Moving Towards Demand-Based Operations in Modernized Irrigation Systems in Pakistan

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Cover photograph by D.J. Bandaragoda: *A gated* outlet in the Lower Swat Canal Irrigation System, Mardan, Norm-West Frontier Province, Pakistan.

Contents

Figures and Tables vii

Foreword ix

Acknowledgements xi

Summary xiii

Chapter 1. INTRODUCTION 1

Chapter 2. BACKGROUND 3

Chapter 3. THEORETICAL FRAMEWORK 11
- Rotation Schedules 12
- Arranged Schedules 14
- Demand Schedules 15
- Rigid Schedules Versus Flexible Schedules 16

Chapter 4. MODERNIZED SYSTEMS IN PAKISTAN 19
- Chashma Right Bank Canal (CRBC) System 20
- Lower Swat Canal (LSC) System 23

Chapter 5. OPTIONS IN PAKISTAN 27
- Options at the Farm Level 28
- Options at the Main System Level 30

Chapter 6. OPPORTUNITIES FOR PILOT STUDIES 33

Chapter 7. CONCLUSION 39

References 41

Figures and Tables

Figure 1. Irrigation water requirements at watercourse head, Chashma Right Bank Canal (CRBC) 22

Figure 2. Irrigation water requirements at watercourse head, Lower Swat Canal (LSC) 25

Table 1. Water allowance in major perennial canals in Pakistan . 5

Table 2. The ratio of water supply to crop consumptive use for typical canal systems in Pakistan 8

Table 3. Definitions of delivery scheduling methods 12

Table 4. Proposed cropping pattern and cropping intensity, Chashma Right Bank Canal (CRBC) 21

Table 5. Projected cropping pattern and cropping intensity, Lower Swat Canal (LSC) 7A

Table 6. Percent of time. over the year for different discharges . .31

Foreword

THE IDEA TO match water supplies with crop water demands has been debated in Pakistan for quite some time. It has not been questioned that supplying water according to the demand of the crops (often called demand-based irrigation) would help improve the efficiency with which water — an extremely scarce resource in the country — is used in irrigated agriculture. The question, however, is how this could be achieved in irrigation systems where, traditionally, water application is supply-driven.

In the North-West Frontier Province, two systems have been modernized and in the design, the possibility has been considered of varying the supply according to the needs of the crops under intensive cultivation. These systems offer an opportunity for pilot-scale studies of a flexible management system. IIMI has been asked to collaborate with the Provincial Irrigation Department in studying the possible implementation of a crop-based distribution of canal water in these systems.

This IIMI Country Paper reviews the various management options for flexible management systems at farm and system levels. The conclusion the authors reach from their penetrating analysis of these options is that several causes, such as the design of the systems, the irrigation practices that irrigation engineers are used to, and the socioeconomic environment, prevent a ready shift from supply-driven to demand-based irrigation operations. They state that even a modified demand-based management, in which the supplies to farmers are subject to limitations in rate, duration or frequency of the supplies, would require major physical changes in the design, and vastly different and complex management forms. Neither fanners nor engineers of the Irrigation Department can be. expected to be ready for such changes without thorough training, continued monitoring and well-informed advisory services.

I trust that the realistic approach of the authors will generate further discussions on the feasibility and desirability of the shift from supply-driven to demand-based irrigation operations in Pakistan. Comments on the paper are cordially invited.

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IIMI Pakistan

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Summary

PAKISTAN'S LARGE **AND** complex irrigation system is characterized by its original design to provide the maximum number of people with reasonable protection against the effects of severe drought, and by its administered operational mode, which **seeks** to achieve this objective in the most equitable manner. **The broad pmtection and equity objectives** were based on a delivery system that assumed full supply level flow of water in distributary channels and open outlets to farmer watercourses, and also a cropping intensity of only about **75** percent of the command area for the two cropping seasons.

Over the years, these conditions have changed. Given the extensive infrastructure network and repetitive fiscal constraints, the maintenance effort has not been able to **sustain** the necessary hydraulic conditions in the physical system. Meanwhile, cropping patterns have changed and cropping intensities have increased. These changes have led to severe water distribution problems particularly affecting the tail-end farmers, and to an increasing realization *of* the limitations of administered supply-oriented irrigation operations.

In the North-West Frontier Province (NWFP) steps have been taken to redesign and remodel some of these irrigation systems with conscious regard to the crop water requirements for more intensive cropping. Though this has resulted in enhanced delivery capacities in the physical systems to meet the peak irrigation demand, it has also introduced some management implications including a requirement for the seasonal and spatial regulation of water delivery without which water wastage and drainage problems are likely to be exacerbated.

As this provides an opportunity to develop and pilot-test management approaches to achieve more appropriate matching of water delivery and crop-water demand, both the Federal and Provincial governments have requested IIMI's participation in a collaborative effort to evolve more responsive management systems. With the assistance from the Asian Development Bank, IIMI has taken steps to launch a pilot-scale action research activity for this purpose in two modernized systems in the NWFP.

Preliminary observations made during the inception stage of this study indicate that, in the present institutional and technical context of Pakistan's irrigation, a shift from the traditional supply-oriented mode cannot be simple and straightforward. More flexible modes of management can only be introduced after many options are critically analyzed, and their associated imperatives of institutional and managerial change are identified, tested and refiied through action research. A concerted effort in this direction is long overdue.

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CHAPTER 1

Introduction

A **SHIFT FROM** the traditional supply-oriented system of irrigation operations to one that is based on demand, or to one that corresponds to crop-water requirements, is among the most challenging issues confronting the Pakistan irrigation sector. The challenges are compounded by the complexity, size and limitations of Pakistan's canal irrigation systems, and the social, institutional and managerial implications related to their operations. Pakistan's National Commission on Agriculture, noting these problems, specifically recommended that plans should be developed on the basis of results from pilot studies for the distribution of irrigation supplies more in line with crop-water requirements in different canal commands.

Two modernized irrigation systems in Pakistan's North-West Frontier Province (NWFP), in which consideration has been given in the designs to the crop-water requirements for intensive cultivation, seem to offer an opportunity for pilot-scale studies of flexible management systems. In these modernized systems, substantial improvements in irrigation performance and consequent agricultural production can he expected, if water requirements of the crops can be met within the given supply constraints. If the modernization of systems is not accompanied by adequate changes in their management and operation allowing for greater flexibility, and if the traditional supply-oriented operations are allowed to continue, the anticipated return on investments may not be achieved, and moreover, significant inefficiencies in water use could exacerbate existing drainage problems. Also, there could be implications of water availability for downstream users.

A flexible management system requires an appreciation by the fanners and agency personnel that the cropping patterns should remain within the limitations of variable water supply, and that the water delivery should closely correspond to the crop-water requirements throughout the cropping seasons. Without this awareness, there could be a tendency for the *ad hoc* utilization of the system's full capacity (which is intended only for the peak requirement), and while this may result in an increased cropped area, or in a change in the cropping pattern, the supplies would have little relation to the variable needs, and the outcome may contribute to a suboptimal agricultural performance and the exacerbation of drainage problems.

Flexibility of management responding to crop-water demand can be achieved in several different forms of demand-based operations. The appropriateness of each, however, depends on a number of situational factors. An understanding of different methods is essential before selecting the most suitable solutions in Pakistan's context.

The objective of this paper is to analyze the potential for more flexible water delivery methods in Pakistan's modernized irrigation systems in the design of which some consideration has been given to the crop-water requirements. In order to place this analysis in the present context, the paper starts with a background of the present canal irrigation operations in Pakistan, and also gives a brief description of the range of irrigation scheduling practices.

The paper is based on a literature review, and the preliminary field work conducted in connection with the development of IIMI's recently initiated research project on Crop-Based Irrigation Operations in the NWFP.

