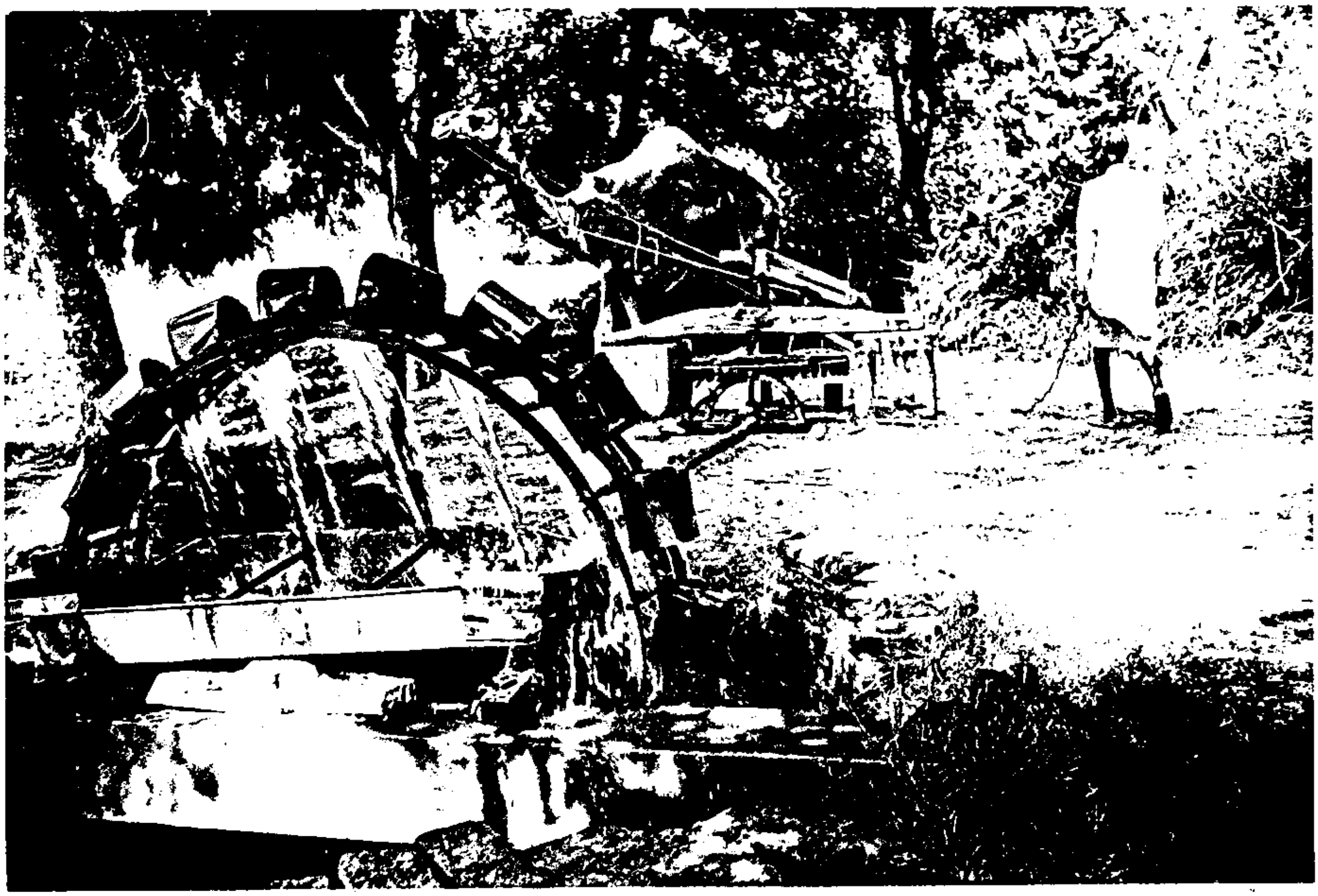
The Appropriateness of Canal Water Supplies: The Response of the Farmers

A case study in the Fordwah/Eastern Sadiqia area, Punjab, Pakistan



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FOREWORD

In May 1992, the International Irrigation Management Institute (IIMI) in Pakistan started a series of publications, which we called Discussion Papers, to disseminate the results of its studies specifically to a Pakistan audience. This audience includes our colleagues in provincial irrigation and agricultural departments, and also policy makers in federal ministries and in donor institutions, as much of what we do has management and policy implications.

The Discussion Papers 6 and 7 are of particular interest to policy makers and donors as they report on research studies carried out in the Fordwah/Eastern Sadiqia area, and on the unusually heavy desiltation campaign undertaken in Punjab canals during the annual closure period of January 1992.

The Fordwah/Eastern Sadiqia area with its high watertables and considerable build-up of profile salinity will be the site of an extensive, World Bank sponsored study, titled "Fordwah Eastern Sadiqia (South) Project, Irrigation and Drainage Research". Quite a few institutions are planning to participate in the study, and the Work Plan for the 1992-93 studies is now being finalized. We expect that the first set of research results of IIMI's study, reported here in Discussion Paper 6, will be of relevance for the larger study about to be started in the area.

The annual maintenance carried out during the canal closure period of January/February was unusual in the sense that it received strong support from the Civil Authorities, under the guidance of the Chief Minister of Punjab, Mr. Ghulam Haider Wyne. IIMI's field staff have monitored the various activities undertaken in IIMI's research areas, both those on a self-help basis and done by contractors. Some farmers reported seeing water in the tail reaches of distributaries for the first time in fourteen years. Apparently, it is physically possible to bring water to tail reaches that had been dry for many years. But what is required to clean distributary canals sufficiently to make that happen? And is that effort sustainable and how often should it be repeated? These are some of the questions tliat have been addressed in Discussion Paper 7.

The data on which Discussion Papers 6 and 7 are based, were collected as part of the study "Managing Irrigation Systems to Minimize Waterlogging and Salinity Problems", entrusted to IIMI by the Government of The Netherlands.

We don't pretend that the studies reported in these two Discussion Papers present any final answers, but we are of the opinion that they raise some interesting points relevant for the management of irrigation systems in Pakistan. We hope that the papers will generate discussion -- that is why they are called Discussion Papers -- and we cordially invite you to send us your comments or suggestions.

Jacob W. Kijne
Director

16 September 1992

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EXECUTIVE SUMMARY

In 1989 IIMI initiated research for the Waterlogging and Salinity Project in three different sites in the Punjab. Extension of the research to an area with a different agro-ecological zone, served by its own distinctive irrigation system was advocated, and in late-1990, IIMI started a study in the Fordwah/Eastern Sadiqia area. The area is located in the south-east of the Punjab, bounded by the river Sutlej, the Cholistan desert and the Indian border.

This (semi-)arid area is served by two main canals, i.e. Fordwah and Eastern Sadiqia Canal, both off-taking from Sutlej river at Suleimanki headworks. The system combines both perennial and non-perennial canals in its command area, the latter receiving water only in Kliarif. When the system was designed (1930) some canals were made non-perennial, for fear of waterlogging in the riparian tract along Sutlej.

Fordwah Branch off-takes from Fordwali Canal and part of its service area was selected as study area, downstream from RD 245 (Chishtian Sub-division). Of the 14 distributaries two were studied in more detail, i.e. Azim distributary and Fordwah distributary, and along these distributaries four sample watcrcourscs were chosen (Azim 63, Azim 111, Fordwah 62 and Fordwah 130). In addition, Fateh distributary, off-taking from Malik Branch of Eastern Sadiqia Canal was monitored, and a sample watercourse (Fateh 184) selected. As such a transect is taken perpendicular to the Sutlej going from the river towards the Cholistan desert.The irrigation system was studied at all levels, from main system level (Fordwali Branch), via distributaries to the watercourse level. Data was collected for one full year, comprising Kharif 1991 and Rabi 199111992.

In this paper, the evaluation of the canal water supplies and the farmers' response are reported.

The discharge at the onset of Kharif is substantially below design at the upstream boundary of the study area. This is due in part to the lower than design discharge at the head of Fordwah Branch, and partly to the higher discharges of the head distributaries off-taking from Fordwah Branch during the beginning of Kharif. This enables farmers in these favored areas to prepare their lands for the rice and cotton crops. The ID responds to the water shortage by implementing a rotation between distributaries within the sub-division. The distribution of water between distributaries is not equitable, with Azim receiving only 60% of its share of water during Kliarif against Fordwah's 90%.ID quotes the better groundwater quality in Azim coininand area as a reason for Fordwah's preference. A better degree of organization among farmers in Fordwah command area is another reason.

During Rabi, water is distributed among tlie live perennial distributaries with non-perennial canals acting as escapes. A rotation is implemented among the three sub-divisions in Fordwah Division resulting in a highly variable discharge at the head of the study areas, ranging from 40 to 180% of design, which in turn leads to the non-perennial canals carrying substantial discharges during Rabi.

The operational preference for Fordwah during Kharif at the cost of Azini has a marked impact on the performance of both distributaries, with Fordwali experiencing 26% dry days at the tail during Kharif and Azim 55%. The situation is compounded by the poor physical condition of tlie distributaries because of siltation in the head reaches, leading to higher water levels. Head-end moghas draw more water than they should due to substantial changes in tlie dimensions of moghas since the design of the system. In Kharif **1991** a DPR of **1.3** was measured for the head reach **of** Azim **and** Fordwah, whereas, for example, watercourses at the tail of Azim receive only 16% of tlie supplies to which they are entitled. Illegal irrigation, as evidenced by cuts and breaches, contributes to a deficient intra-distributary equitability.

The deficiencies of canal supplies at main and secondary level affect farmers differently depending on their location within the system. Farmers in sample watercourses in Azim reported 6 to 24 water turns lost during Kharif, while watercourses in tlie Fordwali command area lost 4 to 12 turns. This wide range in number of turns lost within the same watercourse is partly due to the rigidity of tlie warabandi (water distribution schedule). In addition, in Azim farniers reported theft *of* water turns by powerful farmers as a contributing factor to their losing water turns.

Generally, farniers responded to tlie constraints of the canal water supplies by developing a large number of private tubewells, with site specific differences in tubewell intensity. Fordwah 62 had sufficient canal water supplies, diminishing tlie incentives to install tubewells, while for Fateli 184 groundwater quality discouraged farniers in using groundwater for irrigation. Tubewell densities range from 28 per 1000/ha of CCA (Fateh **184)** to 80 to 95 tubewells per 1000/ha of CCA in tlie other watercourses.

As was to be expected from tlie observed differences in canal water availability, utilization rates of tiibewells vary widely, from less than 5% to **as** much as 45%. Pumping rates in Azim command ***area*** are much higher than in Fordwah. Usually tubewells in command areas of tail watercourses pump more water than those located in command areas of head reach watercourses. Groundwater quality limits the utilization of tubewells in Fateli 184. Moreover, distinctly higher utilization rates are found for electric tubewells than for diesel and PTO driven tubewells, because of the substantially higher O&M costs for tlie latter two types.

At watercourse level, the total Relative Water Supplies are of the same order for all sample watercourses, with the contribution froin groundwater ranging froin 84% for Azim 111 to 12% for Fateh 184. During the season, the proportion of tubewell water in total irrigation water supplies changes with crop water requirements. As has been observed elsewhere, seasonal applications by individual fariners vary greatly, e.g for cotton ranging froin 400 to 1000 mm, depending on tubewell ownership, quality of groundwater, access to canal supplies and operating cost of the tubewells.

Another response by farmers to the inflexible canal water supplies is wide-spread water trading mainly of tubewell water. All non-tubewell owners purchased tubewell water, with the fariners in the Fordwah coininand area being far more active than those in Azim, attributed to the reported lower degree of cooperation between fariners in the coininand area of Azim. The amount of water traded ranges from 20 to 40% of the total tubewell water pumped for the watercourses in Fordwali compared with 5 to 10% in the Azim coininand area. Even in Fateh 184, in spite of the lower groundwater quality, water trading is more active than in Azim coininand area.

Farmers are hardly ever using canal water by itself. They usually inix canal water with tubewell water to augment the discharge in the watercourse in order to achieve reasonable application efficiencies, and also to lessen the effects of low quality groundwater. The relative proportions and qualities of both types of water determine the ultimate quality of the irrigation water. It transpires that Azim, in spite of its better groundwater quality, has a lower final irrigation water quality than Fordwah, because of its limited access to canal water. Likewise, tail watercourses experience lower irrigation water qualities than head watercourses.

Specific management interventions still need to be identified for possible implementation in a joint ID-IIMI effort to improve the inanageinent of the irrigation system in the Fordwah Eastern Sadiqia Area.

I. INTRODUCTION

The Indus Basin of Pakistan is served by the world's largest contiguous irrigation system, supplying more than 125 billion m^3 of water to 14 million hectares of agricultural land annually. Since the introduction of this extensive system of irrigation canals the twin menace of waterlogging and salinity has been clearly recognized. In 1981 the Water and Power Development Authority (WAPDA) estimated that in the Punjab 25 % of the irrigated land was affected by salinity (Soil Salinity Survey, 1981). The same source indicated that a total of 18 % of the irrigated land experienced problems of drainage with a water table of less than 1.80 m.

In 1989 the International Irrigation Management Institute (IIMI) Pakistan started a 5 year research project on "Managing Irrigation Systems to Minimize Waterlogging and Salinity". The main objective of this project is :

> *to identify the incidence of Waterlogging and Salinity as related to Irrigation Management, through detailed field investigations in selected canal system commands, and to develop possible management interventions that can help control Waterlogging and Salinity.*

In a second phase of the project, field-testing of the proposed management interventions would be implemented to evaluate these interventions and to assess their .possible implementation in other parts of the irrigation system.

IIMI was able to build on its previous work in the Punjab, by initially executing its field work for the Waterlogging and Salinity project in the areas already monitored for other projects, i.e. the selected areas in the upper reaches of the Gugera Branch (Farooqabad sub-division), LCC East Circle (see map 1). Soon the area was extended towards the lower reaches of the Gugera Branch, where a second study area was identified in Bhagat sub-division.

In mid-1990 a new research locale was added to the existing study areas : the Fordwah/Eastern Sadiqia area, located in the South-East of the Punjab. In this way research findings of the two existing study areas could be validated for an area with a different agro-climate, being served by an irrigation system with its own distinctive characteristics.

Three years of extensive research on waterlogging and salinity as related to irrigation management have yielded a number of important findings. The inequity in the distribution of canal water is a common feature of the distributaries studied, with head outlets favoured against tail outlets in terms of quantity and variability of canal water supply.

The inadequacy of the surface water supply has forced farmers into developing an alternative source of irrigation water by exploiting the groundwater aquifers through a series of public and private tubewells.

Vandcr Velde and Kijne (1992) found that accelerated use of groundwater, generally of a lower quality than the surface water supply, was causing the emergence of **a** secondary type of salinity in the studied areas. This type of salinization could be dissociated from the problem of waterlogging. The problem of secondary salinization is particularly acute in the lower reaches **of** canal commands, where farmers do not have ready access to sufficient canal water supply.

In this paper the performance of the irrigation system in the Fordwah/Eastern Sadiqia area is evaluated and the response of the farmers to the inadequacy of the surface water supply is analyzed. The paper focuses on the conjunctive use of irrigation water from both sources and intends to illuminate the present management practices of the farmers. This paper **also** serves as an introduction to this new research area of IIMI.

