicate crops that are more drought resistant.

**CMS = Crop moisture sensitivity score. High values indicate crops that are high in their response to a missed irrigation and are, therefore, very sensitive to water stress. Low values indicate crops that are more drought-resistant.

Table 47. Water control and cropping patterns (*kharif*) on watercourses 3 and 5 (n=233).

	Crop and Moisture Sensitivity*									
	Rice (7.19)	Maize (6.55)	Veg (5.03)	S/cane (2.70)	Cotton (1.91)	Sorghum (1.10)	Fodder (1.09)	Fallow (0.00)	CMS Avg.**	% of Change
	% of cultivable area									
Watercourse 3										
Existing	12	9	18	4	3	9	28	18	3.01	
With "adequate" supply	18	12	21	12	3	8	17	9	3.90	
% change	150	133	117	300	0	-10	-54	-50	130	77
Existing		43				58				
With "adequate" supply		63				37				
% change		147				-36				
Watercourse 5										
Existing	1	6	0	4	9	7	27	46	1.12	
With "adequate" supply	42	13	4	18	3	5	13	2	5.03	
% change	4200	216	400	450	-67	-29	-52	-96	449	22
Existing		11				89				
With "adequate" supply		77				25				
% change		700				-72				

*() indicate moisture sensity score for crop.
**CMS = Crop moisture sensitivity score. High values indicate crops that are high in their response to a missed irrigation and are, therefore, very sensitive to water stress. Low values indicate cropping patterns that are more drought resistant.

need for improved irrigation organization to enhance water supply and control at the tail of the system. Improving water control could create the security necessary for farmers to take innovative steps on their own behalf.

2. Water Control and Projected Cropping Patterns in Rabi

Table 48 compares the cropping patterns and intensities under existing and "adequate" water conditions during rabi. The values in Table 48 indicate that the water control situation for Niazbeg farmers is much better in rabi than kharif. The degree of correspondence between rabi cropping patterns associated with existing water and those associated with "adequate" water is much higher than kharif for both head and tail watercourse farmers. In addition to more favorable climatic conditions, the improved agricultural situation can partially be explained by strong market demand for wheat. Farmers reported that they would increase their cultivation of wheat if water control situation improved.

With the exception of the increase in wheat cultivation, Table 48 supports the hypothesis that more adequate farm water supplies will lead to increased cultivation of more water-sensitive crops. Overall, there would be a 22 percent increase in cultivation of vegetables and a 250 percent increase in sugarcane cultivation.

The most dramatic change is among farmers on tail watercourses, who projected a 600 percent increase for area in vegetables. Farmers on head watercourses projected a 400 percent increase in sugarcane production, while farmers on tail watercourses projected no increase. In fact, when the projected increases in water-sensitive corps are averaged, the farmers on the head watercourses projected a slightly higher percent of change than did farmers on tail watercourses (Table 48).

The effect of obtaining "adequate" water would differ for different crops. Tables 46 and 48 indicate that head farmers with relatively good existing water control would choose to increase cultivation in sugarcane if they were to receive "adequate" water supply. Tail farmers whose existing water control is relatively poor would choose to increase rice cultivation in kharif and vegetables in rabi. These findings suggest that improved water control might lead to greater crop diversification. While this possibility was not explored by this research, it is worth noting for future efforts.

D. WATER SUPPLY AND DEMAND

Three steps were undertaken to measure water supply and demand. The first established crop water demand in the root zone. The second measured existing supply in the root zone and the third step was to compute a ratio of supply to demand.

Table 48. Comparison of cropping pattern changes under current and "adequate" water supply (*rabi*) (n=233).

	Crop and Moisture Sensitivity*							
	Veg. (6.55)	S/cane (2.70)	Oilseed (2.27)	Berseem (1.98)	Wheat (1.42)	Oats (1.00)	Fallow (0.00)	CMS**
	%							
Head								
Existing	6	1	1	19	58	7	8	1.71
With "adequate" supply	10	4	1	14	63	4	4	1.99
% change	167	400	0	-27	109	-43	-50	112
Average								
Existing		8			92			
Adequate		15			85			
% change		188			- 8			
Tail								
Existing	1	1	14	10	55	2	17	1.42
With "adequate" supply	6	1	14	9	61	2	7	1.82
% change	600	0	0	-10	111	0	-59	128
Average								
Existing		16			84			
Adequate		21			79			
% change		117			106			
Total								
Existing	3.5	1.0	7.5	14.5	56.5	4.5	12.5	1.57
With "adequate" supply	8.0	2.5	7.5	6.5	62.0	3.0	5.5	1.91
% change	229	250	0	-55	110	-33	-56	122

*() indicate moisture sensitivity for crop.
**CMS = Crop moisture sensitivity score.

For purposes of analysis, crop water demand was measured in terms of average seasonal water requirements and peak water requirements (Appendix J). The calculations used to build these measures were constructed from daily evapotranspiration rates. Estimates of peak water requirements for various crop growth phases were derived from Wattenburger et al. (1987, p. 87-90).

Water delivered to the "source" -- the watercourse outlet for canal water and head of the tubewell for tubewell water -- was measured in cusecs. Then, conveyance losses along delivery channels and field application losses were subtracted from the source supply to obtain the actual supply reaching the crop root zone. Efficiency was typically about 60 percent for canal water delivery and 80 percent for tubewell water delivery. Field application efficiencies were estimated to average about 70 percent. The specific methods are discussed in Wattenburger et al. (1987, p. 88).

Three computational steps were used to calculate the difference between water supply and crop demand. First, the total moisture deficit in the root zone was determined. Second, this deficit was transformed into the amount of water required at the watercourse moqha. Third, the amount of supplemental tubewell water available was established and converted into volumes equivalent to canal supplies. This made it possible to compare the ability of canal and tubewell water supplies to fill crop moisture deficits.

1. Demand and Supply for Kharif Crops

Tables 49 and 50 report the demand and supply situation for the cropping patterns of the six sample watercourses in the Niazbeg subproject area. A qualification is in order before proceeding. The boundaries of the watercourse 4 command area were not clearly delineated; tubewells which did not serve the area may have been included in the measurements of water supply, inflating the values for tubewell contribution to the supply of watercourse 4. Because watercourse 4 obtained the least canal supply (.86 cusec), and because many farmers could not obtain canal water, it was difficult to identify with precision exactly those tubewells which contributed to the duly constituted command area. The research team errored on the side of over-inclusion and possibly inflated tubewell supply values.

Tables 49 and 50 report the kharif water demand and supply relationship on the six sample watercourses. The canal water supply at the crop root zone was calculated to equal an average of 42 percent of the canal water supply at the moqha, while the tubewell water supply at the crop root zone was calculated to equal 56 percent of the water available at the tubewell orifice.

According to the data reported in Table 49, the water supply was adequate during average demand periods on watercourses 2, 4, and 5. However, Table 50 indicates that during peak demand periods, only watercourse 4 farmers had water supplies adequate to meet the demand of their cropping pattern. Much water deficit at the root zone occurs because

Table 49. Crop water demand, supply, and deficit for average crop water requirements for existing cropping pattern in *kharif* (n=234).

Watercourse	Crop Demand (root zone)	Supply: Source Canal	Supply: Source TW*	Supply: Root Zone Canal	Supply: Root Zone TW*	Supply: Total Root Zone Supply	Deficit: Total Root Zone Deficit	Deficit: Additional Water Required Canal	Deficit: Additional Water Required TW
	cusecs								
1	1.79	2.24	1.33	0.94	0.75	1.67	0.11	0.25	0.19
2	2.38	3.55	2.21	1.50	1.24	2.73	0.00	0.00	0.00
3	1.38	1.36	1.27	0.57	0.71	1.28	0.10	0.23	0.17
Subtotal	5.55	7.15	4.81	3.00	2.69	5.70	0.20	0.48	0.36
4	2.41	0.86	5.51	0.36	3.09	3.44	0.00	0.00	0.00
5	1.48	1.67	1.43	0.70	0.80	1.50	0.00	0.00	0.00
6	2.41	1.34	2.88	0.56	1.61	2.18	0.23	0.56	0.42
Subtotal	6.30	3.87	9.82	1.63	5.50	7.13	0.23	0.56	0.42
Total	11.86	11.02	14.13	4.63	8.19	12.83	0.44	1.04	0.74

*TW = Tubewell.

Table 50. Crop water supply, demand, and deficit for peak crop water requirements for existing cropping pattern in *kharif* (n=234).

		Supply					Deficit		
		Source		Root Zone		Total Root Zone Supply	Total Root Zone Deficit	Additional Water Required	
Water-course	Crop Demand (root zone)	Canal	TW*	Canal	TW*			Canal	TW
	cusecs								
1	2.34	2.24	1.33	0.94	0.75	1.68	0.66	1.58	1.18
2	3.10	3.55	2.21	1.49	1.24	2.72	0.37	0.88	0.66
3	1.87	1.36	1.27	0.57	0.71	1.28	0.59	1.40	1.05
Subtotal	7.31	7.15	4.81	3.00	1.59	5.70	1.62	3.46	2.89
4	3.42	0.86	5.51	0.36	3.09	3.45	0.00	0.00	0.00
5	2.00	1.67	1.43	0.70	0.80	1.50	0.49	1.17	0.88
6	3.11	1.34	2.88	0.56	1.61	2.18	0.93	2.22	1.67
Subtotal	8.53	3.87	9.82	1.63	5.50	7.13	1.43	3.39	2.65
Total	15.85	11.02	14.63	4.63	8.19	12.83	3.05	6.85	5.54

*TW = Tubewell.

of losses during conveyance and application. If losses could be reduced, the deficit would be diminished, if not eliminated, for all watercourses. Effective farmer organization could do much to reduce such losses.

Recall that crop demand has been much reduced in the area by farmers shifting to less moisture-sensitive crops and by leaving much land fallow. Therefore, calculations of supply in regard to existing demand do not address what demand would be if water supplies and control were to be increased through organizational development.

Furthermore, Table 49 indicates that if conveyance losses could be reduced, canal water alone would be adequate to meet the average existing crop demands of watercourses 1, 2 and 5. However, it would require effective farmer organization to move specific amounts of water to meet specific crop demand. Average figures, in the absence of effective organizations for water allocation, mean little to farmers.

Table 50 reports that water requirements during peak water demand periods are substantially more than average supply. It is during these peak demand periods that the _warabandi_ system is most likely to fail Niazbeg farmers. Even if conveyance losses could be completely eliminated, only watercourse 2 possessed enough water at the _mogha_ to fulfill peak water demands -- which highlights the importance of tubewell water. While a locational bias favoring head farmers has been generally indicated throughout this paper, during peak water demand periods in _kharif_, head farmers actually have a slightly larger total water deficit than farmers located on tail watercourses -- 1.62 cusecs to 1.43 cusecs. This reflects the fact that favorably situated farmers push hard against their water supply constraints by adjusting their crop mixes and intensities.

According to Tables 49 and 50, tubewell water contributes nearly 62 percent of the total supply of water at the crop root zone across the system. Farmers located on the tail watercourses are extremely dependent on tubewell water. Tubewell water supplies 47 percent of the total water available to the crop root zone on head watercourses, while it contributes 77 percent of the total water available to crop root zones on tail watercourses.

2. Demand and Supply for _Rabi_ Crops

Tables 51 and 52 report the average and peak crop demand and water supply calculations for _rabi_. As noted earlier, _rabi_ is a time of relatively cool temperatures and lower evapotranspiration. However, it is also a time when farmers cultivate more land, which increases cropping intensity and water demand. Farmers on the head sample watercourses increased their cropping intensity from 78 percent in _kharif_ to 92 percent in _rabi_, while those on tail watercourses increased their cropping intensity from 60 percent to 83 percent. Tables 51 and 52 indicate that crop water demands increased during _rabi_.

Table 51. Crop water demand, supply, and deficit for average crop water requirements for existing cropping pattern in *rabi*.

Water-course	Demand (root zone)	Supply: Source Canal	Supply: Source TW*	Supply: Root Zone Canal	Supply: Root Zone TW*	Supply: Total Root Zone Supply	Deficit: Total Root Zone Deficit	Deficit: Additional Water Required Canal	Deficit: Additional Water Required TW
	cusecs								
1	1.76	2.24	1.33	0.94	0.75	1.68	0.08	0.19	0.14
2	2.80	3.55	2.21	1.49	1.24	2.73	0.75	1.79	1.34
3	1.42	1.36	1.27	0.57	0.71	1.28	0.14	0.39	0.25
Subtotal	5.99	7.15	4.81	3.00	2.70	5.70	0.97	2.37	1.73
4	2.70	0.86	5.51	0.36	3.09	3.45	0.00	0.00	0.00
5	2.89	1.67	1.43	0.70	0.80	1.50	1.38	3.29	2.46
6	2.68	1.34	2.88	0.56	1.61	2.18	0.50	1.19	0.89
Subtotal	8.26	3.87	9.82	1.63	5.50	7.13	1.93	4.48	3.35
Total	15.25	11.02	14.63	4.63	8.19	12.83	2.90	6.85	5.08

*TW = Tubewell.

Table 52. Crop water demand, supply, and deficit for peak crop water requirements for existing cropping pattern in *rabi*.

Water-course	Demand (root zone)	Supply: Source Canal	Supply: Source TW*	Supply: Root Zone Canal	Supply: Root Zone TW*	Supply: Total Root Zone Supply	Deficit: Total Root Zone Deficit	Deficit: Additional Water Required Canal	Deficit: Additional Water Required TW
	cusecs								
1	2.50	2.24	2.33	0.94	0.75	1.69	0.81	1.94	1.45
2	3.84	3.55	2.21	1.49	1.24	2.73	1.11	2.65	1.99
3	2.00	1.36	1.27	0.57	0.71	1.28	0.72	1.71	1.29
Subtotal	8.35	7.15	4.81	3.00	2.69	5.70	2.66	5.30	4.73
4	3.67	0.86	5.51	0.36	3.09	3.45	0.23	0.54	0.40
5	3.80	1.67	1.43	0.71	0.80	1.50	2.31	5.49	4.12
6	3.43	1.34	2.88	0.56	1.61	2.18	1.25	2.97	2.23
Subtotal	10.91	3.87	9.82	1.63	5.50	7.13	3.78	9.00	6.76
Total	19.25	11.02	14.63	4.63	8.19	12.83	6.44	15.30	11.49

*TW = Tubewell

As a result of the higher water demand in *rabi*, total water deficit at the crop root zone also increased. Table 51 indicates that while approximately 15 cusecs is required to meet average crop water demands at the root zone, only 13 cusecs are being delivered. The deficit is greater in peak water demand periods, when approximately 19 cusecs at the root zone are required (Table 52).

For all six watercourses, the total average deficit at the crop root zone during *rabi* represented a 670 percent increase over that during *kharif* (Table 51 and Table 49). Table 52 indicates a water deficit in *rabi* peak water demand periods that is 200 percent greater than that in *kharif* (Table 52 and Table 50). Furthermore, the additional water required to make up the average water deficit at the root zone during *rabi* nearly equals that required to make up the deficit during *kharif* peak water demand periods.

Reducing the water deficit in *rabi* by increasing supply in order to fulfill observed crop demand would require enormous improvements in water delivery. Such improvements would require organizational development for canal and tubewell water. To provide the 5.08 additional cusecs at the tubewell head, 10 new tubewells pumping an average of 1.05 cusecs 12 hours a day would be needed. This would only meet the average water deficit. To meet peak water demands, more than 11 additional cusecs would be needed. The resources needed to meet that kind of water delivery capacity through individual private means are probably beyond the reach of Niazbeg farmers. A reduction in the gap between water demands and supply will most likely have to come through organizational (physical tools plus social rules) improvements in the local delivery system. These improvements probably cannot be made unless farmers and main system managers build some organizational capacity to manage water at the distributary and watercourse level.

E. CONCLUSION

Cropping patterns are tied to variations in water supply and control in the Niazbeg system. The greater the farmer water control, the greater is the cultivation of high-yielding, moisture-sensitive crops, and the greater is the cropping intensity. These hypotheses were examined in light of cropping patterns under existing water conditions, and cropping patterns under conditions of "adequate" water supply and control projected by sample farmers.

While the sample farmers tended to grow more moisture-sensitive crops at the head than at the tail of the system, there were important exceptions among the individual watercourses. For example, during *kharif*, the percentage of moisture-sensitive crops grown by watercourse 2 farmers was lower than the percentage grown by farmers on watercourses 4 and 6. Variation in the locational pattern suggests that the additional flexibility of water supply and control afforded by tubewell water is essential to farmers on all watercourses, but especially for those at the tail of the system. The data also suggested that farmers with access to tubewell water are better able to meet the water demands of moisture-sensitive crops than are farmers who have relatively good canal water control, but little access to tubewell water.

The analysis indicated that Niazbeg farmers would shift to more moisture-sensitive crops and higher cropping intensities if they had more adequate water supply and control. The shift would be more dramatic in *kharif* when environmental stress becomes very high, due to extreme heat and high evapotranspiration rates. The shift in *rabi* would be significant, but not as dramatic since *rabi* is a relatively mild season and wheat, a more drought-resistant crop, is the preferred crop.

Finally, the analysis indicated that to meet the crop water demands of farmers' optimal cropping patterns, additional supplies of water at both the *mogha* and the tubewell heads would be necessary throughout the system. However, because tail watercourses currently have relatively lower water control, the greatest increase in water supplies would be needed at the tail of the system.

VIII. WATER CONTROL AND ORGANIZATIONAL SUPPORT

A. INTRODUCTION

This chapter explores the relationship between water control and farmer willingness to support the existing watercourse *warabandi* rules and private tubewell organizations. The central hypothesis is that the greater the capacity of the local organization to provide farmers with adequate quantities of timely irrigation water, the greater the propensity of farmers to support that organization.

Almost nowhere are farmers permitted by the nation-state to "own" water; virtually everywhere, water is viewed as belonging to the public domain. Yet, farmers everywhere must pay a share of the cost of water management. These management costs are those incurred where main system management turns water over to the local farmer organizations. They constitute the costs of running the water to farm fields or field outlets. In Pakistan, farmers cannot "own" water any more than in most other nations, but farmers must bear the costs of 1) watercourse allocation, maintenance, and conflict management; and 2) private pumping and distribution of groundwater in the local watercourse command areas.

Control over water in a watercourse is almost always a function of collective organization -- no farmer can go individually into the marketplace and purchase a meaningful unit of water control. Water control comes by virtue of organizing collectively in ways discussed in Volume 1 of this series. Costs of the collective organization to manage surface water or groundwater must be paid, in cash or kind, in a predictable and legitimate manner.

Farmer reliance on private tubewell technology has already been discussed. In response to inadequate control of canal water, farmers have formed private, typically informal, organizations to develop groundwater and to maintain a delivery system among members. A positive relationship was found to hold between access to tubewell organizations and agricultural productivity.

In principle, an individual farmer might well possess the resources to own and manage one or more private tubewells, since tubewell technology is more divisible than the technology of managing surface flows. It is true that in the Niazbeg sample the modal type of tubewell serves only one farm (Table 53). However, it is equally true that a given farm operation is almost always managed by at least several members of a given kinship (*biradari*) group -- a network, however small or large, of fathers, sons, uncles, brothers, and cousins. Generally, therefore, tubewells serving only one farm require informal joint agreements regarding allocating water to fields, choosing crops, maintaining farm ditches, and sharing farm costs. While a tubewell organization serving 20 farms will be qualitatively different from one serving one farm, the word "organization" generally applies in a meaningful sense to even the smallest of organized groups.

Table 53 reports the distribution of private tubewells identified within the command areas of the six sample watercourses. The distribution ranges from tubewells owned by one farmer and serving one farm unit, to tubewells which each serve as many as 20 farm units. Twelve (26%) of the identified tubewells were owned by a single farmer. Single farmer ownership makes up the largest single category of tubewell ownership.

Tabled 53. The distribution of tubewell organizations in the Niazbeg sample watercourses (n=46).

Watercourse	Tubewells Serving 1 - 4 Farm Units				Tubewells Serving 5 - 20 Farm Units				Total No. of Tubewells
	1	2	3	4	5-9	10-14	15-19	20	
1	3	1	1	0	0	0	0	1	6
2	0	3	3	0	1	2	0	0	9
3	0	0	0	0	0	2	2	0	2
Subtotal	3	4	4	0	1	2	2	1	17
4	2	0	0	2	0	2	1	0	7
5*	4	1	1	3	1	1	0	0	11
6	3	1	2	1	3	1	0	0	11
Subtotal	9	2	3	6	4	4	1	0	29
Total	12	6	7	6	5	6	3	1	46

*Eight of the 11 tubewells serving watercourse 5 are situated outside the command area and primarily serve other, adjacent watercourses.

Because tubewells served farmers who were not necessarily in the sample (that is, they were not the first 20 or the last 20 on the watercourse), the number of farmers who were members of one or more tubewell organizations equaled 247, 7 more than the 240 in the original farmer sample. An important fact not reported in Table 53 is that 31 of the 46 identified tubewells served 72 farms (29 percent of the total tubewell sample (n=247), while the remaining 15 tubewells served 175 farms, (71 percent of the total tubewell sample). Obviously, not all farmers benefited equally from tubewell development. While tubewell water can improve water control, the farmers who rely on the 15 high-demand tubewells have more limited water supply and control compared to those who have access to water from the 31 tubewells serving less demand.

B. FARMER WATER CONTROL AND WILLINGNESS TO PAY ORGANIZATIONAL ASSESSMENTS

The three measures of organizational support employed were 1) farmer willingness to pay organizational assessments (canal/tubewell), 2) farmer support of allocation and maintenance rules (canal/tubewell), and 3) the willingness of organization members to control "free-riders" (canal/tubewell).

1. The Cost of Irrigation Water

Farmer willingness to invest in tubewell development rests on their greater confidence that their groundwater investment will correspond with actual water deliveries and with a greater adequacy and timeliness of those deliveries. That is, farmers believe they get the water they pay for. Even if that water is much more expensive per unit than canal water, the water's worth is at least correspondingly greater because it can be better controlled and thereby made more productive.

The cost of tubewell water varies among the parties who benefit from tubewell development. These parties include owners who use their own tubewell water exclusively, owners who lease out some of their tubewell water, and users who lease in tubewell water. Furthermore, the cost per acre-foot of tubewell water at the point of production varies. To explore the relationships, the costs of tubewell water must be compared to the cost of an acre-foot of canal water supplied at the mogha.

Table 54 reports installation dates for 42 private tubewells on the six sample watercourses. Of these 42 tubewells, 20 were installed after 1980. More than one-third of all tubewells on the sample watercourses had been installed between 1983 and 1985. On watercourse 2 alone, eight tubewells had been installed between 1983 and 1985, dramatically increasing farmer access to groundwater in that command.

Table 54. Dates of tubewell installation (n=42).

Watercourse	Before 1980	1980	1981	1982	1983	1984	1985	Date Unknown
1	0	1	0	1	0	1	0	2
2	4	0	1	1	3	3	2	2
3	2	0	0	0	0	0	0	0
4	7	0	0	0	1	1	0	2
5	3	0	0	0	0	0	3	3
6	6	1	0	0	1	0	0	2
Total	22	2	1	2	5	5	5	11

Table 55 reports cost data for 15 private tubewells installed during 1983-85 -- the three years prior to the field research. Original total cost data were available only for eight tubewells. The average cost of a tubewell was about Rs. 36,000 (or $2,250 at the official exchange rate of Rs. 16 to U.S. $1.00). All eight of these tubewells were financed with private farmer resources. In one instance, Rs. 13,000 rupees was lent by relatives. No loan from the government was reported for any recent tubewell installation.