CHAPTER 2

Background

IRRIGATION ALONG THE rivers and streams has been practiced in Pakistan for centuries. The present irrigation systems, which are essentially confined to the Indus Plains, are the result of the pioneering work of the British, who started them from the middle of the last century. This development was based on the flows of the river Indus and its tributaries, which carried year-round copious supplies derived from the summer monsoons and the snow melt in the Himalayas. These systems, relying on the run-of-the-river flows, could be conveniently developed over large *mas* in the flat plains as water could be transported over long distances when the river levels were high (as in summer), or if they could be raised by constructing weirs or barrages for diverting the low winter flows.

Initial irrigation development, the origin of which can be traced to pre-British times, was through inundation canals which functioned only during periods of high river flows, mainly in the kharifseason. providing some residual soil moisture for winter crops in the rabi season. This was followed by the development of perennial irrigation systems during the British period, in which year-round irrigation supplies could be run. As the winter flows were only about a fourth of the summer flows, two types of systems came into being, non-perennial and perennial, depending upon the appropriation of the low flows.

In Punjab Province, the irrigation systems, which were developed on a river-basin concept (with inter-river transfer), were severed with thecreation of **Pakistan** in 1947. This led to a dispute with India on the **sharing** of the riverwaters. However, it was resolved under the Indus Water Treaty of 1960, with the construction of link canals from the Western rivers (Indus, Jhelum and the Chenab allocated to **Pakistan),** to feed the systems previously supplied by the Eastern rivers (Ravi, Beas and Sutlej) over which India could exercise exclusive control.

In recent years, progressive improvements have been made and barrages have been constructed to control the diversions to all the major systems. **A** significant improvement, following the Indus Water Treaty. has been the construction of surface storage reservoirs with a total initial live storage of 19.07 billion cubic meters (15.46 million acre-feet [MAF]): Mangla on the Jhelum River, 6.59 billion cubic meters (5.34 MAF), Tarbela on the Indus, 11.61 billion cubic meters (9.41 MAF), and Chashma also on the Indus, 0.87 billion cubic meters or 0.71 MAF (WAPDA 1979). Thus, the link canals and the storage have provided an element of flexibility in managing the river flows.

As it stands, the irrigation system of the Indus Plains, with a total culturable command area (CCA) of 13.5 million hectares (ha) (34.556 million acres), of which an extent of 8.4 million ha (20.8 million acres) is perennial, is the most extensive single river basin integrated system in the world. It comprises the Indus and its major tributaries, 3 storage reservoirs, 19 barrages or headworks, 43 canal commands and some 88,600 watercourses. The length of canals with a diversion capacity of 7,318 cubic meters per second or 258,600 cusecs, is about 57.130 kilometers (km) (35,500 miles) and of watercourse and farm channels about 1.6 million km. Although it is one of the first engineered systems and includes pioneering innovations, the irrigation canal system has become strongly constrained in some respects, particularly as regards water management for meeting crop water requirements, both in terms of quantity and timeliness of application.

The physical characteristics of the existing canal systems, conceived under a set of conditions and objectives different from those that prevail today, and their vast geographic scale, are constraints to potential adjustment for current conditions and objectives. The canals were constructed for the purpose of opening up new cultivable but sparsely populated lands, both to realize income to the government from the sale of waste crown lands and to alleviate chronic famines by resettling farmers from poorer areas.

The physical layout and design of the canal system were evolved empirically to fit into the pattern of water supplies available in the unregulated rivers and to meet the objective of "bringing to maturity the largest area of crop with the minimum consumption of water."[1] Due to the limited amount of water available in rabi or the October to April low-flow period, only about 8.5 million ha (21 million acres) of the total CCA could

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1 For details, see the Revenue Manual of the Irrigation Branch. Punjab Public Works Department, Fourth Edition. 1966

be provided with perennial supply, with the remainder receiving water only in the summer high-flow season.

Irrigation intensities, or the total land area to be irrigated in the two crop seasons in relation to the culturable commanded area, were designed to be quite low, averaging about 75 percent (about 50% in kharif and 25% in rabi amounting to 37.5% of full double-crop potential). The idea was to settle as much land as possible. The designed water allowance, or the rate of water supply to the farms was kept at about 0.25 liters per second per ha (3 to 4 cusecs per 1,000 acres) of the CCA for the perennial systems. Table 1 typifies the values for the earlier canal systems and contrasts them with the recent changes in modernized irrigation systems, the Chashma Right Bank Canal (CRBC) and the Lower Swat Canal (LSC).

Traditionally, the allocation and distribution of water within the canal command are controlled essentially by the pattern of water supply received

Table 1. Water allowance in major perennial canals in Pakistan.

Canal system	Year operations started	Canal capacity		Water allowance	
		M^3/sec	(Cusecs)	l/s/ha	(Cusecs per 1,000 acres)
1 Central Bari Doab	1859	73.58	(2,600)	0.23	(3.22)
2 Sidhnai	1887	127.35	(4,500)	0.21	(3.00)
3 Lower Swat	1890	22.64	(800)	0.44	(6.15)
4 Lower Chenab	1892	325.45	(11,500)	0.22	(3.17)
5 Lower Jhelum	1901	150.00	(5,300)	0.20	(2.84)
6 Upper Jhelum	1915	53.77	(1,900)	0.21	(3.03)
7 Panjnad	1929	254.7	(9,000)	0.30	(4.20)
8 Rohri	1932	316.96	(11,200)	0.20	(2.84)
9 Thal	1947	283.00	(10,000)	0.23	(3.18)
10 CRBC	1987	130.1	(4,879)	0.53	(7.53)
11 Lower Swat (Remodeled)	-	55.0	(1,940)	0.78	(11.00)

Sources: Revised Action Programme far Irrigated Agriculture, Vol.I, WAPDA 1979. Item 10 from PC-I (Revised) for CRBC Project. WAPDA May 1981. Item 11 from Final Project Plan. Mardan SCARP, June 1981 (Draft Report) Harza/Nespak Consultants.

at the headworks. This, together with the limited hydraulic flexibility within the canal system, limits the scope for response to variations in demand within the commands. The main water distribution objective, then, is to try to maintain equity of supply throughout the command, especially to the tail reaches during periods of high demand.

Conveyance of water from the canals to the farm field is by watercourses which are supplied through field *moghas* (outlets) that take off from distributaries and minors. Within a watercourse command, ranging from 80 to 280 ha (200 to 700 acres) in size, the shareholders receive a supply of water proportionate to their holdings. This is accomplished by assigning the entire flow of the watercourse, usually between one and three. cusecs, to one farm for a specified time period on a seven-day rotation. The rotation schedule, called the warabandi is established by the Irrigation Department, if not mutually agreed by the fanners.

A basic design concept in the canal system is to provide equitable distribution with minimum opportunity for human interference, and to be operated at low cost by a small staff with limited means of rapid communication over the long distances involved (the distance from the Rohri Canal head regulator to the tail-end regulators is about 320 km). To meet these requirements a simple, but very effective design was evolved. Ungated outlets having a discharge in proportion to the area to be irrigated are used for distribution of the supplies. These outlets operate whenever the minor or distributary channel is running. A minimum number of canal flow regulation structures are provided, and these are used primarily to turn branches and distributaries full on or off, and to prevent overflowing. Very few escapes are provided, and these are located near canal heads, or at major junctions for convenience in emergency use. No tail escapes are provided, with the result that surplus flows are absorbed on the farm land. As is the case with design intensities, these concepts were valid for the conditions of the past, but the inflexibility of the system now is a constraint to water management for maximum crop production.