Thus the objective of this paper can be formulated **as** :

> *to study the appropriateness of the canal water supply in the Fordwah/Eastern Sadiqia area and to evaluate the response of the farmers to the constraints associated with surface water supplies*

The presentation of the research setting is followed by an in-depth analysis of the surface water system and a presentation of tubewells and their operation in selected watercourses. This leads automatically to **a** very important aspect ***of*** irrigation in Punjab, the conjunctive use by farmers of the two waters, surface water and groundwater, and their conjunctive management.

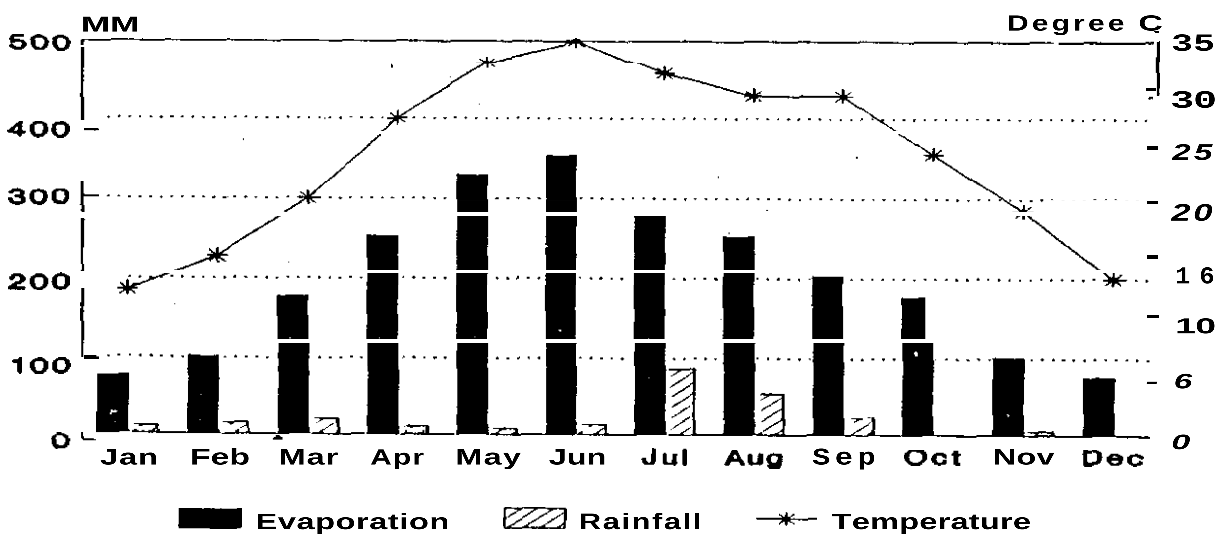
II. THE RESEARCH LOCALE : FORDWAH/EASTERN SADIQIA AREA

*Agro-ecological **aspects***

The command area of Fordwah/Eastern Sadiqia is located in the South-East of the Punjab at a latitude of 30' North and a longitude of 73' Fast. It commands a **gross** area **of** 301,000 ha, out of which **a** total area of 232,000 ha is culturable. The area is bounded to the north-west by the Sutlej river, to the east by the border of India and to the south-east by the Cholistan desert (see map 1). The **area** falls in Bahawalnagar and Bahawalpur district and partially covers the tehsils of Bahawalnagar, Chishtian and Hasilpur. The 1980 census estimated the population of Bahawalnagar district at 1.37 million with an annual growth rate of about **2.9** %.

The climate **is** (semi-)arid with **an** average annual rainfall of 264 mm (1975-1990 average, **Pakistan** Meteorological Department, Regional Office Lahore). In general about 70 % of the rain occurs in the June-September (see **graph** 2.1) monsoon period as high-intensity storms. The remainder falls in the winter period **as** light showers. The pre-monsoon period **is** extremely dry with hot winds blowing from the adjoining desert. The hottest months are May and June when the average maximum temperature is 46°C. January is the coldest month, the mean maximum and minimum temperatures being 24°C and 12°C, respectively. The evaporation rate varies between 2.5 mm/day in December/January to about 13 mm/day in May/June. This amounts to an annual average **of** 2400 mm.

Graph 2.1. Average Monthly Evaporation, Rainfall and Temperature in Fordwah/Eastern Sadiqia area



The soils of the area are alluvial in origin (Sutlej and Hakra rivers) and have been subsequently influenced by wind action. The soils are deep, mostly homogenized but layered in places. The texture of the soils and their topography vary widely. The soils range from moderately coarse to moderately fine material, varying from silly clay loam near the river to loamy sand towards the Cholistan desert.

Fordwah/Eastern Sadiqia is located in the cotton-wheat agro-ecological zone of the Punjab. Crops grown in the area are mainly cotton, rice, wheat, fodder and oilseed (**see** table **2.**I).

Table **2.1**. Cropping pattern in' Fordwah/Eastern Sadiqia Divisions 1990/1991

	Crop	Fordwah Division		E. Sadiqia Division	
		Area (ha)	%	Area (ha)	%
Rabi 90/91	wheat oilseed fodder other	69434 4183 17334 5287	72 4 18 6	55514 26885 36128 3275	46 22 30 2
Total		96238		121802	
Kharif	cotton rice fodder other	451 17 23179 25093 13055	42 22 24 12	67709 5969 24465 **21190**	57 5 21 16
Total		106444		119333	

• Source: Annual Operation Statements of PID

There is a distinct difference in the cropping pattern **of** Fordwah Division and Eastern Sadiqia Division. In Fordwah Division alniost **a** quarter of the area in Kharif is cropped with rice, mainly in the alluvial **areas** of the Sutlej river. In Eastern Sadiqia the area cropped with rice is negligible and instead **a** much larger area is cropped with cotton. In Rabi the area commanded by the Eastern Sadiqia canal is for **a** relatively large part cropped with oilseed. Consequently, the area cropped with wheat is relatively smaller than in the Fordwah Division:

Hydrological aspects

Fordwah Canal and Eastern Sadiqia Canal are both off-taking from the left abutment of Suleimanki Headworks on the Sutlej River (see map 2). Both canal commands are part of the Sutlej Valley Project that was completed in 1932. Before implementation of this project the lower areas along the Sutlej river were irrigated during Kharif (April-October) through a set of inundation canals. The main objectives of the Sutlej Valley Project were to enhance and increase the reliability of the water supplies during Kharif to the area already irrigated by inundation canals and to supply water to the higher lying lands towards the Cholistan desert.

During the planning stages of the project it was envisaged that the supply of surface water would be significantly lower during the Rabi season (roughly one third of the Kharif supply), due to lower levels of discharge in the Sutlej river and its tributary Beas. Rather than spreading the available water over the entire command area it was decided to label certain areas as perennial (i.e. whole year round supply) and others as nun-perennial. The non-perennial areas would be served during Kharif (April-October) only. In "100 Years PWD" (1963) it is indicated how the decision was made to designate certain canals in the Sutlej Valley Project as perennial and others as non-perennial :

> *The Khadar or low lying lands generally had a high sub-soil water level, and most of the area was proprietary and cultivated. Only non-perennial canals were considered proper for such a tract to check waterlogging. Higher desert lands in the interior were mostly State waste, barren and uncultivated, with deep spring levels and fit for perennial irrigation.*

After the 1960 Indus Water Treaty with India the area was brought under the command of Mangla reservoir, from where a number of link canals convey the water to the area (see map 1). Although the water supply to the area was significantly enlianccd after the commissioning of the Mangla dam, supplies are still not sufficient during Rabi to serve all of the area commanded.

The Fordwah/Eastern Sadiqia divisions combine perennial and non-perennial canals in their irrigation system. The water duty fixed for the non-perennial distributaries is much higher (0.5 l/s/ha = 7.0 cfs/1000 acres) than that for the perennial canals (0.25 l/s/ha =3.6 cfs/1000 acres) in the Fordwah/Sadiqia area.

Selection of research areas

The Fordwah/Eastern Sadiqia area was studied from two different angles. Firstly, canal supplies were monitored at different levels of the irrigation system, i.e. main, secondary and tertiary level. Secondly, two transects were drawn going perpendicular from the river towards the Cholistan desert. Along these transects 5 sample water courses were selected.

At main system level a major part of Fordwali Branch, off-taking froin Fordwah canal, was selected. This **is** the part located in the Chishtian sub-division, i.e. from RD 245 to the tail at RD 371 ***(Reduced Distance*** in thousands of feet froin the head of the canal). The hand-over point between Bahawalnagar sub-division and Chishtian sub-division is located at RD 199, but as there are no distributaries off-taking between RD 199 and RD 245, the study area was confined to the stretch between RD 245 and RD 371. This constitutes a total length of 38.4 km with 14 distributaries off-taking in this reach.

At secondary level three major distributaries, located at the tail end of the Fordwah/Eastern Sadiqia irrigation system were studied.

At the tail of Fordwah Branch ***Azim*** distributary and ***Fordwah*** distributary branch off. Fordwah distributary has a length of 42.1 kin and a design discharge of 4.47 m^3/s (158 cfs) (see table 2.2). Aziin distributary originally had a length of 37.8 kin but its tail portion has been cut off (1976) and is now supplied directly froin Bahawal canal. The actual tail of Aziin is now at 36.0 km. The design discharge has not been adjusted accordingly, however, and remains at 6.9 m^3/s (244 cfs). *Fateh* distributary off-takes froin Malik Branch (off-taking from Eastern Sadiqia canal). It has a length of 68.3 kin and **a** design discharge of 12.2 m^3/s (430 cfs). Azim distributary is a non-perennial canal, officially receiving water only during the Kharif season. Fordwah and Fateh distributary are both perennial canals, supplied with water all year round.

There are no public tubewells in this area. However, especially towards the river a large number of private tubewells have been .installed.

Table 2.2. Characteristics of sample distributaries

Name of disty	Off-taking from	Perennial/ perennial	Length (km)	CCA	Number of out lets	Design discharge (m^3/s)
Fordwah	Fordwah Branch	Perennial	42.1	14844	87	4.5
Aziin	Fordwah Branch	Non-perennial	36.0	12327		6.9
Fateh	Malik Branch	Perennial	68.3	39242		12.2

Perpendicular to the river two transects were drawn, cutting across Aziin, Fordwah and Fateh distributaries. Along these transects 5 sample watercourses were selected. The main characteristics of these five watercourses are presented in table 2.3.

The sample watercourses have different access to canal water supply, mainly determined by the (non-)perenniality of the distributary serving the watercourse, but influenced as well by the location of the watercourse within the canal coniniand. The exploitation of groundwater varies widely in the sample watercourses, influenced by the access to canal water supply and the quality of the groundwater.

Of the five sample watercourses only Fateh 184 has been lined under the On Farm Water Management programme, while Fordwah 62 has been included in tlie planning for such a programme. However, due to internal strife among farmers implementation of this programme has been suspended.

Table 2.3. Characteristics of sample watercourses

Watercourse	GCA (ha)	CCA (ha)	Number of land owners	Design discharge (l/s)	Soil salinity (dS/m)
Azim 63620	123	113	14	59.2	1.25
Azim 11 1770	121	101	19	45.9	3.01
Fordwah 62085	131	117	45	33.4	1.39
Fordwah 130100	265	174	42	64.6	0.96
Fateh 184400	344	213	39	69.6	1.17

The soil salinity ranges from less than 1 dS/m in Fordwah 130 to a value of 3 dS/m in Azim 111. At this stage it is not clear whether tlie latter value is a result of residual salinity caused by high water tables in the past or is the result of salinity of a more recent origin.

Farmers in the Fordwah/Eastern Sadiqia area are often divided in two groups. The riparian tract close to the Sutlej, traditionally commanded by the inundation canals, was inhabited long before implenientation of the Sutlej Valley Project. The farmers in this area, often referred to as "**locals**", can be categorized as having larger landholdings (see table 2.3), a higher use of external labour and a more wheat-cotton oriented farming system. The general perception of these locals is that they are non-cooperative, either among theniselves or with outside institutions (**E.G.**van Waayjen, 1991). The command area of Azim distributary **falls** in this area.

Land in the higher areas further away from the river became inhabited after the introduction of irrigation to these areas. Locally known as "settlers", the farmers in these areas are usually viewed as being cooperative and more "progressive". The command areas of Fordwah and Fateh distributary are located in these areas.

***New* Developments**

During the annual closure period in 1992, a highly publicized Province-wide desiltation campaign was launched by the Chief Minister Punjab. Canals, that had been poorly maintained for years were to be upgraded during this closure period. The main canals and larger distributaries were to be cleaned by contractors, whereas the smaller distributaries and niinors were desilted by farmers on **a** 'self-help basis' (see Bandaragoda and Van Waayjen, 1992).

In the study area **a** large portion of the canal system was desilted. In addition to this **a** number of head-end outlets were remodelled, bringing the dimensions of these outlets back to their design. Preliminary findings of IIMI's research indicate **a** positive effect of the desiltation campaign on the distribution of water in the studied distributaries during Rabi 199111992. The ultimate test, however, will be in Kharif when farmers' water demand will be at **its** peak. Already there are signs that head-end farmers succeed in reverting their moghas.

Research Methodology

Our analysis **is** mainly based on **a** comprehensive set of primary data collected from June 1991 to June 1992 in the study area **as** previously defined. In Fordwah Branch discharges were measured at strategic locations along the canal, through **a** set of automatic water level (stage) recorders. These stage recorders ,were also installed **at** the head of Fordwah and Azim distributary and at RD 92 of Azim. Along these two distributaries discharges were measured daily during Kharif 1991 at different locations, i.e. RD 62 and 129 for Fordwah and RD 92 for Azim, in addition to the results automatically available from the stage recorders. The water intake at the moghas **of** the live sample watercourses were recorded every day from June 1991 onwards.

The cropping intensity and the cropping pattern for the sample watercourses were obtained through crop surveys (one per season).

Tubewell data have been collected in different steps. **A** tubewell census, updated now regularly, has first been undertaken in the 5 sample watercourses at the early stages of IIMI's work in the study area in 1990. Location, age, type of tubewell, operational status, ownership characteristics (single owner or shareholders) and other basic information were collected for **all** the private tubewells of the area. It was conipleniented in Rabi 91/92 by a tubewell owner survey focused on the management of the tubewell and its constraints. Tubewells have been monitored regularly by IIMI field staff : operation hours, hours given or sold to other farmers and engine and pump problems have been recorded since June 1991. The costs of operation and maintenance **have** been added to the regular data collection work in November 1991 to gain a better understanding of the economics of groundwater use. Discharge measurements and analysis of the quality of the water supplied by the tubewells have complemented our private tubewell data set.

For 30 tubewell owners (6 in each watercourse), irrigation application data were collected at field level to evaluate the conjunctive use of irrigation water at farm and field level.

A socio-economic survey was undertaken in July 1991 to quantify information on the farming system in the area and to identify the constraints farmers are facing with regard to irrigated agriculture. The management of irrigation water at farm and watercourse level and the marketing of water were important issues addressed in this survey. Sixty farmers (12 per watercourse) were interviewed through **a** formal questionnaire. One of the criteria of selection **of** the farmers for the survey was the tubewell ownership status of the interviewees. This enabled **a** comparison of the socio-economic characteristics of tubewell owners and non-tubewell owners.