Table 55. Installation and operational costs for 15 tubewells (1983-1985) (n=15).

Date Installed	Tubewell Number	Total Cost (Rs.)	Cusecs Delivered	Electricity Cost/Hr (Rs.)	Maintenance Cost/Hr (Rs.)	Total Elec. & Maint. Cost (Rs.)
1983	201	35,000	0.81	6.26	0.63	6.89
	207	28,000	0.98	7.44	0.74	8.18
	211	-	1.10	7.20	0.72	7.92
	409	35,000	1.41	4.22	0.41	4.64
	608	-	1.14	-	-	-
1984	102	-	1.08	6.04	0.60	6.64
	202	25,000	1.24	5.53	0.55	6.08
	204	30,000	0.98	7.25	0.73	7.98
	208	33,000	1.01	-	-	-
	404	35,000	1.48	-	-	-
1985	209	70,000	1.51	5.91	0.59	6.50
	215	-	1.38	-	-	-
	504	-	1.13	7.69	0.77	8.46
	508	-	1.42	14.28	1.43	15.71
	509		1.49	(17.00)	(1.70)	(18.70)
Average		36,375	1.21	7.18	0.72	7.90

The average quantity of water produced by each of the 15 tubewells was 1.21 cusecs. This average amount was more than the quantity of canal water delivered to the mogha of watercourse 4 and nearly as much as was delivered to the moghas of watercourses 3 and 6. Electricity costs averaged Rs. 7.18/hour; maintenance was estimated to be 10 percent of the electrical charges, or Rs. .72/hour operated. The average total operational costs for the tubewells on which information was obtained equaled Rs. 7.90/hour. Operational costs of the one diesel tubewell (#509) installed in this time period was Rs. 18.70/hour. In summary, the average operational cost for tubewell water to the owner-operator was Rs. 7.90/hour for delivering 1.2 cusecs at the tubewell orifice.

Table 56 displays hourly lease rates charged by owners. The cost of tubewell water for non-owners ranged from Rs. 8 to Rs. 20, with an average cost of Rs. 11.60/hour. Tubewell owners on watercourse 1 charged the highest rates per hour (Rs. 18), while tubewell owners on watercourses 2 and 6 charged an average of Rs. 10/hour. Generally, the differences in assessments reflected differences in the operating capacity of the well -- owners of tubewells producing more than 1.4 cusecs of water charged more than owners of the less productive tubewells. With the exception of watercourse 1, the average operating cost excluding labor to a tubewell owner was Rs. 7.90/hour, providing an average margin of Rs. 3.70/hour.

Table 56. Hourly rate for tubewell water on six Niazbeg sample watercourses, charged by owners to sample farmers (n=141).

Watercourse	(n=)	Number of Sample Farmers in Cost Category Rs.8	Rs.10	Rs.12-13	Rs.14-15	Rs.16-18	Rs.20	Avg. (Rs.)
1	(23)	0*	0	0	9	4	10	18
2	(29)	0	29	0	0	0	0	10
3	(21)	12	0	0	9	0	0	11
4	(9)	0	6	0	0	3	0	12
5	(30)	0	15	14	1	0	0	11
6	(29)	0	29	0	0	0	0	10
Total		12	79	14	19	4	10	11.6

High leasing rates on watercourse 1 are at least partially a result of the presence of a local brick-making industry. Owners of three of the six tubewells on watercourse 1 sold tubewell water to brick-makers who were willing to pay more than the going agricultural rates for the advantage of securing a reliable source of water. The owners of the other three tubewells on watercourse 1 were able to charge farmers more because of the competition for water from the brick-making industry.

Cost Per Acre-Foot: Tubewell and Canal Water. The acre-foot cost of tubewell and canal water is presented in Table 57 (Appendices K and L for a description of the calculation procedures). In brief, the average operating cost per hour, plus the average annual operating time per tubewell and the average delivery in cusecs were employed to derive total operational costs per tubewell. The operating time and delivery in cusecs were then translated into a unit of volume (acre-feet). These figures were based on engineering measures made at the tubewell sites and electricity consumption records.

Data were available for 29 tubewells located on all six sample watercourses (Table 57). A similar method of calculation was used to establish canal water charges. The cropping pattern for the area was used to derive total charges for the summer and winter crops. Mogha outlet discharge measurements were used to calculate the amounts of water delivered, which were translated into acre-feet (Table 57). Cost was then divided by acre-feet delivered. A 20-percent surcharge was added to adjust for the fact that the average watercourse delivery loss is 20 percent higher for canal water than tubewell water. The greater canal losses were due to the greater distances the water traveled in the ditches.

Data in Table 57 support the view that location has little effect on tubewell water costs; the average cost of tubewell water is Rs. 79.95 at the head of the system and Rs. 76.21 at the tail. However, there is generally a much higher correspondence between water charges and water delivered for tubewell water than for canal water. That is, costs of canal water per unit volume rise substantially as one moves from watercourse 1 to watercourse 6. Farmers with less access to canal water pay more per acre-foot of canal water, which does not engender great loyalty to the surface system providing the canal water.

Table 57. Cost per acre-foot (Rs.) for tubewell and canal water.

Water-course	Tubewell Water At Pump Head	Canal Water At Mogha	Canal Water 20% Watercourse Loss Adjustment
1	68.23	9.10	10.92
2	82.64	7.55	9.06
3	89.02	12.41	14.89
Average:Head	79.96	9.69	11.62
4	55.87	37.15	44.53
5	83.24	10.93*	13.79*
6	72.46	35.75*	42.90*
Average:Tail	76.21	27.94	33.76
Total Average	78.09	18.82	22.69

*These figures do not include the public tubewell charges assessed to all farmers on watercourses 5 and 6 who use canal water.

The lower the farmer supply and control of canal water, the greater is the cost per acre-foot. It is a perverse result of existing distributary and watercourse management that costs, supply, and control of canal water are inversely related. In fact, the average costs of warabandi water by volume increased approximately 300 percent from head to tail.

The overall average cost of tubewell water throughout the system is about 340 percent higher than the average cost of canal water. However, on watercourse 4 the cost of tubewell water is only 20 percent more than the cost of canal water.

The selling price for a maund of wheat varies from Rs. 72 to Rs. 85, with an estimated approximate value of Rs. 80. The average production of wheat per acre ranges between 20 and 25 maunds for the Niazbeg area. Selling one additional maund of wheat per acre would cover the average cost of an acre-foot of tubewell water for the tubewell owner, and the sale of 1.5 maunds would cover the average cost of one additional acre-foot for the water buyer.

If production could be increased to 35 to 45 maunds per acre, with increased water control accounting for half or more of that increase, the incomes of farmers could be considerably enhanced. The policy issue is one of redirecting attention to improved water control -- for both canal and tubewell water. Enhanced water control could potentially do much for production, which would permit payment of the organizational costs of producing the increased control while significantly increasing farmer net income.

2. Farmer Willingness to Pay Water Assessments

This section examines farmer support of existing assessment rules and farmer willingness to pay potential assessments for increased water control for canal and tubewell water.

Table 58 reports farmer responses to questions concerning agreement with assessment rules, fairness of the rules, and farmer obedience to assessment rules. These responses were incorporated into a scale to score support for tubewell and canal *warabandi* assessment rules. The assessment rule examined for tubewell organizations is simple: tubewell water charges are to be set by the owners, and they must be paid or water will be denied. The assessment rule for the *warabandi* organization specifies varying water charges for different crops (Table 59). The reader may wish to refer to Appendix F for a more detailed discussion of the *warabandi* water charge system.

Table 58. Number of sample farmers rejecting tubewell and *warabandi* assessment rules (n=202).

Water-course	Tubewell Assessment Rule		Warabandi Assessment Rule	
	No.	Total (%)	No.	Total (%)
1	4	2.0	3	1.5
2	3	1.5	2	1.0
3	0	0.0	1	0.5
Subtotal	7	3.5	6	3.0
4	0	0.0	5	2.5
5	0	0.0	6	3.0
6	0	0.0	13	6.4
Subtotal	0	0.0%	24	11.9
Total	7	3.5%	30	14.9

Farmer acceptance or partial acceptance for a rule was recorded as support. A farmer was considered to reject an assessment rule if he rejected the rule on two of the three criteria. For example, if a farmer agreed with an assessment rule, considered it to be fair, but sometimes disobeyed that rule, the response was measured as support for the rule. However, if the farmer obeyed the rule, but disagreed with it and considered it unfair, the response was recorded as non-support.

Table 58 indicates that farmers with greater access to canal water were less likely to support tubewell water assessments, while farmers who had less access to canal water were more likely to support tubewell water assessments. Seven farmers on watercourses 1 and 2, where there is greater access to canal water, rejected tubewell water assessment rules. None of the farmer respondents on watercourses 3 through 6 did so. In addition, only six farmers at the head of the system rejected the canal _warabandi_ assessments, while 24 farmers at the tail did so.

Table 59. _Warabandi_ canal water use charges for Punjab province (1985-86).

Crop	Rate (Rs.)
Sugarcane	85
Sanctioned garden*	52
Vegetables	55
Tobacco & cotton	33
Rice and water chestnuts	35
Edible cil*	25
Wheat	23
Oats	16
Maize	16
Gram*	15.44
Fodder	16
Fallow with _rauni_ irrigation	6

*From Khan, 1985, p. 16.
Source: Wattenburger et al., 1987, p. 64.

Responses reported in Table 58 also indicate that tubewell assessments have a much higher general acceptance among sample farmers. Only seven head watercourse farmers rejected tubewell assessment rules, while 30 rejected _warabandi_ assessment rules. These findings suggest that there is stronger support for tubewell organizations than the _warabandi_ organizational system. Again, the locational bias was evident; rejection of _warabandi_ rules was most pronounced among farmers at the tail of the system.

3. Farmer Willingness to Pay for Increased Water Control

Farmers were asked about their willingness to invest in two alternatives to increase water control. First they were asked whether or not they were willing to invest in private tubewell development. Second they were asked about their willingness to invest in canal water user associations. Because farmers at the head of the system have good water control relative to their counterparts at the tail, it was expected that farmers located toward the tail of the system would be more willing to pay for increased water control than those toward the head.

To gauge farmer willingness to invest in improved water control, respondents were asked if they would be willing to pay to install a private tubewell. Table 60 indicates that of the 200 respondents, 64 (32 percent) would be very willing to invest in a private tubewell and 59 (29.5%) would be somewhat willing to invest in such an endeavor.

The greatest support was found among farmers located on tail watercourses, particularly watercourse 5 and 6. Seventy-two respondents at the tail of the system reported that they would be somewhat or very willing to make such an investment, while only 26 stated that they would not be willing to do so. Farmers located on head watercourses were equally divided on the question, with 51 somewhat or very willing and 51 not willing to invest in installation of a private tubewell. Interestingly, the lowest support for such an additional investment was found among farmers on watercourse 3, where water control was ranked the highest and where cooperative use of tubewell water and conjunctive use of tubewell and canal water have already provided the best water control, in a relative sense.

Table 60. Farmer willingness to pay for installing a private tubewell (n=200).

Watercourse	Not Willing		Somewhat Willing		Very Willing		Combination of Somewhat and Very Willing (%)
	Number	% of Total	Number	% of Total	Number	% of Total	
1	18	9.0	13	6.5	8	4.0	
2	17	8.5	13	6.5	7	3.5	
3	16	8.0	2	1.0	8	4.0	
Subtotal	51	**25.5**	28	14.0	23	11.5	**25.5**
4	7	3.5	13	6.5	8	4.0	
5	11	5.5	14	7.0	14	7.0	
6	8	4.0	4	2.0	19	9.5	
Subtotal	26	**13.0**	31	15.5	41	20.5	**36**
Total	77	**38.5**	59	29.5%	64	32.0	**61.5**

Table 61 reports findings regarding farmer willingness to pay costs for a mutually owned watercourse or field ditch tubewell organization as an alternative to supporting private tubewell development. Costs of such an organization would be funded by allocating total costs to shares. Each share would allocate its fraction of total water just as each share would obligate its owner to pay its fraction of the organizational costs. The data indicate that there was a great deal of support for such organizational development throughout the system. Of the 206 respondents, 144 (70%) stated that they would be willing to invest in such a collective effort to enhance water control (Table 61). In contrast to the responses concerning potential private tubewell development reported in Table 59, location does not appear to influence willingness to invest in organizational development. Table 61 indicates that head farmers and tail farmers are equally supportive of investing in a mutual ditch tubewell organization.

Table 61. Farmer willingness to invest in a field ditch tubewell organization (n=206).

Watercourse	Not Willing Number	Not Willing % of Total	Somewhat Willing Number	Somewhat Willing % of Total	Very Willing Number	Very Willing % of Total	Combination of Somewhat and Very Willing (%)
1	13	6.3	19	9.2	7	3.4	
2	11	5.3	20	9.7	7	3.4	
3	9	4.4	8	3.9	11	5.3	
Subtotal	33	**16.0**	47	22.8	25	12.1	**34.9**
4	3	1.5	13	6.3	13	6.3	
5	20	9.7	16	7.8	4	1.9	
6	6	2.9	12	5.8	14	6.8	
Subtotal	29	**14.1**	41	19.9	31	15.0	**34.9**
Total	62	**30.1**	88	42.7	56	27.2	**69.8**

While farmers were generally supportive of organizational development of mutually owned tubewells to supplement canal supplies, there were important watercourse differences (Table 61). Farmers on watercourse 5, where water control was the lowest of all sample watercourses, were the least willing to support such a collective effort. Fifty percent of watercourse 5 sample farmers stated they were unwilling to finance a field ditch tubewell organization, while only four (10%) stated that they would be very willing to support such an endeavor. One could speculate that the prolonged water difficulties may have split farmers on watercourse 5 to the point where they distrust collective efforts of any nature.

C. FARMER WATER CONTROL AND COMPLIANCE WITH CANAL ORGANIZATIONAL RULES

It was predicted that greater compliance with canal <u>warabandi</u> rules would be found among farmers along the head watercourses, where canal water supply and control is better, via water exchange. Recall that water exchange increased in the head reaches where canal water was more available (Chapter IV). It was further predicted that there would be little locational difference found in compliance with tubewell organizational rules because it was expected that farmers would attempt to control any who would attempt to take water without payment. Therefore, compliance with organizational rules was expected to be much higher among farmers as members of tubewell organizations than among the same farmers as users of canal water. While farmer "X" might not comply with canal rules where free riding is easier and more difficult to sanction, the same farmer "X" could be expected to fulfill demands imposed by neighbors in an informal tubewell organization.

Table 62 gives the degree of reported sample farmer compliance with canal warabandi rules pertaining to allocation, maintenance, and fee assessment. Compliance was measured by three indicators: agreement with the rule, judgment of the rule as a fair one, and obedience to the rule. Farmers were considered to have rejected a rule only if two of the three responses were negative. That is, if a farmer disagreed with a rule, and considered it unfair, but nevertheless obeyed the rule, the response of the farmer was still reported as a rejection. Because farmers were reluctant to candidly criticize the warabandi system or to openly admit to breaches of official rules, it is likely that the values reported in Table 62 substantially underestimate rejection of rules. Nevertheless, the figures do provide some insight into the distribution of compliance, and the relationship between compliance and location.

Table 62. Rejection of warabandi rules: a measure of organizational support (n=206).

	Allocation Rules		Maintenance Rule	Assessment Rule	
Watercourse	Allocation by weekly time period	Head to tail delivery	Participate in maintenance	Assessment by Irrigation Dept.	Total
1	0	0	0	3	3
2	5	5	0	2	12
3	0	0	0	1	1
Subtotal	5	5	0	6	16
4	5	4	0	5	14
5	10	5	0	6	21
6	17	10	8	13	48
Subtotal	32	19	8	24	83
Total	37	24	8	30	99

Of the 206 farmers responding to questions regarding rejection of warabandi rules, 99 rejected the rules (Table 62). Of these, 83 were located on tail watercourses. These figures strongly support the notion that the greater the farmer's canal water supply and control, the greater the farmer's compliance with warabandi allocation and maintenance rules. Responses reported in Table 62 also indicate that compliance with maintenance rules was not the primary basis for granting or withdrawing organizational support. Allocation and assessment rules were most likely to be rejected.

Table 63 indicates that farmers were more supportive of tubewell organizational rules than canal warabandi rules. Only 19 of 206 farmers rejected tubewell organizational rules. Furthermore, looking at locational differences, farmers on tail watercourses gave only one more rejection response than those at the head, indicating that tubewell organizational support was uniformly distributed.

However, note that more than half of the rejections (10) came from farmers on watercourse 6, and that six of the ten farmers rejected the maintenance rules and four farmers rejected the allocation rule. Half of the watercourse 6 farm units depended exclusively on tubewell water -- the total lack of access to canal water may place additional stress on tubewell organizations. Furthermore, it may be speculated that tubewell owners, given their relatively greater monopoly over water on watercourse 6, have been more abusive of non-owners. Farmers located on watercourses 1 and 2, who enjoy relatively good canal water control, but who are faced with steep tubewell water assessments, are more likely to reject the tubewell assessment rule, than the allocation and maintenance rules.

Table 63. Rejection of tubewell organization rules: a measure of organizational support (n=206).

Watercourse	Allocation Rule: Water delivered upon request		Maintenance Rule: Those who use channels should maintain channels		Assessment Rule: Assessment set by owner bound by local market costs		Total	
	No.	% of Total	No.	% of Total	No.	% of Total	No.	%
1	0	0.0	0	0.0	4	1.9	4	1.9
2	1	0.5	1	0.5	3	1.5	5	2.4
3	0	0.0	0	0.0	0	0.0	0	0.0
Subtotal	1	0.5	1	0.5	7	3.4	9	4.4
4	0	0.0	0	0.0	0	0.0	0	0.0
5	0	0.0	0	0.0	0	0.0	0	0.0
6	4	1.9	6	2.9	0	0.0	10	4.9
Subtotal	4	1.9	6	2.9	0	0.0	10	4.9
Total	5	2.4	7	3.4	7	3.4	19	9.2

A comparison of Tables 62 and 63 indicates that there is much more sample farmer support for tubewell organizations than for the canal *warabandi* system. The greatest rejection of *warabandi* rules came from farmers located on tail watercourses, where canal water supply and control is extremely poor. Good canal delivery must be viewed as an important complement to tubewell water to strengthen the bargaining power of the most disadvantaged farmers. The *warabandi* allocation rules were most frequently rejected, followed by assessment rules. The maintenance rule was the least problematic -- all rejections of this rule came from farmers located on watercourse 6, where maintenance is relatively fruitless given the lack of canal water.

D. FARMER WILLINGNESS TO SUPPORT WATER USERS ASSOCIATIONS

An important dimension of the Command Water Management Project of Pakistan is the establishment of water users associations (WUA). However, the focus of these associations is on improving maintenance without directly connecting maintenance contributions to water delivery. Improved maintenance is seen as sufficient incentive for maintaining watercourse organizations once the watercourses have been rehabilitated by lining some portions and through earthen reconstruction of the rest. Increasing farmer water control is not a consideration in policy circles, although some eagerly discuss increasing water control.

As the foregoing discussion indicated, maintenance as currently organized is not the primary concern of sample farmers. Rather, most are concerned with allocation and assessment rules.

Table 64 reports sample farmer responses to questions regarding their willingness to support a water user association if increased water control were provided by that organization. Specifically, farmers were asked if they would be willing to contribute labor and funds, and provide land if the association could provide them with improved canal water supply and control. The categories of response were "not willing," "somewhat willing," and "very willing."

Table 64. Farmer willingness to support water users associations.

	Form a WUA (n=209)			Contribute Labor (n=208)			Contribute Funds (n=208)			Provide Land n=(208)		
	Willingness:			Willingness:			Willingness:			Willingness:		
Watercourse	Not	Some	Very	Not	Some	Very	Not	Some	Very	Not	Some	Very
Head (1-3)	1	36	66	1	12	93	0	44	62	4	37	65
Tail (4-6)	0	7	96	1	6	95	4	20	76	3	14	82
Total	1	43	165	2	18	188	4	64	140	7	51	150

Virtually all sample farmers stated that they would be somewhat or very willing to support a WUA if such an organization could provide increased canal water control. Of these, 79 percent stated they were "very willing." The sample farmers also indicated willingness to contribute labor, funds, and even land. Of these three support indicators, contributions of labor were most enthusiastically endorsed. However, farmers gave an overwhelmingly positive response to all three support indicators.

Table 64 also supports the anticipated relationship between existing canal water control and support for local water users associations. While a majority of farmers located on head watercourses were supportive of such an organization, they did not generate as a large a majority as did farmers located on tail watercourses.

The findings indicate that Niazbeg farmers are willing to make significant investments in building an organization if such investments lead to increased water control. While farmers are unfamiliar with the strategies and techniques of building _warabandi_ water user associations, some have already demonstrated a capacity for making organized joint agreements to manage tubewells.

E. FLEXIBILITY OF SHARE ARRANGEMENTS, WATER CONTROL, AND ORGANIZATIONAL SUPPORT: THE CONTROL OF "FREE RIDERS"

The "free rider" problem centers on the systematic violation of share distribution arrangements, where one or more persons consume the collectively provided good (e.g., canal or tubewell water) without paying for their agreed-upon share of the cost. The problem of collective goods and "free riders" is discussed in some detail in Volume I. If a member of a watercourse or tubewell organization can violate allocation agreements without suffering any negative consequence, support for the organization will be quickly undermined. Others will join the ranks of "free riders" and take whatever benefits are available without paying the heavy costs. Any individual who then continues to pay costs for benefits received is being exploited. The gulf between _de jure_ rules and _de facto_ behavior will widen. The capacity to enforce joint agreements through sanctions that restrict and punish "free rider" behavior is essential if members are to have confidence in organizational arrangements that are designed to match receipt of benefit with appropriate payment.

The guiding hypothesis for the analysis of this section is this: the greater the water control, the greater is the willingness to control "free riders" to defend the continued production of the collectively produced good -- water control. Because tubewell organizations have the capacity to provide more water control, it is predicted that there will be more farmer organizational support to control "free riders" among members of a tubewell organization than among those same farmers for canal water users.

Tubewell organizations have the capacity to directly control water at the tubewell head. Water can be turned on or off by the operator, depending on the demand of the user and the agreements between owner(s), operators, and users. If a person does not pay his or her assessment, water delivery can be withheld to force compliance. If an owner does not deliver the water, or does not otherwise fulfill the mutually established agreements, the user can withhold payment, seek another source of supply, or even take measures such as establishing another tubewell. In other words, sanctions for breaking tubewell organizational rules can be effectively implemented.

On the other hand, canal organizations, as they existed, are primarily oriented toward mobilizing labor for periodic watercourse maintenance. They have no direct control of the source of supply from the canal. Water flows continuously in the watercourse at whatever level is determined by distant authorities. Each farmer obtains an allocated share of watercourse time per week, not a water quantity; when the farmer's time is up, the warabandi schedule requires that the next farmer take the allocated time-share. Water may or may not accompany this time-share and water cannot legally be turned on or off.