The hydraulic design of the existing irrigation channels also has substantial hearing on present water management and potential for water management improvement. Almost all channels are unlined earth structures designed to remain in annual equilibrium or regime under conditions of seasonally varying sediment loads: that is, there should be no net deposition or scour in the canal bed, and the canal should not tend to meander from its alignment by bank erosion and shoaling. A universal requirement of regime operation is that the canal must be operated within a narrow range of discharges — usually between 80 percent and 110 percent of design full supply discharge. Maintaining proportionality of the nonadjustable watercourse outlets also requires that the canal be operated in a narrow discharge range. Under these constraints, the only way to operate the canal system under low water availability or to meet low water requirements is by rotation: that is, alternately operating the canal, or its branches or distributaries, in cycles of full discharge and no discharge. This type of operation at least doubles the interval between irrigation and introduces yield reducing moisture stress in the crop.

Inequities in the irrigation supplies in relation to the crop-water requirements are a pronounced feature of the irrigation systems in Pakistan. Even in those areas where groundwater has been developed as an irrigation supplement, the mis-match persists. A study by the Water and Power Development Authority (WAPDA; 1979) for an average year has brought out significant variations (both positive and negative) between the crop consumptive use and total irrigation supplies, from month to month as well as between different canal commands for all months. The ratio of water supply to crop consumptive use for typical canal systems, from this study is depicted in Table 2.

The characteristics of the canal systems depicted above are seen as having the following consequences:

1. Low productivity as supplies fall short of the crop-water requirements during the growing periods or at critical stages of growth.

2. The inadequacy of supplies at the time of sowing of crops resulting in protracted sowing periods, beyond the proper time, and thus lowering productivity.

3. Inadequate supplies available at the time of sowing restricting the area under crop, although excess supplies are available later in the season.

Table 2. The ratio of water supply to crop consumptive use for typical canal systems in Pakistan.

Canal	Rabi							Kharif							Annual
	Oct	Nov	Dec	Jan	Feb	Mar	Season	Apr	May	Jun	Jul	Aug	Sep	Season	
1 Lower Swat P, LG	0.42	0.78	2.54	1.10	0.86	1.29	0.80	0.94	0.39	0.24	0.37	0.47	0.23	0.36	0.47
2 Upper Jhelum PP, GW	.63	1.25	1.21	2.07	0.93	0.56	1.13	1.29	1.75	0.86	1.82	2.52	1.14	1.40	1.28
3 Sidhnai NP, LG	0.72	1.02	1.11	0.99	0.48	0.38	0.69	0.90	0.99	0.63	0.70	0.61	0.43	0.66	0.67
4 Muzaffargarh NP, GW	1.81	0.81	1.51	1.63	0.78	0.49	0.98	1.09	1.24	1.17	1.62	1.38	1.04	1.27	1.14
5 D.G. Khan NP, LG	[illegible]	0.51	0.43	0.85	0.21	0.08	0.46	0.38	0.58	0.77	1.10	1.06	0.65	0.83	0.68
6 Rohri P, LG	0.82	0.81	1.56	0.35	0.47	0.49	0.67	0.82	0.71	0.59	0.38	0.50	0.69	0.57	0.61
7 Rice NP, LG	1.02	0.01	0.02	0.00	0.00	0.02	0.18	0.50	1.36	0.81	1.04	0.85	0.77	0.89	0.70
8 Beghari	0.54	0.03	0.04	0.09	0.04	0.09	0.13	0.36	0.05	0.55	1.30	1.51	2.82	0.93	0.68

Source: Revised Action Programme for Irrigated Agriculture, Vol.I, WAPDA, 1979.

Notes: P=Perennial, PP=Partly perennial, NP=Non-perennial,
LG=Limited groundwater, GW=Groundwater supplement available.

4. The designed capacities of the systems restricting more supplies to meet the crop-water requirements, even if excess supplies are available in the rivers during summer.

5. Irrigation supplies in excess of the crop-water requirements causing drainage problems and resulting in waterlogging and salinity.

The National Commission on Agriculture (1988) has noted that there is seldom enough canal water to meet the entire water requirements of crops. Shortages occur during critical periods of the crop-growth cycle, resulting in water stress and lower yields. The Commission has, therefore, recommended the development of macro-level water management plans for the distribution of irrigation supplies, including available groundwater more in line with crop-water requirement sin different canal commands. The Commission has, however, cautioned that to bring about a closer link between the irrigation supplies and the crop-water requirements, crop zoning and water scheduling should be taken up initially on a pilot scale before its wider introduction.

CHAPTER 3

Theoretical Framework

IT REQUIRES **HARDLY** any substantiation for the fact that, in irrigation systems, one important prerequisite for optimum agricultural production is the delivery of irrigation supplies to the farms according to the cmp-water requirements and other farming needs. The demand for water by the fanner at his convenienceand as dictated by climatic conditions can vary markedly in different parts of the system and also during the growing season. It is the magnitude of these changes and the extent to which they can be accommodated by the capability and design of the supply system, and its management, which determine the flexibility in the delivery schedules, and, in turn, the overall efficiency of water use.

The way water is delivered in terms of *frequency*, ***rate*** and ***duration*** is expressed by the water supply delivery schedules. The schedules are generally categorized as Rotation, ***Arranged*** and ***Demand*** (ASCE 1984, 1987). These variations in irrigation schedules depend on:

1) the degree of flexibility given to the water user in terms of frequency. flow rates and duration; and

2) the level within the delivery system at which irrigation delivery decisions are made (local, intermediate or central control).

The rotation schedules are preset, as in the case of Pakistan's canal water warabandi system, and do not permit any user control. The arranged schedules require communication with the supplier to arrange the time and thequantity of delivery, whereas the demand schedules provide the user with water as he needs it under his own control within the limits of system capacity.

The definitions of the different scheduling methods, as given by Clemmens (1987), are presented below in Table 3 which brings out, in the order of decreasing flexibility, the choice of the farmers in respect of frequency, rate and duration of the irrigation supplies. Table 3 is followed by the descriptions of the various methods, also as given by Clemmens (1987).

Table 3. Definitions of delivery scheduling methods

Schedule categories	System constraints		
	Frequency	Rate	Duration
Local control			
Demand schedule	U	U	U
Limited rate demand schedule	U	L	U
Arranged frequency demand schedule	A	L	U
Intermediate control			
Arranged schedule	A	A	A
Limited rate arranged schedule	A	L	A
Restricted arranged schedule	A	C	C
Fixed duration arranged schedule	A	C	F
Fixed rate/restricted arranged schedule	A	F	C
Central control			
Central system schedule	V	V	V
Fixed amount schedule	V	F	V
Rotation schedule	F	F	F
Varied amount rotation schedule	F	F(V)	F(V)
Varied frequency rotation schedule	F(V)	F	F(V)
Continuous flow schedule		F(V)	

ROTATION SCHEDULES

Rotation schedules are the most restrictive of all irrigation schedules, as the frequency, rate and duration are fixed by the central irrigation agency and remain fixed for the entire season. Such systems are common in developing countries (e.g., warabandi systems in Pakistan and Northern India). A rotation schedule can be administered with least control over the operations, thus keeping management intensity at a low level, and it is usually considered more equitable than a flexible delivery schedule where intermediate and local intervention are often needed.

Several variations can be seen in rotation schedules, and some of them are:

Continuous flow schedules, which constitute a special case of rotation systems, where the duration is the entire season and the frequency is once per year. Continuous flow systems can be used in places where water is plentiful and the growing season is short, and the efficiency of irrigation practices for maximum yield is not considered essential. Here, flow rates can be varied over the season to meet crop-water needs better. In many cases, while a constant rate is delivered to a farm, the stream is rotated between fields.

Varied-amount rotation schedules, which constitute one way of adjusting the volume of water delivered at various stages during the growing season. In general, the frequency remains fixed, while the duration and/or rate are varied to apply more or less water to a particular area. Adjustments in rate are fairly easily accomplished; however, adjustments in duration without adjustments in frequency are a little more difficult. One example would be to supply water half the time to alternate rotation areas.