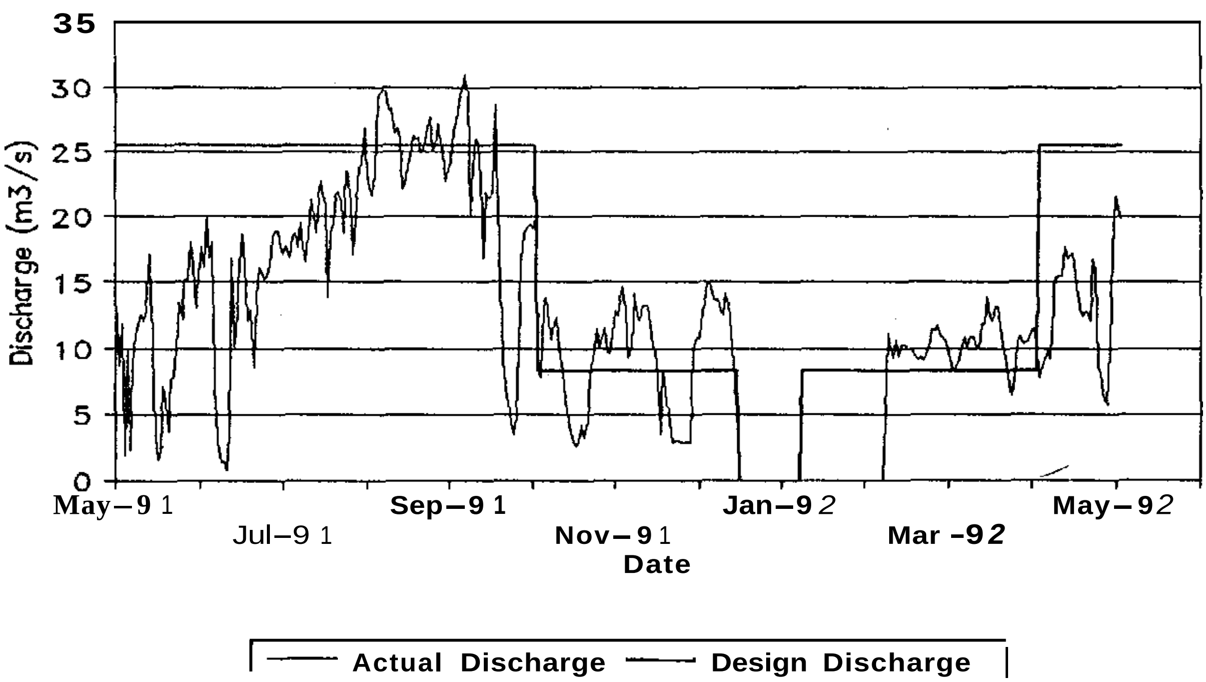
III. THE DISTRIBUTION OF SURFACE WATER

In this chapter the canal water supply at main system and secondary level is evaluated, and its impact on the intake of water of the sample watercourses analyzed.

Inflow in the study area

At the intake point of the study area, i.e. the cross-regulator at KD 245 of Fordwah Branch (see map 3), the discharge has been monitored since October 1990. In graph 3.1, the daily discharges are presented for 1991/1992. During Kharif the design discharge at this structure is ***25.5*** m^3/s, a sum of the discharges of all the distributaries downstream **plus** 15 % seepage losses. The discharge is reduced considerably during Rabi when the design discharge is 8.4 m^3/s, because 9 out of 14 distributaries in Chishtian sub-division are non-perennial.

Graph 3.1. Daily discharges at RD 245, Fordwah Branch (in m^3/s)



In the beginning of the Kharif season (May, June) the discharge at RD 245 is well below the target discharge with large fluctuations in discharge. This reflects a general shortage of water in the Fordwah/Eastern Sadiqia irrigation system at the onset of the Kharif season.

This can be quantified at the intake of Fordwah Branch. Ten year averages[1] of the actual volume of water delivered to the Fordwah Branch show **a** deficit of **27 %** and **8 %** for the months of May and June respectively when compared with the design discharge, accounting for the low water supply at RD 245.

In July the actual discharge at the head of Fordwah Branch is usually equal or close to the design discharge. For July-September the volume of water delivered is generally within **a** range **of** 2-3 % of the design. In July 1991 it even exceeded the target volume by **7** %. It is however only towards the end of July that the situation at RD **245** improves. An explanation for this may be the location of Chishtian sub-division at the tail of the Fordwah Branch. At the beginning of the Kharif season **a** lot of water is required for the *rauni* and first irrigation (rauni is the irrigation needed to wet the land for land pieparation and sowing). Only when the water requirements upstream in the system have been satisfied is water let through to the Chishtian sub-division.

As a consequence **a** certain staggering in planting of the crops can be discerned from head to tail in the Fordwah Branch (see table **3.1**).

Table **3.**1. Dates of Rauni Irrigation
in Fordwah Division for Kharif season

Name of distributary	Offtaking RD Fordwah Branch	Date of Rauni Irrigation
Bahawal	28	May 20 - June **5**
Behkan Wali	73	May **20** - June 1
Azim	**371**	June **01** - June 10
Fordwah	**371**	June 01 - June 10

In the first two weeks of October 1991, the discharge at the head of Fordwah Branch was **also** below design **(a** 10-year average indicates **a** deficit of 29 %), explaining the drop in discharge at RD **245.**

Figure 3.1 **also** shows that the annual closure period in 1992, envisaged to take 3 weeks, was extended to **a** period of almost 7 weeks. Previous IIMI research indicates that the annual closure period usually tends to be prolonged in the Punjab. However, the length of the closure period was unusual in the sense that **a** large scale desiltation programme was initiated by the Chief Minister Punjab in 1992 (see Bandaragoda and van Waayjen, 1992), which further prolonged the closure period. In 1991 the closure period took **5** weeks.

[1] Data collected by the Irrigation Department

In *Rabi* **a** rotation is implemented in Fordwah Branch between the 3 sub-divisions. This explains the peaks and valleys in actual discharge from October 15 onwards, **as** plotted in Graph 3.1. Each sub-division gets first, second and third preference for **a** 7 day period after which the turns are rotated. During the period that Chishtian sub-division is in third preference the discharge drops to about 40 % of the design discharge. When Chishtian sub-division is in first or second preference the discharge shoots **up** to 160-180 % **of** the design discharge, explaining the fact that non-perennial canals are observed to be receiving water during Rabi.

Canal Performance at secondary level

The impact of the discrepancies in the water supply at main system level that were identified in the previous paragraph will now be evaluated for Fordwah and Azim distributaries. Both distributaries are offtaking at the very tail of Fordwah Branch at RD **371.**

To compare the actual discharge delivered to **a** certain point with the design discharge (target) the ***Delivery Performance Ratio***[2] (DPR), **a** hydraulic performance indicator, is presented. In graph **3.2,** the DPR's *of* Fordwah and Azim distributaries during Kharif 1991 are compared.

The plot shows that Fordwah distributary was favoured in terms of actual discharges during Kharif 1991. At the start of the season (May, June) the supply to Fordwah was kept almost constant with any variation in discharge at main system level (see figure **3.**1) passed on to Azim. Later in the season towards the end **of** June **a** rotation was implemented in Chishtian **sub-**division, involving both Azim and Fordwah distributary (see figure **3.2).** The Irrigation Department intended to divide the available water supply more equally between both distributaries. It is, however, 'clear from figure 3.2 that both the length of time **a** distributary was in rotation and the rate *of* supply were substantially different for the two distributaries monitored.

Fordwah distributary was in rotation during Kharif 1991 for 16 days on average whereas Azim **for** 11 days only. Similarly Azim was out of rotation for longer periods of time compared with Fordwah distributary. As soon **as** Fordwah was out of rotation for more than **a** few days, farmers would organize themselves and put pressure on the ID, either directly or through political connections, to ensure that the water supply to their distributary would be restored. No delegation of Azim farmers has approached the ID during this season, indicating once more the lack of cooperation among farmers here. The big landlords in this area, reportedly very powerful (see E.G. van Waayjen, 1991), are not interested in organizing the farmers but are in ensuring that they receive the share **of** water they feel they are entitled to out of **a** diminished water volume delivered. It has been observed **a** number *of* times during Kharif 1991 that the entire distributary was blocked in order to divert water to the lands **of** these big landlords.

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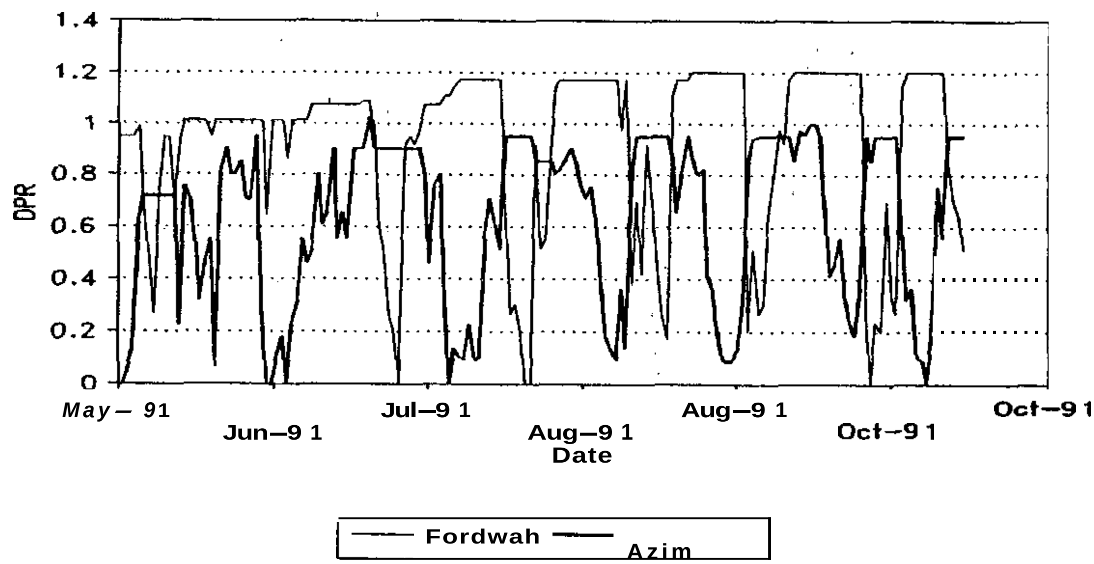
[2] $\text{DPR} = \frac{\text{actual discharge}}{\text{design discharge}}$

Graph 3.2. DPR[3] at head of Fordwah and Azim distributaries



The rate **of** supply for Fordwah distributary, when having first preference, is substantially higher than that for Azim. It amounts to about 120 % of its design discharge, according to ID officials "in order to feed the tail of Fordwah distributary". Azim does not receive **its** due share ***of*** water, even when it is in rotation; ID indicates a few reasons for this. The groundwater in Azim's command area is supposedly of better quality and fit for irrigation whereas Fordwah has a reportedly low groundwater quality. IIMI data support this to a certain extent (see table 4.1, chapter **4**). The relatively better degree of organization among farmers in Fordwah distributary command area is another factor.

All this results in a distinct difference in the total volume of water received by Fordwah and Azim distributary during Kharif 1991 (see table 3.2). The actual volume of water supplied to Fordwah distributary was on average about 90 % of the target during Kharif 1991. In Azim an average **of** 60 % of the target volume was actually obtained.

3 Based on ID data

Month	Fordwah distributary			Azim distributary		
	Actual (10^6 m^3)	Design (10^6 m^3)	%	Actual (10^6 m^3)	Design (10^6 m^3)	%
May	10.9*	12.0	91	9.8	18.5	53
June	10.5	11.6	91	11.8	17.9	66
July	11.0	12.0	92	11.7	18.5	63
August	12.0	12.0	100	11.1	18.5	60
September	10.2	11.6	88	13.4	17.9	75
October	9.8	12.0	82	5.2	9.0	58

* Data taken from ID register

The distribution of water among the distributaries in Chishtian sub-division is more straightforward during Rabi. Only five canals out of 14 have a claim on the water supply during this season. In periods when Chishtian sub-division is in first or second preference, supply to these five distributaries is ensured, and it is only in times of third preference that the perennial canals face shortages.

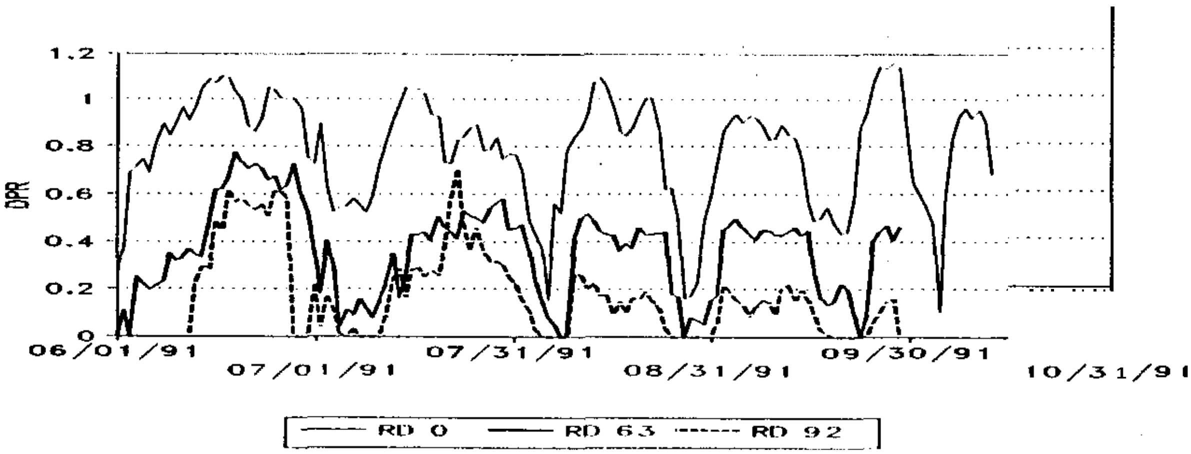
The non-perennial canals are not entitled to canal water supply during Rabi. According to ID the non-perennial canals merely act as escapes for any excess of water in Fordwah Branch. The amounts supplied to non-perennial canals, however erratic, are quite substantial. In November 1991 for example Azim, as a non-perennial canal, received about 28 % of its Kharif design volume. The explanation for this was given earlier: when Chishtian sub-division is in first or second preference the discharge amounts to about 140-180 % of the design discharge at RD 245 of Fordwah Branch.

Water distribution within distributary command

In Kharif 1991 the water distribution was further studied along Fordwah and Aziin distributary. In graph 3.3, the daily DPR's at three different locations within Aziin distributary are depicted.

The impact of the water supply to the head of Azim can be observed in this graph. Whenever the discharge at the head of Aziin falls below 80 %, water does not reach the tail. Supply is erratic at the head, and this is reflected in the DPR towartls the middle and tail *of* the distributary.