Because there are no watercourse employees on the sample watercourses, each farmer is responsible for seeing that the flow of water to his nukka is not disrupted. If another water user decides to divert some of the watercourse flow outside his scheduled time period -- day or night -- it is the responsibility of the offended shareholder to decide whether or not to take action against the transgressor. If there are watercourse leaks during a farmer's warabandi turn, it is that farmer's responsibility to fix the leaks and restore a full flow. If a farmer chooses to take corrective action when another watercourse user is diverting his supply, destructive conflict may ensue. The matter can be brought to the attention of the local leaders for resolution, but this creates a social disturbance in the midst of people who must live together. Thus, appropriate sanctions for control of "free riding" behavior on canals have not been designed, and those which are available to farmers are not easily enforced.

Table 65 indicates that of the 212 respondents, 98 (46%) identified water theft, or taking water out of turn, as a major problem. The table also indicates that theft is as troublesome for farmers at the head of the head watercourses as for those at the tail. Twenty-five (63%) of the farmers on watercourse 2 identified water theft as a major problem -- more than from any other single watercourse. Apparently, the relatively good canal water control enjoyed by the head watercourses does not deter theft. Given poor local organization, greater water availability simply provides more opportunity for "free riding."

Table 65. Number of sample farmers identifying water theft as a major problem (n=212).

Watercourse	Watercourses: Head (1-3) No.	Total (%)	Tail (4-6) No.	Total (%)	Total (1-6) No.	Total (%)
1	10	4.7	8	3.8	18	8.5
2	13	6.1	12	5.7	25	11.8
3	2	1.0	6	2.8	8	3.8
4	6	2.8	8	3.8	14	6.6
5	9	4.2	10	4.7	19	9.0
6	9	4.2	5	2.4	14	6.6
Total	49	23.1	49	23.1	98	46.2

Table 66 lends further support to the view that tubewell organizations are more effective than canal agreements in sanctioning "free riders." The figures indicate that while a large percentage of farmers expect swift consequences for "free riders" from both the *warabandi* system and the tubewell organizations, they are somewhat more confident of the capacity of tubewell organizations to sanction those who break organizational rules. Furthermore, note that farmers may be reluctant to criticize government operations to outsiders, and thus, may have overstated their confidence in the *warabandi* system's ability to sanction "free riders."

Table 66. Farmer reports of consequences for breaking *warabandi* and tubewell organizational rules (n=205).

	Allocation Rules			Maintenance Rules		Assessment Rules	
	Canal		Tubewell	Canal	Tubewell	Canal	Tubewell
Consequences	Timing*	Order**					
None	11	12	3	6	5	7	4
Delayed	15	6	2	2	12	11	5
Swift	74	72	91	90	83	80	91

*Violation of *warabandi* timeshare.
**Violation of *warabandi* rotational order.

F. CONCLUSIONS

The analysis has supported the hypothesis that water control is positively related to organizational support. This relationship between water control and organizational support was examined in terms of farmer support for *warabandi* and tubewell organizations. Generally, the data revealed that tubewell organizations have been better able to provide increased water control, and therefore, have garnered increased support for organizational rules among the farmer members. However, the analysis also indicates that farmers would be willing to support the formation and maintenance of *warabandi* water users associations if those organizations could ensure better canal water control and would predictably sanction "free riders."

Data indicated that farmers with better canal water control were more willing to accept and support existing *warabandi* assessments than those with relatively poorer water control. In the Niazbeg system, this leads to a locational difference in farmer support of the *warabandi* system: farmers located on head watercourses were more likely to support *warabandi* assessments than are their counterparts on tail watercourses. Furthermore, farmers located at tail watercourses, where water control was found to be relatively poor, were more willing to invest in tubewell development than farmers located on head watercourses.

Generally, farmers were more concerned with allocation and assessment rules than with maintenance rules. The less the farmer water control on the canal, the greater the number of farmers who rejected *warabandi* allocation and assessment rules.

Finally, under existing conditions, tubewell organizations provide much greater flexibility in water control because tubewells allow the farmers direct control of the water at the source. However, if a *warabandi* organization at the distributary and watercourse level could provide increased flexibility, farmers would be in a position to make canal water productive. Greater productivity can create incentive for greater organizational support, which in turn creates greater willingness to control "free riders."

IX. TUBEWELL ORGANIZATIONAL ARRANGEMENTS, WATER CONTROL, AND AGRICULTURAL PRODUCTION

A. INTRODUCTION

This chapter examines private tubewell organizational arrangements for allocating water and maintaining delivery canals within the sample watercourses of the Niazbeg system. The analysis then examines the relationship between tubewell ownership arrangements and farmer satisfaction.

B. TUBEWELL SHARE ARRANGEMENTS

Table 67 reports the distribution of single and joint tubewell ownership arrangements. Of the 47 tubewells in the Niazbeg system, 38 (81%) are individually owned and 9 (19%) are jointly owned. The number of shareholders for each tubewell ranges from two to seven. Ten of the 38 individually owned tubewells supply only one farm unit (which is typically jointly-owned), and 12 serve two or three farm units. The remaining 16 individually owned tubewells provide water to 95 farmers, or an average of six farm units each.

Table 67. Distribution of tubewell ownership (n=47).

Water-course	Individually Owned	Joint Owners			Total No. of Tubewells
		2-3	4-5	6-7	
1	6	-	-	-	6
2	9	-	-	-	9
3	-	1	1	-	2
4	5	-	1	2	8
5	9*	-	1	1	11*
6	9	1	1	-	11
Total	38	2	4	3	47

*Eight of 11 tubewells on watercourse 5 lie outside the command area, but deliver water to 22 sample farmers on watercourse 5.

The nine jointly owned tubewells supply water to about 40 percent of all sample farmers. Each tubewell serves an average of about 12 farmers. Three of the jointly owned tubewells each supply water to more than 20 farmers.

Three types of tubewell water arrangements exist in the Niazbeg system: 1) a farmer may individually own a tubewell and distribute water upon demand to his crops and to the crops of kin and neighbors as he sees fit; 2) farmers may jointly own a tubewell and informally negotiate rules and roles among the ownership group for water distribution, maintenance, and assessment; and 3) farmers who do not own a tubewell may buy shares of water from owners. Finally, there are farmers who have no access to tubewell water.

1. Tubewell Water Allocation Arrangements

Table 68 reports allocation rules of the organizations for individually owned tubewells, as reported by the tubewell owners. Data indicate that 8 of the 38 individually owned tubewells make no deliveries to non-owners, while 12 sell water to non-owner users. Of the 12 who sell water to others, 9 allocate water upon demand of the user (when needed for as long as needed), while 3 tubewell owners require that buyers accept a waiting period. Thus, the primary allocation rule for individually owned tubewell organizations is that tubewell water is provided upon request to users, immediately or as soon as possible.

Table 68. Water delivery by individually owned tubewells (n=42).

	Water Delivered to Owners		Water Delivered to Non-owners		
Watercourse	Water supplied when needed as long as needed	Other	No Delivery	Water supplied when needed as long as needed	Water supplied when needed with wait
	number of tubewells				
1-6	22	0	8	9	3

Table 69 reports allocation rules for jointly owned tubewells. The allocation rule for eight of the nine jointly owned tubewells is that water allocations are based on amount of shareholder investment. For shareholders of Tubewell 652, the allocation criterion is acreage owned. The method of allocation for all jointly owned tubewells, except those on watercourse 3 is rotation without exchange.

The prohibition of exchange fixes the delivery schedule, and is similar to the _warabandi_ rotation rule for allocating canal supplies. It enhances the reliability of the water supply in that farmers know when water will be delivered, but it reduces the flexibility needed to meet varying crop water demands. Because tubewell water is expensive, and because these farmers rely heavily on the public watercourse to convey water, tubewell owners run the tubewell water to its users along with canal water to minimize losses to channel wetting. Therefore, canal water constraints affect these tubewell delivery patterns.

Watercourse 3 is the only watercourse where tubewell organizations allocate strictly on demand to owners and non-owners alike. This is possible because canal water deliveries are minimally adequate over most of watercourse 3. As a result of this allocation rule, watercourse 3 farmers have comparatively more flexibility in water allocation. Flexibility is also enhanced because two owners of Tubewell 327 allow exchange within rotation schedules. Because watercourse 3 farmers have developed allocation rules which enhance flexibility of water distribution, they are better able to meet varying crop water demands, even though two tubewells serve more than 30 farmers. Not surprisingly, watercourse 3 farmers have the highest yields, the greatest cultivation of more water sensitive crops, and the highest cropping intensities in _kharif_.

Table 69. Allocation rules for jointly owned tubewell organizations as reported by sample farmers (n=9).

Tubewell Number	Number of Owners	Number of Users	Allocation Rule	Method of Allocation	
				Shareholders	Non-shareholders
326	4	17+	Amount invested	Demand/wait	Demand/wait
327	2	16+	Amount invested	Rotation with exchange	Demand/wait
428	7	10	Amount invested	Rotation without exchange	*
429	6	15	Amount invested	Rotation without exchange	*
430	7	12	Amount invested	Rotation without exchange	*
540	6	12	Amount invested	Rotation without exchange	Rotation without exchange
541	4	8	-	-	-
652	3	6	Acres owned	Rotation without exchange	Rotation without exchange
655	3	3	Amount invested	Rotation without exchange	*

*No information available.

2. Tubewell Organizational Maintenance Arrangements

Table 70 reports the distribution of private ditches for individually owned tubewells and identifies the degree to which these ditches correspond to those of the _warabandi_ system. Of 40 sample tubewells for which information was clear and unambiguous, 12 used the regular watercourses to carry tubewell water and 17 employed farmer-constructed, private ditches, which were completely separate from the _warabandi_ ditches. Three tubewells used canal _warabandi_ and private ditches in nearly equal proportion, and eight tubewells were heavily, but not exclusively, dependent on _warabandi_ ditches. The distribution of reliance on private ditches for jointly owned tubewells was found to be approximately the same as for those which were individually owned.

The degree to which tubewell shareholders use the *warabandi* delivery structures is locationally skewed, however. Private tubewells on the head watercourses use the regular watercourses for water delivery more than those on tail watercourses. Twelve tubewells on watercourses 1-3 use the main watercourse as the primary carrier while only eight did so on watercourses 4-6 (Table 70). At the tail of the system, the situation is reversed. Sixteen tubewells on watercourses 4-6 were served by private ditches separate or partially separate from *warabandi* channels, compared to four tubewells on the head watercourses. Tubewells toward the tail of the system tended to bypass public watercourses which had fallen into disrepair. Tubewell owners and lessors have dug their own ditches to more directly serve their needs.

Table 70. Nature of ditches for individually owned tubewells (n=40).*

Watercourse	No. TWs served by public watercourse	No. TWs served mostly by public watercourse	No. TWs served by public WCs and private ditches in equal proportion	No. TWs served only by private ditches
1	4	1	-	-
2	4	1	1	3
3	2	-	-	-
4	-	5	-	6
5	-	-	2	3
6	2	1	-	5
Total	12	8	3	17

*TW = Tubewell, WC = Watercourse.

The difference in use of *warabandi* delivery channels has implications for organizational maintenance rules. Regular public *warabandi* channels are maintained through the *warabandi* organization and because of silt in canal water, tend to require more maintenance than separate tubewell ditches. The informal tubewell organizations are, of course, responsible for maintaining private ditches, which tend to have more problems with vegetation than with silting.

Table 71 reports arrangements for tubewell delivery channel maintenance for both individually owned and jointly owned tubewells. Tubewell owners in joint arrangements tend to clean their channels every 1-2 months, more frequently than individually-owned tubewells. This may be because jointly owned tubewells are more dependent upon regular public watercourses, which experience greater silting problems. Running the more expensive tubewell water through such channels may create greater incentive to clean. Owners of jointly owned tubewells cooperatively maintain common ditches, while individual water users maintain the ditches within their individual property boundaries.

Table 71. Organizational arrangements for maintaining tubewell delivery channels.

	Frequency of Channel Cleaning (n=28)			Who Cleans and and Repairs (n=31)	
	Every 4-6 months	When needed	1-2 months	User responsible	Jointly with common ditches
Individual ownership	5	5	10	18	4
Joint ownership	1	1	6	2	7

C. TUBEWELL OWNERSHIP ARRANGEMENTS AND FARMER SATISFACTION

To measure farmer satisfaction, sample farmers were asked to rank their satisfaction with the quantity, timing, reliability, and maintenance for canal and tubewell water delivery systems. A scale consisting of six ranks was employed:

0 = no tubewell/canal water received
1 = not at all satisfied
2 = poor
3 = average
4 = good
5 = excellent

Table 72 reports sample farmer responses regarding satisfaction with canal and tubewell water arrangements. Data indicate that farmers were more satisfied with tubewell organizations than with canal organizations. In fact, the differences in degree of reported satisfaction are dramatic in all dimensions except maintenance.

Table 72. Percent of farmers in categories of satisfaction with canal and tubewell water control.*

Level of Satisfaction	Quantity Canal (219)	Quantity TW** (212)	Timing Canal (218)	Timing TW (213)	Reliability Canal (218)	Reliability TW (212)	Quality Canal (0)	Quality TW (210)	Maintenance Canal (221)	Maintenance TW (207)
No water	6	5	6	5	6	5	-	5	6	5
Not at all	25	0	17	1	23	1	-	0	6	1
Poor/little	51	1	35	3	46	6	-	1	6	0
Moderate	14	31	31	27	15	29	-	58	20	19
Good	4	62	11	60	10	55	-	33	62	72
Excellent	0	2	0	4	0	4	-	3	0	3

*() = Indicate number of farmers responding to question.
**TW = Tubewell.

No formal measures were made of farmer satisfaction with canal water quality. However, in the pre-testing and staff training period, farmers indicated a high degree of satisfaction with the quality of canal water. Not only did they indicate that canal water is generally very low in salt content, but they reported that the canal water silt enriched their soils. The quality of tubewell water was judged to be poor by only 1 percent of the respondents, 58 percent reported moderate satisfaction, and over one-third rated tubewell water either good (33%) or excellent (3%). For the most part, farmers were known to prefer canal water to tubewell water if they could obtain it.

Farmer satisfaction with the maintenance of public canal and private tubewell ditches was relatively high -- 62 percent for _warabandi_ share arrangements and 75 percent for tubewell ditch maintenance. However, 12 percent of the farmers ranked watercourse maintenance poor or not at all satisfactory, while only 1 percent did so for tubewell ditch maintenance.

In summary, farmer satisfaction with the quantity, timing and reliability of tubewell water delivery -- and to a lesser extent, maintenance -- far exceeds satisfaction with canal water delivery. Tubewell water share types - with a demand or quasi-demand structure - provide greater farmer water control than the "rotation of turns without exchange" share type of the _warabandi_. Jointly owned tubewells also supply water on rotations without exchange. The difference in farmer satisfaction lies in the fact that it is unlikely that a tubewell rotation turn would come and go without any water actually being delivered, which is frequently the case in _warabandi_ delivery in tail locations.

D. CONCLUSIONS

This chapter examined the different types of private tubewell organizational arrangements for allocating water and maintaining delivery channels in the sample watercourses. The examination revealed that private tubewell organizations located on tail watercourses are virtually autonomous from the existing _warabandi_ system, while tubewell organizations located on head watercourses use _warabandi_ delivery channels to distribute tubewell water. Allocation and maintenance rules for tail tubewell organizations are more informal and established among the shareholders of the tubewells, while the rules for the head tubewell organizations are determined to a greater degree by the _warabandi_ rules for canal maintenance. Problems with delivering and allocating canal water can significantly affect delivery and allocation of tubewell water. Breakdowns in canal _warabandi_ organization undercut the potential of the relatively expensive tubewell water. A healthy and productive irrigated agriculture requires effective local organization(s) to support canal and groundwater use.

The analysis of farmer satisfaction with canal _warabandi_ water compared to tubewell water revealed that farmers are consistently more satisfied with the water control provided by tubewell organizations as measured in terms of quantity, timing, reliability, and maintenance.

X. SUMMARY AND CONCLUSIONS

This report presented the results of a study on the *warabandi* irrigation system in the Niazbeg subproject area in Punjab, Pakistan. The research tested hypotheses related to farmer water control and agricultural production using engineering and sociological data gathered from a sample of 240 farmers representing head and tail locations on each of six sample watercourses. The selection of the six sample watercourses and the 240 sample farmers was guided by the need to maximize variance of location within the Niazbeg system. Therefore, the head and tail watercourses of the head, middle, and tail minors were selected; from these watercourses the head-most and tail-most farmers were selected. Interviews with key informants from the Irrigation Department and the farmer population also provided sociological information. The findings of the Niazbeg research support the general thesis that local farmer organization is a key to improved farmer water control and, hence, to improved agricultural production.

A. FARMER WATER CONTROL, LOCATION, AND INDIVIDUAL ATTRIBUTES

In the absence of an effective local farmer organization, it was hypothesized that location would dictate the distribution of canal water to the farmers. In short, the greater the distance from the source of water supply, the less would be the farmer water control. This hypothesis was tested against potentially rival hypotheses to determine the effect that other farmer attributes might have in explaining variation in water supply and control. These included land owned, land operated, formal education, and caste. A partial correlation analysis demonstrated that these individual attributes could not account for variation in water supply and control. That is, farmers located at the tail of the system received less water than their counterparts at the head of the system, and they did so without regard for land owned or cultivated, education, or caste affiliation. This locational bias was revealed among and within watercourses.

While the relationship between location and farmer water control was strong, the data also indicated that the *warabandi* distribution system provides poor water control for all farmers on the Niazbeg system. Although head watercourses received water in excess of their de jure allocations, the timing and reliability of water was low. Even on relatively water-rich watercourses, farmers could not meet the varying crop water demands. Many farmers on the water-poor tail watercourses had dropped out of the *warabandi* system altogether, irrigating their crops exclusively with private tubewell water.

B. WATER CONTROL AND ORGANIZATIONAL EFFECTIVENESS AT THE MAIN SYSTEM

Water control was measured by the capacity of main system personnel to measure and regulate water distribution through both engineering devices and social organizational mechanisms to control "free riders."

Organizational effectiveness was indicated by correspondence between *de jure* and *de facto* allocation and distribution rules.

The analysis of water control and organizational effectiveness at the main system level indicated that there were inadequate measurement and regulation structures with which officials could gauge or alter water deliveries to the distributary or watercourses. Furthermore, the organizational structure for grievance procedures was cumbersome and ineffective. Watercourses at the head of the system received water supplies in excess of *de jure* allocations, while watercourses toward the tail of the system received less water than officially allocated.

C. WATER CONTROL AND AGRICULTURAL PRODUCTION

The analysis of the relationship between water control and agricultural production (as measured by cropping intensities, cropping patterns, and crop yields) revealed the importance of private tubewell organizations within the Niazbeg system, as well as the degree to which tubewell water control contributes to farmer productivity.

The analysis indicated that the decrease in canal water control at the tail of the system was associated with an increase in groundwater development through tubewell technology and organization. Furthermore, the analysis revealed that tubewell water is a critically important source of irrigation water. Slightly more than one-third of the water supply for the six sample watercourses was provided by canal water and almost two-thirds was supplied by tubewells. Even watercourses at the head of the system revealed a slight predominance of tubewell water over canal water supplies, while many farmers on tail watercourses relied exclusively on tubewell water.

The most significant relationship found was between water control and cropping patterns. Farmers with better water control were more likely to cultivate more moisture sensitive and potentially higher-yielding crops. Furthermore, the availability of tubewell water appeared to be the critical factor in determining farmer cropping patterns. Those farmers with high tubewell water control were more likely to cultivate moisture sensitive crops than those with highest available canal water control, indicating that the flexibility of timing provided by tubewells is more important than simple quantity.

Yields were considerably higher when farmers had better tubewell water control. This measure was at least partly a function of shifting cropping patterns to higher yielding varieties. Interestingly, cropping intensities were found to be inversely related to farmer water control. However, this finding is consistent with the hypothesis that farmer water control is associated with greater agricultural productivity. Farmers with low water control are more reliant on drought-resistant, lower-yielding crops. They tend to compensate for lower yields by cultivating a larger percentage of their land.

D. FARMER WATER CONTROL AND ORGANIZATIONAL SUPPORT

The guiding hypothesis for the relationship between farmer water control and organizational support was that the greater the farmer water control provided by an organization, the greater would be the farmer support for organizational arrangements and rules. The measures of organizational support were 1) farmer willingness to pay for water control, 2) farmer support of organizational rules, and 3) farmer willingness to control "free riders." A comparison of farmer support for _warabandi_ organizational arrangements and for private, informal tubewell organizations was provided.

The analysis indicated that farmers throughout the Niazbeg system give little support to _warabandi_ assessment, allocation, and maintenance rules. Also, the support was considerably weaker among farmers at the tail of the system than at the head. Thus, organizational support for _warabandi_ rules paralleled the locational bias in water control. The greater the distance from the canal water source, the less was farmer water control, and the less was farmer support of _warabandi_ rules. Canal water unit costs jumped markedly as supply and reliability declined. This a perverse outcome of the system.

The _warabandi_ organizational rule which farmers were least likely to support was the assessment rule. The rule they found least problematic, and were most likely to support, was the maintenance rule. The assessment rule is most problematic for farmers because they are charged according to units of time, regardless of whether or not water is delivered during their allocated time.

Sample farmers indicated more support for tubewell assessment rules than for _warabandi_ assessment rules. Even though the price per unit of tubewell water is considerably higher than that of _warabandi_ water, farmers were supportive because they are relatively certain to receive the water for which they have paid. Seventy percent of farmers stated they were willing to invest in water control by financing a field ditch or a collectively owned tubewell. Consistent with the locational patterns of water delivery, farmers at the tail of the system were somewhat more willing to make such an investment than those at the head. Thus, the analysis indicates that farmers are quite willing to invest in cooperative organizational ventures if they thereby gain improved water control.

It was hypothesized that organizational arrangements leading to increased water control were positively related to increased capacity to control "free riders." The hypothesis was supported in a comparison of "free rider" control by the _warabandi_ system and by private tubewell organizations. Sample farmers were more capable of sanctioning, and were more willing to sanction, those who would abuse the allocation arrangements of tubewell organizations than those who abused the _warabandi_ allocation rules.

Sample farmers gave _warabandi_ maintenance rules nearly as much support as they gave to tubewell maintenance rules. It appears that since farmers give more support to maintenance rules (which they establish and enforce among themselves) than to allocation and assessment rules (established and enforced by the main system bureaucracy), farmers are more likely to support organizational rules which they have collectively agreed upon among themselves.

E. FLEXIBILITY OF ORGANIZATIONAL SHARE ARRANGEMENTS, WATER CONTROL, AND AGRICULTURAL PRODUCTION

The relationship of organizational share arrangements to water control and agricultural production was examined. Four different share arrangements were rated on a scale from high to low control: 1) tubewell ownership supplied on demand, 2) tubewell water supplied upon request from non-owner to owner, 3) joint ownership, in which water shares are allocated by rotation without exchange, and 4) canal water supplied by the *warabandi* system (water shares are distributed by time rotation without exchange). These four share arrangements were related to the three measures of agricultural production.

Water control was positively related to agricultural production. Consistent with earlier analysis of agricultural production, cropping intensity was an exception to this pattern. Those with lower flexibility and lower water control tended to have higher cropping intensities. Farmers with poor water control tended to adapt by cultivating a larger percentage of their land in an attempt to compensate for the lower yields of their drought-resistant crops.