Varied-frequency rotation schedules, which constitute another way of adjusting for variations in crop-water use over the irrigation season. Under these schedules, the frequency of delivery is varied. Again, it is somewhat difficult to accomplish without rate and duration variations, except in even multiples, for example, twice the irrigation frequency during peak use periods over that in the early and late seasons.

ARRANGED SCHEDULES

Under arranged schedules, the frequency, rate and duration are arranged between the user (fanner) and the water supply agency. Often, these arrangements are made more on a local level, rather than on a project level, allowing for greater flexibility in arrangements, for example the last-minute changes. The advantage of arranged schedules is that while they provide flexibility for farm operations, they also allow for simpler delivery system operations than do demand systems. In fact, the delivery system operational capabilities have a very direct impact on how flexible an arranged schedule can be. In essence, there is a continuum of possibilities from a pure demand system to a very restricted arranged system. The difference between these schedules and rotation schedules is that in the latter, all decisions are made by a central authority.

The timing of arrangements is an important feature of arranged schedules, and it can have a significant impact on the success or failure of the arranged schedule. The characteristics of the irrigation system would determine whether the lead-time would be short or long. These differences can be significant. particularly for some irrigation scheduling methods. In addition, it may be necessary to change duration (or even rate) during the course of an irrigation. This is easier to accomplish when durations are not fixed by the operating agency, since it may just mean rearranging the start time for the subsequent user. A number of common arranged schedules are given below:

> ***Limited rate arranged schedules*** are very flexible in that restrictions are placed only on the flow rate, with frequency and duration arranged according to farmer needs. These arrangements allow for changes in frequency and duration during the irrigation process, not under direct fanner control, but through arrangement.
>
> ***Restricted arranged schedules*** are somewhat less flexible in that once set for an irrigation, rate and duration are fixed and unchangeable. This precludes any irrigation adjustments for conditions during the irrigation process.
>
> Other schedules include ***the fixed duration arranged schedule*** where the irrigation duration is fixed and unchangeable even by

arrangement, and the *fixed rate* ***arranged schedule.*** where the flow rate is fixed and nonnegotiable.

DEMAND SCHEDULES

Demand schedules. being the most flexible of all irrigation schedules, should allow, in their ideal form, an unrestricted amount of water to be taken from the system at the user's convenience. Such ideal systems would not only be technically impracticable but also prohibitively expensive. Two demand schedules. which seem practicable, are summarized below:

Limited rate demand schedules: Limited rate demand schedules allow the user to determine the frequency, rate and duration, but within a flow rate limited to a maximum amount, and they provide a considerably flexible and at the same time a feasible system of operations. Very little communication is needed between the operator and the user. Several such systems for surface irrigation are in use through the use of reservoirs and level[1] top canals. akin to 'water on tap' in domestic water supply systems.

Arranged frequency demand schedules: Arranged frequency demand schedules add a further restriction on water delivery in that the time an irrigation can begin is arranged; but once the irrigation begins, the user is in complete control of the water supply and delivery. Such a scheduling system would be feasible for trickle or sprinkler irrigation.

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1 John L. Merriam has extensively documented his experience in a pilot project on arranged demand schedules. covering 141 one-hectare farms in Area H of the Mahaweli Project in Sri Lanka (Merriam and Dnvids 1986 Merriam et al. 1987).A similar attempt was made by him in 1989, in a pilot area of 60 acres in Mardan SCARP. NWFP in Pakistan. to demonstrate a demand system based on a flexibly arranged schedule basis. This pilot project was to take supplies from remodeled level top canal facilities to a distribution box, from where an underground concrete pipeline would serve different areas in the watercourse command. The total cost of the pilot project amounted to about Rs. 3,366,000, which was considered by the Pakistan authorities as excessive.

In addition to the three main categories of scheduling methods, a new method of scheduling irrigation operations was proposed by the U.S. Bureau of Reclamation in the 1970s (Clemmens 1987). The idea behind this method, called the *central system scheduling*, was to improve the predictive ability of the project in estimating water needs several days ahead of time. This would hopefully reduce shortcomings in diversions of water, while reducing the lead-timc for ordering water as well. The idea was for the irrigation district to schedule all irrigations for the farmers on a project-wide basis which is based on forecast of future demand. This could be used to better match crop-water needs within flow rate capacity restrictions of the delivery system. However, in the **U S.** projects where this type of schedule had been suggested, it had met with considerable resistance from farmers, since the method tended to reduce the degree of farmer control over their concerns.

RIGID SCHEDULES VERSUS FLEXIBLE SCHEDULES

Rigid delivery schedules (rotation and continuous flow) allow for relatively easy and less-expensive delivery system operations. hut the deliveries may not be according to crop-water needs or at the convenience of the irrigator. In the case of flexible delivery schedules (arranged and demand), water deliveries can be made to match crop-water needs: but this requires sophistication in the physical and management systems, at added cost.

Central system scheduling offers a via media. Here decisions can be made centrally for an area, but frequencies arc varied in accordance with crop-water needs. Such systems are a compromisc between the rigid, but administratively simple delivery schedules, and the more complex supply system operations, which also provide added flexihility to meet the crop-water requirements. It can be applied to large farming operations, with a single decision-making body, where, trade-offs in demands for water can he effected to given "optimum" returns. When a number of individual farmers are involved, the "optimum" allocation and distribution of water for the project may not be acceptable to individual farmers whose interests may not be compatihle. For the system to work effectively, the incentives of the administrative body and those of the farmers should also be compatible. That is, unless the schedulers' rewards are tied to overall project performance in achieving good results, such a system is likely to fail.

A decision between rigid and more flexible schedules depends on an assessment of situational requirements. However, this type of assessment is not made often, even when new systems are designed and/or existing ones are remodeled. Past practices often determine the delivery schedule in use, although it may not be the best schedule to use for a given project. Another neglected aspect, sometimes, is the possibility of using different schedules in different parts of the same project for more effective and economical water distribution.

Though the introduction of flexibility may involve additional costs for upgrading the system and in its operation, this should be viewed in the context of the potential for greater benefits from a flexible system. This aspect has to be examined for each situation. Thus, it is important to select the proper degree of delivery flexibility that allows the farmer to operate reasonably independently, and more productively, while allowing for efficient water distribution system operations.

The overall objective of any delivery schedule must be to better meet the cropwater requirements, and at the same lime it should ensure a greater efficiency in water use on the system and by the farmers. The selection should take into account the farm and system operational conditions, as well as acceptance of the scheduling method by farmers. The farm operational conditions require consideration of such factors as the types of crops to be grown, the sizes of the farms, irrigation practices in use, and the farmers' knowledge of irrigation and water management. The system operational conditions to be considered are system capability. infrastructural and operational requirements, and above all, the economics. The method should be acceptable to the farmers as an appropriate and equitable way of distributing water.

CHAPTER 4

Modernized Systems in Pakistan'

To REDUCE THE imbalance between water delivery and crop-water requirements, some existing systems in Pakistan have been remodeled, and channels appropriately designed with adequate capacity to meet the peak crop-water requirements. Also, design changes have been incorporated on new irrigation systems with similar increases in capacity.

These changes can be seen mainly in the North-West Frontier Province (NWFP) of Pakistan. The *NWFP* is the smallest of the four provinces, and has only 5.9 percent of the country's imgated area, but it is primarily an agricultural province, highly dependent on irrigated agriculture. However, its yield of wheat is only 1.1mt/ha, well below the national average, and the yields of other crops are also comparatively low (National Commission on Agriculture 1988553). The strong interest in experimenting with changes from the traditional canal operations seems to be one of the important features of a strategy aimed at improving the performance of irrigated agriculture in the NWFP.