Graph **3.3.** Perforinance of Azim distributary in Kharif 1991



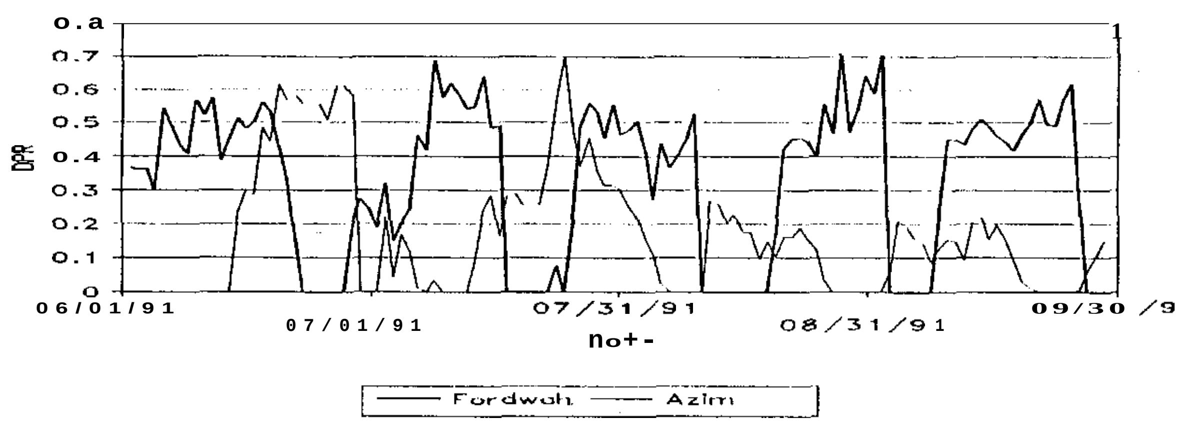
Another observation that can be made is that even when the discharge at the head is at design level (i.e. **a** DPR of 1) the middle and tail do not receive their share of water. A DPR of 1 at the head results in a DPR of around 0.45-0.7 in the middle reach and a DPR of 0.2-0.6 at the tail. **A** reason often quoted by the ID is the problem of siltation causing higher water levels in the upper reaches of distributaries, possibly resulting in higher discharges of moghas in these stretches. Another reason could be deviations in the dimensions of the inoghas in the upper reaches from the original design, resulting in moghas drawing water in excess of their share. Discharge measurements in moghas in the head reaches of Fordwah and Azim distributaries show that the DPR here averages a value of 1.3.

It **is** interesting to compare the DPR of the moghas in the head reaches of Fordwah and Azim distributary. When Fordwah distributary has first preference generally **a** DPR of 1.2 is attained with the moghas in the head reach having an average DPR of I.26. In comparison Azim rarely accomplishes **a** DPR of more than I at the head. In these periods of rotation the inoghas in the head reach have on average a DPR of 1.34. This figure **is** not only higher than the value determined for Fordwah distributary, but in comparison with the DPR established at the intake of the distributary, this figure indicates that the head reach is taking a disproportionate share **of** the water.

A third reason for a low DPR at the tail of Azim is water theft on secondary level, with **a** number of field observations indicating that indeed illegal irrigation occurs. This varies from the blocking of an entire distributary, **as** observed a number of tiines in Azim distributary to smaller cuts and syphons, seen 'both in Fordwah and Azim distributary, especially during the Kharif season.

The tail water gauge in **a** distributary is often quoted **as an** informal performance indicator for secondary canals. The **ID** keeps **a** record of the gauges in almost every distributary. When counting the number of dry days at the tail **of** Fordwah and Azim, it appears that out of **a** total number of 137 days in Kharif 1991 Fordwah tail experienced 36 dry days (26 %). At the tail of Azim **a** total number of 75 days were counted (55 %) (see graph 3.4).

Graph 3.4. **DPR** at the tails of Fordwah and Azim distributaries

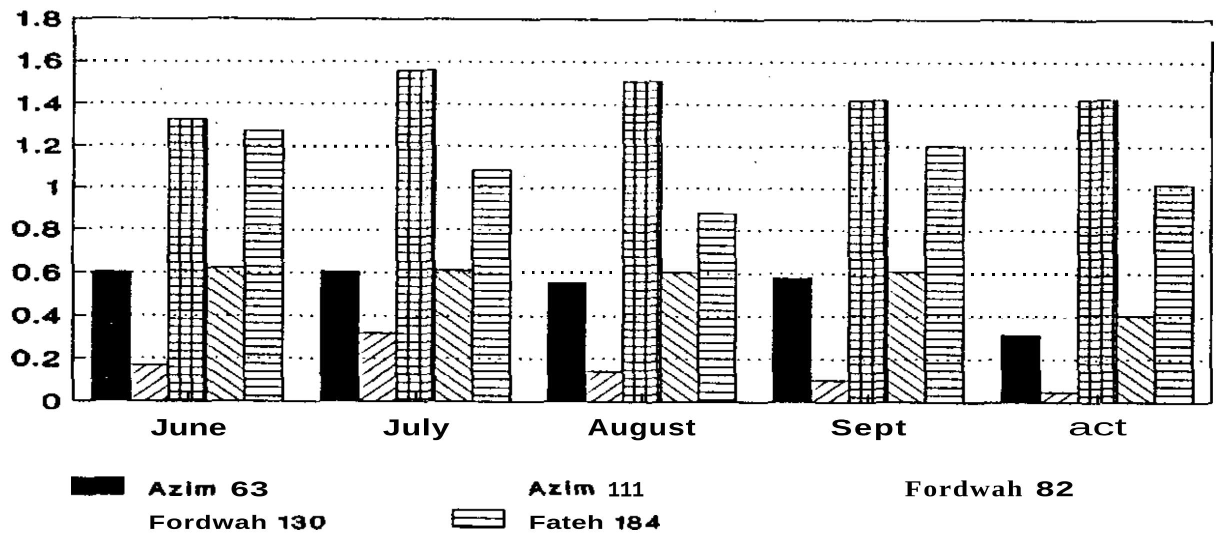


The poor performance at the tail of Azim distributary is **a** culmination of **a** number of factors pointed out in previous sections. The supply to Azim distributary **as a** whole is way below design, with an actual volume of water of only 60 % received during Kharif 1991. The supply to the tail is further curtailed by the problems **of** water distribution at secondary level, **as** previously indicated.

Sample Watercourses

The water supply to the sample watercourses, determined at the intake of these tertiary units, follows the pattern established in the previous sections. The watercourses located **in** Fordwah distributary receive relatively more water than those in Aziin throughout the Kharif season (see graph 3.5). **A** comparison between Fordwah 62 and its counterpart in the middle reach **of** Aziin at **RD** 63 reveals that Fordwah 62 had an average DPR **of** 1.47 for Kharif 1991, whereas Azim 63 scored 0.59 only. Fordwah 130, located in the tail reach of the distributary was relatively far better off than Aziin 111 with an average **DPR** of 0.57 **as** compared to 0.16 for Azim 111.

Graph 3.5. Intake rates for the sample watercourses during Kharif 1991



From these figures it is obvious that the tail watercourses of Fordwah and Azim distributary are receiving relatively less water than the watercourses in the middle rcaclies. The abysmal low **DPR** for Azim 111, explains tlie extensive use of groundwater, to be reported upon in the next section.

Fateh **184,** despite its location towards the tail of the distributary receives an amount **of** water slightly in excess of the amount to which it is entitled. The drop in the discharge in August is explained by tlie fact that the Irrigation Departinent undertook an attempt early August to bring the dimensions of the mogha back to its original design **as** part of **a** rehabilitation programme of 18 moghas in the same stretch of canal. It was felt by tail end farmers that these moghas were drawing water in excess compared with the total available water for the tail of Fateh. The attempt of the ID was not successful for Fateh **184.** The mogha was reverted to its original dimensions within **a** week.

Within the watercourses the water is distributed following **a** roster. This roster, called "pakka warabandi", has been fixed for the five sample watercourses since 1965-1970, with all the farmers having water turns at fixed times. The nuinber of water turns lost for the different watercourses during the season, because of the deficiencies in the water supply **at** main and secondary level, varies. From table *3.3*, it can be seen that the findings here arc in line with what has been indicated before in this report. Farmers in both watercourse's in Azim report **a** higher average number of turns lost compared to the sample outlets in Fateh and Fordwah. In Azim the number of water turns lost in the tail watercourse (Azim 111) is higher on average than tlie number in Azim 63, located in the middle reach of tlie distributary.

Watercourse	No. of turns lost in Kharif	Average	No. of turns lost in Rabi	Average
Aziin 63	6-23	11	-	-
Aziin 111	7-24	16	-	-
Fordwah 62	4-10	7	3- 6	4
Fordwah 130	4-12	8	4- 8	7
Fateh 184	1-16	6	0-10	3

A further reason given by the farmers in the area is that theft of water at watercourse level occurs in the watercourses of Aziin, where powerful landlords are taking water turns from smaller cultivators. No such incidence has been reported in the case of Fateh 184 or the sample watercourses in Fordwah distributary.

Cropping intensities

The ID has fixed cropping intensities for the area commanded by Fordwah\Eastern Sadiqia during implenientation of the Sutlej Valley Project. These intensities are established separately for Kharif and Rabi indicating what percentage of the CCA is entitled to water during a particular season. In Fordwah/Eastern Sadiqia in general a cropping intensity of 80 % for perennial canals (40 % for Kharif and 40 % for Rabi) and 60 % for non-perennial canals have been fixed.

From ID data for the Fordwah/Eastern Sadiqia divisions, it can be derived that the actual irrigation intensities (as tlic area irrigated per season or per year) arc higher. A ten year average for both divisions gives an irrigation intensity of 108 % and 115 % for Fordwah and Eastern Sadiqia divisions respectively.

This is even niore pronounced for the sample watercourses (table 3.4). The irrigation intensities vary from 112 % (Fw 130) to 154 % for Azim 111. A detailed list of crops-is provided in Annex 1.

Table 3.4. Irrigation Intensities[4] for the Sample Watercourses

Watercourse	CCA (ha)	Kharif (%)	Rabi (%)	Total (%)
Azim 63	121	82	43	125
Azim 111	119	76	78	154
Fordwah 62	133	76	74	150
Fordwah 130	256	56	56	112
Fateh 184	261	59	59	118

The cropping intensities for Kharif and Rabi appear to be similar for four out of five sample watercourses. This seems apparent for the watercourses located in the perennial commands of Fordwah and Fateh. For Azim 111 the non-perenniality of the distributary has lost its meaning. Surface supplies (in Kharif) are so erratic that for the decision on cropping intensities, farmers no longer take the surface supplies into account, with tubewells almost completely replacing canal water as the source of irrigation water.

Table 3.4 shows that this is not the case with Azim 63. Although even here the cropping intensity in Rabi is surprisingly high, made possible by the exploitation of groundwater, it is substantially lower than in Kharif. Farmers' dependence on surface supplies in Kharif in Azim 63, results in a lower investment in the development of tubewells.

Fordwah 130 and Fateh 184 both have a considerably lower cropping intensity than the other three watercourses. Both watercourses are located close to desert areas and have large parts of their CCA covered with sand dunes, rendering them barren (18 % and 34 % of the CCA for Fateh 184 and Fordwah 130 respectively). In Fateh 184 it can be readily explained that with the restricted available surface supplies and the low quality ground water extension of the area under cultivation is not possible. In Fordwah 130 farmers' perception of the quality of the ground water, although actually better than in Fateh 184, also prohibits a significant further expansion of the cropped area.

[4] Collected by IIMI in Kharit 1991 and Rabi 1991/1992

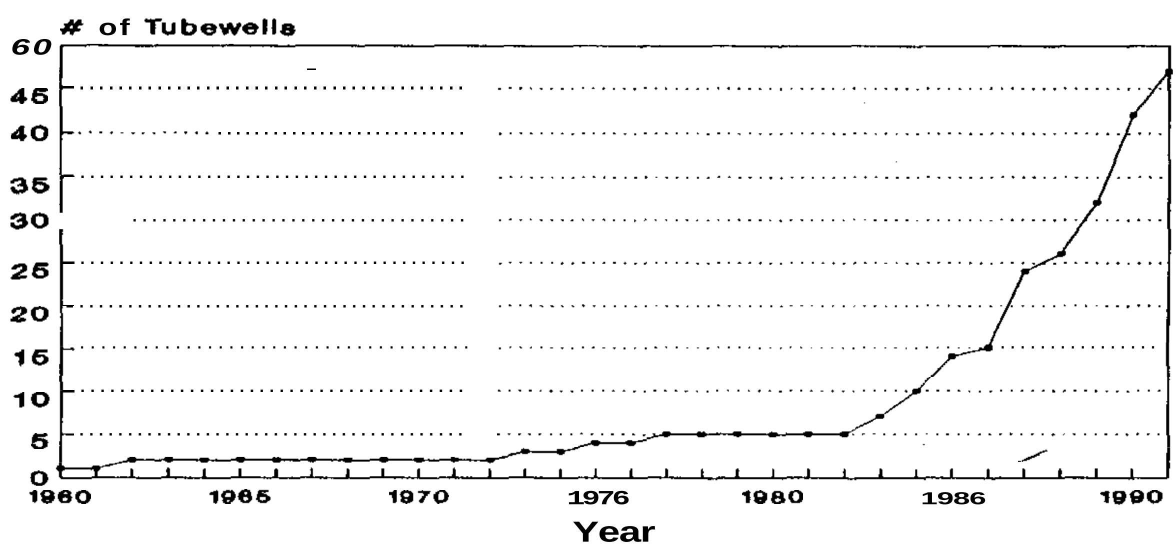
IV. PRIVATE TUBEWELLS WITHIN THE SURFACE WATER SYSTEM

Tubewell Development

In the sixties farmers installed the first private tubewells in the 5 sample watercourses. However, tubewell owners were few and the nuniber of tubewells in the area remained more or less constant for 20 years. A dramatic change took place during the eighties: the number of tubewells in **the** 5 sample watercourse areas jumped from 5 in 1982 to 49 in 1991 (see graph **4.** I), out of which 47 are presently operated. Years with the higher increases were 1987 (+ 9 tubewells) and 1990 (+ 10 tubewells).

Power-Take-Off (PTO) tubewells, run with the help of **a** tractor or **a** diesel Peter engine, represent the first choice of farmers' investment with 45% **of** the total number of tubewells, followed by diesel tubewells **(38%)** and electric tubewells (17% only). In every watercourse, the number of PTO and diesel tubewells is nearly the same. Electric tubewells, however, are only present in the two tail watercourses of Azim and Fordwah distributaries, Azim 111 and Fordwah 130.

Graph 4.1. Tubewell Developnient in 5 watercourses
1960-199 I
(number of tubewells operated)



From one watercourse to the other and from one source of power toanother, different scenarios for the development of private tubewells took place:

The installation of tubewells is **a** recent phenomenon for Fateh 184 and Fordwah **62,** all the tubewells having been installed between 1984 and 1991. In the other three watercourses tubewells were installed, even if they were few, in the period 1960-1970. The low quality of the groundwater in Fateh 184 and the relatively good canal water supply in Fordwah **62** and Fateh 184 are two possible factors explaining the later developinent of tubewells in Fordwah **62** and Fateh **184.**

For Fateh 184 and Fordwah 130, the first tubewell owners were farmers at the head of the watercourse, contrary to what can be observed in Azim 111 where tail farmers were the first to install private tubewells. For Fordwah 62 and Azim 63, there is no trend from the head to the tail of the watercourse. No appropriate answer has been found to explain these differences.

The increase in the number of electric tubewells has been slow and regular, related **to** the installation of new electric lines in parts of the rural areas (in our case at the tail of Azim and Fordwah distributaries, located near Hasilpur town). For diesel **and** PTO tubewells, the rate of increase has been higher than for electric ones. The development of PTO tubewells seems to be more recent than the development of Diesel tubewells. The late development of the PTO tubewells can be explained by the fact that with the observed increase in the number **of** tractors in the area (from 3 tractors in 1982 to 38 in 1991 for the 60 farmers interviewed during Kharif 1991), fariners have now **a** higher incentive to install PTO tubewells with low investment costs even if the operation costs arc higher than for the other types.