Perhaps the most dramatic indicator of farmer organizational support was that farmers were more satisfied with the water control afforded by their tubewell organizations than with that provided by the *warabandi* canal system. The analysis of farmer satisfaction indicates that while farmers were generally satisfied with maintenance provided by the *warabandi* and tubewell organizations, the differences in their satisfaction with quantity, timing and reliability was substantial -- an average of 62 percent satisfaction with tubewell water control compared to an average of 8 percent satisfaction with that of the *warabandi*.

F. IMPLICATIONS FOR POLICY

This research revealed the importance of farmer water control for agricultural production in the Niazbeg subproject area in Punjab, Pakistan. Moreover, it indicated the importance of local farmer organization in achieving improved farmer water control and in providing a mechanism for conflict resolution among farmers of the Niazbeg system.

Farmer organizations at the distributary and watercourse level can provide a mechanism for equitably and efficiently distributing irrigation water within the system. Through local organizations (with the attributes advanced in Volume 1), farmers can better meet their crop water demands and improve agricultural production by cultivating more water sensitive crops that are potentially higher yielding. Furthermore, local organizations provide farmers with a mechanism for immediately sanctioning those who would be "free riders" in the water delivery system.

Without adequate local farmer organizations, irrigation water follows the dictates of location. In the Niazbeg system, canal water control increasingly diminishes for farmers located towards the tail of the system, affecting not only adequacy of supply, but also adequacy of timing and reliability. Among the six sample watercourses selected for this study, farmers on tail watercourses have such poor water control that they have dropped out of the warabandi altogether. While watercourses at the head of the system were found to be relatively water-rich in terms of total quantity of water received, the farmers on these watercourses nevertheless suffered from untimely and unreliable supplies. Some farmers responded to this poor water control by circumventing warabandi rules, thus further accelerating the demise of the system.

The problems stemming from the locational bias of the warabandi could be mitigated, if not eliminated, through effective local farmer organizations (see Volume 1). Through their cooperative efforts in developing tubewell technology and organizations, Niazbeg farmers have already demonstrated the will and capacity to develop viable local organizations, if those organizations can provide greater water control and the means to effectively sanction "free riders." Tubewell organizations have been effective enough that a number of farmers at the tail of the system have been able to rely exclusively on tubewell water. However, the best water control was found on watercourse 3, where farmers have been able to build effective organizations around conjunctive use of tubewell and canal water. Herein lies a critical lesson. Adequacy of groundwater exploitation is linked to adequacy of canal water organization.

In assessing the adequacy of existing warabandi arrangements, the research found that farmers were most supportive of and satisfied with maintenance rules, and were least supportive of assessment and allocation rules. The difference has important implications for water management policy.

Maintenance is the one function which farmers control in the water distribution system; assessment is the task of the main system bureaucracy and is divorced from allocation and maintenance. The research suggests that if farmers were given more responsibility for assessment and allocation tasks, they could, within a viable organizational framework, establish specific rules that would make water delivery dependent upon fulfillment of organizational obligations (see Volume 1). Furthermore, the development of such a farmer organization would leave the main system bureaucracy free to perform the functions which it does best--delivery of relatively large quantities of water to the distributaries. The development of local farmer organization would thus allow for a reasonable division of labor between the government officials and farmers. This division of labor would provide the foundation for developing an effective organization between farmers and main system managers.

It would appear that any organizational design will have to confront the problem of delivering water among watercourses along the Niazbeg distributary, as well as the problem of water control within watercourses. Failure to organize at the distributary level would make water supply delivery to watercourse moghas erratic and deficient, which would doom watercourse organizational efforts.

If water control becomes a reality for farmers in an experimental subproject area such as the Niazbeg via effective local organizations, other local organizations designed to provide agricultural services other than water control may then become viable companions to further agricultural productivity. Without developing a viable organizational mechanism for improving farmer water control, other organizations are highly constrained in any attempt to improve agricultural productivity or well-being of farmers.

Farmer water control is a global issue, relevant to all farmers who rely on irrigated agriculture in more or less developed countries. This research lends empirical support to irrigation policy development that sees water control as critical to enabling farmers to grow more moisture-sensitive crops to achieve greater yields, and which sees water control to be a function of the manner in which farmers are linked to main system management by effective, middle-level, water users organizations. Design of such organizations is addressed in Volume 1 of this series of reports.

XI. REFERENCES

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XII. APPENDICES

APPENDIX A

DATA COLLECTION INSTRUMENTS, PROCEDURES, AND ENUMERATORS FOR MAIN SYSTEM LEVEL OF ANALYSIS

Water flow measurements were made by a combination of engineering instruments; e.g., stilling wells with Stevens F-type stage recorders (for measuring variation in canal flows), current meters, and cutthroat flumes. Colorado State University (CSU) agricultural engineering staff spent a month training the people who took the measurements. CSU staff were continually in the field monitoring measurement processes.

Note that the measures given in this report may not be of normal canal supplies. Officials were aware that this research was being conducted, and the Irrigation Department increased the water supply to the head of the Niazbeg subproject area, enough that more water reached all points of measurement at the heads and tails of the watercourses. This is confirmed in the data measuring the _de facto_ and _de jure_ deliveries to the head of the Niazbeg system. If there is a bias in the data collected, it is probable that the flow rates in the canal and in the deliveries to the _moghas_ were higher than normal.

One key data collection instrument (A.1) was used to gather information on the main canal delivery system from irrigation officials. Considerable pretesting of this instrument was necessary. Consultations with fellow team members, who were familiar with the Pakistan irrigation bureaucracy and with civil and agricultural engineering perspectives, improved the quality of the interview schedule. Note that the questionnaire also included questions relevant to and requested by other team disciplines.

All officials except the local canal officers (_patwaris_) were interviewed. It was reported to those seeking interviews that a new subengineer and _patwari_ were being installed in their positions and were unfamiliar with their role and responsibilities; they were not interviewed. It was possible to spend close to five hours with a key informant who had spent more than twenty years in several roles on the Niazbeg distributary. At best, the information received from key informant interviews could be translated into rough ordinal measures.

Several other "auxiliary" data collection instruments were used. Sections A.2, A.3, and A.4 contain the interview schedules used with On-Farm Water Management officials, Agricultural Extension Department officials, and banking officials, respectively.

In all interviews with officials, reliability was checked by having at least two experienced interviewers present at the interview. If a question was not answered clearly, time was spent obtaining additional clarification. Most farmer informant interviews were conducted individually by trained interviewers. Each interviewer had considerable experience in administering the questionnaire and clarifying questions made by both researchers and enumerators. The conceptual indicators are viewed as possessing face validity at this exploratory phase of research.

A.1 KEY INFORMANT GUIDE: IRRIGATION DEPARTMENT OFFICIALS

We appreciate your agreement to share with us your knowledge of how water is managed in the main system. As part of our diagnostic analysis, it is important to understand how water is allocated to farmers, how the irrigation system is maintained, and the basic problems faced by management in meeting individual farmer needs.

Please be assured that your name will not be used when interviewing other officials, and that the knowledge you provide will be treated with confidentiality and respect.

If you would like a summary of our report, we will be happy to send you one. The report will consist of the soil, crop, water, and organizational analysis, as well as possible solutions.

Key informant would like a summary of report. Yes ___ No ___ .

Mailing address ______________________________

Key informant code ______________

Interviewer's name ______________________________

Date of interview ______________

Office at ______________________________

Reason for choosing this informant ______________________________

____

Title of official's position ______________________________

Where is he/she from? ______________________________

How long at current assignment? ______________________________

JOB DESCRIPTION:

PERSONAL:

- What are the responsibilities of your job?

- What activities take most of your time?

ORGANIZATIONAL:

- How many people do you directly supervise?

- What are their primary responsibilities?

- To whom are you responsible? (or to whom do you report?)

- What are his (the one to whom you report) primary responsibilities?

- What other persons (positions - by job description) do you work closely with?

- How is your job evaluated?

WATER RESOURCE ALLOCATIONS

SANCTIONED SUPPLY (First, ask engineer on OWM staff!)

1. How much water is sanctioned or allocated to arrive at the following locations:

   1) Lahore - B and R outlet to the Lahore section of the Niazbeg:

   2) Niazbeg head (beginning at the control structure near the training center.)

   3) Sub-Project head: (beginning at the control structure)

   4) Sanctioned supply at the following points:
      - Head of the Kamogil minor:
      - Head of the Jaleki minor:
      - Head of the Thatti Uttar Minor:

   5) Amount of water to be supplied at the drop structure on the Niazbeg Canal immediately down from the Thatti turnout:

2. What is the sanctioned supply for the following moghas?
   1. # ____________ (w/c 1) ______________________________
   2. # ____________ (w/c 2) ______________________________
   3. # ____________ (w/c 3) ______________________________
   4 # ____________ (w/c 4) ______________________________
   5. # ____________ (w/c 5) ______________________________
   6. # ____________ (w/c 6) ______________________________

RULES

1. What are the rules or standards that are used to allocate water?
   1) At the W/C mogha:
      1. ____________________
      2. ____________________
      3. ____________________ ?

2) At the head of the minors:
   1. ____________________
   2. ____________________
   3. ____________________

3) At the main system level (BRBD link canal with the Lahore/ Niazbeg Distributary; also find out the rules that govern water distribution to the urban area, including watering of lawns along canal, etc.)
   1. ____________________
   2. ____________________
   3. ____________________

2. How were the rules established? ______________________________

____

3. If current allotment rules can be changed, what are the procedures? Specifically, how have alterations in sanctioned supply been made?
   - at the main distributary level (Niazbeg):

   - at the minor level:

   - at the watercourse level:

MEASUREMENT

1. What water measuring devices are used in the system?

   - BRBD Link Canal outlet to the Lahore/Niazgeg branch

   - From the beginning of the Niazbeg (tng. ctr.) to the beginning of the subproject area? (See SPA engineer)

   - Within the subproject area: (see SPA engineer)

     a) along the distributary:
     b) at the entrance to the minors:
     c) at the mogha:

2. What procedures are to be followed by the Irrigation Department when the sanctioned supply at any of the three levels mentioned above does not correspond with the actual supply?

   a) When it is more than the sanctioned supply:

   b) When it is less than the sanctioned supply:

3. How can farmers know whether they are getting their sanctioned supply?

4. What procedures can farmers on a watercourse follow when they discover that they are not receiving their sanctioned supply?

   - How does the Irrigation Department respond to such situations?

- At what level of assessment should farmers continue to pay when they are not receiving their sanctioned supply:
  Receive only 3/4
  Receive only 1/2
  Receive only 1/4 or less? (ask for rationale of Irrigation Dept.)

MONITORING

1. How do you monitor your water flow measurements throughout the Niazbeg system? (Who--designated roles, rules for monitoring, records for monitoring?)
   - at the distributary level ______________________________
   - at the minor inlets ______________________________
   - at the moghas ______________________________

2. If there are limited monitoring procedures for measurements at various levels of the system, how do you know that the system is operating to insure the various minors and watercourses receive their sanctioned supply?

3. What are the operating principles that govern situations where the sanctioned water supply differs considerably from the actual supply?
   - What happens if a watercourse receives additional water regularly?
   - What happens if a powerful person takes water on a regular basis illegally?
   - What happens if w/c members complain of not receiving their supply?

4. What system improvements, if any, are needed for helping the management of the system in the areas of measurement and monitoring of water allocations?
   - In supplying the sanctioned discharge at the mogha, especially in areas where there are severe discrepancies?

PUBLIC TUBEWELL WATER (find out from OWM engineer whom to see)

1. What are the rules for distributing/allocating public tubewell water:
   - into the distributary or minor (what rules or guidelines does the operator have? ______________________________
     1) How many public tubewells pump into the Niazbeg minor?
     2) How many hours a day do they work?
     3) What happens to the farmers' on the warabundi system when they pay for and depend on public tubewell water, but it does not come because of shutdowns during their turn?

- into a farmers' watercourse (rules or guidelines for the operator) ______________________________

1) How many pump directly into a watercourse?
2) How many hours a day do they usually work?
3) What happens to the farmers expecting water when the tubewell stops working, and part or all of their warabandi turn passes?

- Are there any watercourses supplied by both canal water and a public tubewell that pumps directly into the w/c?
  1) If so what are the operational rules?

2. What is departmental policy regarding turning public tubewells over to a WUA ______________________________

3. What kind of maintenance problems do public tubewells have? ______________________________

   -How are they handled?

4. Are there structural changes needed in the operation and maintenance of public tubewells ____________ If yes, what changes: __________

ALLOCATION VIOLATIONS

1. What sanctions are proscribed for an individual or a w/c that illegally acquires canal water?

2. How are violations of allocation rules usually identified?

3. What happens to violators of allocation rules when they are identified?

4. What are the penalties for mogha tampering?

   - How are they enforced?

DISPUTES AND CONFLICT RESOLUTION

1. What kind of disputes are most often brought to your attention?

2. What kinds of procedures do you have for resolving them?

3. What kind of appeal structures are there for resolving continuing differences?

4. What differences in law apply to the way the Irrigation Department handles disputes on a kutcha and a pucca watercourse?

5. What are the preferences, if any, you and other irrigation officials have for a kutcha or pucca watercourse system? Why?

SYSTEM MAINTENANCE

GENERAL MAINTENANCE

1. How does your department define "maintenance"? What is involved?

2. Please tell us how this system is maintained.

3. What are the rules that govern the maintenance of the system?

4. How are the rules enforced?

5. If maintenance procedures are subject to change, who can initiate change?

6. Who supervises the maintenance of the:
   Distributary: ______________________________
   Minors: ______________________________

7. What is involved in cleaning the distributary?

8. If farmers participate in maintenance of the minors, how are they mobilized? (probe for rules of participation, and sanctioning of non-participants.)

SYSTEM REPAIRS

1. What types of main system repairs are most common?

2. What types of repairs are most needed (if different)?

3. What are your procedures for initiating needed repairs?

COMMUNICATIONS SYSTEM

1. What are the criteria used to determine when the flow of water should be stopped?
   - Main distributary/minors:

   - Watercourses:

2. Who makes the decision to stop the flow of water?

3. How is this "closure information" communicated to the watercourses? The individual farmer?

4. What are some of the difficulties in the communication system of the subproject area that you are aware of?

WATER CHARGES/CROP PRODUCTION CHARGES

Canal Water:

1. How is the water charge set?

2. Who sets it?

3. Who keeps the records? ____________________________
   Who collects the water charges?

4. What happens if an irrigator/farmer does not pay the water charge/ crop assessment? (ask for several illustrations)

5. How are the water revenues utilized?

Tubewell Water:

1. What is the charge for public tubewell water?
   How is it set?
   Who sets it?
   Who keeps the records
   Who collects the charges?

2. What are there possibilities for more extensive development of private tubewell water?
   If so, what are some suggestions?

Exchange Water:

1. What are the practices of farmers on watercourses with reference to exchanging water?

   What does the law say about exchanging watercourse water?
   How is the law enforced?
   How does the law affect farmer behavior
   Does the practice of exchanging water involve charges by farmers?
   If so, how does it work?

2. What charges, if any, would you suggest for:
   De jure statements and sanctions regarding farmer water exchange?

   De facto farmer operations regarding farmer water exchange?

WATER USERS ASSOCIATIONS

1. What might be the advantages of established WUA's for the management of water in this system?

2. What would be the advantages of informal minor associations?

3. What kind of responsibilities could such organizations undertake?

4. In your opinion, how could WUAs and their management role be improved or strengthened as part of the overall management plan?

A.2 KEY INFORMANT OFFICIALS: OFWM QUESTIONNAIRE

GENERAL ROLE DESCRIPTION

1. Please tell us about your job, what you do, what responsibilities you have?

2. What is your geographic area of responsibility?

3. If you have other positions for which you are responsible, how would you describe their role and task/responsibilities?

4. What kind of training is required for the positions for which you are responsible?

5. What kind of continuing education program is arranged for these positions?

INTRA- AND INTER-AGENCY RELATIONSHIPS?

1. What is the working relationship between On-Farm Water Management and the Ag. Research Agency?

2. What is the working relationship between OFWM and Ag. Extension?

3. What is the working relationship with other governmental agencies?

COMMAND WATER MANAGEMENT RELATIONS

(Rehearse the intent of the CWM, namely, to facilitate the integration of resources in the command area for the purpose of increasing farm productivity and assisting rural well being.)

1. How might you see the role of OFWM in the CWM program?

2. What recommendations would you have?

3. Could the OFWM team take responsibility for careful preparation and training of WUA officers and members to think through their organizational roles, rules and tools?

   If so, what would be required to expand the responsibility of the OFWM team in order to do this?

4. In the light of your increasing responsibilities what would you suggest doing with your land leveling program, your equipment loan program, and the yet to be implemented water management extension training program?

Land Leveling program?

Equipment loan program?

Water Management Extension Training Program?

EVALUATION: STRENGTHS AND WEAKNESSES

1. What does OFWM really do best? Where are the strengths?

2. What difficulties do you and those working with you have in responding to your overall task assignment?

3. What problems do the OFWM teams have in doing their job?

4. What requests have the farmers made to you that you cannot respond to?

5. What changes would you like to see initiated, especially in the framework of the CWM Project?

A.3 KEY INFORMANT OFFICIALS: EXTENSION QUESTIONNAIRE

GENERAL ROLE DESCRIPTION

1. Please tell us about your job, what you do, what responsibilities you have?

2. What is your geographic area of responsibility?

3. If you have other positions for which you are responsible, how would you describe their role and task/responsibilities?

4. What kind of training is required for the positions for which you are responsible?

5. What kind of continuing education program is arranged for these positions?

6. What is the working relationship between Extension and Agricultural Research?

7. What is the working relationship between Extension and OFWM?

8. What is the working relationship with other governmental agencies?

COMMAND WATER MANAGEMENT RELATIONS

(Rehearse the intent of the CWM, namely, to facilitate the integration of resources in the command area for the purpose of increasing farm production and assisting rural well being.)

1. How might you see the role of extension in the CWM program?

2. What recommendations would you have?

3. Could the Field Assistant take the same village geography he presently has and work with the watercourses in this geography as his unit of responsibility? (Only within the CWM area.)

4. Is it possible for the A.O. and the field assistants in the CWM area to assume responsibility for water management extension training?

Under what circumstances might this be possible?

EVALUATION: STRENGTHS AND WEAKNESSES

1. What does extension really do best? Where are the strengths?

2. What difficulties do you and those working with you have in responding to your task assignment?

3. What problems do the F.A.'s have in doing their job?

4. What changes would you like to see made, especially in the framework of the CWM project?

A.4 CREDIT QUESTIONNAIRE

NAME OF INSIITUTION: DATE

ADDRESS

1. What is your role in supplying agricultural credit?
2. If a bank, what is your source of funds?
3. How are interest rates determined?
4. What collateral is required of borrowers?
5. What are the repayment terms?
6. How are delinquencies handled?
7. Are the credit needs of small farmers being met? (under 25 acres)
8. What improvements are needed in the agricultural credit system?
9. Is credit adequate to finance investments in tubewells?
10. Are there other irrigation related technologies which would improve farmers' incomes if they could be financed through credit arrangements?
11. Is credit to farmers available through merchants ? If so, which type of merchants, commodities, etc.

APPENDIX B

DATA COLLECTION INSTRUMENTS, PROCEDURES, AND ENUMERATOR TRAINING FOR FARM LEVEL ANALYSIS

The sociology questionnaire is presented in Section B.1. Four graduates of Faisalabad University employed as agricultural officers in the Extension Service at designated posts in the Punjab assisted in data collection. All were fluent in the local dialect and were competent in English.

Two months of interviewer training preceded data collection for those administering the sociology questionnaire. This period was used to pretest the questionnaire, pretest instruments, and train enumerators in the theory and practice of diagnostic analysis as it related to the general context, and specifically to the theory and variables being explored. Many changes were made to adapt the questions being asked to the local situation, improve reliability of items, and coordinate with the team assigned to collect data for the economic analysis.

Questionnaire B.1 was used on the first two watercourses interviewed (3 and 4). Questionnaire B.2 was used on watercourses 1, 2, 5 and 6. Certain issues noted in the text required that additions be made to the original sample farm questionnaire (B.1).

The economic questionnaire is found in B.3. Four research assistants were assigned as enumerators from the Punjab Economic Research Institute in Lahore. It was decided that a sociology and an economic research assistant would compose one team, each interviewing a farmer in the same location. After the interview was completed, the enumerators would then exchange farmer respondents. This method -- requiring approximately two hours of interviewing for each respondent -- was quite effective over the six-week period of data collection on the six sample watercourses. The cohesiveness and objectivity of the team was maintained by regular discussions in organized meetings and by team attendance at periodic, joint cultural events in Lahore.

Entry into the village was carefully managed. Early conversations with the village leadership were arranged. Team leaders, including this researcher and host country nationals, contacted village leaders representative of the community and explained the Command Water Management Project and its intent, sought their cooperation, and answered any questions or objections presented. Usually a climate of suspicion clouded the initial encounters, requiring skillful and patient work before support by the community was elicited.

B.1 SAMPLE FARMER QUESTIONNAIRE COMMAND WATER MANAGEMENT (WATERCOURSES 3,4)

001 Sub-Project Area
002 Canal:Head Mid. Tail
003 Minor:Head Mid. Tail
004 Wtcse:Head Mid. Tail

Interviewer(s): 005 Date: 006
Time: From to 007 Total: hr. Min. 008

SOCIAL IDENTIFICATION DATA

A. Farmer identification:

Name: Code No. 009
Age: 010 Education-years in school: 011
Caste (Qaum): 012 Sub-caste(Gout): 013
Occupation(s):Major: 014 Second: 015
Third: 016
Total No. of household members: 017
Total No. of working age persons - Men 018
How many married couples live in the household? 019

B. Farmland Acreage

CATEGORY	ACREAGE TOTAL	ACREAGE THIS W/C
Owned	020	021
leased in	022	023
leased out	024	025
TOTAL OPERATED AREA:	026	027
Total Irrigated area	028	029
Total barren land (if any)	030	031

C. Animals

Total number of animals owned/kept: 032
Draft Animals: 033 Milk Animals: 034

D. Tubewells

	(035) Self-owned	Share-owned	No. shrhdrs.
1. Tubewell(electric)		035	036
2. Tubewell(diesel)		037	038

NOTE: THE FOLLOWING QUESTIONS ARE MEANT FOR THE FARMLAND AND FARMING PRACTICES ON THIS WATERCOURSE ONLY.