In an effort to improve irrigation management, the planners' preferred strategy appears to be one in which more intensive management becomes necessary. The critical change in the planning of new irrigation systems, leading to substantial increase in the water duty (rate of water delivery per unit area) for more intensive cropping represents a shift in the philosophy of designing systems from a traditionally pursued method of "protective" to one of "productive" irrigation. The revised water duties for channel and outlet designs attempt to provide channel capacities that permit more appropriate matching of water deliveries to crop-water needs, as reflected by an anticipated or desired cropping pattern with optimum productivity levels. To translate these intentions to reality, however, a more intense management structure and an equally well-planned operations system become essential features of the strategy.

The shift in design philosophy can be seen in two major projects: the Chashma Right Bank Canal (CRBC) off-taking from the Indus and the Lower Swat Canal (LSC). which derives its supplies from the Swat River. The design of CRBC and remodeling of LSC are based on main canal capacities adequate for a supply at the outlets of about 0.60 and 0.77 liters per second per hectare (lps/ha) (8.6 and 11 cusecs for 1,000 acres), respectively, compared to the more traditional system capacity of 0.28 lps/ha (4 cusecs/1,000 acres). Both the CRBC and the LSC are located in the upper reaches of the Indus Basin, and have relatively better access to supply of water than the other lower systems.

Another special feature in these two systems is that unlike in other irrigation systems in the Indus Plains, the use of groundwater as a supplement to canal supplies to meet crop-water requirements has not been considered. The bad quality of groundwater may have been the reason in the case of LSC, whereas in the CRBC, the arrival of canal water to the newly developed area has made the few existing tubewells redundant, at least for the present.

The main characteristics of the design changes in the two systems are outlined in the following paragraphs.

CHASHMA RIGHT BANK CANAL (CRBC) SYSTEM

The CRBC is a major perennial surface imgation project designed to irrigate 230,675 ha (570,000 acres) with a 270-km long gravity flow main canal (capacity 138 cubic meters per second or 4,879 cusecs), and a network of subsidiary canals aggregating about 600 km. The project is to be implemented in three stages. Stage I will serve 56,000 ha (140,000 acres), about a quarter of the total Culturable Command Area (CCA), of which 41,600 ha (104,000 acres) fall within the old Paharpur Canal System, remodeled for increased capacity. The distributaries of this system are now being fed from the CRBC by providing link channels. There are 10 irrigation offtakes (distributaries) from CRBC in Stage I, with a design discharge ranging from 709 Ips to 6,400 Ips (25 cusecs to 227 cusecs). Although most of Stage I construction and Paharpur remodeling work has been completed, the main canal's full capacity is not likely to be utilized for the next 10 years until the completion of Stages II and III, and the extension of imgation to new lands.

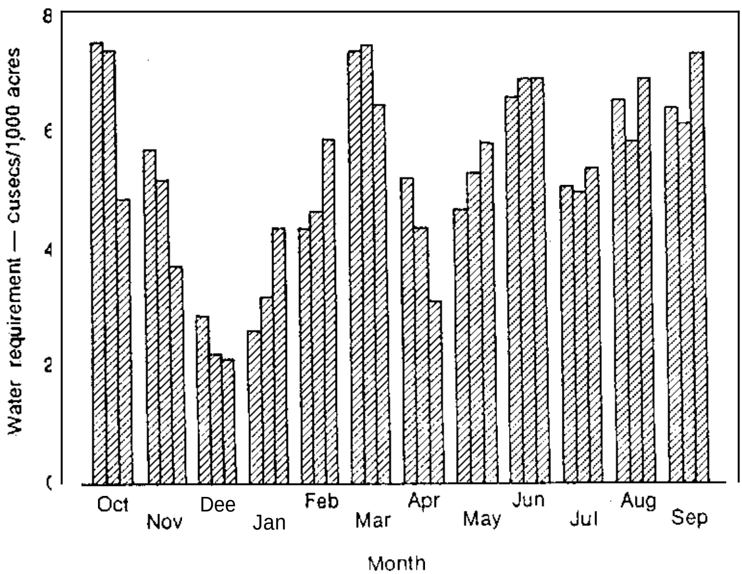
The capacity of the CRBC has been fixed to meet peak crop-water requirements for a projected annual cropping intensity of 150 percent (90% in rabi and 60% in kharif). The water allowance at the watercourse head has been fixed as 0.60 lps/ha or 8.56 cusecs/1,000 acres (about 14% in excess of the theoretical requirement) as against the traditional water allowance of 0.21–0.28 lps/ha or 3 4 cusecs/1,000 acres. Since the outlets are designed for this significant increase, water delivery capacity would not be a consbaint for crop-based irrigation within the planned cropping pattern. The design cropping pattern for CRBC is given in Table 4, and the 10 daily irrigation water requirements at the watercourse head are shown in Figure 1 (p.22).

Table 4. Proposed cropping pattern and cropping intensity. Chashma Right Bank Canal (CRBC).

Crops	Cropping intensity (in %)
Kharif	
Rice	2
Maize	10
Millet	3
Sugarcane	15
Cotton	10
Fodder	10
Gardens	5
Miscellaneous (Vegetables)	5
Total kharif	60
Rabi	
Wheat	45
Grams and Pulses	5
Sugarcane	15
Fodder	10
Oilseeds	5
Gardens	5
Miscellaneous	5
Total rabi	90
Annual total	150

Source: PC-I Proforma Revised). Phase-]. Gravity Flow System, Chashma Right Bank Irrigation Project. WAPDA, May. 1981.

Figure 1. Irrigation water requirements at watercourse head, Chashma Right Bonk Canal (CRBC).



Further, since the CRBC derives its supplies from the combined river flows of the Indus and Kabul rivers, as regulated by the Tarbela Dam on the Indus (live storage of 11. 6 billion cubic meters or 9.4 MAF), and again by the Chashma Barrage (live storage of 0.6 billion cubic meters or 0.5 MAF), water deliveries to the CRBC system may be adjustable to the cropping demands. However, management of the system would have to take account of seasonal supply levels in relation to the possible changes in the cropping pattern.

The main canal has few cross regulators to permit the utilization of channel storage forregulating the flows. Whereas thedistributary heads have manually operated gates, only a few minors offtaking from these distributaries have any control. The flow entering the distributaries and minors is not subject to any further control and they act as free-draining systems, but without provision for escapes for unused water. When the distributaries and minors are running, water will flow continuously to all the *chaks* (service areas), through ungated outlets whose capacity has been determined on the basis of the CCA of the area to be served. As per existing practice, the entire outlet discharge is to he taken by the farmers in a fixed time-based rotation, in individual chaks varying in size from 40 to 200 ha.

LOWER SWAT CANAL (LSC) SYSTEM

The LSC was originally constructed in 1885 and remodeled in 1935 for an authorized full supply discharge of 23.5 cubic meters per second (830 cusecs) for a gross command area of 53,800 ha (134,500 acres) with a CCA of 49,440 ha (123,600 acres). The original design of the LSC was based on an annual cropping intensity of 100 percent (60% in kharif and 40% in rabi) and channel capacities of about 0.42 lps/ha (6 cusecs per 1,000 acres), measured at distributary head. Over the years, the cropping intensity has increased to 150 percent.

As part of a drainage project, SCARP Mardan, the LSC is being remodeled for a diversion capacity of 54.9 cubic meters per second (1.940 cusecs) providing for a water allowance of 77 lps/ha (11 cusecs per 1,000 acres). Because of the increase in outlet discharge, almost 150 watercourses will he converted into minors having generally two outlets. The system consists of a contour feeder channel 35 km long, which provides water to 10 distributaries 112 km in length, and 19 minors with a total length of 133 km.

The LSC derives its water supplies from the Swat River at Munda Headworks. The natural flows of the river are sufficient to supply projected water requirements of the LSC system 98 percent of the time. Shortages are expected during October and November for 1.6 percent of the time, the average shortage being about 23 percent. Thus, for crop-based operation of the canal, the supply is not a constraint for optimum crop yield.