The average discharge for the 49 tubewells is 30 liter per second. Diesel and PTO tubewells have on average **a** discharge higher than electric tubewells (32.5 l/s and 31.5 l/s **for** PTO and diesel tubewells versus 27.0 l/s for electric tubewells). The main characteristics of the tubewells for the **5** sample watercourses **are** given in table 4.1.

Table **4.1** gives the average Electrical Conductivity (EC) for the 5 watercourses, used here **as a** proxy for the groundwater quality. With an average EC of 3.1 dS/m, farmers from Fateh 184 are in an unfavourable position compared to fariners from other watercourses, who pump **a** better groundwater quality (from 0.8 dS/m to 1.3 dS/m).

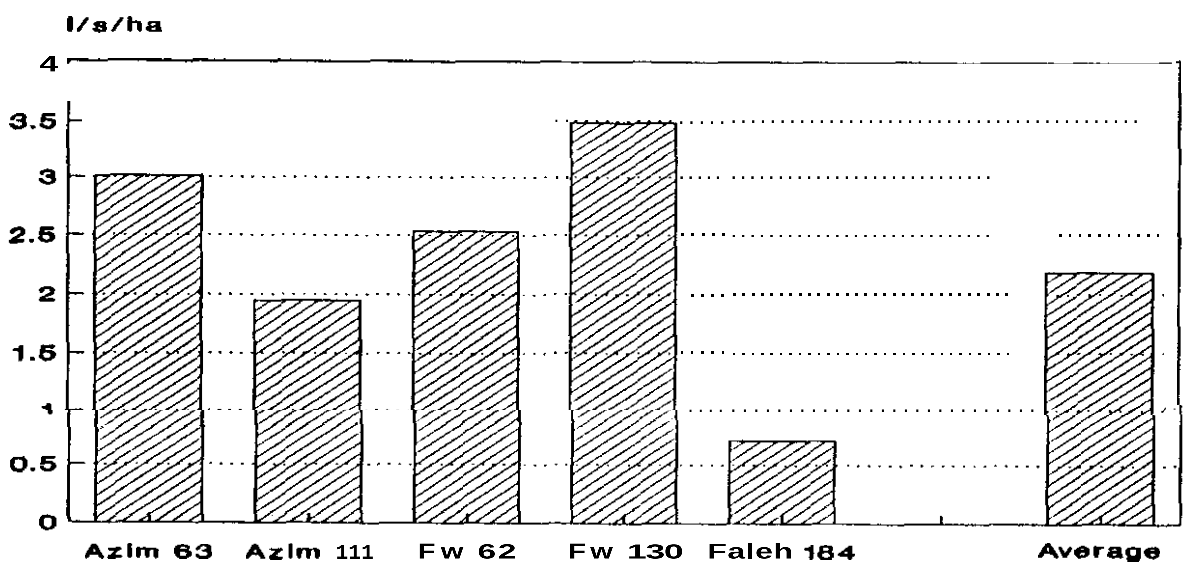
The average tubewell density for the 5 watercourses is equal to 70 tubewells per 1000 hectares of Culturable Command Area (CCA) (or SO tubewells per 1000 hectares of Gross Command Area). Differences between watercourses are high, especially between Fateh 184 (density of 28 tubewells per 1000 **ha** of CCA) **and** the 4 other watercourses (95, 80, 82 and 92 tubewells per **1000** hectares of CCA respectively for Azim 63, Azim 111, Fordwah 62 and Fordwah 130).

Table 4.1. Characteristics of private tubewells

Watercourse	Number of tubewells	Bore-depth (m)	Discharge (l/s)	Av. water quality (dS/m)
Azim 63	9	15-40	17-50	0.8
Azim 111	8	20-60	15-33	1.1
Fordwah 62	10	15-35	15-53	1.1
Fordwah 130	16	25-60	24-53	1.3
Fateh 184	6	30-70	20-30	3.1

The same differences among watercourses are found when looking at the installed capacity of the private tubewells.[5] The main difference between the tubewell density and the installed capacity is that the latter takes the discharge into account. Graph 4.2 shows the differences in installed capacity between the 5 selected watercourses.

Graph 4.2. Installed capacity (1991)



5 Total quantity of water a tubewell pumps, working 20 hours a day, 365 days a year. The remaining 4 hours are required for maintenance, repair. problems of power supply, etc.

The low groundwater quality as well as the relatively high canal water supply are certainly two important factors restraining the installation of tubewells in Fateh 184 command area. For Fordwah distributary, the installed capacity of Fordwah 130 is higher than the one for Fordwah 62, due partly to the difference in canal water supply (*see* chapter 3). For Azim, however, the same pattern is not found, Azim 111 having a lower installed capacity than Azim 63, contradictory to the observed differences in canal water supplies to these two watercourses. Interesting as well is that the installed capacity does not significantly differ between the two distributaries, Azim, non-perennial, and Fordwah, perennial. In fact, differences between the density of tubewells and the installed capacity are difficult to explain with only trends in the distribution of canal water, depending essentially on socio-economic characteristics of the farmers.

Tubewell owners usually locate their tubewells at the head of their larger plots to be in a position to irrigate the largest part of their operated area. Most of the tubewells are close to the watercourse of the surface water system: they use it to transport the water to their fields or to the fields of water purchasers, alone or mixed with some canal water, especially in area where groundwater quality is low (as in Fateh 184).

Out of the 49 tubewells, 13 are located in the head (upper third) of the watercourse command areas, 24 in the middle (middle third), and 12 in the tail part (tail third) of the watercourse command areas. For the two tail watercourses, the repartition is slightly more tail oriented, with respectively 25%, 37.5% and 37.5% of the total number of tubewells for the three thirds (from head to tail) of the watercourse command area. The set of data is not large enough, however, to lead to any significant conclusion regarding the density of tubewells with respect to the position in the watercourse.

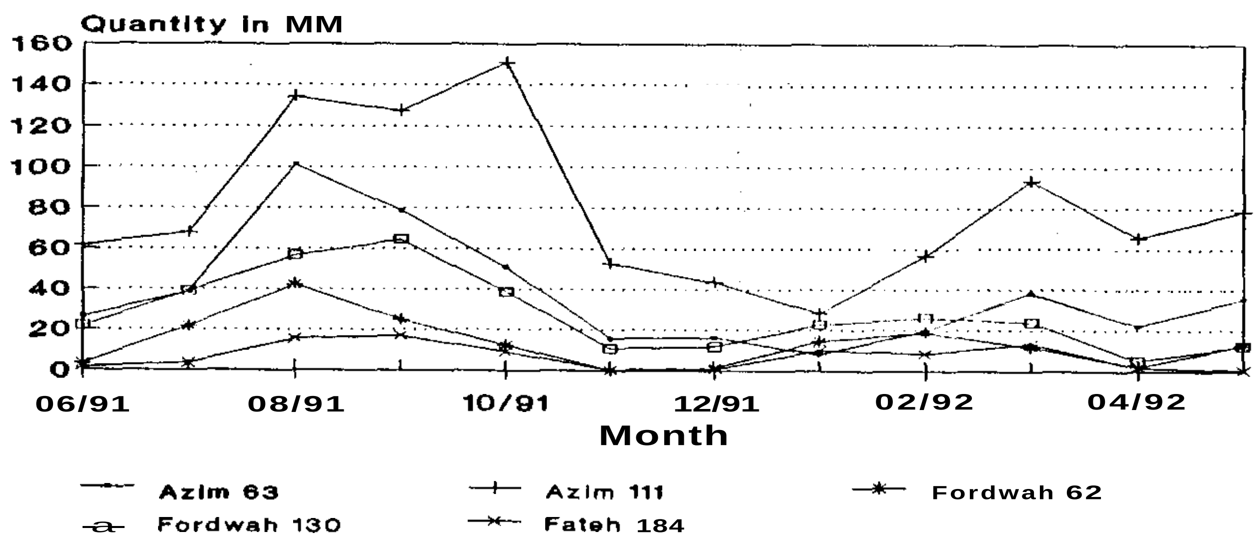
Utilization of tubewells

On average tubewells have operated 620 hours for the 12 month period. equivalent to 51 hours per tubewell per month or an utilization rate of nearly 10%. Differences among tubewells, however, are rather large, the utilization rate ranging from 1% to nearly 45%. Only 25% of the tubewells has a utilization rate higher than 10%. Source of power of the tubewell and the watercourse in which the tubewell is located are two important factors explaining the differences from one tubewell to another. Tubewells from Azim 111 have been operated most on the average (1790 hours/tubewell), followed by (in decreasing order) Azim 63 (550 hours/tubewell), Fordwah 130 (420 hours/tubewell), Fateh 184 (400 hoursltubewell). and Fordwah 62 (190 hoursltubewell). Electric tubewells have been utilized much more (1,930 hours in one year) than PTO and diesel tubewells (350 hours and 340 hours respectively).

The total quantity of water supplied by private tubewells follows a similar trend as the operational hours. In total, 960 mm of groundwater have been supplied to Azim 111, 450 mm to Azim 63, 330 mm to Fordwah 130, 165 mm to Fordwah 62 and 80 mm to Fateh 184. The low quantity of groundwater pumped in Fateh 184 when compared with the utilization rate can be explained by the low tubewell density in this watercourse. Azim 111 has not only the highest tubewell water use for the 12 month period as a whole but **also** for each month separately (see graph 4.3).

The monthly tubewell water pumped shows that for all the watercourses, the **peak** period for the operation of tubewells is the Kharif season. The difference between Azim 111 and the **4** other sample watercourses is particularly marked for the month **of** October. The maximum operation of tubewells is one month delayed for the tail watercourses, Azim 111 and Fordwah 130, if compared to the head watercourses, Azim 63 and Fordwah 62. Delays in the crop cycle (essentially wheat in this case) related to differences in canal water supply **is a** possible explanation for this difference.

Graph **4.3.** Monthly groundwater use per watercourse (91192)



Differences in the quantity **of** groundwater pumped between watercourses can **be** explained by the following factors.

The first one relates to differences in canal water supplies: (i) more water is supplied by tubewells during the Kharif season in Azim distributary than in Fordwah distributary; (ii) the quantity of groundwater supplied by tubewells **is** higher for the tail watercourses (low canal water supply) than for the head watercourses (high canal water supply). This confirms the differences observed between the canal water supply for the two distributaries established above, showing that Azim does receive only 50% of its normal share during Kharif against Fordwah's 90 % (see chapter *3).*

The pump rate is dramatically lower in **Rabi, as a** result of the much lower crop water requirements (evaporation rate). The use of tubewells picks up again in February, after **a** low in December and January. The difference in pump rate between the watercourses in Azim and Fordwah can be explained by the fact that Aziin does not receive any canal water supplies in Rabi. The large difference in the quantity of groundwater puinped between Azim ***63*** and Aziin 1 **I**I is explained by the large percentage of fallow land in **Rabi** (47 %) in Azim **63.** Farmers here choose to cultivate less land, when canal water is not available.

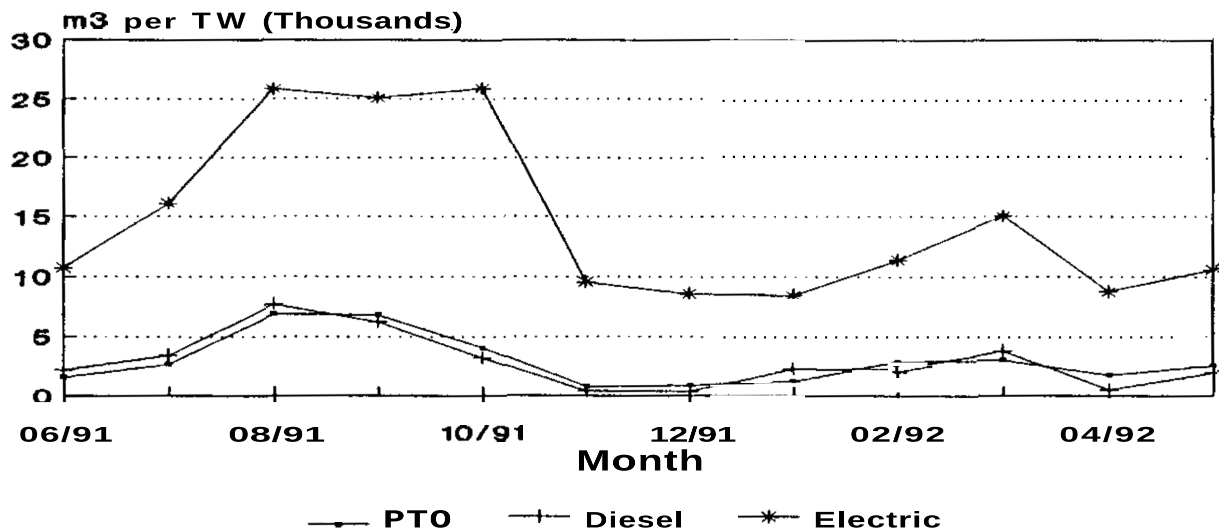
A second important factor is the quality of the groundwater pumped by the tubewells : the tubewell density as well **as** the amount of groundwater used is the lowest in Fateh 184 which has the lowest groundwater quality of the ***5*** sample watercourses.

Changes in cropping pattern among the different watercourses will be another factor explaining the specific operation of, and the water supplied by, private tubewells for each watercourse (see chapter ***5).***

The analysis ***of*** the operational data by source of power shows that there is no real difference in terms of quantity of water supplied by **a** tubewell per month between PTO and diesel tubewells. For electric tubewells, however, the monthly quantity of groundwater pumped is 4 to 10 times higher than for **PTO** and diesel tubewells *(see* graph 4.4).

It has to be noted, however, that this analysis is in fact biased for electric tubewells, as they are located only in two watercourses. Averaged electric tubewell data are **only** representative for the conditions of Fordwah 130 and Aziin 111 and do not integrate the conditions of **all** 5 watercourses **as** is the case for PTO and diesel tubewells. A comparison between the operation **of** the electric tubewells of the two watercourses highlights the difference in operation between them, the electric tubewells of Aziin 111 being operated on average twice **as** much **as** the electric tubewells of Fordwah 130.

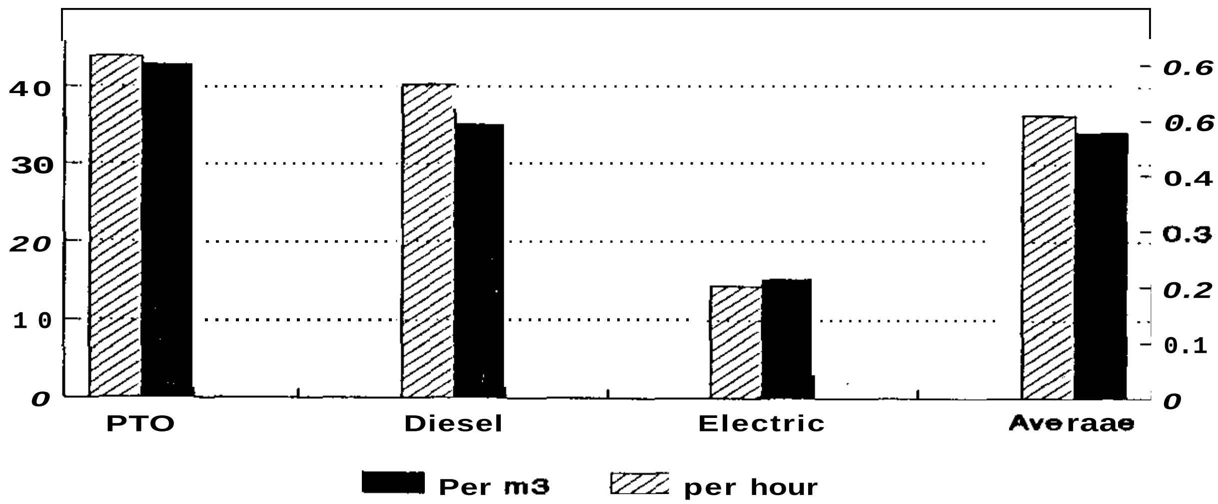
Graph 4.4. Average monthly tubewell water supply
per source of power



Differences in operation between the three sources of power are mainly related to differences in costs of Operation & Maintenance (O&M)[6]: Graph 4.5 shows that the average costs of O&M per m3 and per hour are 2 to 4 times lower for electric tubewells than for diesel and PTO tubewells. Thus owners of electric tubewells are encouraged to apply more water on their crops and will find more buyers for their relatively cheaper tubewell water (see chapter 5).