1. Where on this watercourse is your farmland located? (take out the watercourse map and help him identify his acreage--in one or more locations--on the watercourse
   Head (first one-third of the w/c length): no. of acres
   Middle(middle one-third of the w/c length) no. of acres
   Tail (last one-third of the w/c length): no. of acres

IRRIGATION: GENERAL

1. Where did you get water from for irrigating your crops during the last two cropping seasons?

Season	Relative Percent of Water canal	public t/w	private t/w
Kharif, 1985	051	052	053
Rabi, 1984-85	054	055	056

CROPPING: GENERAL

1. Cropping patterns

SEASON		CROP	ACTUAL INTERVAL BETWEEN IRRIGATIONS (IN DAYS)	ACREAGE CROPPED	FALLOW
Kharif, 1985 :	1.	057	058	059	
	2.	060	061	062	
	3.	063	064	065	
	4.	066	067	068	069
Rabi, 1984-5	1.	070	071	072	
	2.	073	074	075	
	3.	076	077	078	
	4.	079	080	081	082

2. Cropping Intensity

	Kharif 1985	Rabi 1984-85
Total operated area	083	084
Total cropped area	085	086
Cropping intensity =	(this can be done later)	087

3. Reason(s) for leaving farmland fallow:

a) Kharif, 1985: 1) 088

2)

3)

b) Rabi, 1984-85 1) 089

2)

3)

SHARE TYPE: CANAL WATER - Warabandi

1. What type of Warabandi do you have? Pakki Katchi Other 101

2. How much warabandi time have you been allocated? 102

   - number of minutes per acre: 103

3. How much time do you actually get water for irrigation? 104

4. When is your warabandi turn for getting water?
   Day 105 Time a.m./p.m. 106

5. When do you actually get water?
   Day 107 Time a.m./p.m. Comments (if offered)108

6. When does the water usually come to you?
   Kharif 109 Rabi 110

   1) never on time
   2) rarely on time
   3) about half the time on time
   4) most often on time
   5) Always on time

7. How much variation in warabandi water supply do you have from week to week?

	No variation	10% variation	20% var	30%	40%	50% or more
Kharif 111						
Rabi 112						

8. What percent of your total land can you irrigate during your warabandi turn? 113

9. Is the water you get on your turn (wari) sufficient for irrigating your crops?

	Never	very little	some	most	all the time
Kharif 114					
Rabi 115					

10 If your warabandi time is finished, do you get more water when you need it? 116
   Never Seldom Sometimes often all the time

-If you do get more water, what is the source of supply? 117
   Canal Public T/W Private T/W Exchange other

- If you do get more water, how do you acquire the extra water? 118
   Buy it Biradari Excg. Extra-biradari Excg. own t/w

- Does the canal water plus the t/w water provide an adequate supply? 119

Totally Inadequate	1/4 - 1/2 Needed	1/2 - 3/4 needed	More than 3/4 needed	Totally Adequate

11. If your war. time is over and you have not finished irrigating your field, how often can you arrange to complete the irrigation? 120
Never Seldom Sometimes Often All the time

12. When do you have a serious shortage of canal water? (RANK the months from 1 to 6, where 1 is the least serious, and 6 is the most serious.
Kharif season: April May June July August September
121 - 126
Rabi season: October November Dec. Jan. Feb. March
127 - 132

13. What particular losses have you had from serious canal water shortage problems during the last year? 133
No losses Minimum losses 1/4 of crop 1/2crop 3/4 or more

14. Do you ever have surplus water that you cannot use? Yes No 134
If yes, then when in
Kharif: April May June July August September
135
Rabi: October November Dec. Jan. Feb. March
136

15. What do you do with, or how do you dispose of unneeded war. canal water when all your fields are saturated? 137

16. Does surplus water ever damage your crop? you cannot use? Yes No
138 Yes No
If yes, What is the source: Canal Rain Both 139
Other comments:

17. What particular losses have you had from such an over-abundance of water during the last year? 140
No losses Minimum losses 1/4 of crop 1/2 crop 3/4 or more

18. What do you do with, or how do you dispose of unneeded war. water when all your fields are saturated? 141

Standard Operating Procedures of Warabandi Share Type

1. Usually, Who turns the water into the nukka? 142
Yourself Immediate family member Biradari mem. Hired help
W/c employee

2. How do you know that you have come to the end of your time allotment? 143
Watch The next water user Both of these Timekeeper Other

3. Who closes the Nukka when your warabandi time is finished? 144
Yourself family member Biradari member next in line
watercourse employee

POSSIBLE MODIFICATIONS: CANAL WATER

1. Are you satisfied with the following:

	not at all	little	Moderate	good	Excellent
a)canal water quality 145					
b)water quantity 146					
c)water timing 147					
d)water reliability 148					
e)W/c maintenance 149					

What is one important change you would recommend to improve the present warabandi distribution system? 150

SHARE TYPES: PRIVATE TUBEWELL WATER

1. Did you receive private tubewell water in the last Kharif? Yes No 151
2. Did you receive private tubewell water in the last Rabi? Yes No 152

TUBEWELL WATER SHARE

1. What tubewell or tubewells deliver water to you? (locate on map)

NAME OF PERSON	DISTANCE FROM T/W	DESIGNATED TUBEWELL NUMBER
1)	153	154
2)	155	156
3)	157	158

2. What is your "right" to, or "claim" on the water? 159
   1)at the will of the owner
   2)Long standing agreement with the owner
   3)Joint ownership of the T/W
   4)Individual ownership of the T/W
   5)Other

3. How do you get the t/w water? 160
   1) Whenever the owner decides after I ask him
   2)On a weekly rotational schedule
   3)On an other than weekly rotation schedule
   4)When I request or need it

TIMING — LAST KHARIF 161 RABI 162

1. How quickly is the t/w water usually delivered after you have ordered it.
   a) 5 or more days
   b) 3 - 4 days
   c) 1-2 days
   d) within 24 hours

QUANTITY

1. How many times did you need t/w water last?

	ONCE	TWICE	THREE TIMES	FOUR TIMES	5 OR MORE
KHARIF 163					
RABI 164					

2. How many times was the t/w water NOT available when you needed it?

	NONE	ONCE	TWICE	THREE TIMES	FOUR TIMES	5 OR MORE
KHARIF 165						
RABI 166						

3. If you did not get private t/w water when you needed it, how many times did you not receive it for each of the following reasons?

	KHARIF	RABI
a)I could not afford to pay for the water	167	168
b)It was too much money, even though I could afford to pay	169	170
c)T/W water was not available because others were using it.	171	172
d)The owner refused to deliver it	174	174
e)The conveyance system was not available	175	176
f)No electricity/fuel	177	178
g)Mechanical/electrical breakdown	179	180

4. Did you usually get all the water you needed?

	NEVER	SOME OF THE TIME	HALF THE TIME	MOST THE TIME	ALL TIME
KHARIF 181					
RABI 182					

RELIABILITY/DEPENDABILITY

1. How reliable is your t/w water supply?

	NOT AT ALL	POOR	AVERAGE	GOOD	EXCELLENT
KHARIF 183					
RABI 184					

PAYMENT

1. How do you pay for t/w water delivery? 185 186

With cash at time received	What was the rate?
With cash monthly	What was the rate
With cash at the end of the season	Rate
With "in-kind" payment	If so, what was the rate?
With labor	How much labor?

ADEQUACY/SATISFACTION

1. How adequate was your tubewell water supply over the past year in terms of the following items:

	NOT AT ALL	POOR	AVERAGE	GOOD	EXCELLENT
- TIMING 187					
- QUANTITY 188					
- QUALITY 189					
- MAINTENANCE OF DELIVERY CHANNELS 190					
- COST OF WATER 191					

Changes that would be beneficial: What are one or two changes that could improve your private tubewell distribution system? 192

FACILITY MAINTENANCE PATTERN:FLEXIBILITY OF RESPONSE INDEX

I. Immediate Problems/tasks needing attention

	Never fixed	Slow	Average	Immediate
1. Mogha blockage 201				
2. W/C Blockage 202				
3. W/C banks weak/thin 203				
4. Mogha & w/c silting 204				
5. Water theft 205				
6. Weeds in the w/c 206				
7. Nukka leakage 207				
8. Rat holes in w/c 208				
9. Tractor/animal crossing - damage 209				
10. Animals blocking water. 210-11				

What are the three most important problems in the above list in order of importance

1) 212 2) 213 3) 214

II. Seasonal Maintenance Tasks (needs to be refined in the field reconn.)

	Attended to: Never	Seldom	Somewhat	Regularly
1. W/C Cleaning 215				
2. Weed Control 216				
3. Mogha Cleaning 217				
4. Major Repair 218				
5. W/c desilting 219				
6. Nukka repairs 220				

7. rat killing and bank repair
221
8. farm ditch clng.
222
9. w/c straightn'g
223
10. drainage channels
224-25

What are the 3 most important problems in the above list - prioritize
1) 226 2) 227 3) 228

If you had sufficient water, would it be a good idea to employ a person part or full time to manage the maintenance of the w/c?
No Maybe Yes

ON FARM WATER CONTROL

This will be a purposive sample of the farmer's most important field. More specifically,"most important" means that field in which the farmer has invested the most time, energy, and resources. Have him pick from his cultivated lands that plot in which he has made the greatest investment. (Use the map he made previously.) Irrigation periods will be broken down into four: Seeding, growth, flowering and fruiting; the Kharif and Rabi seasons of the past year will be examined.

QUANTITY CONTROL

	KHARIF				RAVI			
	1	2	3	4	1	2	3	4
	SEEDING	GROWTH	FLOWER	FRUIT	SDG	GR	FL.	FRT
QUANTITY CONTROL:Canal Water 1.On this field how would you describe the adequacy of your canal water supply during important periods in the life of the crop this past year. Be as accurate as you can: POOR (1) MODERATE (2) GOOD (3)	301	302	303	304	305	306	307	308
QUANTITY CONTROL: How many times in each period did you purchase or borrow a canal water turn (or part of a turn) to get water for the field? "0" (1),1-2 (2), 3 (3)	309	310	311	312	313	314	315	316
QUANTITY CONTROL: Use of Private Tubewell Water. How many times in each period were you able to apply private t/w water to the field? "0" (1), 1-2 (2), 3+ (3).	317	318	319	320	321	322	323	324

If you applied Private t/wtr.,
how useful was it in mtg. water
req's for the field?
Not useful (1), some(2), very(3

325 326 327 328 329 330 331 332

OFFICIAL RELATIONS

	W/C TIME KEEPER	PUB. T/W OPERATOR	NUMBARDAR	CANAL PATWARI	CANAL OVERSEER
KNOWLEDGE					
1. What is the name of this person? (write it)	401	410	419	428	437 2.
Have you met this official before? (Y/N)	402	411	420	429	438
AVAILABILITY					
3. How available has he been in the past year? Not = N; Somewhat = S; Very = V	403	412	421	430	439
HELPFULNESS					
4. How well does he know his job? N; S; V	404	413	422	431	440
5.How well does he do his job? N; S; V.	405	414	423	432	441
10.How helpful has he been? N; S; V	406	415	424	433	442
FAIRNESS					
1. How fair has he been? N; S; V;	407	416	425	434	443
SATISFACTION					
1. How satisfied overall are you with his role or service? N; S; V	407	417	426	435	444
	408	418	427	436	445

	REVENUE PATWARI	FIELD ASS'T	LOCAL BANK OFFICER	OFWM CONTACT	INPUT SUPPLIER
KNOWLEDGE					
1.Name	446	455	464	473	482
2.met this person before(Y/N)	447	456	465	474	483
AVAILABILITY					
3.How available (N;S;V)	448	457	466	475	484

HELPFULNESS					
4.Knowledge of Job(N;S;V)	449	458	467	476	485
5.How well does job(NSV)	450	459	468	477	486
6.How helpful been (NSV)	451	460	469	478	487
FAIRNESS					
7.How fair has been(NSV)6	452	461	470	479	488
SATISFACTION					
8. Overall satisf'n (NSV)	453	462	471	480	489
	454	463	472	481	490

ORGANIZATIONAL SUPPORT

(INDICES OF SUPPORT RELATE TO THE SPECIFIC RULES ON WATERCOURSES BEING STUDIED, AND MUST BE GATHERED IN THE FIELD. TWO TO FOUR RULES SHOULD BE WRITTEN IN BY EACH TEAM, AND SHOULD BE AVAILABLE FROM THE KEY INFORMANT QUESTIONNAIRE)

	KEN OF RULE	AGREM'T W. R.	EQUITY OF R.	CONFORM'Y TO RULE	CONSEQN OF BRKG
	CL S/C UN/C	FL MOD DISAG	FR SM UNFR	OB SM NO	SW DY NO
WARABANDI W/C ORGANIZ'N					
I. ALLOCATION RULES					
1. Warabandi Timing:same time per acre	501	502	503	504	505
2. War. Order: head to tail (w/o exchange)	506	507	508	509	510
II.MAINTENANCE RULES					
1. W/C Cleaning:All Participate in cleaning	511	512	513	514	515
III. ASSESSMENT RULES					
1.Canal Water Charges: Irr. fixed charge.	516	517	518	519	520

TUBEWELL ORG'N

ALLOCATION RULES: 1.On request by farmers	521	522	523	524	525
II.MAINTENANCE RULES 1.All who use must maintain	526	527	528	529	530
III.ASSESSMENT RULES 1.Charge set by t/w owner	531	532	533	534	535

Cl=clear FL=full FR=fair OB=observe SW=swift
S/C=somewhat MOD=moderate SM=somewhat SM=somewhat DY=delay
UN?C=unclear DISAG=disagree UNFR=Unfair NO=no

WILLINGNESS TO SUPPORT
AN INITIAL ORGANIZATIONAL SUPPORT INDEX

STRUCTURAL SUPPORT	VERY WILLING	SOMEWHAT WILLING	NOT WILLING
1. Form a WUA 601			
2. Help create WUA bye-laws 602			
3. contribute labor 603			
4. contribute funds 604			
5. sacrifice time 605			
6. provide land for w/c if needed 606 - 7			
FINANCIAL SUPPORT			
7. Pay t/w fee (public) 608			
8. Purchase t/w water (private) 609			
9. Obtain credit from ADBP 610			
10. Obtain credit from coop bank 611			
11.Install a t/w (private) 612			

12. Support with others the financing
of a field ditch t/w for 10 or more farms.
613
13. Support with other the financing
(via loan) of one or more w/c t/w's
614 - 5

IMPROVED FARMING PRACTICES SUPPORT

14. Apply more fertilizer.
616
15. Apply more insecticides.
617
16. Apply more weedicides.
618
17. Level farm fields
619
18. Increase cropping intensity?
620
19. grow cash crops.
621
20. grow rice.
622
21. grow vegetables
623 - 25

ON FARM IRRIGATION EVALUATION

1. How many acres in length is the farmer's farm from the head of the watercourse? (Be as exact as possible)

2. How much water do you think you receive at your farm as compared to that being delivered at the mogha?
less than 1/4 1/4 1/2 3/4 100%

3. How many acres were last irrigated with all supply sources?

Crops	Acreage	Time Interval between the last two irrigations for these crops (in days)
1.		
2.		
3.		
4.		

4. Referring back to the particular field in the last section, How many high spots do you find after shutting off the irrigation water?
None 1-2 3-5 6-10 over 10 (Specify if possible)

B.2 SAMPLE FARMER QUESTIONNAIRE
COMMAND WATER MANAGEMENT (WATERCOURSES 1,2,5,6)

001 Sub-Project Area
002 Canal:Head Mid. Tail
003 Minor:Head Mid. Tail
004 Wtcse:Head Mid. Tail

Interviewer(s): 005 Date: 006
Time: From to 007 Total: hr. Min. 008

SOCIAL IDENTIFICATION DATA

A. Farmer identification:

Name: Code No. 009
Age: 010 Education-years in school: 011
Caste (Qaum): 012 Sub-caste(Gout): 013
Occupation(s):Major: 014 Second: 015
Third: 016
Total No. of household members: 017
Total No. of working age persons - Men 018
How many married couples live in the household? 019

B. Farmland Acreage

CATEGORY	ACREAGE THIS W/C	
Owned	020	
leased in	021	
leased out	022	
TOTAL OPERATED AREA:	023	Total

Irrigated area 024
Total barren land (if any) 025

C. Animals

Total number of animals owned/kept: 026
Draft Animals: 027 Milk Animals: 028

D. Tubewells

	(029) Self-owned	Share-owned	No. shrhdrs.
1. Tubewell		029	030

NOTE: THE FOLLOWING QUESTIONS ARE MEANT FOR THE FARMLAND AND FARMING PRACTICES ON THIS WATERCOURSE ONLY.

1. Where on this watercourse is your farmland located? (take out the watercourse map and help him identify his acreage--in one or more locations--on the watercourse
   - 031 Head (first one-third of the w/c length): no. of acres
   - 032 Middle(middle one-third of the w/c length) no. of acres
   - 033 Tail (last one-third of the w/c length): no. of acres

IRRIGATION: GENERAL

1. Where did you get water from for irrigating your crops during the last two cropping seasons?

RELATIVE PERCENT OF WATER: ROUGH INITIAL ESTIMATE

Season	canal	private t/w
Kharif, 1985	034	035
Rabi, 1984-85	036	037

CROPPING AND IRRIGATION PATTERNS

1. Cropping patterns, irrigation intervals, and water sources:

SEASON	MAJOR CROPS	ACTUAL INTERVAL BETWEEN IRRIGATIONS (IN DAYS)		ACREAGE OF CROP	NUMBER OF ACRES BY CANAL WATER	TUBEWELL
KHARIF (pick number one priority crop) 038	1.	From Rauni to first irrig'n(days)	039	040	041	042
		From 1st to 4th (i.e.growth period)	043		044	045
		From flowering(late growth) to harvest	046		047	048
		TOTAL IRRIGATIONS	049			
050	2.	Total irrigations	051	052	053	054
055	3.	" "	056	057	058	059
060	4.	" "	061	062	063	064

FALLOW LAND (in acres) 065

REASONS for leaving fallow: 1

2. 066

SEASON	CROPS	IRRIGATION INTERVALS	ACREAGE	CANAL WATER	TUBEWELL	
RABI	1. 067	From Rauni to 1st	068	069	070	071
		From 1st to 4th	072		073	074
		flower'g to harvest	075		076	077
		TOTAL IRRIGATIONS	078			
079	2.	Total irrigations	080	081	082	083
084	3.	" "	085	086	087	088
089	4.	" "	090	091	092	093

FALLOW LAND (in acres) 094;Reasons for leaving fallow:

1) 2) 095

2. Cropping Intensity

	Kharif 1985	Rabi 1984-85
Total operated area	096	097
Total cropped area	098	099
Cropping intensity =	(this can be done later)	100

SHARE TYPE:CANAL WATER - Warabandi

1. What type of Warabandi do you have? Pakki Katchi Other 101

2. How much warabandi time have you been allocated? 102

   - number of minutes per acre: 103

3. How much time do you actually get water for irrigation? 104

4. When is your warabandi turn for getting water? (If KUTCHA WAR., describe specific changes in day and time over the year.)
   Day 105 Time a.m./p.m.
106

5. When do you actually get water?
Day 107 Time a.m./p.m. Comments (if offered)108

6. When does the water usually come to you?
Kharif 109 Rabi 110

1) never on time
2) rarely on time
3) about half the time on time
4) most often on time
5) Always on time

7. How much variation in warabandi water supply quantity do you have from week to week?

	No variation	10% variation	20% var	30%	40%	50% or more
Kharif 111						
Rabi 112						

8. What per cent of your total land can you irrigate during your warabandi turn? 113

9. How sufficient is your canal water supply for irrigating your crops?

	less than 1/4	1/4	1/2	3/4	totally
Kharif 114					
Rabi 115					

10.If your warabandi time is finished, do you get more water when you need it? 116
Never Seldom Sometimes often all the time

-If you do get more water, what is the source of supply? 117
Canal Public T/W Private T/W Exchange other

- If you do get more water, how do you acquire the extra water? 118
Buy it Biradari Excg. Extra-biradari Excg. own t/w

- Does the canal water plus the t/w water provide an adequate supply? 119

Totally Inadequate	1/4 - 1/2 Needed	1/2 - 3/4 needed	More than 3/4 needed	Totally Adequate

11. If your war. time is over and you have not finished irrigating your field, how often can you arrange to complete the irrigation? 120
Never Seldom Sometimes Often All the time
12. When do you have a serious shortage of canal water? (CHECK the crop development phases where you have the most serious shortages of water)
Do this for the crop listed in ITEM 042: CROP TYPE:
121 Kharif season: Rauni seeding Growth Flowering Maturity
122 Rabi season: Do this for ITEM 067: CROP TYPE:
Rauni Seeding Growth Flowering Maturity
13. What particular losses have you had from serious canal water shortage problems during the last year? 123
No losses Minimum losses 1/4 of crop 1/2crop 3/4 or more
14. Do you ever have surplus water that you cannot use? Yes No 124
If yes, then when in
Kharif: Rauni Seeding Growth Flowering Maturity
125
Rabi: Rauni Seeding Growth Flowering Maturity
126
15. What do you do with, or how do you dispose of unneeded war. canal water when all your fields are saturated? 127

16. Does surplus water ever damage your crop? you cannot use? Yes No
128 Yes No
If yes, What is the source: Canal Rain Both 129
Other comments:
17. What particular losses have you had from such an over-abundance of water during the last year?

	No losses	Minimum	1/4 of crop	1/2 crop	3/4 or more
Kharif: 130					
Rabi: 131					

18. What do you do with, or how do you dispose of unneeded war. water when all your fields are saturate(132

Standard Operating Procedures of Warabandi Share Type
1. Usually, Who turns the water into the nukka? 133
Yourself Immediate family member Biradari mem. Hired help
W/c employee

2. How do you know that you have come to the end of your time allotment? 134 Watch The next water user Both of these Timekeeper Other
3. Who closes the Nukka when your warabandi time is finished? 135 Yourself family member Biradari member next in line watercourse employee

POSSIBLE MODIFICATIONS: CANAL WATER

1. Are you satisfied with the following:

	not at all	little	Moderate	good	Excellent
a)water quality: 136					
b)water quantity 137					
c)water timing 138					
d)water reliability 139					
e)W/c maintenance 140					

2.Do you prefer a PUKKA or KUTCHA Warabandi System? Pukka Kutcha
141 Please state WHY

142

3. What is one important change you would recommend to improve the present watercourse distribution system?

143

SHARE TYPES: PRIVATE TUBEWELL WATER

1. Did you receive private tubewell water in the last Kharif? Yes No
151
2. Did you receive private tubewell water in the last Rabi? Yes No
152

TUBEWELL WATER SHARE

1. What tubewell or tubewells deliver water to you? (locate on map)

NAME OF PERSON	DISTANCE FROM T/W	TUBEWELL NUMBER
1)	153	154
2)	155	156
3)	157	158

2. What is your "right" to, or "claim" on the water? 159
   1)at the will of the owner
   2)Long standing agreement with the owner
   3)Joint ownership of the T/W
   4)Individual ownership of the T/W
   5)Other

3. How do you get the t/w water? 160
   1) Whenever the owner decides after I ask him
   2)On a weekly rotational schedule
   3)On an other than weekly rotation schedule
   4)When I request or need it

TIMING LAST KHARIF 161 RABI 162

1. How quickly is the t/w water usually delivered after you have ordered it.
   a) 5 or more days
   b) 3 - 4 days
   c) 1-2 days
   d) within 24 hours

QUANTITY

1. How many times did you need t/w water last

	ONCE	TWICE	THREE TIMES	FOUR TIMES	5 OR MORE
KHARIF 163					
RABI 164					

2. How many times was the t/w water NOT available when you needed it?

	NONE	ONCE	TWICE	THREE TIMES	FOUR TIMES	5 OR MORE
KHARIF 165						
RABI 166						

3. If you did not get private t/w water when you needed it, how many times did you not receive it for each of the following reasons?

	KHARIF	RABI
a)I could not afford to pay for the water	167	168
b)It was too much money, even though I could afford to pay	169	170
c)T/W water was not available because others were using it.	171	172
d)The owner refused to deliver it	174	174
e)The conveyance system was not available	175	176
f)No electricity/fuel	177	178
g)Mechanical/electrical breakdown	179	180

4. Did you usually get all the water you needed?

	NEVER	SOME OF THE TIME	HALF THE TIME	MOST THE TIME	ALL TIME
KHARIF 181					
RABI 182					

RELIABILITY/DEPENDABILITY

1. How reliable is your t/w water supply

	NOT AT ALL	POOR	AVERAGE	GOOD	EXCELLENT
KHARIF 183					
RABI 184					

PAYMENT

1. How do you pay for t/w water delivery? 185 186

With cash at time received	What was the rate?
With cash monthly	What was the rate
With cash at the end of the season	Rate
With "in-kind" payment	If so, what was the rate?
With labor	How much labor?