The original design of the LSC for distribution of water to watercourses was via adjustable proportional modules (APMs),[1] a typically

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1 APMs arc adjusted for the required discharge when outlets are installed after which they are not readjustable.

supply-oriented system. The system is remodeled now not only to overcome channel capacity constraints for increasing cropping intensity from 100 percent to 180 percent (90% in rabi and 90% in kharif [see Table 5]), but also to replace the APMs with adjustable gates, making discharges to watercourses adjustable in accordance with crop-water requirements. The irrigation water requirements for the designed cropping pattern and intensity have been worked out on a 10-day basis as shown in Figure 2 (p.25).

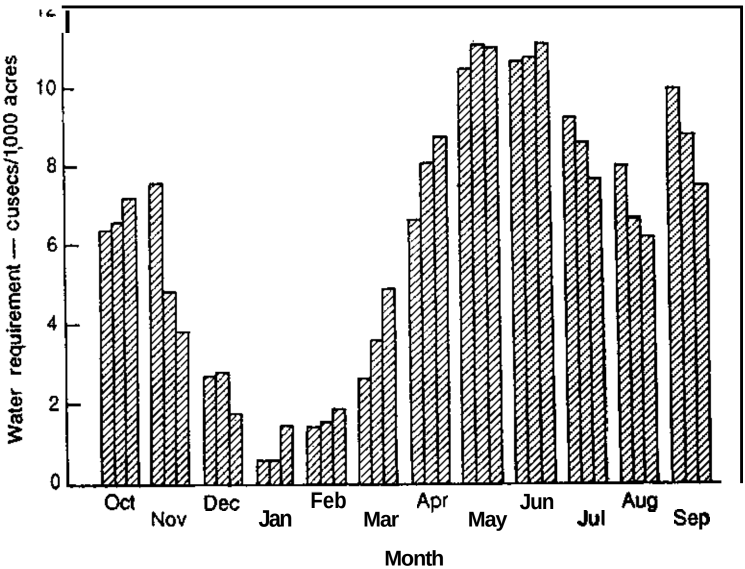
Table 5. Proposed cropping pattern and cropping intensity. Lower Swat Canal (LSC).

Crops	Cropping intensity (In %)
Kharif	
Maize	30
Tobacco	10
Sugarcane	30
Orchard	5
Vegetables	5
Fodder	10
Total kharif	90
Rabi	
Wheat	30
Sugarbeet	10
Sugarcane	30
Orchard	5
Vegetables	5
Fodder	10
Total rabi	90
Annual	180

Source: Operation and Maintenance Manual, Mardan Scarp. Harza-Nespak Consultants, April 1985.

As part of the remodeling effort, all branch, distributary and minor offtakes have been provided with gates and gauges, replacing the traditional open flumes, but no cross regulators have been provided in the system. Escapes have been provided only in the main canal, and not in the distributaries and the minors.

Figure 2. Irrigation water requirements at watercourse head, Lower Swat Canal (LSC).



CHAPTER 5

Options in Pakistan

THE FARM AND system operational conditions, as set out above, are important determinants of delivery system schedules. In the local context these conditions are discussed to bring out the implications for demand-based operations in the modernized systems.

The irrigation systems in Pakistan are essentially all gravity systems fed from natural river flows, which are regulated for inter-seasonal transfer of water by the Mangla and Tarbela dams, and the Chashma Barrage with a total live storage capacity of about 18.5 billion cubic meters (15 MAF) against the mean annual inflow of 172.7 billion cubic meters (140 MAF). Considering that there is no over-year storage, the supply can vary from year to year, and the limited storage available is inadequate for intra-seasonal supply regulation. This situation has serious implications for any type of demand-based operations. However, for the CRBC and LSC, as brought out earlier, the supply side need not pose a problem.

The irrigation systems, consisting of main canals, branches, distributaries and minors are very large in extent and, therefore, pose problems of regulation in the absence of any in-system storage. The lead-times for ordering or curtailing the supplies are also consequently quite large. Designed for a slope to carry the required discharge, the canals themselves do not offer much scope for storage-in-transit, which could be regulated.

The canals are unlined and this restricts the range of discharges that can be run so as to avoid problems of scour and siltation. During periods of high river flows, the supplies to some of the systems have to be cut off to avoid the entry of high silt loads. Even otherwise, the supplies are cut off once a year for a minimum period of one month during the winter to carry out annual maintenance and silt clearance. All these features affect potential demand-based operations and the scheduling method that can be employed.

Few control structures exist in the system and even in the lined portions of the CRBC, there are only a few cross regulators, although this reach of the canal could be kept almost replete with the full supply level to utilize the channel storage for regulation. The supply from the canals is distributed, concurrently throughout the system to **groups** of farms constituting a chak from structures designed to carry a fixed discharge in proportion to the irrigable area of the chak. Within the chak, the supply is taken by each farmer in a weekly rotation for a fixed duration (in proportion to the landholding). **It** is only when the supplies run short that it is rotated at weekly intervals among a group of channels to maintain equity in distribution. With these dominant features in the systems, which are also common in the **CRBC** and **LSC.** the options for demand-based operations are greatly circumscribed.

This does not necessarily mean that the present rigid rotation schedule cannot be changed to a more responsive management system. Field observations indicate that the farmers are already intervening in the official warabandi system, with or without the approval of the authorities, and sometimes in collusion with them. Outlets are being opened and closed at the farmers' will, and unsanctioned outlets and structures are being used for water distribution. In effect, the strict centrally administered rotation system has been replaced by some flexibly arranged scheduling methods.

A recognition by the authorities of this *de facto* flexibility in the field is an initial step toward a proper analysis of the current situation. This will greatly assist in the identification of possible options of managing the main system to meet the reality in the field. The physical constraints that tend to circumscribe the area of action for any change seem to be intrinsically linked to a number of institutional issues. They include a lack of consideration toward the essential design management interactions, which perhaps **arises** from an administrative culture based on feudal and colonial values. The farmer is considered as a passive partner in irrigation management, in that he is expected to accept the new design and obey the new operational rules. **A** similar attitude is probably taken with respect to the "subordinate" officers who are expected to comply. In both aspects, the expectations seem to have been far-fetched, and there is considerable room for improvement.

OPTIONS AT THE FARM LEVEL

Farming conditions in Pakistan have to be taken into account in any consideration of modified irrigation delivery schedules. These cover such factors as land tenure, farm size, cropping and irrigation practices, and fanners' knowledge.

The average size of a farm in Pakislan is about 4.7 ha (12 acres). However. the distribution pattern of farms, in number and size, is skewed. Three percent of the farms are over 30 ha (75 acres) in size and account for 23 percent of the cropped area, whereas 17 percent of the farms are less than I ha (2.5 acres) and cover only 2 percent of the area. In terms of land tenure, 55 percent of the farms are owner-operated, 26 percent are tenant-operated and 19 percent are owner-cum-tenant operated. Preliminary data indicate that the situation in the two project areas, CRBC and LSC, is not far different from these national averages.

A mix of crops is grown on all irrigated farms in both kharif and rabi cropping seasons with areal variations in the cropping patterns.

With the traditional practices of land preparation and leveling, the size of the individual fields, irrigated by the basin method, ranges from 0.04 lo 0.2 ha (0.1 to 0.5 acres).

Fanners in Pakistan receive almost no extension services related to water management. Therefore, they use estimates based on their own experiences in deciding when to irrigate, how often to irrigate and how much water to apply per irrigation.

Starting with the water demand at the farm, the first issue which has to be addressed is whether each farmer should be supplied irrigation water according lo his demand, orwhether the demand should be modulated within a group of farmers on a chak so that the supply caters to the needs of the average cropping pattern in the chak, thus maintaining equity. If equity is maintained at a chak level, the question would then arise whether a disparity in supply between different chaks would be acceptable. These are matters of policy which must be decided first, before any options for water distribution at the chak level can be considered.