6 O&M costs were calculated by using farmers' interview data. Costs included electricity bills and wages of operators. For PTO tubewells, however. costs of maintenance of the tractor itself were riot taken into account, leading to an underestimation of the PTO tubewell O&M costs.

Graph 4.5. Average tubewell O&M costs
for different sources of power



Tubewell *owners*

Tubewell owners represent **a** distinctive class of farmers in our sample watercourses (see table **4.2).** They have bigger landholdings and **a** higher cropping intensity than other farmers. Their cropping pattern has been modified according to the higher irrigation water supply available and the better control over the water resource. Tubewell owners grow more cotton and more wheat but 'less fodder than non tubewell owners. Tubewell shareholders represent an intermediate category between tubewell owners and non-tubewell owners but still,have more in common with the non-tubewell owners. The relatively small difference between shareholders and non-tubewell owners has to be correlated with the water trading activity of the non-tubewell owners (they essentially buy their tubewell water) which compensates partially for their non-access to groundwater.

The access to credit (the amount outstanding on **a** specific date used **as a** proxy for the access to credit) and tractor ownership are two important factors distinguishing tubewell owners and non-tubewell owners: the latter do not have access to credit and own fewer tractors on average than the former.

Table 4.2. Some characteristics of tubewell owners, shareholders and non-tubewell owners

	owner	shareholder	owner
Area operated in the WC	19 ha	8 ha	5 ha
Cropping intensity	171%	145%	137%
% of area under cotton	69%	45%	51%
% of area under wheat	68%	58%	52%
Average number of tractor per farm	0.9	0.5	0.2
Amount of credit outstanding	Rs 83,000	Rs 27,000	Rs 6,000

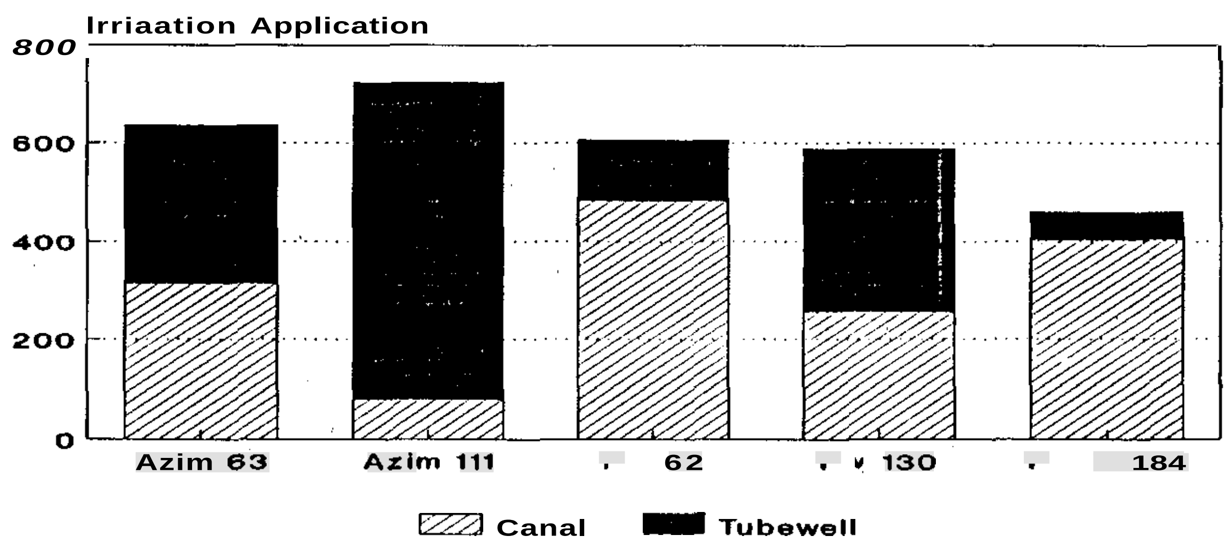
V. THE CONJUNCTIVE USE OF SURFACE & GROUNDWATER SUPPLIES

The main objective of this chapter is to describe features of the conjunctive use of surface water and groundwater at watercourse and farm level. How farmers respond to **a** canal water supply at the same time variable and rigid (through the warabandi system) has partly been answered: they install tubewells and operate them taking into account the canal water supply. However, **a** more in-depth analysis of the conjunctive use and management of the two waters is still necessary to understand the farmers' decision making process related to irrigation water and its impact on the farming system.

Relative share of canal and groundwater supplies

The irrigation water supplied varies from one watercourse to the other in terins of quantity and relative importance of canal and tubewell water. Graph **5.1** gives the total quantity of irrigation water and the relative share of each source (canal and tubewell) for the 5 watercourses for Kharif 1991

Graph 5.1. Irrigation Water Supply
per sample watercourse for Kharif 1991



The differences in water application in the different watercourses during Kharif are quite large, ranging from **a** low **of 462** mm (calculated by dividing the volume supplied by the <u>actual</u> cropped areas) in Fateh 184 to **724** mm (or 50% more) in Azim 111. For Fateh 184, the low level of water supply is certainly correlated to the inability of farmers to exploit fully their groundwater (due to its low water quality) thus explaining the low share **of** tubewell water in the total irrigation water. The high soil salinity in Azim 111 (see table **2.3)** could be a factor influencing the supply **of** irrigation water, if farmers are allocating an extra quantity of water for leaching purposes in order to reclaim their saline fields. Because they receive a very small quantity of canal water, their relatively cheap electric tubewells prdvide the lion's share of the total irrigation supply (84 %). Differences in the total water supplied between Fordwah **62,** Fordwah 130 and Azim **63** are rather small. The canal water supply of Fordwah **62,** however, **is** relatively higher, providing 80% of the total water versus 50% only for the two other watercourses.

During the Kharif season the relative shares of tubewell and canal water vary tremendously. In Azim **63,** for instance, canal water contributes as much as 72 % to the water supply in June and as little as **42 %** in September. The total amount **of** canal water, however, (volume) **is** approximately the **same** for both months, indicating that an increase in the crop water requirements is met by increasing the amount of tubewell water pumped (more than double). The same pattern can be discerned for all sample watercuurses.

When including Rabi in the total amount of the water application, the differences between the watercourses are levelled out. Both non-perennial watercourses in Azim do not receive canal water during Rabi, for which the relatively higher pumping rate of tubewells does not fully compensate.

An important factor, however, has to be added to the analysis: the water needed by the crops, which influences the water allocated by farmers. The Crop Water Requirements for every watercourse, calculated from the respective cropping patterns (see Annex 1) and the requirements **of** each crop has been **the** indicator chosen **to** include crops in our analysis. Crop Water Requirements figures are shown in table 5.1, along with the Total Water Available for crops and the Relative Water Supply (the ratio of the water available to the crops over the crop water requirements).

It is interesting to see that the yearly Relative Water Supplies for the **5** watercourses are similar for all watercourses (approximately between 0.8 and 0.9), showing that farmers in the different watercourses have adapted their cropping pattern to respond to the characteristics of the irrigation water supply.

Table 5.1. Water Availability, Crop Water Requirements and Relative Water Supplies for Sample Watercourses in Kharif 1991.

Watercourse	Crop Water Requirements (mm)	Total Water Availability[7] (mm)	Relative Water Supply (%)
Azim 63	770	700	91
Azim 111	860	750	87
Fordwah 62	740	630	85
Fordwah 130	720	610	85
Fateh 184	610	490	80

Farmers from Fateh 184 face a relatively inflexible irrigation water supply (rigid canal water supply and low groundwater quality limiting the use of groundwater) and have adapted their cropping pattern by growing crops with a lower crop water requirement, such as oilseed. On the other hand fariners in Azim 111 are growing rice, and thus pump a larger quantity of groundwater. The fact that a relatively large area in Azim 111 (20%)is cropped with rice cannot be readily explained. The higher soil salinity, mentioned before, may play an important role here, 8 fariners out of 12 interviewed in this watercourse reporting salinity as the main reason to grow rice.

Table 5.2 highlights differences in the share of the two components in the water application at a watercourse level and for 30 tubewell owners.

Table 5.2. Canal and tubewell water as a percentage of the total irrigation water applied during Kharif 1991

Watercourse	Watercourse average		Tubewell owners	
	Canal	Tubewell	Canal	Tubewell
Azim 63	49%	51%	37%	63%
Azim 111	11%	89%	3%	97%
Fordwah 62	80%	20%	56%	44%
Fordwah 130	44%	56%	37%	63%
Fateh 184	88%	12%	67%	33%

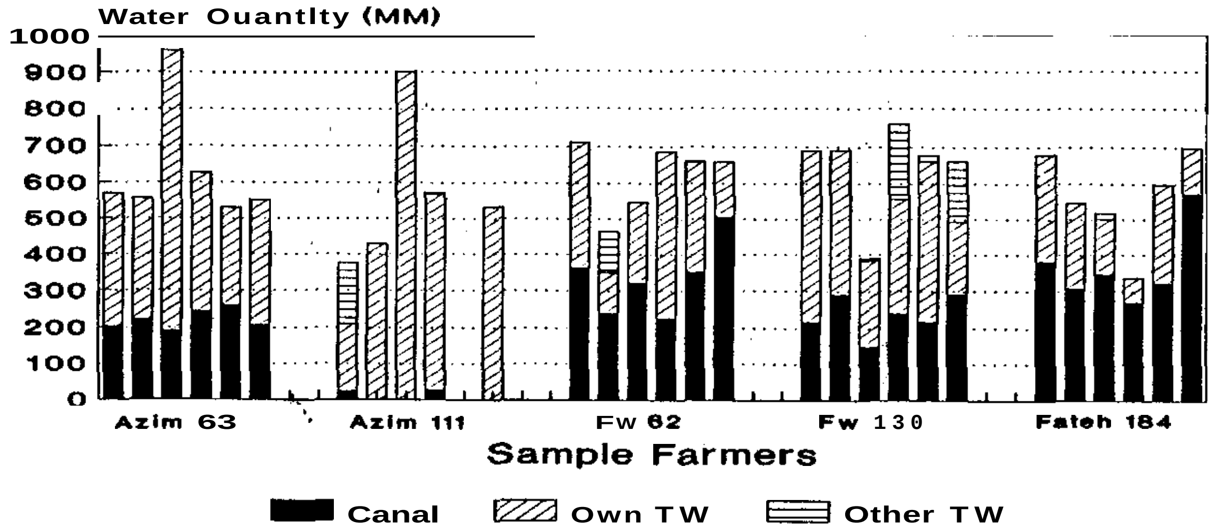
7 Rainfall is included herein

The table shows that ownership of **a** tubewell influences the magnitude of the different shares of canal and tubewell water. Differences are particularly marked for Fordwah 62 and Fateh **184,** watercourses with **a** better canal water supply. It is interesting to note that for Azim 111 and Fordwah 130, differences between tubewell owners and the watercourse averages are small. The reasons differ for the two watercourses: in Azim 111, most of the farniers are tubewell owners or shareholders; an average on **a** watercourse basis or for tubewell owners only is therefore not very different; in Fordwah 130, tubewell owners are much more active water traders (quantity-wise) than in the other watercourses, giving non tubewell owners access to **a** fair amount of tubewell water **as** well.

These average data at watercourse level hide **a** high variability among farmers in the total application of irrigation water, and in the composition of the relative shares of the RWS. Differences in terms **of** quantity applied and relative share of canal and tubewell water, can be partly explained by, (i) the availability of canal water for each farmer; not only are there differences in quantity of canal water supplied to each watercourse, (demonstrated in chapter **3),** but even within watercourses large differences exist, due to losses in water turns, (ii) the water quality, that may vary from tubewell to tubewell even within **a** watercourse **(a** low water quality will lead to **a** relatively low water supply and low share of tubewell water), indicating that farmers have **a** general awareness of the quality of pumped groundwater, (iii) the costs of operation of tubewells (farmers with electric tubewells pump more water than farmers with PTO and diesel tubewells), (iv) tubewell ownership status, and (v) the soil salinity.

Taking the main Kharif crop, cotton, **as** an example the total quantity of water applied varies in the 30 farmers' sample from 400 mm to nearly 1000 mm. Most of the farmers (almost 70 %), however, supply between 500 and 700 mm of water to their cotton crop (see graph 5.2).

Graph 5.2. Irrigation Application to Cotton
for Sample Farmers, Kharif 1991



Water trade

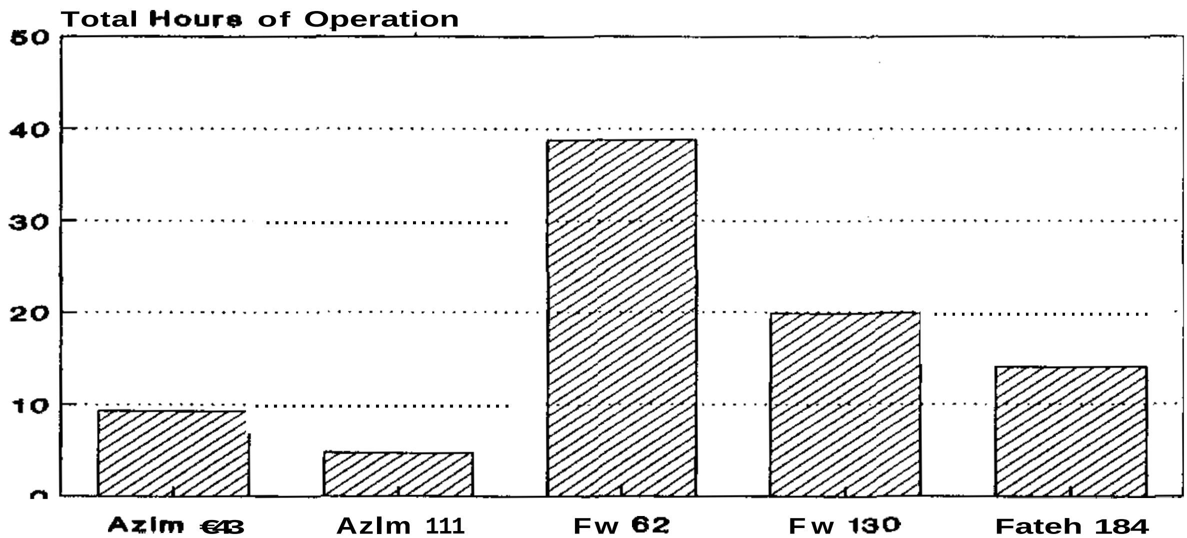
Water transactions are common practice in the farming community in the study area. Canal turns are partially or fully exchanged, canal water is exchanged for tubewell water, and canal and tubewell water is sold/purchased. Most prominent among these various features of water trade, is the sale/purchase of tubewell water, possibly due to its continuous availability.