ADEQUACY/SATISFACTION

1. How adequate was your tubewell water supply over the past year in terms of the following items:

	NOT AT ALL	POOR	AVERAGE	GOOD	EXCELLENT
- TIMING 187					
- QUANTITY 188					
- QUALITY 189					
- MAINTENANCE OF DELIVERY CHANNELS 190					
- COST OF WATER 191					

Changes that would be beneficial: What are one or two changes that could improve your private tubewell distribution system? 192

FACILITY MAINTENANCE PATTERN: FLEXIBILITY OF RESPONSE INDEX

I. Immediate Problems/tasks needing attention

	Never fixed	Slow	Average	Immediate
1. Mogha blockage 201				
2. W/C Blockage 202				
3. W/C banks weak/thin 203				
4. W/c silting 204				
5. Water theft 205				
6. Weeds in the w/c 206				
7. Nukka leakage 207				
8. Rat holes in w/c 208				
9. Tractor/animal crossing - damage 209				
10. Animals blocking water. 210-11				

What are the three most important problems that contribute to your w/c water losses in the above list in order of importance?

1) 212 2) 213 3) 214

II. Seasonal Maintenance Tasks (needs to be refined in the field reconn.)

	Never attended to	Seldom attended to	Somewhat attended to	Regularly attended to
1. Weed control 215				
2. Washout problems at junctions 216				
3. Overspilling at roads and crossings 217				
4. W/C banks are weak and thin 218				
5. W/c desilting 219				
6. Pukka nukka repairs 220				
7. rodent and other holes in banks 221				
8. farm ditch clng. 222				
9. w/c straightn'g 223				
10. Waterlogging from leaky w/c 224-5				

What are the 3 most important problems that contribute to your w/c water losses in the above list? - prioritize

1) 226 2) 227 3) 228

If you had an improved water course, would it be a good idea to employ a person part or full time to manage the maintenance of the w/c?

No Maybe Yes 229

FARMER KNOWLEDGE: FARMING PRACTICES

1. What is your opinion on the DEGREE OF USEFULNESS of the following agricultural practices:

	NOT VERY USEFUL	SOMEWHAT USEFUL	VERY USEFUL	WHY?
a)Tractor				
b)Improved seeds				
c)Chem'l fertilizer				
d)Green fertilizer				
e)Insecticide				
f)Tubewell				
g)Pakka Nakka				
h)Land Leveling				

2. Farmer Behavior: Knowledge building activities:

a) Do you share experiences with other farmers regarding improved farming methods (use of new seed, fertilizer, mechanization, etc.)

Never Sometimes Often

b) Do you like to experiment with new practices in agriculture either on your own, or under the guidance of experts?

Never Sometimes Often

c) Do you participate in agriculture extension classes/meetings or visit demonstration plots of other farmers?

Never Sometimes often

3. Knowledge of agricultural and irrigation information

AGRIC'L INFORM'N	SOURCE OF INFORMATION	DO YOU SEEK OUT INFO? 0 = NO; 1 = YES	USEFULNESS OF INFO 0=POOR;1=FAIR;2=GOOD
INPUT PRICES			
MARKET PRICES			
NEW CROP VARIETIES			
FERTILIZER USE			
INSECTICIDE USE			
LANDLEVELING			
IRRIGATION INFORM'N			
CANAL CLOSURE			
FINANCING PRIVATE T/W INSTALLATION			
CROP WATER NEEDS			
W/C WATER LOSSES			

ON FARM WATER CONTROL

This will be a purposive sample of the farmer's most important field. More specifically, "most important" means that field in which the farmer has invested the most time, energy, and resources. Have him pick from his cultivated lands that plot in which he has made the greatest investment. (Use the map he made previously.) Irrigation periods will be broken down into four: Seeding, growth, flowering and fruiting; the Kharif and Rabi seasons of the past year will be examined.

QUANTITY CONTROL

	KHARIF					RAVI				
Crop on most important field				441	Crop:			442		
Size of field in acres				443	Size:			444		
	1	2	3	4	1	2	3	4		
	SEEDING	GROWTH	FLOWER	MATURITY	SDG	GR	FL.	MAT	QUANTITY	
CONTROL:Canal Water 1.On this field how would you describe the adequacy of your canal water supply during important periods in the life of the crop this past year. Be as accurate as you can: POOR (1) MODERATE (2) GOOD (3)	301	302	303	304	305	306	307	308		
QUANTITY CONTROL: How many times in each period did you purchase or borrow a canal water turn (or part of a turn) to get water for the field? "0" (1),1-2 (2), 3 (3)	309	310	311	312	313	314	315	316		
QUANTITY CONTROL: Use of Private Tubewell Water. How many times in each period were you able to apply private t/w water to the field? "0" (1), 1-2 (2), 3+ (3).	317	318	319	320	321	322	323	324		
If you applied Private t/wtr., how useful was it in mtg. water req's for the field? Not useful (1), some(2), very(3	325	326	327	328	329	330	331	332		
If you applied canal water how useful was it in meeting water requirements for the field? Not useful (1), some(2), very(3)	333	334	335	336	337	338	339	340		

OFFICIAL RELATIONS

	W/C TIME KEEPER	PUB. NUMBARDAR	NUMBARDAR CANAL PATWARI	CANAL REVENUE PATWARI	CANAL FIELD ASSISTANT
KNOWLEDGE					
1. Do you know the name of this person?(Yes/No)	401	408	415	422	429
2. Have you met this person before? (Y/N)	402	409	416	423	430
AVAILABILITY					
3.How available has he been in the past year when you needed to see him?Not=N; Somewhat = S; Very = V	403	410	417	424	431
HELPFULNESS					
4.How well does he supply the services you need? Not so well=N; S; V	404	411	418	425	432
FAIRNESS					
1.Has it been necessary to "please" him with special favors? OFTEN=O; SOMETIMES=S;NEVER=N	405	412	419	426	433
SATISFACTION					
1. How satisfied overall are you with his role or service? N; S; V	406	413	420	427	434
	407	408	421	428	435

ACCESS TO RESOURCES FOR AGRICULTURAL PRODUCTIVITY

Fill in the required columns and ask WHERE and HOW he obtained resources

DESCRIPTION	NOT AVAILABLE	HARDLY AVAILABLE	EASILY AVAILABLE	WHERE OBTAINED	HOW OBTAINED
Fertilizer					
Seed					
Pesticide					
T/W water					
Land leveling					

If some of these inputs were not available, please explain why

Has the farmer tried to get a loan for any of the following inputs before; If no, why not; if yes, what happened; and if the loan was NOT or HARDLY AVAILABLE, why

DESCRIPT'N	FROM WHOM	SOUGHT LOAN BEFORE(Y/N)	IF NO, WHY NOT APPLY FOR LOAN	IF YES, AVAILABILITY NOT HARDLY EASILY	WHY NOT AVAILABLE
Fertilizer					
Seed					
Pesticide					
T/Water					
Purchase T/W					
Land Level'g					

ORGANIZATIONAL SUPPORT

(INDICES OF SUPPORT RELATE TO THE SPECIFIC RULES ON WATERCOURSES BEING STUDIED, AND MUST BE GATHERED IN THE FIELD. TWO TO FOUR RULES SHOULD BE WRITTEN IN BY EACH TEAM, AND SHOULD BE AVAILABLE FROM THE KEY INFORMANT QUESTIONNAIRE)

	KEN OF RULE	AGREM'T W. R.	EQUITY OF R.	CONFORM'Y TO RULE	CONSEQN OF BRKG
	CL S/C UN/C	FL MOD DISAG	FR SM UNFR	OB SM NO	SW DY NO
WARABANDI W/C ORGANIZ'N					
I. ALLOCATION RULES					
1. Warabandi Timing:same time per acre	501	502	503	504	505
2. War. Order: head to tail (w/o exchange)	506	507	508	509	510
II.MAINTENANCE RULES					
1. W/C Cleaning:All Participate in cleaning	511	512	513	514	515
III. ASSESSMENT RULES					
1.Canal Water Charges: Irr. fixed charge.	516	517	518	519	520

TUBEWELL ORG'N

ALLOCATION RULES: 1.On request by farmers	521	522	523	524	525
II.MAINTENANCE RULES 1.All who use must maintain	526	527	528	529	530
III.ASSESSMENT RULES 1.Charge set by t/w owner	531	532	533	534	535

Cl=clear FL=full FR=fair OB=observe SW=swift
S/C=somewhat MOD=moderate SM=somewhat SM=somewhatDY=delay
UN?C=unclear DISAG=disagree UNFR=Unfair NO=no

WILLINGNESS TO SUPPORT
AN INITIAL ORGANIZATIONAL SUPPORT INDEX

IF ADEQUATE WATER WERE TO BE SUPPLIED TO YOU AND OTHERS THROUGH SOME OF THE FOLLOWING ACTIONS TAKEN BY YOURSELF AND OTHER WATERCOURSE MEMBERS, WOULD YOU BE WILLING TO:

STRUCTURAL SUPPORT	VERY WILLING	SOMEWHAT WILLING	NOT WILLING
1. Form a WUA 601			
2. Help create WUA bye-laws 602			
3. contribute labor 603			
4 .contribute funds 604			
5. sacrifice time 605			
6. provide land for w/c if needed 606 - 7			
FINANCIAL SUPPORT			
7. Pay t/w fee (public) 608			
8. Purchase t/w water (private) 609			
9. Obtain credit from ADBP 610			
10. Obtain credit from coop bank 611			
11.Install a t/w (private) 612			

12. Support with others the financing of a field ditch t/w for 10 or more farms.
613
13. Support with other the financing (via loan) of one or more w/c t/w's
614 - 5

IMPROVED FARMING PRACTICES SUPPORT

14. Apply more fertilizer.
616
15. Apply more insecticides.
617
16. Apply more weedicides.
618
17. Level farm fields
619
18. Increase cropping intensity?
620
19. Grow cash crops.
621
20. Grow rice.
622
21. Grow vegetables
623 - 25

COOPERATION AND CONFLICT

1. To what extent do the farmers closest to you cooperate together in the following activities?

	NO COOP	LITTLE	SOME	OFTEN	WHENEVER NEEDED
A) W/C CLEANING					
B) W/C REPAIRS WHEN NEEDED					
C) LOANS TO EACH OTHER					
D) JOINT EQUIPMENT PURCHASE					

2. What kinds of problems have arisen over the past year among those farmers who are closest to you on the watercourse (the above farmers)
NO INCIDENTS   MINOR INCIDENTS How Many?   MAJOR INCIDENTS How Many?
3. When disagreements arise with the farmers closest to you, how are they solved? Not solved   by Irrig'n Dept.   by Village leader   by village officials   Solved by ourselves
4. To what extent do the farmers on the total watercourse cooperate

	NO COOP	LITTLE	SOME	OFTEN	WHENEVER NEEDED
W/C CLEANING					
W/C REPAIRS WHEN NEEDED					
LOANS TO EACH OTHER					
JOINT EQUIPMENT PURCHASE					

3. When disagreements arise among the farmers on the W/C HOW ARE THEY SOLVED? Not solved   by Irrig'n Dept.   by Village leader   by village officials   solved informally by ourselves   solved by   the officers of our WUA

ON FARM IRRIGATION EVALUATION

1. How many acres in length is the farmer's farm from the head of the watercourse? (Be as exact as possible)

2. How much water do you think you receive at your farm as compared to that being delivered at the mogha?
   less than 1/4   1/4   1/2   3/4   100%

3. How many acres were last irrigated with all supply sources?

	Crops	Acreage	Time Interval between the last two irrigations for these crops (in days)
1.			
2.			
3.			
4.			

4. Referring back to the particular field in the last section, How many high spots do you find after shutting off the irrigation water?
   None   1-2   3-5   6-10   over 10   (Specify if possible)

B.3 FARM MANAGEMENT SURVEY QUESTIONNAIRE
DIAGNOSTIC ANALYSIS STUDY

Farmer's Name

Village

Name of Watercourse Access to Private T.W. Yes No

Location of Watercourse Head Middle Tail

FARM SIZE AND TENURESHIP:

1. Area owned acres
2. Area rented in acres
3. Area rented out acres
4. Total land area acres
5. Cultivated area acres

If rented land:
a. Duration of rent
b. Cash rent Rs. acre
c. Crop share:

Crop name	Share of Output	Input contribution

CROPPING PATTERN:

Rabi 1984/85:

Crop Name	Area (acres)	Planting Date (Week/Month)	Harvesting Date (Week/Month)

Fallow

Reason for Fallow

Make note of intercropping practices

Kharif 1985

Crop Name	Area (Acres)	Planting Date (Week/Month)	Harvesting Date (Week/Month)	Previous Crop/s

Fallow

Reason for Fallow

Make note of intercropping practices

Rabi 1985-86

Crop Name	Area (Acres)	Planting or Expected Planting Date (Week/Month)	Previous Crop/s

Fallow

Reason for fallow

Make note of intercropping practices

Ask the farmer to identify and rank two most profitable crops in this area for each of the two seasons.

Rabi: 1. 2.

Kharif: 1. 2.

Observe the actual crop area for the most profitable crops as stated by the farmer and inquire from the farmer the reasons for not allocating more land area to their production. Clearly note the constraints identified by the farmer.

NOTE: If the water was stated by the farmer as the constraint, find out from the farmer as to how he deals with the water shortage situation, e.g. area under crop, type of crops, number of irrigations. Find out what factors other than irrigation water have prevented the farmers from producing more of the profitable crops.

If shortage of irrigation water was identified by the farmer as the constraining factor, then ask the farmer how he would reallocate his land between various profitable crops and crops needed for household consumption and for livestock feed when adequate canal water is made available.

Crop	Rabi Area	Crop	Kharif Area

NOTE: Make sure the acreage of all crops add up to the total available acreage in each season. If fallow was listed, then find out the reason for leaving the land fallow.

YIELD:

Find out from the farmer what was the lowest yield he had obtained for two of the major crops in each season in the past three years.

Rabi Season:

Crop Yield Reason/s Year

Crop Yield Reason/s Year

Kharif season:

Crop Yield Reason/s Year

Crop Yield Reason/s Year

What was the highest yield the farmer obtained for the same major crops noted above in the past three years.

Rabi season:

Crop Yield Reason/s Year

Crop Yield Reason/s Year

Crop Yield Reason/s Year

PRODUCTION PRACTICES:

NOTE: Obtain the following information on two major Rabi and two major Kharif crops.

The amount of application of a specific input such as fertilizer and the associated labor time should be based on the area the crop listed in the area column.

Make sure the information for the following sections is for the same four crops selected for the land preparation.

1. Land Preparation:

Crop	Area	Type of * Operations	Type of Equipment	Total** Cost	Total*** Labor	Hired Labor	Wages
					--Man Days--		Rs/MD

* Operations include plowing, furrowing, smoothing, leveling, and puddling. Indicate the activities and associated costs separately as was incurred by the farmer.

** For the farmer using own tractor and/or animal plow write own in cost column.

*** Obtain the labor information only for the activities that are carried out by animal draft and manually by family and/or hired laborers.

In the estimation of total labor cost assist the farmer in recalling the number of days it took to perform the operation for the area noted in the table and the number and type of laborers used.

2. Seed and Seeding:

Crop	Area	Seed Variety	Quantity Applied	Source* of Seed	Seed Cost	Planting** Method	Total*** Labor hrs

* 1. Own farm 2. Other farmer 3. Seed corporation 4. Market 5.

** 1. Broadcast 2. Plant in furrows 3. Transplant 4.

*** If hired labor, note the labor time and wage rate.

When was the last time the farmer purchased seed from seed corporation or a contact farmer who has obtained improved seed from seed research institute?

Crop 1 Date Crop 2 Date

Crop 3 Date Crop 4 Date

Rice Transplant Operation:

Area	Days Required	Number of Labor Each Day	Number of Labor Hired Each Day	Wages Rs./MD

3. Fertilizer Application:

Crop	Appl. No.	Fertilizer Type	Date Applied	Amount Applied (per acre)	Recommended Rate (per acre)	Total Labor (man days)
	1					
	2					
	3					
	1					
	2					
	3					
	1					
	2					
	3					
	1					
	2					
	3					

Find out from the farmer whether he would be able to increase his yield of , , , and crop by increasing the amount of fertilizer applied.

Yes No

If the answer to the above question is yes, ask the farmer about his rationale and constraints for applying less than the desired and/or the recommended rate.

If the farmer noted the shortage of irrigation water as the reason, inquire from the farmer the rationale for applying less fertilizer when water shortages exist.

If the possibility of crop burn was indicated as the reason, find out when and for what crops did this farmer experience the crop burn problem due to fertilizer application.

Hoeing/Weeding:

Crop	Area	Number of Hoeing or Weeding	Required Time/Hoeing (Days)	Ave. No. of Labor Used Per Day	Ave. No. of Hired Laborers	Wage Rs./MD

What are the farmers thoughts about the adequacy of his hoeing and weeding practices? Has it been adequate in dealing with the weed problem? If the response of the farmer is no, then find out what factors or reasons prevented the farmer from adequate hoeing and weeding.

Plant Protection:

Crop	Area	Type of Pesticide	Amount Applied	Recom. Cost/ Rate Unit	Method of Application	Sprayer Rent	Labor Time

Does the farmer think he is applying an adequate amount of pesticide to prevent or effectively control past attack and infestation? If the answer is no, then find out what factors have prevented the farmer from applying the adequate or the recommended level.

6. Harvesting:

Crop	Area Acres	Number of Days	Average Number of Labor Per Day	Number of Hired Labor	Wage Rate Rs./MD

7. Threshing and Winnowing:

Crop

Note the method and cost.

Crop

Note the method and cost.

CROP OUTPUT AND DISPOSITION

Crop	Area	Total Output	Amount Sold	Month Sold	Market	Price Received

LIVESTOCK HOLDING:

Type of Animal	No. of Animals	Total Market Value	Reasons for which livestock is maintained 1st Reason	2nd Reason	3rd Reason

*1. Farm Work 2. Production milk and meat for farm household consumption 3. Production and selling of milk 4. Raising and selling of livestock.

Number of milking buffaloes   Milk price Rs./kg.
Number of milking cows   Milk price Rs./kg.

LIVESTOCK MARKETING:

Livestock sold in the past 24 months

Type of Livestock	Date Sold	Age	Market*	Price Received

* 1. To another farmer 2. Local butcher 3. Lahore butcher 4. Local fair.

APPENDIX C

DATA COLLECTION INSTRUMENTS, PROCEDURES, AND ENUMERATOR TRAINING FOR INTERMEDIATE LEVEL OF ANALYSIS

Three questionnaires were used to gather data at the intermediate watercourse and tubewell organizational level. The key informant farmer interview schedule (C.1) was used to gather information on warabandi operations and organization from the head and tail of the six sample watercourses. Knowledgeable residents who had resided in the area for some time and who were respected by others were contacted and interviewed.

Two tubewell organization questionnaires were composed. An engineering questionnaire recorded physical measurements of delivery capacities and other measurements (C.2). Most tubewells in the sample were measured, with the exception of several that were missed because of team illness and lack of geographic knowledge. This questionnaire was composed by the groundwater hydrologist of the research team. Persons trained in diagnostic analysis assisted, along with other newly trained pre-engineering students.

The final tubewell questionnaire combined social-organizational questions and economic analysis items (C.3). These were administered by the sociology team enumerators in conjunction with the sample farmer interview schedules.

C.1 KEY INFORMANT GUIDE: FARMERS

We appreciate your agreement to share with us your knowledge of how water is managed along the minor and on your watercourse. As part of our opportunity analysis, our participants wish to understand how water is allocated to farmers, how the irrigation system is maintained, and basic problems faced by farmers in getting water to the crop root zone.

Please be assured that your name will not be used when interviewing other farmers or officials, and that the knowledge you provide will be treated with confidentiality and respect.

If you would like a summary of our report, we will be happy to send you one.

WATERCOURSE NO.

Key informant would like a summary of report. Yes No
Name of key informant
Mailing address
Key informant code
Interviewer's name
Date of interview
Reason for choosing this informant

Number of years managing farm
Irrigator's position on watercourse:

Canal:	Head	Middle	Tail
Minor:	Head	Middle	Tail
Watercse:	Head	Middle	Tail

WATER ALLOCATION

RULES FOR WATER DISTRIBUTION

1. How is the water distribution scheduled on your watercourse. (Please draw the schedule by days on the WATERCOURSE MAP with the marking pen.)
2. How many acres are officially scheduled for irrigation on this watercourse?
3. How much time is allocated for one acre?
4. What type of Warabandi system do you have? Kutcha Puca None
5. How often do you and others get their turn in a week? Once Twice
6. How were warabandi rules made for the watercourse? By:
   Farmers irrigation department Government?
7. What are the rules or principles for:
   1) The amount of water your watercourse is supposed to receive at the Mogha

   2) Changing the size of the Mogha.

   3) Closing the Mogha.

   4) Other rules regulating the Mogha.

8. What are the rules and procedures for supplying water to the nukkas?
   1) How is the order determined?

   2) Who determines the order?

   3) Can more than one nukka be operated or opened at the same time?

   4) Can water be exchanged between farmers?
   5) Can canal water be bought or sold on the watercourse?

9. How many farmers follow the rules?

	All	Most	half	Some	Few
Head					
Middle					
Tail					

11. If all farmers do not support the rules, Why do they not do so?

ALLOCATION:FLEXIBILITY (actual practice in water distribution)
1. Can the supply of water in the watercourse be increased? If so, how can this be done?

2. If you have access to public tubewell water, how is it distributed to the watercourse and nukkas?

   1) How regular is the flow of the public tubewell water?
      very quite half the time quite irregular very Ir.
      What other difficulties, if any, does the watercourse have with the supply of public tubewell water?

3. How many farmers have access to private tubewell water?

	All	Many	Some	Few	None
HEAD					
MIDDLE					
TAIL					

   1) Please describe how private tubewell water distribution works? (Get them to describe the informal organization of one or more private tubewell operations.)

4. What are the practices of farmers for exchanging water on the w/c?
   HEAD
   MIDDLE
   TAIL

5. Does the practice of exchanging water involve charges (cash or kind) by farmers? Yes No
   If so, how does it work?

ALLOCATION: MEASUREMENT
1. What is the sanctioned discharge (of cubic feet per second, or cusecs) of your watercourse?
2. How do farmers on the watercourse know the mogha is delivering its sanctioned discharge?

3. How often does the watercourse get more than the sanctioned discharge?
   - Kharif
   - Rabi
4. How often does the watercourse get less than the sanctioned discharge?
   - Kharif
   - Rabi
5. If your watercourse does not get its sanctioned discharge regularly who do you go to get your proper mogha supply?
   - What problems, if any, have you had getting your sanctioned discharge?

6. Who, if anyone, inspects the mogha discharge?
   From the irrigation department?
   Farmer(s) from the water course?
   Others?
3. Who keeps records of the mogha discharge?