Considering the small size of farms, it would be infeasible to alter the flow rate for individual fanners in an irrigation cycle in a chak as the duration would have to be adjusted accordingly. The flow rate to a chak could, however, be changed from one irrigation cycle to the next if the outlet is gated, permitting the delivery of different volumes of water for successive irrigations. The use of outlets with a fixed discharge (which would obviate tampering and avoid operating needs) would require capacities large enough to meet the peak requirements over the chak within a short period (say 7 days), and the attendant adjustment in the frequency with which the supply is delivered. This option has been reported for the Sardar Sarovar Project in India (Frederiksen 1985) except that the discharge at the gated outlet, fixed at the start of the season could be changed subsequently by mutual agreement. In the case of the LSC, gated outlets have been provided to permit the variation in the flow rate from one irrigation cycle to the next or for specific periods during the season.

The duration for which an outlet should be run at a time should be adequate to meet the irrigation requirements of all the farms served by it. This can be fixed by flow rate for the area served. For the prevalent sizes of the chaks and flow rates appropriate for surface irrigation, this duration is usually fixed as 7 days. Thus, the minimum interval between successive irrigations would also be 7 days. While it can be argued that this interval is too large in some cases, the weekly schedule offers great advantages in its operation as borne out by the warabandi practiced here.

The frequency of imgation, like the flow rate, cannot be tailored to the needs of an individual farmer, and has to be kept the same for all farmers supplied from one outlet. It may be possible theoretically to operate the outlets at varying intervals, but it would create complex distribution problems. A fixed frequency or schedule of operation of the outlets would, therefore, be more appropriate.

A major consideration for any of these options is the organization for monitoring and effecting the schedule. How best the farmers and agency operators can be coordinated for this purpose should be the focus for management-related research associated with finding the feasible options for greater flexibility, as this alone will determine, to a large degree, the success of any new approach.

OPTIONS AT THE MAIN SYSTEM LEVEL

Demand-based operation of an imgation system involves the supply of variable quantities of water during the cropping seasons. For the CRBC and LSC, the systems would have to carry very widely varying discharges for different periods of time over the year to meet the projected crop-water requirement as shown in Table *6*. This has implications for canal operation in which the system configuration can be an important element.

Table 6. Percent of time over the yew for differed discharges.

System	Discharge as percent of capacity			
	100 – 75	75 – 50	50 – 25	< 25
CRBC	28.7	25.0	19.4	27.X
LSC	27.8	25.0	19.4	27.8

As a general rule, it can be stated that **for** easy operation. all outlets on the same distribution channel should follow a common schedule. While this is so, the question arises **as** to how the channels should be operated when the supplies to be carried are a small fraction of the designed capacities. The options could be: 1) running **of** all the channels at partial flows: **2)** rotating the channels at **full** capacity: **or 3)** a combination of the two. There can be different operating procedures linked to the distribution schedules of the outlets. Consideration can be given to the following options, provided that the institutional and managerial challenges they pose can be met:

* Gate the moghas (outlets) and implement a within-distributary rotation that allows each watercourse a reduced time of discharge at essentially design flows. This needs greater patrolling of moghas, and requires a second warabandi **for** all watercourses, such **as** a 3.5-day schedule instead of the 7-day schedule.

* **Cross** regulate distributaries and run channel at **less** than design discharge. This may work without gating moghas, but only if head-end moghas cannot draw much water when cross regulators are open. Problems include determining the number of cross regulators required to maintain design head at reduced discharge, patrolling the cross regulators and risk **of** intense sedimentation, because velocities would be too low to keep sediment in suspension. Increased maintenance is probably one outcome.

* Rotate between distributaries so that design discharge is maintained for discrete periods, followed by distributary closure. This is, in fact, the accepted irrigation department rule, even though it is rarely implemented at distributary level. Problems remain with this option. Long canals will suffer from extended periods of filling up, increased risk of erosion, sedimentation and bank collapse from alternate wetting and drying. It alsoimposesanessentialneedforcoordination between several distributaries to ensure that main canal discharges are not unduly affected by opening and closing of different distributaries at different times.

Thus, there can be several options for operating the irrigation systems toward ensuring that the irrigation supplies are better matched to the demand. There can be no true demand-based systems, and what maybe possible can be termed as "flexible-demand systems." The choice of the particular method which should beadopted would, however, depend upon the configuration of the system, its characteristics and the pattern of water distribution, both spatially and temporally. This choice would also be governed by the feasibility of the institutional arrangements and operating procedures that may be required. The introduction of demand-based operations would, therefore, require a thorough study for each system based on the evaluation of the possible options.

CHAPTER 6

Opportunities for Pilot Studies

THE RECOMMENDATION OF the National Commission on Agriculture (1988) on the problems of traditional supply-oriented canal operations was that scheduling plans should be developed on the basis of results from pilot studies. Such studies were to assess the potential for the distribution of irrigation supplies to be more in line with crop-water requirements in different canal commands, and how tubewells and canals should be operated to adequately meet both drainage and cropwater requirements.

Considering the opportunity offered by two modernized irrigation systems in the NWFP, both the Federal and Provincial Governments have requested the International Irrigation Management Institute (IIMI) to collaborate with Pakistan agencies on possible approaches to the problem. Accordingly, IIMI has undertaken a research study to identify and field-test an appropriate management approach for crop-based imgation operations in two selected distributaries.

In these modernized systems, substantial improvements in performance and consequent agricultural production could be expected, if water requirements of any cropping pattern, that is collectively decided upon, could be delivered within the prevailing supply constraints. If the modernization of systems is not accompanied by adequate changes in their management and operation, and if the traditional supply-oriented operations are allowed to continue, the anticipated return on investment will not be achieved. Further, significant inefficiencies in water use will exacerbate existing drainage problems, possibly depressing productivity of water and overall performance.

Also, if higher irrigation allocations are supplied to these modernized systems irrespective of changing cropping patterns, overall water availability for downstream development is likely to be a recurring problem. A greater awareness among fanners and agency personnel will be necessary to ensure that cropping patterns are within constraints of water supply, and that water delivery closely responds to crop-water requirements throughout the cropping seasons.

While steps have been taken to redesign and remodel these irrigation systems, and to provide larger waterallocations for more intensive cropping, these efforts have not been accompanied by the development of irrigation management procedures to achieve more appropriate matching of delivery and crop-water requirements. The additional water allocated through the normal water-turn (warabandi) system provides capability to increase cropped area, to produce at a higher level in the same cropped area, and to change the cropping pattern. A combination of all three options appears to be taking place in the project areas, but it is unlikely that perlormance is at an optimum, technically, economically or socially. Also, there is a general recognition that the additional opportunities associated with greater flexibility in water use may bring with them the danger of increased inefficiency, and that the higher water allocation through the remodeled system in this context may exacerbate drainage problems.

Consultant reports[1] have suggested the application of an on-demand management system, in which farmers have the opportunity to request water deliveries through a water users' organization, permitting them to manage their own irrigation and agricultural activities. However, the requirements for the implementation of this type of management system, physically and organizationally, are recognized as substantially different from the traditional supply-oriented management system, requiring considerable long-term commitment by extension service.

In both projects, plans for irrigation operations based on crop demand are yet to be fully developed. Many of the new and remodeled system components designed for higher water allocations are presently in the early stages of development; even after completion, these will have to be tested for their sustainable application. In the CRBC Stage I, canal capacity has been enhanced to meet peak requirements of water for the projected cropping intensity, and temporary pipe outlets have been installed with no control arrangements for adjustable discharges. In Stage II, similar design and construction work is under way. The new system in Stage I has heen incorporated into the remodeled Paharpur Scheme, but it is not clear whether the fully designed discharges are being used in the Paharpur area. as

1 See HARZA-NESPAK Consultants. 1985. Mardan SCARP operation and maintenance manual; and Thompson, G.T. 1988. Consultant monitoring report.

anticipated. In the LSC, most of the improvement work is complete, but the control infrastructure in some areas has already been damaged and needs repair.