Data collected through the socio-economic survey carried out in August 1991 support this strongly: all the non-tubewell owners (20) interviewed in the **5** watercourses were **using** purchased tubewell water (with very variable quantities) to complement their canal water supply, making the conjunctive use of water an issue for these farmers **as** well.

The study revealed that even tubewell owners purchased tubewell water. The main reasons for tubewell owners to buy water from other tubewells are the lower cost of the water purchased, the location of some fields far from the owned tubewell and the high crop water needs during certain periods of the Kharif season. Moreover, tubewell owners will buy water, in case **of an** important problem (mechanical or related to the power supply) with their own tubewell.

Graph 5.3 highlights differences in the level of tubewell water sale **(as a** percentage of the total number of hours the tubewells have been operated) from one watercourse to the other.

Graph 5.3. Tubewell water traded during Kharif 1991



The low number of potential purchasers for a low quality groundwater is certainly the main factor explaining the low trading activity in Fateh **184,** compared to Fordwah **62** and 130. In the Fordwah watercourses the tubewell water traded amounts to **20-40 % of** the total amount **of** water pumped.

It is interesting to note that tubewells from Fordwah **130** and Fordwah **62** have **a** much higher percentage of hours sold or given, than for Azim **63** and Azim 111. The differences between the "locals" of Azim and the "settlers" of Fordwah, the latter more cooperative and smaller farmers on average, are certainly important factors having an impact on the level of tubewell water sold.

A similar difference is found with respect to the management of the canal water. Often neighbours in Fordwah and Fateh will combine their canal water turns and manage them jointly to increase the flexibility of the supply. In Azim, however, common management **of** turns by neighbours does not exist.

The fact that in Azim command area more farmers have their own tubewell plays **a** role here **as** well.

Mixing canal water and tubewell water

Out of 60 farmers interviewed during the socio-economic survey in Kharif 1991, none was using canal water alone. The main reasons indicated for mixing canal water with tubewell water were to boost the discharge of canal water in the watercourse and to counteract the low quality of the tubewell water. In table 5.3, the results of the survey have been summarized for all sample watercourses.

In Fordwah 62, Azim 63 and Azim 111, the first reason to mix water is to increase the discharge in the watercourse to be able to irrigate fields in a more effective way, the field application efficiency being directly related to the discharge.

In Fateh 184 and Fordwah 130 the low quality *of* the groundwater pumped by the tubewells is the main reason of mixing the two waters. Farmers from Fateh 184 try to avoid the use of tubewell water alone, but are sometimes obliged to do so when canal water is not available.

In Fordwah 130, all the farmers report mixing waters only for part of their applications, groundwater quality being better than in Fateh 184. In Fordwah 130 the water quantity aspect is important as well and is applicable for half *of* the farmers.

Watercourse	To increase water discharge in the watercourse[8]	because poor groundwater quality
Azini 63	67%	33%
Azim 111	57%	42%
Fordwah 62	72%	36%
Fordwah 130	50%	75%
Fateh 184	33%	60%

Farmers do not always mix the two types of water. Nine farmers (5 out **of** them in Azini III and 3 in ***Azim 63)*** reported that they never mix canal and tubewell waters because they do not receive any canal water. It is in Fateh 184 that we find the higher percentage of farmers always mixing tubewell water and canal water.

When taking a closer look at the argument of low groundwater quality **as** a reason to niix canal water with tubewell water, the use of the average water quality for each sample watercourse is not sufficient. Here also we find a lot of variation between tubewells within watercourses. In a watercourse, where the water quality is relatively good, such as Azim 63 with an average

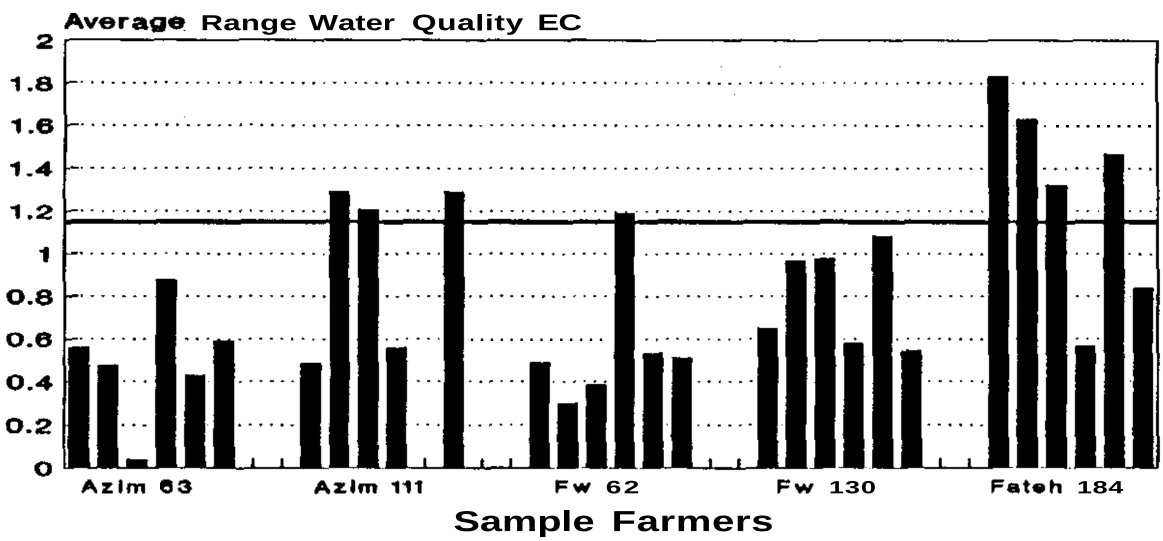
[8] **The sum of the percentages in column two and three can be higher than 100% because the two reasons are not exclusive**

tubewell water quality of 0.9 dS/m, tubewells with a water quality of more than 1.3 dS/m can be found.

It is therefore interesting to see the result of the water mixing on the final quality **of the** irrigation water at farm level. These values were calculated by niultiplying the percentage of canal water and tubewell water applied with the respective EC values, taking the amounts borrowed from other tubewells into account as well. An **EC** value of 0.2 dS/m was determined for canal water.

Graph **5.4** shows the average EC value of the water applied for 30 tubewell owners.

Graph **5.4.** Average **EC** value of irrigation water applied
30 tubewell owners - Kharif 1991



In total, 8 farmers (3 farmers of Azim 111, 1 farmer from Fortlwah 62 and **4** farmers from Fateh 184) have an average value higher than the 1.15 dS/m[9] used as an acceptable limit for the use of irrigation water (other authors use 1.0 dS/m as a threshold). On average, farmers from Fordwah 130 are close to this limit even though none of them attains it.

The type of soil, though important, is not taken into account here.
Thus the use of groundwater of low quality not sufficiently mixed with good quality water could be an important problem in the long run, especially for Fateh 184 and Azim 111.

9 Value adopted by the Punjab Agricultural Department

VI. CONCLUSIONS AND RECOMMENDATIONS

1. When the irrigation systems serving the Fordwah/Eastern Sadiqia area were designed (around 1930), some canals were made non-perennial for fear of developing waterlogging in riparian areas of Sutlej river. Present day operation of the Fordwah Branch does not seem to justify continuation of this practice, and the historical reasons are not relevant anymore. It is recommended to review this matter and in doing so to consider the managerial and operational advantages of making **all** distributaries perennial.

2. The operation of the irrigation system is not based on official rules only. Informal considerations, e.g. based on the perceived differences in groundwater quality in the various command areas, enter **also** into decisions on water distribution. Moreover, it has been observed that farmers themselves can and do influence that process, by their degree of organization and cooperation. It is recommended that these informal aspects of water distribution are studied further and that the positive role farmers can play be stimulated. Irrigation Department staff should view the increasing number of informal groups of water users as an opportunity for solving previously intractable problems, such as illegal irrigation, maintenance of some stretches of canal, and repairs of breaches, rather than as an intrusion on ID's responsibilities.

3. The amount of water available to farmers is site-specific, **as** it varies between distributaries and depends on location along the distributary. Underlying causes are the degree of siltation, which alters the hydraulic features of outlets, and illegal irrigations. Illegal appropriations of water occur in many command areas, and deserve more attention from the Irrigation Department than they presently receive. It is recoinmended that the ID starts to address both causes of the apparent inequity in distribution.

4. Annual values of irrigation water quality at farm level are governed by the proportions of canal water and groundwater received during the year, and the quality **of** the latter. It was found that the average water quality was higher for Fordwah command area than for Azim because **of** the disproportionately low accessibility to canal water for Azim fariiiers. It is recommended that in the distribution of canal water more attention is paid to water quality, to ensure equity of amounts and of water quality, in order to prevent the build-up of salts in rootzones of irrigated lands.

5. The intensive desilting that took place as part of **a** state-wide desiltation campaign during annual closure of 1992, complemented in the study area by remodelling of outlets in head and middle reaches of distributaries, has led to an improved equity of water distribution according to the analysis of Rabi data for the period following annual closure. It is recommended to monitor water distribution in the distributary canals to establish the sustainability of the improved equity, especially when farmers' demands for water are at its peak during early Kharif.

6. Farmers mix canal and tubewell supplies to increase discharge in watercourses and compensate for low quality of groundwater. The total relative water supplies (RWS) are of the same order of magnitude (0.8-0.9) for **all** watercourses that were monitored. This is taken **as** indication for the fact that farmers are stretching the irrigation water to cover **as** large an area **as** possible. It is recommended to further study irrigation applications by farmers to their crops, the proportions of water from groundwater, its quality, and the effect on yield.

7. Tubewell developnient in the area is **a** response by farmers to the scarcity of canal water, and to the inflexibility of canal water delivery. Water from tubewells augments scarce canal water and provides flexibility in water allocations. The share of groundwater in the total irrigation supplies ranges from 20% in the head reach of Fordwah command to **84%** in the tail reach of Azim. Operation and maintenance costs were found to affect the utilization rates of tubewells, with electric tubewells operating on average more than five times **as** much **as** diesel or PTO driven tubewells. It is recommended to the ID to develop conjunctive management of groundwater and canal water, and, if it **is** desirable to further develop groundwater resources in (parts of) the area (something that needs to be investigated thoroughly), to stimulate WAPDA to extend electrification in the region to allow farniers to install electric tubewells.

8. Highly active water trading in the study area supports the notion that farmers desire **a** more flexible water supply system. All farniers without tubewells reported the purchase **of** tubewell water, to the extent that 20 to **40%** of the pumped groundwater was sold to others. Generally low utilization **rates** of tubewells (10% on the average in the study area) indicate that there is room to enhance the trade in tubewell water. It is recommended that water trading should be an integral part of the conjunctive management of canal water and groundwater in the area. Better understanding of trading mechanisms and water pricing is, therefore, needed.

9. The present docunient **is a** first report **of** the existing management and irrigation practices in (part of) the Fordwah/Eastern Sadiqia area. It identifies constraints in operation of the irrigation system and opportunities for improved management of groundwater **and** canal water. It **is** recommended that similar fairly intensive studies are carried out in other parts of the Fordwah/Eastern Sadiqia area, especially in view of the expressed interest of the government **of** Punjab to have an extensive sub-surface drainage system installed in the southern part of the area. It is recommended that IIMI and ID jointly implement some/all of the recommendations mentioned above, and identify and implement possible improvements in the management of irrigation in the area.

ACKNOWLEDGEMENTS

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ANNEX 1 - CROP CENSUS SAMPLE WATERCOURCES

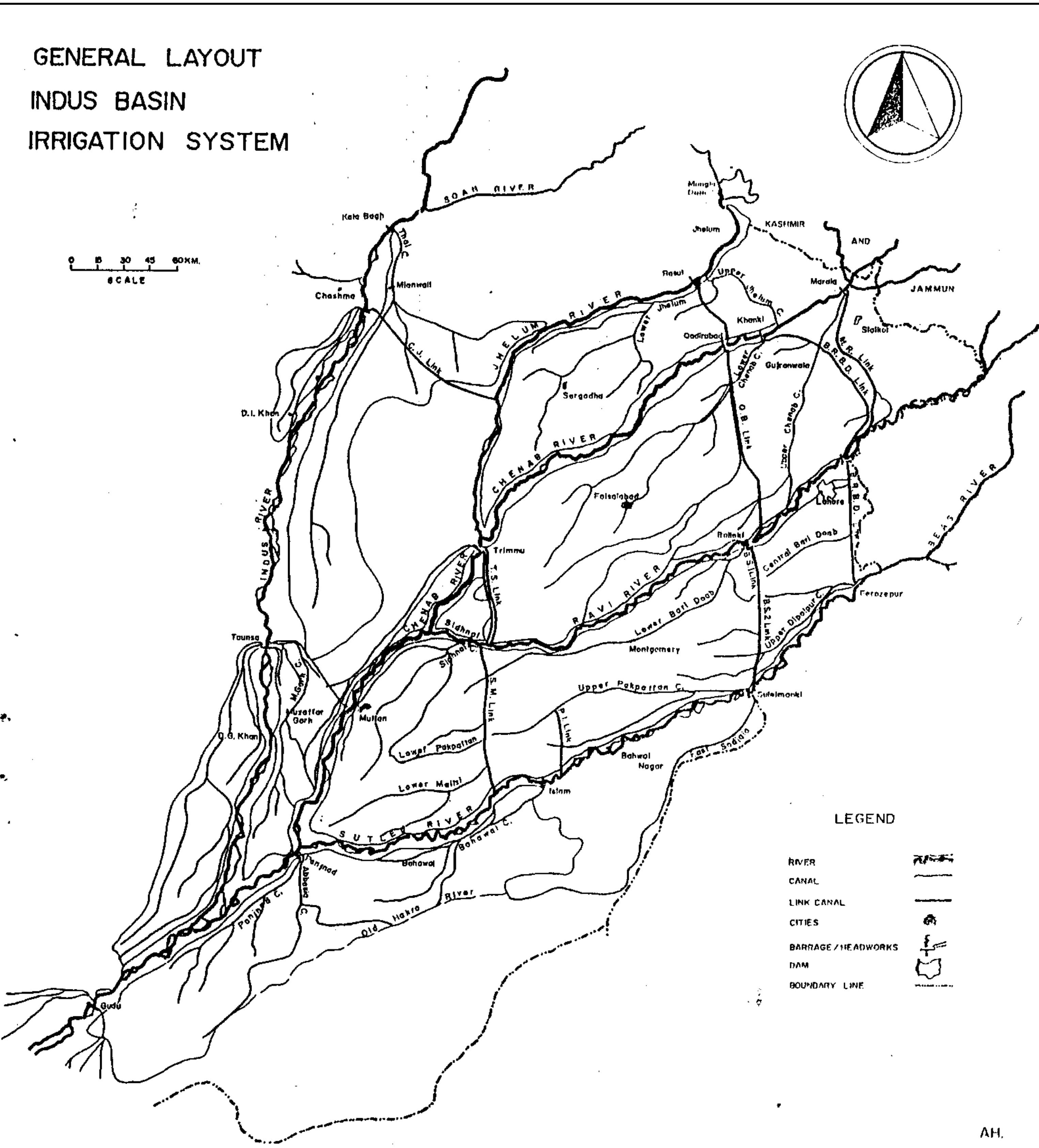
KHARIF 1991.