9. Approximately how much of the sanctioned mogha discharge reaches the farmer's nukkas?

	100%	75%	50%	25% and less
HEAD				
MIDDLE				
TAIL				

ALLOCATION: TIMING

1. Where, if any, did farmers have serious water shortage problems with their last Kharif crops?
   SEEDING STAGE GROWTH STAGE FRUIT STAGE RIPENING STAGE
2. Where, if any, did farmers have serious water shortage problems with their last Rabi crops?
   SEEDING STAGE GROWTH STAGE FRUIT STAGE RIPENING STAGE

3. If members of your watercourse have had a water shortage problem, what do they do to get additional water?

	NONE	FEW	SOME	MANY
- Operate own private tubewell				
- Purchase private tubewell water				
- Purchase canal water from neighbor				
- Exchange canal water				
- can't meet water shortage problem and crops suffer				
- Other: (please specify)				

4. What are the most striking water delivery problems on your watercourse:
   HEAD
   MIDDLE
   TAIL

WARABANDI: RULE VIOLATIONS

1. Who reports the violators of watercourse rules?
2. To whom do they report?

3. How quickly are violators identified?

4. What happens to violators of watercourse rules when they are identified?

5. What kinds of misunderstandings or arguments occur on the watercourse?
HEAD
MIDDLE
TAIL

6. What rule is most frequently violated?

7. Could this rule be improved or changed? How?

ALLOCATION:QUALITY

1. How would you describe the QUALITY of the canal water?
Good Fair Poor
-other comments:

2. How would you describe the QUALITY of the PUBLIC tubewell water?
Good Fair Poor
-other comments:

3. How would you describe the QUALITY of the PRIVATE tubewell water?
Good Fair Poor
-other comments:

ALLOCATION: IMPLICATIONS

1. In your opinion, what is the biggest problem in distributing water on your watercourse?

2. What particular change, if any, needs to be made in the present distribution system?

3. Would other farmers along the watercourse think the same way?
HEAD MIDDLE TAIL

SYSTEM MAINTENANCE

MAINTENANCE :RULES

1. What are the rules, customs or procedures for watercourse maintenance?

   - How are they supposed to work?

   - How do they in fact work?

2. Where does misunderstanding of maintenance rules most typically occur on the watercourse (have the farmer point out problem areas on the map.)

3. If maintenance rules are subject to change, who can initiate change?

4. Who supervises the maintenance of the watercourse?

5. If farmers participate in maintaining the watercourse, how are they mobilized? (probe for rules of participation, and punishment of violators.)

6. When was the watercourse last worked on?

7. Were there any problems?

8. Who identifies violators of maintenance procedures?

9. How quickly are violators identified?

10. What happens to violators?

11. Are maintenance records kept ?If so, by whom?

12. Ask informant to discuss a particular maintenance problem case.

13. What would you say is the main problem in watercourse maintenance?

14. Why does the problem exist?

15. What do you think might be done to deal with the problem?

16. Would most of the farmers on the watercourse agree with you?

17. Who supervises the maintenance of the minor?

18. What is involved in cleaning the minor?

19. Who cleans the minor?
20. When was the minor last cleaned?
21. Where there any problems?

MAINTAINANCE: SYSTEM REPAIRS

1. What are the reasons for stopping the flow of water in the:
   Minor:

   Watercourse:

2. Who makes the decision to stop the flow of water?
   In the Minor:

   In the Watercourse:

3. How are the farmers notified or informed of a canal closure?

4. Where in the system are repairs most frequently needed ?

	MINOR	WATERCOURSE
HEAD		
MIDDLE		

TAIL

5. Are there any public tubewells that supply your watercourse?
   Yes   No
6. How many?
7. Who is responsible for repairs?
9. How often are they in need of repair?
10. Do you have a tubewell? yes   No
11. How many private tubewells are on the watercourse?
    How many are individually owned?   How many are jointly owned
12. What maintenance problems do they have?

13. How often do they need repair?

WATER/CROP PRODUCTION CHARGES

CANAL WATER:

1. What are the charges for canal water?

2. Who keeps the records?
   Who collects the water charges?

3. What happens if an irrigator/farmer does not pay the water charges? (Ask for several illustrations?

4. What happens if an irrigator does not AGREE with the water charges?
5. What would you say is one of the problems with the water charging method or procedure?

TUBEWELL WATER

1. Is there a charge for public tubewell water?
   If so, how is it set?
   Who sets it?
   How much is it?
   Who collects the charges?
2. What problems, if any, do you have with charges for public tubewell water?
3. Is there a charge for private tubewell water?
   How much is the charge?
   How is it set?
   Who sets it?
   Who keeps the records?
   Who collects the charges?
4. What problems, if any, do you have with charges for private tubewell water?

5. Are there possibilities for more extensive development of private or semi-private tubewell water?

SOCIAL STRUCTURE

1. What are the major castes (qaum) of farmers on your watercourse (please name each qaum and biradari, and its number of households.)

QAUM	BIRADARIES
1)	
2)	
3)	
4)	

2. To what extent do the above Qaums and their Biradaries usually work together?

	OFTEN	SOMETIMES	RARELY
1)			
2)			
3)			
4)			

3. Which Qaums work together with other Qaums?

	OFTEN	SOMETIMES	RARELY
1)			
2)			
3)			
4)			

4. On what matters do the Qaums and Biradaries usually agree?
   1)
   2)
   3)
   4)
5. On what matters to they disagree?
   1)
   2)
   3)
   4)
6. Over the last five years, what have been some of the more important disagreements, especially as they have to do with this watercourse?
   1)

   2)

   3)

   4)

SOCIAL ORGANIZATION: WATER USERS ASSOCIATIONS

1. Do you have a WUA on your watercourse? Yes No
   A. If so,
      1. How is it organized?

      2. How does it operate?

      3. What are its strengths?

      4. What are its weaknesses?

5. To what extent has it been supported? Strong Moderate Weak

6. To the extent it has been supported, why in your opinion have the members supported it?

7. To the extent it has NOT been supported, what are the reasons for non-support?

8. In your judgment, what would need to be done to gain renewed member support?

   - Would most of the farmers have similar thinking?

1. B. If not:

   1. Are you aware of the action of the government permitting formation of WUA's? Yes No
      - If so, how did you learn of this?

   2. Are you aware of how WUA's once formed, can apply for watercourse rehabilitation assistance?
      Yes No

   3. Are you aware that WUA's once formed, are a legal body, and can enter into contracts, make loan applications (e.g. for tubewells), can own and maintain common property, and can bring legal suits against offending parties, and can establish their own operating procedures and by-laws?
      Yes No
   4. What are the reasons that you do not have a WUA
      1.
      2.
      3.
   5. If your watercourse organized a WUA, do you think it could be helpful? Yes No
      If yes, how could the farmers of this watercourse be organized into a WUA?
   6. Should the watercourse organization be on a field ditch level as well as the watercourse level? Yes No
   7. Would an orientation program for further explaining the powers of a WUA and how to set it up be useful?
   8. Could an executive committee run it effectively?
   9. Any other suggestions?

C.2 WELL INVENTORY FORM

Your Name   Todays Date

Tubewell - Public   Private   Tubewell No.

Pump Type - Centrifugal   Turbine   Hand   Motor BHP

Power Source - Electric   Diesel   Hand   Depth of Well

Owners Name   Date Drilled

Number of Owners   Area Irrigated

Crop type Irrigated

Cost of Well   NET HOOKUP CHARGE

Delivery Pipe Diameter   units - inches   cm

Well Flow Rate   units - cusec   lps

Method of Measurement - Trajectory   Orifice Plate   Flume   Weir
Channel

DISCHARGE MEASUREMENT DATA

Electric Meter No   KWH Reading

Pump efficiency - Amps   Volts

Power Consumption

Start KWH Reading   Time

End KWH Reading   Time

KWH Used   Duration   hours

KW   Hours Without Electricity Each Day

Pump Efficiency (Discharge*Lift)/(KW*8.8)

Static Depth to Water   Well Elev

Pumping Depth to Water

Specific Capacity (Discharge/Drawdown)

Water Temperature   EC Reading

Hours Pumped each day

C.3 TUBEWELL ORGANIZATION QUESTIONNAIRE
KEY INFORMANT INTERVIEW

SUB-PROJECT AREA
WATERCOURSE NUMBER

Name of
Interviewer
Tubewell Number
Name of person being
interviewed
Date of Interview   Time of Interview

I. Economic Arrangements: (Also see technical measurements/arrangements from the attached groundwater hydrology data collection instrument.)

Initial cost analysis

1) Cost of drilling
2) Cost of pump
3) Cost of motor   Electric   Diesel
4) Cost of pipes, etc.
5) Cost of electrical materials
6) Cost of installation

Initial financing arrangements

1. What was the source and amount of capital

SOURCES		AMOUNT
Own sources		
Loans from relatives and/or friends		
Loans from Bank	(Please specify)	
Other:		

2. Terms of payment (e.g. Interest, length in years of loan, penalties for missing payments, defaulting, etc.)

II. Ownership: Share Arrangement.

Which of the following describes your share arrangement:
1) sole ownership   2)Joint ownership   ;If joint ownership, then:
What is the ownership arrangement for this tubewell?

NAME OF SHAREHOLDER	RELATIONSHIP TO YOU	QUAM	PERCENTAGE OF SHARE
1.			
2.			
3.			
4.			
5. plus (include others on back of page)			

III. Share Arrangement Rules

A. Among several or multiple shareholders.

How do you determine how much tubewell water each shareholder receives?

By amount of money invested

By acreage owned

Other

B. Share arrangement with non-owners.

Have you also sold water to other farmers in the last Kharif and Rabi who are non-share holders? Yes No

If yes, Who:	NUMBER OF	DISTANCE	ACRES IRRIGATED KHARIF	RABI
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				

Name	Number of Times	Distance	Acres Irrigated Kharif	Rabi
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				

(If there are other users, continue numbering them on the back of page 1.

IV. Allocation rules for shareholders:

1. What guidelines or rules do you have for distributing water

TO SHAREHOLDERS	TO NON-SHAREHOLDERS
1)	
2)	
3)	

2.How is the tubewell water distributed:

TO SHAREHOLDERS TO NON-SHAREHOLDERS

1) Rotation schedule without exchange.
2) Rotation schedule with exchange
3) Whenever they need, but some have to wait several days.
4) Whenever they need it as long as they need it.
5) Other

V. RULES: MAINTENANCE.

1. Carrier Ditches:

1)Are the carrier ditches the same as the watercourse ditches?

The same Mostly the same one half the same

Seldom the same Totally separate

2) How are the carrier ditches for the t/w water maintained?

3) Who cleans the carrier ditches?

4) How often are the carrier ditches cleaned?

5) Who makes repairs on the carrier ditches when needed?

V. (cont) MAINTENANCE--RULES

2. Tubewell Pump:

1) What kind of maintenance problems or repairs do you have with the tubewell pump?

2) How often are repairs needed?

3) How do you take care of repair problems?

4) How long does it take to fix the problem(s)?

5) What is the cost of such repairs?

6) What are the procedures for payment for needed repairs?

7) Who makes the payment for needed repairs?

VI. OPERATIONS

1. On the average, how many hours a day is the tubewell operated:

Last Kharif Last Rabi

2. What is the cost of your electricity over the last 12 months?

3. When are payments made for electricity/fuel charges?

VII. CONFLICT RESOLUTION: RULES.

1) What kind of problems, disagreements, or disputes have occasionally happened in distributing t/w water?

2) How have you gone about solving or resolving such problems?

3) What kind of problems, disagreements, or disputes have occasionally happened in maintaining t/w ditch canals?

   Tubewell equipment maintenance?

4) How have you gone about solving or resolving such problems?

VII. PAYMENT/COSTS: AGREEMENTS AND RULES

1. What is the form of payment for water received to:

	SHAREHOLDERS	NON-SHAREHOLDERS
Cash		
-how much?		
Kind:		
-how much?		
Labor:		
-how much?		
Other:		

2. What are some of the agreements or rules for payment of water received by:

   1) Shareholders

   2) Non-shareholders

APPENDIX D

USES AND LIMITS OF ETA AND PEARSON'S R

This research has dependent variables measured at interval and ratio levels, and independent variables that combine four ordinal level indicators into two water control indices or scales. Hence, the most appropriate procedure is one that is able to compute correlation coefficients for ordinal-level independent variables with interval- and ratio-level dependent variables. Eta is an appropriate statistical procedure for variables of this nature.

> "The eta coefficient is appropriate for data in which the dependent variable is measured on an interval scale and the independent variable on a nominal or ordinal scale. When squared, eta can be interpreted as the proportion of the total variability in the dependent variable that can be accounted for by knowing the values of the independent variable. The measure is asymmetric and does not assume a linear relationship between the variables."[1]

The logic of the eta statistic is not designed, as is Pearson's "r", to describe a linear relationship between dependent and independent variables. Rather, it takes the mean of each rank and plots it by the rank ordering stipulated for the particular ordinal variable. If the averages of the rank orders are not the same, then the difference is recorded in the eta coefficient. Eta is "basically an indication of how dissimilar the means on the dependent variable are within the categories of the independent variable. When the means are identical, Eta is zero. If the means are very different and the variances within the categories of the independent variable are small, eta increases toward its maximum value of one.[2]

Several qualifications are noted. first, if there are too many levels within the ordinal scale, the values of the eta statistic become distorted and calculate higher correlation coefficients than warranted. Hence, a scale that allows for averaging a sufficient number of values in computing the means for the particular rank is necessary. In this research, the range is between five to nine ranks. However, when the researcher has deemed it necessary to use Pearson's r (a statistical

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[1]Norusis, M. J. 1986. SPSS/PC+ for the IBM PC/XT/AT. Chicago, IL: SPSS, Inc. p. B-103.

[2]Nie, N. H.; C. H. Hull; J. G. Jenkins; K. Steinbrenner; D. H. Bent. 1975. Statistical package for the social sciences. New York: McGraw-Hill. p. 230.

procedure which has detractors for use with ordinal level data), it is best to eliminate the ranks and use the raw scores for purposes of statistical computation. In this way the ordinal values, rather than the average of ranks, will be utilized to more accurately process the data.

Other limitations of eta are that it does not show the direction of the relation between the dependent and independent variables, nor is it capable of being subjected to partial correlation analysis to take into account the effects of other independent variables on the specified dependent variable. For these reasons, it has been necessary to use the Pearsonian "r" and partial correlation statistical procedures to detect the positive or negative character of the relationship, as well as partialing out the effects of other independent variables. Of the statistical procedures available to this research, this appears to be the most appropriate analytical option. However, comparison of eta and "r" zero-order correlations is useful in order to note the difference in coefficients and the way they inform the strength of the relationship. When making such a comparison, the more appropriate and the more reliable statistic (because of the ordinal character of the independent variable) is the eta statistic. Where eta cannot be utilized, Pearson's "r" is the appropriate statistical option.

APPENDIX E
WATERCOURSE LOSS RATES

Water-course	Distance From Mogha (ft)	Date Measured	Flow at Mogha	Flow on Watercourse	Cusec Loss	Percent Loss	Loss 1000'
1	3100	11/13	1.45	1.15	0.30	10	0.10
	3300	11/19	2.37	1.83	0.54	23	0.16
	5500	11/17	2.15	1.47	0.68	32	0.12
	5700	11/10	2.21	1.35	0.86	40	0.15
	6100	11/24	2.50	1.32	1.16	47	0.19
	6500	11/25	2.82	1.34	1.48	53	0.23
2	3100	11/11	3.33	2.58	0.75	23	0.24
	3200	11/27	3.08	1.96	1.12	36	0.35
	4000	11/14	3.24	2.11	1.13	35	0.28
	5000	11/18	3.71	2.32	1.39	35	0.28
	5500	11/21	3.50	1.74	1.76	38	0.32
	5900	11/23	3.38	1.40	1.98	59	0.34
3	7000	11/13	1.45	1.00	0.45	31	0.06
	7100	11/13	1.45	0.90	0.55	38	0.08
	7600	10/31	1.40	0.90	0.50	36	0.07
	8000	11/14	1.25	0.70	0.55	44	0.07
4	3900	11/21	0.50	0.30	0.20	40	0.05
	4000	11/17	0.50	0.30	0.20	40	0.05
	4000	11/10	1.20	0.80	0.40	33	0.06
	4200	11/17	0.50	0.30	0.20	40	0.05
	5000	11/12	0.80	0.55	0.35	44	0.06
	8000	11/27	1.23	0.50	0.73	59	0.09
5	1100	11/13	1.85	1.84	0.01	1	0.01
	1100	11/20	2.00	1.84	0.16	8	0.08
	1800	11/06	1.60	1.23	0.37	23	0.21
	2000	11/14	1.20	0.69	0.51	43	0.26
	9200	11/07	1.90	0.92	0.98	52	0.11
	9900	11/27	1.55	0.74	0.81	52	0.08
6	5500	11/12	1.30	0.91	0.39	30	0.07
	6600	11/16	1.70	0.93	0.77	45	0.12
	8600	11/25	0.90	0.60	0.30	33	0.03
	8800	11/25	0.90	0.54	0.36	40	0.04
	10300	11/28	1.15	0.57	0.58	50	0.06
	12100	11/19	1.45	0.35	1.10	76	0.09

APPENDIX F

ASSESSMENT AND REVENUE COLLECTION RULES

This appendix describes the assessment rules for *warabandi* water charges, public tubewell water use, and rules in regard to violating the payment of assessments.

Warabandi Assessment Rules: Institutional Arrangements

One of the divisions under the supervision of the subdivisional officer (SDO) is responsible for assessing water charges for crops irrigated by canal sources. The Office of the Assessor (*zillidar*) was instituted to carry out this function. This office parallels that of the sub-engineer or overseer and covers the same geographic area. There are a number of assessment *patwaris* directly under the supervision of the *zilladar*. The common ratio is 1 *patwari* for 5,000 irrigated acres. Their responsibility is to check all the irrigated area under their jurisdiction, and make judgments regarding who is irrigating how much acreage growing what crops.

However, this information is not always easy to determine. Ownership records are not available to *patwaris*, only to the Finance Department. After repeated attempts over the past 10 years by the *patwaris*' association to gain access to land ownership records, no response has been forthcoming. Apparently, Finance Department officials and collectors of revenue view this as their exclusive and inviolable domain. However, the consequence is ambiguity in the field, as the assessment *patwaris* seek to determine who to charge for which crops. In their own evaluation, many of the judgments are arbitrary.

Assessment *patwaris* do not actually collect assessments. They send all assessment records to the Finance Department for their collectors to administer. The Revenue Department collectors work with the local village *lumbardar* (government contact), who does the actual collections at the direction of the revenue *patwari*.

Finally, these revenues do not go to the Irrigation Department as part of their ongoing budgeting process, but rather into the state revenue collection general fund. The Irrigation Department is not dependent on the collection of revenues for its operation.

Warabandi Assessment Rules: Water Charges

The rule for water charges is that land irrigated by canal sources is to be assessed according to the type of crop planted. If the *warabandi* canal water supply is utilized in any amount whatsoever, it is subject to the standard rate prescribed by the Irrigation Department through the mandate of the Secretary of Irrigation. If no water is used, there are no charges. If all of a farmer's land is irrigated by canal sources, he will be charged on an acre rate for the type of crop irrigated. If the land has been irrigated primarily by tubewell water with some canal water applied, full water charges are assessed. If the land has been irrigated exclusively by tubewell water, but the carrier of that tubewell water is the official watercourse constructed for carrying canal water supplies, full charges are assessed. Any conjunctive use of tubewell and canal water carries full warabandi assessments.

There is one modifying rule that remits or modifies a farmer's water charge when there is crop damage. The rule states that only a natural calamity (such as excessive rain, hail, dust storm or saline land) can constitute grounds for negating the water charge. If a farmer thinks that his crops have had excessive damage, he can file a petition for the remission of charges through the office of the SDO. It then goes to the executive engineer, and back to the office of the zilladar, where the assessment patwari investigates the problem and makes a recommendation that then goes through the chain of command before resolution. According to the zilladar, remissions are filed fairly often, but not many are granted. It is the sense of the key informants that these remissions should be made on the authority of the zilladar and assessment patwari, rather than having to go through the prolonged procedure described above.

Unless there is a clear demarcation between private tubewell water application and canal water application, warabandi water charges will be assessed. Hence, in a number of instances, farmers have blocked off the canal, as in watercourses 4 and 6. Others have eliminated field channels that formerly transported canal water in order to ensure that there is no connection with the main delivery channel. Without such evidence, warabandi assessments are made on all irrigated crops.

Water charges have little, if anything, to do with receiving the duly sanctioned warabandi share. Rather, charges are tied only to whether or not a particular parcel of land used canal water one or more times during the season. One farmer could thoroughly irrigate one or more acres of vegetables with a very high return because he receives more than his sanctioned supply, while another farmer might apply only one warabandi application on the same amount of acreage with his major supplies coming from tubewell water. Both would have identical warabandi assessments. Hence, a farmer pays different rates depending on access to the warabandi water supply, which, as has been demonstrated, is significantly affected by location in the system and on the watercourse. Water charges are not connected with the amount of water used.

Key informants have described the practice of altering assessments in collaboration with farmers in such a way that farmers pay a reduced assessment and split the savings with the revenue patwari. The direct evidence we do have demonstrates that the patwaris cannot fulfill their job description because they do not have the tools (revenue ownership maps) with which to do an accurate assessment.

Public Tubewell Water Assessment Rules

Public tubewell water for two of the six watercourses in the sample was pumped into the *warabandi* canal delivery system and therefore should be treated as a part of that system. Public tubewell water in a number of other locations in the Niazbeg system was supplying a single watercourse. These watercourses most often had little or no access to canal water supplies. There were a total of 39 active public tubewells operating in the Niazbeg subproject area. However, they were not managed and run by watercourse personnel, but by a separate wing of the Irrigation Department that manages public tubewell water supplies. Its administrative center is in Lahore. The report on the Niazbeg diagnostic analysis provides the following organizational background:

> "The government tubewells were installed by WAPDA (Water and Power Development Authority). After an initial testing period, the organizational management of these tubewells was turned over to the Irrigation Department. The subdivisional officer (SDO) for tubewell operations is directly responsible for monitoring and operating the tubewells. The tubewell SDO for Niazbeg subproject is in Lahore. A different tubewell SDO is responsible for maintaining and repairing the tubewells. His office is also in Lahore. While the interaction of the tubewell SDOs with SDOs who are responsible for operating the canal system was not ascertained during this DA, it appears that relatively little interaction occurs." (Wattenburger et al., 1987, p. 118)

Two watercourses in the sample located on the Thatti Uttar minor at the tail of the Niazbeg system (watercourses 5 and 6) received tubewell water pumped into the minor canal.

APPENDIX G

DROUGHT RESISTANCE SCALE

The drought resistance scale was created in consultation with Mr. Muhammad Rafiq Chaudhary, a doctoral student in agricultural engineering at Colorado State University. This particular scale was difficult to construct and required considerable research and application to the Pakistani Punjab environmental and climatic conditions.

The major source utilized was from a paper written by Doorenbos and Kassam.[1] Two major values were used to calculate the percent of reduction in yield at four phases of crop growth. The first is the reduction in the ratio of ETA (actual evapotranspiration) to ETP (potential evapotranspiration) (1 - ETA divided by ETP). The second is the sensitivity coefficient for each of the four stages, arrived at through considerable crop experimentation. These two values are multiplied, thereby producing an estimate of the percent of reduction in yield at each of four growth stages (vegetative, flowering, yield formation, and maturity) for each specified crop.

In utilizing these values from Doorenbos and Kassam (1979), Chaudhary found that they were consistent with field experiment research done in the Pakistani Punjab for wheat by Chaudhry, Ibrahim and Eckert.[2] Vegetable crops required further investigation to calculate their values.