Even after completion of these items, the newly established systems need to be tested for sustainable application. Preliminary observations suggest that farmers within these system areas are not yet prepared to use the increased water allocations effectively and show a preference to grow crops with higher water requirements, such as rice and sugarcane. In the Girsar Minor of the Paharpur Scheme, the extent of rice increased from 783 acres in 1985 to 1,115 acres in 1989; sugarcane acreage increased from 126 to 301 during the same period. This raises concerns about the likelihood of increased waterlogging, and the effects of such cropping patterns on downstream water availability.

The lack of preparedness among farmers to adjust to a system of increased water allocations seems to correspond to a similar lack of awareness and enthusiasm about the new requirements among agency personnel at the operational level. This surfaces the need for a special effort to identify and implement a sustained program of research, training and extension. Three main problems that can form the basis for pilot studies are that:

i. water resources are limited or constrained despite increased irrigation allocations;

ii. inefficient use of increased irrigation allocations may result in drainage problems and deprive downstream areas of water resources; and

iii. agency personnel and fanners are not prepared for effective use of increased irrigation allocations.

Out of these constraints, supply limitations for both systems, the CRBC and the LSC, are considered less restrictive than those in other systems in Pakistan. In both cases, the peak supply levels, even after the systems have been fully developed, are very much more than the national average of 0.28 lps/ha. Similarly, the current efforts in providing drainage facilities can have some effect on the increased water table. What remains as a major obstacle, however, is the lack of institutional preparedness for the effective application of improved water management methods and any form of flexible system management approach.

The main thrust of the pilot study, therefore, would have to be a carefully planned and executed effort on institution building, both at system management and farm levels.

Considerable research effort is to be spent in identifying and defining the interactive issues between the physical and social systems. Still greater effort is needed to get the actual causes of the problems of system performance clarified. To what extent are they attributable to the defects in the design, construction and maintenance of the physical system, and to what extent are they caused by the institutional deficiencies ?

For instance, preliminary observations in the two system areas have already surfaced some acute problems in water management: the absence of warabandi or any alternative to it; inequity in water distribution; and water shortage during peak crop demand. The identification of significant causes for these problems and their order of contributing effect would greatly help in developing the possible management solutions to the problem. The pilot study will attempt to know what contributions the physical features (such as the location of moghas, low supply levels at the source, seepage or leakage due to bad maintenance, and changes in the design characteristics in the canal) and the institutional deficiencies (such as lack of supervision, wrong procedure, inadequate manpower and other resources, influence of big landowners or any other form of institutional constraint) make toward creating these problems. It is more difficult to identify the latter set of problems and still more difficult is to find solutions to them.

The institutional component of the pilot study will concentrate on studying three interrelated aspects of irrigation institutions as they relate to the study areas:

1. ***Organizations.*** Irrigation Department, Agriculture Department, WAPDA, and other support service agencies and farmers' organizations. The study of this aspect will include their respective work programs, division of responsibility, delegation of authority, supervision and accountability, distribution of staff and their performance assessment methods, and also the intra- and inter-agency, and agency-farmer coordination mechanisms. Information exchange and feedback mechanisms will also form an element in this aspect.

2. Formal *rules.* Acts, promulgations, subsidiary laws, manuals of procedure, official instructions, constitutions of associations, agreements and tribunal decisions.

3. *Informal* rules. Traditional practices such as kachcha warabandi, norms, conventions, and other forms of accepted informal behavior.

In the two systems, LSC and CRBC, new design changes have resulted in physical systems that are partly different from the model type of canal systems elsewhere in Pakistan. While increased system capacity is a new feature common to both systems, the LSC has an additional new feature of regulation with adjustable gates at the watercourse heads. Basically, both these physical features envisaged in their design, a new organizational arrangement for water delivery, at least to regulate the flow when water at the peak requirement level is not needed in the field. Clearly, this change in the organization has not only occurred but has not been even planned. This is illustrative of the gap between technical and institutional considerations. Reasons for this gap have to be investigated and perceived solutions have to be ascertained.

At the stages of identifying and field-testing new management approaches, the institutional and managerial components of the pilot study will take a more action-research orientation. The effort will be in developing close collaborative relationships with the operating agencies and the farmers. The intended methodology is to form several Working Groups to meet and deliberate regularly on the identified issues, and to select components of research findings that would make viable implementation options. IIMI staff will play a prominent role in facilitating and coordinating group discussions, and providing for this purpose the necessary technical inputs, and also in initiating a problem-oriented training program. In the selection of the most appropriate option, the relevant policy level personnel will necessarily be involved. The Study Advisory Committee and the Project Coordination Committee will be particularly useful at this stage. The Working Group processes will be closely documented and used in successive meetings as well as in training programs.

As for measures to obtain farmer participation, the final product should best be from an evolutionary process. A prudent approach would be to assist the farmers to identify the need for organizing themselves and to assist them

in establishing the mechanisms to meet that need. At this stage the project does not seem to require formal farmers' organizations, but may initially require some mechanism for farmers and agency personnel to decide on seasonal plans for their respective involvements and to deliberate on some of their operational issues.

CHAPTER 7

Conclusion

THE DESIGNS OF the irrigation systems, the traditionally ingrained irrigation practices and operating modes and the peculiar socioeconomic conditions in Pakistan present such binding constraints that a shift to demand-based irrigation operations, in their *true* forms, must be regarded for the time being as extremely far-fetched. Even the modified demand systems, in which the indents of the irrigators may be subject to limitations in the frequency, rate or duration of the supplies would require major physical changes in the design of the systems and vastly different and complex management forms. There would also be a need for coordination mechanisms for the articulation of the demands that can be accommodated over the cropping seasons and within the system's capability.

The distribution of irrigation supplies, more in accord with the crop-water requirements, would require modifications in the canal operating procedures with the introduction of some regulating structures and mechanisms. The recently modernized or newly built irrigation systems in the North-West Frontier Province of Pakistan, in which the designs are based on meeting the irrigation requirements for intensified cropping patterns. and for which the supplies are not a particular constraint, offer the opportunity for the introduction of crop-based irrigation operations, under which the operating agency *can* endeavor to distribute the supplies according to the crop-water requirements in consultation with the farmers. While this is not the same as meeting the individual irrigators' demands, it still represents a step forward and implies a participatory role for the water users.

Introduction of crop-based irrigation operations would involve the evaluation of the physical design features of the particular irrigation systems in order to identify the most appropriate and cost-effective infrastructural modifications, which would permit the supplies to be varied, both spatially and temporally without creating undue maintenance problems in earthen channels. At the same time, it would require a change from the traditional form of operation characterized by administration to the other form, based on management. This in itself would imply Consideration of policy options and related legislation as well as the evaluation of the different strategies for defining an appropriate management approach.

For the involvement of the fanners, the socioeconomic and sociological environment would have to be taken into account so that workable forms of farmer participation could be defined. For effective farmer involvement in decision making, a prolonged and sustained effort in mutual understanding by the fanners and the agency personnel is imperative. Finally, for all the innovations to be workable and sustainable, they will have to be acceptable to the fanners, agency personnel and the policymakers, and also they should be convinced of the tangible benefits accruable by such innovations.

Thus, approaching a crop-based operation must necessarily be a slow process as the complexities of the particular situation must he evaluated through an initial field-research program before any feasible options can be decided upon. These must then be tested on a pilot scale, and improved upon under an action-research phase. It may be the most prudent initial step in moving toward demand-based operations in modernized irrigation systems in Pakistan.

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