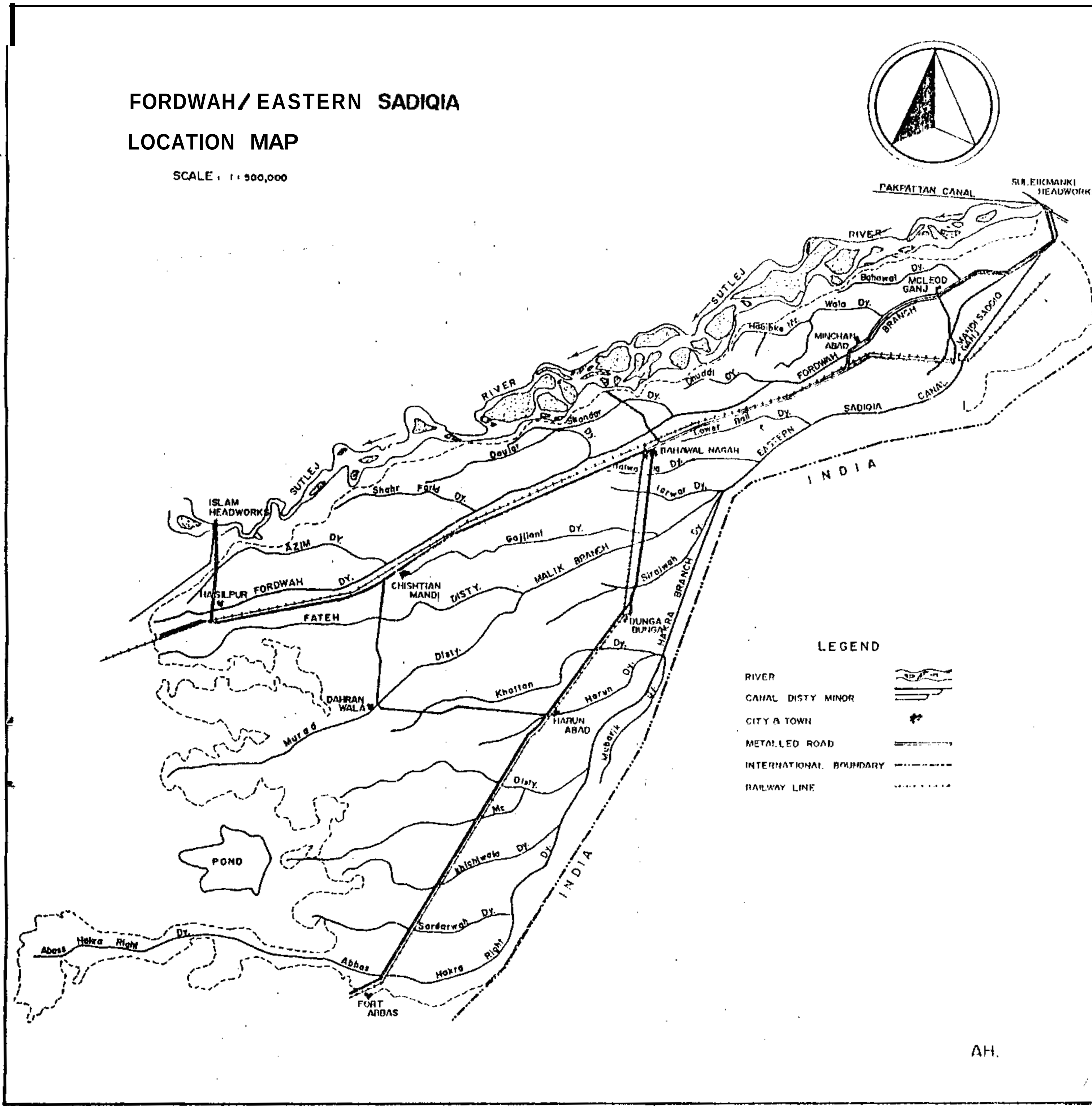
	AZIM 63-L		AZIM 111-L		FORDWAH 62-R		FORDWAH 130-R		FATEH 184-R	
	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%
COTTON	89.2	80.2	63.8	63.4	74.4	66.3	108.7	64.1	111.0	52.6
FALLOW	12.7	11.5	10.0	10.0	11.4	10.2	25.0	14.7	57.6	27.3
FODDER	5.8	5.3	6.4	6.4	16.5	14.7	26.0	15.3	34.1	16.2
S.CANE	2.1	1.9	0.4	0.4	7.2	6.4	4.5	2.7	0.6	0.3
O-SEED	0.2	0.2	0.2	0.2	0.2	0.2	3.7	2.2	0.1	
VEGE	0.1		0.4	0.4	0.3	0.2	1.1	0.6	2.4	1.1
ORCHARD					0.2	0.2	0.6	0.4	5.3	2.5
RICE	1.0	0.9	19.3	19.2	2.0	1.8				
TOTAL	111.2	100.0	100.2	100.0	112.3	100.0	169.6	100.0	210.9	100.0
BARREN	111.4		19.3		16.3		93.5		132.2	
GCA	122.7		119.5		128.6		263.1		343.1	

RABI 1991-92.

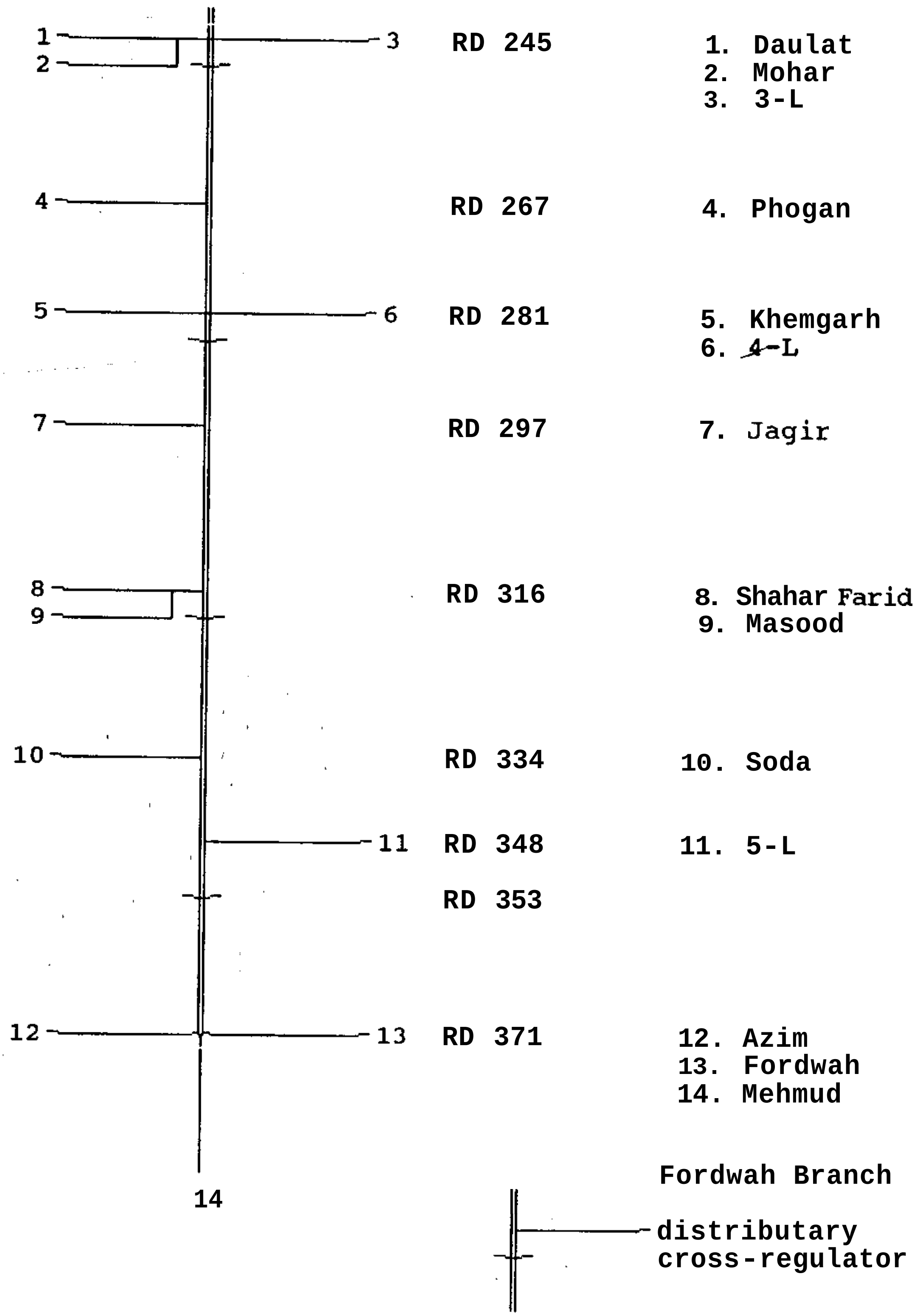
	AZIM 63-L		AZIM 111-L		FORDWAH 62-R		FORDWAH 130-R		FATEH 184-R	
	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%
WHEAT	42.3	36.8	75.7	75.0	77.0	68.9	117.6	69.0	112.4	55.8
FALLOW	63.4	55.1	7.7	7.7	13.9	12.4	27.7	16.2	48.0	23.8
FODDER	4.6	4.0	3.6	3.6	14.2	12.7	17.8	10.5	12.0	6.0
S.CANE	4.7	4.0	0.2	0.2	3.6	3.3			0.4	0.2
O.SEED			0.1	0.1	0.5	0.4	5.1	3.0	10.5	5.2
VEGE			0.1	0.1	1.2	1.0	1.6	0.9	1.5	0.8
ORCHARD							0.2	0.1	2.8	1.4
OTHERS	0.1	0.1	13.5	13.4	1.4	1.2	0.4	0.2	8.2	4.1
WHEAT+ORCH									5.5	2.7
TOTAL	115.1	100.0	100.9	100.0	111.7	100.0	170.4	100.0	201.4	100.0
BARREN	10.5		20.5		25.1		83.5		140.4	
GCA	125.6		121.4		136.8		253.8		341.8	

BARREN includes villages, canals, sanddunes, etc.
GCA: Gross Command Area


GENERAL LAYOUT
INDUS BASIN
IRRIGATION SYSTEM
0 15 30 45 60KM.
SCALE
SOAN RIVER
Kala Bagh
Thal C.
Mangla Dam
Jhelum
KASHMIR
AND
JAMMUN
Rasul
Upper Jhelum C.
Marala
Mianwali
Chashma
JHELUM RIVER
Lower Jhelum
Khanki
Qadirabad
Sialkot
C.J. Link
M.R. Link
B.R.B.D. Link
Lower Chenab C.
Gujranwala
Sargodha
D.I. Khan
CHENAB RIVER
Q.B. Link
Upper Chenab C.
INDUS RIVER
Faisalabad
Lahore
B.R.B.D.
BEAS RIVER
Balloki
Central Bari Doab
Trimmu
B.S.I. Link
T.S. Link
RAVI RIVER
Ferozepur
CHENAB RIVER
Lower Bari Doab
B.S.2 Link
Sidhnai
Taunsa
Montgomery
Upper Dipalpur C.
Sidhnai C.
M.Garh C.
Upper Pakpattan C.
Sulaimanki
Muzaffar Garh
Multan
S.M. Link
P.I. Link
D.G. Khan
Lower Pakpattan
East Sadiqia
Bahawal Nagar
Lower Mailsi
Islam
SUTLEJ RIVER
Bahawal C.
Panjnad
Abbasia C.
Bahawal
Panjnad C.
Old Hakra River
Gudu
LEGEND
RIVER
CANAL
LINK CANAL
CITIES
BARRAGE / HEADWORKS
DAM
BOUNDARY LINE
AH.


FORDWAH/ EASTERN SADIQIA
LOCATION MAP
SCALE : 1:500,000
PAKPATTAN CANAL
SULEIKMANKI HEADWORKS
RIVER
SUTLEJ
RIVER
SUTLEJ
ISLAM HEADWORKS
MCLEOD GANJ
MINCHAN ABAD
FORDWAH
BRANCH
MANDI SADIQ GANJ
SADIQIA CANAL
BAHAWAL NAGAR
EASTERN
INDIA
AZIM DY
HASILPUR
FORDWAH DY.
CHISHTIAN MANDI
FATEH
DISTY.
MALIK BRANCH
DUNGA BUNGA
HAKRA BRANCH
DAHRAN WALA
HARUN ABAD
Murad
Khattan
Harun
Disty.
Sardarwah Dy.
Hakra Right
Abbas
FORT ABBAS
POND
INDIA
LEGEND
RIVER
CANAL DISTY MINOR
CITY & TOWN
METALLED ROAD
INTERNATIONAL BOUNDARY
RAILWAY LINE
AH.

MAP 3 - LAY-OUT FORDWAH BRANCH



ANNEX 1 - CROP CENSUS SAMPLE WATERCOURCES

KHARIF 1991.

	AZIM 63-L		AZIM 111-L		FORDWAH 62-R		FORDWAH 130-R		FATEH 184-R	
	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%
COTTON	89.2	80.2	63.8	63.4	74.4	66.3	108.7	64.1	111.0	52.6
FALLOW	12.7	11.5	10.0	10.0	11.4	10.2	25.0	14.7	57.6	27.3
FODDER	5.8	5.3	6.4	6.4	16.5	14.7	26.0	15.3	34.1	16.2
S.CANE	2.1	1.9	0.4	0.4	7.2	6.4	4.5	2.7	0.6	0.3
0-SEE0	0.2	0.2	0.2	0.2	0.2	0.2	3.7	2.2	0.1	
VEGE	0.1		0.4	0.4	0.3	0.2	1.1	0.6	2.4	1.1
ORCHARD					0.2	0.2	0.6	0.4	5.3	2.5
RICE	1.0	0.9	19.3	19.2	2.0	1.8				
TOTAL	11.2	100.0	100.2	100.0	112.3	100.0	169.6	100.0	210.9	100.0
BARREN	111.4		20.5		25.1		93.5		132.2	
GCA	122.6		121.4		137.4		263.1		343.1	

RABI 1991-92.

	AZIM 63-L		AZIM 111-L		FORDWAH 62-R		FORDWAH 130-R		FATEH 184-R	
	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%	AREA (HA)	%
WHEAT	42.3	37.7	75.7	75.0	77.0	68.9	117.6	69.0	112.4	53.3
FALLOW	60.4	53.9	7.7	7.7	13.9	12.4	27.7	16.2	57.5	27.3
FODDER	4.6	4.1	3.6	3.6	14.2	12.7	17.8	10.5	12.0	5.7
S.CANE	4.7	4.2	0.2	0.2	3.6	3.3			0.4	0.2
O.SEED			0.1	0.1	0.5	0.4	5.1	3.0	10.5	5.0
VEGE			0.1	0.1	1.2	1.0	1.6	0.9	1.5	0.8
ORCHARD							0.2	0.1	2.8	1.3
OTHERS	0.1	0.1	13.5	13.4	1.4	1.2	0.4	0.2	8.2	3.9
WHEAT + ORCH									5.5	2.6
TOTAL	112.1	100.0	100.9	100.0	111.7	100.0	170.4	100.0	210.9	100.0
BARREN	10.5		20.5		25.7		92.7		132.2	
GCA	122.6		121.4		137.4		263.1		343.1	

BARREN includes villages. canals, sanddunes, etc.
GCA: Gross Command Area