Table G1 provides these values and the percent of reduction in yield for each crop stage. These values were summed for each crop to provide a total score that served as the drought resistance or moisture sensitive values used in calculating a composite score for each farm unit.

Each farm unit was given a drought resistance/moisture sensitivity score derived from the values in Tables G1 and G2 for rabi and kharif. The following procedures were used in calculating those values.

1. Assign each crop the drought resistance value given in Table G1.

2. Divide each crop acreage by the total area cropped. Multiply by 100 to get percent of the total.

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[1]Doorenbos, J.; Kassam, A. H. 1979. Yield response to water. Irrigation and Drainage Paper 33. Rome: FAO.

[2]Chaudhry, N. M.; Ibrahim, M.; Eckert, J. 1975. The effects of delayed first irrigation on spikelet differentiation and yield in wheat. Mimeographed field report on wheat stress experiment in Punjab, Pakistan. Fort Collins: Engineering Research Center, Colorado State University. 18 pp.

3. Multiply each crop percentage as obtained in step 2 by the appropriate drought resistance scale.

4. Sum the crop values calculated in step 3 to construct an overall drought resistance/moisture sensitivity coefficient.

The base coefficients calculated for kharif are given in Table G2. The same procedures were used to calculate the base coefficient for kharif as were used in Table G1.

Table G1. Drought resistance scale values for rabi (winter).

	Wheat	Vegetables (tomatoes)	Berseem	Oats	Oilseed
(Reduction in relative evapotranspiration $1 - \frac{ETA}{ETP}$	.18	.40	.32	.15	.15
Crop Stages		**Sensitivity Coefficient**			
Vegetative	0.2	0.4	1.0	0.2	0.2
Flowering	0.6	1.1	1.1	0.5	0.8
Yield form'n	0.5	0.8	-	0.4	1.0
Matur'y	0.0	0.4	-	0.0	0.5
Crop Stages		**Reduction in Yield***			
Vegetative	3.6	16.0	32.0	3.0	3.0
Flowering	10.8	44.0	32.0	7.5	12.0
Yield form'n	9.0	32.0	-	6.0	15.0
Maturity	0.0	16.0	-	0.0	7.5
Total	23.4	108.0	64.0	16.5	37.5
Base Coefficient**	1.42	6.55	3.87	1.0	2.27

*These values are a product of ETA divided by ETP x the sensitivity coefficient.

**The total of the four drought resistance scores for oats were used as a base of 1.0. Thus, the coefficient 16.5 is transformed into a base 1.00 and all other scores are reduced proportionally by this 16.5 divisor.

Table G2. Drought resistance scale values: base coefficients calculated for kharif (summer).

Crop	Rice	Maize	Veges	Sugarcane	Cotton	Sorghum	Fodder
Base Coefficient*	7.79	6.55	5.03	2.70	1.91	1.10	1.09

*The base coefficient was calculated on the same basis as Table G1.

APPENDIX H

EVAPOTRANSPIRATION: ACTUAL SCALE (ETA)

A second measure of variation in the cropping pattern variable was constructed, namely the daily evapotranspiration rate for crops grown in central Punjab. M. Rafiq Chaudhary assisted in formulating this scale. The data from which this scale was constructed was taken from "The Irrigation Guide."[1] The chart from which the information was gathered was titled "Seasonal and Peak Daily Consumptive Use Rates, Central Punjab Climatic Zone."

This measure is not as sensitive to the changing crop water requirements, or to the event of a missed irrigation, as the drought resistance scale (Appendix G). It is a measure that takes the total water requirements for a particular crop and calculates the average daily water requirements for the specified crop.

Tables H1 and H2 show the ETA values and the base values. The daily evapotranspiration rate for wheat (2.62 mm/day) was used as the base value (1.00). All other rates were appropriately adjusted to this designated base value.

The same four procedures noted in this appendix were utilized to formulate a single ETA value for each farm unit by combining the base seasonal crop values into a composite score as an indicator of the cropping pattern variable.

Specifically, this indicator was used in Chapter VII as a primary measure in calculating the supply and demand average and peak water requirements for existing and adequate water situations for each of the six sample watercourses. It was also used in the general analysis of water control and its impact on crop productivity variables in Chapter VI.

Note that both of these cropping pattern variable indicators (Appendices G and H) are experimental in nature, and to this writer's best knowledge have not been previously used. Therefore, further critique and usage will illuminate their future and potential usefulness. They appeared to adequately serve the purposes of this research.

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[1]Government of Pakistan. 1984. Water users associations in Pakistan. Islamabad: Ministry of Food, Agriculture, and Cooperatives (water management wing). p. 42.

Table H1. Daily evapotranspiration/actual rates and their transformation into base values for constructing a measure for the cropping pattern variable (*rabi*).

	Rabi Crops				
	Wheat	Vegetables	Berseem	Oats	Oilseed
ETA/day*	2.62	3.33	4.01	2.62	2.01
Base Ratio	1.00	1.27	1.80	1.00	0.80

*All values on this line are in mm/day.

Table H2. Daily evapotranspiration/actual rates and their transformation into base values for constructing a measure for the cropping pattern variable (*kharif*).

	Kharif crops						
	Rice	Veges	Sugarcane	Maize	Cotton	Fodder	Sorghum
ETA/day*	6.99	4.76	4.44	4.32	4.28	4.11	3.68
Base Ratio	2.60	1.82	1.69	1.65	1.63	1.57	1.40

*All values on this line are in mm/day.

APPENDIX I

CONSTRUCTION OF TIMING INDICATORS FOR THE TUBEWELL WATER CONTROL SCALE

In constructing the composite measure for tubewell water control, four indicators were used (the first two measures are described in the text):

1. An ordinal measure of the sufficiency of supply -- a measure of quantity control.

2. An ordinal measure of the reliability of supply.

3. Timing measure 1: a measure of the responsiveness of delivery by the owner of tubewell water to a request for water.

4. Timing measure 2: a ratio measure of the times water was needed to the times water was actually available.

The two timing measures were formulated as follows.

Timing Measure 1

Farmers were asked how long it took for tubewell water to be delivered once it was requested. The greater the time it took to receive water, the less the water control. Often, a delay can curtail the growth and yield of a plant, as noted in chapters I and II. Therefore, values were squared to give greater weight to early delivery of tubewell water after the request was made.

within 24 hours:	the value 4 was squared to equal	16
within 1-2 days:	the value 3 was squared to equal	9
within 3-4 days:	the value 2 was squared to equal	2
5 or more days:	the value 1 was squared to equal	1
did not receive tubewell water:		0

Timing Measure 2

This measure was a ratio between times needed and times available. For example, if a farmer needed tubewell water five times, and he received it five times, a value of 10 would be awarded. If he received water four times, a value of eight was recorded, and so on. In other words, the formula "times received" divided by the "times needed" multiplied by 10 provided the range of values from 1 to 10 for this indicator of timing control.

APPENDIX J

PROCEDURES FOR DESIGNING WATER DEMAND AND SUPPLY MEASURES FOR EVALUATING CROP YIELDS IN THE NIAZBEG SUBPROJECT AREA

Three calculations were necessary to provide watercourse level data for this measure of water demand and supply. First, it was necessary to determine the crop water demand at the root zone for both present and adequate water supply situations. A subset of this task was determining average daily crop water requirements (average daily evapotranspiration rates) for the watercourse cropping pattern. This was made possible by thoroughly listing all crops for all sample farmers for both kharif and rabi. Aggregate measures of crop acreage for both existing and adequate water supply situations were then constructed. (See Appendix I.)

Second, an estimate of the actual amount of water delivered to the crop root zone for present and adequate water cropping patterns for each sample watercourse was obtained. It was possible to get estimates of the water supply because canal and tubewell water measurements were taken during the diagnostic analysis, and researchers had access to electricity use records for over 80 percent of the tubewells in the sample. Note that these are rough estimates. However, every effort was made to get accurate measurements for both types of water delivery.

These measures were declared rough because the canal water measurements were only taken over a six-week period. During this period, the Irrigation Department made a concerted effort to adequately supply the project. Also, the absence of 20 percent of the electricity records creates room for error, even though the attempt was made to obtain data on every tubewell in the sample. However, the margin of this error should be minimal and relatively equally distributed.

Third, an estimation of the crop water deficit/excess between demand and supply was calculated from estimations of both demand and supply values. Each of these steps is presented in greater detail relative to procedures for calculating supply and demand measures in the following pages.

Procedures for Calculating Crop Water Demand for Sample Watercourses

The procedures for calculating the crop water demand "at the root zone" for each watercourse required translating the average evapotranspiration per day for each crop grown and its acreage in relation to the total area into acre-feet per week and then into cubic feet per second (cusecs) required at the root zone. Table J1 shows the procedures followed for each watercourse in making these calculations for kharif and rabi, and for present and adequate water supply situations. In brief, crop water requirements per day (ETA), for all crops was translated into the total crop water requirement at the root zone for each watercourse's cropping pattern.

Table J1. Crop water demand and supply analysis for present cropping pattern on watercourse 1 in *kharif*.

Demand: Crop Water Req'd at Root Zone							Supply at Root Zone		Deficit	
Crop	ETA mm/ day	ETA ft/ week	% of area for crop	Tot. area	ETA acre-ft/ week	Req'd at root zone	Req't met from canal	Req.t met from TW	Canal water req'd at mogha	TW water req'd at mogha
Rice	6.99	0.16	12	457	8.80	0.63				
Maize	4.32	0.10	8	457	3.63	0.26				
Veg.	4.76	0.11	4	457	2.00	0.14				
S/c	4.44	0.10	1	457	0.47	0.03				
Cot.	4.28	0.09	15	457	3.59	0.26				
Sorg.	3.68	0.09	15	457	5.79	0.42				
Fod.	4.11	0.09	30	457	12.94	0.93				
Total						2.68				
Rainfall						0.89				
Net average req'd						1.79	0.94 Tot.	0.75 = 1.69	0.25	0.19
Net peak req'd						2.35	0.94	0.75	1.58	1.18

The root zone water requirements were then totaled for all the crops. The average rainfall (over the past 18 years) in cusecs was then deducted. This left the "net average cusecs required" at the root zone for the present or adequate water cropping pattern at the watercourse level. To get the "net peak crop water requirement," the total water requirement was increased approximately one-third. Specific values were calculated to determine the amount of additional water needed that was consistent with the crop water requirements for the watercourse cropping pattern. These values are displayed in Table J2.

The values for calculating the average rainfall to the Niazbeg area were obtained by Mr. Mohammad Rafiq Chaudhary (1987), who assisted in the construction of these measures. They were obtained from the Chuharkana Observatory, Soil and Water Investigation Division (WASIC), WAPDA, Lahore, over an 18-year period.[1]

[1] Chaudhary, M. R. 1987. Optimal conjunctive use of surface and groundwater in a watercourse command area of the Indus Basin. Fort Collins: Department of Agricultural and Chemical Engineering, Colorado State University. [Dissertation]

Table J2. Percentage increases for meeting peak crop water requirements by sample watercourses in *kharif* and *rabi* for actual and adequate water situations.

	Watercourse					
	1	2	3	4	5	6
	-- Percent increase in crop water req'd --					
Kharif						
Present water sit.	31	30	36	35	35	29
Adeq. water sit.	43	33	27	35	36	28
Rabi						
Present water sit.	42	37	41	36	32	28
Adeq. water sit.	41	36	33	37	32	33

Regarding the crop water requirements for the peak crop growth period, which often corresponds with the flowering and seed formation crop phases, several qualifications are in order. Dr. Paul Wattenburger, an engineer from CSU who participated in the data gathering process during the research, calculated the estimates that were used for this research (Table J2). These estimates may be low.[2] If this is the case, as it appears to be, such an increase in crop water requirements during the peak period would only strengthen the support for the hypothesized relationship between water control and crop yields, and further explain the reasons for low yields in the subproject area.

Procedures for Calculating Crop Water Supplies

The water measurements taken over the six-week data collection period for canal deliveries to watercourse *moghas* and tubewell water production were transformed into cusecs delivered to the root zone with the assistance of M. Rafiq Chaudhary.

The average amount of water delivered to the watercourse was assumed to be the rate delivered for both seasons. The extent to which this corresponds with actual deliveries during this unknown period informs the reliability of the measure. It was presumed that the averages were slightly higher than usual for reasons mentioned above. Both Chaudhary and Wattenburger agreed that realistic estimates for watercourse delivery efficiencies and field application efficiencies were, respectively, 60 percent and 70 percent. In other words, the proportion of water delivered to the crop root zone was estimated as the product of these two estimators, or 42 percent. As previous measures of watercourse losses indicated, the estimate of 40 percent watercourse losses is within .005 of the average measured watercourse losses in this research: head water-

[2]Wattenburger, P.; R. Luebs; R. Tinsley; E. Quenemoen; E. Shinn; J. Warner. 1987. Command Water Management, Punjab: pre-rehabilitation diagnostic analysis of Niazbeg subproject. WMS Report 52. Fort Collins: Water Management Synthesis II Project, Colorado State University. p. 103.

courses (1-3) had a 62.5 percent delivery efficiency, and tail watercourses (4-6) had a 57 percent delivery efficiency. Thus, the average rate of water delivered to the outlet of each watercourse was reduced by subtracting these losses, making all reported values of supply "deliveries to the root zone area."

The same basic procedures were applied to measures of tubewell water. However, there was one major difference: tubewell water delivery losses were estimated at 20 percent, or a delivery efficiency of 80 percent. The field efficiency application remained the same, with a total estimated delivery efficiency of 56 percent (in contrast to 42 percent for canal delivery).

These measures were difficult to construct, requiring hundreds of man-hours. Without the assistance of other disciplines, such as agricultural engineering, such an effort would have been beyond the capacity of this researcher.

APPENDIX K

PROCEDURES FOR DETERMINING COST OF TUBEWELL WATER

The following procedures were performed to calculate the average cost of tubewell water for each watercourse. Table K1 gives the average estimated cost per acre-foot for all six sample watercourses.

1. Average operating cost per hour. Three factors contributed to the tubewell operational cost: electricity charges, tubewell maintenance charges, and an operating charge per month (Rs. 250) that is added to the electricity use charges.

   Calculations for electricity charges were based on the rate of 51 paisa per kilowatt-hour. This figure was divided by the electricity consumption rate, to get the number of kilowatt-hours used. If 10 kW were consumed in one hour, the electricity charge would be Rs. 5.10. If the tubewell was operated for 250 hours a month, another rupee would be added (base monthly charge) for a subtotal of Rs. 6.10. Dr. James Warner, the groundwater hydrologist, estimated that maintenance costs amounted to 10 percent of the electicity charge (51 paisa). Thus, total operating costs in this hypothetical case would be Rs. 6.52/hour.

2. Average yearly operational time. The average yearly operating time in hours was calculated. Table K1 shows the hours of operation for each tubewell.

3. Determination of total yearly cost. The average operating cost per hour was multiplied by the total number of hours operated during the year (1 x 2).

4. Average discharge in cusecs. The discharge for each tubewell was measured during the research.

5. Determination of the total amount of water pumped in the two cropping seasons in cubic feet. The average discharge in cusecs (from step 4 above) was multiplied by 3,600 (cubic feet per hour) and by the average yearly operational time (in step 2, above).

6. Determination of number of acre-feet produced by the tubewell. The total amount of water pumped (step 5) was divided by 9; and that number was divided by 4,840.

7. Cost Per Acre-Foot. The total yearly cost (step 3) was divided by the number of acre-feet produced by the tubewell (step 6).

Table K1. Cost of tubewell water per acre-feet for six sample watercourses in the Niazbeg subproject area.

Water-course	(n=)*	Average Operational Cost/Hour (1)	Average Yearly Operated Time (2)	Total Yearly Cost (3)	Average Discharge in Cusecs (4)	Total Yearly Pumped Water in ft^3 (5)	Acre-Feet (6)	Cost/Acre-Foot in Rs. (7)
1	2	5.87	5,417	31,798	1.04	20,281,248	466	68.23
2	9	7.18	1,853	13,305	1.05	7,004,340	161	82.64
3	2	9.49	4,308	40,883	1.29	20,006,352	459	89.02
Average								79.96
4	7	6.65	3,314	22,038	1.44	17,179,776	394	55.87
5	4	8.53	3,202	27,313	1.24	14,293,728	328	83.24
6	5	8.54	2,781	23,750	1.32	13,215,312	303	78.28
Average								72.46
Average of 1-6								76.21

*n = All tubewells on each watercourse for which the following measurements were obtained: cusec discharge, kilowatt hourly consumption rate, and yearly hours of operation (derived from official WAPDA electrical consumption figures for each tubewell).

APPENDIX L

PROCEDURES FOR CALCULATING COST OF CANAL WATER PER ACRE-FOOT

The following procedures were used to determine the acre-foot cost of canal water. Mr. M. Rafiq Chaudhary, agricultural engineer and doctoral candidate, assisted in constructing this scale. Table L1 provides the procedures and calculations for determining the cost for sample watercourse 1. On each watercourse, the particular crop and its acreage were identified.

1. Determine the acreage under cultivation for each crop. Water charges were assigned for every cultivated acre on the watercourse unless there was exceptionally clear evidence presented to the canal revenue *patwari* that no canal water had reached a particular field or fields. The evidence must be relatively incontrovertable. It was assumed that the acreage under cultivation received some canal water. Although this was not the case with all watercourses, especially watercourses 4 and 6, the water distribution system was designed to deliver canal water to all the fields. That it does not do so suggests that the cost of canal water for the amount delivered is excessive. Hence, the calculations will assume -- for the purposes of this study -- that all acreage with the designated crops receive canal water.

2. Determine water charges per acre. As mentioned above, *warabandi* water charges are assessed if any canal water is applied to the crop acreage or if the main delivery canal is used to transport tubewell water. If it cannot be conclusively proved that canal water was not applied, the charges were assessed to farmers' crops. This appears to be simple enough. However, if public tubewell water is also carried by an official *warabandi* watercourse, all fields receiving this water are charged approximately Rs. 33/acre on top of the regular *warabandi* crop charges. In this sample, two watercourses on the tail minor were subjected to these additional charges, with the consequence that many farmers, especially on watercourse 6, physically withdrew from the *warabandi* delivery system, refusing to receive canal water.

   However, to get comparative costs across watercourses, this additional charge of Rs. 33/acre was not included in the per-acre cost calculated for the sample watercourses. Nevertheless, note that this is an actual cost and should be recognized as such, which strengthens the analysis regarding the relationship of water control to organizational support. Finally, the calculations do not include informal or extra-legal water charges.

3. Determine the total water charges. This was accomplished by multiplying the crop area by the rate officially designated for that crop. For example, if 10 acres were planted in rice and the cost per acre was Rs. 35, the total water charges for the watercourse for the rice crop would be Rs. 350. Table L1 shows these figures for watercourse 1.

4. Determine the average mogha discharge. Measurements of the average discharge over the six-week study were used for this step.

5. Determine the total annual hours of operation. The figure used for all watercourses was 365 minus 31 days, or 8,016 hours.

6. Determine the total flow in acre-feet. The formula used for calculating this was average cusecs (step 4) x annual hours of operation (8,016) x 3,600 (seconds per hour).

7. Calculate the cost of canal water per acre-foot. The cost of canal water per acre-foot was calculated by dividing the total water charges (step 3) by the total flow in acre-feet (step 6). Table L1 shows this operation for watercourse 1.

Table L1. Procedures for determining the acre-foot cost for canal water on watercourse 1.

Crop	Area Under Each Crop (ac) (1)	Water Charges in Rs. (2)	Total Water Charges in Rs. (3)	Mogha Discharge in cusecs (4)	Annual Hours of Operation (5)	Total Flow in Acre-Feet (6)	Cost per Acre-Foot (7)
Rice	45	45	1,575	2.13	8,016	1411.1	9.10
Veges	7	55	385				
Grains	77	16	1,232				
Sugar-cane	5	85	425				
Fodder	96	16	1,536				
Cotton	30	33	990				
Wheat	178	23	4,094				
Veges	20	55	1,100				
Berseem	50	16	800				
Oilseed	0	-					
Oats	44	16	704				
Total			12,841				

APPENDIX M

GLOSSARY OF ABBREVIATIONS AND TERMS

ac	acre
ADBP	Agricultural Development Bank of Pakistan
barrage	control headworks
belldar	laborer
biradari	kinship group
BRBD canal	Bedran-Dipalpur Link Canal
BS Canal	Balloki-Suleimanke Canal
C	Centrigrade
CCA	cultural command area
CMS	Crop moisture score
CSU	Colorado State University
cusec	cubic feet per second
CWM	Command Water Management Project
de facto	actual; observed
de jure	official
doab	finger of land lying between rivers in the Punjab
eta	a statistical procedure (Appendix D)
ETA	average evapotranspiration
ETP	potential evapotranspiration
F	Fahrenheit
free rider	person who obtains a benefit, but who does not pay for that benefit
ft	feet
ha	hectare

kg	kilogram
kharif	summer (June-September)
kutcha	when used to describe the *warabandi*: informal agreements among farmers for distributing water
kW	kilowatt
maund	1 maund is approximately 82 pounds
mogha	outlet on a distributary
nukka	outlet to a field or farm ditch
patwari	local irrigation revenue official
pukka	when used to describe the *warabandi*: a formal, written set of agreements for water distribution, adjudicated by the Irrigation Department
quom	caste
rabi	winter
Rs.	rupees
SDO	subdivisional officer
TW	tubewell
USAID	United States Agency for International Development
WAPDA	Pakistan Water and Power Development Authority
warabandi	rotational system of canal water distribution
WC	watercourse
WUA	water users association
zilladar	assessor

APPENDIX N

LIST OF WATER MANAGEMENT SYNTHESIS II PROJECT REPORTS

WMS 1 Irrigation Projects Document Review

Executive Summary
Appendix A: The Indian Subcontinent
Appendix B: East Asia
Appendix C: Near East and Africa
Appendix D: Central and South America

WMS 2 Nepal/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 3 Bangladesh/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 4 Pakistan/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 5 Thailand/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 6 India/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 7 General Asian Overview

WMS 8 Command Area Development Authorities for Improved Water Management

WMS 9 Senegal/USAID: Project Review for Bakel Small Irrigated Perimeters Project No. 685-0208.

WMS 10 Sri Lanka/USAID: Evaluation Review of the Water Management Project No. 383-0057.

WMS 11 Sri Lanka/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 12 Ecuador/USAID: Irrigation Sector Review

WMS 13 Maintenance Plan for the Lam Nam Oon Irrigation System in Northeast Thailand

WMS 14 Peru/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 15 Diagnostic Analysis of Five Deep Tubewell Irrigation Systems in Joydebpur, Bangladesh

WMS 16 System H of the Mahaweli Development Project, Sri Lanka: 1982 Diagnostic Analysis

WMS 17 Diagnostic Analysis of Farm Irrigation Systems on the Gambhiri Irrigation Project, Rajasthan, India: Volumes I-V

WMS 18 Diagnostic Analysis of Farm Irrigation in the Mahi-Kadana Irrigation Project, Gujarat, India

WMS 19 The Rajangana Irrigation Scheme, Sri Lanka: 1982 Diagnostic Analysis

WMS 20 System H of the Mahaweli Development Project, Sri Lanka: 1983 Diagnostic Analysis

WMS 21 Haiti/USAID: Evaluation of the Irrigation Component of the Integrated Agricultural Development Project No. 521-0078.

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